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MICROBIOLOGICAL CONTAMINATION OF FERMENTED CASSAVA PRODUCTS SOLD IN LOCAL MARKETS, YAOUNDE (CAMEROON)

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ABSTRACT: *Locally processed cassava is a desirable staple food in Cameroon; however, microbiological hazards during processing, handling and/or consumption have been significantly ignored. This study investigated the microbiological quality of five fermented cassava products locally called Kum-kum, Garri, Water-fufu, Bobolo and Mintoumba, which are widely consumed and sold in local markets across Yaounde. A total of 200 samples (n=40 per food product) were analysed using microbial culture techniques. In addition, three parameters, moisture content, water activity, and pH were measured as indicators of each product shelf-life. The results showed that all food types were slightly acidic, ranging between 4.1 (Water-fufu) and 6.3 (Garri). Moisture and water activity were highest in Water-fufu (58.52% and 0.94) and lowest in Kum-kum (3.35% and 0.51) respectively. The presence of E. coli and coliforms (5.61log$_{10}$ CFU/g to 8.67log$_{10}$ CFU/g) indicated potential faecal contamination and improper product storage. Specifically, the mean total viable bacteria, yeast and mould count indicated unsatisfactory levels for human consumption and ranged from 5.33log$_{10}$ CFU/g (Mintoumba) to 7.22log$_{10}$ CFU/g (Water-fufu), and 4.23log$_{10}$ CFU/g (Garri) to 6.59log$_{10}$ CFU/g (Kum-kum) respectively. In terms of foodborne pathogens, all cassava products contained at least one pathogen of public health significance. Water-fufu significantly contained Bacillus cereus (33%), Vibrio cholerae (28%), Salmonella spp. (23%) and Campylobacter spp. (13%), and Staphylococci and Listeria monocytogenes were most prevalent in Kum-kum at 21% and 13% respectively. The results showed the short shelf-life characteristics of fermented cassava products consumed in Cameroon, and importantly, indicated a significant route of human exposure to enteric pathogens.*

KEYWORDS: Fermented cassava products, Food safety, Foodborne pathogens, Local markets, Public health risk, Cameroon.

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INTRODUCTION

The consumption of unsafe food causes about 137,000 deaths in Africa each year and this is equivalent in magnitude to malaria, HIV/AIDS, and tuberculosis (Havelaar et al., 2015; Morse et al., 2018). Although often unrecognised or under reported, enteric diseases such as cholera, non-typhoidal Salmonella, and *Escherichia coli* account for almost 70% of foodborne diseases in sub-Saharan Africa (Grace, 2015; Havelaar et al., 2015; Onyeaka et al., 2023). In such rural settings, food vending in informal or local markets is very common and more than 80% of the local population purchase foods including cassava products from these markets (Grace, 2015; Roesel & Grace, 2014; Ze et al., 2021). However, there is a high risk of foodborne diseases in local markets due to poor food handling, personal hygiene, and weak food safety regulations (Grace et al., 2010; Morse et al., 2018; Nijhawan et al., 2023; Roesel & Grace, 2014).

Cassava (*Manihot esculenta* Crantz) is consumed by more than 700 million people around the world and is perhaps one of the highest-value calorie foods in tropical countries (Halake & Chinthapalli, 2020; Ze et al., 2021). Its global production is currently estimated at 168 million tons per year, and Africa alone produces more than half of this amount (Adebayo-Oyetoro et al., 2013; Ze et al., 2021). Cassava roots are considered a nutritionally rich staple and contain almost twice the calories of potatoes (*Solanum tuberosum)*, together with valuable vitamins (folates, thiamin, pyridoxine, riboflavin) and minerals (zinc, magnesium, copper, iron, and potassium) (Halake & Chinthapalli, 2020).

