AJFAND ONLINE
Volume 10 No. 8
August 2010
ISSN 1684 5374
Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

DRYING CHARACTERISTICS AND SOME QUALITY ATTRIBUTES OF *RASTRINEOBOLA ARGENTEA* (OMENA) AND *STOLEPHORUS DELICATULUS* (KIMARAWALI)

Oduor-Odote PM*[1], Shitanda D[2], Obiero M[1] and G Kituu[2]

Peter Oduor-Odote

*Corresponding author email: podote@kmfri.co.ke

[1]Kenya Marine and Fisheries Research Institute, Box 81651, Mombasa.

[2]Jomo Kenya University of Agriculture & Technology, BEEDS, Box 62000, Nairobi

AJFAND ONLINE Volume 10 No. 8 August 2010 ISSN 1684 5374 Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

ABSTRACT

Rastrineobola argentea common name *Omena* and *Stolephorus delicatulus* common name *Kimarawali* are fishes that live in the freshwater and marine waters, respectively. Both are small in size, move in schools and are landed in large numbers during their peak landing seasons. Both go by the name Dagaa or sardines. In this study, they were dried in a locally fabricated solar tunnel dryer and on a drying rack in Gazi, South coast of Kenya for 14 hrs and their drying characteristics were evaluated using drying curves. Organoleptic analysis was carried out to compare some attributes of unsalted rack dried with salted spiced solar dried *Kimarawali*. The final moisture content of unsalted tunnel dried *Kimarawali*, unsalted rack dried *Kimarwali*, unsalted rack dried *Omena* and unsalted solar dried *Omena* was 0.161 kg/kg dry basis (db) (13.9% wet basis: wb), 0.163 kg/kg db (14.0% wb), 0.137 kg/kg db (12.7% wb) and 0.145 kg/kg db (12.1 wb)% respectively after 14 hrs of drying. The fish in the solar dryer attained moisture levels of 15% suitable for prevention of mould growth in 8 hours. The drying rate constants for unsalted tunnel dried and rack dried *Omena* were 0.23 and 0.22 with coefficient of determination (R^2) values of 0.899 and 0.940, respectively. The corresponding drying rate constants for *Kimarawali* were 0.18 and 0.21 with coefficient of determination (R^2) values of 0.814 and 0.932 respectively. There were no significant differences in drying rate after 14 hrs of drying for the two types of fishes and drying methods. The mean drying temperature for the tunnel dryer and drying rack during the 14 hrs of drying were 40.2±9.42 and 32.1±2.71 ^{o}Celsius respectively. The corresponding relative humidity values were 53.7%±20.34 and 70.08%±2.72, respectively. There was no significant difference in the quality attributes between the tunnel and rack dried fishes. The score for overall acceptability was however higher for the spiced tunnel dried *Kimarawali*.

Key words: Dryer, Organoleptic, Quality, Humidity, Temperature

INTRODUCTION

Fish preservation in Kenya must be elastic to involve newer techniques than the traditional methods. Although fresh fish is currently preferred by consumers and is available in major urban centres and in villages in the vicinity of landing sites, cured fish whether in the form of smoked, sun-dried or salted products are heavily marketed in remote rural areas, which are far from major fisheries and distribution routes.

Freshwater sardine commonly known as *Omena* (*Rastrineobola argentea*) comprises 44% of total catch of fish from Lake Victoria on the Kenyan side. Dried form of this fish is the most widespread commodity with a relatively long shelf life, and can be sold in small portions to meet needs of the rural poor [1]. In the marine sector, another "*Omena*-like" sardine commonly known as *Kimarawali*, (*Stolephorus delicatulus*) is also processed by drying [2]. Traditionally, both *Omena* and *Kimarawali* are dried by laying the fish on the ground, resulting in their contamination with sand and animal waste. This lowers the quality of the dried products as well as income. Drying racks, which are raised ventilated platforms have been used occasionally in the drying of fish. The racks rely on air circulation around the product to evaporate the excess moisture, and their use reduces soiling of fish during drying. However, infestation by insects, aerial contamination and rain remain a problem during rack drying [3].

Efforts to improve the drying of *Omena* in Lake Victoria by introducing racks are currently practised in Suba District [4, 5]. In the Coastal region, rack drying of fish has been introduced in Gazi [6]. A further improvement to rack drying is the use of solar dryers where drying in the enclosed chamber prevents insect infestation and rain, dries fish faster and more hygienically [7]. Value addition can be undertaken by spicing and salting the fish [8]. Spices are grown locally and have been known to enhance aroma and flavour of foods [9]. Salt is a well known flavour agent and a combination of salt and spices enhances taste [8].

