

Microflora of fresh ginger rhizomes and ginger powder produced in the North-West Region of Cameroon

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Key words

Zingiber officinale, bacteria, yeasts, moulds

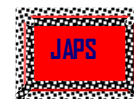
1 SUMMARY

This study investigated the microflora on fresh ginger (*Zingiber officinale* Roscoe) rhizomes and ginger powder in North-West Region of Cameroon with the aim of (1) identifying ginger producing locations with the best quality fresh ginger in terms of low bacterial and fungal load and (2) developing the best processing techniques to ensure low counts of microorganisms in the ginger powder. Thirty-six (36) rhizome samples were collected, and samples of powder were produced using four different treatments. All rhizome and powder samples were analysed for total colony counts of bacteria, yeasts and moulds. The total colony counts of bacteria were higher ($\times 10^9$ cfu/g) than those reported in the literature ($\times 10^6$ cfu/g). The colony counts of all microorganisms for the rhizomes were significantly different ($P < 0.05$) across locations and in different sites within the same locations. Total colony counts of microorganisms in the powder indicated a reduction of 3 log cycles for bacteria ($\times 10^9$ to $\times 10^6$ cfu/g); and 2 log cycles for yeasts and moulds ($\times 10^6$ to $\times 10^4$ cfu/g) compared to the counts in the rhizomes. Some processing treatments had similar average total colony counts of bacteria (raw oven dried, 7.31×10^6 cfu/g and heat-treated sun dried, 7.48×10^6 cfu/g); and yeasts and moulds (raw, sun dried 7.72×10^4 and raw oven dried, 7.68×10^4 cfu/g; ($P > 0.05$)), while others were significantly different ($P < 0.05$) (raw sun dried, 4.32×10^6 cfu/g and heat-treated oven dried, 9.98×10^6 cfu/g for bacteria; and (heat-treated sun dried, 5.85×10^4 and heat-treated oven dried 1.25×10^5 cfu/g for yeasts and moulds). The best ginger rhizomes were produced in Bafut and Mbengwi locations. There was general reduction of microbial counts on processing the rhizome into powder. The best processing techniques were slicing and sun drying without heating for bacterial counts, and slicing, heating and sun drying for yeasts and moulds. The results of this study will be useful to people involved in ginger cultivation, processing and utilisation as a spice or ingredient in food formulations and marketing especially exportation from the North-West Region of Cameroon.

2 INTRODUCTION

The ginger plant (*Zingiber Officinale* Roscoe) is a member of the *Zingiberaceae* family (Conley, 1997). It is a perennial, slender plant that grows to a height of 2 to 3 feet, from underground

rhizomes in tropical and subtropical climates of Asia, Africa, India, Jamaica, Mexico, China, Australia and Haiti. It has grass-like leaves that may grow up to a foot in length. The flowers



are white or yellowish-green (Kemper, 1999). Ginger grows well where the soil is not waterlogged and the annual rainfall exceeds 1500mm. It requires rich soils and both natural and artificial fertilisers may be added to obtain a good harvest. The rhizome that grows elongated underground is the useful part of the plant for human consumption.

Ginger is used worldwide as a cooking spice. Jideani *et al.* (2001) observed that ginger was the most important single spice in the production of a staple food (Fura) for the Fulanis and Hausas of northern Nigeria. Aniedu *et al.* (2002) produced a ginger blended pineapple drink, while Libouga *et al.* (2006) used ginger to flavour soft cheese that was well appreciated. According to McGee (2004) and Conley (1997) fresh ginger or the ginger powder may be added to soups, stew and juices and in meat and vegetable dishes. The taste imparted to a dish depends upon when ginger is added during cooking. It is a more subtle flavour when added at the beginning and a more pungent taste if added at the near end.

Ginger is reported to have antibacterial effect especially against the *Staphylococci* species and also exhibits antifungal activity against a wide variety of fungi including *Candida albicans* (Ficker *et al.*, 2003), though *Penicillium brevicompactum* actually grows on ginger causing rot during post-harvest storage (Overy & Frisvad, 2005).

