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Effectiveness of Surfaces used for Sun-drying *Rastrineobola argentea* along Lake Victoria shoreline, Uganda

EUGENE EGESA[1*], MARGARET MASETTE[2], GLADYS BWANIKA[3], FREDRICK MUYODI[3] and PETER AKOLL[3]

[1]*Fisheries Resources Sector, Busia District Local Government, PO Box 124, Busia, Uganda*
[2]*Food Bioscience Research Centre, National Agricultural Research Laboratories, National Agricultural Research Organization, PO Box 7852, Kampala*
[3]*Department of Zoology, Entomology and Fisheries Sciences, College of Natural Sciences Makerere University, PO Box 7062, Kampala, Uganda*

Corresponding author Email: egesao@gmail.com

Abstract
Mukene (Rastrineobola argentea) makes up 60% of the total fish catch in Lake Victoria and it is preserved by open sun-drying on various surfaces. This study evaluated drying time and the quality of *mukene* dried on bare-ground, concrete, net-on-grass, shade-net rack and wire-mesh rack. The drying time on all surfaces ranged from 7 hours on shade-net to 8hours on wire-mesh except on the net-on-grass which took 9.4 hours. The total bacterial load ranged from 1.0 x 10^5cfu $g^{-1}$to 2.3 x 10^8cfu g^{-1} while total volatile base nitrogen (TVB-N) varied from 17.2 mgN100g^{-1} to 23.8 mgN100g^{-1} in fish dried on shade-net and bare-ground respectively. It was concluded that the type of surface significantly affected drying time, contamination by bacteria, animal and plant detritus and pebbles, as well as concentration of total volatile base nitrates (TVB-N) in *mukene* during drying.

Keywords: Contamination, Faecal coliforms, Peroxide value, Spoilage, Sun-drying, Total bacterial load, Total volatile base nitrates,

Introduction
Rastrineobola argentea, locally referred to in Uganda as *mukene* is a small pelagic fish that makes up about 60% of the catch on Lake Victoria (Onyango *et al*., 2015, NaFIRRI, 2016). The fish is mainly preserved through sun-drying (FAO, 2010; Onyinge *et al*., 2015) although this is a slow and weather-dependent preservation method, resulting in significant quality and physical losses. Consequently, post-harvest losses in the *mukene* fishery on the lake is estimated at 30-40%, compared to a 10% global estimate for artisanal fisheries (Akande and Diei-Ouadi, 2010; Onyango *et al*., 2015). Thus, although *mukene* makes up 60% of the total catch, its economic contribution is lower than that of Nile tilapia (*Oreochromis niloticus*) and Nile perch (*Lates niloticus*), the other major commercial fisheries on the lake.

Besides sun-drying, other preservation methods include deep frying, smoking, chilling and fermentation, but their adoption is low owing to higher investment and operational costs (Legros and Masette, 2010; Kumolu-Johnson and Ndimele, 2011). Consequently, up to 98% of the catch is preserved through sun-drying and most other preservation methods are also partially dependent on sun-drying for dripping purposes (Mustapha *et al*., 2014; Onyango *et al*., 2015). Sun-drying involves laying the fish on bare ground, sometimes with old fishing nets laid on it, or on grass and pebbles. Some of these surfaces harbour contaminants that lower the quality of *mukene* and accelerate spoilage processes (Mustapha *et al*., 2014; Onyango *et al*., 2015). Being a slow process, sun-drying allows time for the proliferation of bacteria leading to higher bacterial loads and spoilage levels on

dried fish (Legros and Masette, 2010). Because of its poor quality, up to 30% of the catch is used as an ingredient in livestock feed, despite its nutritional superiority to other local fishes (Masette, 2013; Ogonda *et al*., 2014; Roberts *et al*., 2014). Whereas animal feed producers pay little attention to quality and safety issues, using poor quality fish as a feed ingredient can significantly decrease productivity in poultry (Masette, 2008; Jeyasanta *et al*., 2014). The high post-harvest losses persist despite declining per capita fish consumption and high malnutrition levels in the lake basin (Harvey *et al.*, 2010, Masette, 2013).