Drying of fish is generally characterized by the constant and falling rate periods. In the constant rate period, drying continues at a constant rate equal to the rate of evaporation from a free water surface. Initially drying is governed by evaporation from the surface or near surface areas [10, 11]. In the falling rate period, moisture transfer takes place largely by diffusion in the material. Since diffusion is generally slower than surface evaporation, diffusion limits the drying rate. This period is generally characterized by a slow decreasing rate of drying at least partially due to the fact that the drier the product, the further the water must diffuse to reach the surface [11, 12].

In this study, therefore, the drying characteristics of solar tunnel and rack dried *Omena* and *Kimarawali* were evaluated. Organolaptic quality was also evaluated for salted spiced dried *Kimarawali*.

MATERIALS AND METHODS

Rack Dryer

The traditional rack dryer was constructed with some modifications [3]. The rack was 10 m long, 1 m wide and 1 m high and was made from mangrove poles that provided the support frame. The top was covered by a layer of nylon manila mesh size 1.2 mm. The nylon manila stretched from end to end not allowing sagging when fish was placed, owing to the inter-linked mangrove support structure below it. The mesh was chosen because it does not rust and is therefore ideal for use by the sea (Figure 1).

Figure 1: Fish on rack dryer in Gazi, South coast of Kenya

Solar Tunnel Dryer

The solar tunnel dryer was constructed with modifications [7, 13]. The dryer was designed and fabricated at Jomo Kenyatta University of Agriculture and Technology (JKUAT) in consultation with Kenya Marine and Fisheries Research Institute (KMFRI). It had 3 main components namely solar collector, drying chamber and power system (Figure 2).

Figure 2: The solar tunnel dryer in Gazi, South coast of Kenya

Site selection

This was a community based project. The site selected was in Gazi area of South coast of Kenya. The area was chosen because the community there had accepted implementation of the project. Gazi is set on a mangrove filled bay just off the road going South Coast, about 50km from Mombasa town and lies 4^{o}25', 39^{o}30'E. It is in Kwale district of the Coast Province of Kenya and the area has typical coastal weather.

Sample Preparation

Freshly harvested *Omena* were purchased in Kusa beach of Nyakach division in Kisumu District and iced upstream by specially hired fishermen. They were given two ice boxes (*Coleman*) of 100 litre capacity. One ice box contained crushed ice used for icing the fish upon fresh hauling from water. During icing, a thin layer of ice was laid at the bottom of the ice box followed by fish and finally an ice layer at the top. The ice boxes with fish were then sealed. The fish were transported for about 13 hours from Lake Victoria for solar drying at Gazi.

Freshly harvested *Kimarawali* were purchased at Jasini village in Vanga. They were iced and transported for about 2 hours by road to Gazi. A total of 50 kg of fish was preserved in each of the ice boxes.

The fish was washed in freshwater to remove dirt and drained in baskets, then transferred to the solar tunnel dryer and drying rack. About 48kg each of *Omena* and *Kimarawali* were used for the experiment. Both were divided into 3 parts of 16 kg each. One part of each fish was immersed in 2% brine solution for 10 minutes (Salted *Omena* or Salted *Kimarawali*). The second part of similar weight was placed in a solution containing 2% salt and 0.5% hot pepper (Salted Spiced *Omena* and

AJFAND ONLINE
Volume 10 No. 8
August 2010
ISSN 1684 5374
Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

Kimarawali) and treated the same way as the first sample. The third batch was only washed once more in water (Unsalted *Omena* and *Kimarawali*).

Solar Drying of Fish

The drying characteristics were determined with some modifications [13]. The average wet weight of *Kimarawali* and *Omema* was 3.5 g ±1.3. All the 3 batches were removed from the respective solutions and spread in clearly demarcated areas on wire mesh trays to remove excess water. Only a few batches were selected because of the many samples. The selected batches were Rack Unsalted *Omena*, Tunnel Unsalted *Omena* (RUO, TUO); Rack Unsalted *Kimarawali,* Tunnel Unsalted *Kimarawali* (RUK, TUK). They were placed on clearly demarcated areas in the drying rack and the tunnel dryer and labeled clearly. Salted Spiced Tunnel Dried *Kimarawali* (TSSK) was also selected but used for organoleptic comparisons only.

From each selected batch of fish being dried, 6 fishes were taken at random and their weight determined at the start of drying. Weight loss, drying air temperature and humidity inside the drying cabinet and ambient were measured after every 2 hours. Temperature and humidity during drying was measured using a DICKSON TH300 (USA) and weight using an electronic SALT PETER field balance (SALTPETERSK 2000-BLACK & DECKER, USA). On day 1, measurements were taken from 13.00 hr to 17.00 hr and from 08.00 hr to 16.00 hr on day 2. The fishes were left in the dryer overnight and the first reading taken at 08.00 hrs. The fish in the drying rack were kept inside overnight and returned to the rack at 06.00 hr the following day. The measurements were stopped when constant weight was observed in 3 consecutive weighings. At every weighing time, the weighed fish were removed and wrapped in aluminium foil, placed in polythene bags, labelled clearly and transported to KMFRI where they were placed in a freezer for moisture analysis. The data collected was used to plot graphs of moisture content (kg/kg wb) and moisture ratio against drying time [13]. The inlet and outlet dryer fans in the solar tunnel dryer were turned on during drying on day 1 as the weather was occasionally damp.

