E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2017; 5(5): 212-218

www.fisheriesjournal.com
Received: 27-07-2017
Accepted: 28-08-2017

James Banda
Fisheries Science Department, Mzuzu University, Private Bag 201, Mzuzu 2. Malawi, East Africa

Petros Chigwechokha
Fisheries Science Department, Mzuzu University, Private Bag 201, Mzuzu 2. Malawi, East Africa

Wales Singini
Fisheries Science Department, Mzuzu University, Private Bag 201, Mzuzu 2. Malawi, East Africa

John Kamanula
Chemistry Department, Mzuzu University, Private Bay 201, Luwinga, Mzuzu 2. Malawi, East Africa

Orton Msiska
Fisheries Consultant, P.O. Box 833. Mzuzu, Malawi, East Africa.

Jupiter Simbeye
Mathematics Department, Chancellor College, P.O Box 280, Zomba, Malawi, East Africa.

Correspondence
James Banda
Fisheries Science Department, Mzuzu University, Private Bag 201, Mzuzu 2. Malawi, East Africa

The Shelf life of Solar Tent Dried and Open Sun Dried *Diplotaxodon limnothrissa* (Ndunduma)-Pisces; Cichlidae

James Banda, Petros Chigwechokha, Wales Singini, John Kamanula, Orton Msiska and Jupiter Simbeye

Abstract
The study evaluated changes in chemical, physical, microbial quality of solar tent dried and open sun dried *Diplotaxodon limnothrissa* fish species from Malembo landing site after 9 weeks of storage at ambient temperature. The shelf life of solar tent dried and open sun dried *Diplotaxodon limnothrissa* fish species was estimated at 7 and 3 weeks respectively. Spoilage indicators Total Volatile Basic Nitrogen (g/100mg) and pH range were 15.45-17.31, 6.26-6.6.35 for solar tent dried fish and 15.74-20.56, 6.32-6.41 for open sun dried fish. At the period of sensory rejection, total bacteria viable counts, Total Volatile Basic Nitrogen and pH were 5.7×10^6 cfu/g, 18.98 and 6.38, respectively, for open sun dried. On the other hand, solar tent dried fish registered 4.1×10^2 cfu/g total bacteria viable counts, 17.28 Total Volatile Basic Nitrogen and pH 6.33. Relatively higher levels of *Esherichian coli, Salmonella, Vibrio* and *Micrococcus* bacteria were detected in open sun dried compared to the solar tent dried fish. Protein range for solar tent dried and open sun dried samples were 63.3±0.15-61.09±0.07% and 63.3±0.34-58.19±0.21% respectively. Moisture content remained constant and significant (p= 0.001) at 8.3±0.12 and 17.0±0.01% for solar tent dried and open sun dried *Diplotaxodon limnothrissa* respectively. Visible fungal growth was observed from week 2 of storage in open sun dried fish and the isolates of *Aspergillus* 3.3×10^1 and *Penicilium* 3.3×10^1 were identified. The results confirmed the application of solar tent drying as an efficient technology for fish processing in Malawi. The study recommend use of solar tent drying to increase shelf life and safeguarding markets for value addition of small fish products in Malawi.

Keywords: *Diplotaxodon limnothrissa,* sensory, microbiological analysis, chemical analysis, Lake Malawi

1. Introduction
The global consumption of fish and fish products has greatly increased in recent decades, due to a number of factors [1]. Foremost among these factors is the growing knowledge that fish constitute an important and healthy part of the human diet, mainly owing to the presence of ω-3 polyunsaturated fatty acids, which play an essential role in human health, presence of micronutrients (vitamins, minerals) and proteins with a high biological value [2]. Fish constitute a significant proportion of diets in Malawi, contributing over 50% total animal protein consumption by the population [3]. Several fish species, including *Diplotaxodon limnothrissa* probably the most abundant cichlid with high biomass estimates in the pelagic zone alone are popular diet constituents in Malawi. The species is exploited commercially in the South Eastern and Western Arm of the lake [4].
Fish is recognised as being highly perishable, having a relatively short shelf life. Fish's shelf life is influenced by a number of factors. The peculiarity chemical composition of fish is a major factor responsible for their high perishability [5]. The high content of water, non-protein nitrogenous compounds, unsaturated fatty acids, presence of bacterial flora on the skin surface and in gastro-intestinal tract and the activity of endogenous enzymes contribute to the high perishability of fish. Furthermore, the high ambient temperature hastens fish spoilage by accelerating the activities of bacteria, enzymes and chemical oxidation of fat in fresh fish [6]. This call for proper processing technologies to minimize rate of spoilage and increase shelf life of processed fish. It is reported that fish processing reduces spoilage and microbial contamination that would pose a threat to the health and safety of the consumer [7]. A number of studies have indicated that quality is still the key buying cue for fish purchasers [8].