The high perishability of fish rapidly compromises its quality and safety after harvest, and so preservation or processing is required shortly after harvest (Mustapha *et al.*, 2014). Spoilage is much faster in small, fatty fishes like *mukene* (Abbas *at el.*, 2009, Kabahenda *et al*., 2011). This process is attributed to a combination of microbial, biochemical and enzymatic processes (Huss, 1995) and preservation techniques are applied to slow down or stop spoilage (Abolagba and Igbinevbo, 2010; Immaculate *et al.*, 2013). The microbial, biochemical and enzymatic processes responsible for fish spoilage are driven by the amount of moisture in fish therefore; the reduction of moisture through drying inhibits spoilage (Jeyasanta *et al*., 2014).

To improve the quality of sun-dried fish, raised racks have been widely promoted as a faster and cleaner technique (FAO, 2010; Oduor-Odote *et al*., 2010; Jamila *et al.*, 2012). Despite promoting this technique, drying on bare ground, pebbles, mats, nets laid on bare ground or on live grass still dominate *mukene* preservation (Kumolu-Johnson and Ndimele 2011; Onyango *et al*. 2015). There is limited information on the effectiveness of these surfaces and their influence on the quality of fish, as such; this study was designed to determine the time taken to dry the fish, the physical and bacterial contamination loads, and the levels of chemical spoilage in *mukene* dried on five different surfaces.

Methods

The experiment was set up at Kiyindi landing site (0°16'N, 33°09'E), located on the shore of Lake Victoria, about 15 km directly southwest of Jinja, Uganda, which is a major *mukene* landing, processing and trading centre. During the study, ambient temperature, relative humidity and wind velocity at the study site were recorded at hourly intervals. Temperature and humidity were measured with an air temperature/humidity meter (Model: PCE-HT 11, UK) with measuring ranges of 0°C to 50°C and 10% to 95% respectively, while wind velocity was measured using a wind velocity meter (Model: Beaufort 1438, No. 501789, UK) with measuring range 0-30 m s^{-1}.

During the present study, five different *mukene* drying surfaces were evaluated at Kiyindi landing site. These measured 1 m x 2 m and included (a) bare-ground, characterized by sandy soils and demarcated by nylon string and pegs, (b) concrete with a tilt of 1% to facilitate draining, (c) net-on-grass, with *mukene* fishing netting laid on live grass in an area demarcated by bricks, (d) a rack made of shade-net, and (e) a wire-mesh rack. The racks were constructed with poles and nails and their tops covered with 4-mm mesh shade-net or 6-mm wire mesh. The 2-m^2 drying surfaces were each subdivided into four 0.5-m^2 sections to accommodate quadruplicate 1 kg samples during the drying experiments.

Fish were harvested from the same fishing ground approximately 10 nautical miles (18 km) offshore on each fishing trip. Fishing was done at around 0500 hours and the fish landed at the experimental site by 0700 hours. At the experimental site, the by-catch was removed and 170 g of wet fish sampled, sealed in aluminium foil and preserved under ice for transportation to the laboratory for moisture, bacterial and chemical analyses. Then 1 kg of *mukene* was spread out on each section of each drying surface.

The fish on one section of each drying surface was weighed after 3 hours of drying and subsequently at 1½ hour intervals until constant weight was recorded on two consecutive weighing events. At every weighing event, 5g of fish was sampled from each of the other three sections of every drying surface. These were tightly sealed in aluminium foil, then in polythene bags, and preserved on ice for transportation to the laboratory at the end of each drying event for moisture analysis. Once constant weight had been reached, 20-g, 100-g and 150-g samples were collected from the three sections of each drying surface for bacterial, physical and chemical analysis respectively. These were also sealed in aluminium foil, preserved and transported on ice to the laboratory. There, these samples were preserved for bacterial (-4°C), chemical

(-20°C) and moisture content (-20°C) analysis. While the samples were drying, ambient and surface temperatures were recorded at hourly intervals throughout the drying period. The moisture content (%) of the samples was determined by the procedure in Oyelese *et al.* (2013) and plotted against drying time (hours) for each surface and the time taken to reach a 10% moisture content was determined by extrapolation.

The total bacterial count was estimated using nutrient agar incubated at 37°C following the procedures in AOAC (1995). Bacteria were then enumerated and expressed as colony forming units per gram of *mukene* (cfu g^{-1}). Faecal coliforms were enumerated by the membrane filter method on MacConkey agar incubated at 44.5°C for 24 hours (APHA, 1998) with incubation being done in a Model: D-91126 incubator (Schwabach FRG, Germany). Physical contaminants such as animal and plant detritus, and pebbles, were isolated and counted from 100g of dried *mukene* from each of the five drying surfaces.

