Hindawi
Journal of Food Quality
Volume 2022, Article ID 5604342, 16 pages
https://doi.org/10.1155/2022/5604342

Research Article

Process and Product Characterization of *Aliha*, A Maize-Based Ghanaian Indigenous Fermented Beverage

Felix Kwashie Madilo,[1,2] **Angela Parry-Hanson Kunadu**,[2] **Kwaku Tano-Debrah**,[2] **Gloria Ivy Mensah**,[3] **Kwesi Firibu Saalia**,[2] **and Unathi Kolanisi**[4]

[1]*Department of Food Science and Technology, Faculty of Applied Sciences and Technology, Ho Technical University, Volta Region, Ho, Ghana*
[2]*Department of Nutrition and Food Science, University of Ghana, Greater Accra Region, Legon Accra, Ghana*
[3]*Bateriology Department, Noguchi Memorial Institute for Medical Research, University of Ghana, Greater Accra Region, Legon Accra, Ghana*
[4]*Department of Consumer Science, Faculty of Science and Agriculture, University of Zululand, Richards Bay, South Africa*

Correspondence should be addressed to Felix Kwashie Madilo; fmadilo@htu.edu.gh and Angela Parry-Hanson Kunadu; aparry-hansen@gmail.com

Received 27 April 2022; Revised 6 June 2022; Accepted 28 June 2022; Published 30 July 2022

Academic Editor: Parise Adadi

Aliha is a maize-based traditional fermented beverage prepared and consumed in Ghana, predominantly in the Volta Region and other parts of Ghana. The study sought to characterize the production processes, the nutritional values, and microbial composition of *aliha*. A total of 126 *aliha* producers in the Volta, Greater Accra, and Ashanti Regions were sampled using snowballing to identify and to recruit the producers for the study, using a pretested self-administered questionnaire. The physicochemical and microbial composition were carried out using standard methods. Four different production techniques were identified across the production sites. The variations identified during the production existed across the production chain. The main ingredients used for *aliha* production are corn, caramel, sugar, and water. However, *aliha* produced by the 'original' method (DN2) presented the best nutritional values (proteins, energy, and calcium), followed by backslopping techniques, AG1 (total carbohydrates and ash), and AG2 (fats and oils and phosphorus). Fungi and Enterobacteriaceae dominated the initial fermentation stages (24 h) with low acid values. However, as the fermentation time increased from 24 h to 72 h, the acid contents of the fermenting beverage increased sharply leading to a drastic reduction of fungi and Enterobacteriaceae contents with increasing records of lactic acid bacterial counts. Even though DN2 presented the best nutritional values, it was highly contaminated. Hence, the producers must be encouraged to use backslopping techniques for safety and to shorten the duration of production.

1. Introduction

Cereal-based foods account for as much as 77% of total caloric consumption and contribute significantly to the dietary protein intake in Africa [1]. Most cereal-based traditional foods and beverages in Africa are processed through natural fermentation. Fermentation as a processing technique is used to preserve substantial amounts of food and beverages through lactic acid, alcohol, acetic acid, and alkaline fermentation. The process of fermentation also reduces cooking times and fuel requirements [1]. Some examples of cereal-based fermented beverages with their local names in Africa include *Burukutu* (Ethiopia, Nigeria); *Pito* and *Kaffir beer* (Ghana); *Busaa* (Nigeria); *Merissa* (Zambia); *Seketeh* (Nigeria); *Bouza* (Egypt); *Mahewu* or *Magou* (South Africa) [2]. For most of these cereal-based beverages, maize or sorghum is the predominant cereal used as raw material in their processing.

Aliha is a traditional fermented beverage prepared and consumed in several communities in the Volta Region of

Ghana. The etymology of the name *aliha* was coined from its indigenous origins in the *Ewe* language of Ketu South of the Volta region of Ghana, where it is known to be produced using *'hali'* (corn malt) and allowed to ferment (*aha)*, hence, the name. During preparation, corn is steeped, malted, milled, mashed, boiled, and fermented, and the fermented wort is caramelized before consumption. Nonpackaged or refrigerated *aliha* has to be consumed within few hours; else, fermentation will advance to a point where the beverage will become too sour for human consumption. *Aliha* is considered by the local consumers as a refreshing drink. It is also a source of essential nutrients and has medicinal values; hence, it is consumed throughout the day. Currently, it is prepared, marketed, and consumed in all the sixteen (16) political regions in Ghana.

Additionally, due to extensive efforts that have been put into studying the nutritional importance of beverages such as *kwete* (maize and millet-based beverage from Uganda), *mangisi* (Zimbabwean beverage produced from millet malt), *pito* (millet-based, Ghana), *burukutu* (Nigerian beverage produced from guinea corn), *amgba* (sorghum-based opague beer produced by Cameroonians), *dolo* (sorghum beer produced by Burkina- Faso), *kunu-zaki* (millet-based beverage produced by Nigerians), and many others during their fermentations, most of these beverages have been commercialized. However, the nutritional composition of *aliha* is yet to be investigated.

The fermentation of the most traditional beverages is initiated by the action of fungi (alcohol fermentation), and lactic acid bacteria (LAB) (lactic acid fermentation) for unique and pleasant sensory properties. As the fermentation period increases, several bacterial, mold, and yeast species appear at the various stages including the final products, making it difficult to determine the quality of the final products [3, 4]. Unlike other fermented beverages (*pito, mahewu, dolo, burukutu,* and *busaa*), there is limited information about the production process and the microbial community associated with *aliha*. Pérez-Armendáriz and Cardoso-Ugarte [3] reported that several species of Enterobacteriaceae, fungi, and LAB were isolated from all the fermentation stages of *pozol*. Robledo-Marquez et al. [5] added that as the fermentation time of *pozo* increased, the acidity of the fermenting wort increased, which led to a significant reduction of Enterobacteriaceae, yeasts, and molds in the final beverage. Due to diversity of microbiota, which characterizes the spontaneous fermented products, their qualities and safety may not be assured. Hence, this study was designed to evaluate the production techniques, the nutritional values, and the microbial qualities of *aliha*.

2. Materials and Methods

2.1. Survey on Aliha Production. A survey of *aliha* production was conducted in the Volta Region Keta Municipal (Anloga, Keta, Dzita and Dzelukope), Ketu South Municipal (Denu, Agbozume and Aflao), Ho Metropolis (Ho Central; Greater Accra Region (Madina and Teshie Salem), and Ashanti Region (Anloga Junction, Ayeduase and Ayigya) of Ghana (Figure 1). These sites were chosen because they were the predominant *aliha* production regions. A semistructured questionnaire was developed to investigate the production techniques. The questionnaire was structured into three sections with seventeen questions. Section A dealt with demographic characteristics such gender, age, education, marital status, and primary and secondary occupations; section B contained fourteen questions based on production; and section C contained three questions based on product quality control. The questionnaire was validated by experts in beverage production and piloted among five (5) producers from *Tregui*, a village in Keta District, and Adina-Amutinu, twin villages in Ketu-South Municipal. These villages were eventually excluded from the sampling plan. The feedback from the piloting was used to modify the questionnaire, which was used for the data collection in the study.

2.2. Sampling Technique and Sample Size. Snowballing, a nonprobability method was used to identify *aliha* producers in the Volta, Ashanti, Northern, Greater Accra, Central and Eastern Regions of Ghana. Based on the number of producers identified in these regions, Volta, Ashanti, and Greater Accra Regions were chosen for the study. Due to the unwillingness of some of the producers to give out the needed information, a convenient sampling technique was used to recruit one hundred and twenty-six producers (126) across the three regions. The distribution of the sample size is presented in Table 1.

2.3. Sample Collection. Due to the variations that exist in the production processes of traditionally prepared *aliha,* the purposive sampling method was used to select five (5) producers: two each from Anloga (AG1, AG2) and Denu (DN1, DN2) in the Volta region and one from Madina, Greater Accra Region of Ghana (ACC) for sample collection. A total of thirty (30) samples were collected, three (3) from each producer in duplicate. At each of the sampling points (0 h, 24 h, and 72 h), about 500 ml of the *aliha* samples were collected in duplicates in sterilized bottles and transported immediately after collection on ice to the University of Ghana, Microbiology laboratory of Nutrition and Food Science Department to obtain the microbial pellets for further analysis. Ten milliliters from each of the samples was centrifuged (Centric 150, Clifton) at 7,500 rpm for 10 mins. The pellets were kept in 30% glycerol at −20°C until they were transported on ice to South Africa, University of Zululand, Consumer Science Department for microbial identification. Ethical clearance certificate for the study was obtained from Ethics Committee for Basic and Applied Sciences (ECBAS), University of Ghana.

