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Evaluation of Solar Tent and Drying Rack Methods for the Production of Quality Dried Fish Used in Lake Tana Area

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Abstract: A study was conducted at Bahir Dar Fish and Other Aquatic Life Research Centre to evaluate solar tent and drying rack methods of fish drying. Three different fish types (*Labeo barbus*, *Clarias gariepinus* and *Oreochromis niloticus*) were sampled from Lake Tana during the period May, 2006 to April, 2008. The sampled fish were filleted and dried either in solar tent dryer (made of wood and plastic) or in the open air on a drying rack. Solar tent dried the fish in filleted form with better product quality. The moisture content of the product decreased to <25% and as a result it had a longer shelf life. Duration of drying was significantly shorter with solar tent (2 days) than with drying rack (4 days). Duration of drying was also shorter during the pre-rainy and dry season (1-2 days) than the main rainy and post-rainy season (3-5 days). Clarias gariepinus dried in solar tent had higher moisture content than *Labeo barbus* and *Oreochromis niloticus* but the moisture content was <25%. Calculated weight loss showed statistically significant difference with respect to both dryer types and seasons ($p<0.05$). Quantification of bacterial load, qualitative analysis and biochemical test showed that the bacterial load had pooled median abundance of log 3.64ACC per gram of fish and t ranged from log 1.9-6.04. The bacterial load increased after 6 months of storage. There was no salmonella detected in the stored dried fish. There was significant difference in hedonic scale values in dryer type ($p<0.05$). A further study on microbial load of dried filleted fish should be done in order to observe seasonal and species variation in microbial load.

Key words: Solar tent, drying rack, microbial load, product quality, dry season

INTRODUCTION

Fish is an important food item that has significant socioeconomic contribution as a source of income, employment and cheap protein for marginal people in developing countries including Ethiopia. Lake Tana is one of the major fisheries in Ethiopia. There are many fishermen that fish from the lake, tributary rivers of the lake and seasonal ponds (Sewmehon, 2003).

Fish from Lake Tana is provided to the market in different forms, such as fresh whole fish, fresh gutted and washed, frozen gutted and filleted using traditional and improved ways. Production and sale of quality product is required to increase income of the producers and to provide healthy cheap protein source to the consumers. However, fish spoils very quickly. It was reported that in the high ambient temperature of the tropics, fish spoils within 12 h (Maas-van Berkel *et al*., 2004).

Spoilage of fish can be prevented using different preservation methods including freezing, smoking, drying, salting and fermentation. Preservation slows down or prevents spoilage by micro organisms. Preservation helps in the retention of the original quality and properties of the foods and prevention of radical change which results in new product with completely different qualities and properties (Maas-van Berkel *et al*., 2004).

Fishermen far from markets either has to sell their fish in fresh condition at low price or use drying to preserve their fish harvested into less perishable product and sell it for a better price. Dried fish trade is a very important seasonal source of livelihood for many people including women and is well adapted to relatively remote places (Gordon *et al*., 2007).

Fish can be dried using open air (rack drying) or solar tent dryer. Rack drying has many limitations. Long periods of sun shine without rain are required, drying rate is low in areas of high humidity and thus, it is often difficult to dry the fish sufficiently. The quality of rack dried fish is likely to be low due to slow drying, insect damage and contamination from air born micro organisms and dust and it is difficult to obtain a uniform product (Trim and Curran, 1983). Thus as an alternative to traditional rack drying method, improved solar tent drying method has been suggested. It is the simplest and

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cheaper way of solar dryer. Solar tent works by concentrating solar radiation resulting in increased temperature in the tent and in turn lower humidity.

In solar tent, the drying rate can be increased and lower moisture content can be attained and the product quality is higher. Solar tent dryer are less susceptible to variation in weather, although the drying rate is slower during bad weather (low temperature, high humidity and low wind speed). Solar tent prevents entry of rain and contamination from pests, dust and air-borne organisms. It is possible to attain temperature as high as 45°C in side solar dryer and it has been suggested that this relatively high temperature offers some protection against attack by flies, beetles and other vermins (FAO, 1992; Trim and Curran, 1983).

The objective of the current study was to evaluate the solar tent dryer and rack fish drying methods for their appropriateness for quality fish production under the conditions of the Lake Tana Region.