Besides, in order to secure food safety, it is important to keep the quality of processed fish products acceptable to consumers over a range period of time [9].

In Malawi, common fish processing methods include para boiling, smoking and sun drying [10]. The characteristic of dried fish that renders them long shelf life is the low water activity that prevents growth of spoilage microorganisms [11, 12]. Although sun drying is used most frequently, it is very imperfect during the rainy season due to excessive rainfall, high relative humidity and cloud cover. Sun drying is also fraught with other problems such as contamination by dust and insect infestation that carry faecal material and result in poor quality of the processed fish due to high microbial load [13]. A number of studies have indicated that contamination of food with mycotoxin is unavoidable and unpredictable hence posing a unique challenge to food safety [14]. Furthermore, food safety issues are a concern worldwide due to increased risks related to food borne illnesses such as melamine, *salmonella*, and cholera [15]. To get better quality-dried fish with longer shelf life, it is very essential to use improved methods of fish drying. In additional, it is also important to maintain required hygiene during the different phases of fish drying. Shelf life studies provide important information to both researchers and consumers ensuring that consumers appreciate a high quality product for a significant period of time after production. Thus, in the search for improved drying techniques using naturally abundant solar energy, solar tent drying systems have been investigated and tested on Lake Malawi by the Fisheries Research Unit of the Department of Fisheries as an alternative to open sun drying.

The fact that the solar tent drying is a new processing technology for processing small fish species like *Diplotaxodon limnothrissa* in Lake Malawi underscores the need for estimating the duration of safety for processed fish. The information is greatly required by consumers, processors and for adequate post-harvest management and processing. It is against this background that shelf life of solar tent dried and open sun dried *Diplotaxodon limnothrissa* were assessed for the chemical, physical and microbiological changes after storage at room temperature for nine weeks.

2. Materials and methods

2.1 Study area

The study was conducted at Malembo landing site in South West Arm (SWA) of Lake Malawi at Monkey bay in Mangochi district. Mangochi is in the Southern region of Malawi covering an area of 6, 273 km^2 with a population of 610, 239 [16].

2.2 Solar tent dryer

The Solar tent dryer was made up of a UV treated polythene 200 µm sheet worn over a wooden frame (Fig 1.0). The dimensions of the solar tent dryer were 12m x 5m x 5.5m (length x width x height at the center). The height at the side was 2.5m. The solar tent dryer consisted of inlet air vents on the bottom with a dimension of 30cm × 30cm and outlet vents up on both sides of the vertex with a dimension of 40cm x 40cm. This enhanced natural circulation of air through the convection current process. Both vents well sealed with galvanized fine meshed gauze wire to prevent entry of flies. The dimensions of the drying racks were 11m x 1 m (length x width). In order to provide air circulation, the gap between drying racks was 90cm.

Fig 1: Solar Tent Dryer

2.3 Sample collection, preparation and processing

Fresh *Diplotaxodon limnothrissa* fish species were collected from pair fish trawlers at Malembo landing sites in the South West Arm of Lake Malawi. The fish were thoroughly washed and arranged on the racks within the solar tent dryer and open sun drying racks in sub samples of 4000g.

Fig 2: Fish processing methods employed. Solar tent drying (a) and open sun dying (b)

2.4 Analytical procedures

Dried samples of *Diplotaxodon limnothrissa* were used for the analytical procedures. Fresh dried samples from the solar tent dryer and open sun drying were packed in sealed plastic packet in 60 µm polythene papers. Samples for each processing technique were kept in separate shelves at ambient atmospheric temperature for 9 weeks. Shelf life determination of the products was carried out by using turn-over time, end point study and accelerated testing.

In all these methods, quantity of samples were subjected to laboratory tests for microbiological organisms, chemical factors, physical and sensory evaluation which were carried

out at weekly intervals. For the preparation of samples, whole dried fish samples were homogenised before analysis.

