



Journal of Food Resource Science

ISSN 2224-3550

science
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Biochemical and Nutritional Quality of Dried Sardines using Raised Open Solar Rack Dryers off Kenyan Coast

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ABSTRACT

Normally sardines are traditionally sun dried unhygienically by spreading on sandy seashores, mats or tarpaulins along the Kenyan coast. However, these convectional traditional solar methods of drying fishes intended for human consumption have serious health hazards due to employment of improper and unscientific methods. Quality assurance of processed seafood is therefore of utmost concern that has greater public health implications. Therefore, in order to overcome the traditional sun drying drawbacks, an investigation was carried out to assess the biochemical and nutritional quality changes in dried sardines using a raised open rack system. The system performance was evaluated in terms of sardine drying rates, biochemical and nutritional quality attributes. Quality attributes were assessed by determining proximate composition, yeast, mold and bacterial counts, peroxide value and color L, a, b values. The results indicated a significant variation in drying rates and assessed quality attributes compared to the convectional traditional sun drying method.

Key words: Solar rack dryer, biochemical and nutritional quality, quality, sardines, fish drying

INTRODUCTION

Fishes play important roles in human diets as good sources of animal protein that also provide other important elements necessary for maintenance of healthy bodies (Ravichandran *et al.*, 2012). On the other hand, fish is an extremely perishable commodity and quality losses occur very rapidly after catch (Dewi *et al.*, 2011; Musa *et al.*, 2010; Khan and Khan, 2001). As a result, the oldest and least expensive fish preservation methods of salting and sun drying (Balachandran, 2001) has been mostly used to reduce water activity (Eyo, 1983) and enhance chemical factors such as diffusion, osmosis and a series of other complicated chemical and biochemical processes for product preservation (Turan *et al.*, 2007). However, these traditional solar drying methods are often rudimentary and good hygiene is rarely practiced. Thus, according to a (MAF., 1995) report, small pelagic landings in Oman, for example, were 41496 t out of which 80% were sardines (*Sardinella longiceps*) (33054 t). Out this 33054 t of the landed sardines, 33000 t were traditionally dried and only a small portion was used for human consumption and export with majority being used in the livestock feed industry (Sablani *et al.*, 2002) similar to the Kenyan case.

Solar drying is a traditional low cost fish preservation method practiced in many parts of the world (Sachithanathan *et al.*, 1985; N'jai, 1985; Eyo, 1983). Though, these traditional low cost

curing and drying preservation techniques vary with type, nature, size and fish condition; improper handling and processing can result in poor quality products due to spoilage, loss of dried products to rats, cats, dogs, birds and insect infestation (a major problem with the traditional drying of sardines in Kenya). These losses can reach up to between 30-40% of total production leading to reductions in the fishermen revenues. Several solar dryer designs including Convection Cabinet (CC) design, electric tent design and Multi-rack Dome (MD) design have therefore been constructed and tested for different fish species (N’jai, 1985; Sachithananthan *et al.*, 1985; Obanu *et al.*, 1988). However, their usages have not been utilized in large scales due to the required initial huge infrastructural costs especially in the tropics where spoilage is rapid even at ambient temperatures (Igene, 1983). This makes certain irreversible spoilage and deterioration reactions to begin taking place within 12-20 h depending on the captured fish species, methods of capture and if not processed immediately after capture (Connell, 1995).

Fish preservation methods in Kenya are currently evolving with improvements made on the traditional solar drying techniques as a result of the increased demand for cured fishery products in major urban areas. This has made the packaged solar dried form of the freshwater Cyprinid, *Rastrineobola argentea*, commonly referred as Omena or Dagaa in Kenya, being sold in major supermarkets within the country. In the marine sector, three different Clupeid sardine fishery species locally known as “Simsim” [*Sardinella melanura*-Cuvier, 1829]; “Kata shingo” [*Sardinella neglecta*-Wongratana, 1983 (Whitehead, 1985)] and “Kimarawali” [*Spratellomorpha bianalis*-Bertin, 1940 (Whitehead, 1985)] similar to the freshwater Cyprinid fishery exists in south coast of Kenya at Jasini-Vanga. All these species, just like “*Rastrineobola argentea*-Omena”, are processed by solar drying either by broadcasting on the sandy sea shore beaches, mats, tarpaulins, mosquito nets (Fig. 1). For “simsim” [*Sardinella melanura*-Cuvier, 1829 and “Kata shingo” [*Sardinella neglecta*-Wongratana, 1983 (Whitehead, 1985)], the fishes are first boiled in water and then sun dried on sand, mats, nets, tarpaulins on the ground (Fig. 2).

