Vol. 15(2), pp. 52-59, July-December 2023
DOI: 10.5897/IJFA2023.0850
Article Number: F1BC94F71337
ISSN 2006-9839

http://www.academicjournals.org/IJFA

ACADEMIC JOURNALS
expand your knowledge

International Journal of Fisheries and Aquaculture

Full Length Research Paper

Proximate composition, mineral content, peroxides and rancidity in open sun and solar-tent dried small sardine fish in Malawi

Dorothy Banda[1]*, William Kasapila[1], Victoria Ndolo[2], James Banda[3], Martin Likongwe[2] and Kingsley Kamtambe[3]

[1]Department of Food Science and Technology, Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi.
[2]Department of Human Ecology, University of Malawi, Malawi.
[3]Postharvest Department, Monkey Bay Fisheries Research Station, Monkey Bay, Malawi.

Received 6 June, 2023; Accepted 3 August, 2023

This study examined protein and fat content, mineral composition and peroxides of fresh and dried small sardines (*Engraulicypris sardella*), locally known as *usipa* in Malawi. This species of fish is endemic to Africa, neglected and consumed largely by low-income families. Samples were collected immediately after harvesting, drying, transportation and marketing for three days. Association of Official Analytical Chemists (AOAC), peroxide and thiobarbituric acid methods were used to analyse them. Results show that *E. sardella* is a good source of protein among foods that are cheaply available to these families, with values ranging from 43.22±1.85 to 44.16±1.21 in open sun and 43.22±1.85 to 44.92±0.34 for solar tent dried samples. Mineral analysis has shown that the fish, in both fresh and dried forms, is also a good source of zinc, calcium and iron with contents that can help meet recommended daily allowances for both children and adults. Fat decreased from 33.73 ±3.82 in fresh to 25.26±0.59 in open sun-dried samples and 28.02±0.66 in samples from the solar tent dryers due to lipid oxidation and drippings during drying. Peroxides and thiobarbituric acids, by-products of lipid oxidation, conversely increased with drying time, although the levels were not significant to cause rancidity and spoilage. The context of these findings and their implications are discussed in the study's conclusion and recommendations.

Key words: *E. sardella*, drying, fish, lipid oxidation, rancidity.

INTRODUCTION

Fish is a vital staple food for millions of people worldwide. It is eaten regularly, even daily in most parts of the world, and in different forms, which adds diversity to diets and contributes to the pleasure of eating. Fish is an important relish consumed boiled, stewed, roasted and grilled besides being eaten by itself and used for industrial purposes such as the production of oils and spices. Freshly harvested fish is also dried to enhance storage

*Corresponding author. E-mail: dorotbanda@gmail.com; Tel: +265880834163.

and sensory characteristics. Nutritionally, fish accounts for more than 70 to 80% of daily protein in the majority of the countries and is an important source of nutrients, including essential fatty acids, vitamins and minerals like iron, calcium, sodium, potassium, and phosphorus (Jim et al., 2017; Nankwenya et al., 2017), which are important for human health. In addition, fish is a low-cost food source that is naturally and easily accessible to low-income households.

Nevertheless, the Food and Agriculture Organisation of the United Nations (FAO) estimates post-harvest losses (PHL) of fish to be at 40% due to physiological and microbial activities if not preserved and processed immediately. The PHL spoilage and losses of fish have negative impacts on the food, nutrition and income of the general population, with Malawi losing approximately US$42 million in 2016 alone. They occur due to lack of appropriate processing techniques, and poor packaging, handling and transportation to the market. Small-scale fishers, processors and traders also lack refrigeration, storage facilities and knowledge to keep large quantities of fish safe from physical and microbial contamination. High deterioration of fresh fish and losses incurred necessitate the need for science-based and approved processing techniques to reduce moisture content and enhance quality and taste.

This study is particularly important because it is one of the first of its kind to investigate poor man's fish and small species like sardines (*Engraulicypris sardella*), locally known in Malawi as *usipa*. Sardines in general remain under investigated and as a result data on proximate composition, micronutrients and quality after the fish undergoes various stages in the drying process remains scanty in the scholarly literature. Similar studies have focused on different species of fish and not sardines (Ahmed et al., 2016; Banda et al., 2017a, b; Deb et al., 2017; Katola and Kapute, 2017; Khumbanyiwa and Jian, 2017; Majumdar, 2017; Likongwe et al., 2018). Other studies have done modelling to forecast yield (Makwinja et al., 2018; Mulumpwa et al., 2020), economic and profitability analysis (Gumulira et al., 2018; Mbamba et al., 2018; Torell et al., 2020), microbiological safety (Pal et al., 2016; Mgwede et al., 2018) and surveys of the value chain (Tsutsu and Singini, 2021).