In Cameroon, two varieties (green and yellow) of ginger are cultivated and used in different parts of the country. In the North West Region, ginger cultivation is prominent in

3 MATERIALS AND METHODS

3.1 Fresh ginger rhizomes: A total of thirty-six (36) green ginger (*Zingiber officinale* Roscoe) rhizome samples, four (4) from each sampling site were collected from 9 major ginger growing villages or neighbourhoods in 5 locations within four of the seven administrative divisions of the North-West Region. The locations and sites were as follows: A) Bali, with two sampling sites; B) Befang with one sampling site; C) Bafut with three sampling sites, D) Bamessing with one sampling site and E) Mbengwi with two sampling sites. Sample collection points

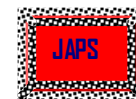
the low and mid altitudes (400-1500 metres) with the use of manure where it is naturally present especially along abandoned cattle tracks. The green variety dominates and some 283 farmers cultivated ginger on about 80 hectares of land and harvested about 170.5 tons in the year 2002 (Mendi *et al.*, 2003). Major constraints in ginger production include poor yields due to cultivation on unsuitable soil types, post harvest losses due to lack of proper storage facilities, lack of training in processing techniques and low prices offered by buyers from the cities who frequent the village markets.

Some farmers and small-scale processors produce ginger powder and ginger drinks which they sell in local markets. There is also some production of fresh ginger rhizomes and ginger powder for export to Nigeria, Gabon, Holland, Malaysia, France and Germany, hence the necessity to have information on the microflora and microbial load of the fresh rhizome and the resulting products especially the powder. It is also of great interest to identify the optimum processing techniques for best quality ginger powder.

The present study aimed at identifying ginger producing locations with the best fresh ginger in terms of low bacterial and fungal load, and developing the best processing techniques to ensure low counts of microorganisms in the ginger powder. The results of this study will be useful to people involved in ginger cultivation, processing and utilisation as a spice or ingredient in food formulations and marketing, especially exportation from the North-West Region of Cameroon.

were the local village markets where ginger harvested the previous day was brought for sale. The maximum number of samples at one collection was 8. Stratified random sampling was carried out so as to draw samples from the mature fresh perennial crop and from all the different geographical orientations of that locality.

On arrival at the sample collection site, it was ascertained that samples were purchased from people coming from different villages or neighbourhoods; that the samples were matured and



fresh, harvested at most one day before the market day. Where more sellers were qualified, there was random selection and the required quantities of ginger rhizomes, based on appearance (large, whole and fresh, without blemishes and few internodes) were purchased. The samples were carried in sterile plastic containers, in order to ensure same conditions for all samples, to the laboratory.

3.2 Preparation of samples

3.2.1 Fresh ginger paste: In the laboratory, 10 rhizomes were picked from each of four samples from one sampling site and prepared for microbiological analysis. The ginger was washed to remove soil from the field, peeled with knives that had been swabbed with 70% alcohol and rinsed with previously boiled and cooled water and then sliced into thin pieces. Slicing was done by cutting the rhizomes at an inclined angle of about 45° so as to obtain very thin slices. The pieces were macerated in a porcelain mortar and pestle that were swabbed with 70 % alcohol before use. The resulting product could be described as a paste.

3.2.2 Ginger powder: For ginger powder, four samples were prepared in six replicates using ginger from all locations sampled in the study. The samples were bulked and the powder samples prepared as follows:

1-Powder from raw sun dried ginger; 2-Powder from raw oven dried ginger; 3-Powder from heat-treated sun dried ginger, and 4-Powder from heat-treated oven dried ginger.

The rhizomes were washed to remove soil from the field, peeled and washed again in clean water and sliced into thin pieces. Five hundred (500) grams of the sliced ginger was heat-treated by adding 200ml of clean water and steaming on the largest ring of a kitchen gas cooker for 5–8 minutes in an aluminium pot, to a temperature of 85–90 °C, to a light brown colour. Two hundred and fifty (250) grams of the heat-treated ginger were dried in an oven (Carbolite 22265, Fison Way, Thetford U.K.), at 56–60°C for 24–26 hours to a moisture content of 9.9–12.2%. The moisture content was determined in triplicates using a moisture balance (Adam Equipment AMB 310, U.K) following instructions contained in the user's manual . A few slices (16.7–18.5g) of ginger were placed and spread evenly on the weighing pan of the balance, a drying temperature of 102°C was selected and the balance switched on. At steady conditions, the weight of the sample, drying

time and moisture content in percentage were recorded.

