grocentre.is/ftp Final Project 2021

FEASIBILITY STUDY ON A PROPOSED SOLAR TENT DRYER TO IMPROVE ECONOMIC STATUS OF MARINE *DAGAA* (Family Engraulidae) PROCESSORS ALONG TANZANIA COASTLINE

Gladys Kedmon Manyika
Tanga City Council
P.O Box 178, Tanga, Tanzania
gnyika@yahoo.com

Supervisors:

Arnheiður Eyþórsdóttir: arnh@unak.is
Guðrún Arndís Jónsdóttir: gudruna@unak.is

ABSTRACT

Marine small pelagic fish species, known locally as *dagaa* and belonging to the family Engraulidae, are important fisheries resources in Tanzania. The fish support the livelihood of coastal communities, who process them by boiling and drying under open sunlight. However, drying of marine *dagaa* experience losses during rainy season. The objective of this study was to conduct an economic feasibility study on a proposed solar tent dryer. To meet this objective, qualitative and indicative quantitative data on *dagaa* losses were collected using IFLAM and later validated using QLAM. A total of eight (8) solar tent dryers were proposed to be constructed in pilot districts. To determine the economic feasibility of a proposed dryer, a cost benefit analysis was carried out. The study found that approximately 1 million USD is lost annually during processing, while the government loses an additional 33,000 USD in fish levies at local or national markets and 123,000 USD at regional markets. The estimated cost for constructing eight dryers was found to be 19,800 USD with annual maintenance cost of 8,300 USD. The study found an overall annual financial net benefit of 21,000 USD and a net present value (NPV) of 74,528 USD for using solar tent dryers, with a payback period of nine months. These findings indicate that solar tent dryers are economically feasible, offering higher returns, a quick cash inflow for *dagaa* processors, and increased revenue for the government.

Keywords: feasibility study, solar tent dryer, family Engraulidae, marine dagaa, dagaa processors, Tanzania.

This paper should be cited as: Manyika, G. K. 2022. *Feasibility study on a proposed solar tent dryer to improve economic status of marine dagaa (Family Engraulidae) processors along Tanzania coastline.* GRÓ Fisheries Training Programme under the auspices of UNESCO, Iceland. Final project: https://www.grocentre.is/static/gro/publication/1796/document/Manyika22prf.pdf

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AU-PHLMS:	African Union Post-Harvest Loss Management Strategy
BoT:	Bank of Tanzania
EEZ:	Exclusive Economic Zone
FAO:	Food and Agricultural Organization of the United Nations
FRU:	Fisheries Research Unit
IDRC:	International Development Research Centre
IFLAM:	Informal Loss Assessment Method
KII:	Key Informant Interviews
KSTD:	Kainji Solar Tent Dryer
LGAs:	Local Government Authorities
MALF:	Ministry of Agriculture, Livestock and Fisheries
MLF:	Ministry of Livestock and Fisheries
MLFD:	Ministry of Livestock and Fisheries Development
MOA:	Ministry of Agriculture
MOF:	Ministry of Finance
MoFEA:	Ministry of Finance and Economic Affairs
NEM:	Northeast monsoon
NPHLMS:	National Post-Harvest Loss Management Strategy
NPV:	Net Present Value
NSGRP II:	National Strategy for Growth and Reduction of Poverty phase II
PHLA:	Post Harvest Loss Assessment
PHLs:	Post-harvest losses
PVC:	Polyvinyl Chloride
QLAM:	Questionnaire Loss Assessment Method
ROI:	Return on Investment
SDGs:	Sustainable Development Goals
SEM:	Southeast monsoon
TAFIRI:	Tanzania Fisheries Research Institute
TZS:	Tanzania Shillings
UNU-FTP:	United Nations Fisheries Training Programme
USD:	United States Dollar
VICOBA:	Village Commercial Bank
VICOBA:	Village Commercial Banks
ZFRPU:	Zonal Fisheries Resources Protection Units

1 INTRODUCTION

Tanzania is blessed with marine waters that harbours numerous fish species which provide coastal communities with livelihood, food security and nutrition, as well as earning export revenues and economic development for the country. The country has a coastline of about 1,424 kilometres extending from the northern border with Kenya to the southern border with Mozambique. It has territorial marine water of about 64,000 square kilometres and an Exclusive Economic Zone (EEZ) of 223,000 square kilometres. Tanzania marine fisheries are divided into artisanal and commercial fisheries. Artisanal marine capture fisheries involve the use of traditional fishing crafts and gears while commercial fisheries are operated by Distant Water Fishing Nations in EEZ (MALF, 2016).

Over the past decade, Tanzania's marine artisanal fisheries production has ranged from 47,000 to 61,000 metric tonnes annually (Figure 1). In 2019, artisanal marine fisheries landed approximately 61,000 metric tonnes, accounting for about 14% of the country's total fisheries landings, which includes freshwater capture fisheries and aquaculture (MLF, 2019). According to MLF (2020) about 8,000 metric tons of marine *dagaa* was landed in 2020.

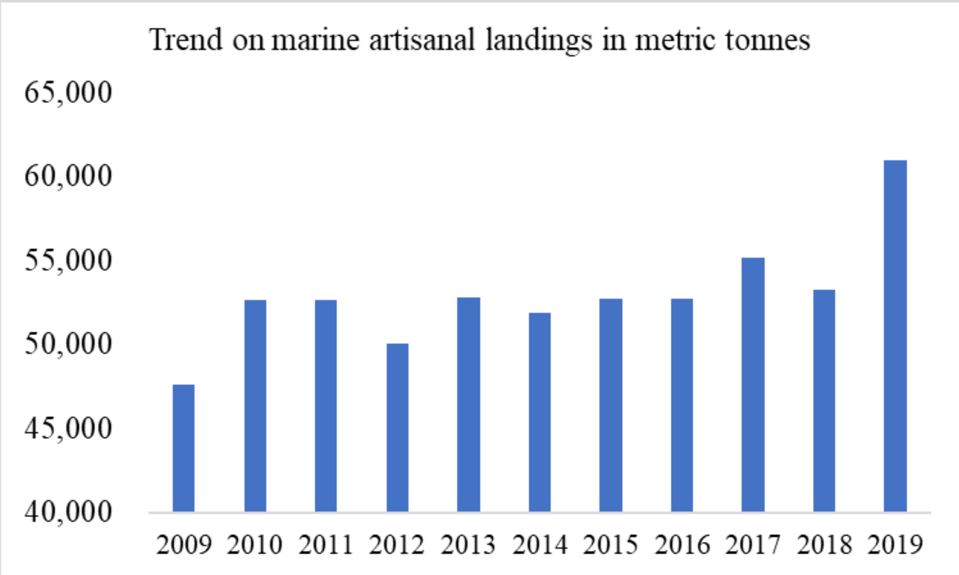


Figure 1: Total fish landings for marine artisanal fisheries along Tanzania coastline (2009-2019), (MLF, 2019).

Marine small pelagic fish species are important fisheries resources from Tanzania. Their distribution extends over territorial and internal waters of Tanzania mainland (Muhando & Rumisha, 2008). The fishery plays an important role in terms of income generation, food security and job creation to attain the United Nations Sustainable Development Goals (SDGs) as well as the national goals. The sector also benefits other people along the coastline who depend on small pelagic fish as local food. The fish whether dry or fresh, are part of the diet in fishers' and porters' households almost daily and is a common dish at the local restaurants along the Tanzanian coastline (Mwaipopo & Mahongo, 2020).

1.1 Marine small pelagic fish species (*dagaa*) along Tanzania coastline

Small pelagic fish species are a group of small forage schooling fish species that live in the surface and near-surface waters across the continental shelf, and they have relatively short lifespans, rapid growth and large biomass (Sekadende, *et al.*, 2020). They feed on plankton and are said to have a vital function in marine food web (Isaacs, 2016). The small pelagic fish species of coastal East Africa (including Tanzania) were first described in 1961 (Losse, 1964).

Small pelagic fishes that are mostly caught in Tanzanian marine waters fall under three families namely, Engraulidae (anchovies), Clupeidae (sardines) and Scombridae (mackerels), and are caught by using purse seines, ring nets and scoop nets (Breuil & Bodiguel, 2015). The small pelagic fishes have a special place with low-income families along the coastline as they are more affordable, available and accessible compared to other fish species. They are generally known as *dagaa* in swahili (local language in Tanzania).

In this study, the term *dagaa* is used to refer to all species of the family Engraulidae found in the marine fisheries of Tanzania.

1.2 Description of *dagaa* from family Engraulidae

The Engraulidae (anchovies) is one of the five families commonly recognized within the suborder Clupeoidei (Clupeiformes). They are small, silvery schooling fishes that feed on plankton. Nine (9) species of *dagaa* from family Engraulidae have been identified in Tanzania marine waters. These species are *Stolephorus indicus*, *Encrasicholina punctifer* (Figure 2a) *Stolephorus commersonii* (Figure 2b*), Encrasicholina devisi, Encrasicholina heteroloba, Stolephorus insularis*, *Thryssa baelama*, *Thryssa setirostris* and *Thryssa vitrirostris* (Anderson & Samoilys, 2016); (Bianchi, 1985).

The research conducted along the Tanzanian coast reported that most of *dagaa* caught range from 8-10cm in total length (TAFIRI, 2019). The species are geographically distributed in marine waters of all the administrative coastal districts of mainland Tanzania, from north to south. Large concentration of *dagaa* were reportedly fished in the nearshore water areas of Tanga, Dar es Salaam, Mafia, Rufiji and Kilwa (TAFIRI, 2019); (Breuil & Bodiguel, 2015).

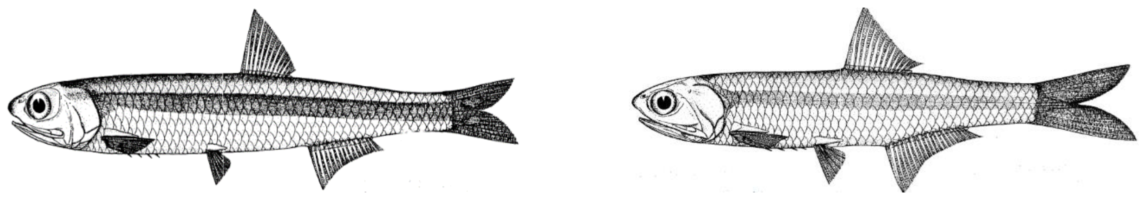


Figure 2: *Encrasicholina punctifer* (a) and *Stolephorus commersonii* (b) from family Engraulidae *(Bianchi, 1985)*.

1.3 History of *dagaa* fishery in Tanzanian marine waters

The fishery began in 1961 (Losse, 1964) and some literatures reported that the fishing was conducted using "ring nets" which was known as the "Greek method", because it was introduced by Greek fishers (Anderson & Samoilys, 2016). Planked boats with either inboard or outboard engines, ranging from 7 to 15 metres in length are used, although the majority

(90%) are less than 11 metres (Garrido & van der Lingen, 2014). Fishing takes place at night. Planked boats without fishing nets, locally known as *ngwanda* and dinghies are fixed with either kerosine lamps, on-board generators or are battery powered to attract schools of *dagaa*. The light attracts *dagaa* before the planked boat with ring net is called over to catch the fish. A crew of about 10-20 fishers are employed in each planked boat with ring net while about 3-4 fishers are employed in *ngwanda*.

Fishing *dagaa* takes place around the cycle of the moon, during the night using lights. Monsoon winds have some influence on *dagaa* landings (Jebri, *et al.*, 2020). During the North East Monsoon, NEM (November- March) landings are thought to be greater since winds are less strong, the sea is relatively calm and fishing grounds are more easily accessible, while during the South East Monsoon, SEM (April to October) air temperatures are lower, winds are stronger and the sea-state is more dangerous, reducing the access of artisanal fishers to fishing grounds, and thus fish landings are lower (Figure 3), (Breuil & Bodiguel, 2015); (Jiddawi & Öhman, 2002); (Sekadende, *et al.*, 2020). It was additionally reported that high catch of *dagaa* during NEM season is associated with upwelling caused by strong winds during SEM season that bring nutrient rich water into the productive layer (Nyandwi, 2013).

Due to monsoon winds, fishing takes place during 15-20 darkest nights of the lunar cycle, however most *dagaa* fishers go fishing for about 20 darkest nights of the lunar cycle (about 20 days each month). On the remaining days (full moon periods), no *dagaa* fishing or very few boats will go out fishing, hence no processing activities take place.