These processing types however lower the product quality as well as income through market penetration hindrance. Therefore, taking into consideration that at present, about 1.4 million metric t of fish accounting for about 8.0% of the total world catch is cured and utilized



Fig. 1(a-b): “Kimarawali” (*Spratellomorpha bianalis* [Bertin, 1940]) being prepared for the market from the drying net (Left) and (Right). The dried products with sand particles embedded on their body after processing



Fig. 2(a-b): Boiling of “Simsim” (*Sardinella melanura* [Cuvier, 1829]) and “Kata shingo” (*Sardinella neglecta* [Wongratana, 1983]) fish (Left) before drying on laid nets on the ground (Right)



Fig. 3: Raised open solar rack dryers used in the study

in China, Japan, USSR, Indonesia, Philippines, Ghana, Canada and India (FAO, 2000), there is need to significantly control the quality of the raw materials for maintenance of good nutritional value and aseptic hygienic conditions by using low cost improved solar processing units such as the raised open rack dryer design systems (Fig. 3). In order to overcome the traditional sun drying drawbacks, an investigation was carried out to assess the biochemical and nutritional quality changes in dried sardines using a raised open rack system.

MATERIALS AND METHODS

Fresh sardine fish samples were obtained in bulk from the local Jasini artisanal fishermen in Vanga (S 04°40'16.11", E 039°13'36.96"), Kenya. They were then quickly transferred to large

insulated cooler boxes containing crushed ice and transported to the processing sites where the solar rack dryers were installed in Jasini-Vanga next to the landing site. The purchased initial sardines' moisture content was 73% (wet basis). The individual fish masses and lengths however varied from 17-45 g and 40-60 mm, respectively. Their individual belly widths on the hand, varied from 15-40 mm. At the processing site, the fish samples were divided into two equal portions for the raised open rack dryers (consisting of an ivory mesh net, raised 0.30 m from the ground to allow for air movement) and traditional ground drying processing on nets. The raised open rack dryer cover was kept open during the entire period of study.

Data collection

Air temperature, relative humidity and drying rate experiments: The environment (i.e., air and weather conditions) influences the product drying process. Hence it is important to monitor air conditions inside and outside the processing unit area. Remote data loggers (Hobo Model H08-004, Onset Computer Corporation, MA) were used to monitor temperature and relative humidity inside the processing area at intervals of 30 min from 9.00-16.00 h daily. During the project, monthly drying experiments were also carried out continuously for 5 days (equivalent to 60 h) during the day for 5 months of the experiment. A total 10 kg of sardines was spread out on each rack. Five different whole fishes were randomly picked and labeled in each of the four corners and at the center of each drying unit and weighed at various time intervals over the drying period. A top loading Salter digital balance model 2010 with an accuracy of 0.01 g was employed for weighing the fish samples.

Chemical composition: The samples water content of the fish samples was expressed on a dry basis (kg water/kg dry solids). The chemical composition of the dried material was determined using a standard method of analysis (AOAC., 1990). For measuring total bacterial plate counts, samples (5 g), in triplicate, were aseptically removed from the dried fish and homogenized in 45 mL of sterile 0.1% peptone in a blender. Serial dilutions of the fish homogenates were prepared using the same solution. Each dilution (1 mL) was dispersed with and poured in duplicate with plate count agar for total viable counts using aerobic incubation at 35°C for 48 h (Gulf Standard, 1996). Results were expressed as CFU/g fish. Peroxide Values (PV) were measured using 0.5 g of dried fish sample as per the procedure given by Egan *et al.* (1981). The peroxide values were expressed as milliequivalents of peroxide oxygen per kg of sample (mEq kg^{-1}).