For many years, open sun drying has been the method of drying small species of fish like sardines in Malawi and other countries in Africa. Open sun drying is, however, associated with so many challenges. In Malawi, for example losses are high during the peak of the fish production period, between January and April, when there are more rains and high humidity, which make the traditional open sun drying almost impossible. Open sun drying additionally exposes the fish to fly, insect, microbial, sand and dust contamination, all of which make the dried products to be of poor quality and unsafe for human consumption. Theft by humans and destruction by vermin (ants, rats, cats and birds) are also rampant. LEAD and other organizations introduced solar tent dryers, which are made of polythene plastics worn over a wooden frame, 2007 in Malawi as a novel technology to reduce post-harvest losses and overcome these challenges. However, a large proportion of small-scale fishers and processors are still adhering to open sun drying because solar tent dryers are expensive to construct and require high initial capital. A number of projects in Malawi have been constructing solar tent dryers on their behalf to familiarize them. Besides ensuring hygiene, solar tent dryers are deemed more effective than direct sun drying because the heat-trapping capacity of the black polythene sheets used hastens drying.

The main objective of this study was to determine proximate composition, micronutrients and lipid degradation of *E. sardella* dried using open and solar tent drying techniques in Malawi. The results will guide interventions on post-harvest losses and be useful to fishers, processors, traders, consumers and the food composition tables that the country is compiling.

MATERIALS AND METHODS

Study areas and sample preparation

The study was approved by the ethics committees of Lilongwe University of Agriculture and Natural Resources (LUANAR) and Chancellor College in Malawi. Two fish processors were identified at Cape Maclear in Mangochi district of the country, where the fish is caught in abundance, to participate in the study. One processor dried *E. sardella* directly in open sun and the other one used the solar tent dryer. Fresh samples were collected before the processors started drying the fish. Drying was done between August and October 2021, when it is hottest in the country, and took 3 days for both methods. Levels of drying were determined by the local method of twisting a few pieces of fish as days elapsed. Difficulties in breaking meant the fish was fully dry. Additional samples were collected soon after drying for analysis. Processors then sold the dried fish to small-scale traders who came from Limbe market in the commercial city of Blantyre (Malawi). The study collected other samples from transporters and sellers after the fish spent three days at the market. After collection, all the samples were packed in zip-lock bags, labelled, put in cooler boxes containing ice and transported through cold chains to the Chemistry Laboratory at the University for analysis. In the laboratory, samples were ground and blended to prepare homogeneous samples that were kept in a freezer at -20°C prior to analysis. Proximate composition (percentage of moisture, protein, fat and ash) of the samples was analysed in triplicate. Figure 1 illustrates processes followed and stages at which samples were collected for analysis.

Proximate analysis

Proximate analysis is used for quantification of food and food substances in terms of moisture, crude protein, total fat, total carbohydrates and dietary fibre. Proximate analysis in this study covered moisture, crude protein and fat. It did not include total carbohydrates and dietary fibre because different species of fish do not contain a lot of these nutrients according to previous studies. Species (type), size, geographical zones, feeding and reproductive