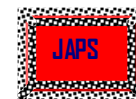
The other portion of 250g of heat-treated ginger slices were dried in the sun, on a solar tent, for 2-3 days in the dry season or 3-5 days in the rainy season to similar moisture content level as obtained when dried in the oven (9.9-12.2%). Two hundred and fifty (250) grams of raw sliced ginger were dried in the oven and another portion of 250 grams in the sun. The dried ginger was ground into powder using an electric kitchen blender (National MX-T2GN, China) and sieved through a metallic sieve of calculated pore-size of 0.39 mm². All equipments that came in contact with samples were steam sterilised or swabbed with 70 % alcohol before use.

3.3 Microbiological analyses: Microbiological analyses were carried out following routine analytical methods described by Harrigan and McCance (1976), and Seenappa and Kempton (1981).

3.3.1 Preparation and plating of samples: Ringer diluent was supplied in tablet form (BR 52, 100 tablets, Oxoid; England) and quarter-strength ringer solution was prepared by dissolving one tablet in 500 ml distilled water, dispensed in 90 ml and 9 ml amounts, respectively, into universal dilution bottles and sterilised in an autoclave (Dixons Surgical Instruments Ltd. U.K), for 15 minutes at 121 °C.

The work bench was swabbed with 70% ethyl alcohol and Bunsen flames were lit to provide a sterile working environment. Small glassware were autoclaved (Dixons Surgical Instruments Ltd. U.K), at 121°C for 20 minutes before use. Previously washed Petri dishes were sterilised by heating in a vacuum oven at 120 °C for 3 hours and allowed to cool still wrapped or in their canisters to be removed just before use. Without opening the Petri dishes, they were labelled externally using a permanent marker, with the sample code number and the dilution level. The diluent, already distributed into universal dilution bottles, was arranged according to the number of dilutions to be made.

The fresh ginger rhizomes that were already prepared into a paste were aseptically weighed (10 g) on a top loader electronic balance and placed in a sterile stomacher-blending bag. The diluent (90 ml of quarter-strength Ringers solution) was added and the sample blended for one minute in a Stomacher (Stomacher Model 400 Circulator, Seward-England). Serial dilutions of up to 10⁻¹⁰ were prepared for each sample.



Dilutions 10^{-7} , 10^{-8} , 10^{-9} and 10^{-10} were plated in duplicates in glass Petri dishes, on Plate Count Agar (PCA). The plates were incubated at 30 °C for 72 hours for the total colony counts of bacteria.

3.3.2 Bacterial colony counts: All the media were products of Diagnostic Pasteur 3, BD Raymond Poincare 92430 Marnes La Coquette, France. The media were rehydrated and sterilised as described by Harrigan and McCance (1976). The medium used was Standard Plate Count Agar (A.P.H.A). For *Bacillus subtilis* counts, the culture medium was Mannitol Egg-yolk Polymyxin Phenol red (MEPP) agar. And for coliforms, the medium used was Violet Red Bile Agar. For coliform counts, duplicate sets of plates were poured from 10^{-1} , 10^{-2} , and 10^{-3} dilutions of the fresh ginger paste samples. The plates were incubated at 35 °C for 24 hours. For counts of *Bacillus subtilis*, the dilutions 10^{-1} , 10^{-2} , 10^{-3} and 10^{-4} were plated on Mannitol Egg Yolk Polymyxin Phenol Red Agar (MEPP). The Petri dishes, in duplicates, had been poured with about 15 ml of medium and well dried before use, and were inoculated by aseptically transferring 0.1 ml of sample to each of the duplicate plates. The inoculum was spread evenly over the surface of each plate with a bent glass rod and the plates were incubated at 30 °C for 48 hours.

3.3.3 Yeasts and moulds: The medium used was Potato Dextrose Agar (PDA). Dilutions 10^{-2} , 10^{-3} , 10^{-4} and 10^{-5} were plated in duplicates Petri dishes

on Potato Dextrose Agar (PDA). The plates were incubated at 22-24 °C for 5 days for total colony counts of yeasts and moulds.

In all cases colonies were counted manually on an electric lit background of a Gallenkamp Colony Counter. The positions of colonies counted were marked externally on the Petri dish with a permanent marker to avoid re-counting.