MATERIALS AND METHODS

Study area: The study was conducted at Bihar Dar Fishery and Other Aquatic Life's Research Center (11°4'N and 37°3'E). The minimum and maximum temperature is 22 and 30°C, respectively with annual rain fall of 1300 mm. The fish were sampled from three selected sites of Lake Tana, Abagerima, Zegie and Gelgel Abbay (Fig. 1). Lake Tana is the largest (3150 km^2) and most elevated (1830 m) lake in Ethiopia with a maximum depth of 14 m and average depth of 9 m (Tesfaye, 1998). There are four distinct seasons of the year around lake Tana, dry season (November to April), pre-rainy season (May to June), main rainy season (July, August) and post-rainy season (September to October) (Eshete, 2003).

Fishing and drying: Samples of the fish species *Oreochromis niloticus* (tilapia), *Labeo barbus* (large barbus) and *Clarias gariepinus* (catfish) were fished using gillnet of mesh size 6-14 cm every month from May, 2006 to April, 2008. The fish were filleted using knife, weighed and soaked in salt solution (6% brine solution, 60 g salt dissolved in 1 L of water). They were then dried both on drying rack and in solar tent. Weight after drying has been taken to obtain the calculated weight losses. This activity was conducted at the Bihar Dar Fishery Research Centre.

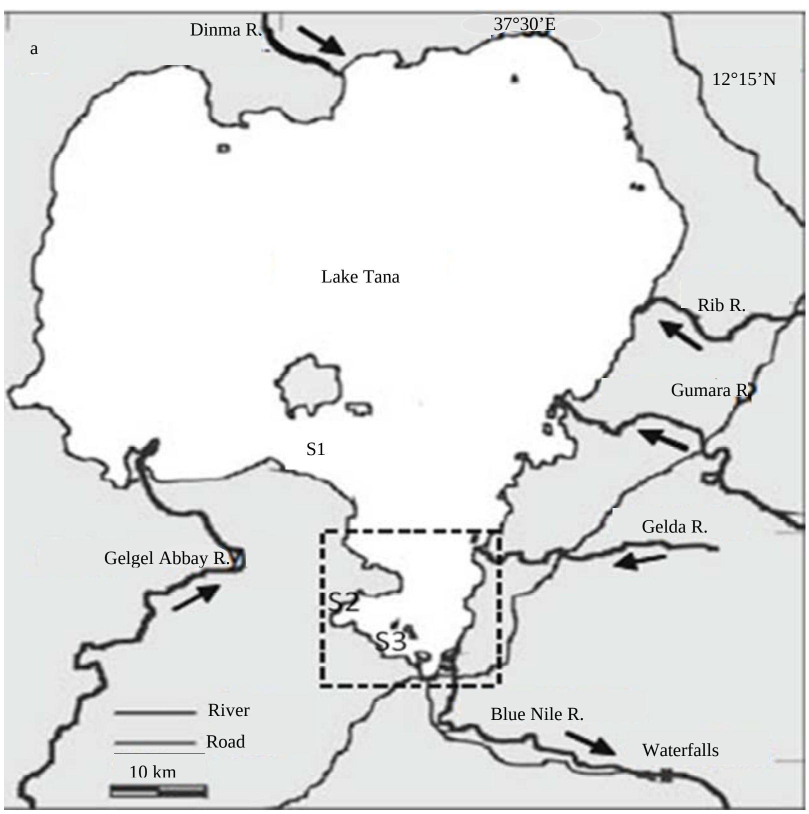

Fig. 1: Map of Lake Tana showing sampling sites, Gelgel Abbay (S1), Zegie (S2) and Abagerima (S3)

Moisture content analysis: Moisture content analysis was done at Bahir Dar University. The 10 g of dried fish from the three fish species (large barbus, Nile tilapia and catfish) dried by the two drying methods (solar tent and drying rack) were sampled. The samples were covered with aluminum foil and put in oven. The weight change of the samples was observed and kept in the oven until the weight change became constant. The moisture content was then calculated as a difference between the initial and final weights.

