Microbial Changes During the Fermentation of Aerial Potato (Discorea bulbifera Linn)

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Authors’ contributions
This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Discorea bulbifera is one of the under-utilized tubers in Nigeria both for food and medical purposes. Microbial changes during the fermentation of aerial potato after being subjected to different treatment were monitored using standard methods, the changes in microbial load and type of microorganisms was reported. It was observed that unpeeled backslopping fermented samples had the highest total viable bacterial count (7.06±0.05 x 10^5 cfu/g), lactic acid bacterial count (67.74±1.17 x 10^7 cfu/g) and fungal count (0.81±0.16 x 10^6 sfu/g), while total viable bacterial, LAB and fungal in peeled samples were 30.40±2.00 x 10^10 cfu/g, 298.17±2.36 x 10^7 cfu/g and 133.30±0.15 x 10^6 sfu/g at 120 hour of fermentation respectively. Some of the bacteria isolated include Shigella flexneri, Escherichia coli, Staphylococcus aureus, Lactobacillus delbrueckii, Lactobacillus fermentum, Lactobacillus plantarum, Lactococcus lactis, while the fungal isolates were Fusarium oxysporum, Geomyces pannorum, Geotrichum candidum, Penicillium brevicompactum, Penicillium corylophilum, Saccharomyces cerevisiae, Candida tropicalis and others species. The treatment methods employed had a significant effects on the microbial load of fermented aerial potato. The fermentation methods employed have significant effects on the microbial load and type of microorganisms in the fermented aerial potato. Fermentation can be used as a food processing method to eliminate unwanted microorganisms in fermented food, which will enhance the food shelf life.

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1. INTRODUCTION

*Dioscorea bulbifera* commonly known as the aerial potato, air potato, air yam, aerial yam, bitter yam, cheeky yam and parsnip yam is a species of true yam in the yam family, Dioscoreaceae. In Nigeria, *Hausas* called it ‘dóóya’, *Igbos* ‘Agukwu’ and *Yorubas* call it ‘émína’, ‘éwura-esi’ and ‘isu ahum’ [1,2]. The yam is native to Africa, Asia and northern Australia, however, over 600 varieties of yam exits and 95% of them are grown in African [3,4] for which Nigeria is one of the highest producers in Africa. Aerial yam is a perennial vine with broad, alternate leaves, and two types of storage organs. It typically climbs to the tops of trees and has a tendency to take over native plants. New plants develop from bulbils that form on the plant, and these bulbils serve as a means of dispersal. The aerial stems of air potato die back in winter, but re-sprouting occurs from bulbils and underground tubers [5] especially at the beginning of the rainy season in Nigeria.

*D. bulbifera* has been found to possess profound therapeutic potential. It is commonly used in traditional Indian, African and Chinese medicine in the treatment of sore throat [6] breast cancer [7] and type II diabetes mellitus [1,2,8,9]. *D. bulbifera* has proved effective in the treatment of sub-acute thyroiditis [10] Also, *D. bulbifera* could significantly induce apoptosis of HCT116 human colorectal carcinoma cells [11] and also has shown anti-helminthic activity against *Fasciola gigantica* and *Pheritima posthuma* [12]. More so, *D. bulbifera* has been reported to have Anti-HIV-1 integrase compounds [13,14]. The plant also possesses antibacterial effects against multi-drug resistant bacteria *Enterobacter aerogenes* EA289, *Klebsiella pneumoniae* KP63, *Pseudomonas aeruginosa* PA124, *Mycobacteria* strain and *Staphylococcus aureus* [15]. It also possesses antioxidant activity against free radicals [16].

The tuber is rich in some phytochemicals such as saponins, tannins, flavonoids, sterols, polyphenols, glycosides [1,2] and steroidal saponins [17]. The composition may vary according to the geographical locations [18]. Despite the numerous uses of this plant as stated, aerial potato is one of the under-utilized tubers in Nigeria both for food and medical purposes (Kwong-Niding and Misai, 2002 [9]. For better utilization, the yam is subjected to fermentation in order to remove the toxins, better preservation, round the year availability and improved safety for consumers. This study therefore aimed at presenting the microbial changes during the fermentation and processing of aerial potato.

