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Comparison of Microbiological and Sensory Qualities of 'fufu' Processed from Grinding Machines and the Traditional Method at Ayigya in the Kumasi Metropolis, Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MGA and KB designed the study, performed the statistical analysis, wrote the protocol and managed the analyses of the study and the literature searches. Author AHM managed the analyses of the study and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study compares the bacteriological and sensory characteristics of' fufu' processed using grinding machines and traditional method at Ayigya, a suburb of Kumasi between December 2018 and February, 2019. Samples were collected from three different sites for fufu grinding machine and three sampling areas for traditional method using mortar and pestle and were coded GM_1, GM_2 and GM_3; and MP_1, MP_2 and MP_3 respectively. Bacterial counts and isolation from all the samples were done using standard methods. Morphological and biochemical characterization of the isolates were done and the organisms were identified using standard identification key. The sensory qualities of the samples were evaluated by a 20 member panelists of regular consumer of fufu. Bacterial counts of fufu processed using grinding machine ranged between 4.90×10^3 and 5.88 x 10^3 CFU/g while those obtained through traditional method of processing were between 2.01×10^3 and 2.76×10^3 CFU/g. Of the 72 bacterial isolates, 47(65.3%) of the isolates were Gram negative while 25(34.7%) were Gram-positive. The most frequent isolates in the samples were *Staphylococcus* sp. (34.7%),

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Escherichia coli (30.6%), *Klebsiella* sp. (22.2%) and *Proteus* sp. (12.5%). Consumer acceptance of 'fufu' obtained from the use of traditional pestle and mortar was significantly higher ($P < 0.001$) than those obtained from the use of grinding machine. The study concluded that *Klebsiella*, *Staphylococcus*, *Proteus* and *E. coli* are associated with both the fufu grinding machines and the traditional mortar and pestle products and that consumers prefer the processed 'fufu' from the traditional source to the grinding machine.

Keywords: Grinding machines; pestle; mortar; traditional; microbial; processing; consumer.

1. INTRODUCTION

Fufu is a traditional staple dish popularly eaten in Ghana and most African countries [1,2]. It is described as a local delicacy in Ghana particularly in the Ashanti region. Though some prepare it using yam or cocoyam, it is mostly made from cassava processed into starchy staples with smooth consistency [3]. Adeyeye and Aye [4] reported that the crop's ability to provide a staple food base is a function of its flexibility in terms of planting and harvesting strategies and because of its relative tolerance of poor soils and pest/disease problems. It is reported that cassava provides a relatively cheaper energy source for more than 800 million people around the world with a moisture content of 65% to 70% on dry weight basis [5].

Details and methods of fufu preparation vary from locality to locality and this may greatly affect the quality of the finished product [6]. Traditionally, it involves the use of mortar and pestle for pounding boiled cassava into athick paste (fufu). This is done repeatedly accompanied by driving and application of water using the hand to get a smooth consistency [7]. However, this process often requires a lot of labour and sometimes described as an unhygienic preparation method. In line with this, efforts have been made to do away with the traditional method which involves the use of mortar and pestle.

Recently, technological advancements in Ghana have led key institutions to devise new and innovative methods of preparing fufu [8]. These institutions developed a locally manufactured machine that shortens the process of fufu preparation, improve the hygienic conditions under which the food is prepared and do not require intensive labor. These machines are used on commercial basis and are mostly found in market places and some communities.

Despite the ease of usage, there are concerns over the hygienic practices of the operators. This is because cassava and its products, like other food materials, have the potential for supporting the growth of both pathogenic and spoilage microorganisms [9]. Also, since these machines are stationed in the markets and the community, there is a high risk of introducing microbial contamination directly from handlers or the environment during processing and transportation. In addition, improper routine cleaning of the grinding grooves of the machine may results in food particles sticking between the grooves and can therefore serve as a source of microbial contamination and may pose a potential health risk to humans. Currently, there is scanty literature with regards to the microbial quality of fufu products from these newly created technological machines currently used by large populations in Ghana especially Ashanti region. Therefore, the present study was aimed at comparing the bacteriological and sensory characteristics of 'fufu' processed using grinding machines and traditional method at Ayigya, a suburb of Kumasi.

2. MATERIALS AND METHODS

2.1 Sample Collection

Triplicate samples were obtained from motorized grinding machine from three milling sites in the Ayigya suburb during the months of December, 2018, January and February, 2019 and were coded as GM_1, GM_2 and GM_3. Another batch of triplicate samples were obtained from three sites which use mortar and pestle as a form of traditional method of fufu preparation. They were labelled as MP_1, MP_2 and MP_3. All samples were transported to the microbiology laboratory in the department of Theoretical and Applied Biology-KNUST for further processing.