Organoleptic test: Organoleptic test was done at Bahir Dar Fishery Research Centre. Five men from Bahir Dar Fishery and Other Aquatic Life Research Center were selected and trained on how to identify good quality dried fish, using organoleptic method (texture, color, odor and fragility). Representative dried fish samples dried by rack and solar tent, from each fish type (catfish, Nile tilapia and large barbus) stored for 1, 3, 6, 9, 12 and 15 months in plastic bag at room temperature were labeled with letters and given to the 5 men to test the quality using organoleptic methods. The test was done based on Hedonic scale of 5 based on the methods of Doe and Olley (1990).

Assessment and quantification of bacterial load: Representative samples were taken from different treatment groups aseptically. The treatments were raw fish, filleted fish after 1 h salting, 1, 3, 6, 9, 12 and 15 months shelf life stored at ambient temperature. Plate count agar for standard heterotrophic plate count was used. Media were prepared according to manufacturers instructions. The 10 g of fish from each treatment was taken and mixed with 90 mL of 1% peptone diluents (PW) (1%) and digested in seaward stomacher (Model 400). And 1N HCl and 1N NaOH were added as buffer to maintain the pH of the solution. Litmus papers which were capable of distinguishing pH units with a range of 5.0-8.0 were used. Pour plate technique was employed. A portion of the product blended with (PW) (1%) is mixed with a specified agar medium. Those plates used to enumerate mesophilic bacteria were incubated at 37°C for 18-24 h aerobically. Aerobic colony counts were determined for Plate Count (PC). Single dominant colony was isolated from each countable representative PC plates and incubated at the earlier specified temperature for further microscopy and biochemical tests. Macckonkey media was used for salmonellosis tests. Under the microscope; morphology/shape, presence/absence of spores and gram reactions were investigated. The biochemical tests included KOH and gram reactions.

Supplementary data: Meteorological data including; wind speed, humidity, temperature and rain fall were collected from Metrological Agency, Bahir Dar Branch, Ethiopia.

Statistical analysis: Descriptive statistics, independent t-test and univarate analysis were used to analyze the data. For meteorological data taken, log transferred value were used. Statistical package SPSS version 12 was used for the analysis.

RESULTS AND DISCUSSION

Moisture content and drying rate: Moisture content of catfish, Nile tilapia and large barbus fish samples dried in solar tent and drying rack in different seasons of the year is presented in Table 1. The moisture content of the fish samples dried in solar tents was lower than those dried in drying rack for all the three fish species and in all the four seasons. Moisture content is an important factor determining the shelf life of dried fish. The less the moisture content the longer is the shelf life of dried fish products. Season of the year has showed a significant effect on the moisture content of the dried fish samples ($p<0.05$). The moisture content was highest in the main rainy season (low wind speed, low temperature and high humidity) and lowest in the pre-rainy season and dry season (low humidity, high wind speed and temperature) for fish samples dried on drying rack. However, effect of season on moisture content is not clear for samples dried in solar tent. There is inconsistency across fish species.

There was significant differences among the four seasons in weather elements (Table 2; $p<0.05$). The effect of season on moisture content, particularly for fish samples dried on drying rack, is consistent with the differences in weather elements (temperature, wind speed and humidity) among the four seasons (Table 2). The lowest moisture contents were found in samples dried

Table1: Average moisture content of catfish, Nile tilapia and large barbus fish samples dried in solar tent and drying rack in different seasons of the year

Fish species	Seasons	Tent	Rack
Tilapia	Dry	7.0	20
	Pre-rainy	6.5	15
	Post-rainy	9.0	18
	Main rainy	9.0	25
Barbus	Dry	11.0	22
	Pre-rainy	7.0	15
	Post-rainy	10.0	24
	Main rainy	8.0	26
Catfish	Dry	16.5	22
	Pre-rainy	9.5	18
	Post-rainy	12.5	26
	Main rainy	11.5	30

Table 2: Mean value of weather elements in the four seasons of the year

Weather elements	Seasons	Mean log value	p-values
Humidity	Dry	1.686	0.01
	Pre-rainy	1.797	-
	Post-rainy	1.800	-
	Main rainy	1.905	-
Temperature	Dry	1.434	0.03
	Pre-rainy	1.435	-
	Post-rainy	1.408	-
	Main rainy	1.379	-
Wind speed	Dry	1.167	0.018
	Pre-rainy	1.425	-
	Post-rainy	1.025	-
	Main rainy	1.025	-