2.5 Chemical analysis

2.5.1 Total Volatile Basic Nitrogen (TVB-N)

Total Volatile Bases (TVB-N) were determined by a slight modification of Conway Microdiffusion Method [17]. About 25g of the fish samples muscle tissues were removed, chopped and thoroughly mixed with 75 ml distilled water in a 250 ml beaker. The pH was adjusted to 5.2 by addition of few drops of 2N HCl, followed by heating at 70 °C and cooling to room temperature. After cooling, the sample was filtered into a conical flask with the aid of a Whatman No. 1 filter paper. After that, 2ml of 0.025N HCl was transferred to the central compartment of the microdiffusion dish by pipetting, followed by the addition of 2ml of the extract and 1ml of saturated K_2CO_3 solution into the outer ring. The dish was covered immediately with a glass plate and the set-up was left at room temperature for 24hours. Thereafter, the HCl in the inner compartment was titrated with 0.025N NaOH using 2-3 drops of methyl red indicator. Results were reported as TVB-N in mg/100 of fish flesh using the formula shown below.

$$TVB-N\ mg/100 = \frac{V \times C \times 14 \times 100}{Weight\ of\ sample}$$

Where
V= Volume of hydrochloric acid added for titration and C= Concentration of acid added for titration

2.5.2 pH analysis

About 10 g of the fish muscle was removed, weighed and homogenized in 50 ml of distilled water. The sample was then centrifuged in 10000 rpm using a Yamato Mag-Mixer Model MH 800 (Yamato Scientific Company Limited, Japan) and the mixture was filtered using Whatman filter paper No.1. A calibrated pH meter (Model No. WTW-8120, West Germany) electrode was then inserted into the homogenate to measure the pH at ambient temperature after calibration using standard buffers of pH 7 and 4 at 25 ^oC.

2.5.3 Protein content

Crude protein content in dried fish samples was determined following the Kjeldahl method 1g fish sample selected from the two processing methods were separately digested in a kjeldahl flask using sulphuric acid (98%) and catalyst made from Cupric Sulphate and Potassium Sulphate. The two samples were distilled and the distillate titrated against standard 0.05N sodium hydroxide (NaOH) solution. To quantify the crude protein%, the nitrogen was converted to protein by multiplying with a conversion factor of 6.25. (Protein contains 16% nitrogen hence 6.25 is 100/16).

2.5.4 Moisture content

One gram sample of ground fish was placed in a crucible and dried at 105 degrees Celsius to a constant weight after the initial weighing. Moisture content of the fish was calculated by subtracting the initial from the final weight of the fish sample.

2.6 Microbial analyses

The microbiological analysis of fish samples in this study followed a previously used procedure [18]. Fish sample (1 g) selected from the two processing methods were blended and mixed properly in a sterile mortar then ascetically transferred to a sample viral containing 9 ml of 0.1% sterile peptone water. The viral was closed and shaken thoroughly for 10 minutes then was allowed to stand for 20 minutes, after which the top part was used to carry out a 6 fold serial dilution in duplicates. Viable bacterial counts were enumerated in standard plate count agar after incubation at 37 °C for 48 hours. Results were reported in CFU/g.

2.6.1 Identification and enumeration of bacteria

Morphological characteristics of the various bacterial isolates *in vitro* were observed in the agar plates, and under microscopy. After staining reactions and several biochemical tests, individual microbial species were identified. Representative isolates were re-plated on various selective media to observe their habits and specific colony attributes.

2.7 Sensory evaluation

Organoleptic properties such as appearance, colour, odor and general acceptability of the dried samples of *D. limnothrissa* from the two processing techniques were evaluated by 10 randomly chosen adult volunteers (age >25). The volunteers were asked to judge the organoleptic properties of the dried samples using a 5-point hedonic scale which were as follows: very good (5), good (4), fair (3), poor (2), and bad (1).

2.8 Data analysis

Data on chemical, microbial analyses and sensory evaluation was entered into Microsoft Excel and analysed using SPSS for Windows version 16.0 software at $P<0.05$. Treatment means were compared using one way Analysis of Variance (ANOVA) at 5% level of significance.

3. Results

The shelf life of solar tent dried and open sun dried *Diplotaxodon limnothrissa* stored at ambient temperature was carried out using total volatile basic nitrogen (TVB-N), pH, protein, moisture content, total viable counts and sensory evaluation.