2.4. Determination of Changes in Temperature, pH, and Titratable Acidity of Aliha Samples. The temperature and pH of the *aliha* were checked immediately after sampling using digital thermometer [Major Tech (PTY) LTD, MT630, Isando 1600, South Africa] and pH meter (Crison Instrument, S.A. Riera Principal, 34–36 E-08328 Alella—Barcelona), respectively. Using phenolphthalein

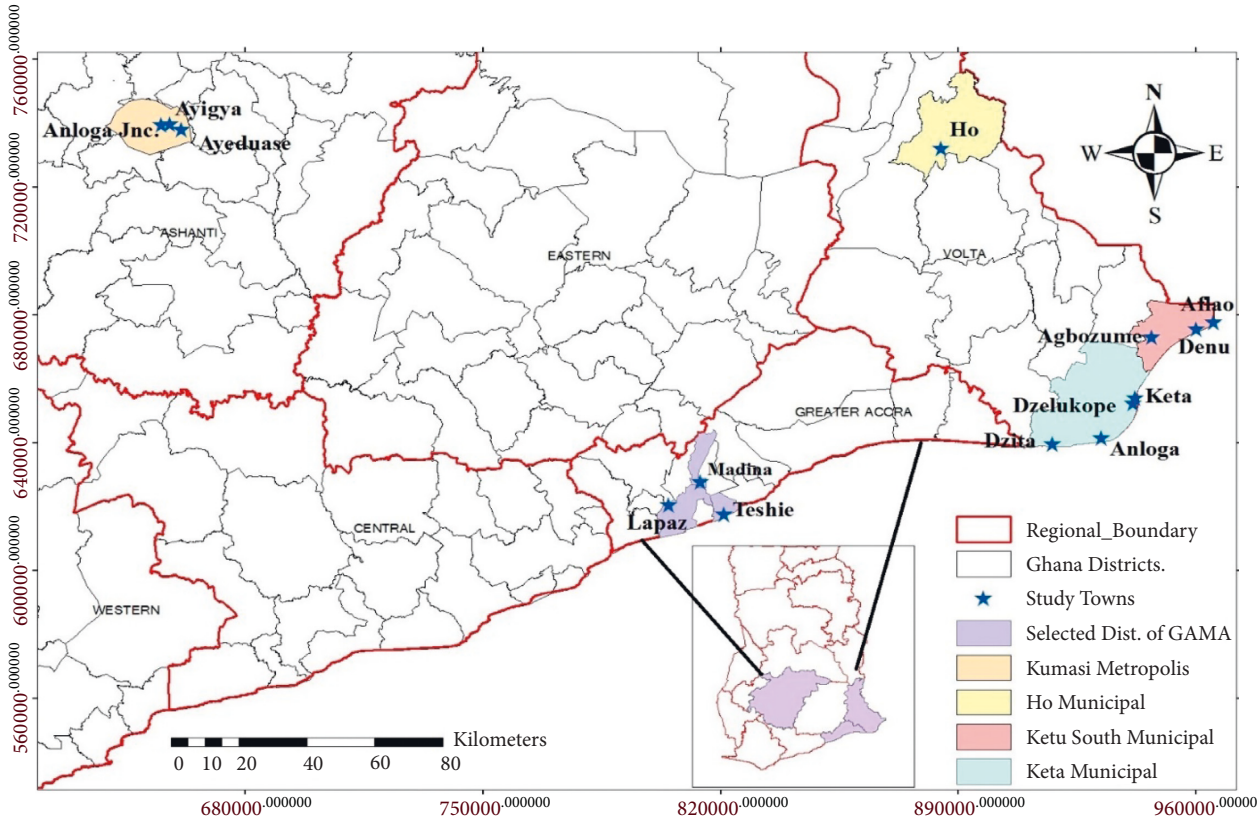

Figure 1: Part of map of Ghana indicating the studied Municipals and Districts.

Table 1: Sample size distribution across the selected regions.

Region/Municipal	Town	Producers	Total
Volta			105
Keta Municipal	Anloga	22	
	Dzita	10	
	Dzelukope	9	
	Keta	7	
	denu	14	
Ketu South Municipal	Agbozume	17	
	Aflao	16	
Ho Municipal	Ho central	10	
Greater accra			15
	Medina	5	
	Teshie salem	3	
	Lapaz	7	
Ashanti			6
Kumasi Metropolis	Anloga junction	3	
	Ayeduase	1	
	Ayigya	2	
Total	—	—	126

indicator, total titratable acidity was determined by titrating a mixture of 10 mL sample and 90 mL distilled water against a 0.1 M sodium hydroxide (NaOH) solution [6]. The percentage acid was calculated using the following formula:

$$\%\text{Lactic Acid} = \frac{\text{ml of 0: } 1M \text{ NaOH} \times \text{normality of NaOH} \times \text{mol weight of acid}}{10\text{ml of sample}}. \quad (1)$$

2.5. Proximate Analysis of Traditional Fermented Aliha. Moisture, ash, protein, calcium, and phosphorus of *aliha* were determined as described by AOAC [6]. While total fats (Werner Scmid), energy (Atwater factor) and iron (2,2—bipyridyl Calorimetric) were analyzed using their corresponding methods, total carbohydrates including fiber determinations were done by calculation [% TC = 100−% (moisture + protein + fat + ash)]. The alcohol content was measured using the following method: after *aliha* was properly mixed, a drop was made onto the lens of the Abbe refractometer (2WAJ, Optika, Italy), and the refractive index was taken. The alcohol content was determined after comparing the values using the refractive index table. The analyses were done in the Analytical and Microbiological Testing Laboratory of Food and Cosmetic Technologies, Durban, South Africa, and repeated in the Chemistry Department of Food Research Institute (FRI), Ghana.

2.6. Enumeration of Bacteria and Fungi. Microbial analysis was carried out in triplicate. For each analysis, 10-fold serial dilutions were carried out by inoculating 9 ml of buffered peptone water (0.1% [w/v] peptone, 0.85% [w/v] NaCl; pH 7.2) with 1 ml of stored concentrated sample pellets in 30% glycerol. Hundred microliters (100 μl) of the dilutions was surface spread onto de Man Rogosa and Sharpe (MRS) agar (acumedia®, LAB223) for *Lactobacilli*, M17 agar for *Lactococcus* species and other cocci, Potato Dextrose (PDA) agar (NEOGEN®, NCM0018 A, UK) for fungi and MacConkey agar (MERCK, biolab) for Enterobacteriaceae. MRS and M17 agar plates were supplemented with 1% ciprofloxacin/cycloheximide (Sigma-Aldrich; Steinheim; Germany) to inhibit the growth of fungi and enteric bacteria, while PDA plates contained 1% streptomycin to prevent the growth of bacteria [7]. Microorganisms plated on MRS agar and M17 agar were incubated anaerobically using anaerobic jar with AneroGenTM 2.5 L (Oxoid LtD, Wade Road, Basingstoke, Hants) at 30°C for 72 hours, while MacConkey agar and PDA were incubated aerobically at 37°C for 24–48 hours, and 25°C for 3 to 5 days, respectively. Colonies between 30 and 300 on the various bacterial agar plates and 15 and 150 for fungal plates were selected for enumeration. The fungal colonies selected were equal to or greater than 0.5 mm in diameter [7]. The counts were calculated and recorded as means of three determinations and were expressed as colony forming units (cfu) per millimeter. Plates (10^{-5}) with discrete colonies were selected, and four (4) representative colonies from a quadrant of the plates were picked randomly and transferred into 10 ml MRS broth for LAB, Nutrient broth (OXOID, CM0001) for Enterobacteriaceae and fungi. The tubes were incubated using the incubation conditions described above. They were subsequently subcultured on their respective media to obtain pure cultures. The cultures were then stored at −80°C in sterile Eppendorf tubes containing MRS broth (LAB) and Nutrient broth (Enterobacteriaceae and fungi) supplemented with 30% (v/v) glycerol as cryoprotectant for further analysis.