2.2 Microbiological Analysis

Swabs used to rub the inlet of the fufu grinding machine and one gram of fufu and before, during and after the grinding of the fufu from each of the sites (in triplicate) was wrap separately and homogenized in 9.0 ml of sterile peptone water.

The surfaces of the mortar, its crevices and the brush of the pestles were also swapped and kept in peptone water. Serial dilutions were made up to 10^{-10} dilution. Isolation of bacteria was done according to descriptions outlined by Collins and Lyne (1984). Nutrient agar and MacConkey agar were used for the isolation process and incubation of plates were done at 37°C for 48 h. Total viable counts of bacteria were determined by enumerating the colony forming units (cfu/g) by pour plating 1.0 ml of10^{-5} dilution. In all cases, the experiments were repeated in triplicates. Pure and discrete cultures of bacteria isolates were obtained on the nutrientagar and MacConkey agar.

2.3 Characterization and Identification of Isolates

Initially, bacterial isolates were grouped by examining the colonies macroscopically. This was followed by colony counting after which several colonies were picked at random and differentiated based on their cultural properties followed by physiological and biochemical tests (Citrate test, indole test, starch fermentation test, catalase test and methyl red test). The characteristics were compared with those in Bergey's Manual of Determinative Bacteriology 9th Edition of 1992. Gram staining was also done to determine gram positive and gram-negative bacteria.

2.4 Sensory Evaluation of 'fufu' Product from Grinding Machines and Mortar and Pestle

Sensory analysis was carried out on the texture, odour, taste and colour of the products. A 20 member panelists who regularly patronize and consume fufu from these machines and fufu eating joints respectively were recruited in this exercise. Questionnaire for panelists using a 7-point Hedonic scale to indicate the various characteristics as: 1- Extremely unacceptable, 2- Moderately unacceptable, 3- Slightly unacceptable, 4- Neither acceptable nor unacceptable, 5- Slightly acceptable, 6- Moderately acceptable, 7- Extremely acceptable.

2.5 Data Analysis

The plate counts were expressed in colony forming unit (CFU/ml). Data obtained were subjected to statistical analysis using Microsoft excel. Significance differences were established when $p < 0.001$.

3. RESULTS

3.1 Bacterial Isolates

Tables 1 and 2 showed the microbial counts of samples obtained from the use of both the machines and the mortar and pestle. Colony counts of the isolates were obtained in discrete forms after serial dilutions and pour plating on nutrient agar. The number of colonies were counted and averaged for each dilution factor. Comparing microbial numbers obtained from fufu grinding machines at Ayigya, GM_2 had the highest microbial numbers for serial dilution factor 10^{-1} with 5.88 x 10^3 CFU/ml as compared to GM_1 and GM_3 which recorded 5.76×10^3 CFU/ml and 4.90×10^3 CFU/ml respectively (Table 1).

Also, when the samples obtained from the mortar and pestle were enumerated and compared, MP_3 recorded the highest microbial numbers for the serial dilution factor 10^{-1} with a value of 2.76×10^3 CFU/ml followed by samples MP_1 and MP_2 which recorded 2.07×10^3 CFU/ml, 2.01×10^3 CFU/ml respectively whilst the sterile mortar and pestle (SMP) sample recorded the least value of 1.98×10^3 CFU/ml. For the serial dilution factor of 10^{-2}, sample MP_3 recorded the highest microbial numbers of 2.13×10^3 CFU/ml.These values were not significantly different ($P > 0.001$) compared with the values obtained for the sterile mortar and pestle samples (Table 2).

3.2 Biochemical Test and Isolates

In all, 72 pure cultures were isolated from all the samples obtained from grinding machines and mortar and pestle. Distinct colonies were isolated based on colour, shape, margin, elevation, and opacity. From the Gram staining reaction, 47(65.3%) of the isolates were Gram negative while 25(34.7%) were Gram positive. Table 3 shows the dominant microorganisms isolated from all the samples. These organisms were identified to be belonging to *Staphylococcus* sp., *Escherichia coli, Klebsiella* sp. and *Proteus* sp., respectively (Table 3).

The most frequent isolates in the sample were *Staphylococcus* sp. (34.7%), *Escherichia coli* (30.6%), *Klebsiella* sp. (22.2%) and *Proteus* sp. (12.5%) in that order.