3.3.4 Ginger powder samples: The ginger powder samples were subjected to total colony counts of bacteria, and yeasts and moulds. Similar quantity (10g) of the powder samples were weighed and prepared as described above for the fresh samples. The determination was carried out in triplicates for the first set of trials. In the second set of trials, ginger powder was produced using a different set of fresh rhizome samples, and after the first colony counts, the rest of the powder samples were preserved in sterile plastic bottles at ambient temperatures for subsequent analysis over the following two weeks.

3.3.5 Data analysis: Data were subjected to analysis of variance (ANOVA) using the STATA Software version 9.0 and XLSTAT Version 2007.8.04 software was employed for student t-test. Means were separated using Fisher's (LSD) test.

4 RESULTS AND DISCUSSION

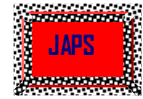
4.1 Fresh Ginger rhizomes

4.1.1 Total colony count of bacteria: The minimum total colony counts of bacteria (Table 1) was 10^9 colony forming units (CFU) per gram of sample while the maximum count was 1.38×10^{10} cfu/g of sample. The maximum average count was 9.35×10^9 cfu/g while the minimum average was 1.99×10^9 cfu/g. The average total colony counts of bacteria for samples from the two sites in Bali and Mbengwi were significantly different (6.04; 9.35×10^9 cfu/g and 2.06; 3.18×10^9 cfu/g) $P < 0.05$. Meanwhile counts of samples from sites 4 and 6 in Bafut and 8 in Mbengwi were not significantly different (1.99; 1.99; 2.06×10^9 cfu/g) $P > 0.05$.

The observed total colony counts of bacteria were higher ($\times 10^9$) than those ($\times 10^6$) reported by Oiye and Muroki (2002) for spices including ginger. In similar previous studies the dominant bacteria in the counts have been reported to include *Pseudomonas solanacearum* (Tsang & Shintaku, 1998) or *Ralstonia solanacearum* (Mondal *et al.*, 2004; and Shanmugam *et al.*, 2004), *Enterobacter cloacae* (Nishijima *et al.*, 2004),

that are associated with post harvest rot of the ginger rhizome. Others could be *Pseudomonas aeruginosa* that has been noted not to be completely inhibited by ginger extract (Paramasivam *et al.*, 2007) and *Lactococcus lactis* isolated from the ginger rhizome by Janes *et al.* (1999).

Ginger antimicrobial activities have been reported by Akoachere *et al.* (2002) against human pathogens such as *Staphylococcus aureus*, *Staphylococcus pyogenes*, *Streptococcus pneumoniae* and *Haemophilus influenzae*. Azu and Onyeagba (2007) observed antibacterial activity of ethanolic extracts of ginger against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Ginger extract at 5% concentration inhibited the growth of *Vibrio parahaemolyticus*, *Bacillus cereus*, *Protens mirabilis* and *Pseudomonas aeruginosa* (Paramasivam *et al.*, 2007). Jagetia *et al.* (2003) found that ginger extract given to mice had a dose-dependent antimicrobial activity against *Pseudomonas aeruginosa*, *Salmonella typhimurium*, *Salmonella typhi* and *Escherichia coli*.



Janes *et al.* (1999) reported the isolation of a bacteriocin from *Lactococcus lactis* that was growing on the ginger rhizome. This bacteriocin was found to have broad spectrum activity, inhibiting *Bacillus*, *Clostridium*, *Listeria*, *Enterococcus*, *Leuconostoc*, *Pediococcus* and *Staphylococcus* species. The bacteriocin remained active at very high temperatures (90°C) and wide pH range (2-9) in various organic solvents. However, the high numbers of bacterial colonies observed on the ginger rhizome samples analysed, was indicative of the contamination of ginger produced in this region.

According to Weil (1995) ginger has a balancing ability that stimulates and inhibits the growth of toxic bacteria but allows friendly ones to grow. Bola and Aboaba (2004) isolated *Lactobacillus* from ginger beer, and therefore, many useful bacteria could be growing on the ginger rhizome enhancing its beneficial use as a spice or as an ingredient in the food industry especially where preparation of fermented foods uses *Lactobacilli* species as starter cultures.