2. MATERIALS AND METHODS

2.1 Collection of Aerial Potato Samples

Aerial potato tubers (Plate 1) were purchased from Kogi State, Nigeria in a sterile bag and transported to the Laboratory, Department of Microbiology, Federal University of Technology, Akure for laboratory examination. The samples were sorted, separated to remove tubers that are spoilt by rodent attack or physical injuries and sand.
2.2 Fermentation of Aerial Potato

Five hundred grams (500 g) of aerial potato tubers labeled as samples A to F were diced and soaked in 1500 ml of water in 2 litres plastic container at room temperature (27 °C) and allowed to undergo natural fermentation for 7 days. For backslapping fermentation, Fifty grams (50 g) of previously fermented samples (A to F) were added to 450 g of raw samples A to F in a respective manner, and submerged in 1500 ml of water in 2 litre plastic container at room temperature (27 °C) for 7 days. Five hundred grams (500 g) of aerial potato samples A to F were inoculated with starter cultures of dominant microorganisms and submerged in 1500 ml tap water inside 2 litre plastic container at room temperature (27 °C) for 7 days. During the fermentation, microbial load of aerial potato in backslapping, sample fermented with starter and mixed culture were monitored every 24 hours.

2.3 Isolation and Identification of Microorganisms

Isolation of total viable bacterial, yeast and mould were carried out during fermentation using the methods of Oluitiola et al. [20]. The cultural, morphological and microscopic examination of the isolated bacteria, yeast and mould were done according to Hunter and Bamett [21] and Fawole and Oso [22].

2.4 Statistical Analysis

Data obtained was statistically analysed using SPSS version 20, means of values were separated by new Duncan’s Multiple Range test and significant difference was value at p ≤ 0.05.

3. RESULTS

3.1 Microbial load in Fermented Aerial Potato with Different Methods

Table 1 shows the total viable bacterial counts in aerial potato fermented with mixed culture, backslapping fermented aerial potato and aerial potato fermented with starter culture. The result revealed that the bacterial counts increased as the fermentation period increased, the highest bacterial counts were observed in all the treatments at 120 hours was higher in peeled (30.40±2.00 x 10^10 cfu/g), peeled and parboiled (1.93±1.51 x 10^10 cfu/g) and peeled boiled (8.22±1.83 x 10^10 cfu/g) than the corresponding unpeeled samples. However, the bacterial load reduced at the end of fermentation period (168 hours) where unpeeled parboiled (9.40±1.33 x 10^7 cfu/g) had the highest bacterial counts, followed by peeled (7.50±0.17 x 10^6 cfu/g) and peeled boiled (2.58±0.01 x 10^5 cfu/g) samples. In backslapping fermented aerial potato, it was observed that the bacterial count increases as the fermentation period increased until 120 and 144 hours. At the end of fermentation (168 hours), all the peeled samples (peeled (203.00±0.77 x 10^5 cfu/g); peeled parboiled (101.00±0.51 x 10^3 cfu/g); peeled boiled (544.00±3.57 x 10^5 cfu/g)) had the highest bacterial load compared with the corresponding unpeeled samples. In aerial potato fermented with starter culture, it was noted that bacterial count increases as fermentation period progressed. At the end of fermentation (168 hour), the highest bacterial count were noted in peeled sample (44.13±0.16 x 10^5 cfu/g) followed by unpeeled>peeled parboiled >unpeeled boiled>unpeeled parboiled >peeled boiled. Lactic acid bacterial (LAB) count of aerial potato fermented with different methods are shown in Table 2. In aerial potato fermented with mixed culture, the highest LAB count was observed in different samples at different period of fermentation, the highest LAB counts was observed in peeled (526.70±2.08 x 10^6 cfu/g) at 72 hour, unpeeled (79.40±10.61 x 10^5 cfu/g), peeled parboiled (824.00±1.55 x 10^6 cfu/g) at 48 hour, unpeeled parboiled (456.00±0.77 x 10^6 cfu/g), peeled boiled 392.30±2.98 x 10^4 cfu/g at 96 hour. Lactic acid bacterial (LAB) count in backslapping fermenting aerial potato had the highest LAB counts at the end of fermentation period (168 hour) as 7330.00±0.58 x 10^6 cfu/g in peeled sample. The least value was observed in unpeeled boiled (17.00±0.00 x 10^6 cfu/g). Lactic acid bacterial (LAB) count in aerial potato fermented with starter culture was increased till 120 hours during fermentation and a gradual decrease at 144 and 168 hour. At the end of fermentation period, it was observed that peeled (7.80±0.32 x 10^7 cfu/g) had the highest LAB count, followed by peeled boiled (5.44±3.57 x 10^7 cfu/g) and unpeeled parboiled (2.43±0.12 x 10^7 cfu/g). There was no significant (p<0.05) difference in the LAB counts of unpeeled, peeled parboiled and unpeeled boiled.
Table 1. Total viable bacterial count (cfu/g) in aerial potato fermented with different methods and hours