Moisture content was determined and expressed as dry basis moisture content using equation 1, where M is moisture content (kg/kg, db), W_t is weight of wet sample and W_d weight of dry sample [13, 14].

$$M = \frac{W_t - W_d}{W_d} \qquad (1)$$

Based on the Newton model of thin layer drying for material drying under varying relative humidity as in solar drying, the moisture ratio equation can be expressed as equation 2 where MR is the moisture ratio (dimensionless), M_0 is the initial moisture content (kg/kg, db), k is the drying rate constant (per hour) and t is the drying time (hour) [15,16,17].

$$MR = \frac{M}{M_0} = \exp(-kt) \qquad (2)$$

Published by African Scholarly Science Communications Trust
Josem Trust Place, Bunyala Road, Upper Hill, Nairobi
P.O. Box 29086-00625 Tel: +254-20-2351785 Fax: +254-20-4444030, Nairobi, KENYA
Email: oniango@iconnect.co.ke OR info@ajfand.net www.ajfand.net

AJFAND ONLINE
Volume 10 No. 8
August 2010
ISSN 1684 5374
Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

Sensory Evaluation

This was carried out with some modifications [18]. The semi-trained panelists were drawn from KMFRI staff. The organoleptic parameters that were evaluated included appearance, taste and texture with provision for a score on overall acceptability. A hedonic scale with scores of 1-5 (1=lowest acceptability and 5= highest acceptability) for various attributes was used. A score below 2 was considered not acceptable. The fish samples were coded with numbers of 2 digits indicating no information about the sample detail to avoid bias in preferred treatments.

Analysis of variance (ANOVA) was carried out on the data obtained using statistical program NCSS 2000 (NCSS, Utah, USA) and significance level set at 0.05 (=0.05).

RESULTS

Drying Characteristics

The drying characteristics were as shown in Figures 3 -5 and the drying equations are shown in Table 1. The variation of moisture content with time for *Omena* and *Kimarawali* drying in the solar tunnel and rack dryer are shown in Figure 3. The moisture ratio curves for *Omena* and *Kimarawali* dried in the solar tunnel dryer and on the rack are presented in Figure 4. The change in the natural log of moisture ratio versus time for the solar tunnel and rack drying of the fish is presented in Figure 5. Moisture dropped from 2.71 kg/kg db (73.0% wb) for TUO and RUO to 0.145 kg/kg db (12.7% wb) for TUO and 0.137 kg/kg db (12.1% wb) for RUO; from 2.417 kg/kg db (70.7% wb) to 0.163 kg/kg db (14.0% wb) for RUK and 2.549 kg/kg db (71.7% wb) when fresh to 0.161 kg/kg db (13.9% wb) after 14hrs of drying for TUK.

The moisture content of TUO, RUO, RUK and TUK after 8 hrs was 0.170 kg/kg db (14.8% wb) for TUO, 0.230 kg/kg db (18.6% wb) for RUO, 0.230 kg/kg db (19.5% wb) for RUK and 0.180 kg/kg db (15.1% wb) for TUK.

Published by African Scholarly Science Communications Trust
Josem Trust Place, Bunyala Road, Upper Hill, Nairobi
P.O. Box 29086-00625 Tel: +254-20-2351785 Fax: +254-20-4444030, Nairobi, KENYA
Email: oniango@iconnect.co.ke OR info@ajfand.net www.ajfand.net