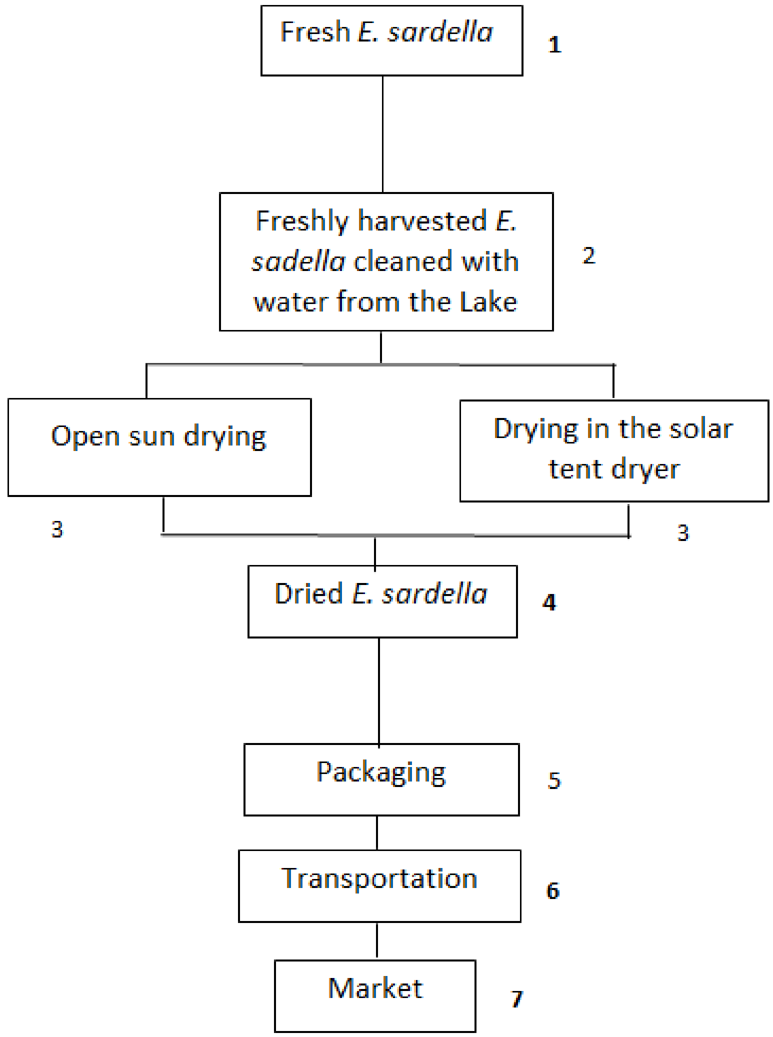

Figure 1. Value chain stages for processing *E. sardella*. Samples were collected at stages 1, 4, 6 and 7 in bold. Once fish has dried, people in Malawi eat it at any of these stages either raw or cooked.

status affect chemical composition of the fish. The analysis was done based on methods by AOAC (2016).

Determination of moisture content

Samples of ground fish (3 g) were placed in a crucible and dried at 105°C in an oven to a constant weight after the initial weighing. Moisture content of the dried samples was determined by calculating the difference between the final and initial weights.

Crude protein: The study used Kjeldahl method to determine crude protein. Two grams of ground fish samples were digested in Kjeldahl flask using 98% sulphuric acid with a catalyst from Cupric Sulphate and Potassium Sulphate. The resulting distillate was steam-distilled and titrated to a pink and wine-red colour using 0.01 hydrochloric acid (HCl). The whole procedure was repeated three times for each sample. Digestion converted nitrogen (N) in fish samples into ammonia, and other organic matter to carbon dioxide (CO_2) and water (H_2O). The percentage of crude protein was calculated as (N × 6.25).

Fat determination

The Soxhlet ether extraction method was used to analyse the fat content. Ten grams of homogenized samples were weighed on an analytical balance and recorded. Petroleum ether at a boiling point of 40 to 60°C was added to the samples and placed in an extraction apparatus called a thimble. Extraction was carried out for 16 h, after which the ether had evaporated to dryness and only fat remained in the flask. The amount of fat was obtained as the difference in the weight of the flask before and after drying.

Ash content

A 2 g sample of ground fish was placed in a crucible and burnt to ashes at 550°C for 5 h in carbolite muffle furnace. This was followed by cooling to room temperature. The amount of ash was

Table 1. Proximate composition along the value chain of the *E. sardella**.

Value Chain Node	Drying technique	Ash (%)	Moisture (%)	Protein (%)	Fat (%)
Fresh	Open sun	10.7±1.45[a]	69.74±0.17[d]	43.22±1.85[a]	33.73±3.82[b]
	Solar tent	10.7±1.45[a]	69.74±0.35[d]	43.22±1.85[a]	33.73±3.82[b]
Dried	Open sun	9.51±0.13[a]	12.81±0.51[b]	43.95±1.00[a]	25.26±0.59[a]
	Solar tent	9.40±0.49[a]	14.29±0.48[b]	44.58±0.95[a]	28.02±0.66[a]
Transported	Open sun	9.58±0.1[a]	12.48±0.8[b]	44.16±1.21[a]	24.98±0.86[a]
	Solar tent	9.57±0.43[a]	13.21±0.45[b]	44.92±0.34[a]	27.94±0.06[a]
Marketed	Open sun	10.54±0.11[a]	11.18±0.20[a]	43.62±1.13[a]	23.78±1.3[a]
	Solar tent	10.08±0.44[a]	11.53±0.41[a]	44.05±0.65[a]	26.35±0.9[a]

*Data expressed as means and standard deviation (SD) values. Different superscript letters within a column are significantly different at $p<0.05$.

estimated as the difference in weight of the crucible before and after cooling.

Mineral analysis

A calibration curve of absorbance versus concentration in parts per million (ppm) was plotted for standard solutions to analyse zinc, selenium and iron in Atomic Absorption spectrophotometer (AAS). Mineral content was obtained in mg/100 g. AOAC (2016) procedures were used to do the mineral analysis.