| Aerial Potato Fermented with mixed cultures | Initial (x 10⁵) | 24 (x 10⁵) | 48 (x 10⁵) | 72 (x 10⁵) | 96 (x 10⁵) | 120 (x 10⁵) | 144 (x 10⁵) | 168 (x 10⁵) |
|--------------------------------------------|----------------|------------|------------|------------|------------|------------|------------|------------|
| Peeled                                     | 0.06±0.00      | 2.69±0.17  | 2.47±0.32  | 5.87±0.12  | 4.63±0.21  | 30.40±2.00 | 20.73±0.12 | 7.50±0.17  |
| Unpeeled                                   | 4.80±0.86      | 1.57±0.12  | 4.99±0.18  | 4.79±0.30  | 2.32±0.37  | 10.79±2.22 | 20.28±3.24 | 1.07±0.00  |
| Peeled parboiled                           | 0.00±0.00      | 0.50±0.01  | 0.70±0.18  | 0.55±0.81  | 0.77±1.00  | 1.93±1.51  | 0.05±0.30  | 1.58±2.27  |
| Unpeeled parboiled                         | 0.14±0.15      | 2.82±0.31  | 3.29±0.31  | 9.95±1.33  | 4.54±0.90  | 1.18±1.59  | 5.07±0.92  | 9.40±1.33  |
| Peeled boiled                              | 0.10±0.00      | 0.75±0.73  | 0.75±0.73  | 3.27±0.31  | 3.13±0.08  | 8.22±1.83  | 4.46±0.49  | 2.58±0.01  |
| Unpeeled boiled                            | 0.00±0.00      | 0.00±0.00  | 1.20±0.00  | 2.10±0.00  | 0.07±0.01  | 4.60±0.00  | 1.63±0.00  | 0.04±0.00  |

| Aerial Potato in back slope Fermentation   |                  |            |            |            |            |            |            |            |
|--------------------------------------------|----------------|------------|------------|------------|------------|------------|------------|------------|
| Peeled                                     | 9.00±0.00      | 113.00±0.12| 106.30±0.03| 443.00±0.40| 943.0±0.15 | 109.70±0.15| 204.30±0.40| 203.00±0.77|
| Unpeeled                                   | 706.00±0.05    | 383.00±0.21| 20.30±0.59 | 579.00±0.18| 41.00±0.31 | 18.40±1.32 | 231.00±1.37|            |
| Peeled parboiled                           | 2.00±0.00      | 100.00±0.00| 10.10±0.68 | 222.00±1.52| 51.00±0.59 | 30.50±0.04 | 15.10±1.02 | 101.00±0.51|
| Unpeeled parboiled                         | 23.00±0.21     | 39.00±0.02 | 4.30±0.30  | 8.00±0.03  | 17.00±0.05 | 5.70±0.39  | 2.30±0.13  | 43.00±0.12 |
| Peeled boiled                              | 13.00±0.09     | 492.00±0.19| 16.30±0.98 | 155.00±1.10| 24.00±0.07 | 67.20±0.47 | 23.40±0.48 | 544.00±3.57|
| Unpeeled boiled                            | 5.00±0.00      | 2.00±0.00  | 18.70±0.00 | 233.00±0.00| 1.00±0.00  | 21.30±0.00 | 16.30±0.00 | 2.00±0.00  |