4.1.2 *Bacillus subtilis*: The minimum colony counts of *Bacillus subtilis* of 10^5 cfu/g was observed in samples from site 5 in Bafut but the minimum average counts of 2.11×10^5 cfu/g was shown by samples from site 9 in Mbengwi (Table 1). The maximum colony counts of 1.11×10^6 cfu/g and the highest average colony counts of 9.44×10^5 cfu/g was observed in samples from site 2 in Bali

There were significant differences in counts of microbes in samples from sites in the same locations for all locations with more than one sampling site. This observation could be explained by the different soil types on specific sites and cultural practices by untrained farmers cultivating the crop. Meanwhile, there was no significant difference in counts from samples from site 1 in Bali and site 3 in Befang (6.05 and 6.12×10^5 cfu/g). And the observation was similar for site 5 in Bafut and site 9 in Mbengwi (2.23×10^5 cfu/g and 2.11×10^5 cfu/g, $P > 0.05$). This observation of similar counts from across different locations could be as a result of the application of the knowledge of the technical training received by farmers from the extension services of the Ministry of Agriculture on ginger production.

Bacillus subtilis occurs in a variety of habitats including the soil hence their presence on fresh ginger rhizomes. Seenappa and Kempton (1981) isolated these bacteria from unprocessed ginger. The involvement of *B. subtilis* in food spoilage, especially canned foods, like meats, ropiness in bread, gas production and coagulation of milk suggests their

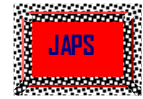
tolerance to sanitation and some processing techniques. It was observed that sporulating *B. subtilis* showed remarkable resistance to disinfection chemicals, and their exposure for 10 minutes to 2% alkaline glutaraldehyde, free chlorine and 1% Povidone-iodine had no detrimental effect (Gorman *et al.*, 1984). *Bacillus subtilis* was also heat resistant for up to 85 °C (Frazier & Westhoff, 1991). Nelson and Onyeagba (2007) found that neither the raw ginger nor the cold-water ginger extract exhibited any antibacterial effect on *B. subtilis*, which could explain their growth on the samples plated.

4.1.3 Coliform bacteria: Coliform counts were very high in samples from sites in Bali with a maximum of 1.21×10^3 and a minimum of 0.38×10^3 cfu/g (Table 1) compared to samples from Mbengwi with maximum counts of 0.06×10^3 cfu/g. The maximum average count was 0.68×10^3 cfu/g and the minimum average count was 0.02×10^3 cfu/g.

There was significant difference of colony counts of coliforms for samples within the two sites of Bali: 0.04×10^3 and 0.68×10^3 cfu/g; three sites of Bafut: 0.04×10^3 , 0.07×10^3 and 0.15×10^3 cfu/g; and two sites of Mbengwi: 0.04×10^3 and 0.2×10^3 cfu/g; $P < 0.05$). There was no significant difference for samples of sites 1 in Bali, 4 in Bafut and 8 in Mbengwi, thus, 0.04×10^3 cfu/g ($P > 0.05$).

Coliforms are associated with faecal material and indicate possible contamination by those who handle the food (Rowe, 1993). However, the coliforms on the ginger rhizomes could originate from the soil if animal manure was used or from contaminated vessels in which the produce was transported to the market. However, this is a serious quality concern as some of the ginger may be consumed without sterilisation. Producers need to handle their produce more hygienically to avoid high microbial contamination and possible health risks.

4.1.4 Yeasts and moulds: The minimum total colony counts of yeasts and moulds were 10^6 cfu/g, observed in samples from Bafut. The maximum count of 1.23×10^7 cfu/g and the maximum average count of 9.2×10^6 cfu/g were observed in samples from Befang while the minimum average count of 1.18×10^6 cfu/g was shown by samples from Bamessing (Table 1). Colony counts in samples from sites in Bali, Bafut and Mbengwi were significantly different (6.24 and 5.41×10^6 cfu/g; 2.95 ; 2.11 and 1.39×10^6 cfu/g; and 2.01 and 3.13×10^6 cfu/g $P < 0.05$).