Color measurements: The color measurement of dried whole fish was carried out using a Minolta Chroma meter (model CR-310, Minolta, Japan). The equipment was calibrated with a white standard calibration plate provided by the manufacturer. Five whole dried sardines from each dryer method were used to measure the color at dorsal and belly. At least 10 measurements were recorded for each sample portion. The results were expressed in Hunter L, a, b values in which L represents the sample lightness or darkness (black, L = 0; white, L = 100), +a redness, -a greenness, +b yellowness and -b the blueness.

Statistical analyses: All data were analyzed using Microsoft 2007 excel statistical package. The biochemical and nutritive drying sardine effects of using raised open rack dryer units and conventional traditional drying methods was analyzed using the one-way ANOVA followed by a post-hoc test between groups using Turkey's multiple comparisons test. All data were expressed as Mean±Standard deviation (STDEV) and probability tested at 95% level of significant ($p < 0.05$).

RESULTS

Temperature, humidity profiles and drying rates: The mean ambient air temperatures varied from 25-32°C (Fig. 4) while the generated relative humidity within the processing area varied from 20-87% depending upon the time of day (Fig. 5) during the experimental period. The appropriate traditional sun drying activity of sardines on the other hand takes between 5-7 days depending on the prevailing weather conditions for proper drying, but only between 2-3 days on raised open racks. The individual sardine samples initial moisture content was 2.33 kg water/kg dry solids. The final moisture contents at the end of drying were 1.66 and 1.11 kg water/kg solids for the traditional and raised open rack dryings, respectively (Table 1).

Biochemical and nutritional quality of dried sardine fishes: Fresh fish samples had a moisture level of 41.3%, whereas the hygienically dried samples on raised open fish racks and the

Table 1: Mean proximate (biochemical) composition of dried sardines during the study period. ^akg/100 kg sample; values in the brackets are standard deviations

Drying method used	Moisture (SD)	Protein (SD)	Fat (SD)	Ash (SD)
Raised open rack	11.10 (0.49)	49.13 (0.88)	8.52 (0.22)	12.88 (0.39)
Traditional ground laid net	16.60 (0.07)	56.82 (1.55)	9.42 (0.39)	13.66 (1.04)

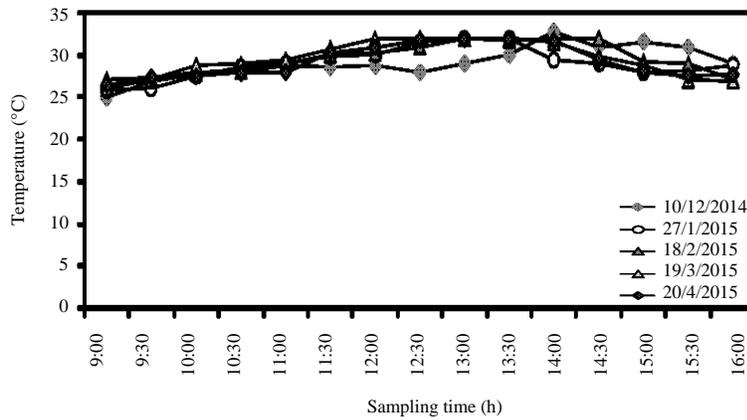


Fig. 4: Monthly daily temperature variations during the drying experiment

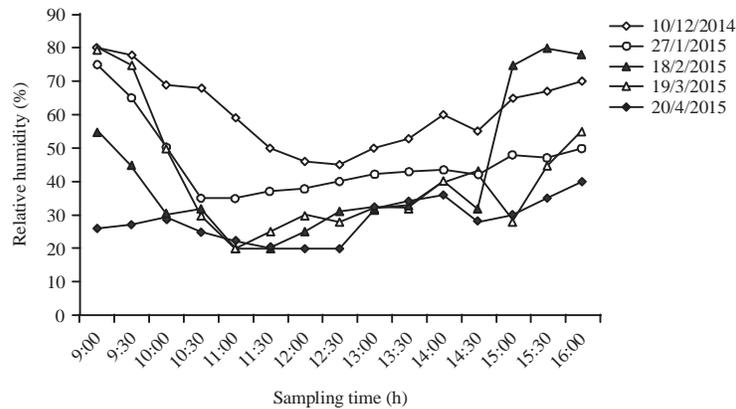


Fig. 5: Monthly daily relative humidity of air inside the processing unit during the experiment