| Aerial Potato Fermented with starter culture|                  |            |            |            |            |            |            |            |
|--------------------------------------------|----------------|------------|------------|------------|------------|------------|------------|------------|
| Peeled                                     | 9.04±0.00      | 6.31±0.06  | 27.04±1.10 | 12.15±0.14a| 20.73±0.12 | 29.67±0.02 | 54.82±0.21 | 44.13±0.16 |
| Unpeeled                                   | 12.11±0.86     | 5.22±0.53  | 21.31±0.32b| 15.41±0.36b| 20.28±0.24 | 28.44±0.26 | 41.44±0.03 | 31.06±0.07b|
| Peeled parboiled                           | 9.43±0.06a     | 3.14±0.07b | 17.44±0.06a| 9.70±0.70a | 1.05±0.30a | 9.11±0.18a | 36.08±0.47a| 30.05±0.50a|
| Unpeeled parboiled                         | 10.66±0.13a    | 1.86±0.11a | 11.76±0.16a| 10.06±0.03a| 5.07±0.92ab| 11.35±0.33ab| 33.19±10.0 | 27.33±0.11b|
| Peeled boiled                              | 10.81±0.07a    | 2.41±0.02a | 11.54±0.54a| 8.59±0.33a | 4.46±0.49a | 12.42±0.16ab| 37.06±30.0 | 20.41±0.13a|
| Unpeeled boiled                            | 9.42±0.31a     | 1.55±0.01a | 10.31±0.07a| 7.37±0.57a | 1.63±0.00a | 9.55±0.11a | 29.11±42.0 | 29.16±0.42a|

Values are presented as mean±SE, values in the same column carrying same superscript are not different significantly according to new Duncan’s Multiple Range test at p<0.05.
Table 2. Lactic Acid Bacterial (LAB) count in Aerial Potato Fermented with different methods and hours

| Aerial Potato Fermented with cultures | LAB counts (cfu/g x 10^6) | Aerial Potato in back slope Fermentation | LAB counts (cfu/g x 10^6) |
|--------------------------------------|---------------------------|----------------------------------------|---------------------------|
|                                      | Initial 24 48 72 96 120 144 168 |                                        |                           |
| Peeled                               | 0.00±0.00 276.70±0.58 173.30±1.53 526.70±2.08 46.70±2.08 41.70±2.08 61.60±2.08 100.00±1.00 | 30.00±0.00 160.00±0.00 470.00±0.58 730.00±1.53 600.00±1.00 1067.00±0.58 4330.00±0.12 7330.00±0.58 | 1.04±0.00 1.58±2.27 7.80±0.32 33.40±1.06 25.13±0.11 7.80±0.32 |
| Unpeeled                             | 3.00±0.00 3.60±0.00 79.40±10.61 1.10±0.16 11.00±1.42 39.00±5.32 11.30±1.63 49.00±0.00 | 50.00±0.04 668.00±11.54 3335.00±2.84 180.00±0.04 1320.00±0.66 1900.00±1.39 800.00±0.51 390.00±0.19 | 2.07±0.01 2.80±0.03 49.99±0.18 4.79±0.30 6.32±0.37 10.79±2.22 20.28±3.24 1.07±0.00 |
| Peeled parboiled                     | 0.00±0.00 860.00±1.82 824.00±1.55 105.90±1.48 21.00±0.17 1.90±0.01 33.00±0.41 76.00±0.00 | 50.00±0.01 0.00±0.00 220.00±0.14 1860.00±1.28 2450.00±1.65 570.00±0.54 8190.00±0.55 144.00±0.32 | 2.10±0.01 1.57±0.12 4.99±0.18 4.79±0.30 6.32±0.37 10.79±2.22 20.28±3.24 1.07±0.00 |
| Unpeeled parboiled                   | 7.00±0.04 191.80±2.19 308.60±3.82 111.90±1.18 456.00±0.77 22.70±1.55 92.00±7.93 77.00±1.20 | 0.00±0.00 29.30±4.00 56.10±4.83 19.80±2.79 392.30±2.98 298.17±2.36 298.17±4.36 38.80±0.00 | 10.00±0.00 8.40±0.00 1.00±0.00 4.00±0.00 5.00±0.00 6.00±0.00 1.00±0.00 1.00±0.00 |
| Peeled boiled                         | 0.00±0.00 9.00±0.00 1.00±0.00 4.00±0.00 5.00±0.00 6.00±0.00 1.00±0.00 1.00±0.00 | 0.00±0.00 9.00±0.00 1.00±0.00 4.00±0.00 5.00±0.00 6.00±0.00 1.00±0.00 1.00±0.00 | 1.06±0.00 2.69±0.17 2.47±0.32 5.87±0.12 4.63±0.21 33.40±1.06 25.13±0.11 7.80±0.32 |
| Unpeeled boiled                       | 1.00±0.01 1.33±0.31 1.20±0.00 2.10±0.00 2.07±0.01 4.60±0.00 1.63±0.00 1.04±0.00 | 1.02±0.00 0.50±0.01 1.70±0.18 1.55±0.81 1.77±1.00 1.93±1.51 1.05±3.00 1.58±2.27 | 1.23±0.21 0.39±0.02 1.43±0.30 1.08±0.03 2.17±0.05 2.57±0.39 2.23±1.30 2.43±0.12 |