3.3 Sensory Evaluation

The result of the sensory evaluation is shown in (Table 4). Sensory characteristics of any food

item contribute significantly to its consumer acceptance or rejection. Though there were changes in all the GM samples, there was no significant difference in all the sensory properties tested ($p > 0.05$). This pattern was also observed among all the PM products. In all the parameters considered in the sensory evaluation, the MP products were rated high compared to the GM products. Generally, consumers acceptance of fufu products from the traditional pestle and mortar (MP_1, MP_2 and MP_3) preparation was very high and over 90% compared to products from the machine. There was a significant difference ($p < 0.001$) in terms of texture between the GM and the MP products with the former having texture quality below 50%.

4. DISCUSSION

The test results showed high microbial numbers occurring in the fufu grinding machine as compared to mortar and pestle, the traditional method of pounding fufu. The mean count of microbes in the fufu grinding machines GM_1, GM_2 and GM_3 were relatively higher (Table 1) thansamples taken from the mortars and pestles (MP_1, MP_2 and MP_3). This is in agreement to a study conducted by Amreeta et al. [10], who explained that this might probably be attributed to the numerous crevices in the machine and hence serve as a fertile ground for microbial growth. The presence of gutters, dirty floors and a nearby toilet facility around some of the places where these machines are sited could also serve as a source of contamination.

In this study, 47(65.3%) of the isolates were Gram negative while 25(34.7%) were Gram positive. The isolates were identified to belong to Staphylococcus sp., *Escherichia coli, Klebsiella sp.* and Proteus sp. The most frequent isolates in the sample were Staphylococcus sp. 25(34.7%),

Table 1. Microbial counts in fufu samples prepared by motorized grinding machine which collected from three different milling sites

Dilution	GM_1 (CFU/ml)	GM_2 (CFU/ml)	GM_3 (CFU/ml)
10^{-1}	5.76×10^{3}	5.88×10^{3}	4.90×10^{3}
10^{-2}	5.30×10^{3}	5.44×10^{3}	4.53×10^{3}
10^{-3}	3.99×10^{3}	4.86×10^{3}	3.59×10^{3}
10^{-4}	3.17×10^{3}	3.53×10^{3}	2.97×10^{3}
10^{-5}	2.76×10^{3}	2.97×10^{3}	2.26×10^{3}
10^{-6}	2.43×10^{3}	2.64×10^{3}	1.84×10^{3}
10^{-7}	1.93×10^{3}	2.18×10^{2}	1.17×10^{3}
10^{-8}	1.02×10^{2}	1.77×10^{2}	8.70×10^{2}
10^{-9}	6.40×10^{1}	1.38×10^{2}	6.20×10^{1}
10^{-10}	2.90×10^{1}	1.09×10^{2}	2.40×10^{1}

Table 2. Microbial counts in fufu samples prepared by mortar and pestles from three different milling sites

DILUTION	MP_1 (CFU/ml)	MP_2 (CFU/ml)	MP_3 (CFU/ml)	SMP / (CFU/ml)
10^{-1}	2.07×10^{3}	2.01×10^{3}	2.76×10^{3}	1.98×10^{3}
10^{-2}	1.72×10^{3}	1.67×10^{3}	2.13×10^{3}	1.32×10^{3}
10^{-3}	8.63×10^{2}	8.14×10^{2}	8.79×10^{2}	8.02×10^{2}
10^{-4}	6.16×10^{2}	5.98×10^{2}	6.36×10^{2}	5.87×10^{2}
10^{-5}	4.74×10^{2}	4.23×10^{2}	4.93×10^{2}	4.17×10^{2}
10^{-6}	2.18×10^{2}	1.98×10^{2}	2.37×10^{2}	1.87×10^{2}
10^{-7}	1.14×10^{2}	1.02×10^{2}	1.49×10^{2}	9.80×10^{1}
10^{-8}	7.90×10^{1}	7.60×10^{1}	9.20×10^{1}	7.40×10^{1}
10^{-9}	4.30×10^{1}	4.10×10^{1}	5.40×10^{1}	3.98×10^{1}
10^{-10}	1.60×10^{1}	1.20×10^{1}	1.80×10^{1}	1.10×10^{1}

MP_1- Mortar and pestle sample1; MP_2- Mortar and pestle sample 2; MP_3- Mortar and pestle sample 3; SMP- Sterile mortar and pestle sample

