Microbial Quality Assessment of Open Sun and Solar Tent Dried Barbus paludinosus in Lake Chilwa Basin

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Abstract This study assessed the effects of two processing methods; open sun drying and solar tent drying on microbial quality of Barbus paludinosus, (straight fin barb locally known as Matemba), a species of ray-finned fish in the family Cyprinidae that supports a significant fishery sector in Malawi. Barbus paludinosus (Matemba) were dried using open sun drying and solar tent driers. Samples were collected in newly bought polythene bags, well labelled and collected in cooler boxes transported ready for laboratory analysis. One gram (1g) representative sample was obtained aseptically from the muscle of the fresh and dried straight fin barb (Matemba) samples. The samples were grounded and serial dilutions (10-1 to 10-5) of the homogenized samples were made using sterile distilled water. Fish samples were analysed for total plate count (TPC), E. coli counts and for pathogenic organisms (Salmonella) following the methods prescribed by (AOAC, 2000). Each analysis was carried out in triplicates. There were significant differences (P<0.05), with respect to total viable bacterial counts between open sun dried and solar tent dried B. paludinosus (1.6 x 10^8 cfu/g, 1.4 x 10^8 cfu/g, respectively). Open sun dried B. paludinosus harboured significantly higher total viable counts as well as a higher population of Escherichia coli compared to solar tent dried Barbus paludinosus. Overall, bacterial populations were not above the marginally acceptable norms (1 x 10^7 cfu/g) for both processing methods implying that the two methods can be deployable without public health concerns.

Keywords Solar tent drier; Open sun drying; Microbial analysis; Barbus paludinosus; Fish processing; Salmonella typhi

Background Fishing has been regarded as very significant to Malawi as it contributes to the livelihood of Malawians. The fishing industry contributes about 4% to the Gross Domestic Product (GDP) for Malawi and employs about 60000 fishers and indirectly employ over half a million Malawians through processing, fish marketing and boat building and repair. Many of these employees are rural women involved in fish processing and marketing (Government of Malawi, 2012).

In Malawi, fisheries are an important part of food security as fish is a reliable source of food and nutritional security. Fish accounted for 70% of animal protein intake and 40% of total protein consumed by the Malawian population in the 1970s. The trend has however changed as there has been a decline in fish landings and increase in population over time during the past thirty years. This has led to the decline of per capita fish consumption from 14 kg per person per year in the 1970s to about 5.6 kg in 2011 (Government of Malawi, 2012).

The fish landings in the Lake Chilwa have been declining over the years with mean total landings for period 2000-2009 pegged at 7537 tonnes per year which are lower than the peak of 12000 tonnes per year in the 1990s (EAD, 2004). The decline in the fish landings brings to light the need to preserve the harvested fish to reduce post-harvest losses which are estimated at 30% of the fish landings (Jamu et al., 2012). Thus adoption of processing technologies offers an opportunity to the processors to preserve as much fish as possible.

In spite of fish being a highly nutritious and economically viable food, it is also one of the most perishable because of its suitable medium for growth of microbes after harvest. Spoilage and deterioration is much faster amongst tropical fish species because of high ambient temperature prevalent in the tropics. Most tropical fish...
species could become unfit for consumption within 12-20 h of capture unless it is subjected to some form of processing (ECA, 1984; Ames et al., 1999; Aberoumand, 2013) which include preservation by drying. Various factors such as fish health status, parasites, wounds and bruises, mode of capture, handling, and preservation after capture are responsible for fish spoilage (Akinneye et al., 2007; Tawari and Abowej, 2011). Chemical, microbial, and enzymatic actions on captured fish bring about spoilage with resultant deterioration in the flesh, body tissues, and organs of the fish through physical and biochemical changes (Ghaly et al., 2010).

Barbus paludinosus (Matemba) a small fish which is endemic to the Lake Chilwa and is widely consumed in Malawi as a common relish and liked by many. The fish is a good source of proteins and micronutrients such as calcium, iron (Beveridge et al., 2013). Considering the importance of this fish and its distribution, it was necessary to study the drying processes of the fish and the effect of the drying methods on the microbial quality of fish. Fishing of Matemba is usually done from March to October.

According to Kapute (2008), fish processing methods in Malawi include drying, smoking, boiling, and pan roasting. In order to reduce post-harvest losses fish processors in the Lake Chilwa basin use different processing methods to preserve the fish before the fish is sold to wholesalers, retailers and consumers. Matemba are commonly dried using open sun drying methods on raised drying racks.