2.7. Statistical Analysis. All data collected were presented on excel sheet, imported, and coded into the Statistical Package for Social Scientists (SPSS) for windows, version IBM 25.0. Frequencies were generated using descriptive analysis. Significant differences were determined using Analysis of Variance (ANOVA) and post hoc tests. The figures were developed using MS excel 2016. Computation was used to obtain the predators and the significant association ($P \leq 0.05$) among some demographic characteristics, and experience and average production capacity were investigated using Spearman's rho correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity, and homoscedasticity [8].

3. Results and Discussion

3.1. Sociodemographic Characterization of Aliha Producers. The results of sociodemographic characteristics of *aliha* producers summarized in Table 2 reveal that the majority of the respondents were females (96%), married (67.5%), and had between 1 and 5 (72.2%) children. It was not surprising to notice that almost all the producers were females because cooking traditionally was believed to be the sole responsibility of a woman [9] in most of the African countries including Ghana; hence, the majority of the production of *aliha* is carried out by females. Further analysis of the data had also proven that the 4% of the producers who were men were largely supported by their wives. Members of this minority group (men) were between the ages of 30 and 39 and had no formal educational. It was also realized that most of the producers who were divorced and single had between 6 and 15 children and were 50 to 60 years old (data not shown). Most of the producers had primary (31%) or no formal education (10%). However, the majority of *aliha* producers were between 50 and 59 years of age (Table 2). The

Table 2: Sociodemographic characteristics of *aliha* producers.

Parameter	Variable	Frequency	Percent
Gender	male	5	4.0
	Female	121	96.0
Age	˂20	13	10.3
	20–29	10	7.9
	30–39	18	14.3
	40–49	31	24.6
	50–59	43	34.1
	>60	11	8.7
Education	tertiary	9	7.1
	JHS	43	34.1
	SHS	22	17.5
	Primary	39	31.0
	Others	13	10.3
Marital	single	26	20.6
	Married	85	67.5
	Divorced	7	5.6
	Widow	8	6.3
Having children	yes	115	91.3
	No	11	8.7
No. of children	1–5	91	72.2
	6–10	29	23.1
	11–15	6	4.8

NB: JHS–Junior High School; SHS–Senior High School.

respondents who had tertiary education (7%) such as university, Polytechnics, Nursing training, and College of education were government employees and engaged in *aliha* business as a secondary occupation.

The sociodemographic results of the study reported above were almost comparable to surveys conducted on the production of *gowe* [10], *Akpan* [11], and *Ablo* [9]. All the three survey studies reported that the traditional processing of *gowe* (a malted and fermented cereal-based beverage from Benin), *Akpan* (a yoghurt-like cereal product from West Africa), and *ablo* (West Africa steamed cooked moist bread) was the sole responsibility of women (100%). However, most producers of *gowe*, *akpan,* and *ablo* (52.4%) were between 35 and 30 (55%), 26 and 50 (86.2%), and 25 and 45 (54.5%) years old, respectively, and they had no formal educational.

Majority (30.2%) of respondents have been producing *aliha* for 6 to 10 years followed by 1 to 5 years (26.2%), while the least was 26 to 30 years (Figure 2). Further analyses of the results revealed that those who have been producing for 1 to 10 years were within the age group of below 20 to 39 years. This group also produced more frequently about twice a week and in larger quantities of between 100 and 500 liters. The producers older than 49 years indicated that they produced less frequently in smaller capacities because they could not stand the heat of the production and could also not carry it up and down for sale as they used to, but they rather produced for retailers and on contracts for occasions such as funerals, weddings, naming ceremonies, and marriage engagements. This admission confirmed the tedious nature of *aliha* production and retail. Furthermore, a few of the respondents confirmed that they preferred to produce on contracts rather than carrying it to the market for sale. More importantly, about 78.6% of the respondents learnt and inherited the business from their family members, 19.8% learnt the production techniques at a paid training, and 1.6% observed and learnt from friends. The 19.8% who went into intensive training were between the ages of 20 and 39, had only primary education, and produced the beverage on large scale (200–500 L).

These results clearly indicate that *aliha* processing business is providing livelihood to the producers, particularly the unemployed or uneducated young women, and the production sustainability was extremely high due to the fact that the majority of the processors (56.4%) were young and less than 10 years in the business. Similarly, Sacca et al. [11] demonstrated that 54% of their respondents had less than 5 years in *akpan* business. They concluded that the production of *akpan* could be a sustainable venture since more new stakeholders were joining the sector.

3.2. Association between Years of Experience, Average Production Capacity, Age, and Education. The relationship between years of experience, average production capacity, age, and education was investigated using Spearman's rho correlation coefficient. The result summarized in Table 3 indicated that the age and educational background of producers had no statistical correlation between frequency of production and production capacity ($P < 0.05$). This implies that education and age of a producer were not factors to determine how frequently they could produce *aliha* or how much of *aliha* they could produce within a time period. However, years of experience have a positive bearing on the producer's production capacity ($P < 0.05$). This suggests that the longer they stay in the business, the more experience they gain to handle larger productions suggesting business growth.

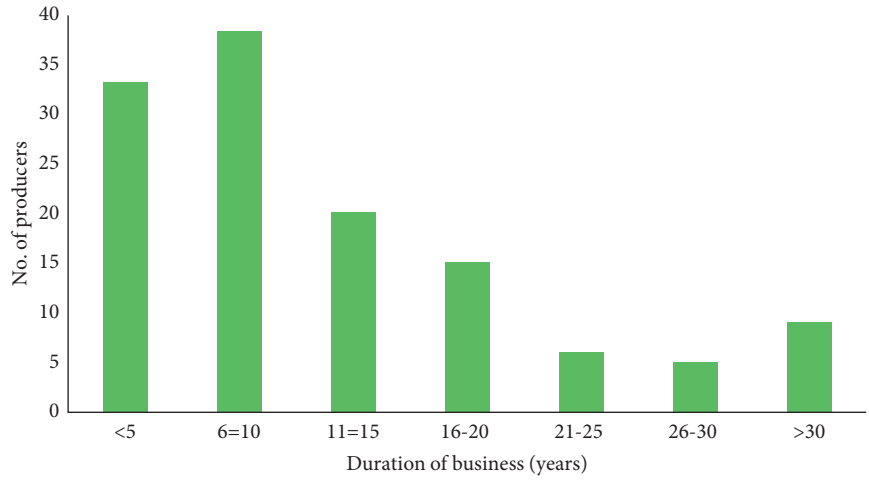

Figure 2: Duration the producers have been in *aliha* business.

3.3. Process Characterization of Traditional Aliha. Maize or corn, sugar, caramel, and water were the major raw materials required for the production of *aliha* across all the production centers in the three regions. There were no other raw materials or substitutes when the major raw materials were not available. However, there were four (4) identified variations across the regions and communities of production. These differences were noticed either at the malting stage or during the brewing process and also varied from community to community. The variations existed within the following stages: steeping, germination, milling, and mixing with water, before or during boiling, and fermentation (Figures 3(a)–3(d)).

All the producers surveyed from *Aflao* and *Denu* in the Volta region soaked the grain overnight at ambient temperature, allowed to germinate for 2 to 3 days, and the green malts were then sun-dried for 4 to 7 days depending on the weather. Most of the respondents coarse-ground the malt (using corn mill) and mixed with cold water. The mixture was immediately added to a boiling water and allowed to cook for about 3 to 4 hours with constant stirring to avoid burning. The mixture was strained (using muslin) after cooling and allowed to ferment for three days (Figure 3(a)). This process was identified as the original process; hence, a few respondents from other sampling communities such as Dzelukope, Zita, and Keta used it with some alteration (Figure 3(b)). The pictorial production process is displayed in Figure 4.

The producers from *Anloga* and Ho from the Volta region rather preferred to soak the grains for 3 nights and allowed to germinate for 4 days. They also considered to add old *aliha* during or after boiling before fermentation (Figure 3(c)), a process known as backslopping. They indicated that when the backslopping was done during boiling, the final mixture was fermented for 2 days, but when backslopped after boiling and cooling, the mixture was fermented for only 1 day. This was because the microbial population would die during boiling and will not speed up the fermentation process.

Table 3: Relationship between years of experience, average production capacity and age.