Peroxide value

The study followed methods used in previous studies (Pal et al., 2016; Alaba et al., 2017; Kumar et al., 2017) to measure peroxides. Samples weighing 5 g were placed into 50 mL tubes with a red screw cap. 10 mL of ice-cold solvent was added into the tubes and homogenized at 6000 rpm for 10 s. 5 mL of the sodium chloride solution was added to the homogenized content and centrifuged at 5100 rpm (2350 g) for 5 min at 4°C. 3 mL of the bottom layer was collected and transferred using a pipette into a 15 mL tube (with red screw cap). Thereafter, 500 µL of the bottom layer was added to Eppendorf tubes followed by 5 µL of ammonium thiocyanate and ferrous chloride solution in the ratio of 1:1. The content was vortexed and allowed to stand for 10 min at room temperature. At this stage, 100 µL was placed in the PP microplate and read at 500 nm. The results were calculated in mmol/kg.

Determination of thiobarbituric acid substances (TBARS)

To measure thiobarbituric acid-reactive substances (TBARS), as secondary by-products of lipid oxidation after the production of peroxides, the study used procedures by Alaba et al. (2017) and Kumar et al. (2017).

Data analysis

The data obtained in the study were analysed using IBM SPSS Statistics 25 subjected to T-test and ANOVA at 5% significance level. The means were separated and compared using the turkey test.

RESULTS

Proximate composition of the *E. sardella*

Table 1 shows proximate composition of the *E. sardella* samples. The study found no significant differences in ash content with values ranging from 9.51±0.13 to 10.54±0.11. Conversely, moisture decreased significantly from fresh to dried samples at the market as expected. To avoid physical damage, samples were packed in cartons prior to transportation. However, this prevented them from air and sunlight, which are factors that enhance drying. As a result, there was no statistical difference in moisture content between dried and transported fish. Fat also decreased significantly from 33.73±3.82 in fresh to 25.26±0.59 in open sun-dried samples and 28.02±0.66 in samples from the solar tent dryers (Table 1). Protein values did not change significantly along the value chain. They ranged from 43.22±1.85 to 44.16±1.21 and 43.22±1.85 to 44.92±0.34 for open sun and solar tent dried samples, respectively.

Lipid degradation

Lipids degrade in fish if exposed to heat, light and oxygen. They produce peroxides and thiobarbituric acids (TBAs) as primary and secondary by products, respectively. Peroxide values are expressed in milliequivalents of oxygen (meq O_2)/kg fat and TBARs in mg of malonaldehyde (MAD)/kg. Table 2 shows that peroxides and TBAs increased in the dried, transported, and marketed samples of *E. sardella* due to increased exposure to heat, light, and oxygen as explained earlier. TBAs, being secondary by-products, had lower values at

Table 2. Peroxide values and TBARS determined in the samples studied*.

Value chain node	Peroxide value (meq O_2/kg fat)		Thiobarbituric acids (mg MAD/kg)	
	Open Sun	**Sola Tent**	**Open Sun**	**Solar Tent**
Fresh	1.83±0.33[a]	1.83±0.33[a]	0.25±0.13[a]	0.25±0.13[a]
Dried	6.68±0.55[b]	5.22±0.23[b]	0.76±0.22[ab]	0.63±0.95[ab]
Transported	6.8±0.48[b]	5.31±0.35[b]	0.77±0.18[ab]	0.75±0.90[ab]
Marketed	8.28±0.65[c]	6.82±0.60[c]	1.11±0.83[ab]	1.06±0.46[ab]

*Data expressed as means and SD values of 3 replicates. Different superscript letters within a row and column are significantly different at $p<0.05$.