Typical in most African countries, cassava roots have gone from beyond a ‘boil and eat’ to several processed products resulting from fermentation, roasting, and drying (Halake & Chinthapalli, 2020; Njukwe et al., 2014). In Cameroon, cassava contributes to about 7.6% of starchy calorie intake and it is consumed daily in over 80% of rural and urban households (Essono et al., 2008; Fon & Djoudji, 2021; Donfack et al., 2021). It occupies more than 60% of the Cameroonian market share for roots and tubers, that is, 40% for processed fermented products and 20% for the fresh root (Fon & Djoudji, 2021). Indeed, fermented cassava products, typically processed by retting, are widely traded in African local markets (Bauer, 2019; Halake & Chinthapalli, 2020; Ze et al., 2021).

Several research (Bauer, 2019; Dufour, 2013; International Fund for Agricultural Development, 2017; Igwacho et al., 2016; Nchang, 2008; Njukwe et al., 2014; Ze et al., 2021) have focused on the development of improved cassava varieties and/or on enhancing women’s livelihood through cassava processing in Cameroon. However, there is no existing data on the microbial quality of these cassava products, which are largely processed and sold under unregulated food safety conditions. Acknowledging that cassava processing is an important pathway to reduce poverty in Africa, human exposure to foodborne pathogens during cassava processing, handling and/or consumption could be devastating to public health.

The purpose of this study was to investigate the microbiological quality of fermented cassava products sold in different local markets in Yaounde, Cameroon. In addition, the moisture content, water activity, and pH were measured as indicative parameters of each product shelf-life.

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MATERIALS AND METHOD

Study Area, Sample Collection, and Preparation

The study was carried out between November 2022 and April 2023 in Yaounde. Yaounde is the political capital of Cameroon and is located between latitude 3°47′ to 3°56′N and longitude 11°10′ to 11°45′E (Tanyitiku et al., 2023). Its population is estimated at 2.5 million and is the second largest populated city in Cameroon after Douala (Edima et al., 2014; Tanyitiku et al., 2023). Five locally fermented cassava products, called *Kum-Kum, Garri, Water-Fufu, Bobolo,* and *Mintoumba,* were sampled for analysis. The local methods used to process these fermented cassava products are outlined in Figure 1. Freshly harvested cassava roots are manually peeled and washed, then soaked in water for 3 to 4 days to soften (Fon & Djoudji, 2021; Halake & Chinthapalli, 2020). Once fermented, they are drained, manually pressed with heavy stones or wood to obtain: *Water-fufu*, or sun dried for *Kum-kum* or sieved and toasted with or without palm oil for *Garri* or ground into cassava paste that could be used to prepare cassava sticks (*Bobolo* or *Miondo*) or *Mintoumba* (Dufour, 2013; Fon & Djoudji, 2021; Ze et al., 2021).

In total, 200 samples (40 samples per food product) were purchased weekly from six randomly selected women who sold at six main local markets, namely Acacias, Mendong, Mokolo, Nsam, Mfoundi, and Etoudi in Yaounde, Cameroon. Each sample was placed aseptically in a sterile polythene bag, labelled, and transported in ice packs to the laboratory. Specifically for *Mintoumba* and *Bobolo* that were gelatinised through steaming, samples were prepared for analysis as described by Tanyitiku et al. (2023) with slight modifications. Each purchased sample was aseptically separated from the wrapped leaves (*Megaphrynium marostachyum*) and finely chopped using a sterile steak knife and cutting board. 500 g of each chopped sample was weighed and transferred to a different polythene bag. The procedure was repeated for all food samples, with the cutting board and knife cleaned and sterilised between samples to prevent cross-contamination. All samples were analysed in triplicate within one hour after sample collection.

Moisture, Water Activity, and pH Measurements

Twenty (20) randomly selected samples per food product were used to determine the moisture content, water activity and pH. Moisture was obtained according to AOAC (2010). It was the weight difference when 5 g of each sample was oven-dried at 105°C for 24 h. Water activity (a_w) was measured using a water activity meter (Aqualab, USA), according to manufacturer's guidelines. pH was measured as described by Adebayo-Oyetoro et al. (2013) using a pH meter (Hanna Instruments, Spain). 10 g of each sample was briefly vortexed in 100 mL of deionised water and using a glass probe, pH readings were taken in triplicate.