Predictors	*P* value
Years of Exp. VS Average Production Capacity	0.024
Age VS Years of experience	0.292
Age VS Average Production Capacity	0.516
Education VS Years of experience	−0.072
Education VS Average Production Capacity	0.422

Correlation is significant at the 0.05 level (2-tailed).

Few producers in *Anloga* added caramel (for color) before boiling and not in the finished beverage as other producers do.

Conversely, backslopping was not used intentionally in many of the producing centers for the production of *aliha*. They considered old *aliha* as "spoilt" due to the high acidity (Table 4). Hence, this group needs to be educated on the advantages back-slopping offers.

Respondents from Agbozume (Volta region), Accra (Greater Accra), and Kumasi (Ashanti region) ferment their malt slurry (or mash) overnight before boiling. Some preferred to strain before boiling. Instead of milling the malt in the machine, they rather used mortar and pestle to pound for size reduction (coarse powder) and, hence, had their final beverage, which was lighter than those who milled and boiled with the spent malt. They also added caramel before the fermentation process. As a result, instead of the usual 3 days of fermentation, they have their products fully fermented within 2 days (Figure 3(d)).

Adinsi et al. [10] reported that the expansion of *gowe* to a new market depends largely on the quality of the final product, which, to date, varies considerably from one producer to another as well as between successive processing operations. Novellie and de Schaepdrijver [12], Haggblade and Holzapfel [13], and Daiber and Taylor [14] held the view that steps such as mashing, cooking, souring, straining, and fermentation for alcoholic beverages have significant biochemical effects on the final product. Hence, technical know-

Figure 3: (a) Traditional process of *aliha* from producers in Denu and Aflao. (b) Traditional process of *aliha* from producers in Keta, Dzita and Dzelukope. (c) Traditional process of *aliha* typical of Anloga and Ho communities. (d) Traditional process of aliha typical of Agozume, Accra and Kumasi.

how is needed by the traditional producers to improve upon their product quality and enhance the nutritional and food safety status of their products on the market. Hébert [15] and Nout et al. [16] explained that since the indigenous African beverages are processed rudimentarily, they are considered to be of poor quality with varying end products. Devautour and Nago [17] confirmed that, "because of unstable and erratic quality, the trade in these traditional beverages is extremely limited."

More importantly, 99.2% of the respondents produced their own malt. They indicated that it was cheaper to produce it themselves than to purchase it. They also mentioned that a bad quality malt leads to bad quality final product, hence their decision to produce their own malt. The 0.8% of producers who always purchased the malt indicated that their primary occupation could not allow them to go through the processes involved in malting the maize grains, so they found it convenient to buy.

Figure 4: Pictorial indigenous processing of *aliha*.

Table 4: The summary of responses on storage and quality control checks of *aliha* production process.

Question	Response
What is the water to malt ratio during production?	1 kg of corn to 100 L (1 : 100) 1 kg of corn to 5 L (1 : 5) 1 kg of corn to 6 L (1 : 6) 1 kg of corn to 10 L (1 : 10) Not measured
How do you assess good quality malt?	All grains germinate, Green leaves appear, Green leaves must not appear, Shoot must be twice the size of the grain
What attributes of the product that attracts customers the most?	Aroma, taste, color and thickness,
How do you tell a bad quality product?	When test for foam fails, sourness, tasteless, no aroma, too light, over fermentation, when too much yeast is added, when it's alcoholic
What do you do with beverage which is not fresh to be sold/drunk?	Add to the newly produced ones and boil Reheat with malt It is disposed off
What is the average shelf life of the product?	3–7 days, 7 days, One month, 4 or more weeks
How do you preserve the product to extend shelf life?	Keep without touching or water droplets Cooking it for long Refrigerate when caramel and sugar are added (all respondents) Keep without sugar (all respondents) It must be well cooked

On how they determined whether the malt they produced was of good quality, the responses were: "when all the grains germinate," "when green leaves begin to appear," "green leaves must not appear," and "when the shoot is twice the size of the grain" (Table 4), among others. However, the quality that dominated the list was "the green leaves must not appear," which was correct because the moment the green leaves start appearing, they would begin to use the available nutrients in the grain to develop leaving the beverage with a little or no nutritional value. Additionally, the quality of the grain used for malting must be disease-resistant, as it is necessary for germination.

Their view was confirmed by Taylor and Dewar [18] who stated that when the malting process is not properly controlled, but rather allowed to be dependent on the prevailing weather, the quality of the malt will be very low and inconsistent. Palmer [19] and Bamforth and Barclay [20] indicated that, for "the production of malt of a good and consistent quality, it is a prerequisite that a high proportion of the grain must germinate." Briggs et at. [21] admitted that "not all grains are suitable for malting." They added that the characteristics to consider for a good quality malt must include "rapid and even germination of the grains, even hydrolysis of the endosperm, and an adequate complement of enzymes after drying/kilning."

The respondents indicated that competing products for *aliha* are beverages such as *sobolo/bissaps*, *burukutu, asaana, pito*, ginger drink and *tsukutsuku*. *Asaana, sobolo,* and ginger drinks are predominant in Greater Accra region; *tsukutsuku* and *burukutu* are from Volta region, while *pito* and *asaana* are from Ashanti region. However, the producers were quick to add that these competing beverages did not pose any threat to their business. Table 5 summarizes the responses of the producers in terms of the social events where they mostly market *aliha* apart from the regular retail at the main traditional market canters.

When asked about indices they used to determine the final product quality, the majority of the respondents mentioned color (66.7%) and aroma (60.3%) as the major parameters (Table 5). A one-way *t*-test sample determined that there were significant differences ($P = 0.00$) across the responses (Table 5). Moreover, they maintained that the product attributes that attracted the customers mostly were good taste, good aroma, light color, and thickness of the beverage. This response, however, corresponded to the quality parameters the producers were looking for in their final product. It could be inferred that the producers were aware of the product qualities important to their clients, and they tried to meet them.

In responding to parameters, which determine bad quality of *aliha*, the respondents cited over fermentation, product being too light, alcoholic, tasteless, sourness, and when testing for foam failed, among others as the main parameters (Table 5).

Again, the beverage was largely patronized by all the age groups across all the production communities. Some producers stated categorically that the youth and children mostly patronized the product (data not shown). This indication actually made *aliha* production a huge business in the Volta Region in particular. Figure 5 presents how *aliha* was displayed in the markets.

Table 5: Qualities of final product and occasions where *aliha* is patronized.

Parameter	Yes (%)	No (%)	Mean ± SD	*P*-value
What do you look out for in a good quality final product?				
Color	84 (66.7)	41 (32.5)	0.68 ± 0.48	0.001
Aroma	76 (60.3)	50 (39.7)	0.60 ± 0.49	0.001
Sourness	28 (22.2)	98 (77.8)	0.22 ± 0.42	0.001
Alcohol	34 (27.0)	92 (73.0)	0.27 ± 0.45	0.001
Others	6 (4.8)	120 (95.2)	0.05 ± 0.21	0.014
Which occasions do you sell the beverage?				
Funerals	117 (92.9)	9 (7.1)	0.93 ± 0.26	0.001
Weddings	114 (90.5)	12 (9.5)	0.90 ± 0.30	0.001
Naming ceremonies	112 (88.9)	14 (11.1)	0.89 ± 0.32	0.001
Outdooring	120 (95.2)	6 (4.8)	0.95 ± 0.21	0.001
Engagements	116 (92.1)	10 (7.9)	0.92 ± 0.27	0.001

Similarly, several studies have published that traditional fermented beverages are consumed by all age groups. Bhalla et al. [22] revealed that sorghum beer was mostly consumed by friends and family members. Abegaz et al. [23] also suggested that African indigenous fermented beverages were largely patronized by all people, particularly the low-income consumers who might not be able to purchase industrialized foods or beverages since it is relatively cheaper to produce. Adinsi et al. [10] also maintained that *gowe* is consumed by all classes of people.