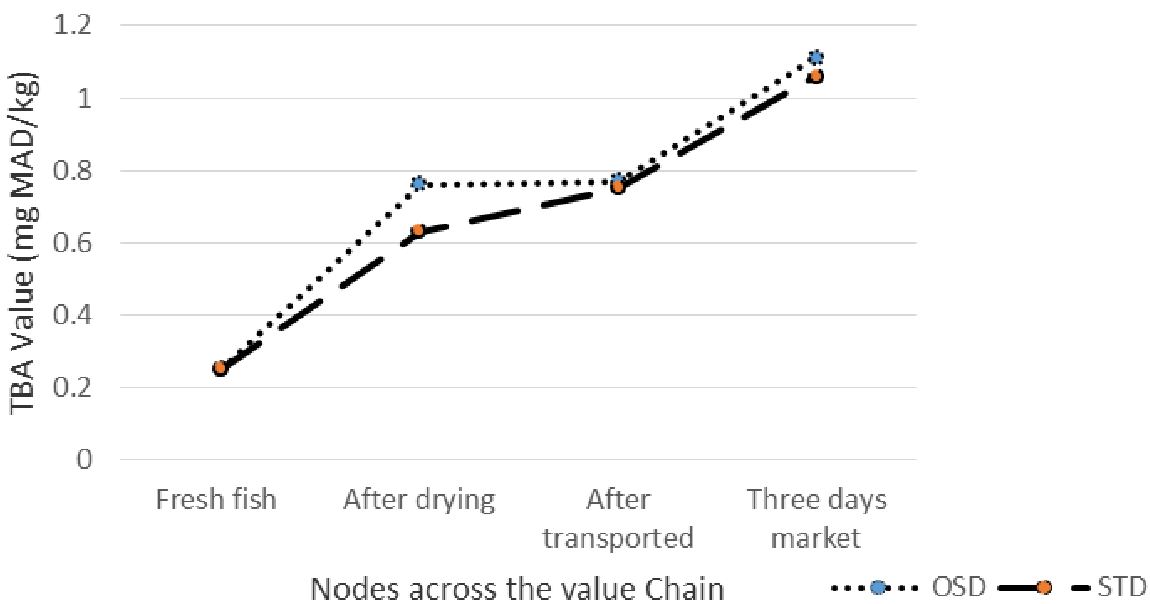

Figure 2. An increase in TBAs in the studied fish sample from the lake to the market.

1.11 and 1.06 mg MAD/kg in open sun and solar-tent dried samples compared to those for peroxides (Table 2). Figure 2 shows the increment in these substances.

Mineral composition of the *E. sardella*

The study found zinc content of 13.37 mg/100 g, calcium 421.67 mg/100 g and iron 15.11 mg/100 g in the open-sun dried *E. sardella*. The values for samples from the solar-tent dryers were 13.85, 421 and 15.4 mg/100 g, respectively. These figures were not significantly different from those found in fresh samples (Table 3).

DISCUSSION

The aim of the present study was to provide data on proximate and mineral composition as well as lipid degradation of fresh, dried, transported and marketed samples of *E. sardella* from Malawi. The main contribution of the study is the contribution to the limited literature available on the subject matter. *E. sardella* is a small pelagic cyprinid growing to a maximum length of 13 cm and one of the under investigated fish species endemic to sub-Saharan Africa. Its smallness in size, traditional drying involved and selling in heaps or buckets in open-air markets without being packaged makes it poor man's and largely underutilized fish. Lack of local research in turn means that no data is available elsewhere to give profile of its nutritional and microbial quality. Despite this, *E. sardella* is increasingly becoming Malawi's common fish as millions of people reside in rural areas and find solace in it for being cheap and easily available almost in every market across the country. Fresh and dried *E. sardella* is cooked and eaten as relish for main meals. It is also blanched before drying and cooking to enhance its taste and flavour. Blanched and dried *E. sardella* is cooked differently by adding groundnut flour and tomatoes, which further enhances nutrition for low-income

Table 3. Mineral composition of the studied *E. sardella**.

Value chain node	Zinc (mg/100 g)		Calcium (mg/100 g)		Iron (mg/100 g)	
	Open sun	Sola tent	Open sun	Solar tent	Open sun	Solar tent
Fresh	13.1±0.31[a]	13.1±0.31[a]	422.17±1.46[a]	422.17±1.46[a]	15.24±0.43[a]	15.24±0.43[a]
Dried	13.11±0.34[a]	13.17±0.74[a]	418.83±0.52[a]	420.08±2.01[a]	15.28±0.21[a]	15.30±0.22[a]
Transported	13.45±0.28[a]	13.49±0.01[a]	422.67±2.98[a]	422.75±0.87[a]	15.32±0.24[a]	15.32±0.21[a]
Marketed	13.37±0.33[a]	13.85±0.13[a]	421.67±0.63[a]	421±2.63[a]	15.11±0.29[a]	15.4±0.13[a]

*Data expressed as means and SD values of 3 replicates. Different superscript letters within a row and column are significantly different at $p<0.05$.

Figure 3. Solar tend dryer (left) used by the study and the inside view. Besides problems with air vents to allow easy circulation of air, no black surface was placed inside to help with heat absorption in this design.

families. Results from the study are equally important to other countries that consume small fish species in the family of sardine.