Microbiological Analysis

In Table 1, several microbiological analyses were carried out. 25 g of each sample was homogenised in 225 mL of sterile buffered peptone water (BPW) using a stomacher and incubated at 37 ° C for 20 h. Serial dilutions (10^{-1} to 10^{-6}) were then prepared using 9 mL of BPW and 50 µL of each diluted sample was plated on the respective agar media and incubated conditions in Table 1. In particular, *Salmonella* spp. and *Campylobacter* spp. were preenriched in MSRV and Bolton broth, respectively.

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Colonies were presumptively identified by Gram staining and biochemical tests (catalase, and oxidase). Gram reaction included crystal violet stain, Gram's iodine, 95% acetone as decolourizer and safranin as counterstain. 3% hydrogen peroxide solution and oxidase strips were used for catalase and oxidase tests respectively.

Statistical Analysis

Statistical analysis was carried out using Microsoft Excel 365 and IBM SPSS statistics 23. All enumerated and identified bacteria colonies were expressed in $\log_{10}$ CFU/g as mean ± standard deviation. One-way ANOVA was used to compare the mean and when significant ($p<0.05$) differences between means were observed, the means were separated using Tukey's test. In addition, the results were expressed in microbial prevalence (%), that is, the occurrence of each pathogen in the total number of samples (n=40).

RESULTS AND DISCUSSION

Moisture, Water Activity, and pH of Cassava Products

The moisture, water activity (a_w) and pH values varied significantly ($p <0.05$) from one fermented cassava product to another (Table 2). The mean moisture and water activity were highest in *Water-fufu* (58.52% and 0.94) and lowest in *Kum-kum* (3.35% and 0.51) respectively. *Garri* and *Kum-kum* had significantly ($p <0.05$) lower moisture and water activity as compared to *Water-fufu* or *Bobolo*. This could have been due to additional toasting and sun-drying after fermentation. After seven days of exposure to humidity, Adewale et al. (2009) reported higher moisture content in *Gari* (29.64%), *Fufu* (17.68%) and *Lafun* (22.2%). Also, Adetunji et al. (2018) recorded a moisture content range of 6.21% (*Garri)* and 72.25% (*Fufu*) in fermented cassava food products sold in the Ilorin-west local government area, Nigeria. While moisture content is the amount of water present in a food sample, water activity measures the water available for biological reactions. For example, food spoilage bacteria will normally grow when a_w is greater than 0.91, while moulds and yeasts will grow at a_w less than 0.80 (Mitrevski et al., 2023). These research results thus indicated that a shorter shelf life could be expected in *Water-fufu, Bobolo, Mintoumba, Garri*, and *Kum-kum*.

On the other hand, the pH readings were slightly acidic, and was lowest in *Water-fufu* (4.1) and highest in *Garri* (6.3). Consistent with our findings, Padonou et al. (2009) reported pH values ranging between 6.2 and 5.9 in ordinary *Lafun* and *Chigan lafun*, a fermented cassava product consumed in Benin, Nigeria. Likewise, Olopade et al. (2014) reported pH values ranging between 4.76 and 4.94 (yellow *Gari*), and 4.78 and 4.91 (white *Gari*) in fermented cassava (*Gari*) sold in Ota Ogun state, Nigeria. Notably, microorganisms, including yeast and moulds, are very sensitive to the pH of food, as a very low or very high pH will inhibit growth. Ozoh et al. (2023) highlighted that the presence of lactic acid bacteria during fermentation (also enumerated in this research in Table 3) could reduce the pH of fermented cassava products. However, processing techniques such as cutting, pressing and sifting in addition to the action of endogenous enzymes, could lead to loss in the cassava structure, thus increasing the surface area for microbial growth (Ozoh et al., 2023).