Mustapha et al. (2014) have reported that sun drying of fish is one of the traditional methods used to preserve fish in many sub-Saharan African countries because of the richness in availability of high solar radiance for a greater part of the year. Sun drying helps to remove water from the fish by evaporation (Eyo, 2001) and this reduces water activity of the fish which results in the slowdown of autolytic activity, enzymatic reactions, and microbial activities. Sun drying of fish which is usually done in the open exposes fish to contaminants such as dust, insect, pest, bird and animal attack. The fish are also vulnerable to infection by microorganisms, enzymatic reaction which leads to poor quality and spoilage of preserved fish. As a way of overcoming the shortfalls associated with sun drying, solar driers have been introduced and adopted as a way of drying fish and these have resulted in speeding up drying of fish resulting in high quality products with a longer shelf-life (Oparaku et al., 2010; Mustapha et al., 2014). The study therefore assessed the effects of processing methods (open sun drying and solar tent drying) on Barbus paludinosus.

1 Results

The study showed that highest total viable counts were observed in open sun dried fish (1.6 x 10^6 cfu/g) as compared to solar tent dried fish (1.4 x 10^6 cfu/g) and these results were different significantly (P< 0.05) (Table 1). The bacteria that were also isolated from the open sun dried and solar tent dried fish were total coliforms (2.1 x 10^5 and 4.8 x 10^5 cfu/g), E. coli (9.6 x 10^4 and 0 cfu/g) and Salmonella (3.5 x 10^4 and 0), respectively.

| Sample ID | Total Plate Counts | Total Coliforms | E. coli | Salmonella |
|-----------|-------------------|----------------|--------|------------|
| Fresh Barbus paludinosus | 7.7 x 10^5 | 1.5 x 10^5 | 1.0 x 10^6 | 2.9 x 10^4 |
| Open sun dried Barbus paludinosus | 1.6 x 10^6 | 2.1 x 10^6 | 9.6 x 10^5 | 3.5 x 10^4 |
| Solar tent dried Barbus paludinosus | 1.4 x 10^6 | 4.8 x 10^5 | 0 | 0 |

Low moisture content and higher temperatures were recorded in solar tent drier than in open sun drying (Table 2). The study also showed that the free fatty acid, which is a tertiary product of rancidity, which increases during storage (four weeks), was lower in the solar tent dried fish than open sun dried fish. Free fatty acid ranged from 0.017±0.000 in solar tent dried fish to 0.058±0.001 in open dried fish (Table 3).

| Fish treatment | Moisture content % | Temperature | Relative Humidity (%) |
|----------------|-------------------|-------------|-----------------------|
| Fresh Barbus paludinosus | 77.6±0.9^b | 23.6°C | 74.3 |
| Open sun dried Barbus paludinosus | 30.4±2.6^a | 23.6°C | 74.3 |
| Solar tent dried Barbus paludinosus | 23.3±1.1^c | 31.8°C | 62.7 |
Table 3 Free fatty acid values of fish samples

| Sample                     | Free fatty acid % |
|----------------------------|-------------------|
| Fresh *Barbus paludinosus* | 0.034±0.005       |
| Open sundried *Barbus paludinosus* | 0.058±0.001 |
| Solar tent dried *Barbus paludinosus* | 0.017±0.000 |

2 Discussion
Salmonella and *Escherichia coli* were not detected in solar tent dried fish which is implies drying was effective as there were recorded higher temperatures and low relative humidity in the solar tent drier as compared with open sun drying. This enhanced moisture loss and created an environment not conducive for microbial growth. This shows that solar tent driers were efficient in reducing microbial load in the dried fish. Both these pathogens are associated with food borne illnesses and are an indicator of poor hygiene (Banda et al., 2017). Salmonella is a pathogen of public health as such it is important to look at source of contamination and encourage proper and hygienic handling of fish during processing.

The results in Table 1 show that the fresh fish sample had fewer microbes (7.7 x 10^5) than the dried fish samples (1.6 x 10^6 and 1.4 x 10^6) for open sun drying and solar tent drying respectively. This means that there was encouraged growth of microorganisms during the drying time especially in the initial stages as the fish had more moisture content then. These results also show that there are possibilities of contamination through handling of the fish during drying process. Other contamination may also be attributed to the drying facilities as these are not thoroughly cleaned before drying new consignment of fish. Most of the facilities are used by many people as the facilities are either communal or individually owned but hired out to other processors.

Adegunwa et al. (2013) previously reported that the International Commission on Microbiological Specification for Food (ICMSF) has set the maximum recommended bacteria count for good quality fish products at 5.0 x 10^5 cfu/g and 1 x 10^7 cfu/g as the maximum for marginally acceptable quality products and for *Listeria monocytogenes* and Salmonella spp., the level in the presence of organism is zero tolerance. This calls for more sensitization on hygienic practices for all processors and fishers during handling and processing of fish. Solar tent dried *Barbus paludinosus* had lower moisture content (23.3±1.1%) than open sun dried (30.4±2.0).

Fish spoilage has been shown to be a function of moisture content. Patterson and Ranjitha (2009) have reported that high total plate counts, *E. coli* were recorded in processed fish which had high moisture content. Fish that were dried to moisture levels of 6 to 8% had retarded rate of microbial spoilage because of low water activity which in turn increases the shelf life. The higher temperatures recorded during drying of the fish in the solar tent drier helped to remove more water from the fish though in this study the moisture content was still higher than the recommended moisture for dried fish. This was so because the study used the fish in the normal way fish processors dry the fish. This resulted in the higher moisture content which might have encouraged microbial growth as shown by the results. However, the study has shown that solar tent driers were more efficient in drying the fish and also reducing the microbial load in the dried fish.