Total volatile base nitrogen (TVB-N) was determined by the semi-micro distillation method (Kirk and Sawyer, 1991). In order to determine the peroxide value (PV) and free fatty acid (FFA) content, lipids were extracted from samples using a continuous Soxhlet extraction unit with n-hexene as a solvent. A rotary evaporator (Hedolph Laborota 4000) was then used to separate the lipid extract from the solvent. The peroxide value and the free fatty acid (FFA) content was determined according to procedures in Kirk and Sawyer (1991).

One-way analysis of variance (ANOVA) was used to explore differences in the time taken to dry *mukene* across drying surfaces with the Tukey HSD test. The Kruskal-Wallis (H-test) was used to explore the influence of drying surfaces on bacterial loads, TVB-N, FFA and PV. Where significant differences were indicated, multiple Mann-Whitney tests were used to examine pairwise differences between the mean values. All statistical tests were performed at significance level of $p < 0.05$ using SPSS/16 software for Windows (Dyno Tech Company Westland, MI).

Results

Drying time

Drying can be affected by both relative humidity and wind speed. During this investigation, the average relative humidity was 73.3% with the highest value (94.0%) being recorded on day 8 and the lowest (54.5%) on day 6 (Table 1). The mean maximum and minimum temperatures on drying surfaces were generally higher than the ambient temperature but the differences between it and the wire-mesh rack were relatively small (Figure 1).

Table 1: Daily ambient (mean and range) humidity and wind speed at Kiyindi during the study. Values are means with the range in brackets

Batch	Day	Relative Humidity (%)	Wind velocity (m s^{-1})
1	1	70.2 (65.5-82.5)	0.9 (0.5-2.0)
	2	67.9 (60.5-81.5)	1.1 (0.5-2.0)
2	3	71.6 (87.0-64.0)	1.0 (0.5-1.0)
	4	71.0 (67.0-77.0)	0.9 (0.5-1.0)
3	5	69.9 (66.0-85.0)	1.1 (0.5-2.0)
	6	65.1 (54.5-75.0)	0.7 (0.5-1.0)
4	7	79.5 (72.0-82.0)	1.2 (0.5-2.0)
	8	74.9 (65.0-94.0)	0.9 (0.5-2.0)
Mean		73.3 (67.2 – 90.1)	1.0 (0.5-1.6)

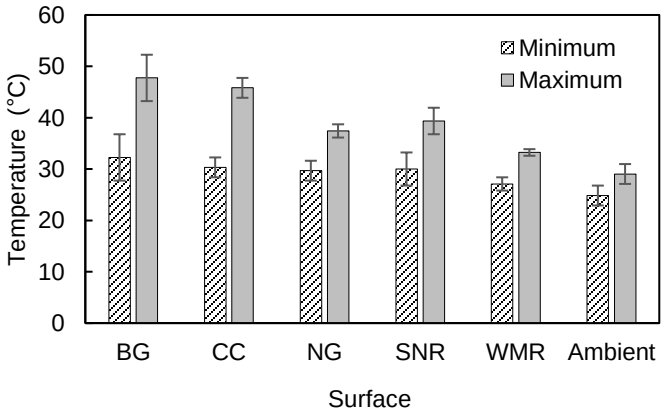

Figure 1: The mean minimum and maximum ambient and drying surface temperatures (°C) during the drying. Abbreviations are BG = bare-ground, CC = concrete, NG = net-on-grass, SNR = shade-net rack, and WMR = wire mesh rack.

The net-on-grass and shade-net rack temperatures were higher than ambient but fairly close while the maximum temperatures on bare-ground and concrete were very much higher than on the other surfaces. The drying time on all surfaces ranged from 7.0 hours on Shade-net to 8.0 hours on wire-mesh except on the net-on-grass which took 9.4 hours to dry (Figure 2). This was significantly longer than time taken to dry on shade-net rack (ANOVA, $P < 0.05$).