Table 2: Mean microbial and chemical characteristics of the dried sardines during the experimental period

Characteristics	Raised open rack	Traditional ground laid net
Yeast and mould (CFU g ⁻¹)	1.48×10 ^{2b} (0.62×10 ³)	3.68×10 ^{2b} (3.75×10 ³)
Bacteria (CFU g ⁻¹)	1.56×10 ^{2b} (0.47×10 ³)	7.00×10 ^{2b} (1.46×10 ³)
Peroxide value (mEq kg ⁻¹)	0.539 ^b (0.027)	0.653 ^b (0.046)

Values in the brackets are standard deviations, same letter in a row indicate no significant difference (p>0.05)

Table 3: Color browning (L, a, b values) of dried sardines during the experimental undertaking

Drying method	L	a	b
Belly coloring			
Raised open rack	73.8 ^b	-4.74 ^c	9.54 ^b
Traditional ground laid net	47.9 ^c	-2.24 ^a	10.08 ^b
Dorsal coloring			
Raised open rack	88.5 ^a	-6.10 ^b	11.94 ^a
Traditional ground laid net	46.8 ^c	-1.30 ^a	11.52 ^a

Same letter in a column indicate no significant difference (p>0.05)

convectonal traditional fish drying method had 11.10 and 16.60% moisture levels respectively. The crude protein content in fresh samples was 20.26 (20.3%) and increased in dried samples (49.13-56.82). The lipid content in fresh samples was 10.5 and also varied in dried fish samples (8.5-9.4) with high values noted in samples dried using the traditional method of drying. The ash content on the other hand also varied between samples with lower value 12.88 (0.13%) observed in samples dried using the raised open rack dryers. Protein content also varied between samples and higher values were noted in samples dried using the traditional drying method (Table 1 and 2). The biochemical (p = 0.81) and microbial quality attributes (p = 0.29) showed no significant differences (p<0.05) with the two drying methods.

Color measurements: The Hunter Lab L-values usually employed to indicate the browning of foods during processing was used to determine the browning effect of the two drying methods. The traditional ground laid net dried samples showed the highest browning (Table 3) indicated by lower L-values.

DISCUSSION

Sardine fish harvesting being seasonal in Kenya, fresh sardines are not available throughout the year making their dried products to be in demand during such periods of scarcity. In addition, during abundance seasons, sale glut results making it necessary to preserve the products in dry form sale during lean seasons. However, the conventional traditional drying method mostly used is always unhygienic with no particular standards. This makes the quality of dried fish dried to be unsatisfactory due to yellowing discolorations, off-odors, high sand contents, insect infestations, belly bursting, disintegration and high product microbial loads. This uncontrolled growth of microbes in such cured products leads to serious public health implications and keeping of quality and safety of the product is of utmost importance.

The products moisture content seems to be an exact susceptibility indicator for the product to undergo microbial spoilage. This is because dried fish products microbial stability during processing and storage is dependent upon their moisture contents (Sugathapala *et al.*, 2012; Scott, 1957; Waterman, 1976; Troller and Christian, 1978). Thus, when the dried product moisture is high, it favors microbial growth and infestation of the product by flies resulting to serious consumer food borne illnesses (Huang *et al.*, 2010). It has therefore been reported that a well dried fish of 0.25 (i.e., 25%) moisture content, will not be affected by microbes and if further dried to 0.15 (15%), the

growth of mould will cease and thereby increase the products shelf life (Glucas, 1982). In view of the foregoing, the experimental results showed that there was a positive final moisture reduction of the samples that favored using of raised open racks in sardine drying. In addition, it takes lesser days of drying than the traditional method. This was probably due to the efficient air circulation beneath the racks which blew away the humid water vapor collecting below the racks, availability of mesh pores raised above the ground that allowed water dripping from the samples and a wider flatter surface allowing single spreading of samples. Moisture reduction of the raised open racks becomes even more evident from the samples final moisture contents' larger standard deviations (Table 1).