Table 3: Effect of season on calculated weight loss of fish dried in solar tent and rack

	Mean calculated weight loss	
Seasons	Tent	Rack
Dry	0.822[a]	0.723[c]
Main rainy	0.797[b]	0.601[d]
Post-rainy	0.801[b]	0.680[d]
Pre-rainy	0.828[a]	0.702[c]

during the dry and pre-rainy season which had the highest temperature, highest wind speed and lowest humidity. It is known that fish dry quickly in conditions with low humidity, high wind speed and high temperature (Clucas and Ward, 1996).

Drying rate is expressed as the difference between the fresh and dried fish weight and calculated as ((Wi - Wf)/Wi×100). Weight loss is affected by factors, such as season and dryer type. Table 3 presented calculated weight loss in fish dried in different seasons of the year. The calculated weight loss was significantly higher in dry and pre-rainy season ($p<0.05$) due to low humidity and high wind speed. The high rate of drying in pre-rainy and dry seasons for fish samples dried on drying rack is consistent with the low final moisture content of these samples. Although, the final moisture content of the fish samples dried in solar tents was not consistent across species, the drying rate or the weight loss was higher in solar tent.

Table 4 shows effect of fish drying method or fish dryer type on calculated weight loss. Fish samples dried in solar tent lost more weight than those dried on drying racks. This result is consistent with the lower final moisture content of fish samples dried in solar tent (Table 1). The higher calculated weight loss solar tent dried fish means a better drying rate than drying rack. Dry and pre-rainy season and winter were better seasons for drying because they had low humidity, high wind speed and high temperature.

Fish drying time (duration) vary considerably depending on the thickness of the fish, weather or season and dryer type (conventional or improved method) (FAO, 1981). Table 4 shows duration of

Table 4: Effect of fish dryer on calculated weight loss

Dryer type	Mean calculated weight loss	Mean duration of drying days
Rack	0.702	4
Solar tent	0.877	2

Table 5: Duration of drying with in different season of the year both in solar tent and rack

	Duration of drying in days	
Seasons	Solar tent	Drying rack
Dry	1-2	3-4
Main-rainy	2-3	4-5
Post-rainy	1-2	3-4
Pre-rainy	1-2	3-4

drying as affected by drying method (dryer type). Differences in duration of drying in the two dryer types was statistically significant ($p<0.05$). Filleted fish dried within shorter period of time (2 days) in solar tent than on drying rack (4 days).

Table 5 shows duration of drying as affected by season of the year. Solar tent took shorter duration for drying in all seasons compared to drying rack. Drying fish in the main rainy season took significantly longer ($p<0.05$) time than the other seasons.

How long fish must dry depends on the type of fish, its size and the weather condition. The final moisture content must be <25% to prevent microbial spoilage. Solar tent dryer is low cost. The fish dried in solar tent is also free from any contamination while in the process of drying since it has plastic cover. Fish dried in solar tent dryer had moisture content <25% in all seasons and in the three fish species. As a result the dried product had long shelf life (12 months) and hence, the dried product was of high quality as tested with organoleptic test.

On the other hand, drying rack took long duration of drying and the dried product had moisture content >25% in main rainy season which made the product to be spoiled. Furthermore, fish dried in drying rack were highly exposed to insect larvae and other contaminants. Thus, fish product dried on drying rack is of low quality. Drying rack cannot also be used in all seasons of the year.

There are also other factors that determine the type of fish preservation process that can be used. These include geographical location, socioeconomic factors and the food habit of local people and the demand abroad (FAO, 1992). Best drying result can be achieved by combining salting with drying. Salting the fish before drying is strongly recommended because itensure amon other things that during drying the microorganisms at the surface are inhibited and other insects and vermi ar kept away. Thus, spoilage of the material is slowed. Moreover, salting gives stable dried product with longer shelf life (Clucas and Ward, 1996).