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Microbial Quality of Fermented Cassava Products

The microbiological contamination of the fermented cassava products examined in this research is presented in Table 3. In general, all food samples were highly contaminated with microorganisms. *Garri* and *Mintoumba* indicated a relatively ($p < 0.05$) lower microbial count than *Water-fufu, Kum-kum* and *Bobolo*. Specifically, *Water-fufu* food samples were largely infested with microbial contaminants indicating that subsequent processing could have influenced the rate of microbial growth in *Kum-kum, Garri, Mintoumba* and *Bobolo.*

The mean aerobic colony count ranged from $5.33\log_{10}$ CFU/g (*Mintoumba*) to $7.22\log_{10}$ CFU/g (*Water-fufu*). Like aerobic colony count, mean *E. coli* and coliforms count were high ranging between $5.61\log_{10}$ CFU/g (*Mintoumba*) and $8.67\log_{10}$ CFU/g (*Water-fufu*). In contrast to these results, Adebayo-Oyetoro et al. (2013) reported lower bacterial count of $3.2\text{-}5.3\text{x}10^6$ CFU/mL in fermented cassava flour (*Lafun)* sold in Ogun and Oyo states markets, Nigeria. Olopade et al. (2014) recorded aerobic plate count of $2.0\text{x}10^2\text{-}1.1\text{x}10^4$ CFU/mL (white *Gari*) and $1.0\text{x}10^2\text{-}5.0\text{x}10^3$ CFU/mL (yellow *Gari*) in fermented *Gari* sold in Ota Ogun state, Nigeria. Plate count of aerobic organism is an indicator for food quality and reflect the existence of favourable conditions for the multiplication of such microorganisms (Nyenje et al., 2012). *E. coli* and coliforms are common faecal indicator organisms in food that suggest a general lack of cleanliness in handling as well as improper storage (Centre for Food Safety, 2014). While *Water-Fufu, Garri,* and *Kum-kum* are raw fermented cassava products that require additional cooking into a dough prior to consumption, *Bobolo* and *Mintoumba* are ready-to-eat foods. The HACCP-TQM (Total Quality Management) Technical Guidelines (2000) laid down the microbial quality of raw foods as food containing $<10^4$ CFU/g are rated as 'good', $10^4\text{-}5\text{x}10^6$ CFU/g as 'average', $5\text{x}10^6\text{-}5\text{x}10^7$ CFU/g as 'poor' and $>5\text{x}10^7$ CFU/g as 'spoilt' (Tanyitiku et al., 2023). Also, in fully cooked ready-to-eat foods such as *Bobolo* and *Mintoumba*, the acceptable bacterial count for human consumption should be $<5\log_{10}$ CFU/g (Health Protection Agency, 2010; Nyenje et al., 2012). With this, this research results thus indicated the unsatisfactory limits of fermented cassava products consume in Cameroon (Center for Food Safety, 2014).

The mean lactic acid bacteria (LAB) isolated in this research ranged between $2.54\log_{10}$ CFU/g (*Garri*) and $7.97\log_{10}$ CFU/g (*Water-fufu*). Yeast and moulds ranged between $4.23\log_{10}$ CFU/g (*Garri*) and $6.59\log_{10}$ CFU/g (*Kum-kum*) (Table 3). In a similar study, Adegbehingbe et al. (2019) reported an increase in LAB and fungi from $2.0\text{x}10^5$ CFU/mL to $7.6\text{x}10^6$ CFU/mL, and $1.5\text{x}10^3$ CFU/mL to $1.0\text{x}10^6$ CFU/mL respectively during a three-day fermentation period of Nigerian *Fufu*. In this research, the *Garri* and *Mintoumba* food samples significantly ($p < 0.05$) contained a lower LAB count, which could have been due to the antibacterial properties of palm oil that was added during processing (Laloučková et al., 2019).