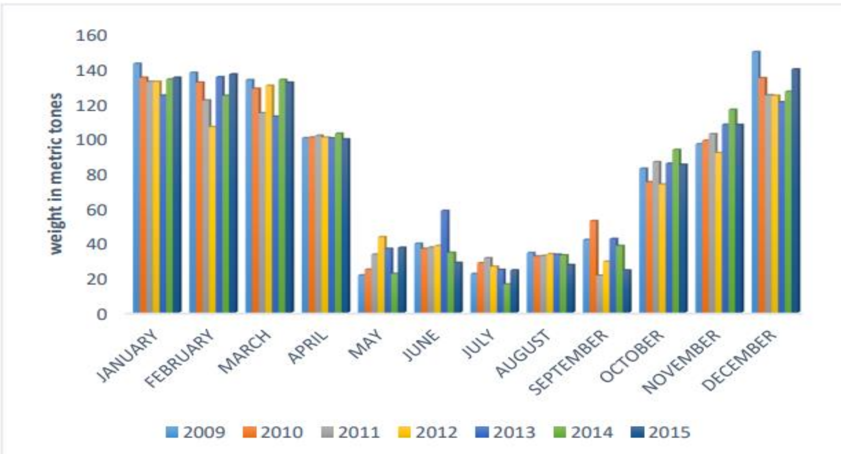


Figure 3: Marine small pelagic fish catch trend by month and years in Mafia Island. Source: *(Mayala, 2016)*.

1.4 Drying marine artisanal *dagaa* during rainy season

In Tanzania, heavy prolonged rain period starts from the month of March to May and light rain period is from December to January. Since *dagaa* processors use traditional methods to dry *dagaa* (old fishing nets, nylon sheets or raised racks under open sunlight), most of *dagaa* is lost due to prolonged heavy rains. Absence of sunlight and very high humidity during this period does not favour *dagaa* drying on ground (Figure 4). From December to January there is also light rain that may deteriorate the quality of *dagaa* which may result in economic loss to processors.

Figure 4: Drying boiled marine artisanal *dagaa* on old fishing nets and nylon sheets (left); boiled *dagaa* covered by nylon sheets (right) during rainy season at Kasera landing site, Tanga, Tanzania. Photos taken by author on 19th July 2020.

1.5 Economic importance of *dagaa* processing in Tanzania

Marine resources are critical to Tanzania's economic and social development as they support livelihoods in the coastal communities who depend on them to earn a living. Marine frame survey carried out in 2016 reported about 1,032 ring-net boats that were targeting small pelagic fish species. Although the 2018 survey did not report the number of vessels by fishery-type, it shows that there were about 53,000 people directly employed as marine artisanal fishers while another 26,000 people were involved in other ancillary activities (fish traders (47%), fish processors (27%), fish transporters (14%), net and boat repairers (3.4%) as well as fish carriers (2.6%)) (MLF, 2018).

The sector also contributes to growth of national economy as *dagaa* is exported to regional markets which earns the country revenue. In 2019, the Tanzanian government earned about 70,000 USD royalty fee from export of 223.5 metric tons of marine small pelagic fish to regional markets in the Democratic Republic of Congo, Zambia, Malawi and Rwanda (MLF, 2019).

1.6 Problem statement and justification

Processors of *dagaa* along the Tanzanian coast have been experiencing fish losses both physical and quality, which result in economic loss. It has been reported that a lot of *dagaa* is being thrown way or rot during rainfall. The use of ineffective drying methods was mentioned as one of the causes (MLF, 2020). Despite the causes of these losses being known and reported, little attention has been given to combat *dagaa* PHLs. Limited research has been conducted on the losses incurred by processors, primarily women, during rainfall, as well as on the key actors involved in this sub-sector.

Although no studies have been conducted on physical or economical losses that are associated with traditional methods of open-air, sun-drying of boiled marine *dagaa*, field observation has revealed that *dagaa* processors encounter losses especially during rainy season. Most *dagaa* is sold at a low price due to deterioration in quality and some is discarded (thrown away) due to prolonged rain or washed away. Tanga and Mafia districts were mentioned among coastal districts that experience these losses though the amount of *dagaa* discarded was not known (MLF, 2020). This study assessed economic loss that processors incur by throwing away or discarding *dagaa* during rainy season as well as economic losses due to low quality of dried *dagaa*.

Through this study, it was anticipated that implementation of solar tent dryers will reduce economic losses of marginalized coastal communities whose livelihoods are affected due to lack of effective *dagaa* drying facilities. The use of solar tent dryers has been considered a success in reducing post-harvest fish losses in Uganda and Malawi (Chiwaula *et al.*, 2020). Solar tent dryers were listed as one of the potential dried fish post-harvest loss reduction intervention initiatives in sub–Saharan Africa (Akande & Diei-Ouadi, 2010). To propose the solar tent dryer that will combat *dagaa* losses especially during rainy periods, this study assessed the economic feasibility of proposed solar tent dryers that are expected to be implemented in four pilot coastal districts of Tanga City, Kinondoni, Mafia and Kilwa. To meet this goal, an assessment of all costs and expected benefits that are associated with adopting solar tent dryers were evaluated. Costs and benefits were used to calculate net benefits and Net Present Value (NPV) to determine the feasibility of investing in solar tent dryers for drying boiled *dagaa*. Lastly, payback period was analysed to support the researcher´s decision on approving the analysed solar tent dryers.

1.7 Research objectives

The overall objective of this study is to conduct an economic feasibility study on proposed solar tent dryers that will be adopted by Tanzanian marine *dagaa* processors during rainy season.

The study sets out the following specific objectives:

- Outlining the structure of boiled dried marine *dagaa* processing.
- Assessing physical and economic losses associated with drying *dagaa* during rainy season.
- Assessing all costs and expected benefits that will be associated with adopting proposed solar tent dryer.
- Determining the Net Present Value and payback period from adopting the proposed solar tent dryer.

1.8 Research questions and hypothesis

Based on this research goals and literature review, the following research questions were developed to guide this study.

- Who are involved in processing boiled dried *dagaa* along Tanzanian coastline?
- What quantity of dried *dagaa* is lost due to spoilage, discarded or washed away during rainy season?
- How much income (money) is lost by processors due to spoilage or the throwing away of processed *dagaa* during rainy season?
- Are the *dagaa* losses incurred by processors significant?
- What are the expected costs and benefits of using proposed solar tent dryer?
- Is investing in proposed solar tent dryer economically feasible?

1.9 Limitation of the study

Allocation of financial resources and time for data collection was limited in this study hence the study focused on interviewing key informants and *dagaa* processors only. Data collection started during full moon period and some processors had already left their processing areas. This was solved by adding two additional landing sites of Tumbuju in Mafia and Mbuyuni in Kilwa to interview *dagaa* processors.

2 LITERATURE REVIEW

2.1 Historical evolution and working principle of open sun drying

Drying is defined as a moisture removal process due to simultaneous heat and mass transfer (El-Sebaii & Shalaby, 2012). Drying is done to improve shelf life, enhance appearance and flavour, and preserve nutritional value (Chou & Chua, 2001). Natural sun drying has been used since ancient times for drying agricultural products. In most developing countries, it has been estimated that about 40% of fish landing is still preserved by either sun-drying or salt curing and drying (Visavale, 2012). During drying, solar radiation that falls on the surface of the fish is partly reflected and partly absorbed (Figure 5a). The absorbed radiation and surrounding air heat up the surface of the fish and part of this heat is utilized to evaporate moisture from the internal parts of the fish to the surrounding air (Sahdev, 2014). This method of drying is known as open sun drying.

Open sun drying is traditional; it is the oldest, most common, simplest, and cheapest method of food preservation. Drying of fish is done in the open air, under sunlight in which the product is spread on the ground directly exposed to solar radiation. Open sun drying is the most widespread method of drying fish along Tanzania´s coastline. Due to the inexhaustible and abundant nature of solar radiation in tropical countries like Tanzania, the use of open sun drying appears to be the most convenient and cheapest way of drying fish (Immaculate *et al.*, 2012); (Szulmaye, 1971).

Fish can also be spread on simple raised racks which came as an improvement to drying fish on the ground or rocks. The use of racks (raised about 1 metre) only allows some protection to fish against crawling pests and contamination from dust, but not flies, during the rainy season. In some areas of coastal regions like Mafia Island in Tanzania, raised racks covered with nylon sheets are used during rainy season (Figure 5b).

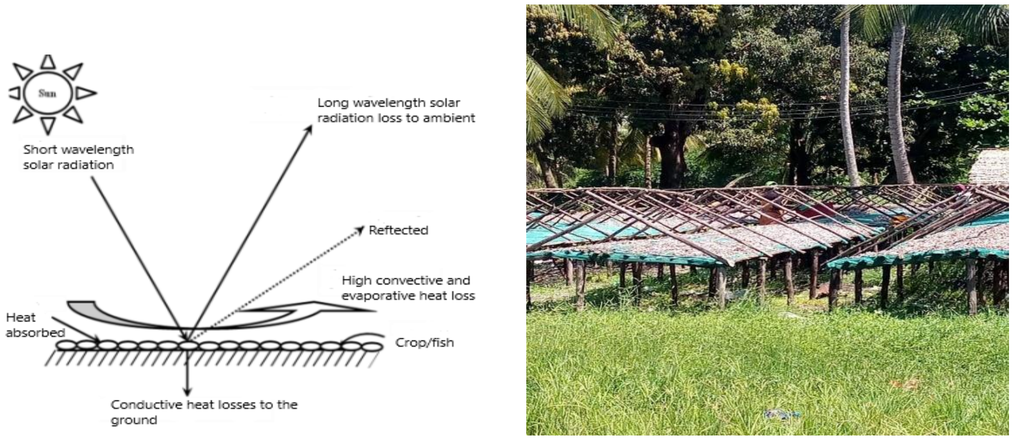


Figure 5: a) Working principles of open sun dryer *(Sahdev, 2014)* (b) open raised racks in Mafia Island

2.2 General overview of processing boiled dried marine *dagaa* in Tanzania

Boiled dried marine *dagaa* is a processed product of small pelagic fish from family Engraulidae, processed through rapid cooking followed by open sun drying. At many fish landing sites, marine artisanal *dagaa* is auctioned off to traders or fish processors directly from vessels anchored in shallow water. Most of the coastal districts have one landing site that is known specifically for *dagaa*. According to studies conducted by Ibengwe *et al.*, (2022) marine *dagaa* processors are divided into three major categories: facility owners, porters (*dagaa* carriers) and casual labourers. Facility owners are processors who own facilities such as *dagaa* boiling stoves, nylon sheets, old fishing nets, perforated plastic buckets and storage services. Due to lack of cold storage facilities at most of landing sites, *dagaa* is processed immediately after being landed. Facility owners purchase *dagaa* from fishers and they employ "fish carriers" or "porters", who are mostly women to carry freshly caught *dagaa* (on their heads) by using large plastic basins or baskets to the processing areas. Facility owners also employ casual labourers in activities such as sorting, boiling, drying, sieving, weighing, packaging, storage and guarding.

Marine *dagaa* processing is mostly carried out by women who boil the *dagaa* in brine for about 3-5 minutes using perforated buckets. Boiled *dagaa* is then dried under the open sun using either raised racks, old fishing nets or nylon sheets which are spread on the ground. Drying may take 6-8 hours depending on intensity of sunlight. Dried *dagaa* is then packed into big sacks of about 100 kg each and either stored or sold to wholesale traders. The traders then transport to domestic markets and sell to retail traders or (for those who own export licence) export to regional markets. Flow chart of boiled dried *dagaa* processing path is described in Figure 6 below.

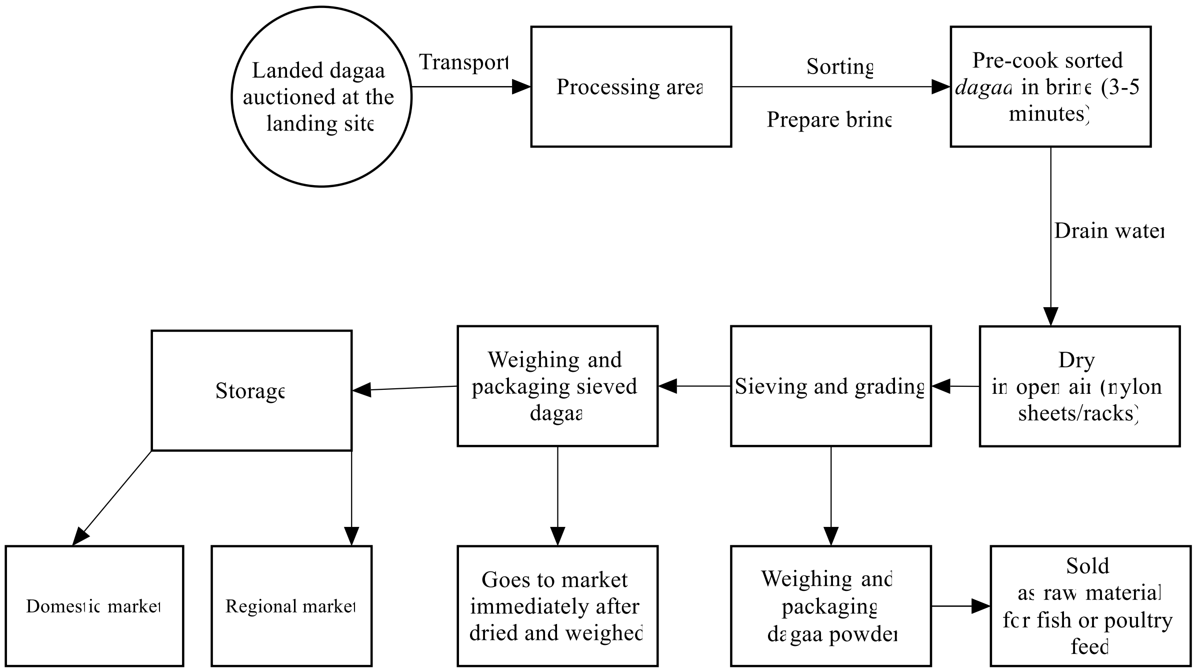


Figure 6: Flow diagram of Tanzanian marine *dagaa* processing

2.3 Economic implication of drying fish under open air

The use of open sun drying in fish preservation has been reported to have some drawbacks. A major problem is the loss of quality due to contamination with dust, sand and excreta from birds and other animals and insect infestation. Losses also occur during rainy season when *dagaa* can be washed away or rot (MLF, 2020). Moreover, it is difficult to control drying process and parameters in open air due to weather uncertainties. Open sun drying needs large drying area and is labour intensive as well. This may result in economic loss to processors. Although there are limited studies on marine *dagaa* economic post-harvest losses, studies conducted in 2010 revealed that Lake Victoria fresh water *dagaa* processors incurred financial loss of about 1,139 USD per annum for each 5 metric tons of fresh water *dagaa* that was dried on the ground (Ibengwe L. , 2010).