**Table 1: Total colony count of microorganisms on fresh ginger rhizomes**

Location	Sampling Sites	Bacteria (x10 ⁹ cfu/g)	<i>B. subtilis</i> (x10 ⁵ cfu/g)	Coliform bacteria (x10 ³ cfu/g)	Yeasts & Moulds (x10 ⁶ cfu/g)
Bali	1	6.04±1.7 ^a (1.5 – 10.95)	6.05 ± 1.0 ^a (2.65 – 7.25)	0.04 ± 0.01 ^a (0.03–0.06)	6.24 ± 1.36 ^a (2.5 – 9.75)
	2	9.35 ± 1.76 ^b (4.25 – 13.75)	9.44 ± 0.86 ^b (6.95 – 11.1)	0.18 ± 0.16 ^b (0.38 -1.21)	5.41±1.29 ^b (2.35 – 8.9)
Befang	3	3.74 ± 0.71 ^c (2.05 – 5.9)	6.11 ± 1.38 ^a (4.15 – 10.85)	0.06 ± 0.01 ^c (0.04–0.09)	9.2 ± 0.93 ^c (7.35 – 12.3)
Bafut	4	1.99 ± 0.83 ^d (1.0 – 4.85)	4.0 ± 0.90 ^c (2.4 -7.0)	0.04 ± 0.01 ^a (0.02 – 0.08)	2.95 ± 1.50 ^d (1.05 – 8.15)
	5	5.43 ± 1.58 ^e (2.5 -10.75)	2.23 ± 0.86 ^d (1.0 – 5.2)	0.07 ± 0.01 ^d (0.04 – 0.10)	2.11± 0.39 ^e (1.0 – 3.2)
	6	1.99 ± 0.49 ^d (1.2 – 3.6)	3.46 ± 1.25 ^e (1.6 – 7.75)	0.15 ± 0.03 ^e (0.10 – 0.23)	1.39 ± 0.16 ^f (1.05 -1.9)
Bamessing	7	3.05 ± 0.87 ^f (1.28 – 4.95)	3.03 ± 0.15 ^f (2.6 – 3.4)	0.06 ± 0.01 ^f (0.03 – 0.08)	1.18 ± 0.06 ^f (1.05 – 1.35)
Mbengwi	8	2.06 ± 0.50 ^d (1.05 – 3.7)	6.65 ± 1.22 ^g (4.4 -10.65)	0.04 ± 0.01 ^a (0.03 – 0.06)	2.01± 0.31 ^e (1.5 – 3.05)
	9	3.18 ± 1.6 ^f (1.05 – 8.7)	2.11 ± 0.68 ^d (1.05 – 4.4)	0.02 ± 0.01 ^g (0.02-0.04)	3.13 ± 0.51 ^d (1.85 – 4.3)

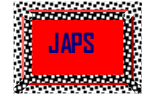
Mean ± SE (Standard Error; n = 4), Range in brackets

Means along the column with different superscripts are significantly different (P<0.05); ANOVA Fisher's LSD.

4.2 Ginger Powder: Total colony counts of bacteria in ginger powder samples from various treatments are presented in Table 2. Powder from the following treatments: A (raw sun dried), B (raw oven dried), C (heat-treated sun dried) and D (heat-treated oven dried) ginger, showed significant differences (P<0.05) for average count for treatments A and D (4.32 x 10⁶ cfu/g, and 9.98 x 10⁶ cfu/g), respectively. There was no significant difference in average total colony counts of bacteria for the samples of treatments B and C, (7.11 x 10⁶ cfu/g and 7.48 x 10⁶ cfu/g; P>0.05), respectively.

Therefore, drying raw pieces of ginger in the oven before grinding into powder had the same

effect on the bacteria content of the powder as if the sliced pieces of ginger were heat-treated and sun dried. Tsang and Shintaku (1998) in their study found that *Pseudomonas solanacearum*, the pathogen that causes bacterial wilt in ginger root was eliminated when the root was exposed to 50°C for 30 minutes, or hot air at 75% RH. The low colony counts of bacteria (4.32 x10⁶ cfu/g) for treatment A (raw, sun dried) could be attributed to some potent effect created by solar radiation within the solar tent on some bacteria species similar to that reported during solarisation treatment of ginger rhizome seeds against bacterial wilt disease caused by *Ralstonia solanacearum* (Kumar *et al.*, 2005), while high counts from heat-treated or



oven dried samples could be due to heat activation of spores of the microorganisms during heat treatment, which then germinated and grew on the culture medium.

There was no significant difference ($P>0.05$) in the counts of yeasts and moulds for raw ginger powder samples either oven or sun dried. However, there was significant difference ($P<0.05$) in the counts for raw and heat-treated samples, and heat-treated sun or oven dried (Fig.1).

Table 2: Colony counts of bacteria, and yeasts and moulds on ginger powder.