Microorganisms such as LAB, yeast and moulds have been found to play significant roles in the fermentation of cassava products. The cassava roots are softened, the tissue structure is disintegrated and starch is hydrolysed to glucose and cyanohydrins (Halake & Chinthapalli, 2020). Although these processes are desirable in terms of improved nutritional, sensory aroma and flavour, the sources of these microorganisms during local cassava processing are usually uncontrolled and either 1) generated during cassava soaking or 2) from the raw cassava itself, or 3) from unhygienic practices leading to numerous transfers of microbial load from dirty hands, traditional utensils used, as well as from surrounding rodents and uncaged animals (Halake & Chinthapalli, 2020; Adegbehingbe et al., 2019; Shehu & Ridwan, 2022; Tefera et al., 2014). Nonetheless, moulds are common environmental contaminants due to their ability

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to proliferate and produce spores (Olopade et al., 2014). This could explain the high yeast and moulds in *Kum-kum*, which is usually sun-dried under weather dependent conditions on polythene sacks or on tarred roads and highways. Moreover, the presence of yeast and moulds, in combination with the corresponding water activity (in Table 2), further indicates the shorter shelf-life characteristics of fermented cassava products sold in local markets and/or consumed in Cameroon.

IMPLICATION TO RESEARCH AND PRACTICE

The practical implication of this research could be seen directly from the bacterial pathogens isolated in this study. In Table 3 and Figure 2, foodborne pathogens of significant public health importance are presented, namely, *Bacillus cereus, Vibrio cholerae, Listeria monocytogenes,* coagulase positive staphylococci, *Salmonella* spp., and *Campylobacter* spp. All cassava products contained at least one foodborne pathogen examined. *Water-fufu* food samples were significantly ($p < 0.05$) higher in *B. cereus* ($5.60\log_{10}$ CFU/g), *V. cholerae* ($7.45\log_{10}$ CFU/g), *Salmonella* spp. ($7.57\log_{10}$ CFU/g) and *Campylobacter* spp. ($3.40\log_{10}$ CFU/g) with a bacterial prevalence of 33%, 28%, 23%, and 13%, respectively. *Kum-kum* food samples were highest in Coagulase-positive Staphylococci ($5.64\log_{10}$ CFU/g, 21%) and *L. monocytogenes (*$5.82\log_{10}$ CFU/g, 13%), which could have been due to multiple manual handling and direct contact with the soil during sun-drying in unpredictable weather conditions and 2) during unpackaged vending practices at the local markets. Consistent with this research results, Sama et al. (2023) isolated *Actinobacter, Bacillus cereus, Pseudomonas auruginosa,* and *Pseudomonas plecoglossicida* in *Water-fufu* samples obtained from local processors in Buea, Cameroon. Shehu and Ridwan (2022) isolated *Staphylococcus aureus, Lactococcus lactis, Bacillus cereus Bacillus megaterium, Alcaligenes faecalis, Citrobacter freundii, Bacillus subtilis, Aeromonas hydrophila* in cooked cassava sold in Sokoto market, Nigeria. Likewise, Olopade et al. (2014) isolated *Bacillus* spp., *Enterobacter* spp., *Pseudomonas, Staphylococcus,* and *Klebsiella* spp. in *Gari* sold in Ota, Ogun State, Nigeria.

Several socio-economic, environmental, and hygienic conditions have been highlighted to contribute to the microbial quality of these processed cassava from other African countries. For example, in two studies from Nigeria, Olopade et al. (2014) recorded coliforms ranging between 6.0×10^3 CFU/g (yellow *Garri*) and 7.1×10^3 CFU/g (white *Garri*), and this was attributed to post-processing contamination, such as *Garri* sifting after toasting, spreading in open air to dry, and the practice of selling unpackaged *Garri* at local markets. Lateef and Ojo (2015) attributed microbial contamination of *Lafun* (cassava flour) to the local processor's living conditions, namely, 1) people living at nearly 50 m to waste dumping sites that also serves as human toilets, 2) cassava being processed around domestic animals such as goats and poultry, and 3) the used of poorly sourced water from the rain, wells, and flowing river that are subsequently stored in open or rusty containers (Lateef & Ojo, 2015). In line with these conditions of the rural setting in Cameroon, Bate, (2020) described the waste disposal and management system in Buea as 'poor' 'pathetic' and 'rudimentary orchestrated' that could increase the prevalence of diseases. Kuitcha et al. (2010) reported higher faecal coliforms (34053 ± 94225.5 CFU/100mL) and faecal streptococci (15107.6 ± 50515 CFU/100 mL) at several water points in Yaounde. The level of bacterial load was high in rivers (127866.67 ± 155254.57 CFU/100mL), wells or boreholes (2966.10 ± 3786.15 CFU/100mL) and springs (340.67 ± 557.98 CFU/100mL) (Kuitcha et al., 2010). As such, the use of water from such

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sources to process cassava could have contributed to the adverse microbial quality of fermented cassava products in the study area.