Other economic implications on the use of open sun drying especially during rainy and high *dagaa* seasons have been observed along Tanzania coastline (MLF, 2020). Fish losses lead to income loss which may later result in indebtedness, then poverty and domestic tension can result from inadequate income to cater for family expenses. This was mentioned as one of the reasons that resulted in fish dryers in Ghana not being able to pay for higher education for their children (Akande & Diei-Ouadi, 2010). Coastal communities and low-income families are affected the most since they depend on dried *dagaa* as their main source of livelihood.

The government also loses revenue from levies and export earnings as most of the catch deteriorates or is sold at lower prices than the market price for a good quality product. This does not only affect the government and *dagaa* processors, but it affects the whole chain that is involved in *dagaa* processing related activities. Fishers' livelihoods are threatened mostly since they depend on processors who are the main buyers. During rainy season, *dagaa* fishers increase fishing effort to compensate for the lost income due to the quality loss (Akande & Diei-Ouadi, 2010). This coping strategy of *dagaa* fishers during rainy season increases pressure on fishery resources which threatens the sustainability of the resource. Jobs of "*dagaa* carriers" or porters, who are mostly women, mothers and wives taking care of their families, are also at stake especially during rainy season when most of processors are afraid to purchase fresh *dagaa* as they have nowhere to dry. In Tanzania, along Lake Victoria, an opportunity cost associated with drying *dagaa* on the ground has been reported, as children skipped school to guard the drying fish from animals and theft, receiving dried fish as payment (Ibengwe L., 2010). Research conducted in Malawi has shown that open sun drying of fish results in an economic loss of over one third of the potential value (IDRC-CRDI, 2020).

2.4 Evolution of solar tent dryers and their working principle

Solar tent dryer, as its name implies, has a tent-shaped structure with frames made of planks, bamboo sticks or sisal poles which are low-cost and available locally. The dryer is covered with clear polythene nylon except at the base and top where ventilators are placed to allow air entrance (at the bottom) and moisture escape (through the top) (Chiwaula *et al.,* 2020). Inside the dryer, rectangular raised racks are constructed stretching along the sides of the tent and fish is placed on racks to dry.

Solar tent dryer was first designed in 1977 in Bangladesh (Doe *et al.,* 1977). The dryer was named after the founder, Doe, and was constructed using polythene tent, wooden frames, PVC (black) polythene that was spread out on the base of the tent and a drying rack. Black polythene was used to generate heat inside the dryer. Doe's solar tent was also constructed by using sticks which were simply dug into the ground, tied up together and polythene sheet fastened around the sticks using stappling pins. A fold was left under the tent to allow air into the tent (Olokor *et al.,* 2009). Later in 2009, Kainji Solar Tent Dryer (KSTD) was constructed as a modified solar dryer of Doe's solar tent in Nigeria. KSTD was constructed using transparent polythene tent, wooden frames, mosquito nets, black igneous rocks (to generate heat), zip (used as a door) and drying racks. Since then, several solar dryers have been designed, developed and tested in different African countries like Malawi and Uganda.

Solar tent dryer is used as an upgrade from open sun dryer to reduce losses to processors and improve food security and nutrition. It minimizes some of the limitations of open sun drying. Since they are made of polythene sheets placed over wooden frame, they dry fish using the greenhouse principle. When they are set up in the sun, solar energy passes through transparent polythene and get trapped within the dryer, hence raises up internal heat. Cool air that flows through the lower vents gets heated up and moves out moisture from fish through the top vents (Figure 7). The fish are laid on raised racks inside the tent and warm air that is trapped inside the dryer speeds up the drying process of fish, hence extends shelf life and reduces losses.

They have been proven to save energy inside due to their enclosed structure, save time, use small area for drying, improve quality of dried product and are efficient and environmentally friendly (Chiwaula *et al.*, 2020); (Abraha, *et al.,* 2017).

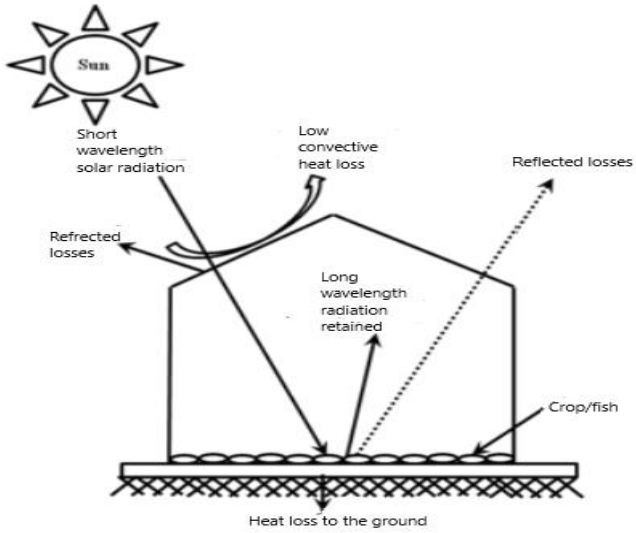


Figure 7: Solar tent dryer working principle *(Sahdev, 2014)*.

Economic feasibility study of proposed solar tent dryer was carried out based on the one that was recently constructed in Malawi to find out if it can be replicated along the Tanzanian coastline as it is argued that most of *dagaa* is lost due to ineffective drying methods (MLF, 2020). This dryer is furthermore said to be constructed using locally available materials and according to the cost-benefit analysis that was conducted in Malawi, it was found to have a 1-to-2-year payback period (Chiwaula *et al.*, 2020).

2.5 Performance of solar tent dryer during rainy periods

Solar tent dryer uses trapped energy efficiently for drying fish even on cold and windy days, hence reduces losses (Immaculate *et al.*, 2012)**.** It is rain-proof, thus can be used continuously even in rainy periods under high humidity (Olokor *et al.*, 2009). Several studies have revealed enclosed structured solar tent dryers to be more effective in comparison to open sun dryers.

The study was conducted to evaluate performance of solar tent dryer in four seasons of the year named dry season, pre-rainy season, post-rainy season and main rainy seasons. It was found that fish drying time in solar tent was shorter (1-2 days) in comparison to open racks which used 3-5 days. Moisture content which is an important factor that determine shelf life of dried fish was found to be lower throughout all four seasons in fish that was dried in solar tent in comparison to fish dried on open racks. Fish dried in solar tent during main rainy season had moisture content of less than 25% in all four seasons and the dried products had longer shelf life of 12 months. On the other hand, fish dried under open racks in main rainy season had moisture content above 25% which made the product to be spoiled. Higher moisture content in dried product was reported to facilitate deterioration which resulted into lower prices of dried fish hence economic loss to processors. The study further stressed out that open racks cannot be used in all seasons of the year (Tessem *et al.*, 2013).

A solar tent dryer was designed and tested in Malawi to reduce post harvest losses of small fish species especially during the months of January and April which are associated with rains and high humidity. It was discovered that the dryer achieved up to 10% moisture content which increased shelf-life of dried small fish species to seven weeks compared to three weeks for open sun-dried products and the dryer was able to be used all year round. The study further identified the solar tent dryer was economically and socially feasible as it reduced labour costs for women who are the main users. The use of tents also reduced fishing effort due to increase in small fish consumption and utilization (Nagoli *et al.,* 2017).

A study by the Canadian International Development Research Centre in Malawi showed that, during the 2020 rainy season, solar tent dryers reduced physical and quality losses of fish from 7.9 percent to 1.9 percent and from 9.2 percent to 1.4 percent, respectively (IDRC-CRDI, 2020). Moreover, solar tent dryer showed shorter drying time compared to open racks. Dried product from solar tent dryer was found to have significantly less moisture content in comparison to open racks (Chiwaula *et al.,* 2020). Solar tent dryers were also found to have higher air temperature inside 45^0C, and relative humidity of 42% in comparison to open sun dryer which was recorded to have an average temperature of 35^0C and relative humidity of 47%. Higher temperature and lower relative humidity in solar tent dryers were mentioned as strongest factors for drying fish (Abraha, *et al.,* 2017).

2.6 Perceived economic benefits of using proposed solar tent dryers

Selection of a solar tent dryer is determined by its drying characteristics, quality requirements, as well as the economic gains brought by using it (Leon *et al.*, 2002). Performance of a dryer is also influenced by parameters such as drying air temperature, humidity, airflow rate, as well as dried product variables such as moisture content, and dimensional variables of the dryer (width, length, height, and capacity).

Demand for dried products including marine products have been increasing in developing countries like Tanzania (Sahdev, 2014). Proper preservation of fish using solar tent is important to provide processors and the government with economic benefits. A study conducted in Malawi shows that the use of solar tent dryers reduced fish losses by half to 17.7 percent from 35.5 percent (IDRC-CRDI, 2020). The study further analysed the profitability of fish processors using solar tents and established that when fish processors use solar tents, on average, they make a gross profit of approximately 635,850 Malawian kwacha (about 779 USD) per month and hence manage a payback loan of 2,500,000 Malawian kwacha (3062USD) to purchase solar tents within 20 months. The study further concluded that solar tents are bankable (IDRC-CRDI, 2020).

2.7 Physical and quality losses of fish

Two types of PHLs (physical and quality losses) that occur during processing, packaging and storage of *dagaa* are considered in this study as they may result in loss of income to processors. With reference to this study, physical losses mean losses associated with discarding or throwing away *dagaa* after prolonged rainfall as well as losses associated with *dagaa* that has been washed away by rain. This occurs especially when *dagaa* spoil due to improper drying during prolonged rain, hence processors discard or throw away (Diei-Ouadi & Mgawe, 2011). Physical loss may be expressed in terms of weight or monetary value, and this occurs mainly when the fish is entirely removed from the value chain.

Quality loss of fish refers to the fish that has undergone changes due to spoilage or physical damage and has suffered quality deterioration. It is the difference between the potential value of fish at its best quality and the value of the same fish after quality degradation. Quality degradation may be due to processing already spoiled or poor quality *dagaa*, drying fish on ground, breakage, insect infestation, growth of mould and discoloration (Diei-Ouadi & Mgawe, 2011).

2.8 Policy implications on post-harvest practices

Recognition of fish post-harvest practices is reflected in Tanzania Fisheries Policy 2015, chapter 3.8; - on utilization, processing and marketing of fisheries products which emphasizes promoting the use of improved and appropriate technologies in fish handling, preservation, processing, utilization, and value addition (MLF, 2015). For proper utilization of marine artisanal small pelagic fish species, Tanzania Ministry of Livestock and Fisheries developed management plan for Tanzanian artisanal fishery for small and medium pelagic fish species which addresses the issue of developing, processing and marketing skills on small and medium pelagic fish species (MLFD, 2013); (MLF, 2016). Similarly, Tanzania´s Five Year Development Plan II of 2016/2021 addresses fish post-harvest treatments by aiming to nurture industrialization for economic transformation and human development (MOF, 2016). Additionally, PHL is addressed in the Tanzania National Strategy for Growth and Reduction of Poverty phase II (NSGRP II) under goal 2 (poverty reduction), Goal 3 (job creation for women and youth), and Goal 4 (food and nutritional security), (MoFEA, 2010).

To combat PHLs, Tanzania, under the Ministry of Agriculture, formulated a National Post-Harvest Loss Management Strategy (NPHLMS) (2019-2029) with a vision to reduce post-harvest losses along the commodity value chains to contribute to national food and nutrition security as well as national economy by ensuring availability of appropriate post-harvest and value-addition practices and technologies (MOA, 2019). As a member of African Union, Tanzania adopted an African Union Post-Harvest Loss Management Strategy (AU-PHLMS) which has the aim of reducing PHLs in agricultural, livestock and fisheries products (AU, 2018). Despite existing policies and strategies, there remains a need for the Ministry of Fisheries and Livestock to develop a Post-Harvest Loss Management Strategy specifically for the fisheries sector. The current NPHLMS, developed by the Ministry of Agriculture, does not address fisheries issues, resulting in fish post-harvest losses in Tanzania being excluded from the AU-PHLMS. This exclusion occurred because the African Union Commission used the Agriculture Ministry’s strategy as the baseline for developing the AU-PHLMS.