The solar tent drier which is an enclosure protected the fish from dust, flies, rain and predators (Tiwari, 2016). The temperature within the drier was in the range 29.8-42.8°C which was higher than in open sun drying (18.1-33.6°C).

Drying methods of *Barbus paludinosus* resulted in significant differences in moisture content of the processed fish (P < 0.05). The solar dried fish as shown in Table 2 had lowest moisture content of 23.27% which is in agreement with results found by Immaculate et al. (2012) in that open sundried fish had higher moisture content than solar tent dried fish, though they recorded much lower moisture content in the fish. The moisture content results showed that all the processed fish still had higher moisture content which would result in encouraged microbial growth as in all the samples the moisture content was higher than 20% with the lowest moisture content of 23.27±1.13% recorded in solar tent dried fish.
According to Eyo (1993) rancidity in fish oils becomes evident when the free fatty acid which is calculated as oleic acid is between 0.5 and 1.5 and in this research all the samples were below this limit. This means that the fish were of good quality and that the microorganisms that were found during the study may have been due to handling and might have been on the fish before processing.

3 Materials and Methods

3.1 Study sites
The study was carried out in Zomba District at Mchenga beach in the Lake Chilwa basin where a CultiAf project funded by International Development Research Centre (IDRC) and Australian Centre for International Agriculture Research (ACIAR) was being implemented.

3.2 Study design
A completely randomised design was used when samples were collected from fish processors after processing for microbial analysis. All the samples were collected from fish processors soon after processing; 2 kg for each processing method (fresh fish, open sun dried and solar tent drier dried). The fresh fish after being collected from the landing sites were open sun dried (Figure 1) and solar tent dried (Figure 2) on the raised drying racks. The samples were put in new polythene bags, labelled and collected in cooler boxes transported ready for laboratory analysis. Fresh samples were immediately put on ice before being taken to the laboratory while other samples were processed and collected immediately after and transported to the laboratory. Both the fresh and processed samples were collected from the same batch after purchase. At the laboratory samples were composited from each batch for subsequent analysis.

Figure 1 Open sun drying of fish

Figure 2 Solar tent drier in Mchenga beach, Lake Chilwa

3.3 Solar tent drier description
The Solar tent drier was made up of a UV treated polythene 200 μm sheet worn over a wooden frame (Figure 2). Its dimensions were 12 m × 5 m × 5.5 m (length × width × height at the centre). The height at the side was 2.5 m.
The solar tent drier had an inlet air vent on the bottom with a dimension of 30 cm × 30 cm and outlet vents up on both sides of the vertex with a dimension of 40 cm × 40 cm. The vents provided circulation of air to speed up drying process through convection current and these were sealed with galvanized fine meshed gauze wire to check entry of flies. Inside the solar tent drier are drying racks used to dry fish which were 11 m × 1 m (length × width).

3.4 Microbiological analyses
One gram (1 g) representative sample was obtained aseptically from the muscle of each of the dried samples. The samples were grounded and serial dilutions ($10^{-1}$, $10^{-2}$, $10^{-3}$) of the homogenized samples were made using sterile distilled water. Each analysis was carried out in triplicates. The fish samples were analysed for total plate count, total coliforms, *E. coli* and pathogenic microorganisms (*Salmonella*). All microbial analyses were done following the methods prescribed by (AOAC, 2000). The results were reported in cfu/g.

Aliquots of suitable dilutions were transferred separately to plates count agar for total plate count, *Salmonella-Shigella* agar for salmonellae count, MacConkey agar for *E. coli* count and Violet Red Bile agar for total coliforms count.

3.5 Moisture content analysis
Moisture content was analysed using oven drying methods according to methods of AOAC (2010) and Bradley (2010).

3.6 Free fatty acids determination
Fat was extracted using Soxhlet method. Free fatty acids were analysed using methods of Oparaku et al. (2010).

3.7 Data analysis
All analyses were done using the SPSS software for Windows (version 16) (SPSS Inc., 2006, Chicago, IL). One-way analysis of variance (ANOVA) where P < 0.05 was applied to the different sample values obtained.

4 Conclusion
The findings of the study have shown that solar tent drier would help in processing of small fish and having them processed in high quality. The solar tent driers have an advantage also over open sun drying in that fish was dried even during adverse weather conditions and the fish was also protected from dust, flies and other predators.

Authors’ contributions
ML collected samples, conducted the experiment, evaluated data and prepared the manuscript. PM prepared samples for analysis, evaluated data, reviewed manuscript. MK helped in collecting samples, prepared samples for analysis and data processing. WK evaluated data and critical review of manuscript. All authors read and approved the final manuscript.

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