Furthermore, the foodborne pathogens isolated in this research have also been associated with other food products sold in Cameroon. For example, Tanyitiku et al. (2022) recorded a high prevalence of *Campylobacter* spp. (75%), *Yersinia* spp. (71%), *Listeria* spp. (86%), *Salmonella* spp. (69%), and Shiga-toxigenic *E. coli* (57%) in edible African land snails sold in local markets. Djoulde et al. (2015) isolated *E. coli* (30%), *Bacillus cereus* (23%), *Staphylococcus aureus*, (19%), *Salmonella* spp. (15%), yeast and moulds (5%) in street-vended roasted beef, pork, chicken, and sun-dried beef locally called *Kilishi*. Assessing the food vendor's faeces, Assob et al. (2012) isolated more than one faeco-orally transmissible parasite, namely: *Entamoeba coli (14.0%), Entamoeba histolytica (12.67%), Ascaris lumbricoides (11.33%), Ankylostoma duodenalis (10.67%), Blastocystis hominis (4.67%), Giardia lamblia (3.33%), Enterobius vermicularis (2.00%), Balantidium coli (1.35%), and Trichuris trichiura (1.33%).* Moreover, it should be noted that detection of foodborne pathogenic bacteria, especially *Campylobacter* spp. *Salmonella* spp. and *V. cholerae* in ready-to-eat foods represent an unacceptable risk to health regardless of the number of bacteria present (Health Protection Agency, 2010). With this, this study strongly indicated that the consumption of these contaminated cassava products could have fatal health consequences, particularly at a time when Cameroon, among other countries in Central Africa, is leading the cholera pandemic at a rate of 3.3%, with 6,158 cases and 201 deaths registered in August 2023 (Africa Centers for Disease Control and Prevention, 2023; Health Protection Agency, 2010; Tack, 2019).

CONCLUSION

To our knowledge, this research is the first to examine selected microbial pathogens in fermented cassava products sold in local markets in Yaounde, Cameroon. The results have shown that locally processed cassava products contained foodborne pathogens that could pose a significant risk to public health.

FUTURE RESEARCH

From the findings of this research, further research could be carried out to:

1. validate the microbial isolates in this research, for example, using molecular characterisation and identification techniques,
2. identify the different routes of microbial contamination of locally fermented cassava products,
3. understand these microbial survival characteristics, which could be used to limit microbial growth during fermentation and product storage, and
4. establish clinical cases that further provide evidence that local cassava processing, handling, and consumption practices could be a credible source of transmission of food-related illnesses to the studied population.

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Notwithstanding, the findings of this research indicated that food handlers and consumers are significantly at risk of foodborne diseases in fermented cassava activities. There is therefore an urgent need to mitigate this health risk through effective food safety regulations and interventions from cassava production to consumption in Cameroon.