In the long run it is expected that the results of this study will be helpful in developing Fish PHLs strategy which will be incorporated in the NPHLMS as well as in AU-PHLMS.

2.9 The inclusion of women in preserving *dagaa* using solar tent dryers

Worldwide, the contribution of women in fisheries sector has long been poorly documented and undervalued with a notion that men participate in capture fisheries while women participate in processing and marketing. The division of labour in most African fisheries is highly gendered with men dominating the fishing operations and marketing of high prices fish species while women dominate in processing and marketing of small fish species (Chiwaula *et al.*, 2012); (Coastal Resources Center, 2016).

Women have less control and access to business resources such as financing and market information compared to men which limit them in adopting new technologies that can improve their income. They also have limited time to process fish due to unpaid household responsibilities which results in drying fish in open-air, on the ground. or on open air racks which has been found to have some drawbacks such as post-harvest losses. These losses have negative implications on fish supply and incomes especially for women who are involved in fish processing. Although women are major fish processors, they have limited to access fish processing technologies due to unequal division of labour, limited incomes and time to manage fisheries resources, as well as other social injustices such as taking care of family and kids (Ngwira, 2001); (Chiweza, 2005).

The use of solar tent dryer is sought to enable women to overcome these losses. A study conducted in 2018 shows that the closed structure of solar tent saves a significant amount of time for women when drying their products as they no longer guard or chase animals away. This helped them to create new economic opportunities and improved their livelihood (Chiwaula et al., 2018). The dryer also enabled women to earn income throughout the year as they operate all the year round even during rainy seasons. In addition to the benefits women gain from adopting solar tent dryers, a study examined their willingness to pay for these dryers and proposed the development of an innovative, gender-inclusive financing mechanism to boost adoption rates among women. The study also highlighted the need to improve women's access to government extension services and training in technical and business skills, areas where women currently have lower access than men (Chiwaula *et al.*, 2018). This will also enable women to own solar tent dryers as they generally do not have opportunity to own individually important assets for fishing or transportation of fish to markets, unlike men. Solar tent is anticipated to enable women to have enough time to attend to other household chores (WorldFish, 2017).

3 METHODOLOGY

3.1 Description of study areas

This study was conducted in six fish landing stations of Kasera (Tanga City), Kunduchi (Kinondoni District), Kilindoni and Tumbuju (Mafia District), and Magengeni and Mbuyuni (Kilwa-Kivinje, Kilwa District) as shown in Figure 8. These districts are among eighteen coastal districts along Tanzania´s coastline. The six landing stations were chosen in this study because they are renowned in landing, processing and trading large volumes of marine *dagaa* and were mentioned to be among landing sites where processors experience *dagaa* losses. Tanga City and Mafia Districts were reported to discard or throw away *dagaa* during rainy season which led to physical and economic losses (MLF, 2020). Selection of the landing sites was also based on large number of *dagaa* processors, their accessibility and number of people who depend on *dagaa* to support their livelihood. It was reported that about 70% of Tanga city residents depend on Kasera landing site for fish consumption and trade and is the main market for small pelagic fish in Tanga (Mwaipopo & Mahongo, 2020).

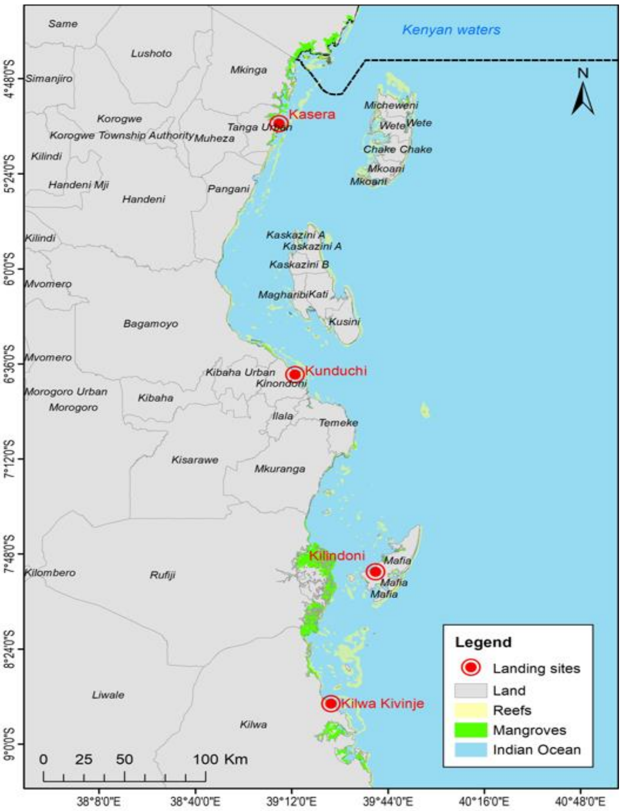


Figure 8: Map showing study areas along Tanzanian coastline

3.2 Sampling procedure

Systematic sampling was carried out to determine sample size for this study. To start with, lists of processors from four districts were used to systematically select processors to fill in questionnaires. The second (2nd) processor was selected first followed by selecting every third (3rd) subsequent processor on the list. This was done for processors in three districts of Tanga, Kinondoni and Mafia. For the case of Kilwa district, due to its large population size, sample size was systematically chosen by selecting the second (2nd) name first, followed by every fourth (4th) name afterwards. A sample size of 183 respondents (179 processors and 4 KII) was determined for this study.

3.3 Study tools and data collection strategies

To meet the set objectives, both primary and secondary data were collected. Qualitative and indicative quantitative data on *dagaa* PHLs were collected using IFLAM which was developed by Ward and Jeffries (2000) to generate an explanatory understanding of the types and sources of PHLs that *dagaa* processors incur as well as their perception of PHLs. IFLAM (Informal Fish Loss Assessment Method) was applied in reviewing previous studies, observation, semi-structured interviews, flow diagrams as well as interviewing key informants as was recommended by Diel-Ouadi and Mgawe, (2011). It was used to utilize local knowledge, understand local situations and to generate a good general understanding of PHFLs. This was done through administering standardized questionnaires that were pre-tested and designed to minimize or control possible bias, as well as checking for the validity and reliability of data collection tools. The questionnaires (Appendix 1) were distributed to 179 *dagaa* processors in the four study sites. QLAM (Questionnaire Loss Assessment Method) was used to validate or cross-check the data obtained from IFLAM.

Four open-ended questionnaires were administered to District Fisheries Officers (KII) in study areas to complement the information obtained from *dagaa* processors (Appendix 2). KII was also aimed to obtain information on levies charged by the government for dried *dagaa*. This information was then used to evaluate losses the government incur due to the ineffective drying methods that are currently used.

3.4 Fabrication of proposed solar tent dryers

Proposed solar tent dryers will be constructed in four pilot districts (two in each district) based on the guidelines developed by Chiwaula *et al.*, (2017).

3.4.1 Construction materials for proposed solar tent dryers

Proposed solar tent dryers will be constructed using locally available materials such as UV polythene sheet (200 μm) that will be worn over wooden frame (planks), plastic fine meshed gauze (mosquito net), quarry stones, chicken wire for drying rack, nails and hinges, bricks and sand. By using a guide for solar tent dryer construction from (Chiwaula *et al.*, 2017) and based on the amount of marine *dagaa* available for drying, a bill of quantities (Table 2) was prepared and sent to Tanzania to obtain the current cost of all construction materials and their availability in study areas.

3.4.2 Dimensions and capacity of proposed solar tent dryers

The design of proposed solar tent dryers to be constructed in Tanzanian pilot districts was adopted from the guide developed by Chiwaula *et al*, (2017) as shown in figures 9a and b. The proposed dryer is 15 m long and 8 m width and has three (3) double decked drying racks 11 m long and 1m width with a gap of 90 cm between drying racks to allow air circulation. The height at the centre and the sides is 6 m and 3 m respectively. It has top air vents of 40 cm x 40 cm and bottom vents of 30cm x 30cm. The top vents are used as outlets while bottom vents are inlets.

According to marine *dagaa* catch data from MLF, between 30 and 150 metric tons of *dagaa* is landed, monthly during SEM and NEM seasons in each of the pilot district respectively. Since most of *dagaa* is boil dried and some fried for immediate consumption or sold as fresh by street vendors, it was assumed that about 70% remains for boiling-drying or drying without boiling. Furthermore, *dagaa* fishers go fishing for the 20 darkest nights in a month hence about between 1 and 5 metric tons of *dagaa* will be left for drying daily during SEM and NEM seasons. The average amount of *dagaa* to be dried was determined by assuming that the dryer will be used to full capacity for six months of the year (NEM including prolonged and light rains seasons) and 70% of capacity during the SEM (six other months). The data was assumed based on observed *dagaa* landings data from LMF.

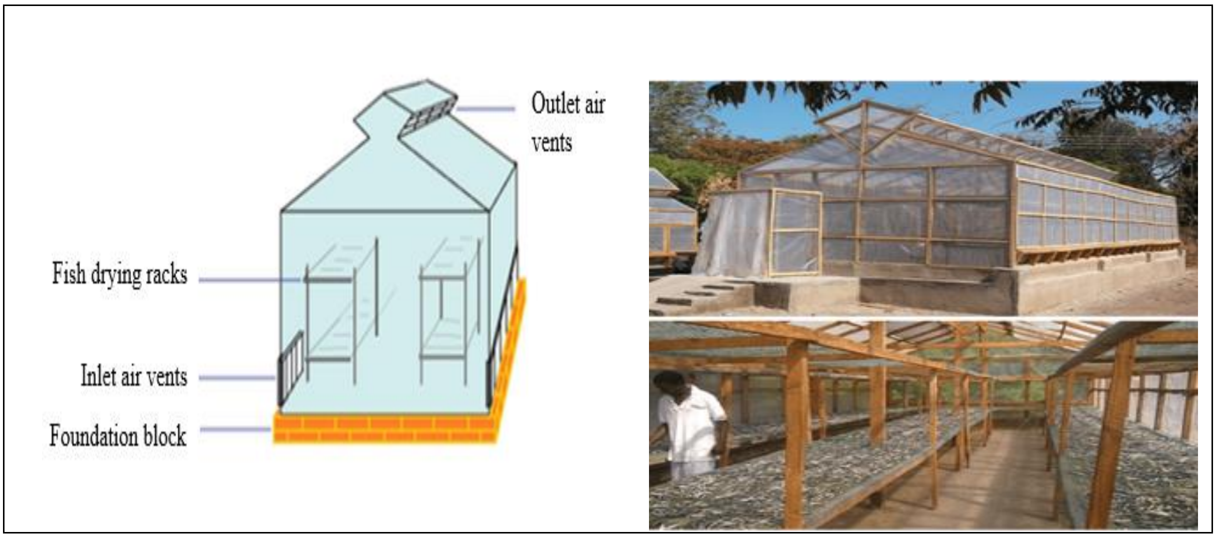


Figure 9:a) Design of solar tent dryer adopted from Malawi and (b) completed solar tent dryer constructed in Malawi (FRU, 2017).

3.5 Cost- benefit Analysis

3.5.1 Assessment of all losses associated with open sun drying during rainy season

Data on average price for good and low quality dried *dagaa* as well as data on amount of dried *dagaa* that was sold at lower price due to quality deterioration were recorded from questionnaires given to *dagaa* processors. Quality losses that were assessed include losses associated with downgraded *dagaa* after quality deterioration due to reasons such as discolouration, the purchase of low quality fresh *dagaa*, breakage, presence of mould or improper dried product. The amount of processed *dagaa* that was sold at a lower price due to downgrading was used to calculate the total value of downgraded *dagaa* and was then subtracted from the total value of a good quality dried *dagaa* to obtain quality loss in monetary terms.

Amount of *dagaa* (wet weight) that was discarded or washed away by rain was quantified from the questionnaires and later converted to equivalent dry weight based on output/input ratio of 35% (Table 4 below). The dry weight equivalent was calculated based on amount of fresh *dagaa* purchased for processing and amount of dried (processed) *dagaa* throughout the year and during low and high seasons of *dagaa*. The calculated equivalent dried weight of the discarded or washed away *dagaa* was then multiplied by the average market price of a dried product to get the monetary loss of discarded or washed away *dagaa* during rainy season. Losses associated with theft were not part of this study.

The monetary value from quality losses and physical losses were summed up to get the total monetary loss that processors (facilities owners) incur both along the Tanzanian coastline and in the pilot districts. This was done by assessing losses that are incurred by marine *dagaa* processing facility owners along the Tanzanian coastline who are estimated to be about 1,500 (MLF, 2018), as well as for facility owners in the four pilot districts. Data on losses in pilot districts were used to determine if investing in solar tent dryer in the pilot districts was feasible.