Proximate composition of the studied *E. sardella* samples is shown in Table 1. Moisture content is the amount of loss on drying of water and volatile substances. Moisture is used for estimation of quality and shelf life of food, including fish. The amount of moisture is one of the main factors in storage, due to the proliferation of microorganisms. Reduction of moisture in fish to levels below 15% stops enzymatic reactions, bacterial activities and the growth of moulds (Pal et al., 2016). This study took place in the hot season, from August to October, and fish samples dried in 50 and 51 h (2 days) in the direct sun and solar tent dryers, respectively. At the point when fresh fish samples were considered dry, moisture content was found to be 12.8% for open sun drying and 14.3% in the solar tent dryer, down from 69.7%. Statistical results show that there were insignificant differences in both drying times and moisture levels after drying between the two techniques. Higher humidity levels, recorded in the solar tent drier, delayed the drying process by limiting the amount of moisture from fresh fish the air could absorb. The moisture was not taken away adequately and fast enough by the air entering into the dryer from below and escaping through the top exit. Improvements in the inlet and outlet air vents are needed. Results from previous studies are mixed. Solar tent dryers are superior to open sun drying for the majority of studies (Al-Azawiey and Hassan, 2016; Banda et al., 2017a, b; Cyprian et al., 2017; Zebib et al., 2017; Likongwe et al., 2018; Patterson et al., 2018; Lithi et al., 2020). A few other studies have found no differences. Discrepancies in construction, materials and air vents used in the solar dryers by different studies account for the variations. Polythene plastic sheets (black versus white) and the bulkiness of fish on the drying racks are additional factors, with small-scale fishers and processors doing it differently for the same species of fish. Sixteen years have now elapsed since the introduction of solar tent drying technology in Malawi in 2007. There is need to standardize the design and increase training of fishers, fish processors and traders on how to utilize them to achieve desired results.

There are three types of solar tent dryers: direct-type, indirect type and mixed-mode. Direct-type solar dryers, like the one used in this study (Figure 3), use the natural movement of heated air and solar radiation is directly absorbed by the product dried. An indirect solar dryer collects heat from the sun using a solar collector and pass it through the dryer. A mixed-mode type of dryer, on the other hand, requires energy from the sun rays that enters through the collector. The inside surface of the collector is painted black. The mixed-mode dryer leads to the highest drying rate when compared to the other two kinds of dryers (Regupathi and Balasubramanian, 2018). Without proper training and guidance, small-scale fishers and processors make each type differently based on the available resources, which affect the results. Mixed mode dryers should be scaled up to enhance quality.

Fresh *E. sardella* contained 43.2% of protein (Table 1). Open sun and solar-tent samples had protein content of 43.6 and 44.1% on dry matter basis, respectively. These values make *E. sardella* a good source of protein among foods that are cheaply available to low-income families. Fat content in fresh *E. sardella,* on the other hand, was at 33.7% (Table 1). It decreased significantly to 23.8 and 26.4% in the open sun and solar-tent dried samples, respectively. Three factors contributed to the decrease: 1) lipid oxidation as a result of direct exposure to heat, light and oxygen, 2) drippings during the drying process, and 3) broken skin on the fish due to multiple factors, making it easy for lipids to dissolve and drip off.

Lipid oxidation is the degradation of lipids that causes rancidity in fish. It mainly occurs in fish species that are high in fatty acids, in particular polyunsaturated fatty acids (PUFAs), since the acids contain multiple double bonds, which are reactive to hydrogen. Rancid odours become noticeable when peroxide values are in the ranges of 10-20 meq O_2/kg (Alaba et al., 2017). Table 2 shows that peroxides were lower in the market samples at 8.28 for open sun and 6.82 meq O_2/kg for the solar tent drying. These values were not significantly different at $p<0.05$ (Table 2). *E. sardella* was subjected to lipid degradation equally in the marketplace because regardless of the drying method small-scale traders displayed and exposed it to heat, light and oxygen on benches in the same way.

Thiobarbituric acids (TBA) are formed during decomposition of hydro peroxides to aldehydes and malondialdehyde. They increased to 1.11 in open sun and 1.06 mg MAD/kg for solar-tent dried samples (Table 2). The increase signified initial stages of lipid oxidation, which never advanced as the fish dried. According to Kumar et al. (2017), during the first stages of lipid oxidation, peroxides increase and reach their topmost level before starting to decline. This time, the rate of production of secondary peroxidation products, such as malondialdehyde whose concentration is quantified as thiobarbituric acid reactive substances (TBARS), starts increasing. Low levels of TBARS found (Table 2) suggest that by the time all the samples were fully dried, oxidation was still in the early stages. This means that the peroxide values had not yet reached the peak point. TBA values greater than 3 to 4 mg MAD/kg indicate a loss of product quality (Kumar et al., 2017). Both open sun and solar-tent dried samples were therefore of good quality. Rancid flavours were neither detected objectively nor subjectively through sensory perception.