FIGURES

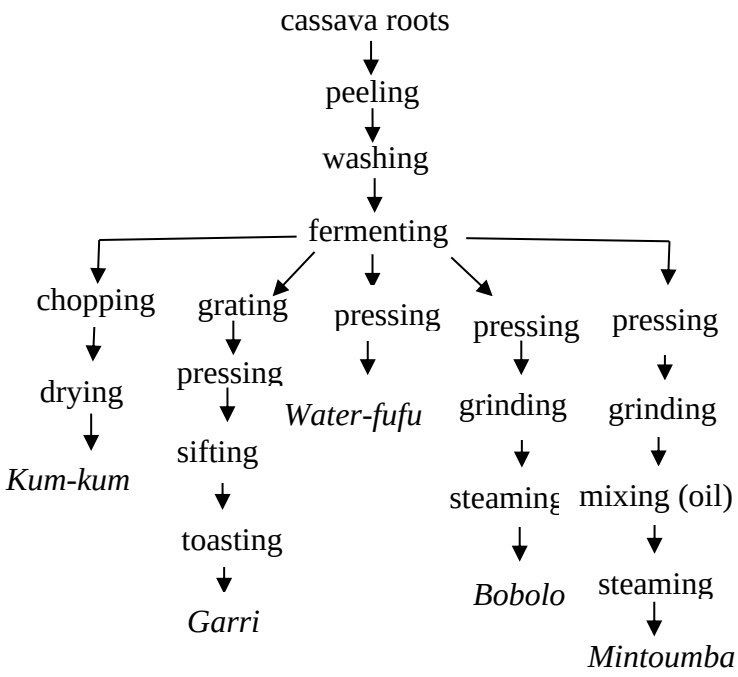

Figure 1: Fermented cassava products consumed in the study area (Fon & Djoudji, 2021).

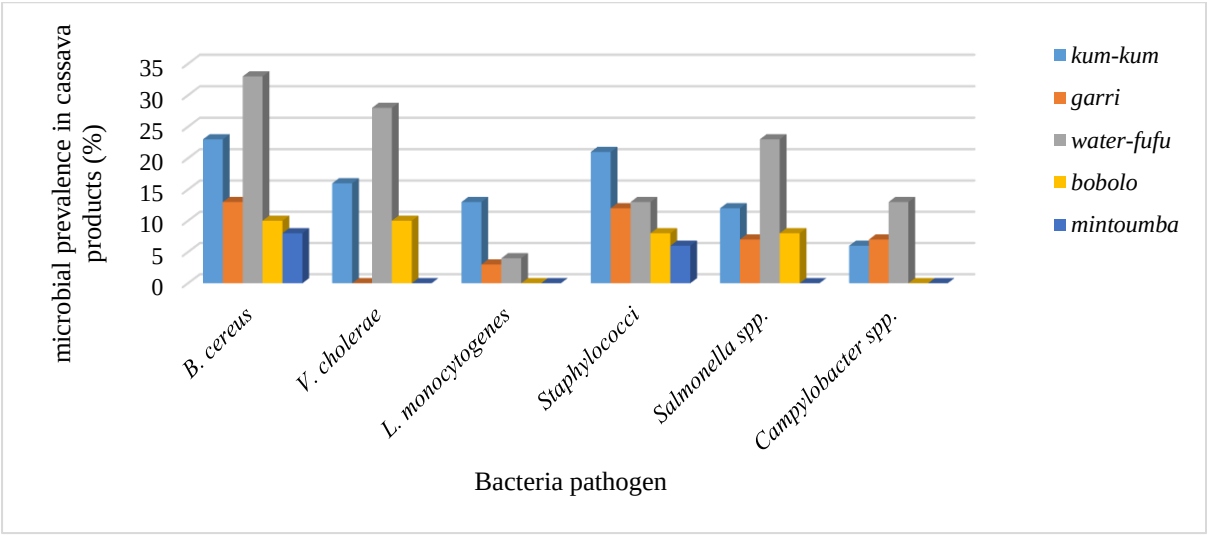

Figure 2: Microbial prevalence in fermented cassava products sold in Yaounde, Cameroon