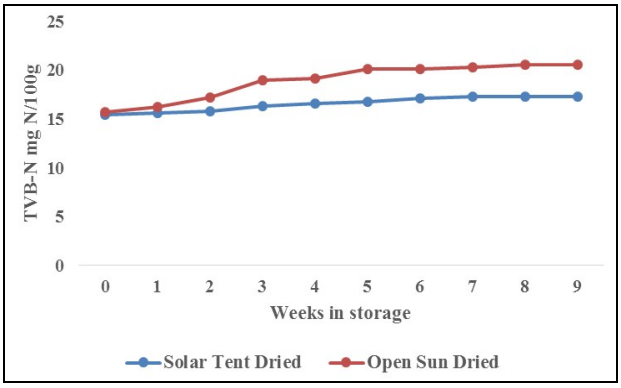

Fig 3: Total Volatile Basic Nitrogen (TVB-N) g N/100mg of stored *D. limnothrissa*

Level of TVB-N g/100mg for solar tent dried and open sun dried fish range were 15.45-17.31 and 15.70-20.56 respectively. At the period of sensory rejection, the level of TVB-N were 17.20 g/100 and 17.14 for open sun dried and solar tent dried fish respectively. It was observed that TVB-N levels increased with storage time but the increase was very pronounced in open sun dried *D. limnothrissa* indicating a shorter storage life.

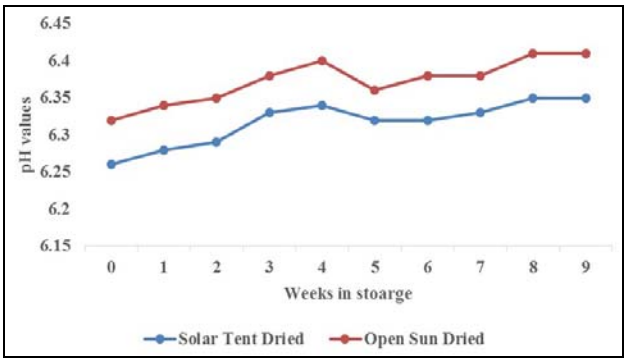

Fig 4: Changes in pH values of dried *D. limnothrissa* as time of storage progressed

The level of pH significantly increased throughout the storage period up to week four from initial pH of 6.32 to 6.40 in open sun dried *D.limnothrissa* than 6.26 to 6.34 for solar tent dried *D. limnothrissa*. It then fluctuated between week 5 and week 9 from 6.36 to 6.41 and
6.32 to 6.35 for open sun dried and solar tent dried *D. limnothrissa* respectively.

Table 1: Protein and Moisture content of dried *D. limnothrissa* under storage

	Solar tent dried		Open sun dried	
Period (weeks)	**Protein (%)**	**Moisture (%)**	**Protein (%)**	**Moisture (%)**
0	63.3±0.15	8.3 ±0.12	63.3±0.34	17.0±0.01
1	63.16±0.13	8.3±0.12	62.02±0.12	17.0±0.01
2	63.04±0.11	8.3±0.12	61.2±0.10	17.0±0.01
3	62.55±0.13	8.3±0.12	60.32±0.14	17.0±0.01
4	62.31±0.12	8.3±0.12	60.28±0.15	17.0±0.01
5	62.20±0.13	8.3±0.12	60.21±0.14	17.0±0.01
6	61.34±0.10	8.3±0.12	59.13±0.07	17.0±0.01
7	61.22±0.11	8.3±0.12	59.04±0.16	17.0±0.01
8	61.17±0.09	8.3±0.12	58.44±0.11	17.0±0.01
9	61.07±0.07	8.3±0.12	58.19±0.21	17.0±0.01

Protein ranged from 63.3±0.15% - 61.07±0.07% and 63.3±0.34% -58.19±0.21% for solar tent dried and open sun dried *D. limnothrissa* respectively. Moisture content remained constant at 8.3% and 17.0% for solar tent dried and open sun dried *D. limnothrissa*. At rejection by sensory panels 61.22±0.11% and 60.32±0.14% protein for solar tent dried and open sun dried *D. limnothrissa* were obtained. There were greater reductions in protein content of open sun dried than solar tent dried *D. limnothrissa*.