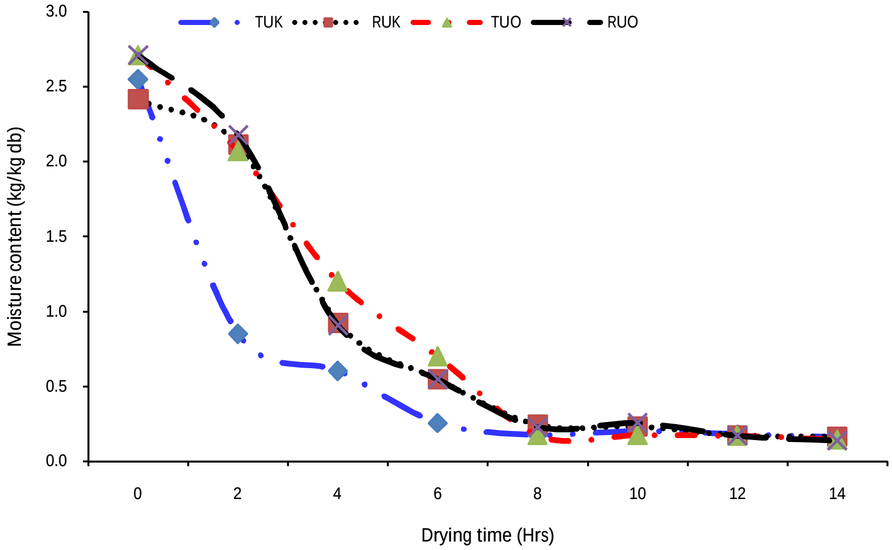

Figure 3: Variation of moisture content with drying time

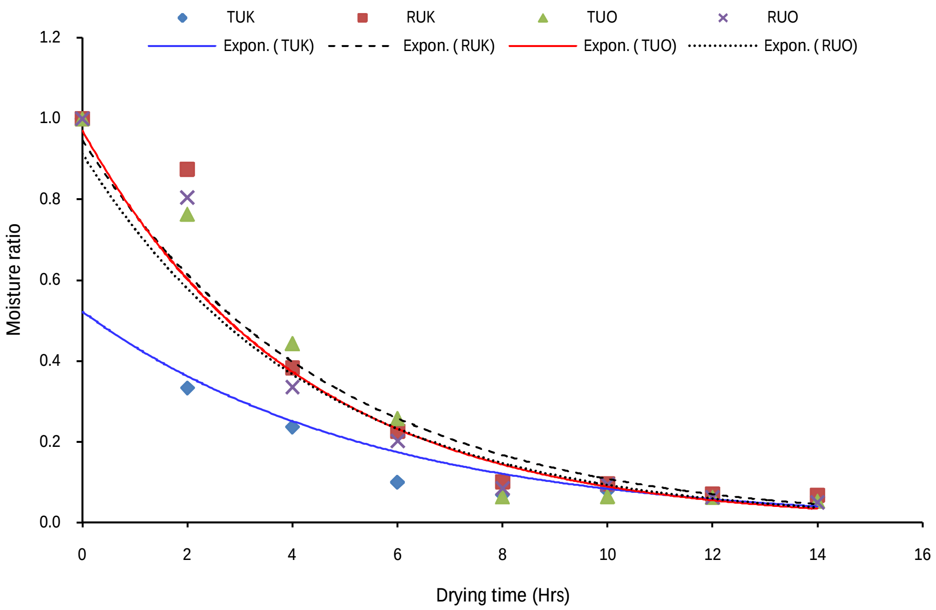

Figure 4: Variation of moisture ratio with drying time

AJFAND ONLINE
Volume 10 No. 8
August 2010
ISSN 1684 5374
Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

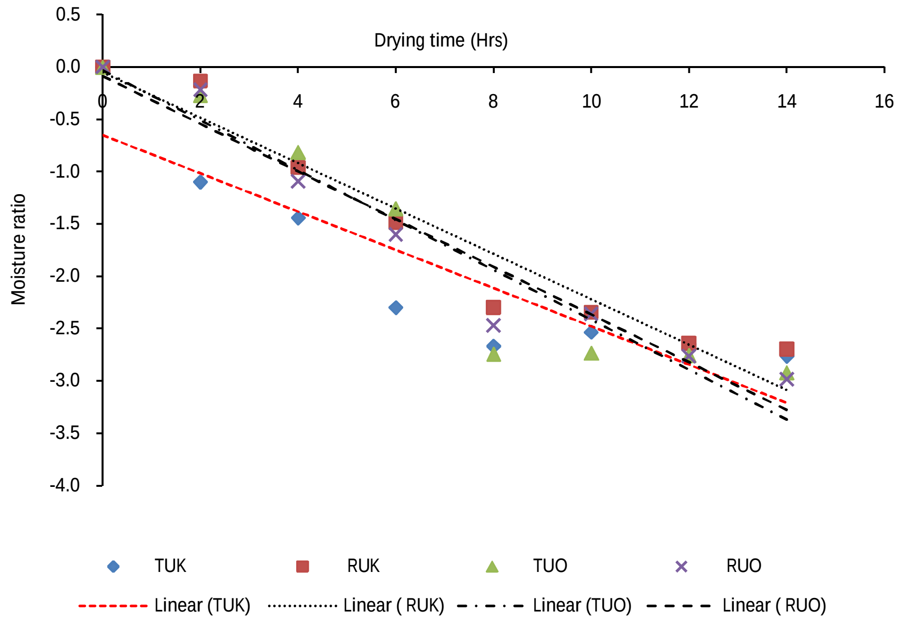

Figure 5: Natural log moisture ratio drying curves

For *Omena* dried in the solar tunnel dryer and drying rack (TUO and RUO) the drying rate constant was 0.23 and 0.22 respectively and the coefficient of determination (R^2) was 0.899 for TUO and 0.94 for RUO. The drying rate constant for *Kimarawali* dried under similar conditions was 0.18 and 0.21 for TUK and RUK respectively with R^2 values of 0.814 and 0.932. The slopes of the drying equations were –0.238 and -0.227 for TUO and RUO respectively with coefficient of determination (R^2) of 0.899 and 0.814 respectively. For TUK and RUK the slopes were -0.182 and -0.216 respectively. The coefficients of determination (R^2) were 0.814 and 0.932 respectively. There were no significant differences (p>0.05) in drying rate during drying after 14 hours of drying.

