Comparative Analysis of Physical Post-harvest Losses of *Rastrineobola argentae* Dried using Various Drying Methods along Lake Victoria, Tanzania

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Abstract

Rastrineobola argentae (Dagaa) has been the major commercial fishery of Lake Victoria contributing 67.4 % of total fish catch. In Tanzania it constitutes over 38% of the total fish landings from the Lake. However, there is a high level of post-harvest loss of about 59%. To minimize the losses, various post-harvest innovations processing methods have been developed in previous studies, but still there is limited empirical evidences showing the effectiveness of these innovations to justify their adoption. In the present study, a completely randomised experimental design was conducted to determine the effect of three drying methods of dagaa namely, solar tent, bare sand, and raised racks in reduction of physical post-harvest losses of dagaa in Mwanza, Lake Victoria. Data were collected by simple random sampling of dagaa from boats, key informant interviews and desk review of secondary data. The results showed that solar tent reduced post-harvest losses up to 24.9% compared to raised racks (14.9%) and bare sand (10%). The results showed significance differences (p<0.00), whereby the differences were noted between solar tent with raised racks (p=0.02) and between solar tents with bare sand (p=0.00) only. Based on the findings the study recommends that solar tent innovation should be promoted to commercial scale to contribute in reducing dagaa post-harvest losses. The reduction of post-harvest losses implies more quantities of dagaa will be available for nutrition and income.

Keywords: Resource Poor producers, processors, quality, quantity, *Rastrineobola argentae*

Introduction

In the fisheries sector post-harvest losses are a major concern and occur in most fish distribution chains throughout the world. In response to this situation the field activities within the regional post-harvest loss assessment programme in small-scale fisheries in Africa (FAO regular programme conducted from 2006 to 2008) tested and validated three key fish loss assessment methodologies that have been developed over the past two decades: the Informal Fish Loss Assessment Method (IFLAM), Load Tracking (LT), and the Questionnaire Loss Assessment Method (QLAM) (Ward *et al.,* 2000; FAO, 2011). While the IFLAM is used to generate qualitative and indicative quantitative post-harvest fish loss data that can be used to inform decision-making or to plan the use of LT and the QLAM, the latter are quantitative assessment methods.

Load tracking is used to quantify losses at stages along the distribution chain or losses related to specific activities, such as fishing, transport, processing and marketing. Key data related to the cause and effects of losses from an IFLAM study are validated using the QLAM before any suitable intervention is introduced (FAO, 2011). A combination of the IFLAM, LT and QLAM could then be used to monitor and evaluate the effects of an intervention. These methods have been used in Gambia, Ghana, Kenya, Malawi, Mali, Nigeria, Senegal, Uganda and United Republic of Tanzania in Africa as well as in several Asian countries. The methods are seen as practical ways of investigating, understanding and measuring fish loss. They help to identify significant losses affecting Small scale fisheries operators and set the scene for interventions to reduce the losses (FAO, 2011).

The IFLAM tries to utilize local knowledge and understand local situations, and in this case, it generates a good general understanding of post-harvest fish Losses. The IFLAM relies on the active involvement and participation of fishery operators and others knowledgeable about the post-harvest sector and fish losses (Ward *et al.,* 2000; FAO, 2011). The method helps to develop a qualitative understanding of losses and provides indicative quantitative data on post-harvest fish losses (PHFLs). It is especially good for understanding the type of losses, trends and seasonal variations in loss levels; causes of loss; variables that affect losses such as fishing gear type and processing method; stakeholders affected by losses, and how they are affected; perceptions of stakeholders about losses; ideas for loss reduction; initiatives being taken to reduce losses; important institutions involved in loss assessment research and reduction. The IFLAM also consists of several key elements including a review of secondary data, field observation, semi-structured interviews, flow diagrams, and key-informant interviews.

The Questionnaire Loss Assessment Method (QLAM) is a formal questionnaire survey approach used to quantify and validate key loss data. The method relies on the administration of questionnaires that focus on information generated by the IFLAM and LT. The QLAM can help determine how representative data are over a wide geographical area or across different communities or locations (Ward *et al.,* 2000; FAO, 2011). The QLAM helps generate statistically valid data on the following: type of loss; reasons for loss; frequency of loss; variables that affect losses, such as fishing gear type, seasonality, livelihood activities and profile of those affected by fish loss. Generally, the QLAM is used to validate or cross-check data obtained from the IFLAM and LT. Typical objectives for QLAM include validation of qualitative data on losses incurred by fishermen, processors and traders, in particular geographical area; quantification of key data on the causes of losses associated with a particular fishery in a geographical area (Ward *et al.,* 2000).