Values are presented as mean±SE, values in the same column carrying same superscript are not different significantly according to new Duncan’s Multiple Range test at p<0.05
3.2 Fungal counts in Fermented Aerial Potato

Fungal counts of aerial potato fermented with different methods and hours is shown in Table 3. In aerial potato fermented with mixed cultures, there was gradual increase in fungal counts until 72 hours when the fungal counts began to decrease. Fungal counts in backslopping fermented aerial potato had the highest fungal counts at 120 hour, unpeeled at 96 hour, peeled parboiled 144 hour, unpeeled parboiled 72 hour, peeled boiled 48 hour, and unpeeled boiled 168 hour. At the end of fermentation (168 hour), peeled (380.00±0.20 x 10^4 sfu/g) had the highest fungal counts followed by unpeeled boiled (32.00±0.00 x 10^4 sfu/g). In aerial potato fermented with starter culture, it was noted that peeled and unpeeled samples had the highest fungal counts at 144 hour. At the end of fermentation period (168 hour), fungal counts of peeled (93.42±0.11 x 10^5 sfu/g) and unpeeled (86.11±0.03 x 10^5 sfu/g) samples were higher than what was observed in other samples while the least fungal count was observed in boiled samples.

3.3 Occurrence of Microorganisms in Fermented Aerial Potato

Occurrence of bacteria in fermented aerial potato is shown in Table 4. The most frequent bacterial isolate were Bacillus subtilis and Lactococcus lactis 15(12.71%), followed closely by Lactobacillus plantarum 13(11.02%) while the least are Dickeya chrysanthemi 2(1.69%) and Citrobacter freundii, Moraxella caprae, Shigella flexneri and Yersinia massiliensis 3(2.54%). The frequency of bacterial isolates were higher in peeled (11) and unpeeled (10) mixed culture fermentation compared with others. It was observed that, the genus Lactobacillus and Lactococcus were present in all the starter culture fermented samples, Escherichia coli was present in peeled and unpeeled mixed culture fermentation and in peeled and unpeeled parboiled mixed culture, Bacillus subtilis was present in all the fermented samples except unpeeled, peeled boiled and unpeeled boiled starter culture fermented samples. Occurrence of fungal isolates in fermented aerial potato is shown in Table 5. The most frequent fungi are Candida tropicalis 18(36.00%) which is present in all the samples followed by Saccharomyces cerevisiae 12(24.00%) while the least frequent fungal isolates were Aspergillus fumigatus, Aspergillus terreus, Geomyces pannorum, Penicillium brevicompactum and Penicillium corylophilum, they are mostly isolated from mixed culture fermentation. Aspergillus parasiticus was isolated from mixed culture fermented peeled and unpeeled aerial potato only, Fusarium oxysporum was isolated from all the fermentation processes in unpeeled parboiled samples. Also, there was no presence of Aspergillus in all the peeled backslopping and starter culture fermented samples.