Humidity and temperature during drying are as shown in Figure 6. The mean temperature in the solar tunnel dryer (SD) and drying rack (DR) (in parentheses) during the first 8hrs in degrees Celsius was 36.62 ±8.39 (31.84±3.33) and 46.2±9.0 (32.7±1.80) in the last 6 hrs. The mean drying temperature in the 14 hr period was 40.2±9.42 (32.1±2.72). The mean humidity in the solar tunnel dryer and drying rack (in parentheses) during the first 8hrs was 61.58% ±18.41 (75.22%±14.35 and 40.7%±9.80 (61.5%±6.6) in the last 6 hrs. The mean humidity in the 14 hr period was 53.7%±20.3 (70.1%±2.7). Humidity in the drying rack was always higher.

AJFAND ONLINE
Volume 10 No. 8
August 2010
ISSN 1684 5374
Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

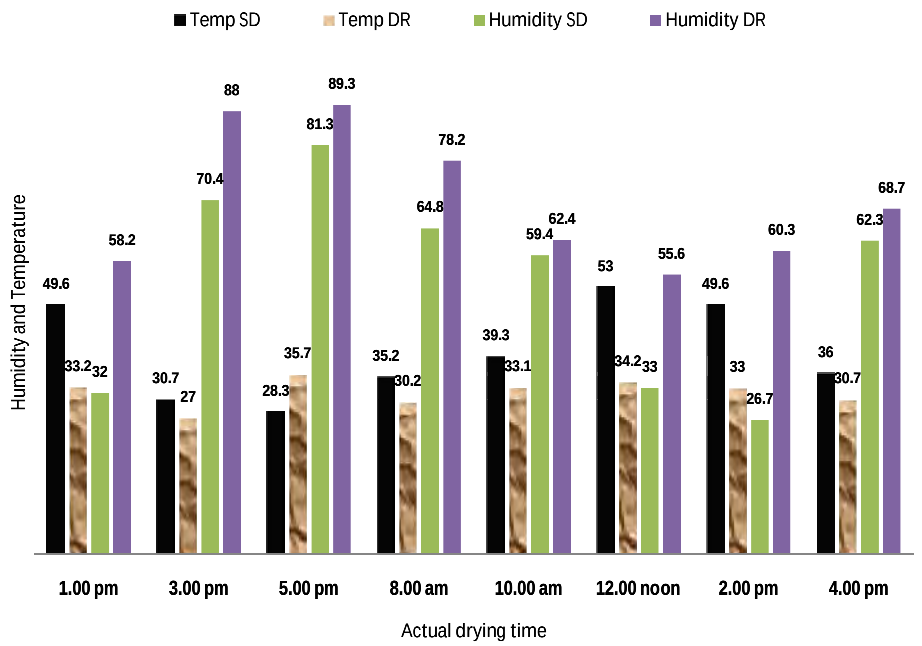

Figure 6: Humidity and Temperature variation during tunnel and rack drying of fish

Sensory evaluation

Data for sensory evaluation is reported for RUK and TSSK to compare unsalted rack dried *Kimarawali* with salted spiced solar dried *Kimarawali*. Organoleptic scores shown in Table 2 for RUK and TSSK indicated that there was no significant difference (p>0.05) by pairwise comparison between sample groups with regards to attributes appearance, taste, texture and overall acceptability.

DISCUSSION

There is a reduction in moisture content with time for both types of drying enviroments.More rapid drying took place in the first 8 hours (Figures 3-5). Drying rate is a function of air velocity, air humidity, temperature, product surface area, amount of heat transferred from air to product per unit of time and other variables like heat flow to the product [10,11,12,19]. The predominant factor that contributes to drying is heat,which causes evaporation of water from the fish,while the contribution of air in drying is effective when the moisture is at the surface [10,11,12,19].*Omena* and *Kimarawali* drying whether in the drying rack or solar tunnel dryer fell in both the constant rate and falling rate period. The constant rate drying period was in the first 8 hours of drying and the falling rate period was after the 8th hour till the 14th hour (Figures 3-5). The moisture loss during the first 8 hours of drying was from 2.709 db (73.0% wb) to 0.173 db (14.8% wb) in TUO and 2.709 (73.0%) to 0.228 (18.6%) in RUO. In RUK it was from 2.417 db (70.7% wb) to 0.242 db (19.5% wb) and from 2.549 (71.7%) to 0.177 (15.1%) in TUK. The final moisture in the solar and rack