Table 3. Biochemical and morphology characteristic of bacteria isolates

Test characteristics of isolate	A	B	C	D
Gram Reaction / Shape	- (Rod)	+ (Cocci)	- (Rod)	- (Rod)
Morphological Characteristics	White with flat, smooth and round colonies	Golden yellow with flat, wavy and filamentous edges	Yellow with raised, smooth and round edges	Cream with drop like, smooth and round edges
Catalase Test	+	+	+	+
Indole Test	-	-	-	-
Methyl Red Test	+	+	+	+
Citrate Test	-	-	-	-
Glucose Fermentation	AG(+)	A(-)	AG(+)	A(-)
Lactose Fermentation	-	AG(+)	AG(+)	A(-)
Maltose Fermentation	-	AG(+)	AG(+)	A(-)
Sucrose fermentation	AG(+)	AG(+)	AG(+)	A(-)
Galactose Fermentation	AG(+)	AG(+)	AG(+)	AG(+)
Probable Identity	*Proteus* sp.	*Staphylococcu s*sp.	*Escherichia coli*	*Klebsiella* sp.

Isolate A B- Isolate B (+) Positive reaction C- Isolate C D- Isolate D (-) Negative reaction AG (+) Acid and gas present

Table 4. Mean sensory characteristics of 'fufu' productaspercentage (%)

Codes of samples	Texture	Odour	Taste	Colour	Acceptability
GM_1	40^c	80^b	72^c	66^c	72^b
GM_2	44^c	84^b	77^c	72^c	68^b
GM_3	48^c	88^b	68^c	70^c	70^b
MP_1	96^a	95^a	88^b	72^a	92^a
MP_2	91^a	98^a	95^a	78^a	98^a
MP_3	86^a	91^a	91^a	75^a	90^a

Means with the same letters in a column are not significantly different (P>0.05)

Escherichia coli 22(30.6%), *Klebsiella sp*. 16(22.2%) and Proteus sp. 9(12.5%) in that order. Staphylococcus was mostly isolated from the samples obtained from the fufu grinding machine (GM). The presence of Staphylococcus in the GM samples may be due to either or contamination of the following; mixing and moulding in the machine from the skin, mouth, or nose of the handlers or hawkers. It might also be sweat falling into the product during pounding or through the handling of the fufu during milling. Staphylococcus is one of the microorganisms associated with food poisoning when ingested [11,12]. Mbaeyi et al. [13] also reports that, other possible sources of Staphylococcus in fufu may include polluted air and environmental contamination.

Generally, most *E. coli* strains are harmless and form part of the normal flora of the gut, this notwithstanding, some serotypes cause serious food poisoning in humans. *E. coli* can be found in the urinary tract which is its natural habitat. The source of *E. coli* contamination of the fufu samples in the present study may probably come from the water used to wash the machine and the mortar and pestle prior to their use or the water used in moulding or pounding the fufu. Unhygienic environments may have also contributed to the presence of *E. coli* since the locations of these machines and the fufu food joints were very poor in sanitary conditions. In this study, all the products from both the commercial grinding machines and the mortars and pestles recorded *Klebsiella sp.* A possible explanation for this contamination may be due to the fact that, all the commercial machines and the fufu eaten joints were found outdoor and has a close proximity to the bare ground (soil). Klebsiella has also been reported to be a causal agent for urinary tract infection [14,15].

Proteus sp. represents the least number of isolates 9(12.5%) and were found in two of the grinding machines (GM_1 and GM_2) together with the mortar and pestle (MP_2) products. These organisms could have gained access into the fufu grinding machine through faecal contamination from persons operating the machine and at the same time kneading the fufu. Cruickshank, [16] reported that Proteus sp. is mostly associated with faecal contaminations and widely distributed throughout the environment especially in animals, sewage and soils. The presence of Proteus may cause infections such as urinary tract infection, pneumonia, gastroenteritis and bacteraemia [17].

Sensory characteristics of any food item contribute significantly to its consumer acceptance or rejection [18]. Therefore, sensory evaluation of food using panelists is routinely carried out by food scientists to help evaluate the acceptability or otherwise of any new food product [19]. In this study, the overall acceptability for texture, odour, taste and colour in the traditional mortar and pestle products was significantly higher ($p < 0.05$) compared to the grinding machine products. This acceptability rate could be due to the fact that, many people prefer the traditional products compared to the machine products which is a new technology.

5. CONCLUSION

The present study identified *Klebsiella*, *Staphylococcus*, *Proteus* and *E. coli* to be associated with both the fufu grinding machines and the traditional mortar and pestle products. It showed that consumers prefer the processed 'fufu' from the traditional source to the grinding machine. The microbial load and sensory characteristics from the different samples showed the lack of adherence to strict hygienic practices, especially, by the milling operators. It is important that further studies be conducted to find the health risk associated with these products since the microbial load in most cases were significant. Education on hygienic practices can help reduce the microbial load and also to promote this new technology of preparing fufu.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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