3.5.2 Assessment of all costs for adopting proposed solar tent dryer

Based on the guide for construction of solar tent dryer developed by Chiwaula *et al.*, (2017), a quotation note for construction materials of proposed dryer was prepared and sent to Tanzania. Quotation requests for quantities of construction materials were sent to several hardware store to avoid overestimation and underestimation of construction materials. Estimated data on labour costs and transportation of construction materials based on experience from project supervisors of previous construction projects in Tanzanian LGAs.

The monetary cost of reducing loss through implementation of proposed solar tent dryer was calculated based on the equation 1,

$$C\ (t) = \sum_{j=1}^{j} w\ (j,t) x\ (j,t) \qquad \ldots\ldots 1$$

Whereby,

C = cost of different items (investment, operational and implementation costs)

t = time of year when costs were assessed,

∑= summation of all costs,

w= the price of one unit of input j at time t,

x= quantity of input j at time t (Boardman et al., 2018).

3.5.3 Assessment of benefits associated with adopting proposed solar tent dryer

An estimate of all anticipated direct benefits (economic gain) earned by processors from drying *dagaa* using proposed solar tents during rainy periods were assessed based on estimations on amount of *dagaa* to be processed. In addition, it was estimated that solar tent dryers will reduce losses by 50% based on studies by a Canadian International Development Research Centre (2020). The increase in revenue by the government through collection of fish levies was also assessed based on data from District Fisheries officers (KIIs) who reported that about 3% of the value of dried *dagaa* is charged by Local Government Authorities (LGAs) as fish levies and 0.16 USD per kilogram of marine dried *dagaa* is charged as royalty fee for export of *dagaa*. The study also anticipated that solar tents would accommodate *dagaa* that was discarded or washed away due to prolonged rainfall.

To obtain the total benefit associated with implementing proposed drying mechanism, the monetary gain obtained after implementation of the proposed solar tent dryer was summed up using equation 2.

$$B(t) = \sum_{i=1}^{i} p(i,t)\ q\ (i,t) \qquad \ldots\ldots 2$$

Whereby,

B = Benefit of drying *dagaa* on proposed solar tent

∑= Summation of all monetary gain,

p = price of output i at time t,

q = quantity of output i at time t,

t = time when the benefit was evaluated (Boardman et al., 2018)

3.6 Evaluation of Net benefit and Net Present Value (NPV)

NPV is the present value of the cash flows at the required rate of return of project compared to initial investment. It is used to calculate return on investment (ROI) for a project or expenditure (Galo, 2014). Net Present Value (NPV) was calculated by using total costs and benefits associated with adopting proposed solar tent dryer and was later used to assess investment decision on proposed solar tent dryer.

To compare changes in benefits and costs of implementing the proposed project, values were discounted back to present period to determine present value. Discount rate was used to determine the present value of future cash flows. The discount rate of 0.05 (5%) was used in this study as per Central Bank of Tanzania (BoT) (BoT, 2020).

To obtain NPV, first, the present value of future costs and benefits were calculated using equations 3 and 4

$$PV\ (B) = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t} \quad \ldots\ldots 3$$

$$PV\ (C) = \sum_{t=0}^{n} \frac{C_t}{(1+s)^t} \quad \ldots\ldots 4$$

Whereby,

PV (B) = Present value of benefits

PV (C) = present value of costs

B_t = Benefit for drying *dagaa* on proposed solar tent at time t

C_t = Cost for implementing/maintenance of proposed solar tent dryer

∑= Summation of all the costs or benefits

s = discount rate

t=time when the cost or benefit was evaluated

n= lifetime of a project in years21809

Then NPV was calculated as in equation 5 below to determine if the project is worth it (feasible) to be undertaken.

$NPV = \sum PV(B) - \sum PV\ (C)$ ……………………………………………………….5
(Boardman et al., 2018)

3.6.1 Payback period of a proposed project

Payback period is the estimated amount of time it takes to recover the initial cost of an investment. It is the period that a project requires to recover the money invested in it and is mostly expressed in years (Sreekuma *et al.*, 2008). Payback period was calculated in this study to support the making of the decision on whether investing on proposed solar tent dryers was feasible. The calculation was done by estimating the life span of the dryer to be 5 years according to findings by Chiwaula *et al.*, (2020). Payback period was computed based on the following equation.

Payback Period = Full Years Until Recovery + (Unrecovered Cost at the Beginning of the Last Year/Cash Flow During the Last Year) ……………………………………………………6

3.7 Data processing and Analysis

Data cleaning was performed on the completed questionnaires and later recorded, input into Microsoft Excel and coded for analysis. Quantitative data were analysed using Microsoft Excel and frequencies, means, percentages were calculated and presented in tables and charts. Content analysis method was used to analyse qualitative information.

4 RESULTS AND DISCUSSION

This section presents the results and discussion from *dagaa* processors and KIIs in four pilot districts. The results and discussion mainly focus on demographic characteristics of the respondents, the outline of *dagaa* value chain, physical and economic losses that respondents incur as well as the cost benefit analysis of the proposed solar tent dryers.

4.1 Demographic characteristics of sampled *dagaa* processors

4.1.1 Gender ratio and age of respondents

Gender comparison between male and female respondents show that more women participate in *dagaa* processing in comparison to men as shown in Figure 10 (left) below. About 59 percent of respondents were female while men were 41 percent. Mafia district was found to have the highest number of female processors with Kinondoni being the least. The findings of this study are supported by a study that was carried out along the Tanzanian coast which discovered that women dominated in *dagaa* processing and marketing sector (Bradford & Katikiro, 2019).

This study also observed that most respondents (43 percent) were above 40 years of age, while youth who are between 18 to 25 years were the smallest group involved in *dagaa* processing (Figure 10 below, right). This was observed in all pilot districts with the exception of Kinondoni which had the highest percentage of respondents between 34 and 40 years old, and Tanga City which had no youth respondents (18-25 years). Ibengwe *et al.*, (2022) identified the facility owners, casual labourers and porters as three categories of marine *dagaa* processors along the Tanzanian coastline. In this study, respondents were people who owned land based marine *dagaa* processing facilities for boiling and open air drying of boiled *dagaa*. Facility owners employ casual labourers and porters to process *dagaa* on their behalf. Based on respondents' views, most facility owners have families and are settled in one place with collateral which makes it easier for them to access business loans in financial institutions. They were family members or *dagaa* boat owners unlike youth who do not have collateral such as house or land unless they form registered groups to have access to LGAs loan for youth (4%) which is limited. This led more youth to be employed as porters or casual labourers.

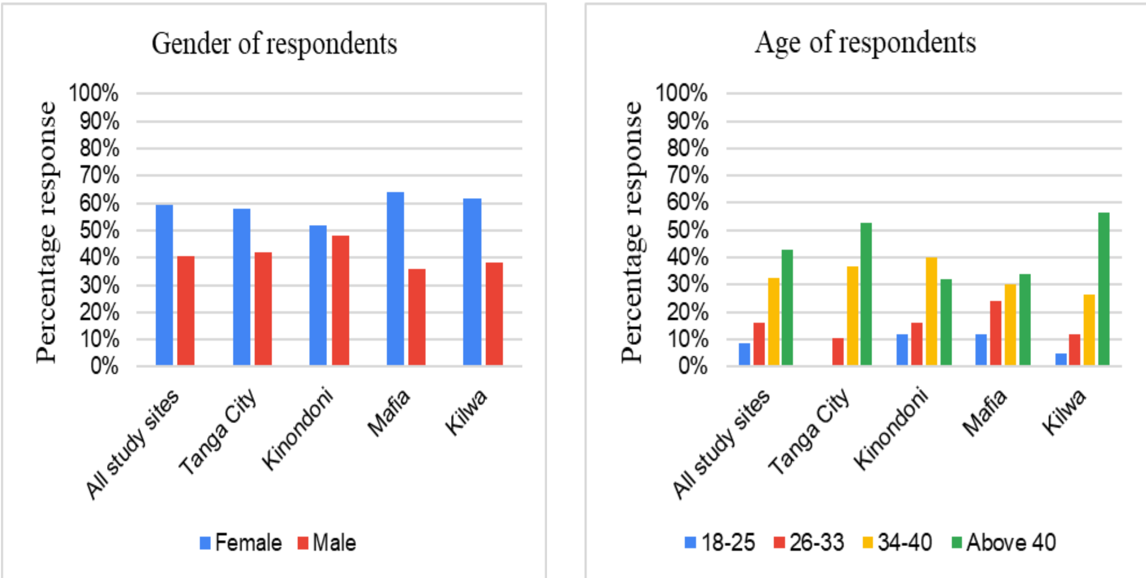
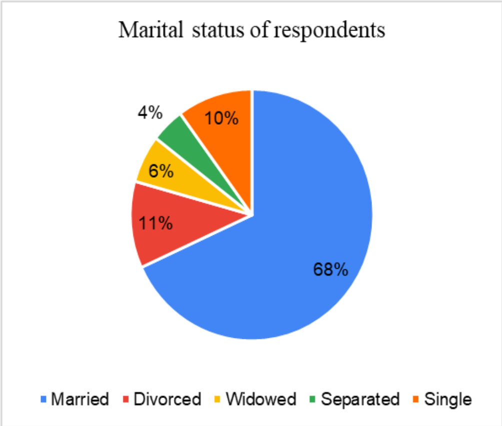


Figure 10: Percentage gender of respondents (left) and age of respondents (right)

4.1.2 Marital status and education level of respondents

Findings indicate that 68 percent of respondents were married (Figure 11, left), while only 4% were separated. According to respondents' views, *dagaa* boat owners bear more trust to processors who are married with families as they consider them as "settled", hence can be given fresh *dagaa* on loan to process and they repay their debts after selling dried products. This is especially during rainy and high *dagaa* seasons.

The study further shows that most of *dagaa* processors (67.6 percent) have attended primary education while only 8.9% are illiterate (Figure 11, right). In Tanzania, a person is considered literate if he is 15 years of age or above and can read and write understanding short simple statements. This indicates that a higher literacy rate of respondents may have a positive impact on the acceptability of the proposed innovation.



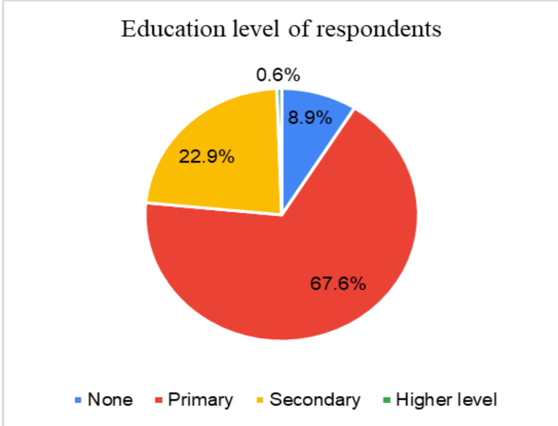


Figure 11: Marital status (left) and education levels of respondents (right)

4.1.3 Experience of respondents in dagaa processing

The findings from the study indicate that 40.2 percent of respondents have experience of more than six (6) years in processing *dagaa* while about 5.6 percent of respondents had the least experience in *dagaa* processing (less than one year) as shown in Figure 12 (left). This shows that *dagaa* processing is carried out by more experienced people.

Furthermore, the study revealed that 68.7 percent of respondents were locals, while one third of respondents were immigrants coming from other districts on Tanzania mainland or from the islands of Unguja and Pemba (Figure 12, right). The migration of processors to study sites might be due to earning income enabling them to cover for family expenses. It has become a way of life for local fishermen and processors to migrate to other coastal districts for the purpose of saving for family expenses, including education, celebration of birth of Prophet Mohammed (Maulid), the end of fasting (Ramadhan) and end of the year migrating (Wanyinyi *et al.*, 2016). This migration of fishermen or processors is locally known as *dago*. Migrant fishers are said to migrate to areas that offer abundant fish compared to their home place and they spend longer periods at the destination to earn more. This attracts *dagaa* processors from other areas who migrate to the landing sites with abundant fish for processing. This was revealed in the study by Wanyinyi *et al.*, (2016) where economic drivers were mentioned to be the most prominent factors for people to migrate to specific destinations, since immigrants are considered to have the ability to save money for investing in development activities at home including improving the standard of living for the family, building better houses and starting businesses.