Dried *E. sardella* has also shown to be a good source of zinc, iron and calcium, all of which are important micronutrients in the diet. Market samples had values in the range of 14.9-14.97 zinc, 513.77-517.75 calcium, and 16.6-16.74 iron mg/100 g of edible portion (Table 3). Mineral composition did not change during drying, transportation and marketing due to the nature of minerals which makes them stable even under very high temperatures Consumption of dried *E. sardella* should be encouraged to increase intake of these micronutrients in the general population.

This study was not without limitations. It focused on the largest *E. sardella* only, leaving out smaller and smallest sizes to avoid making the research design complicated. Actual drying was done during the dry and hottest season in Malawi. However, small-scale fishers and processors dry fish throughout the year, including in winter and rainy months, with low temperatures and high humidity that prolong drying and affect quality of the fish. Protein, fat, micronutrients, peroxides and TBARS differ with fish sizes. Smaller and smallest species of *E. sardella* may therefore give different results altogether if studied. Also, the study neither quantified microorganisms of importance nor evaluated sensory quality of the dried fish samples despite the need. These gaps should inform the design and methodologies of future research.

In conclusion, sardines remain one of the smallest, most neglected, and underutilized fish species despite being nutritious, unique and readily available to the rural masses at risk of undernutrition. Low consumption is due to multiple factors. However, traditional drying in open air is the major problem as it has shown to be unhygienic because of high contamination by physical and biological hazards, both of which pose threats to consumers' health. While drying times and moisture levels may not differ much between the two methods in hot seasons based on the results of this study, solar tent dryers should be promoted to improve drying quality of the fish and reduce post-harvest losses during cold and rainy months. Solar tent dryers for fish have been there for 16 years now in Malawi since their introduction in 2007. However, the majority of small-scale fishers and processors are still unable to construct and use them because of cost, with initial investment estimated at over MK3,500,000 (US$3,290) and returns achieved in less than 2 years. More efforts by key players in the sector are needed to increase adoption and quality of dried fish.

CONFLICT OF INTEREST

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

This work was carried out with the aid of a grant from the International Development Research Centre (IDRC, Ottawa, Canada [Grant number: 108865-001]. We are indebted to Professor Chiwaula for continuous guidance throughout the study. We are thankful to the analytical laboratories at LUANAR and Chancellor College of Malawi for helping with chemical analysis.

REFERENCES

Ahmed M, Pickova J, Ahmad T, Liaquat M, Farid A, Jahangir M (2016). Oxidation of lipids in foods. Sarhad Journal of Agriculture 32(3):230-238. http://dx.doi.org/10.17582/journal.sja/2016.32.3.230.238.

Al-Azawiey SS, Hassan SB (2016). Heat absorption properties of ground material for solar chimney power plants. International Journal of Energy Production and Management 1(4):403-418. DOI:10.2495/EQ-V1-N4-403-418.

Alaba J, Famurewa V, Akise OG, Ogunbodede T (2017). Effect of storage methods on the nutritional qualities of African Catfish *Clarias gariepinus* (Burchell, 1822). African Journal of Food Science 11(7):223-233. https://doi.org/10.5897/AJFS2016.1514.

AOAC International (2016). Official methods of analysis of AOAC International. 20th ed. Gaithersburg, MD, USA. AOAC International P 3172.

Banda J, Chigwechokha P, Singini W, Kamanula J (2017a). The shelf life of solar tent dried and open sun dried *Diplotaxodon limnothrissa* (Ndunduma) -Pisces; Cichlidae. International Journal of Fisheries and Aquatic Studies 5(5):212-218.

Banda J, Katundu M, Chiwaula L, Kanyerere G, Ngochera M, Kamtambe K (2017b). Nutritional, microbial and sensory quality of solar tent dried (Samva Nyengo) and open sun dried *Copadichromis virginalis* Utaka (Pisces; Cichlidae). International Journal of Marine Science 7(11):96-101.

Cyprian OO, Nguyen MV, Sveinsdottir K, Tomasson T, Thorkelsson G, Arason S (2017). Influence of blanching treatment and drying methods on the drying characteristics and quality changes of dried sardine (*Sardinella gibbosa)* during storage. Journal of Drying Technology 35(4):478-489. https://doi.org/10.1080/07373937.2016.1187161.

Deb NK, Nabadeep S, Pulakabh C (2017). Comparative study on quality of dry fish (*Puntius spp*.) produce under solar tent dryer and open sun drying. Agricultural Extension Journal 1(3):88-91. https://www.researchgate.net/publication/320271109.

Gumulira I, Forrester G, Lazar N (2019). Bioeconomic analysis of *Engraulicypris sardella* (USIPA) in the *Southeast* arm of Lake Malawi*.* International Journal of Fisheries and Aquaculture 11(4):86-96. https://doi.org/10.5897/IJFA2018.0714.