Organoleptic assessment: The quality of fermented fish was assessed subjectively by visual and/or organoleptic inspection method. The main quality parameters used in organoleptic inspection usually are texture, color, odour and fragility (FAO, 1992). Properly dried fish was difficult to bend (texture). If the fish did not dry properly it tend to break up easily during storage and packing (fragility). Properly dried fish has nice odour. The color of dried fish varies depending on the type of fish species. Properly dried *Oreochromis niloticus* and *Labeo barbus* had light yellow color and nice odor whereas *Clarias gariepinus* had dark red color and the odor was not as nice as *Oreochromis niloticus* and *Labeo barbus*. There is significant different in color, taste odor and fragility between fish dried in solar tent and drying rack ($p<0.05$). The shelf-life of fermented fish is an important quality characteristic. At high moisture content or low salt levels, insects tend to lay eggs on the product which eventually develop into maggots and destroy the fish. Very dry fermented fish without salt is easily infested by termite species. Dry fish can be stored for nearly 6 months but the soft or semi-dry ones have a shelf life of up to 3 months.

Microbiological assessment: Microscopic investigation and biochemical characterization of the pinpointed dominant colonies indicated that the bacterial load ranged from log 1.9-6.04 ACC (aerobic colony counts) per gram of Nile tilapia. The bacterial load had pooled median abundance of log 3.64. The non-pathogenic bacteria load increased as shelf life prolonged, especially to 6 months. The microbial assessment did not consider season. The non-pathogenic bacteria load decreased after 6 months due to the fact that moisture content decreases as shelf life increased. No salmonella were detected in any of the fish samples. All the bacterial load observed are gram positive which are non-pathogenic (Table 6).

In a study conducted by Nerquaye-Tetteh *et al.* (1978) to isolate various micro-organisms, no *Salmonella* sp., were isolated from samples of fermented fishery products obtained from the open markets in Ghana. The absence of *Salmonella* sp., from fermented fishery products could be attributed to the high salt level and low water activity of the products. These conditions do not favor the growth of salmonella. Solar tent dryer can attain about 45-55°C that can kill salmonella together with the salt.

Table 6: Microscopic and biochemical test results of pinpointed dominant ACC of bacteria colonies per gram of Nile tilapia fish having different shelf life stored at ambient temperature

Treatments	Gram reaction	KOH tests	Morphology
F	+	+	Staphylococci
0	+	+	Staphylococci
1	+	+	Diplococcic, rod shape
3	+	+	Staphylococci
6	+	+	Long rods with spores
9	+	+	Rod, Coci
12	+	+	Staphylococcus. Long rod shape Bacillus

F = Fresh filleted; O = Salted for 1 h; 1 = 1 month shelf life; 3 = 3 months shelf life; 6 = 6 months shelf life; 9 = 9 months shelf life; 12 = 12 months shelf life

Bacterial load in fish dried on racks had much more mold than solar tent dried fish. Moulds are able to grow under dry conditions better than bacteria. For this reason, moulds are often associated with dried fermented fishery products. Spores of moulds which are often present in the air and soil contaminate fish during processing. Insects and mites are also known to cause mould contamination by carrying the spores on their bodies. The moulds commonly associated with dried cured fish in storage are *Aspergillus halophillus*, *A. restrictus*, *Wallemia sebi*, *A. glaucus* group, *A. candidus*, *A. ochraceus*, *A. flavus* and *Penicillum* sp. (Christensen and Kaufmann, 1974).

CONCLUSION

Although, traditional fishing and drying process is a low cost option for many small fishermen around Lake Tana, there is a large loss in term of wasted fish. Solar tent dryer is a low cost improved drying material solar tent can be used to produce high quality dried fish product with long shelf life. The microbial load assessment showed the presence of only non-pathogenic gram positive bacteria and no Salmonella was detected. Therefore, the heat concentrated in solar tent may have the capacity to kill salmonella. The microbiological study did not consider seasonal variation and the tests were limited. Therefore, further study that considers seasonal variation and different fish types should be done.

Dried filleted fish production can be an option to preserve excess fish when the fish production is in excess and the market for fresh fish is absent. Filleted dried fish is an accepted form of dried fish in Ethiopia. However, different forms of fish products should be assessed to meet demands of other markets, such as Sudanese markets which require whole dried fish. In addition, a further study on the nutritional content of dried fish in solar tent is required.

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