On the other hand, since post process changes in dried fish products results from the fish's chemical reactions and from the presence and activity of microorganisms; the observed increase of product proteins in dried fish samples than fresh fish products during the project (Table 1), resulted from dehydration of water molecules present between the proteins and causing aggregation of proteins in the dried fish products (Ninawe and Rathnakumar, 2008). Cowey and Sargent (1947) also reported that reduced moisture content increased protein contents in *Hyperopisus bebe occidentalis*. Chukwu and Shaba (2009) investigated protein content increase in cat fish (*Clarias gariepinus*) and reported that since protein nitrogen was not lost during drying, aggregate and causes protein contents to increase with the reduced moisture content. The lipid contents were lower in dried than fresh samples and the variation could have resulted from the evaporation of moisture content with lipids. The ash content was lower in the raised open rack dried samples in an outcome that was in accordance with earlier findings of Tunison *et al.* (1990) and Ojutiku *et al.* (2009).

Mean microbial load in the raised open rack dried samples was less (1.48×10^2 CFU g^{-1} for yeast and molds and 1.56×10^2 bacteria) than those dried using the convectional traditional drying method (Table 2). This was due to the clean and safe practices followed during processing. This microbial load reduction in the raised open rack dried sardines suggests a safer product similar to that reported by Rahman *et al.* (2000) in the case of convection air-drying where they observed significant differences in total bacterial counts. The fat oxidation (peroxide value) in sardines dried using raised open rack dryers was also lower than for those dried using the convectional traditional drying method (Table 2). This was similar to the observations reported by Rahman *et al.* (2002) in peroxide value variations in tuna dried using air, vacuum and freeze drying methods.

The samples from the raised open rack dryer units also showed less browning (Table 3). This was also clearly evident from visual observation of the samples. In general, the raised open rack dryer units showed good quality in terms of appeal, microbial load, moisture content, color retention and fat oxidation Peroxide Value (PV) resulting from the non-enzymatic anti-oxidant activity compound produced from the products' protein and non-fatty part reducing the PV (Karel, 1986). However, the product quality values were slightly lower in terms of protein, fat and ash contents. This probably resulted from the nutrient concentrated waters dripping away from the samples through the rack pores during processing.

CONCLUSION

The experimental drying quality studies showed that final moisture content was lower in the case of sardines dried in raised open rack solar dryer units while their quality attributes showed variations between the convectional traditional drying method and raised open rack drying method. Mean microbiological colony forming unit values were also lower in the case of sardines dried using

the raised open rack dryer units with no statistical significance difference ($p = 0.29$) compared to those dried using the convectional traditional drying method (Table 2). Peroxide values of samples dried using the convectional traditional drying method were also higher compared to those dried using the raised open racks. The browning color change was also mostly pronounced in the samples dried using the convectional traditional drying method than in those dried using raised open racks. The dried sardines protein, fat and ash biochemical composition were slightly lower in values with no statistical significance difference ($p = 0.81$) for the raised open rack dried samples suggesting that different drying methods have no major effects on the biochemical composition of dried products (Table 1). However, the dried sardine samples using raised open rack dryers have a comparatively good appealing (Table 3), nutritional values and hygienic status compared to those dried using conventional traditional drying method.

ACKNOWLEDGMENTS

The authors are grateful to World Bank funded Kenya Coastal Development Project (KCDP) for funding the study. Thanks also go to Raymond Ruwa, Christine Migwi, Winnie Atieno and Winnie Jefwa for their assistance with laboratory work during the project. Special thanks also go to the Director and the entire Kenya Marine and Fisheries Research Institute (KMFRI) staff for providing laboratory space and goodwill for the accomplishment of the study.

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