Treatment	Total colony counts of microorganisms			
	Bacteria ($\times 10^6$ cfu/g)		Yeasts & Moulds ($\times 10^4$ cfu/g)	
	Mean	Range	Mean	Range
Raw, sun dried	4.32 ^a \pm 0.03	0.6 – 12.3	7.72 ^{ab} \pm 0.03	1.0 -25.0
Raw, oven dried	7.31 ^{ab} \pm 0.03	1.0 – 20.7	7.68 ^{ab} \pm 0.03	1.1 – 29.6
Heat treated, sun dried	7.48 ^{ab} \pm 0.03	0.75 – 29.0	5.85 ^b \pm 0.03	1.0 – 13.9
Heat treated, oven dried	9.98 ^b \pm 0.03	0.75 – 30.0	12.49 ^a \pm 0.03	1.25 – 29.6

Mean values \pm SED (standard errors of differences of means; n=18)

Means with different superscripts along the columns are significantly different ($P<0.05$); ANOVA Fisher's LSD.

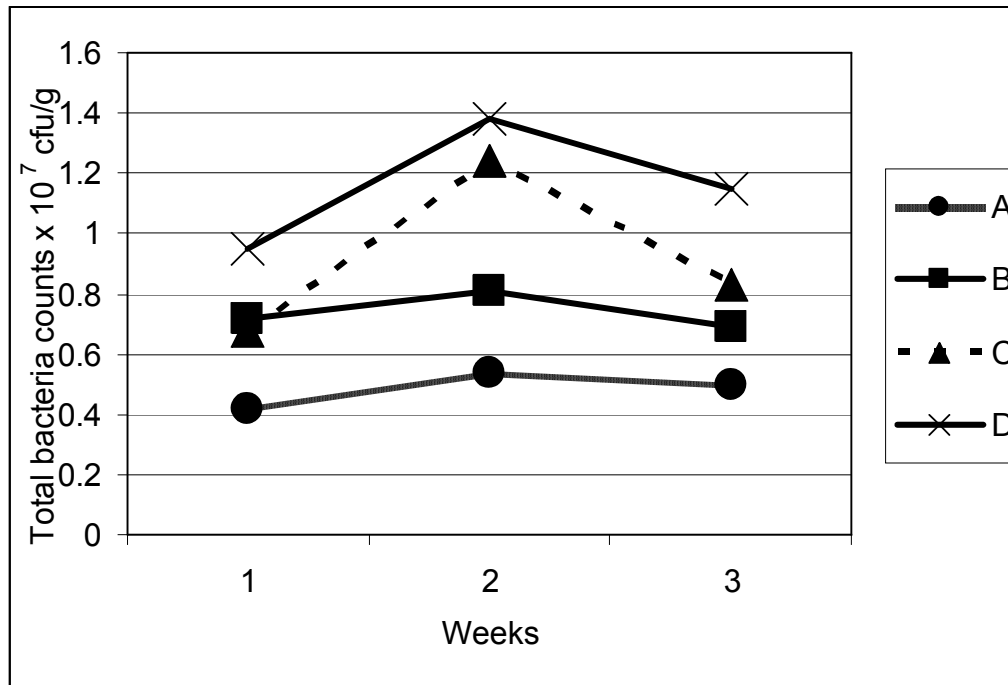


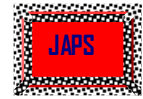
Figure 1: Total colony count of bacteria on ginger powder during storage.

Legend: A: Raw, sun dried; B: Raw, oven dried; C: Heat treated, sun dried; D: Heat treated oven dried

4.3 Counts of bacteria, yeasts and moulds after storage for three weeks: The total colony counts of bacteria, yeasts and moulds in ginger powder stored for three weeks are shown on Figs.1 and 2. The total colony counts of bacteria for all the treatments increased at the second week and

decreased slightly at the third week, but not significantly ($P>0.05$) (Fig.1).

For the total colony counts of yeasts and moulds, there was a decrease from the first to the third week for all the treatments (Fig.2). However, only the decrease for the raw, oven dried treatment (B) of week 1 was significantly higher than those of



week 2 and week 3 ($P < 0.05$). Also, the heat-treated oven dried treatment (D) of week 2 was significantly higher than that of week 3. Qaher (2005) isolated *Aspergillus*, *Penicillium*, *Rhizopus*, *Cladosporium* and *Trichoderma* as the predominant fungal genera from spices, while Salama (2002) observed a decrease in the count of yeasts and moulds in cakes during storage when 2.5% ginger was incorporated before baking.