Table 2: Total Viable Counts of *Diplotaxodon limnothrissa* stored at room Temperature

	Solar tent drying		Open sun drying	
Period (weeks)	**TVC (cfu/g)**	**Fungi (cfu/g)**	**TVC (cfu/g)**	**Fungi (cfu/g)**
0	3.9×10^2	0	5.2×10^6	0
1	3.9×10^2	0	5.2×10^6	0
2	4.1×10^2	0	5.5×10^6	2.0×10^1
3	4.3×10^2	0	5.7×10^6	3.1×10^1
4	4.3×10^2	0	5.9×10^6	3.3×10^1
5	4.5×10^2	0	6.1×10^6	3.5×10^1
6	4.5×10^2	0	6.3×10^6	3.7×10^2
7	4.5×10^2	0	6.5×10^6	4.0×10^2
8	4.7×10^2	0	7.1×10^6	4.1×10^2
9	4.7×10^2	0	7.1×10^6	4.1×10^2

Open sun dried had significant ($p = 0.002$) higher total viable count ranged from 5.2×10^6 cfu/g to 7.1×10^6 cfu/g than solar tent dried which had lower total viable counts ranging from 3.9×10^2 to 4.7×10^2cfu/g. At the time of sensory rejection which was weeks 3 for open sun dried bacterial population were 5.7×10^6 cfu/g and 2.0×10^1cfu/g for moulds. Week 7 was the rejection period for solar tent dried with bacterial population being at 4.5×10^2 cfu/g respectively (Table 2.0). The overall observation was that total viable bacterial counts for open sun dried fish increased constantly during the storage period. However, populations were not above acceptable norms (10^8cfu/g^2) [19].

Table 3: Sensory evaluation of *D. limnothrissa* stored at room Temperature

	Solar tent drying			Open sun drying		
Storage (weeks)	**Appearance**	**Colour**	**Acceptability**	**Appearance**	**Colour**	**Acceptability**
0	4.8±0.43	4.6±0.52	4.9±0.32	4.1±0.57	4.0±0.67	3.9±0.32
1	4.6±0.52	4.4±0.52	4.7±0.48	3.7±0.6	3.8±0.63	3.6±0.52
2	4.4±0.67	4.2±0.79	4.5±0.53	3.3±0.52	3.4±0.52	3.2±0.63
3	4.2±0.42	3.9±0.39	4.1±0.32	2.6±0.62	2.5±0.56	2.4±0.57
4	3.9±0.74	3.7±0.67	3.6±0.52	2.5±0.53	2.4±0.52	2.4±0.57
5	3.6±0.52	3.4±0.52	3.3±0.48	2.1±0.73	1.8±0.42	2.1±0.70
6	3.3±0.67	2.8±0.42	2.9±0.57	1.8±0.42	1.5±0.53	1.9±1.3
7	3.1±0.62	2.5±0.53	2.6± 0.70	1.5±0.53	1.3±0.52	1.5±0.52
8	2.7 ± 0.70	2.2±0.57	2.3 ± 0.52	1.3 ±0.52	1.1±0.51	1.2±0.52
9	2.4 ± 0.74	2.0±0.59	2.1 ± 0.53	1.0 ±0.55	1.0±0.52	1.0±0.51

Sensory attribute scores namely appearance, colour, and overall acceptability for open sun dried *D. limnothrissa* decreased steadily throughout the storage period compared to solar tent dried *D. limnothrissa* which remained in steady acceptability by consumers (table 3.0).

4. Discussion

As expected, solar tent dried samples of *Diplotaxodon limnothrissa* had higher shelf-life than sundried samples. This was confirmed by Total Volatile Base Nitrogen (TVB-N) which is an important compound providing a measure of the progress of spoilage that is dependent on sensory assessment. In the present study, the TVB-N content of solar tent dried and open sun dried *D. limnothrissa* were found to vary from 15.45 (0 week) to 17.31 mg N/100g (9 weeks) and 15.74 (0 week) to 20.56 mg N/100g (9 weeks) respectively (figure 3.0). The trend was similar to dry, wet and mixed salting of *Sardinella eba* and *Clupea harrengus* [19]. The level of TVB-N in fish and fish products are mostly used as spoilage indicator through bacterial activity [20]. In this study, the rate of TVB-N formation was different, being highest for open sun dried than solar tent dried *D. limnothrissa.* The values did not exceed

level for rejection of TVB-N which is 30-40mgN/100g for dried fish stored at ambient temperature [21, 22]. The increase in these volatile bases was pronounced in open sun dried fish that led to deterioration of colour in dried fish. This is evidenced with the dimeric scores of dried *D. limnothrissa*. Furthermore, high TVB-N values are associated with unpleasant smell in fish and meat [23]. This is due to the extent of degradation of proteins and non-protein nitrogenous compounds which can be explained by proteolysis, due to enzymatic and microbial activities in the samples upon storage [24].