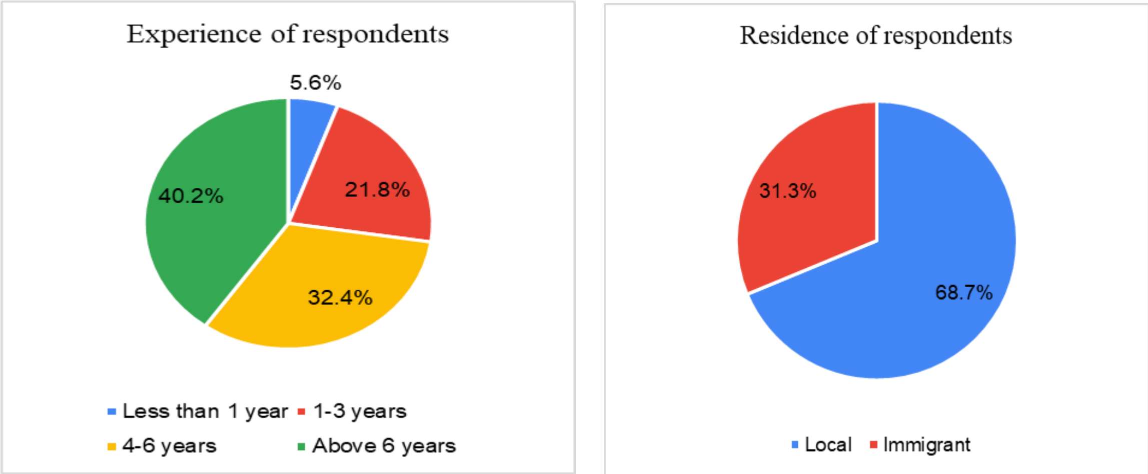


Figure 12: Experience of respondents (left); Residents of respondents (right)

4.1.4 People employed in dagaa processing in study areas

The study revealed that about 1,442 people were employed by respondents in 2020. Majority of employees were part time, while 34 percent were full time (figure 13, left). From responses to this study, full time employees are those who are employed from the start to the end of the fishing season, either SEM or NEM, while part time employees are those who are paid daily depending on the availability of fresh *dagaa* for processing. The study further shows that majority of employees (54 percent) were involved in carrying *dagaa* (porters) from fishing boats to processing areas while others were employed in boiling, drying, sieving, guarding, packaging, weighing and some performed all activities together (Figure 13, right). Ibengwe *et al.*, (2022) categorised these employees except for porters as casual labourers.

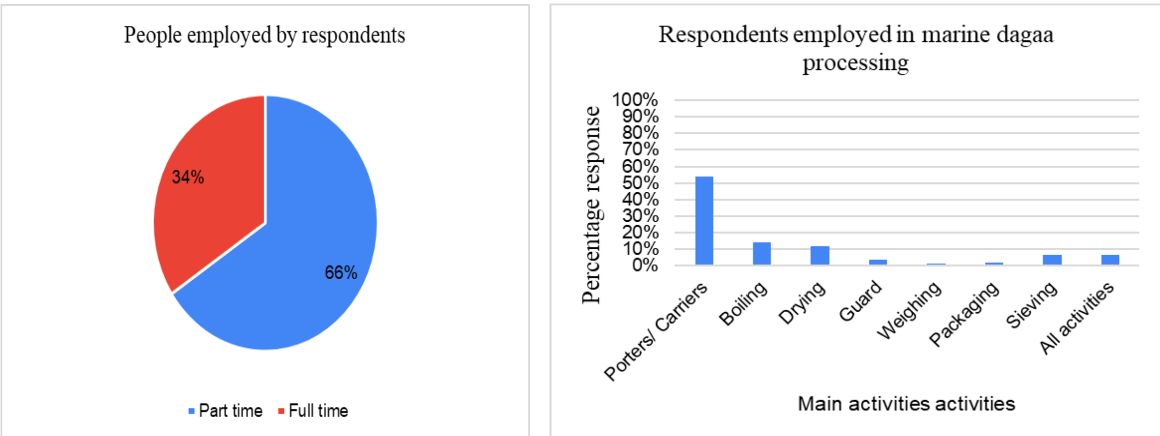


Figure 13: People employed in marine *dagaa* processing (left) with their major roles (right)

The findings further indicate that women play important roles in marine *dagaa* processing as porters or casual labourers. It was revealed that about one third of all people employed by facility owners are women who work as porters carrying *dagaa* (on their heads using plastic basins or baskets) to processing areas while other women were employed as casual labourers in boiling (16.6%), drying (10.8%) and sieving (11.2%). Men were mostly employed as casual labourers in packing *dagaa* (4.7%), guarding (2.6%) and weighing (1.9%) (Table 1 below). These are results from Kilwa District which has more than 40% of all employees in study sites.

The findings are in line with the results from the study carried out along Lake Victoria in Tanzania where women were involved in offloading freshwater *dagaa*, drying and selling (Medard, 2012). Another study conducted along Tanzanian small pelagic fishing community also revealed that women are mostly considered to engage in “petty trades” such as offloading of fish from fishing boats, as well as boiling and drying of *dagaa*. Other studies revealed that more women are engaged in offloading fish since it gives them access to a more reliable and immediate source of income. Women are also thought to prefer offloading fish since it earns them about five (5) times more income a day than if they would engage in other activities such as food vending. Women porters considered that offloading fish gives them more dignity as independent income earners (Mwaipopo & Mahongo, 2020).

Packing, guarding and weighing were considered men’s jobs by respondents which made them employ men in such activities. Some women were found to prefer doing all activities by themselves. This might be due to low income earned by women which means they are unable to pay for labour costs as was revealed by a study carried out along Lake Victoria in Tanzania showing the income of women working in fisheries value chain is often lower in comparison to men (Bradford & Katikiro, 2019).

Table 1: Gender ratio for *dagaa* processing employees in Kilwa District (about 40% of all employees in the study sites).

Activities	No. of Female employees	%Female employees	No. of Male employees	% Male employees
Carrying	298	38.7%	74	9.6%
Boiling	128	16.6%	5	0.6%
Drying	83	10.8%	12	1.6%
Sieving	86	11.2%	2	0.3%
Weighing	2	0.3%	15	1.9%
Packaging	4	0.5%	36	4.7%
Guarding	0	0.0%	20	2.6%
Do myself	5	0.6%	0	0.0%

4.2 Structure of marine *dagaa* processing

The study outlined the key stages and key actors involved in processing marine *dagaa* along Tanzanian coastline. The study discovered that processing marine *dagaa* was aligned across eight key stages: purchasing and carrying, sorting, boiling, drying, sieving, weighing and packaging, storage and selling. Guarding was done throughout the process to overcome theft. Table 2 summarizes the key stages, actors and their roles within the processing node. The data was retrieved to validate the flow chart in Figure 6 above.

Table 2: Key stages, actors, their roles and functions within marine *dagaa* processing

Sno.	Key stage	People involved	Functions performed
1.	Purchasing and carrying	Facility owners & carriers/ porters	-Purchase fresh *dagaa* from fishers -Carriers/ porters carry *dagaa* to processing areas.
2.	Sorting (grading)	Casual labourers	Sort *dagaa* to remove unwanted materials (debris, leaves, stones etc.) Grade *dagaa* (Engraulidae) from *dagaa* of other families, especially large ones that are not suitable for boiling.
3.	Cooking/ boiling	Casual labourers	-Prepare cooking stoves (firewood) -Prepare brine and boil -Place sorted *dagaa* into perforated buckets and dip into boiling brine -Boil perforated buckets with sorted *dagaa* into saline for 3-5 minutes -Drain water from boiled *dagaa*
4.	Drying	Casual labourers	-Spread drained *dagaa* on nylon sheets or racks for open air drying -Turn fish over once or twice a day depending on the intensity of sunlight to allow drying on both sides -Cover *dagaa* with nylon sheets if it rains
5.	Sieving	Casual labourers	-Use large handheld sieve shaker to separate dried *dagaa* from *dagaa* powder.
6.	Weighing and packaging	Casual labourers	-Weigh sieved *dagaa* and pack into sacs ready for storage or transportation to the market. -Weigh *dagaa* powder from sieving to be sold as poultry feed.
7.	Storage	Casual labourers & Facility owners	-Store already dried, sieved and packed *dagaa* ready for selling -Store *dagaa* powder to be sold as a by-product
8.	Wholesaling and retailing	Facility owners	-Selling to regional markets or domestic markets at wholesale and retail

4.3 Respondents' perception on performance of open-air dryer during rainy season

The study assessed respondents' satisfaction on performance of *dagaa* open air dryer (nylon sheets, old fishing nets or raised racks) by using a 5-point Likert scale where "1" was very satisfied and "5" very dissatisfied (Table 3). The findings show that respondents were not satisfied with the drying time, economic gain, space for drying, labour costs as well as shelf life of dried *dagaa* during rainy season. Majority of respondents (70%) were not satisfied with the time spent for drying *dagaa* during rainy season. The results suggest that there is a need to adopt improved methods of drying *dagaa* during rainy season that can improve economic gain, shelf life of the dried product as well as a method that will reduce drying time. Furthermore, findings show that processors might be motivated to implement proposed project as about 76% confirmed that they spend about 24-72 hours drying *dagaa* during rainy season while 16% spend about 96-144 hours, and 8% who decide not to process during rainy season (Figure 14).

Table 3: Percent responses on satisfaction of performance of open air drying during rainy season.

Respondents' satisfaction (179)	**1=very satisfied**	**2= satisfied**	**3=Neutral**	**4=dissatisfied**	**5=Very dissatisfied**
Drying time during rainy season	1%	5%	3%	21%	70%
Shelf life	12%	23%	18%	32%	15%
Labour costs	4%	17%	26%	33%	20%
Space for drying	3%	13%	15%	38%	31%
Economic gain	4%	27%	21%	39%	9%

Responses were measured with 5-point Likert scale where 1=very satisfied, 2 = moderately satisfied, 3 = neutral, 4 = moderately dissatisfied and 5= very dissatisfied.

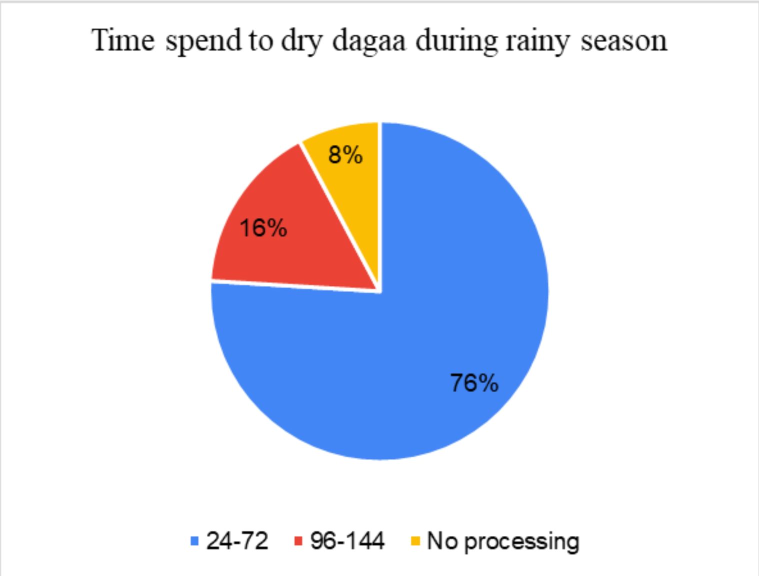


Figure 14: Time spent to dry *dagaa* during rainy season

4.4 Physical and economic losses associated with drying *dagaa* during rainy season

Due to the challenges that *dagaa* processors face along Tanzanian coastline, this study assessed the percentage equivalent dry weight of fresh *dagaa* based on output/input ratio. The equivalent dry weight was used to estimate dry weight of marine *dagaa* that was discarded or washed away due to prolonged rainfall. It was found that the average percentage equivalent dry weight of marine *dagaa* was 35% output/input ratio (Table 4).

Table 4: Equivalent dry weight of marine *dagaa* processed by respondents.

	Weight (kg)
Total amount purchased (fresh)	221,770.00
Total amount processed (dried)	77,337.50
Equivalent dry weight	35%
Total purchased high season	174,957.50
Processed high season	61,374.00
Equivalent dry weight	35%
Purchased low season	46,812.50
Processed low season	15,963.50
Equivalent dry weight	34%
Average equivalent weight (output/input)	35%

The study further revealed that about 770 metric tons of *dagaa* was lost in 2020 due to physical and quality losses (Table 6 & Table 7 below). This incurred a monetary loss for processors of approximately 1 million USD. According to data from district fisheries officers (KIIs) about 3% of the value of dried *dagaa* is charged by Local Government Authorities (LGAs) as fish levies. Due to the loss that processors incur, this led to a loss of approximately 33,000 USD for the government. This is the loss in revenue collection from local and national trade. With reference to the fisheries (amendment) regulation of 2018, gazetted on 24th August 2018 under the Government Notice number 468, 0.16 USD is charged per kilogram of marine dried *dagaa* that is exported (MLF, 2018). Therefore, the government is estimated to have lost about 123 thousand USD in 2020, if the lost *dagaa* was to be exported.

Based on amount of marine *dagaa* landed in 2020 (MLF, 2020), about 70% of the landed *dagaa* is estimated to be processed by boiling and drying while the remaining is either left for immediate consumption or processed by other methods. The study revealed a total marine *dagaa* loss of about 39% due to *dagaa* quality deterioration, discarding, and/or washed away by rainfall (Table 5).