4. DISCUSSION

Initial increase in microbial load in all the samples of aerial yam observed in this study could be due to the fact that aerial potato is very rich in carbohydrate (73.62% in tuber), which could sustain the growth of microorganisms. Bello and Akinyele (2007) and Sanjeet et al. [3] reported that growth of some microorganisms are inhibited by the metabolic products of others in the growth medium thereby accounting for decrease recorded in microbial load of the aerial potato during fermentation. However, higher microbial counts in samples that was subjected to back-sloping fermentation agreed with the findings of [23] who reported that back-sloping fermentation has been proven to accelerate the fermentation rate and improve food quality. Also, higher lactic acid bacterial counts observed in peeled backslopping fermented samples could increase the nutritional contents of the sample and as well reduce the presence of pathogenic microorganisms. The occurrence of Shigella, Escherichia and Staphylococcus which are potential pathogens in food could make aerial potato unfit for human consumption, however, the presence of Lactobacillus and Lactococcus, which are mostly involved in the fermentation processes help reduce their effects. Also, the lactic acid bacteria could increase the bioavailability of nutrients with a significant increase in the shelf life. The low occurrence of bacteria recorded in the backslopping and starter culture fermented samples could be as a result of suppression of other bacteria by the presence of lactic acid bacteria confirmed by the absence of Escherichia coli in backslopping and starter culture fermented samples respectively [18]. However, presence of Alternaria, Aspergillus, Cladophialophora, Fusarium, Geomyces and Geotrichum which are either toxin producing or spoilage fungi could affect the safety of fermented aerial potato for human consumption, while presence of Saccharomyces and Candida species could improve the quality and shelf life of the final product. Backslopping and starterculture...
Table 3. Fungal counts of mixed culture of Fermenting Aerial Potato

| Aerial Fermented mixed cultures with Potato | Initial | 24 | 48 | 72 | 96 | 120 | 144 | 168 |
|-------------------------------------------|---------|----|----|----|----|-----|-----|-----|
| Peeled                                    | 0.00±0.00 | 0.00±0.00 | 17.03±0.06 | 30.90±0.06 | 14.01±2.08 | 2.30±0.58 | 0.34±0.59 | 4.17±0.08 |
| Unpeeled                                  | 3.30±0.00 | 8.01±0.11 | 49.04±0.06 | 95.02±0.13 | 14.04±0.23 | 1.30±0.23 | 0.09±0.10 | 0.00±0.00 |
| Peeled parboiled                          | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 14.03±0.15 | 0.71±0.01 | 0.19±0.27 | 0.04±0.00 |
| Unpeeled parboiled                        | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 2.60±0.26 | 0.42±0.00 | 0.02±0.03 | 0.01±0.01 |
| Peeled boiled                             | 1.10±0.01 | 1.00±0.00 | 0.00±0.00 | 0.00±0.00 | 1.10±0.01 | 43.4±0.63 | 4.34±0.60 | 0.39±0.00 |
| Unpeeled boiled                           | 2.00±0.00 | 1.00±0.00 | 0.00±0.00 | 3.01±0.00 | 7.41±0.00 | 2.02±0.00 | 0.06±0.00 | 0.03±0.00 |

| Aerial Potato in back slope Fermentation (sfu/g x 10^6) |
|--------------------------------------------------------|
| Peeled                                                  | 0.00±0.00 | 43.00±1.53 | 17.00±0.52 | 40.70±0.12 | 467.00±1.53 | 1333.00±0.15 | 900.00±2.00 | 380.00±0.20 |
| Unpeeled                                                | 80.10±0.16 | 6.00±0.04 | 12.00±0.01 | 34.00±0.02 | 44.40±0.03 | 11.40±0.10 | 8.00±0.05 | 3.00±0.02 |
| Peeled parboiled                                        | 14.00±0.00 | 1.00±0.00 | 2.00±0.01 | 2.00±0.01 | 5.00±0.03 | 4.00±0.00 | 7.00±0.01 | 4.00±0.00 |
| Unpeeled parboiled                                      | 1.10±0.01 | 2.00±0.00 | 1.00±0.00 | 8.00±0.01 | 3.00±0.01 | 6.00±0.00 | 7.00±0.00 | 6.00±0.00 |
| Peeled boiled                                            | 16.00±0.00 | 0.00±0.00 | 4.40±0.03 | 8.00±0.05 | 2.00±0.01 | 2.00±0.00 | 1.00±0.00 | 2.00±0.00 |
| Unpeeled boiled                                          | 4.00±0.00 | 3.00±0.00 | 0.00±0.00 | 4.00±0.00 | 9.00±0.00 | 2.00±0.00 | 1.00±0.00 | 3.00±0.00 |