Published by African Scholarly Science Communications Trust
Josem Trust Place, Bunyala Road, Upper Hill, Nairobi
P.O. Box 29086-00625 Tel: +254-20-2351785 Fax: +254-20-4444030, Nairobi, KENYA
Email: oniango@iconnect.co.ke OR info@ajfand.net www.ajfand.net

dried *Omena* after 14 hrs of drying was 0.145 db (12.7% wb) and 0.137 db (12.1% wb) while for *Kimarawali* it was 0.161 db (13.90 %) and 0.163 db (14.0%) respectively. Fresh fish typically contain 75 to 85% water. Most spoilage bacteria cease growth below 25% moisture level and moulds rarely grow below 15% moisture content [7,19]. The solar tunnel dryer, therefore, dried the fish to the required 15% moisture level unsuitable for mould growth within 8 hours of drying. The mean temperature in the solar tunnel dryer and drying rack during the constant rate period was 36.62°C±8.39 and 31.84°C±3.33 respectively and the mean humidity was 61.58% ±18.41and 75.22%±14.35 respectively. The mean temperature in the solar tunnel dryer and drying rack was 46.2±8.99 and 32.66±1.78 respectively while the mean humidity in the solar tunnel dryer and drying rack was 40.66%±18.99 and 61.53%±6.63 during the falling rate period. During this period, water is transferred by diffusion from the muscle interior to the surface before it can evaporate. Diffusion rate is a function of product structure, temperature, diffusion path length and other variables and the moisture loss in this period could be explained in this study as due to any of these factors [10,11,15,19]. The slow decreasing rate of drying at least partially is due to the fact that the dryer the product, the further the water must diffuse to reach the surface. In the 14 hour period the mean temperature was 40.21±9.42 in the dryer and 32.14±2.71 in the rack. The mean humidity in the 14 hr period was 53.73%±20.34 in the dryer and 70.08%±2.72 in the drying rack. Similar results have been reported [11,12].

Such high values of humidity in the ambient air surrounding the drying rack suggested that its role was minimal in influencing drying rate because humidity influences drying rate by limiting the amount of water the air can absorb [19].

The effects of temperature on drying rate result from the effect of temperature on heat transfer and effect of temperature on relative humidity. The temperature difference in the drying rack and solar tunnel dryer was not significant during the first 8 hrs of drying though both temperatures were high enough to cause drying of the fish in both the dryer and the rack. The mean temperatures were 36.8°C and 31.8°C which had been used in drying fish that are even bigger than *Omena* and *Kimarawali* [20].

Dryers that give better drying rates have lower humidity and higher temperatures inside the drying units [21]. Drying temperatures of 50°C and humidity up to 50% have been considered ideal in the drying of fish [7]. These conditions however do not consider small fish like *Omena* and *Kimarawali* whose surface area to body ratios are high and thus with faster drying rates at the lower temperatures experienced in this study. Thinner or smaller fish would normally dry faster than bigger or thicker ones. The surface area to volume ratio of smaller fish is normally higher resulting in faster drying rates [22].

It can be postulated that the faster drying rate of the fish in the first 8 hours in the solar tunnel dryer compared to the drying rack was due to higher temperatures maintained inside the solar tunnel dryer as a result of solar insolation on the collector. This is followed by subsequent transfer of the heated air by forced convection over the fish coupled with direct radiation into the cabinet dryer. Lower humidity and the high surface area volume ratio of the fish were also responsible. The equally high ambient temperature surrounding the rack and the high surface area to volume ratio of *Omena* and *Kimarawali* was responsible for the relatively fast drying of *Omena* and *Kimarawali* in the drying rack.

The rack was located by the sea side where wind is strong. The sea side wind increased the drying rate by removing more surface moisture and creating room for more moisture migration to the surface. However, the drying potential still needed to be increased by heat, which for purposes of drying *Omena* and *Kimarawali* which are small in size, was high enough, hence the relatively faster drying or weight loss in the drying rack. Although wind alone can cause surface drying and might not influence the internal water content of the fish significantly, the rapid drying rate is because air currents at the height of the raised rack are strong and pass freely over and below the fish, picking any available moisture, thereby increasing moisture migration to the surface of the fish [3].

Fish drying contributes towards fish preservation by dehydrating the fish. Flavour, odour and taste in fish are influenced by different extractives [23,24,25,26,27]. *Kimarawali* is only washed and sun dried on the ground or on mats at the coast. Salted spiced solar dried *Kimarawali* would provide a new value added product. The organoleptic scores for unsalted rack dried *Kimarawali* and salted spiced solar dried *Kimarawali* as shown in table 5 indicated that the scores for appearance, taste, texture though not significantly different were above 3 and fell in the range for accepted products. The scores for overall acceptability for unsalted rack dried *Kimarawali* was 2.8 while that for salted spiced solar dried was 3.5 showing a better preference for the value added *Kimarawali* product.