Table 5: Percentage marine *dagaa* loss during rainy season

Amount landed in 2020 (fresh weight, mt.)	Estimated amount remain for boiling and drying (~70%)	Equivalent dry weight (35%, output/input ratio) in mt.	Amount lost during rainy season (mt.)	% Loss
8,000	5,600	1,960	772.1	39

4.4.1 *Economic losses due to marine dagaa quality deterioration along Tanzanian coastline*

The study shows that 88% of respondents sold *dagaa* at prices lower than the market value due to spoilage (Figure 15, left). The price of dried *dagaa* was reduced due to reasons such as presence of mould, change in colour (discolouration), presence of odour and maggots (Figure

15, right). Other factors that contributed to downgraded dried *dagaa* include improper drying due to rainfall, breakage of dried *dagaa* and purchase of low quality fresh *dagaa*. The same reasons were mentioned to be the causes of sun-dried fresh water *dagaa* losses along Lake Victoria (Akande & Diei-Ouadi, 2010).

The majority of respondents (79%) declared that they encountered discolouration in processed *dagaa* which resulted into downgrading, hence lower prices than the market value, while only 4% encountered presence of maggots. Discolouration in dried fish is considered as one of the signs for deterioration. Discolouration might be caused by rancidity which is said to be more pronounced in oil rich fishes like *dagaa* when exposed under open air, hence change in the colour of the fish to brown. The presence of impurities in salt that is used for processing as well as metal traces from the cooking pots might also accelerate discolouration (CIFT, 2021).

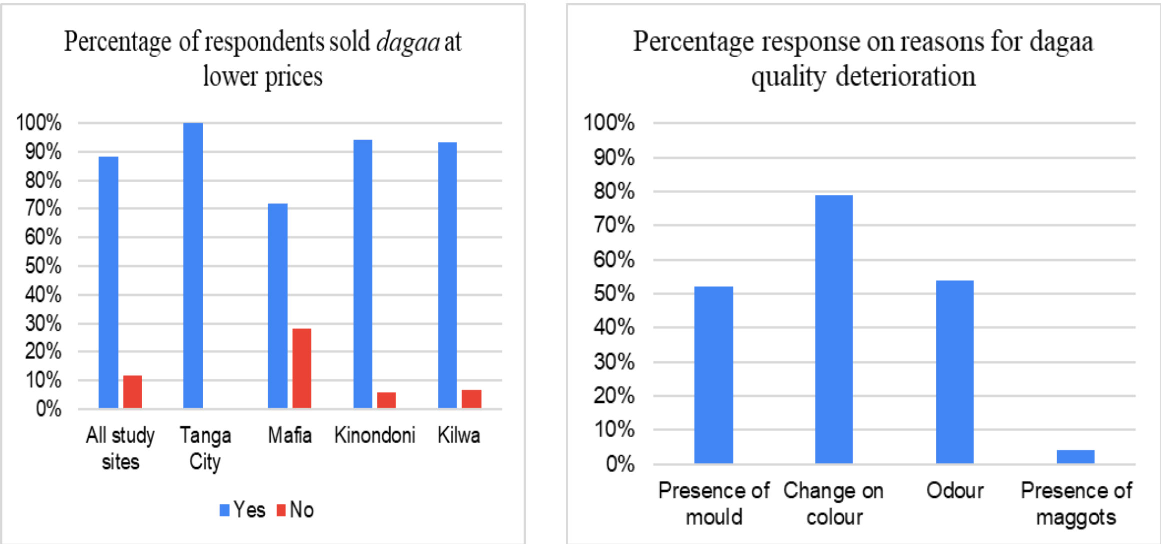


Figure 15: Percentage of respondents sold *dagaa* at lower price due to quality deterioration (left); Percentage response on reasons for quality deterioration (right).

This study further revealed that each respondent sold about 450 kilograms of dried *dagaa* at prices lower than the market value which incurred each a loss of about 600 USD. According to data from questionnaires, the price of downgraded dried *dagaa* was approximately half the market price of dried *dagaa* per kilogram (Table 6). It was then estimated that there are about 1,500 *dagaa* processors along the Tanzanian coastline (MLF, 2018). Therefore, about approximately 700 metric tons of dried *dagaa* were sold at a price lower than the market value due to quality deterioration (Table 6). This resulted into monetary loss of about 900,000 USD. The study further revealed that discolouration was the main reason for quality deterioration as it contributed to about 52% of the total *dagaa* quality loss (Table 6).

Table 6: Economic loss due to downgraded dried *dagaa* during the rainy season.

Reasons for spoilage	Dry weight (mt.)	Income from good quality *dagaa* (T.sh in millions)	Income from low quality *dagaa* (T.sh in millions)	Economic loss in 2020 (T.sh in millions)	Economic loss in 2020 (USD)
		Quality losses			
Improper drying	312.3	1,873	937	936.5	407,328
Breakage	4.2	25	12.7	12.5	5,510
Purchase Low quality *dagaa*	19.2	115	57.5	57.3	24,988
Improper packaging and storage	1.6	9.5	4.7	4.6	2,043
Change in colour	369.1	2,214	1,107	1,107.2	481,391
Total quality losses	**706.4**	**4,237**	**2,118.9**	**2,118.1**	**921,261**

4.4.2 Physical losses of marine dagaa along the Tanzanian coastline

The study further indicates that 40% of respondents discarded *dagaa* after prolonged rainfall with 47% of respondents coming from Tanga City Council (Figure 16, left). This might be because all processors in Tanga City Council dry boiled *dagaa* on the ground (on nylon sheets or old fishing nets) which make it difficult to collect if it rains. It was also observed that only 9% of respondents declared that their *dagaa* was washed away by rain (Figure 16, right). This might be due to several traditional mechanisms that respondents adopted to minimize losses such as covering *dagaa* on the ground with nylon sheets, removing *dagaa* as soon as there are signs of rain, and for those using racks, covering *dagaa* with nylon.

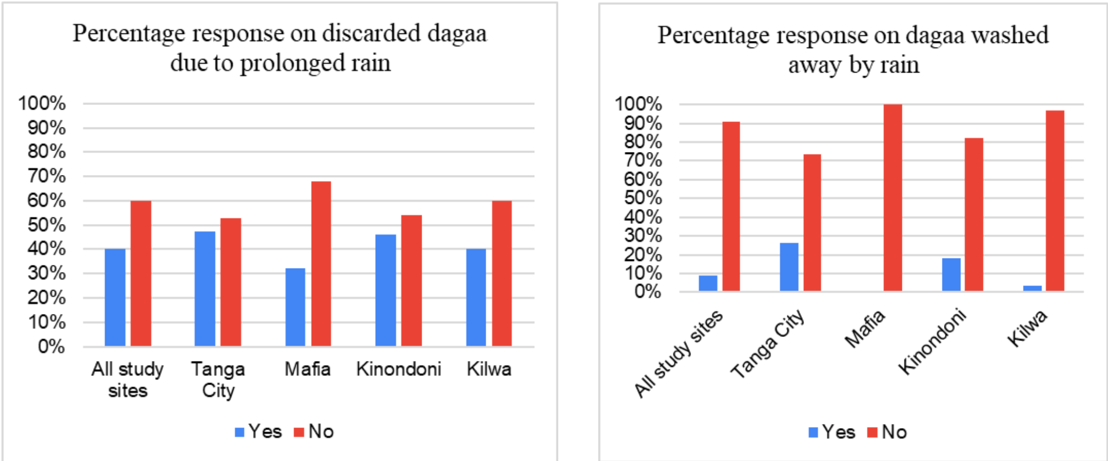


Figure 16: Percentage response on discarding *dagaa* due to prolonged rain (left); Percentage response on *dagaa* washed away by rain (right).

The study further shows that a total of 55.1 tons of *dagaa* (equivalent dry weight) was discarded while 10.6 tons (equivalent dry weight) washed away due to prolonged rain. This amount responds to about 170,000 USD (Table 7). The Tanzanian MLF also reported that processors throw away or discard *dagaa* during rainy season due to the highly dependence on open sun drying which is not effective during rainy season (MLF, 2020).

Table 7: Physical marine *dagaa* loss during rainy season

	Physical losses		
Reasons for losses	**Calculated Dry weight (m.t)**	**Income loss (T.sh in millions)**	**Income loss (USD)**
Amount thrown away/discarded after prolonged rain	55.1	330.9	143,000
Amount washed away by rain	10.6	63.8	27,000
Theft	Not quantified		
Total physical losses	**65.6**	**394.7**	**170,000**

4.4.3 Estimation of losses in four pilot districts

To determine losses incurred by processors in four pilot districts, it was estimated that there are 639 *dagaa* processors in pilot districts (data from DFsO in pilot districts). It was also assumed that the processors were trained, hence were aware of the proposed solar tent dryers. The study revealed that processors incur an approximate 300 metric ton loss of *dagaa* which led to a monetary loss of approximately 460,000 USD (Table 8).

Table 8: *Dagaa* losses during rainy season in pilot districts

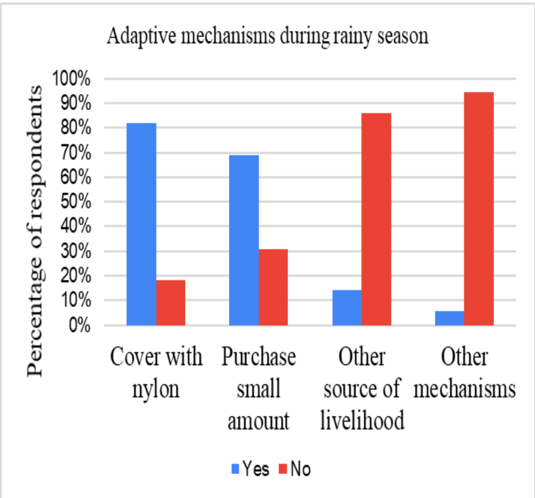
Reasons for losses	**Amount of *dagaa* lost (mt.)**	**Monetary loss (t.sh. in millions)**	**Monetary loss (USD)**
	Quality losses		
Improper drying	133	399	173,521
Breakage	1.8	5.4	2,347
Purchase Low quality *dagaa*	8.2	24.5	10,645
Improper packaging and storage	0.7	2	870
Change in colour	157.2	471.7	205,072
	Physical losses		
Discarded	23.5	141	61,286
Washed away	4.5	27.2	11,825
Total losses (physical and quality) in 2020	328.9	1,070.8	465,569

4.5 Preventive measures used by *dagaa* processors during rainy season

Due to losses that marine *dagaa* processors face during rainy season, they have adapted to several mechanisms to minimize the impact. The study revealed that majority of respondents (82%) use nylon sheets to cover *dagaa* to prevent it from being rained on, while about 69% preferred to purchase small amount of *dagaa* for processing during rainy season (Figure 17, left). Covering *dagaa* with nylon sheeting is said to restrict air movement, hence slows the drying process within the racks (El-Sebaii & Shalaby, 2012). This might be one of the reasons for *dagaa* losses along Tanzanian coastline.

The study further reveals that about other 14% of respondents prefer not to process during rainy season and they change to other sources of livelihood, while only 6% prefer other adaptive mechanisms such as collecting spread *dagaa* and place inside their houses if there is sign of rain.

The study further indicates that 52% of respondents, despite carrying out *dagaa* processing activities, also have other sources of livelihood (Figure 17, right). In three pilot districts, more than 50% of respondents had other sources of income, except for Mafia district, where only 46% of respondents had other sources of livelihood. This might be because Mafia district is an island and its economy is based on fishing and fisheries-related activities, tourism, and subsistence agriculture. The lives of people on Mafia district island have been traditionally closely related to the sea and over 40% are said to depend on fisheries with women concentrated in fish processing and retail businesses while men go fishing (Mulyila et al., 2012).



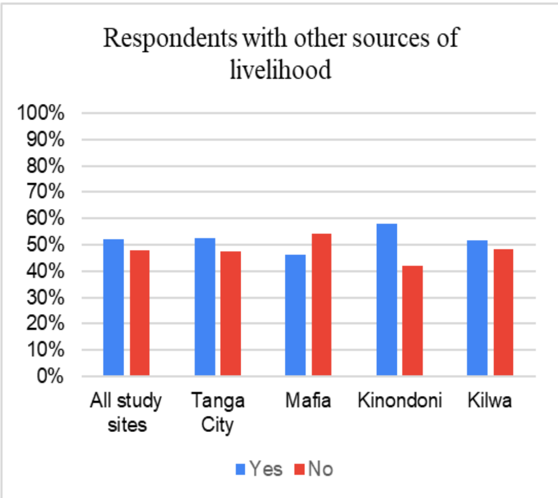
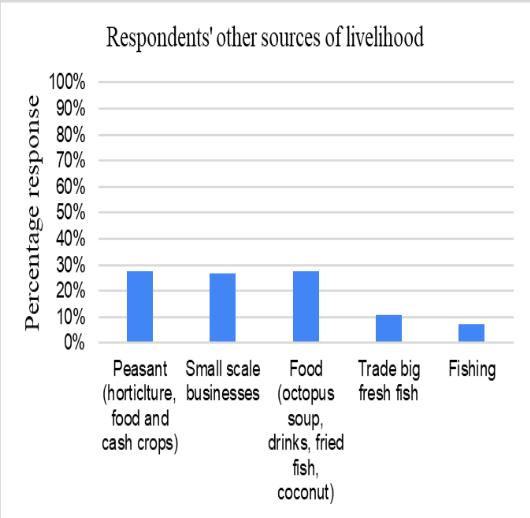


Figure 17: Adaptive mechanisms used by *dagaa* processors during rainy season (left); Percentage of respondents processing *dagaa* with other sources of livelihood (right).