While the Informal Fish Loss Assessment Method (IFLAM) provides an understanding of key losses, load tracking (LT) is a method that is used to measure specific losses. It is typically used to measure losses during fishing, processing, transportation or marketing. The present study focused on the Load tracking method for assessment of *dagaa* post-harvest losses. The method relies on evaluating the quality and/or weight of a sample of fish as it moves through a supply chain under conditions that are as near as possible to the same as "normal" practice (Ward *et al.,* 2000; FAO, 2011).

In summary, LT can be used for assessing how fish quality and/or quantity can change within a distribution chain; identifying why and where losses occur; estimating the value of losses in monetary terms; measuring the effect of interventions to reduce losses. The objective of LT can be derived from IFLAM findings and it must be desirable and achievable. For example: to quantify the physical and quality fish losses of fish species X along the distribution chain Y; to quantify the physical losses during packaging and transportation of sundried sardine; to measure the physical losses during the processing stage (FAO, 2011, Ibengwe *et al.,* 2012). In the present study the Load Tracking method was used to assess the physical post-harvest losses of *dagaa* at the processing stage at New Igombe beach in Lake Victoria, Tanzania. The performance of three drying methods namely solar tent, raised racks and bare sand in reduction of moisture contents and post-harvest loss were assessed.

Materials and Methods

Location of the study area

The study was conducted at New Igombe beach located in Mwanza city along Lake Victoria. Mwanza city lies at an altitude of 1,140 metres above sea level with mean temperature ranging between 25.7^{o}C and 30.2^{o}C in hot season and 15.4^{o}C and 18.6^{o}C in the cooler months. The city also experiences the average annual rainfalls between 700mm and 1000mm (MCC, 2016). The majority of the residents (64.8%) in Mwanza region are informally employed in

Agriculture sector.

Experimental design

The *dagaa* drying experiment was conducted at New Igombe landing site which is located in Bugogwa ward of Ilemela municipality (Fig. 1) in the city. The landing site is about 17.2 km away from Mwanza city centre towards the North. The location of the experiment was randomly selected from the two major *dagaa* landing sites of Kayenze and New Igombe (Luomba, 2013; Kashindye, 2015). Other *dagaa* landing sites in Mwanza city include Kabangaja, Bwiru, Nyegezi, and Miama. The selection was done by first writing names of the landing sites on pieces of paper, thereafter the pieces of paper were folded and mixed up, and finally one folded piece of paper was picked up and unfolded to read what appeared on it and was picked as a study landing site. The reconnaissance survey also provided information that helped to identify appropriate sources for collection of secondary data, particularly data on *dagaa* market information and identification of appropriate key informants for interviews.

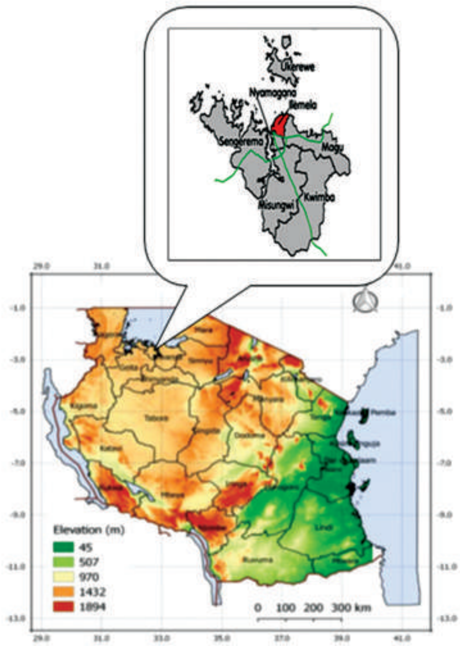

Figure 1: The map of Tanzania showing location of Ilemela municipality
Source: URTb (2017)

A completely randomized (CRD) experimental design (Casella, 2008; Bowerman *et al.,* 2011; GSARS, 2018) and key informant interviews were employed (Bon *et al.,* 2017; Young *et al.,* 2017). The CRD experimental design was represented by the model given by

$Y_{ij} = \mu + T_i + e_{ij}$, where:
Y_{ij} = observation j for treatment i,
μ = The overall mean,
T_i = The treatment effect, and
e_{ij} = The error term.