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TABLES

Table 1: Microbiological Analysis of Fermented Cassava Products

Microorganisms	Agar media	Incubation	Reference
Aerobic colony count	PCA (Oxoid, CM0325)	37°C, 48h	Loy-Hendrickx et al. (2018)
E. coli and coliforms	RAPID'*E coli* 2 (Bio-Rad 3564024)	37°C, 24h	Loy-Hendrickx et al. (2018)
Yeasts and moulds	YGC (Bio-Rad, 3564104)	25°C, 5days	Loy-Hendrickx et al. (2018)
Lactic acid bacteria	MRS (Oxoid, CM0361) +1.4 g/L sorbic acid	30°C, 3days	Loy-Hendrickx et al. (2018)
Bacillus cereus	MYP (Oxoid, CM0929)	30°C, 24h	Loy-Hendrickx et al. (2018)
V. cholerae	TCBS (Oxoid, CM0333)	37°C, 24h	Huq et al. (2012)
L. monocytogenes	RAPID'*L.mono* (Bio-Rad, 3555294)	37°C, 24h	Loy-Hendrickx et al. (2018)
Coagulase-positive Staphylococci	BP (Oxoid, CM1127)	37°C, 48h	Loy-Hendrickx et al. (2018)
Salmonella spp.	MSRV (Oxoid, CM1128) + SR0181[a], then XLD (Oxoid CM0469)[b]	42°C, 24h[a] 37°C, 24h[b]	Solís et al. (2022)
Campylobacter spp.	Bolton broth (Oxoid, CM0983)[a], then Skirrow (Oxoid, CM0331)[b]	37°C, 24h[a] 42°C, 48h[b]	Solís et al. (2022)

The same superscripts, a and b, as in the same row, correspond to agar media and incubation conditions, respectively.

Table 2: Moisture and Water Activity of Cassava Products

Food types	Moisture content (%)	Water activity	pH
Kum-kum	3.35±0.51[a]	0.51±0.02[a]	5.0±0.02[a]
Garri	5.49±0.34[b]	0.67±0.00[b]	6.3±0.00[b]
Water-fufu	58.52±0.47[c]	0.94±0.04[c]	4.1±0.02[c]
Bobolo	15.40±0.65[d]	0.84±0.02[d]	5.6±0.04[d]
Mintoumba	16.94±0.18[e]	0.73±0.00[e]	4.9±0.02[e]

Results are expressed as mean ± standard deviation of three replicates, different superscripts (a, b, c….) within the same column are significantly ($p < 0.05$) different.

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Table 3. Microbial counts of the cassava products examined.

Organisms	**Microbial count (log_{10}CFU/g)**				
	Kum-kum	*Garri*	*Water-fufu*	*Bobolo*	*Mintoumba*
Aerobic colony count	6.32±0.18^{ab}	5.75±0.80^{ac}	7.22±0.71^{a}	6.15±0.63^{ab}	5.33±0.82^{ac}
E. coli and coliforms	7.44±0.51^{ac}	6.91±0.45^{a}	8.67±1.02^{ac}	6.89±0.96^{a}	5.61±1.06^{a}
Yeasts and moulds	6.59±0.22^{a}	4.23±2.56^{b}	6.45±0.63^{a}	5.19±1.26^{a}	4.59±0.24^{b}
Lactic acid bacteria	6.28±0.13^{a}	2.54±0.04^{b}	7.97±0.51^{c}	5.66±0.02^{d}	3.10±0.71^{e}
Bacillus cereus	4.43±0.46^{a}	3.83±0.33^{a}	5.60±0.02^{b}	2.95±0.11^{c}	1.54±0.90^{d}
V. cholerae	6.54±0.18^{a}	ND	7.45±0.74^{c}	6.29±1.36^{a}	ND
L. monocytogenes	5.82±0.08^{a}	2.08±0.00^{b}	1.29±0.43^{c}	ND	ND
Coagulase-positive staphylococci	5.64±1.34^{a}	2.39±0.21^{b}	2.08±0.31^{b}	3.89±0.24^{c}	5.66±0.88^{a}
Salmonella spp.	5.58±0.45^{a}	3.66±1.46^{b}	7.57±0.62^{c}	6.11±2.12^{d}	ND
Campylobacter spp.	1.04±0.43^{a}	2.32±0.59^{b}	3.40±0.85^{b}	ND	ND

CFU: colony-forming units, ND: Not determined, results are expressed as mean ± standard deviation of three replicates, different superscripts (a, b, c, etc.) within the same row are significantly ($p < 0.05$) different.

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