Souhair and Nefisa (1980) observed that ginger at 10% concentration inhibited up to 100%

aflatoxin formation but stimulated the mycelial growth of *Aspergillus flavus* at higher concentration. However, Madhyastha and Bhat (1985) reported that the ginger rhizome was a good substrate for the growth of *Aspergillus parasiticus* and aflatoxin production. Oiye and Muroki (2002) also reported the growth and aflatoxin production by *Aspergillus flavus* on spices. However, with the decrease in yeast and mould counts in ginger powder during storage, the risks of aflatoxin production may be reduced.

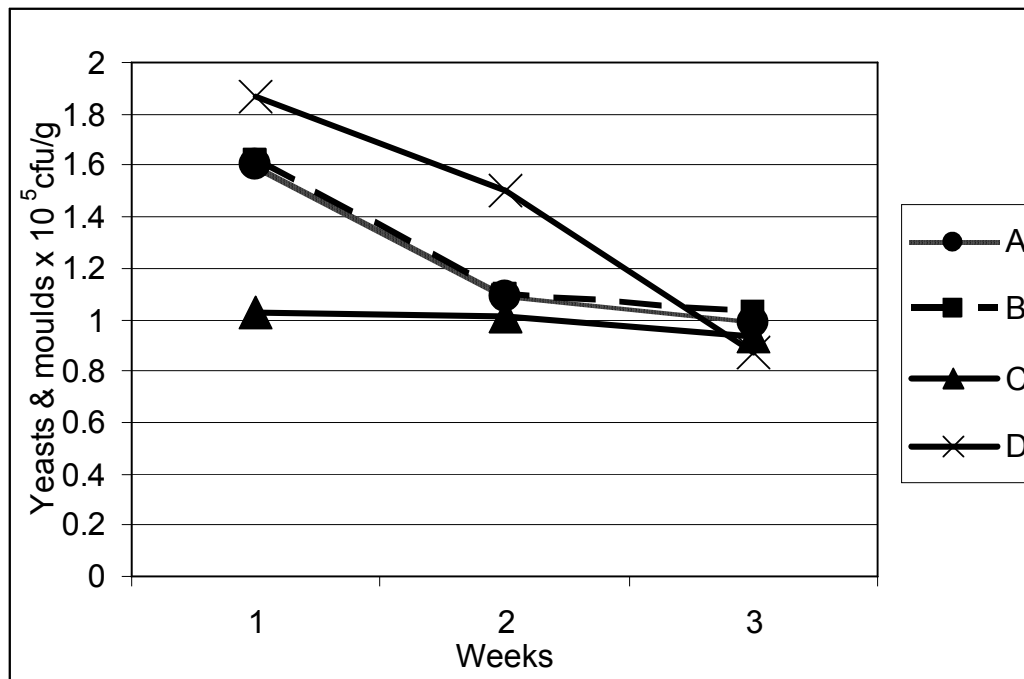


Figure 2: Total colony count of yeasts and moulds on ginger powder during storage.

B week 1 > week 2 and week 3; D week 2 > week 3 ($P < 0.05$)

Legend: A: Raw, sun dried; B: Raw, oven dried; C: Heat treated, sun dried; D: Heat treated, oven dried.

CONCLUSIONS

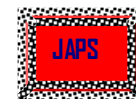
The best ginger rhizomes in terms of low bacterial counts were produced in Bafut and Mbengwi, while good ginger rhizomes in terms of yeasts and moulds counts were produced in Bamessing, Bafut and Mbengwi Farmers at these localities practice ginger production as an important activity; they work in groups and share information. It would be of advantage for farmers of other localities to get together and learn from others so as to improve on the quality of their produce.

Processing of ginger rhizomes into ginger powder resulted in decreased microbial load. The processing technique resulting into the lowest bacterial colony counts was slicing, drying in the sun

and grinding into powder, while slicing, heating the slices and then sun drying before grinding was best for reducing yeasts and moulds counts.

People involved in the processing of fresh ginger rhizomes into ginger powder should be more rigorous in their sanitation and hygiene practices especially as the counts of *Bacillus subtilis* were high in some of the ginger rhizomes.

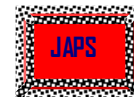
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