Prior to the experiment a reconnaissance survey was conducted to collect information from various stakeholders in the city. These stakeholders included *dagaa* processors at landing sites, alliances of fish traders, and the Kirumba International Fish Market administration. Others were the National Fish Quality control laboratory for Lake Zone, Municipal Fisheries Office and Beach Management Units at landing sites in Ilemela municipal. The data collected include *dagaa* processing environment and major drying methods.

The experimental set up for *dagaa* drying

The fish samples for the experiments was a batch of 2kg of fresh *dagaa* with individual lengths ranging from 3.6±0.5 cm to 5.8±0.6 cm. Measurements of lengths were taken by using a common 30 cm plastic ruler. The experimental set up comprised of three treatments/drying methods namely; solar tent (Plates 1a and 1b), raised racks (Plate 2a) and bare sand (Plate 2b). Each treatment was replicated nine times. The bare sand drying method was the control treatment.

The dimensions of the drying racks used in the solar tent (Plate 1a) were 1m x 0.5m x 1.5m (length x width x height). The dimensions of drying racks used outside the tent were 1.5m x 1m x 0.9m (length x width x height). Lastly the dimensions of the drying sand plots were 1.5m x 1m (length x width).

The solar tent dryer (Plate 1a and 1b) consisted of a transparent plastic polyethene sheet with a thickness of 200µm stretched over a wooden house-like frame work with the dimensions (1.5m wide by 3.5 m long by 2m high on sides and 2.4m high at the apexes). Two plastic meshed air inlets at the base from the in-blowing wind side of the tent were made with dimensions 10cm x 50cm each. On each side of the top most sides of the tent (the apex) one plastic meshed vent was made with a common size of 800cm^2 for releasing moisture from *dagaa* as adapted from Abrahah *et al.* (2017).

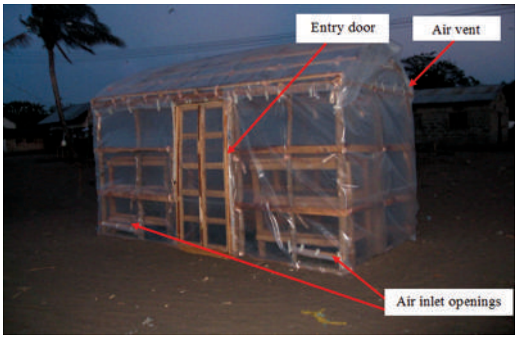

Plate 1a: The general structure of the solar tent (Front view)

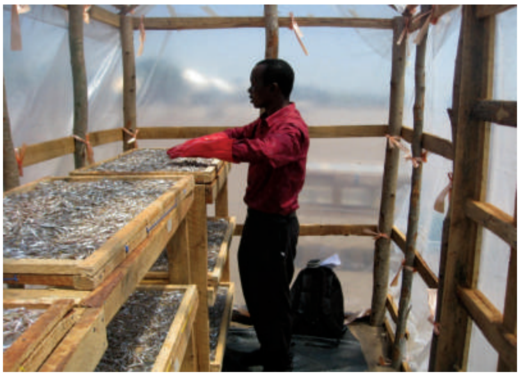

Plate 1b: Drying dagaa inside the solar tent

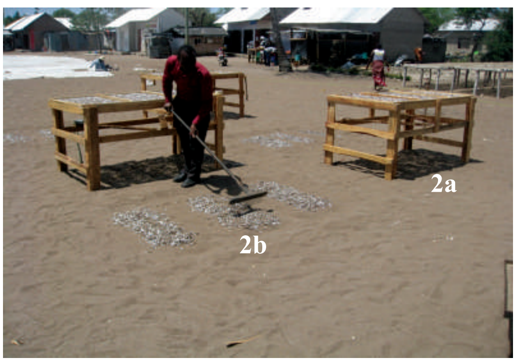

Plate 2: Drying dagaa on open raised rakes (2a) and bare sand (2b)

A 25kg spring balance Salter weighing scale of Model 235 with a resolution of 100g was used to weigh *dagaa* before and after drying and a digital camera was used for taking photos. Other materials included two pairs of plastic cushioned gloves, a black PVC carpet of size 3m x 1.5m for collecting heat from the sun inside the solar tent, 2 plastic crates with a loading capacity of 30kg for carrying *dagaa*, a plastic bucket, a plastic dish, a plastic bowl and water for washing *dagaa*, a plastic ruler, digital thermometer Model HI 98509-1 which was correct to ±0.1^{o}C, measuring a maximum of 100^{o}C.