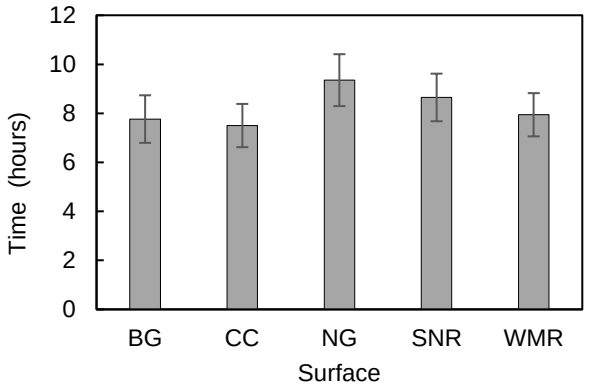

Figure 2: The time taken to dry *mukene* on the five experimental surfaces. Abbreviations as in Figure 1.

Contaminant load

The total bacterial count in wet *mukene* was significantly lower than it was in all dried samples (Table 2). Among these, the total bacterial load was significantly higher on fish dried on bare ground and on net-on-grass surfaces, but the bacterial load on those dried on the other surfaces did not significantly differ from each other (H-test, $P < 0.05$). The faecal coliform loads on fish dried on bare ground and net-on-grass did not significantly differ from each other but they were both significantly higher than the loads on fish dried on the shade-net, wire-mesh racks and concrete. Over 95% of physical contaminants recorded on the dried fish were on samples dried on bare-ground and net-on-grass surfaces; these included animal and plant debris, and pebbles (Table 3). The most important plant and animal contaminants were dry grass, as well as twigs and leaves and black ants respectively.

Table 2: Total bacterial and faecal coliform counts (cfu g^{-1}) on *mukene* samples

Drying Surface	Total bacteria	Faecal coliforms
Wet fish	(4.13 x 103)a	(3.89 x101)e
Bare-ground	(2.34 x108)b	(1.32 x105)f
Net-on-Grass	(1.57 x 106)c	(1.83 x 104)f
Concrete	(2.75 x 105)d	(2.08 x 102)e
Shade-Net Rack	(1.02 x 105)d	(1.54 x 102)e
Wire-Mesh Rack	(1.22 x 105)d	(1.50 x 102)e

Table 3: Frequency of physical contaminants in 100g of *mukene* dried on different surfaces

Drying surface	Mean contaminants			
	Pebbles	Plant debris	Animal debris	Total Contaminants
Bare- ground	50.3	16.0	4.4	70.7
Concrete	0.8	0.7	0.8	2.3
Net-on-grass	3.6	6.0	10.9	20.5
Shade-net rack	0.2	0	0.3	0.4
Wire-mesh rack	0.3	0.4	0	0.8
Total	55.2	23.1	16.4	94.7

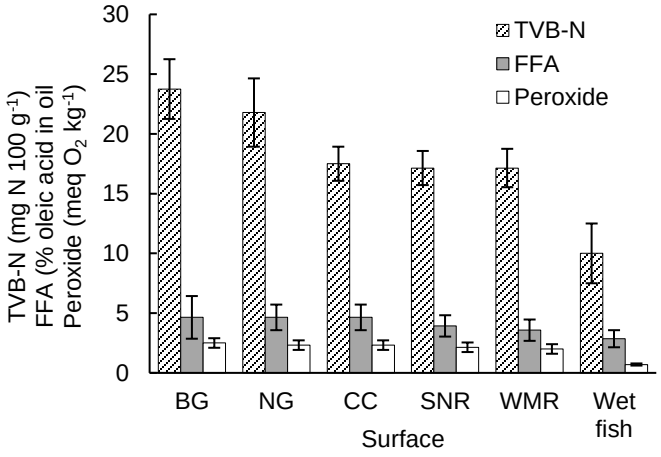

Figure 3: Chemical indices of spoilage in *mukene* samples. Abbreviations as in Figure 1.

Chemical indices of spoilage

The total volatile base nitrogen (TVB-N) concentrations were significantly higher in the dried *mukene*, especially those dried on bare ground or net-on-grass surfaces where the concentrations were more than double those in wet fish (Figure 3). The levels of

TVB-N were significantly higher in fish dried on bare-ground than those dried on the other surfaces (H-test, $p < 0.05$) and the latter were not significantly different from each other. There were no significant differences in the concentrations of free fatty acid (FFA) between any of the dried fish or the wet ones. The peroxide values (PV) in the dried fish did not differ significantly but they were all about twice as high as the value in wet ones and therefore differed significantly (H-test, $p<0.05$).