The level of pH is an indicator of the extent of microbial spoilage in fish and some proteolytic microbes producing acid after decomposition of carbohydrate, which increases the acid level of the medium. The normal pH in fresh fish is almost neutral [25]. In this study, pH values were found to vary from 6.26 in week (0) to 6.35 in week (9) for solar tent dried and 6.32 in week 0 to 6.41 in week (9) for open sun dried *D. limnothrissa* (figure 4.0). The pH values of dried *D. limnothrissa* from both processing methods showed a gradual increase with storage period up to week 5. However, the increase was more pronounced in open sun dried *D. limnothrissa*. This was due to decomposition of nitrogenous compounds leading to an increase in pH in the stored fish [26]. The increase in pH indicates the loss of fish quality with storage time. Dried fish products are acceptable up to a pH of 6.8 but are considered to be spoiled above pH of 7.0 [27]. The pH values later on dropped and fluctuated between week 5 and 8. The drop might have been caused by accumulation of end products of spoilage of both alkaline and acidic nature which tend to neutralize each other. The increase in pH coincided with increase in Total Viable Counts toward sensory rejection for open sun dried fish in this study. This indicates accumulation of alkaline compounds as well as volatile bases produced by autolytic activities and metabolism of spoilage bacteria [28]. This explains the rapid spoilage and reduced shelf life for open sun dried *D. limnothrissa* as demonstrated by sensory demerit scores. The important link between increased pH and spoilage of dried fish is that it favours more microbial activity [29], hence high total viable counts for open sun dried than solar tent dried *D. limnothrissa.*

Protein forms the largest component of dry matter in fish and its amount in fish muscle is usually between 15% and 20% [30]. Changes in crude protein of dried fish samples during storage was more pronounced in open sun dried than in solar tent dried *D. limnothrissa* denoting loss in nutrient content (table 1.0). The gradual degradation of the initial crude protein to more volatile products such as total volatile bases which was also higher in open sun dried *D. limnothrissa* in turn affected the colour and consumer acceptability of the dried fish products [6]. Consequently, it is apparent that the pronounced reduction of crude protein for open sun dried *D. limnothrissa* during storage is a nutritional concern. Moisture content of dried *D. limnothrissa* remained constant in both processing methods, however, it was noted that moisture content of the dried fish product seems to be an exact indicator of the liability of a product to undergo microbial spoilage and eventually reduced storage life. In this study, solar tent dried *D. limnothrissa* had lowest moisture content that prevented multiplication of bacteria as well as growth of moulds that led to increase storage life than open sun dried *D. limnothrissa* (table 2.0). It has been reported that fish well dried or moisture content reduced to 25% will not be affected by microbes and if further dried to 15%, the growth of mould will cease and thus increasing the shelf life [31]. Total Viable Counts of stored dried packed fish indicated high level of bacteria for open sun dried than solar tent dried fish. Although dried fish from both processing methods had microbial load below the permissible limit, it was high in open sun dried fish due to unhygienic condition of the drying process and higher moisture content of the dried *D. limnothrissa*. The least bacterial load for solar tent dried fish was due to hygienic condition of the processing method and low moisture content of the dried *D.limnothrissa* which retarded the bacterial growth. Furthermore, open sun drying created a conducive environment and was in favour of spore-former fungi as a result there was spreading of spores by air since the fish were exposed to ambient atmosphere during open sun drying. This probably explains the occurrence of fungi colonies in open sun-dried *D. limnothrissa* from week 2 of storage. Fungi are commonly related to food contamination [32]. This emphasizes the economic losses caused by these contaminants and human health problems from mycotoxins which are secondary metabolites. Enumeration of pathogenic microbes in open sun dried fish during storage proved the loss of shelf life for the dried fish. Apparently, this possess highest food safety risk because the products are most susceptible to microbiological deterioration and possible for growth of pathogenic organisms.

Sensory attribute values namely appearance, colour, and overall acceptability for open sun dried *D. limnothrissa* decreased steadily throughout the storage period compared to solar tent dried *D. limnothrissa* (table 3.0). Decrease in the sensory attribute values during storage might be due to excessive microbial and enzymatic proteolysis of the tissue causing tissue disintegration [33]. Consumers showed high level of preference for solar tent dried fish than open sun dried as confirmed further by scores for appearance, colour and general acceptability which were 4.8, 4.6, 4.9 and 4.1, 4.0, 3.9 respectively. [34, 35, 36] indicated that enclosed solar dried fish gave superior quality during storage. Consumers started disliking open sun dried *D. limnothrissa* after 2 weeks of storage and eventually rejected the samples after 3 weeks of storage. Week 7 was the rejection point of solar tent dried fish and the scores for appearance, colour, and general acceptability were 3.3, 2.8 and 2.9. The high scores during sensory evaluation indicates the possibility of general acceptance of solar tent dried *D. limnothrissa* products in the market.