Another material was fresh *dagaa* amounting to a total weight of 60 kg and a note book with a pen for recording. For the purpose of ensuring validity of measurements the thermometer and the weighing scales were calibrated before using them for taking measurements. The thermometer was calibrated by measuring water temperature at 100^{o}C to cross-check that it measures correctly. The weighing scale was calibrated by weighing five 1kg packets of sugar to check its correctness. Both the thermometer and the weighing scale were found to correctly measure temperature and weight respectively.

Dagaa sampling

Simple random sampling without replacement was done by selecting fishing boats containing *dagaa* for sale at New Igombe landing site. At this stage 10 boats out of 20 boats were selected when they landed on 8 August 2018 at 06.00 and 7.00 a.m. The sample size was equal to 50% of the total boats landed on site. This is in line with FAO (2002) and Taherdoost (2016) who established that a sample size of 50% is adequate to be an accurate representative of the population for small populations. The selection of boats was done by writing the boat registration numbers on 20 pieces of paper which were later on folded to hide the numbers. Thereafter the papers were mixed up and initially the first paper was picked up and unfolded to see boat number which appeared on it and it was recorded as the first choice. The remaining 19 folded papers were remixed again for making the second choice. This process was repeated until it reached ten times in order to obtain the 10 boats for sampling *dagaa*. The landing site was about 400 meters away from the experimental site.

After selecting the boats 6kg of *dagaa* were purchased from each selected boat making a total of 60kg. After the purchase, the samples were carried to the experimental site in plastic bags packed in 2 crates. Before experimentation the *dagaa* were mixed up and washed in a plastic basin with clean freshwater. After washing the *dagaa* were sieved in a sieving rack enclosed with a plastic mesh and a PVC lid for preventing contact with insects such as flies. The sieving lasted for one and a half hours i.e from 9.00 to 10.30 am. From the 60kg of *dagaa* 27 samples of fresh *dagaa* were weighed in units of 2kg each as an experimental unit.

The sample size was determined based on the framework for assessment of fish post-harvest losses which was developed by FAO in collaboration with Natural Resources Institute of Greenwich University of United Kingdom (Ward *et al.,* 2000; FAO, 2011). The framework stipulates two important conditions. The first is that the experimental unit should contain at least 5 fish. The second condition is that the sample size should result to at least two-digit degrees of freedom in the analysis of variance. This means that (n-1) should result to a minimum of 10 degrees of freedom for a meaningful statistical analysis. Therefore, for the sample size of 27 the degrees of freedom (n-1) were 26 which satisfied the condition of 2-digit degrees of freedom. For each drying treatment i.e. solar tent, raised racks and bare sand, 9 replicates of 2kg of fresh *dagaa* were made and the 2kg lot was considered as an experimental unit. So, this made a total of 18kg of fresh *dagaa* for each treatment.

The experimental units were assigned to the treatments at random for the purpose of randomising the treatments. Initially 3 experimental units were assigned to the solar tent, then 3 units to the raised racks and last 3 units to the bare sand plots. In the second time, 3units for each treatment were assigned starting from the bare sand plots, then to the raised racks and last to the solar tent. Finally, the 3 experimental units were first assigned to the raised racks, then to the solar tent and last to the bare sand plots. The allocation of the experimental units to the treatments took about 30 minutes.

Data collection from the experiment

Dagaa for all the three drying methods were dried for eleven hours that is from 11.00 am to 6.00 pm for day 1 and from 8.00 am to 12.00 noon on the second day. The data collected in the experiment were: the initial weights of 27 samples of fresh *dagaa* bought, weight of *dagaa* after drying, number of hours taken to dry *dagaa* for each drying method and temperature value inside the solar tent and outside the tent taken on an hourly basis. After field experiment 250g of *dagaa* was sub-sampled from each treatment and packed in plastic bags for moisture content testing. The samples were submitted to the National Fish Quality Control Laboratory of Mwanza.