Discussion

The finding that *mukene* took longer to dry on net-on-grass is consistent with those of Akande and Diei-Ouadi (2010)and Jamila *et al.* (2012) who also found that under ambient conditions, fish dried faster on shade-net racks. This was attributed to better ventilation with air currents sweeping over and under the fish (FAO, 2010; Oduor-Odote *et al.,* 2010; Modibbo *et al.,* 2014) evacuating moisture-loaded air and replenishing it with fresh air which in turn absorbed more moisture (UNIFEM, 1998). In addition to ventilation, the high temperatures recorded on shade-net racks and concrete surfaces contributed to the higher rate because drying is governed by temperature, which drives vaporization, diffusion and evaporation (Reza *et al.*, 2009; Omodara and Olaniyan, 2012; Bassenel *et al*., 2013). Moisture from the ground or from grass transpiration could also have contributed to the slower drying on the net-on-grass surface.

The total bacterial count in wet *mukene* was within the acceptable limits ($1x10^2$-$1x10^5$cfu g^{-1}) for freshly harvested fish suggesting these were of good quality (ICMSF, 1986; Obodai *et al.,* 2011). The total bacterial load in wet fish was significantly lower than in all dried fish samples, implying that continued bacterial growth or/and contamination occurred during the drying process (Onyango *et al*., 2015) as noted by Owaga *et al*., (2009) who found 5.58 log cfu $g^{-1}$and 6.16 log cfu g^{-1}in wet and dry *mukene* and Legros and Masette (2010) who obtained estimates of 1 x 10^3 cfu g^{-1} and 2 x 10^8 cfu g^{-1} in wet and dried fish respectively. During the study, the mild ambient temperatures which ranged from 25 ºC to 31ºC could not have inactivated bacteria, allowing further proliferation during drying process (Novotny *et al.,* 2004; Onyango *et al*., 2015). Furthermore, the long drying period allowed more time for the high moisture and nutrient content in *mukene* to support bacterial growth (Owaga *et al*., 2009; Legros and Masette, 2010).

The high frequency of physical contaminants recorded on fish dried on bare-ground and net-on-grass surfaces further confirms their unhygienic state. Similar results were obtained by other workers who found that fish dried on bare-ground were also contaminated with animal, plant and inorganic matter picked up from the surface (Bille and Shemkai, 2006; Jumbe *et al*., 2010; Immaculate *et al.,* 2013; Onyinge *et al*., 2015).

The total volatile base nitrogen (TVB-N) concentration in wet *mukene* were within acceptable levels in freshly caught fish (5-20 mg N 100 g^{-1}) (Huss, 1995) and its increase in the dried fish suggests that spoilage continued during the drying process. The breakdown of amino acids in fish muscles by bacteria and enzymatic activities is the main source of TVB-N (Immaculate *et al*., 2013; Singh *et al.,* 2013) and the higher concentrations of TVBN in fish dried on bare ground and net-on-grass could be attributed to elevated bacterial contamination recorded on fish dried on these surfaces. Previous studies have also reported an increase in TVB-N with increasing bacteria counts. (Jumbe *et al*., 2010; Wogu and Maguakor, 2010; Jeyasanta *et al.,* 2014). These results are also within the previously recorded range of 9.42 to 29.51 mg N 100 g^{-1} (Owaga *et al*., 2009) but they were all within the acceptable limits of 35-40 mg N 100 g^{-1} for dried fish (Immaculate *et al.,* 2013).

All fish samples, including the wet fish, had the free fatty acid (FFA) concentrations above acceptable limits (0.5-1.5% oleic acid in fats) which suggests extensive degradation of fats on slaughter (Connell, 1995). Oxidation of unsaturated fatty acids by atmospheric oxygen is the main cause of fat degradation and the primary source of PV (Huss, 1995), the levels of which were all higher in the dried fish.

The promotion of raised rack and concrete surfaces among artisanal *mukene* processors could significantly improve the current poor quality of the final product and excessive post-harvest losses. This would contribute to an increase in the quantities of this fish available for direct human consumption and contribute to reducing the decline of per capita fish consumption and hidden hunger in the region.

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