In terms of shelf life and quality control checks of *aliha,* it was observed that the shelf life of *aliha* varied from one production community to another. The predominant duration as shelf life of *aliha* according to the producers included 7 days and between 3 and 7 days under ambient temperature (Table 4). The few who mentioned more than 7 days explained that, at that period, the beverage would not be fresh to be sold but could be reheated with some malt flour and sold the following day or added to the newly prepared one. Some, however, indicated that the shelf life of *aliha* was dependent on how long it was cooked. This means that the longer the boiling time, the longer the shelf life. However, this practice might also have adverse implications on the nutritional value of the final product and cost of fuel for cooking. They also suggested bad handling practices such as frequent touch, access of condensates into the beverage or fetching with wet containers and adding caramel without refrigeration (Table 4). They emphasized that *aliha* is unfriendly to water during the period of fermentation.

Similar studies on sorghum beer and *gowe* [10] revealed that the shelf life of sorghum beer was approximately 5–10 days after straining, whilst that of *gowe* was between 2 and 3 days under room temperature due to the development of molds and increased acidity. They added that, due to the short shelf-life, *gowe* was not produced in large quantities, as observed in *aliha*. Contamination by mold and bacteria when not handled effectively could lead to rapid deterioration of the products and consequently shorten the shelf life [24,25].

Figure 5: Aliha with ice displayed in the Marketing.

Taylor and Dewar [18] and Taylor and Joustra [26] added that the causes of short shelf-life of a beverage were not limited to what happened during cooking and fermentation periods, but also extended to the time of malting. Furthermore, they explained that "when the degradation of the endosperm, which naturally sustains the development of the growing embryo or germ during germination, has progressed to only a limited extent, the maltster terminates both its degradation and the growth of the germ to produce a shelf-stable product, by drying the grain."

Aliha after the fermentation process is strained and stored in cleaned and dried fermenters or transferred into large vessels (Figure 6). The vessels are then transported to the market and repackaged after addition of sugar and icing for sale.

3.4. Determination of Changes in Temperature, pH, and Titratable Acidity. The results of changes in temperature, pH, and titratable acidity during *aliha* fermentation have been summarized and presented in Figures 7 and 8. Figure 7 reveals that the temperatures change steadily across the various fermentation stages within the 72 hours of fermentation. However, DN2 recorded the lowest gradual mean change in temperature from 30.7°C to 23.6°C within the 72 hours. Statistically, there were, however, no significant differences between changes in temperatures across the various samples ($P > 0.05$).

Usually, temperature fluctuations affect the growth rate of microorganisms. Temperatures below room temperature are considered beneficial for microbiological quality [27]. The report of Korzeniwska et al. [28] showed that temperatures between 5 and 22°C had no effect on the number of microorganisms studied. Hence, the low temperatures recorded in the final products of this study might also contribute to increase in microbial communities in the beverage.

The pH of the samples from ACC and DN1 decreased rapidly from 6.40 to 4.20 and further to 2.60 for 0 H, 24 H, and 72 H, respectively (Figure 8). However, there were no significance differences among the changes in pH across the five samples ($P > 0.05$). Similarly, the acidity of samples DN1 increased by about 2.33 units within 24 h and further increased to 2.99 units after 72 hours of incubation. However, sample AG2 registered the slowest (1.0 unit) increase in acidity of the final beverage. These rapid increases in acidity could be as a result of high microbial activities on the sugars to generate lactic acids in the various final beverages.

Ray and Joshi [27] reported that the titratable acidity (TA) of kirario increased from 1.04 to 3.15 during fermentation, while the pH exhibited a sharp decline from the initial value of 6.4 to 4.0 within 24 hours and further declined to 3.0 for 48 hours of fermentation, which was similar to the current results. Namugumya and Muyanja, [29] also reported that the mean values of TA of *Kwete* shot-up from 0.84 to 1.43 with a corresponding mean pH decreased from 4.89 to 3.35 during 72 hours of fermentation, which was slightly different from *aliha*. Total titratable acidity of *mangisi* also increased from 0.13 to 0.67%, which resulted in a decrease in pH from 6.10 to 3.98 (Zvauya et al.) [30]. Furthermore, Zvauya, et al. [30] explained that the gradual increase in acidity of the product could be as a result of the activities of LAB breaking down sugars to produce lactic acid.

Furthermore, for the nutritional composition, Table 6 reveals that DN2 contained the highest amounts of protein, energy, and calcium. This is followed by AG2 (total carbohydrates and ash) and AG1 (phosphorous and fats and oil); therefore, *aliha* produced by original method (Figure 3(a), DN2) was the most nutritious beverage, followed by *aliha* produced by backslopping technique (AG1 and 2). AG2 presents the highest alcohol content (0.70 ml/100 ml); hence, *aliha* is classified as a low alcoholic beverage. Apart from the geographical locations (different regions), which might influence the nutritional composition and alcoholic contents of *aliha*, the variations are basically as a result of differences in the processing techniques since the same raw materials, and variety, are produced and harvested in the same seasons used for the production.

The nutritional studies of Nigeria *pito* [31], *Tchapalo* [32], and Sweet wort of *tchapalo* [32], which were maize-based beverages, revealed that Nigeria *pito* contained 5.42 g of proteins, 0.001 g of ash, and 3.4 g carbohydrates; *Tchapalo*

Figure 6: Vessels used for fermentation and marketing of *aliha*.

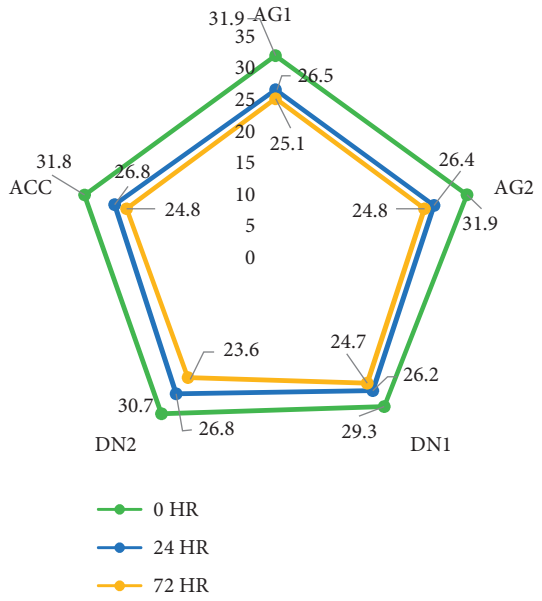

Figure 7: Mean changes in temperature during fermentation of *aliha*. ACC-Accra; AG-Anloga; DN-Denu.

constituted proteins (0.03 g) ash (0.27 g) and carbohydrates (0.53), while Sweet wort of *tchapalo* contained proteins (2.7 g), ash (0.3 g) and carbohydrates (3.6). However, no calories, fats, and sodium were determined for the three beverages. Comparatively, the mean values of the nutritional contents of the various *aliha* present *aliha* as nutritionally better than Nigeria *pito*, *Tchapalo*, *kunun-zaki* [33,34], *dolo* [35], and *burukutu* [36]. They were, however, more alcoholic (2.3–5.2%) [37] than *aliha* (0.56%). Statistically, there were significant differences among the nutritional values ($P < 0.05$) across the production centers (Table 6)

3.5. Microbiological Characterization. The microbial community associated with traditional fermented *aliha* has been enumerated with the results analyzed and presented in Tables 7 and 8, and Figure 9. The highest counts for AG1, DN2, and AG2 under 0 H, 24 H, and 2 H, respectively, were recorded for *Lactobacillus* species. The highest counts recorded for *Cocci* species were from ACC, AG2, and DN2 under 0 H, 24 H, and 72 H, respectively. While fungi (yeasts and mold) recorded its highest count for 0 H, 24 H, and 72 H under AG1, Enterobacteriaceae recorded its highest counts for 0 H, 24 H, and 72 H under AG1, ACC, and ACC (Table 7). It was also interesting to note that fungi and Enterobacteriaceae occurrence increased drastically within 24 hours of incubation but decreased sharply from 24 H to 72 H across all the samples. Particular references could be made to DN2, which has fungi counts increased from 2.26 to 2.95 log cfu/ml and then decreased to 2.40 log cfu/ml, while Enterobacteriaceae increased from 4.53 to 6.85 log cfu/ml within the first 24 h