Limitations of the Sstudy

Due to limitation of financing the study could not examine air flow rate at air inlet control points and humidity levels inside the solar tent which required anemometers and hygrometers respectively for taking measurements. Similarly, other laboratory quality tests such as the level of microbial contamination in dried *dagaa* could not be done. For the same reason the experiment could not be extended to the rainy season to examine the operational performance of the solar tent in the wet season. In order to minimise some effect of the limitations, hygiene during experiment was highly observed to reduce contamination by wearing gloves for turning *dagaa* during drying, washing the *dagaa* with clean water before the experiment, closing the solar tent door tightly soon after entry or exit of the solar tent.

In order to control humidity levels inside the solar tent fog was observed on inner walls of the tent to detect excessive humidity levels. When fog was observed more air-flow inside the tent was allowed at the air-inlet control points until the fog disappeared.

Data analysis

Descriptive statistics that includes arithmetic means and percentages of moisture content in dried *dagaa* were computed. The purpose was to check whether it could achieve the recommended moisture content level of not more than 12% as stipulated by the East African

Community Standard for *dagaa* trade (LVFO, 2016). This standard moisture content for *dagaa* limits the activity of harmful microbial organisms that cause *dagaa* post-harvest losses. The analysis was done by using SPSS software.

Analysis of variance for moisture content and post-harvest losses

Prior to conducting One-way Analysis of Variance (ANOVA), Levene's test for homogeneity of variance (Nordstokke *et al.,* 2010; Para, 2013; Kim *et al.,* 2018) was conducted as a pre-condition for analysis of variance. After the homogeneity testing, ANOVA test was conducted to evaluate the significance of using solar tent drying method for reducing *dagaa* moisture content to the optimum level.

An F-Statistic was employed to test the hypothesis that "Drying *dagaa* in solar tent leads to significantly less than 12% moisture content than drying on raised racks or bare sand". The hypothesis was tested at a probability level of p<0.05. Finally, Tukey's post-hoc analysis (Kim *et al.,* 2018) was conducted to identify the actual source of differences among the various pairs of means of moisture content. However, Kruskal-Wallis, a non-parametric test was used to test the hypothesis that "Drying *dagaa* in solar tent creates significantly less physical post-harvest losses than drying on raised racks and bare sand." The non-parametric test was used because the mean variances for post-harvest losses were found to be heterogeneous after Levene's test even after square root transformation of the original data. The test was also done at a probability level of p<0.05. Thereafter Games Howell post-hoc test was conducted to identify the pair of means that makes a difference among the various means of *dagaa* post-harvest losses. The analysis was done by using SPSS software.

Results and Discussion

Moisture content of dried *dagaa*

The minimum and maximum temperatures observed during the drying period were 35°C and 42°C inside the solar tent, 25°C and 38°C on raised racks and 33°C and 41°C on bare sand. The results showed that *dagaa* dried in solar tent had the least average moisture content followed by that dried on open raised racks and highest values was recorded in *dagaa* dried on bare sand (Table 1). There was a significant difference in moisture content among the three drying methods (F-Statistical test values p<0.05). Post-hoc comparison (Tukey's test) revealed significant difference between solar tent and raised racks and between solar tent and bare sand. However, there was no significant difference in moisture contents between raised racks and bare sand drying methods (Table 1).

Table 1: Moisture content in dagaa based on drying method

Dagaa Drying Methods	**Solar tent**	**Raised racks**	**Sand bed**
Moisture content (%)	8.3	9.7	11.1

Statistical results	**F-test at p<0.05**	**Tukey's post hoc test at p<0.05**		
		Solar tent Vs Raised Racks	Solar tent Vs Bare Sand	Raised Racks Vs Bare Sand
Significance level	0.00	0.00	0.00	0.05

The highest moisture content in *dagaa* dried on bare sand could be caused by soil particles and other contaminations from sand. These results are similar to the study conducted by Banda *et al.* (2017) around lake Nyasa in Malawi who found that moisture content was significant at (P=0.001) at 8.3±0.12% and 17.0±0.01% for solar tent dried and open sun dried *Diplotaxodon limnothrissa* respectively. Another study by

Chiwaula *et al.* (2017) also found similar trend of 7.22% moisture content for longer shelf life (from time span of 3-7weeks; to 7-16 weeks) of dried *dagaa* (*Engraulicypris sardell*).