Jim F, Garamumhango P, Musara C (2017). Comparative analysis of nutritional value of *Oreochromis niloticus* (Linnaeus), Nile tilapia, meat from three different ecosystems. Journal of Food Quality. https://doi.org/10.1155/2017/6714347.

Katola A, Kapute F (2017). Nutrient composition of solar-dried and traditionally smoked *Oreochromis*. International Food Research Journal 24(5):1986-1990.

Khumbanyiwa DD, Jian Y (2017). Fishery resources and their management in Lake Malawi. Journal of Fishery Information and Strategy 32(1):1-9.

Kumar GP, Xavier KAM, Nayak BB (2017). Effect of different drying methods on the quality characteristics of *Pangasius hypophthalmus*. International Journal of Current Microbiology and Applied Sciences 6(10):184-195. https://doi.org/10.20546/ijcmas.2017.610.024.

Likongwe MC, Kasapila W, Katundu M, Mpeketula P (2018). Microbiological quality of traditional and improved kiln smoked catfish (*Clarias gariepinus*) in Lake Chilwa Basin. Food Science and Nutrition 7(1):281-286. https://doi.org/10.1002/fsn3.885.

Lithi UJ, Surovi S, Faridullah Md, Roy KC (2020). Effects of drying technique on the quality of Mola (*Amblypharyngodon mola*) dried by solar tent dryer and open sun rack dryer. Research in Agriculture Livestock and Fisheries 7(1):121-128. https://doi.org/10.3329/ralf.v7i1.46840.

Majumdar BC (2017). Comparison of the changes in nutritional quality of three important small indigenous fish species in Bangladesh at room temperature (27°-31°C): A review. Journal of Animal Research and Nutrition 2(2):15. https://doi.org/10.21767/2572-5459.100035.

Makwinja R, Singini W, Kaunda E, Kapute F, M'balaka M (2018). Stochastic modeling of Lake Malawi *Engraulicypris sardella* (Gunther, 1868) catch fluctuation. International Journal of Fisheries and Aquaculture 10(4):34-43. Doi: 10.5897/UFA2017.0642.

Mbamba D, Valeta J, Harawa D, Kapute F, Singini W, Mzengereza K (2018). Profitability analysis of value added *usipa* (*Engraulicypris sardella*) by packaging in Nkhotakota, Malawi. Journal of Ecology and Natural Resources 2(3):1-5. https://doi.org/10.23880/jenr-16000134

Mgwede CW, Msiska O, Kapute F (2018). Comparative assessment of microbiological safety of fresh and parboiled *Engraulicypris sardella* (Usipa) from selected selling points in the city of Mzuzu, Malawi. MOJ Food Processing and Technology 6(4):355-360. DOI: 10.15406/mojfpt.2018.06.00187.

Mulumpwa M, Jere W, Kakota T, Mtethiwa A, Kang'ombe J (2020). Modelling and forecasting of *Engraulicypris sardella* (Usipa) yields from Mangochi Artisanal Fisheries of Lake Malawi using holt exponential smoothing method. Malawi Journal of Science and Technology 12(1):66-86.

Nankwenya B, Kaunda E, Chimatiro S (2017). The demand for fish products in Malawi: An almost ideal demand system estimation. Journal of Economics and Sustainable Development 8(16):63-71.

Pal M, Ketema A, Anberber M, Mulu S, Dutta Y (2016). Microbial quality of fish and fish products. Journal of Beverage and Food World 43(2):1-34.

Patterson J, Kailasam S, Giftson H, Immaculate JK (2018). Effect of drying technologies on the biochemical properties of *Stolephorus commersonnii*. Food Quality and Safety 2(3):153-158, https://doi.org/10.1093/fqsafe/fyy010.

Regupathi ER, Balasubramanian S (2018). A study on solar drying system for fish preservation. Asia Pacific Journal of Research 1(88):137–142. Torell EC, Jamu DM, Kanyerere GZ, Chiwaula L, Nagoli J, Kambewa P, Brooks A, Freeman P (2020). Assessing the economic impacts of post-harvest fisheries losses in Malawi. World Development Perspectives 19(2020):100224.

Tsutsu RB, Singini W (2021). Value Chain Analysis of Usipa (*Engraulicypris sardella*) of Lake Malawi. Journal of Nutrition and Food Science 11(2):790-796.

Zebib H, Teame T, Meresa T (2017). Evaluation of solar dryers on drying and sensory properties of salted Tilapia filets, Tigray. Journal of Food and Agriculture Science 7(2):10-18. https://doi.org/10.5897/ISABB-JFAS2017.0065.