Rack drying, salting and spicing provide a new product which is more hygienically dried by avoiding sand on the ground or dried enclosed in a solar drier and spiced and salted to enhance flavor and taste. Consumers prefer taste and appearance and in this case the scores for taste and appearance were high suggesting that salted spiced solar dried Kimarawali is an acceptable product. The score for taste was 3.8 against 3.1 for the unsalted one. The preference was confirmed further by scores for overall acceptability which were also high at 3.5.

Findings where enclosed solar dryers have given superior quality have been reported [11,12,28]. If a value added fish product can have high scores during organoleptic assessment then the possibility of acceptance of the products in the market is there.

The lack of significant difference in the overall acceptability score could provide need for further work to optimize the concentration of salt and spices required to produce the desirable effect.

CONCLUSIONS

The solar tunnel dryer dries fish to the desired moisture content much faster than the rack dryer, and therefore saves time. Rack drying which involved bringing in the fish every evening was labour intensive. With the rack dryer placed by the sea and with strong wind value, drying can be as competitive as in the solar tunnel dryer for small fishes like ***Omena*** and ***Kimarawali*** with high surface area to volume ratios. Introduction of spiced salted ***Kimarawali*** has chances of acceptability as a new product. Production conditions need to be optimized further. Value added ***Kimarawali*** products can later be produced on a larger scale since they are acceptable. The rack dryers can be introduced in areas where small fishes are landed and where wind value is strong.

ACKNOWLEDGMENT

The authors would like to thank the Lake Victoria Research Initiative (VicRes) and Lighthouse Foundation (Germany) for funding, the Director Kenya Marine Fisheries Research Institute (KMFRI), Jomo Kenyatta University of Agriculture and Technology (JKUAT) for technical support, Cyprian Odoli for data analysis, Maurice Omega for technical assistance, ***Mpaaji ni Mungu*** Women Group in Gazi and Mzee Rashid of Jasini Vanga for their time input during the project.

AJFAND ONLINE
Volume 10 No. 8
August 2010
ISSN 1684 5374
Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

Table 1: Moisture ratio constants, coefficients and slopes during drying of unsalted fish

	Drying rate constants K (hr^{-1})	Coefficient of determination (R^2)	Ln moisture ratio slopes	Coefficient of determination (R^2)
TUO	0.23	0.899	-0.238	0.899
RUO	0.22	0.940	-0.227	0.941
TUK	0.18	0.814	-0.182	0.814
RUN	0.21	0.932	-0.216	0.932

Table 2: Appearance, taste, texture and overall acceptability of unsalted rack dried and salted spiced solar dried Kimarawali (n=9)

	Attributes			
Treatment	**Appearance**	**Taste**	**Texture**	**Overall acceptability**
RUK	3.8	3.1	3.3	2.8
TSSK	3.5	3.8	3.0	3.5
p-value	0.552	0.119	0.632	0.21

Published by African Scholarly Science Communications Trust
Josem Trust Place, Bunyala Road, Upper Hill, Nairobi
P.O. Box 29086-00625 Tel: +254-20-2351785 Fax: +254-20-4444030, Nairobi, KENYA
Email: oniango@iconnect.co.ke OR info@ajfand.net www.ajfand.net

REFERENCES

1. **FAO.** Fishery country profile: Republic of Kenya. FID/CP/KEN FAO, Rome, 2007.

2. Fisheries Annual Report. Department of Fisheries, Ministry of Livestock and Fisheries. Kenya, 2004.

3. **Chamberlain T and G Titili** *Seafood Processing*. Community Fisheries Training USP Marine Studies Programme, Pacific Series **6**: 2001.

4. **USAID.** Rack drying technology expands in Suba District. Kenya business development service program-monthly newsletter July/August 2006: http://www.kenyabds.com.

5. **Aguilo PL, Esperence A, Mbau E, Palmer P, Patel A** and **T Sparkman** Attracting investment to Kisumu: Opportunities and Challenges. Report Prepared for Earth Institute, Millenium Cities Initiative, Columbia University, 2007.

6. **Oduor-Odote PM** Comparative drying performance of Mackerel (*Rastrelliger kanagurta*) in a solar tunnel dryer and an open-air raised drying rack. A Performance Contract Technical report-Kenya Marine and Fisheries Research Institute. Submitted to Ministry of Fisheries Development, 2009.

7. **Bala BK** and **MRA Mondol** Experimental investigation on solar drying of fish using solar tunnel dryer Drying Technology 2001; **19** (2): 427-436.