5. Conclusion

The chemical, physical and microbiological changes during storage were much less in the solar tent dried fish as compared to the open sun dried fish. The solar tent dried have shown to be superior over open sun dried *D. limnothrissa* throughout the storage period. Thus solar tent drying can be regarded as suitable improved methods of drying *D. limnothrissa* in Lake Malawi. This would help fish processors to supply safe and high-quality fish-products that have a longer shelf life hence giving a unique value for the processed fish. However, in order to further improve on quality, it might be necessary to treat samples with brine.

6. Acknowledgments

This work was carried out with the aid of a grant from Canada's International Development Research Centre (IDRC), www.idrc.ca, and the Australian Centre for

International Agricultural Research (ACIAR), www.aciar.gov.au. We also thank members of staff in the Department of Biology at Chancellor College and Aquaculture and Fisheries Science at Bunda College of Agriculture, Malawi for accommodating this study at their laboratories. Many thanks are expressed to Levision Chiwaula, Joseph Nagoli, Geoffrey Zentute Kanyerere and Essau Thunga Gandifolo Chisale for the conceptualization of the whole project idea.

7. References

1. Muzaffarian D, Rimm EB. Fish intake, contaminants, and Human Health: Evaluating the Risks and Benefits. Journal of the American Medical Association. 2006; (15):1885-1899.
2. Ruxton CH, Reed SC, Simpson MJ, Millington KJ. The health benefits of omega- 3polyunsaturated fatty acids: a review of the evidence. Journal of Human Nutrition Diet 2004; (17):449-459.
3. Phiri LY, Dzanja J, Kakota T, Hara M. Value chain analysis of Lake Malawi fish: a case study of *Oreochromis* species. (Chambo). International Journal of Business and Social Science. 2013; 4(2):170-181.
4. Kanyerere G. Age, Growth and Yield-per-recruit analysis of Ndunduma, *Diplotaxodon limnothrissa* (Teleostei: Cichlidae), in the Southeast Arm of Lake Malawi. Rhodes University, 2003.
5. Regenstein MJ, Regenstein CE. Introduction to Fish Technology. Van Nostrand Reinhold, New York, 1991.
6. Eyo AA. Fish Processing Technology in the tropics. National Institute for Freshwater Fisheries Research. University of Ilorin Press, 2001, 66-70.
7. Olokor JO, Eyo AA, Mdaihli M, Okomoda JK, Ayanda JO. Promotion of fish drying using solar energy in villages around Kainji Lake. In: S.A. Garba Biotechnology and Sustainable Development in Nigeria. Proceeding Of 10th Annual Conference of Biology and Technology Society of Nigeria. Minna. 2009, 212-220
8. Alasalvar C, Grigor JM, Ali Z. Practical evaluation of fish quality by objective, subjective, and statistical testing. In: Alasalvar C, Shahidi F, Miyashita K, Wanasundara U, editors. Handbook of seafood quality, safety and health applications. New Delhi: Blackwell Publishing Limited. 2011, 13-29.
9. Hyldig G, Martinsdóttir E, Sveinsdóttir K, Schelvis R, Bremner A. Quality Index Methods. In: Nollet LML, Toldrá F, editors. Handbook of seafood and seafood products analysis. New Jersey: CRC Press, 2010, 463-481.
10. Kawarazuka. The contribution of fish intake, aquaculture, and small-scale fisheries to improving nutrition: A literature review. The World Fish Center Working Paper No. 2106. The World Fish Center, Penang, Malaysia 2010, 51.
11. Antonios EG, Michael GK. Effect of salting and smoking- method on the keeping quality of chub mackerel (*Scomber japonicas*): biochemical and sensory attributes. Journal of food chemistry. 2005; (93):511-520.
12. Rorvik LM. *Listeria moncytogenes* in the smoked salmon industre. International Journal of Food Microbial. 2000; (62):183-190.
13. Akinola OA, Akinyemi AA, Bolaji BO. Evaluation of traditional and solar fish drying systems towards enhancing fish storage and preservation in Nigeria. Journal of Fisheries International., Pakistan. 2006; 1(3-4):44 -49.
14. Park DL. Effect of processing on aflatoxin. Advanced Experimental Medical Biology. 2002; (504):173-179.
15. FAO. FAO Fisheries and Aquaculture. Rome, Italy, 2005.
16. GOM. Ministry of Mines Natural Resources and Environmental Affairs. Fisheries Department. Lilongwe, Malawi. 2009; 3(21):98-9.
17. AOAC. (Official Methods of Analysis). 17th Edition. Association of Official Analytical Chemists. Washington, D.C. USA 2000, 56-61.
18. Okoro CC, Aboaba OO, Babajide OJ. Quality Assessment of a Nigerian Marine Fish, Mullet (*Liza falcipinnis*) under different Storage Conditions. New York Science. Journal. 2010; 3:1-8.
19. ICMSF (International Commission on Microbiological Specifications for Foods. 2nd edn Microorganisms in Foods, Sampling for Microbiological Analysis. Principles and Specific Applications, Blackwell Science, Oxford. 1986, 211-217.
20. Zhou R, Liu Y, Xie J, Wang X. Effects of combined treatment of electrolysed water and chitosan on the quality attributes and myofibril degradation in farmed obscure puffer fish (*Takifugu obscurus*) during refrigerated storage. Food Chemistry 2011; 129(4):1660-1666.
21. Connell JJ. Control of fish quality. Fourth edition published by fishing Books, a division of Blackwell Scientific Ltd. 1995, 116-123.
22. Limbo S, Sinelli N, Torri L, Riva M. Freshness decay and shelf life predictive modelling of European sea bass (*Dicentrarchus labrax*) applying chemical methods and electronic nose. LWT Food Science and Technology. 2009; 42(5):977-984.
23. Erkan N, Ozden O. Quality assessment of whole and gutted sardines (*Sardina pilchardus*) stored in ice. International Journal of Food Science and Technology. 2008; 43(9):1549-1559.
24. Erkan N, Tosun SY, Ulusoy S, Uretener G. The use of thyme and laurel essential oil treatments to extend the shelf life of bluefish (*Pomatomus saltatrix*) during storage in Ice. Journal für Verbraucherschutz und Lebensmittelsicherheit. 2011; 6(1):39-48.
25. Mohammed GF, Hegazy EM, Abdellatef M. Physicochemical Properties and *Mycootoxins* contents of *Tilapia* Fish Fillets after Solar Drying and storage. Global Veterinaria Journal 2011; 7(2):138-148.
26. Gandotra R, Meenakshi K, Sweta G, Shallini. Change in Proximate Composition and Microbial Count by Low Temperature Preservation in Fish Muscle of *Labeo rohita* (Ham-Buch) IOSR Journal of Pharmacy. Biological Science. 2012; 2(1):13-17.
27. Liu. Quality evaluation of tray packed tilapia fillets stored at 0 °C based on sensory, microbiological, biochemical and physical attributes. African Journal of Biotechnology 2010; 9:692-701.
28. Huss HH. Quality and quality changes in fresh fish. FAO fisheries technical paper No 348. Food and Agriculture Organization (FAO) of the United Nations, Rome Italy, 1995.
29. Ravichandran S, Kumaravel K, Florence EP. Nutritive