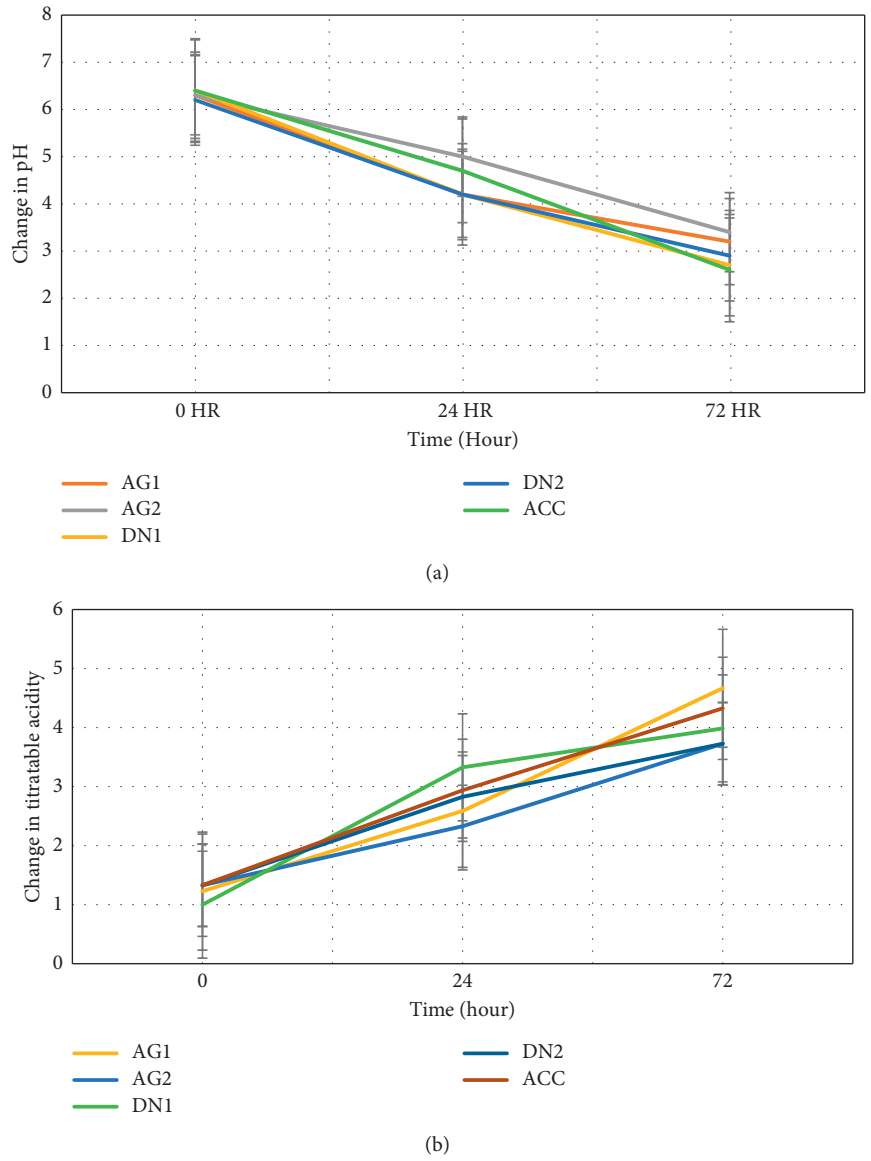

Figure 8: Mean changes in pH and titratable acidity during 74 h fermentation periods of aliha. (a) Mean changes in pH during fermentation of aliha. (b) Mean changes in titratable acidity during fermentation of aliha, ACC-Accra; AG-Anloga; DN-Denu. Data presented are mean ± SD of triplicates of independent experiments.

but decreased sharply to 5.23 log cfu/ml under ACC within 48 hours (Table 7). The appearance of Enterobacteriaceae in *aliha* from the beginning of incubation to the last day might result from the materials used for straining and fetching, open transfer from the cooking pot to fermenters, the containers used as fermenters, and compromising personal hygiene practices.

These results might be interpreted to mean that the sharp increase in fungi and enteric bacteria within 24 hours of incubation might have resulted from the increase in pH and lowering in titratable acidity (TA), which sought to create favorable environment or conditions for their growth. However, the drastic inhibition of these groups of organisms within 48 hours could also be as a result of the decrease in pH, which led to increase in TA and, hence, made the environment unconducive for their survivals.

Moreover, while DN1 and ACC present the first and second highest LAB (*Bacilli*), both DN1 and DN2 register the first and second highest for LAB (*Cocci*), respectively (Figure 9). While AG2 recorded the highest occurrence for presumptive fungi followed by DN2, DN2 and DN1 recorded the first and second highest Enterobacteriaceae, respectively. However, under 72 hr, DN1 recorded the highest microbial community, followed by DN2 and the least count by AG1 with their corresponding mean values as $[4.03 \pm 72.43]$, $[4.00 \pm 56.92]$ and $[3.85 \pm 40.11]$ $\log_{10}$·cfu/ml (Table 8). Statistically, there was no significance difference ($P > 0.05$) among the counts across the various samples.

Microbial studies on *kwete* (Namugumya and Muyanja, [29]; *kirario* (Kunyanga et al. [38] and *burukutu* beer (Faparusi et al. [39] presented similar results for lactic acid bacterial occurrences. However, while Kunyanga et al. [38]

Table 6: Chemical composition of traditional prepared *aliha* [Fisher's Least significance difference (LSD)].

Parameters	ACC	AG1	AG2	DN2	DN1
Moisture (g/100 g)	94.93 ± 0.01^{b}	96.31 ± 0.05^{a}	93.71 ± 0.01^{d}	94.00 ± 0.23^{c}	94.86 ± 0.03^{b}
Protein (g/100 g)	0.33 ± 0.01^{b}	0.54 ± 0.57^{a}	0.63 ± 0.01^{ab}	1.01 ± 0.01^{a}	0.36 ± 0.03^{b}
Ash (g/100 g)	0.09 ± 0.06^{b}	0.11 ± 0.01^{b}	0.19 ± 0.01^{a}	0.12 ± 0.01^{b}	0.09 ± 0.00^{b}
Total fats (g/100 g)	0.26 ± 0.01^{ac}	0.77 ± 0.07^{a}	0.22 ± 0.01^{c}	0.27 ± 0.01^{ac}	0.29 ± 0.00^{b}
Total Carb./fiber (g/100 g)	4.39 ± 0.01^{c}	2.27 ± 0.02^{d}	5.34 ± 0.05^{a}	4.60 ± 0.02^{b}	4.40 ± 0.01^{c}
Energy (Kcal/100 g)	32.00 ± 0.15^{c}	33.70 ± 0.31^{b}	25.38 ± 0.01^{d}	57.70 ± 0.06^{a}	21.65 ± 0.20^{e}
Iron (g/100 g)	11.36 ± 0.01^{a}	1.30 ± 0.26^{d}	10.65 ± 0.01^{c}	11.03 ± 0.01^{b}	11.36 ± 0.10^{a}
Calcium (g/100g)	55.21 ± 0.01^{c}	1.80 ± 0.15^{d}	53.50 ± 0.01^{a}	56.75 ± 0.01^{b}	56.49 ± 0.80^{b}
Phosphorus (g/100 g)	14.07 ± 0.01^{c}	22.29 ± 2.83^{a}	15.83 ± 0.01^{ac}	18.67 ± 0.01^{ab}	17.65 ± 2.68^{b}
Alcohol (ml/100 ml)	0.53 ± 0.00^{c}	0.53 ± 0.00^{d}	0.70 ± 0.00^{a}	0.53 ± 0.00^{c}	0.53 ± 0.00^{b}

Note: Values with different superscripts in the same row are significantly different at $p \leq 0.05$. Data presented are mean ± SD of triplicates of independent experiments. ACC-Accra; AG-Anloga; DN-Denu

Table 7: Microbial population and occurrence in indigenous fermented *aliha* under different hours of production.