8. **Bille GP** and **HR Shemkai** Process development, nutrition and sensory characteristics of spiced smoked and sun dried Dagaa (*Rastrineobola argentea*) from Lake Victoria, Tanzania. African Journal of Food Agriculture Nutrition and Development, 2006; Vol **6** No. 2.

9. **Negbenebor CA, Adetunji IS** and **JO Igene** The effect of clove and ginger dip on quality of solar tent dried *Clarias anguilaris*. 7th FAO Expert Consultation on Fish Technology in Africa. Saly-Mbour-Senegal. FAO Fisheries Report No. **712**: 69-72, 2001.

10. **Potdukhe PA** and **SB Thombre** Development of a new type of solar dryer: Its mathematical modelling and experimental evaluation. Short communication. International Journal of Energy Research, 2008; **32**: 765-782.

11. **Reza S, Bapary AJ** and **N Islam** Optimization of marine fish drying using a solar tunnel dryer. Journal of Food Processing and Preservation, 2009; **33:** 47-59.

12. **Chavan BR, Yakupitiyage A, Kumar S and SK Rakshit** Experimental investigation on biochemical, microbial and sensory properties of Mackerel (*Rastrilliger kangurta*) dried by solar-biomass hybrid cabinet dryer. Journal of Food Agriculture and Environment 2008; **6 (3&4)**: 167-171.

13. **Kituu GM, Shitanda D, Kamali CL Mailutha JT, Njoronge CK, Wainaina JK and PM Oduor-Odote** Influence of brining on the drying parameters of Tilapia (*Oreochromis niloticus*) in a glass-covered solar tunnel dryer. Agricultural Engineering International, The CIGR E-Journal 2009; Vol **XI:** Manuscript number EE 1349.

14. **AOAC.** Official Methods of Analysis of the Association of Official Analytical Chemists International. Airlington, USA. 1990.

15. **Rafiee SH, Keyhani A, Sharifi A, Jafari H, Mobli H and A Tatabaeefar** Thin layer drying properties of soybean (*Viliamz Cultivar*). Journal of Agriculture Science and Technology 2009; Vol **11**: 289-300.

16. **Kingsly RP, Goyal RK, Manikantau MR and SM Ilyas** Effects of pre-treatments and drying air temperature on drying behaviour of peach slices. International Journal of Food Science and Technology 2007; No **42**: 65-69.

17. **Uluko H, Kanali CL, Mailutha JT and D Shitanda** A finite element model for the analysis of temperature and moisture distribution in a solar grain dryer. The Kenya Journal of Mechanical Engineering 2006; **2 (2)**: 47-56.

18. **Oduor-Odote PM and M Obiero** Lipid oxidation and organoleptic response during shelf storage of some smoked marine fish in Kenya. African Journal of Food Agriculture and Nutrition 2009; **9**: 3.

19. **Wheaton FW and TB Lawson** Processing Aquatic Food Products. John Wiley and Sons, New York, 1985.

20. **Olgun H and S Kose** Solar drying of rainbow Trout. International Journal of Energy Research 1999; **23**: 941-948.

21. **Sablani SS, Rahman MS, Haffar Mahgoub IO, Al-Marzouki AS, Ruzeiqi MH, Al- Habsi and RH Al-Belushi** Drying rates and quality parameters of sardines processed using solar dryers. Agricultural and Marine Sciences 2003; **8 (2)**: 79-86.

22. **Mujaffar S and CK Sankat** The air drying behavior of shark fillets. Canadian Biosystems Engineering 2005; **47 (3)**: 11-21.

23. **Chung YH, Yeung WC, Kim JS and F Chen** Static Headspace analysis-olfactometry (SHA-O) of odour impact components in salted-dried white herring (*Ilisha elongata*). Food Chemistry 2007; **104:** 842-851.

24. **Guillén MD, Errecalde MC, Salmeron J** and **C Casas** Headspace volatile components of smoked swordfish (*Xiphias gladius*) and cod (*Gadus morhua*) detected by means of solid phase microextraction and gas chromatography-mass spectrometry. Food Chemistry 2006; **94**: 151-156.

25. **Hwang DF, Chyuan-Yuan Shiau TC** and **S Jeng** Seasonal variations of free amino acids and nucleotide related compounds in the muscle of cultured Taiwanese puffer *Takifugu rubripes*. Fisheries Science 2000; **66**: 1123-1129.

26. **Murray J** and **JR Burt** The composition of fish. Torry Advisory Note No ***38,*** 2001.

27. **Huss HH** Quality and Quality Changes in Fresh Fish. FAO Fisheries Technical Paper No **348**, 1995.

28. **Oyero JO, Sadiku SOE, Ajisegiri ESA** and **AA Eyo** Biochemical evaluation of enclosed solar dried and salted *Oriechromis niloticus* Research Journal of Animal Sciences 2007; **1** (3):97-101.