composition of some edible fin fishes. International Journal of Zoological research. 2011; 7(3):241-251.
30. Ochei J, Kolhatkar A. Medical Mycology in Medical Laboratory Science Theory and Practice, Ochei, J. and A. Kolhatkar (Eds.). Tata-McGraw Hill, New Delhi, India 2000; 2:1047-1050.
31. Samson R, Hosekstra ES, Frisvad JC, Filtenbong O. 2004. Introduction to food and airbone fungi. Utrecht, the Netherlands: Central Bureau Voor Schianmel Cultures (CBS). 2004, 519.
32. Silva LYA, Prinyawiwatkul W, Moody MW, Day D. Microbial quality of West African dried, smoked catfish during six-week storage. Food Microbiology: Meat. Poultry and Safood 2002; 6-8.
33. Oduor-Odote PM, Obiero Lipid M. oxidation and organoleptic response during shelf storage of some smoked marine fish in Kenya. African Journal of Food Agriculture and Nutrition. 2009; 9:3.
34. Chavan BR, Yakupitiyage A, Kumar S, Rakshit SK. Experimental investigation on biochemical, microbial and sensory properties of Mackerel (*Rastrilliger kangurta*) dried by solar-biomass hybrid cabinet dryer. Journal of Food Agriculture and Environment. 2008; (6):167-171.
35. Reza S, Bapary AJ, Islam N. Optimization of marine fish drying using a solar tunnel dryer. Journal of Food Processing and Preservation. 2009; (33):47-59.