Time (h)	Sample [Log_{10} Cfu/Ml]				
	DNI	DN2	AG1	AG2	ACC
LAB [Lactobacilli]					
0 H	2.63 ± 86.3^{ab}	0.00 ± 0.00^{b}	2.65 ± 30.9^{a}	2.51 ± 6.33^{a}	1.88 ± 45.4^{c}
24 HR	4.04 ± 7.21^{c}	4.10 ± 7.21^{a}	3.92 ± 7.01^{a}	3.96 ± 5.86^{a}	4.18 ± 6.71^{a}
72 HR	4.36 ± 6.71^{d}	4.99 ± 7.79^{a}	4.08 ± 22.9^{a}	5.06 ± 4.07^{a}	4.05 ± 7.21^{a}
LAB [Cocci]					
0 HR	2.53 ± 2.93^{a}	0.00 ± 0.00^{c}	1.30 ± 45.4^{c}	2.99 ± 3.04^{b}	3.69 ± 3.12^{a}
24 HR	2.91 ± 7.01^{b}	3.07 ± 6.33^{a}	3.43 ± 5.86^{ab}	4.16 ± 4.04^{b}	4.08 ± 14.0^{a}
72 HR	4.28 ± 6.71^{a}	5.25 ± 13.8^{a}	4.02 ± 14.0^{d}	4.99 ± 14.89^{b}	4.92 ± 7.79^{a}
FUNGI [Yeast and Mold]					
0 HR	2.28 ± 43.0^{a}	2.26 ± 1.89^{b}	3.11 ± 6.06^{a}	2.26 ± 42.9^{c}	2.41 ± 6.33^{c}
24 HR	2.66 ± 7.01^{a}	2.95 ± 30.9^{b}	4.05 ± 4.04^{b}	3.21 ± 3.04^{b}	2.79 ± 6.33^{b}
72 HR	2.41 ± 86.3^{b}	2.40 ± 3.04^{c}	4.04 ± 22.9^{c}	3.23 ± 4.07^{b}	2.26 ± 30.9^{c}
Enterobacteriaceae					
0 HR	3.78 ± 5.86^{b}	4.21 ± 4.04^{a}	4.57 ± 14.0^{c}	3.71 ± 6.06^{d}	53 ± 7.79^{d}
24 HR	4.23 ± 6.71^{b}	5.13 ± 13.8^{a}	4.72 ± 7.79^{c}	4.95 ± 7.79^{d}	6.85 ± 22.9^{c}
72 HR	4.22 ± 4.07^{b}	4.21 ± 14.0^{a}	4.23 ± 6.71^{c}	4.15 ± 7.21^{d}	5.23 ± 86.3^{c}

[1]Values are means of triplicate determinations from three independent trials; ± standard deviations (SD), ACC-Accra; AG-Anloga; DN-Denu. [2]Means with same letters and "ab" as superscripts in a row are significantly different ($P < 0.05$).

Table 8: Prevalence of mean microbiota for each fermentation period (Log_{10} cfu/ml).

Sample	0 hr	24 hr	72 hr	Mean ± SD	sig. (2-Tailed)
DN1	3.56	4.02	4.26	4.03 ± 72.43	0.124
DN2	3.58	4.05	4.17	4.00 ± 56.92	0.094
AG1	3.49	3.83	4.04	3.85 ± 40.11	0.094
AG2	3.38	4.06	4.80	3.94 ± 55.14	0.111
ACC	3.37	3.98	4.14	3.93 ± 58.09	0.125

ACC-Accra; AG-Anloga; DN-Denu.

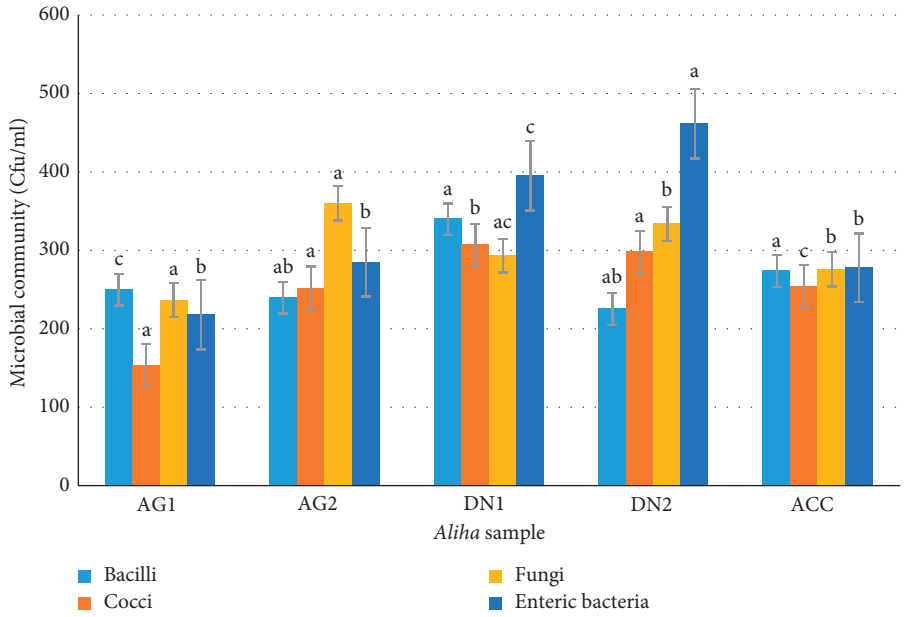

Figure 9: Occurrence of microbiota in traditional fermented aliha. Note: Values with the same superscripts on the same row are not significantly different at $P \leq 0.05$; Data presented are mean ± SD of triplicates of independent experiments. ACC-Accra; AG-Anloga; DN-Denu.

did not report any counts on enteric bacteria, Namugumya and Muyanja, [29] recorded slower decrease in fungi counts in *kwete* [5.03 ± 0.37 $\log_{10}$·cfu·ml to 4.48 ± 0.01 $\log_{10}$·cfu/ml] within 48 hours of fermentation as compare to fungi numbers in *aliha*.

4. Conclusion

There were four main *aliha* production processes identified across the three production regions. These differences were identified throughout the production chain, starting from soaking to fermentation. This diversity contributes to the inconsistencies in the final beverage and must be ironed out by developing a standard operation procedure (SOP) to be used for the production. This will however pave the way for industrializing the beverage. The age group of the producers was a factor that gives the beverage not only a lasting future, but also a viable venture.

The nutritional analysis also revealed that *aliha* produced by "original method" was the best followed by backslopping technique; however, aliha produced by "original method" was highly contaminated as compared to backslopping technique. Hence, using defined starter cultures to develop a SOP will be a better option for safety and to reduce the duration of production. Apart from the mean changes in titratable acidities of all the samples, which varied significantly within the 72 hours of fermentation, and no significant difference ($P > 0.05$) existed among temperature and pH. Moreover, as the pH decreased, titratable acidity increased leading to a significant decline in Enterobacteriaceae and fungi counts and massive increase in lactic acid bacteria counts in the final beverage across the production centers. The decrease in Enteric bacterial and fungal counts will lead to product safety, while the increase in the lactic acid bacteria will contribute to enhanced organoleptic properties of the final beverage and, hence, the need to identify the group of the LAB, characterize them and the most suitable strains of the dominant species used as starters for upscaling the production process.

Data Availability

The data used for the findings of this study are included within the article.

Conflicts of Interest

The authors declare no potential conflicts of interest.

Acknowledgments

University of Ghana Research Funds (UGRF) and Pan-African Doctoral Academy (PADA) under the "Building A New Generation of Academics in Africa (BANGA-Africa)" University of Ghana chapter. The authors acknowledge the research skills received from The World Academy of Science (TWAS) at the University of Zululand, South Africa.

References

[1] A. Ojokoh and B. Bello, "Effect of fermentation on nutrient and anti-nutrient composition of millet (Pennisetum glaucum) and soyabean (Glycine max) blend flours," *Journal of Life Sciences*, vol. 8, no. 8, 2014.

[2] O. C. A. P. Fnifst, *The Role of Traditional Food Processing Technologies in National Development: The West African Experience*, John R Lupien, Wrentham, MA, USA, 2008.

[3] B. Perez-Armendariz and G. A. Cardoso-Ugarte, "Traditional fermented beverages in Mexico: biotechnological, nutritional, and functional approaches," *Food Research International*, vol. 136, Article ID 109307, 2020.

[4] C. Wacher, "La biotecnología alimentaria antigua: los alimentos fermentados," *Retrieved from Revista Digital Universitaria*, vol. 15, no. 8, pp. 4-5, 2014.

[5] K. Robledo-Marquez, V. Ramírez, A. F. Gonzalez-Cordova, Y. Ramírez-Rodríguez, L. García-Ortega, and J. Trujillo, "Research opportunities: traditional fermented beverages in Mexico. Cultural, microbiological, chemical, and functional aspects," *Food Research International*, vol. 147, Article ID 110482, 2021.

[6] AOAC, *Official Methods of Analysis*, Association of Official Analytical Chemists, Inc. HII, Arlington, VA, USA, 1984.