| Aerial Potato Fermented with starter culture (sfu/g x 10^6) |
|-------------------------------------------------------------|
| Peeled                                                      | 1.14±0.08 | 7.64±0.33 | 21.32±0.77 | 77.68±0.06 | 104.13±0.15 | 207.31±0.21 | 293.10±0.31 | 93.42±0.11 |
| Unpeeled                                                   | 46.70±1.53 | 24.11±0.06 | 24.16±0.34 | 31.44±0.13 | 112.03±0.51 | 153.16±0.09 | 187.30±0.90 | 86.11±0.03 |
| Peeled parboiled                                           | 1.14±0.23 | 5.31±0.41 | 11.59±0.16 | 21.62±0.33 | 94.13±0.53 | 83.44±0.31 | 27.14±0.16 | 19.41±0.33 |
| Unpeeled parboiled                                         | 1.44±0.03 | 11.11±0.02 | 16.02±0.02 | 34.11±0.18 | 100.05±0.16 | 72.16±0.42 | 34.11±1.31 | 21.17±0.42 |
| Peeled boiled                                              | 1.14±0.15 | 9.42±0.16 | 15.11±0.11 | 21.08±0.08 | 92.15±0.03 | 55.41±0.16 | 18.41±0.41 | 10.14±0.38 |
| Unpeeled boiled                                            | 1.05±0.03 | 3.31±0.08 | 18.41±0.07 | 36.41±0.03 | 107.31±0.01 | 61.22±0.22 | 22.63±0.17 | 15.05±0.06 |

Values are presented as mean±SE, values in the same column carrying same superscript are not different significantly according to new Duncan’s Multiple Range test at p<0.05
Table 4. Occurrence of bacteria in Fermented Aerial Potato

| Bacterial isolates                  | Peeled MCF | Peeled BSF | Peeled STF | Unpeeled MCF | Unpeeled BSF | Unpeeled STF | Peeled boiled MCF | Peeled boiled BSF | Peeled boiled STF | Unpeeled boiled MCF | Unpeeled boiled BSF | Unpeeled boiled STF | Total (%) |
|-------------------------------------|------------|------------|------------|--------------|--------------|--------------|-------------------|-------------------|-------------------|---------------------|---------------------|---------------------|------------|
| Acinetobacter radioresistens       | + - - -    | + - - -    | - - - -    | + - - - -    | + - - - -    | + - - - -    | 4(3.39)           |                   |                   |                     |                     |                     | 4(3.39)   |
| Bacillus farraginis                 | - - - -    | + - + -    | - - - -    | + + - - -    | + - - - -    | + - - - -    | 4(3.39)           |                   |                   |                     |                     |                     | 4(3.39)   |
| Bacillus subtilis                  | + + + -    | + - - -    | + - - -    | + + + + +    | + + + + +    | + + + + +    | 15(12.71)         |                   |                   |                     |                     |                     | 15(12.71) |
| Citrobacter freundii               | + - - -    | + - - -    | - - - -    | + - - - -    | + - - - -    | + - - - -    | 3(2.54)           |                   |                   |                     |                     |                     | 3(2.54)   |
| Citrobacter sedlakii               | - - - -    | + - - +    | - - - -    | - - - - -    | - - - - -    | - - - - -    | 4(3.39)           |                   |                   |                     |                     |                     | 4(3.39)   |
| Dickeya chrysanthemi               | + - - -    | + - - -    | + - - -    | - - - - -    | - - - - -    | - - - - -    | 2(1.69)           |                   |                   |                     |                     |                     | 2(1.69)   |
| Escherichia coli                   | + + - +    | + - - +    | + - - +    | + + - - +    | + + - - +    | + + - - +    | 6(5.08)           |                   |                   |                     |                     |                     | 6(5.08)   |
| Lactobacillus delbrueckii          | + + + +    | + + + +    | + + + +    | + + + + +    | + + + + +    | + + + + +    | 10(8.47)          |                   |                   |                     |                     |                     | 10(8.47)  |
| Lactobacillus fermentum            | + + + -    | + + - -    | + + - -    | + + + + -    | + + + + -    | + + + + -    | 10(8.47)          |                   |                   |                     |                     |                     | 10(8.47)  |
| Lactococcus lactis                 | + + + +    | + + + +    | + + + +    | + + + + +    | + + + + +    | + + + + +    | 15(12.71)         |                   |                   |                     |                     |                     | 15(12.71) |
| Lactobacillus plantarum            | + + + +    | - - - +    | - - - +    | + + + + +    | + + + + +    | + + + + +    | 13(11.02)         |                   |                   |                     |                     |                     | 13(11.02) |
| Moraxella caprae                   | - - - -    | + - - -    | + - - -    | - - - - -    | - - - - -    | - - - - -    | 3(2.54)           |                   |                   |                     |                     |                     | 3(2.54)   |
| Morganella morgani                 | - + + +    | - - + -    | - - + -    | + + + + +    | + + + + +    | + + + + +    | 8(6.78)           |                   |                   |                     |                     |                     | 8(6.78)   |
| Pseudomonas aeruginosa             | + - - +    | + + + +    | + - - +    | + + + + +    | + + + + +    | + + + + +    | 10(8.47)          |                   |                   |                     |                     |                     | 10(8.47)  |
| Staphylococcus aureus              | + + + +    | - - - -    | - - - -    | + + + + +    | + + + + +    | + + + + +    | 5(4.24)           |                   |                   |                     |                     |                     | 5(4.24)   |
| Shigella flexneri                  | - - - +    | + - - -    | + - - -    | + + + + -    | + + + + -    | + + + + -    | 3(2.54)           |                   |                   |                     |                     |                     | 3(2.54)   |
| Yersinia massiliensis              | - - - -    | + + - -    | + - - -    | + + - - -    | + + - - -    | + + - - -    | 3(2.54)           |                   |                   |                     |                     |                     | 3(2.54)   |
| Total                              | 11 8 6     | 10 9 7     | 6 4 6      | 8 5 7        | 4 5 5        | 6 6 5        | 118               |                   |                   |                     |                     |                     | 118       |