With these results it implies that solar tent dryer is the best dryer as it dries *dagaa* to reach the moisture content of 8.3% that is below the maximum recommended moisture content limit of 12% (LVFO, 2016). The low moisture content limits potential post-harvest losses of *dagaa* due to quality deterioration in storage.

Physical Post-Harvest losses of *dagaa*

The results showed lower post-harvest loss for *dagaa* dried in solar tent compared to *dagaa* dried on raised racks and those dried on bare sand (Table 2). There were significant difference in physical post-harvest loss among the three drying methods ($p<0.05$). The differences were noted between solar tent and raised racks ($p<0.02$) and between solar tent and bare sand ($p<0.00$). However, there was no significant difference in post-harvest loss between raised racks and bare sand ($p>0.05$).

These findings showed that drying *dagaa* in solar tent reduces post-harvest losses by 24.9% compared to drying *dagaa* on raised racks 14.9 % and on bare sand 10.0%. These values are relatively higher to those reported by Chiwaula *et al.* (2017) in Malawi who found that the use of solar tent in drying *dagaa* reduced post-harvest losses by 10% in comparison with drying *dagaa* on open raised racks.

The post-harvest losses that occurred in raised racks and on bare sand methods of drying were due to *dagaa* being mainly consumed by birds and dogs during drying (Plate 3a, b) A number of birds were observed during the drying process and had to be scared to avoid the losses. For the sand dried *dagaa* another potential loss could be attributed to left overs during collecting after drying. Picking *dagaa* from bare sand was difficult and more tedious and some were left on sand especially the smaller one. The negligible percentage of post-harvest loss for *dagaa* dried in solar tent is due to the closed nature of the

Table 2: Dagaa post-harvest losses based on drying method

Dagaa Drying Methods	**Solar tent**	**Raised racks**	**Bare sand**			
Average losses in %	0.7	15.6	25.6			
Statistical result	**Kruskal-Wallis test at p<0.05**			**Games Howell test at p<0.05**		
				Solar tent Vs Raised Racks	Solar tent Vs Bare sand	Raised Racks Vs Bare sand
Significance level			0.00	0.02	0.00	0.15

Plates 3a, b. Show potential predators of dagaa dried on bare sand (Birds and dog)

solar tent prohibiting birds to get in the tent to eat the *dagaa*, hence causing the losses. Based on these results it means that solar tent is the best dryer as it showed the highest percentage of reducing post-harvest losses of 24.9% compared to drying *dagaa* on raised racks and bare sand.

Conclusions and recommendations

Conclusions

Based on the findings it is concluded that drying *dagaa* by using solar tent reduces moisture content significantly less below the maximum limit of 12% recommended by the East African Community Trade Protocol compared to drying on raised racks or bare sand. Drying *dagaa* in solar tent reduced the moisture content level in *dagaa* to 8.3%. Under the normal conventional methods of drying *dagaa* more than 30% post-harvest losses occur after poorly processing the *dagaa* which normally goes beyond the maximum limit of 12% moisture content. However, results from this study showed that the conventional methods of drying *dagaa* also achieved the recommended moisture content.

Drying *dagaa* in solar tent created significantly less physical post-harvest losses than drying on raised racks and bare sand. The reduction in post-harvest losses has an implication on availability of *dagaa* to consumers, more income to traders and more employment opportunities to fisheries related economic activities.

Recommendations

Based on the findings of this study it is recommended that solar tent should be promoted for drying *dagaa* at large scale due to its high initial capital requirement which would not be feasible for small scale *dagaa* processors. This will highly contribute to reduction of post-harvest losses of *dagaa* and ensure sustainable *dagaa* harvesting in Lake Victoria. In addition to reduction of post-harvest losses the use of solar tent reduces the problem of limited space of land at lake shores. Drying *dagaa* by using solar tent also ensures high quality of the product by limiting possible contaminations by sand, dust, insects and animals such as cats and dogs.

Promotion of the solar tent drying innovation could be done by various stakeholders who have interest in *dagaa* subsector and can capitalize on information from this study to address post-harvest losses in the fisheries industry. This will in turn make more *dagaa* available for consumption to the people of Tanzania and for export.

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