[7] G. V. Reddy, Z. Zhao, and R. A. Humber, "Laboratory and field efficacy of entomopathogenic fungi for the management of the sweet potato weevil, Cylas Formicarius (Coleoptera: brentidae)," *Journal of Invertebrate Pathology*, vol. 122, pp. 10–15, 2014.

[8] P. Z. Mgqibandaba, F. K. Madilo, C. J. Du-Preez, J. Mjoka, and K. Unathi, "Evaluating food safety and hygiene knowledge and practices among foodservice staff of feeding scheme in the primary schools in Soweto, South Africa," *Journal of Food Safety*, vol. 40, no. 3, 2020.

[9] F. Hongbété, J. Kindossi, and N. Akissoé, "The Traditional Production System of Ablo, West Africa Steamed Cooked Moist Bread," *International Network for Natural Science*, vol. 11, 2017.

[10] L. Adinsi, G. Vieira-Dalode, N. Akissoe et al., "Processing and quality attributes of gowé: a malted and fermented cereal-based beverage from Benin," *Food Chain*, vol. 4, no. 2, pp. 171–183, 2014.

[11] C. Sacca, L. Adinsi, V. Anihouvi et al., "Production, consumption, and quality attributes of Akpan—a yoghurt-like cereal product from West Africa," *Food Chain*, vol. 2, pp. 207–220, 2012.

[12] L. Novellie and P. De Schaepdrijver, "Modern developments in traditional African beers," *Progress in Industrial Microbiology*, vol. 23, pp. 73–157, 1986.

[13] S. Haggblade and W. H. Holzapfel, "Industrialization of Africa's indigenous beer brewing," *Industrialization of Indigenous Fermented Foods*, Marcel Dekker, New York, NY, USA, 1989.

[14] K. Daiber and J. Taylor, *Opaque Beers. Sorghum and Millets: Chemistry and Technology*, American Association of Chemists, Inc, St Paul, MN, USA, 1995.

[15] M. Hébert, "Co-élaboration du sens dans les cercles littéraires entre pairs en première secondaire: étude des relations entre les modalités de lecture et de collaboration," 2003, https://papyrus.bib.umontreal.ca/xmlui/handle/1866/6794.

[16] M. R. Nout, "Traditional fermented products from Africa, Latin America and Asia," 2003, https://www.researchgate.net/publication/40127577_Traditional_fermented_products_from_Africa_Latin_America_and_Asia.

[17] H. Devautour and M. C. Nago, *Le maïs au Sud-Bénin: Innovations technologiques et alimentation*, John libbey eurotext, Montrouge, France, 1989.

[18] J. Taylor and J. Dewar, "Sorghum malting technology," in *Proceedings of the 5th Quadrennial Symp Sorghum and Millets ICC*, Paris, 1992.

[19] G. H. Palmer, O. U. Etokakpan, and M. A. Igyor, "Sorghum as brewing material," *MIRCEN Journal of Applied Microbiology and Biotechnology*, vol. 5, no. 3, pp. 265–275, 1989.

[20] C. Bamforth and A. Barclay, "Malting technology and the uses of malt," *Barley: Chemistry and Technology*, American Association of Cereal Chemists, St. Paul, MN, USA, 1993.

[21] D. E. Briggs, J. S. Hough, R. Stevens, and T. W. Young, *Malting and brewing science: malt and sweet wort*, Springer Science & Business Media, Berlin, Germany, 1981.

[22] K. Bhalla, S. B. Singh, and R. Agarwal, "Quantitative determination of gibberellins by high-performance liquid chromatography from various gibberellins producing Fusarium strains," *Environmental Monitoring and Assessment*, vol. 167, no. 1-4, pp. 515–520, 2010.

[23] K. Abegaz, F. Beyene, T. Langsrud, and J. A. Narvhus, "Indigenous processing methods and raw materials of borde, an Ethiopian traditional fermented beverage," *Journal of Food Technology in Africa*, vol. 7, no. 2, pp. 59–64, 2002.

[24] K. Hell, K. Cardwell, M. Setamou, and H.-M. Poehling, "The influence of storage practices on aflatoxin contamination in maize in four agroecological zones of Benin, West Africa," *Journal of Stored Products Research*, vol. 36, no. 4, pp. 365–382, 2000.

[25] M. Temba, P. Njobeh, and E. Kayitesi, "Storage stability of maize-groundnut composite flours and an assessment of aflatoxin B1 and ochratoxin A contamination in flours and porridges," *Food Control*, vol. 71, pp. 178–186, 2017.

[26] Taylor and Joustra, "Sorghum malt effect of hydrostatic pressure on malt quality," *Paper Presented at the Proceedings of the 4th Aviemore Conf. On Malting, Brewing and Distilling*, FG Institute of Brewing, London, UK, 1994.

[27] C. Ray Ramesh and V. K. Joshi, "Fermented Foods: Past, Present and Future," 2014, https://www.researchgate.net/publication/268740847_Fermented_Foods_Past_Present_and_Future.

[28] E. Korzeniewska, Z. Filipkowska, S. Domeradzka, and K. Wlodkowski, "Microbiological quality of carbonated and non-carbonated mineral water stored at different temperatures," *Polish Journal of Microbiology*, vol. 54, pp. 27–33, 2005.

[29] C. Muyanja and B. S. Namugumya, "Traditional processing, microbiological, physiochemical and sensory characteristics of kwete, a Ugandan fermented maize based beverage," *African Journal of Food, Agriculture, Nutrition and Development*, vol. 9, no. 4, 2009.

[30] R. Zvauya, T. Mygochi, and W. Parawira, "Microbial and biochemical changes occurring during production of masvusvu and mangisi, traditional Zimbabwean beverages," *Plant Foods for Human Nutrition*, vol. 51, no. 1, pp. 43–51, 1997.

[31] I. F. Fadahunsi, S. T. Ogunbanwo, and A. O. Fawole, "Microbiological and nutritional assessment of burukutu and pito (indigenously fermented alcoholic beverages in West Africa) during storage," *Nature and Science*, vol. 11, pp. 98–103, 2013.

[32] S. Aka, KF. N'Guessan, YZ. Nanga, YG. Loukou, AI. Mazabraud, and KM. Djè, "Characterization of Lactobacillus species isolated from mash, sour wort and tchapalo produced in Côte d'Ivoire," *Food*, vol. 4, no. 1, pp. 49–54, 2010.

[33] R. Adeleke and O. Abiodun, "Physico-chemical properties of commercial local beverages in Osun State, Nigeria," *Pakistan Journal of Nutrition*, vol. 9, no. 9, pp. 853–855, 2010.

[34] N. A. Amusa and O. A. Odunbaku, "Microbiological and nutritional quality of hawked kunun (a sorghum based non-alcoholic beverag) widely consomed in Nigeria," *Pakistan Journal of Nutrition*, vol. 8, no. 1, pp. 20–25, 2009.

[35] F. M. Abdoul-latif, I. H. N. Bassolé, and M. H. Dicko, "Proximate composition of traditional local sorghum beer

dolo manufactured in Ouagadougou," *African Journal of Biotechnology*, vol. 12, no. 13, pp. 1517–1522, 2013.

[36] V. Eze, O. Eleke, and Y. Omeh, "Microbiological and nutritional qualities of burukutu sold in mammy market Abakpa, Enugu State, Nigeria," *American Journal of Food and Nutrition*, vol. 1, no. 3, pp. 141–146, 2011.

[37] S. Aka, G. Konan, G. Fokou, K. M. Dje, and B. Bonfoh, "Review on African traditional cereal beverages," *American Journal of Research Communication*, vol. 2, no. 5, pp. 103–153, 2014.

[38] C. N. Kunyanga, S. K. Mbugua, E. K. Kangethe, and J. K. Imungi, "Microbiological and Acidity changes during the traditional production of kirario: an indigenous Kenyan fermented porridge produced from green maize and millet," *African Journal of Food, Agriculture, Nutrition and Development*, vol. 9, no. 6, pp. 1419–1435, 2009.

[39] S. I. Faparusi, M. O. Olofinboba, and J. A. Ekundayo, "The Microbiology of burukutu beer," *Zeitschrift f ur allgemeine Mikrobiologie*, vol. 13, no. 7, pp. 563–568, 2007.