Key: - = absent, + = present, MCF = mixed culture fermentation, BS = backslopping fermentation, ST = starter culture fermentation
### Table 5. Occurrence of fungi in Fermented Aerial Potato

| Bacterial isolates            | Peeled | Unpeeled | Peeled parboiled | Unpeeled parboiled | Peeled boiled | Unpeeled boiled | Total (%) |
|------------------------------|--------|----------|------------------|--------------------|---------------|-----------------|-----------|
|                             | MCF    | BSF      | STF              | MCF                | BSF           | STF             |           |
| Alternaria alternate        | -      | -        | +                | +                  | -             | -               | 3(6.00)  |
| Aspergillus fumigatus       | -      | -        | +                | -                  | -             | -               | 1(2.00)  |
| Aspergillus niger           | -      | -        | -                | +                  | -             | -               | 3(6.00)  |
| Aspergillus parasiticus     | +      | -        | -                | -                  | -             | -               | 2(4.00)  |
| Aspergillus terreus         | -      | -        | -                | -                  | -             | +               | 1(2.00)  |
| Cladophialophora carrionii  | -      | -        | -                | -                  | -             | -               | 2(4.00)  |
| Candida tropicalis          | +      | +        | +                | +                  | +             | +               | 18(36.00) |
| Fusarium oxysporum          | -      | -        | -                | -                  | -             | +               | 3(6.00)  |
| Geotrichum candidum         | -      | -        | -                | +                  | -             | -               | 2(4.00)  |
| Geomyces pannorum           | -      | -        | -                | -                  | -             | +               | 1(2.00)  |
| Penicillium brevicompactum  | -      | -        | -                | -                  | -             | +               | 1(2.00)  |
| Penicillium corylophilum    | -      | -        | -                | -                  | -             | +               | 1(2.00)  |
| Saccharomyces cerevisiae    | +      | 1        | 2                | 4                  | 3             | 3               | 12(24.00) |
| Total                        | 3      | 1        | 2                | 4                  | 3             | 4               | 50        |

Key: - = absent, + = present, MC = mixed culture fermentation, BS = backslopping fermentation, ST = starter culture fermentation
fermentation process was able to eliminate the presence of *Aspergillus* and this could be due to the production of some antimicrobial compounds.

5. CONCLUSION

In conclusion, presence of some potential pathogenic bacteria as well as toxin producing and spoilage fungi in fermented aerial potato is a challenge to public health. Backslipping and starter culture fermentation methods were able to eliminate majority of these microorganisms especially in peeled and peeled boiled samples, therefore, these two methods can be employed in the processing of aerial potato for food.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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