The study further indicates that respondents in Figure 17, right, were engaged in other activities such as cultivating food and cash crops (28%), small scale (27%) and food businesses (28%) (Figure 18, left). Previous studies shows that processors are engaged in alternative sources of livelihood to enable them to have a greater choice of flexibility, hence this reduces their vulnerability upon fishing impacts. Coastal communities are said to adopt many alternative sources of livelihood due to the decline in marine fish catches (Silas, et al., 2020).

This study also investigated ways in which respondents with no other sources of livelihood (48%) meet their family needs during the rainy period. It was found that the majority of respondents (67%) with no other sources of income use their savings from processing *dagaa* during sunny periods while 27% reduce their expenditures and only 8% of respondents borrowed money from other sources to meet their family needs (Figure 18, right).



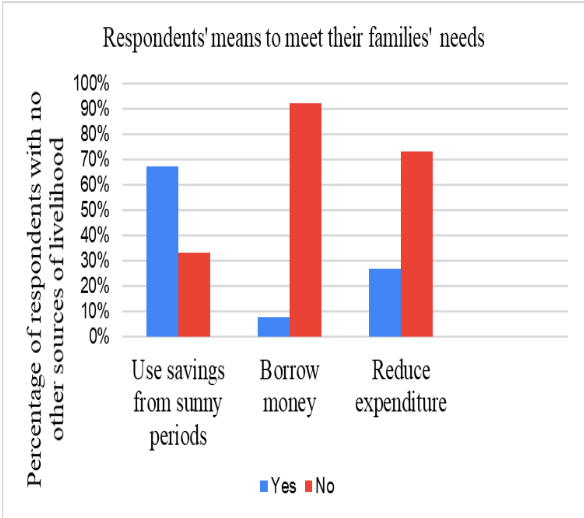


Figure 18: Alternative sources of respondent livelihood (left); respondents with no other sources of livelihood (right).

4.6 Support and assistance given to marine *dagaa* processors

Due to challenges that *dagaa* processors face and the traditional adaptive mechanisms they use to minimize the impact of *dagaa* losses, this study investigated the support and assistance that respondents received to help them overcome losses. The study revealed that some respondents received assistance in terms of training and loans while others were assisted in joining village commercial banks (VICOBA) which provided them with loans to run *dagaa* processing businesses. The type of support that respondents received was divided into training and financial support or working equipment provided by the government and/or other development partners.

4.6.1 Fish handling and processing training to dagaa processors

The study shows that only 23% of respondents were trained on fish handling and processing from 2014 to 2021. Majority of trained respondents (36%) are from Mafia district while no respondent from Tanga City was trained on fish handling and processing (Figure 19, left). Most of trained processors (65%) got their training from Fisheries Officers from government bodies (MLF and or LGAs), but 26% were trained by NGOs and CSOs like Worldwide Fund for Nature and Sea (Fig. 19, right).

The findings show that there is a need to strengthen awareness on fish handling and processing to *dagaa* processors who are mostly women. Since most women take care of families, any support provided to their processing businesses will improve their livelihood as well as benefit the economy of coastal communities who are considered as marginalized. To minimize the impacts of PHLs, governments, development agencies, and civil society organizations need to make substantial investments in creating awareness to processors to improve their capacity to minimize losses.

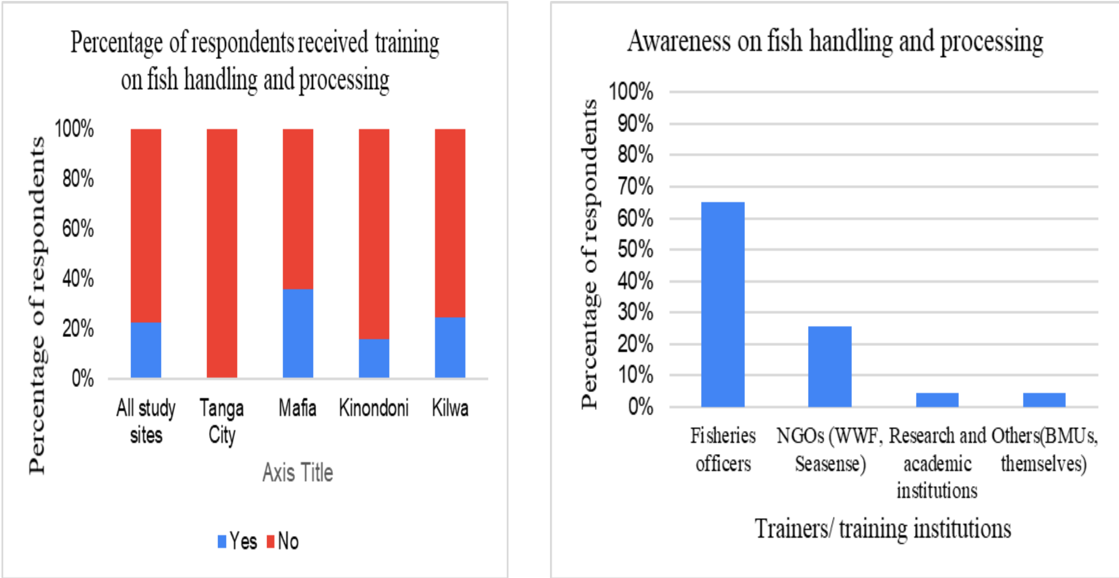


Figure 19: Awareness training on fish handling and processing (left); Institutions providing training (right).

4.6.2 Government support given to respondents

The findings of this study show that only 15% of respondents received support from the government. Majority of respondents (67%) who received support from the government were in terms of loan from LGAs (Figure 20). In 2019, the Tanzanian Local Government Finance Act of 1982, CAP 290, section 37A, was amended to mandate local councils to set aside 10% of their own sources of revenue, at no interest rate, to empower registered groups of women (4%), youth (4%) and disabled people (2%) with loans (MOF, 2019). In this study, all of respondents (100%) who received loan from LGAs were women.

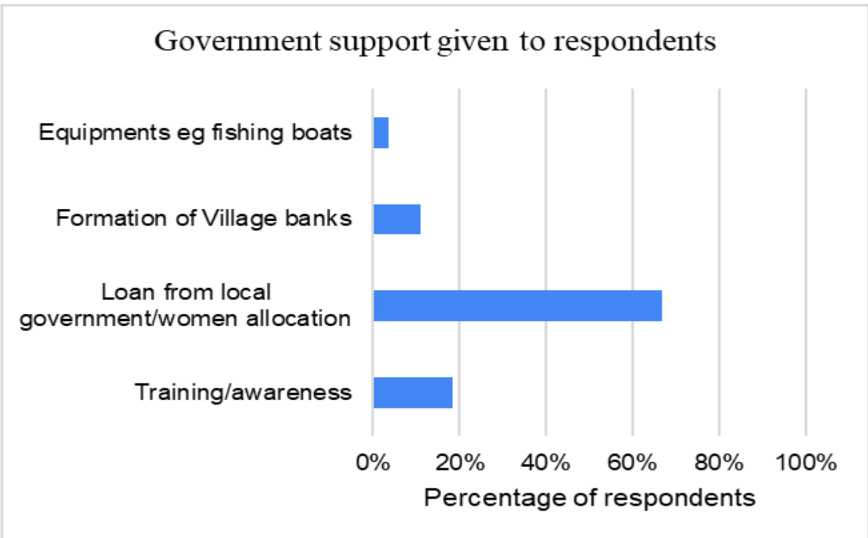


Figure 20: Government support given to marine *dagaa* processors.

4.7 Cost benefit analysis of proposed project

Cost benefit analysis was used to determine whether adopting proposed solar tent dryers to reduce *dagaa* losses, especially during rainy season, will have positive public value in the future. This study evaluated all the construction and operational costs for proposed solar tent dryers as well as the benefits that will be generated by the proposed project.

4.7.1 Costs associated with implementation and investment of proposed solar tent dryers

Table 9 below shows the cost for construction of one (1) proposed dryer (investment, operational and implementation) for one year. About 2,400 USD is needed to construct one proposed dryer. Maintenance of proposed solar tent will be performed annually with replacement of polythene sheets that cover the solar tent as well as chicken wire and plastic gauze on drying racks, hence about 1000 USD will be needed for maintenance of one tent (Table 10, below).

In this study, two (2) proposed solar tents will be constructed in each of the four pilot districts which will need investment and maintenance costs of about 19,800 USD and 8,300 USD respectively (Table 10 below).

Table 9: Estimated costs for construction of a proposed solar tent dryer

COST FOR CONSTRUCTION OF ONE SOLAR TENT DRYER					
ITEM	**DESCRIPTION/ UNITS**	**QUANTITY**	**PRICE (TZS)**	**TOTAL (TZS)**	**TOTAL (USD)**
INVESTMENT COST					
200 µm UV Polythene sheet	100 m	2	100,000	200,000	**87**
Building the base/foundation					
Bricks	No.	800	200	160,000	70
Sand	tones	6	18,500	111,000	48
Quarry stones	tones	6	27,000	162,000	70
Cement	bags	30	15,000	450,000	196
Sub total					**384**
Building the wall and vents					
planks.	2”x 6”	40 pc @ 12ft	1,200/ft	576,000	250
ripped planks	2”x 3”	45 pc @ft 6	800/ft	216,000	94
Fine meshed gauze	50m	1pc @50m	4,000	200,000	87
Sub total					**431**
Building a door					
planks	2” x 4”	45pc @ 8ft	1,200	432,000	**188**
Building raised racks					
planks	2”x 2”	40 pc @ 4ft	450	72,000	31
chicken wire	50m	4 pc @50m	5,000	1,000,000	435
plastic gauze	50m	3 pc @50m	4,000	600,000	261

Nails	1”	20 kg @1”	6,000	120,000	52
Nails	2”	20 kg @1”	4,000	80,000	35
Nails	3”	20 kg @1”	4,000	80,000	35
Nails	4”	20 kg @1”	4,000	80,000	35
Nails	6”	20 kg @1”	4,000	80,000	35
Sub total					**918**
OPERATIONAL COSTS					
Labour	Estimate			1,000,000	435
Transport				100,000	43
	Subtotal				**478**
IMPLEMENTATION COST					
Monitoring and evaluation			-	-	-
GRAND TOTAL				**4,819,000**	**2,487**

4.7.2 Benefits associated with implementation and investment of proposed solar tent dryers

In this study, benefit evaluation was based on the improved economic gain expected through acquiring market price for improved product as well as *dagaa* that was saved from discarding or washed away due to prolonged rain after implementation of proposed solar tents.

According to the guide developed by Chiwaula *et al.*, (2017), one solar tent is estimated to have a capacity of drying about 850 kilograms of fresh *dagaa* per one drying cycle which is on average equal to one day during rainy season. It was estimated that 8 dryers (in pilot districts) would dry 6,800 kilograms of fresh *dagaa* that would yield about 480 tons of dried *dagaa* per year. The estimated amount of *dagaa* to be dried was determined by assuming that the dryer will be used to full capacity for six months of a year (NEM) and 70% of capacity during other six months (SEM). This was estimated based on variations in marine *dagaa* landing data during NEM and SEM seasons. The proposed solar tents are anticipated to reduce losses by 50% from the current 39% to 20%, thus about 390 tons of dried *dagaa* will be available for sale, hence it is anticipated that a revenue of about 840,000 USD will be generated annually (Appendix 3).

Apart from revenues that will be gained by *dagaa* processors, the findings of this study show that the government will also benefit from implementation of solar tents. It is anticipated that the government will earn about 25,000 USD each year during the project implementation. This will be revenue collected from fish levies in local and national trade and for the regional trade, the government is estimated to earn approximately 62,000 USD annually. Solar tent dryers are anticipated to save government revenues (fish levies) from national or local fish trade and regional trade by about 77% and 50% respectively (Appendix 4).

4.8 Net benefit and Net Present Value (NPV) for the proposed project

The overall financial net benefits of using solar tent dryer in pilot districts is presented in this section. It was found that the net benefit for using solar tent is about 21,800 USD each year in all pilot districts with the NPV of 74,528 USD (Table 10). The proposed solar tent dryer project was then considered feasible as the NPV > 0. This means that the money that will be earned on investing solar tent dryers will be more than the money invested hence it is a beneficial project to be carried out.

Years	**0**	**1**	**2**	**3**	**4**	**5**
COSTS						
Initial investment (USD)	19,892					
Capital cost		814,226	814,226	814,226	814,226	814,226
Maintenance cost						
Replacement of polythene sheet each year		696	696	696	696	696
Chicken wire		3,478	3,478	3,478	3,478	3,478
Plastic gauze		2,087	2,087	2,087	2,087	2,087
Labour costs		1,739	1,739	1,739	1,739	1,739
Transport		348	348	348	348	348
Total maintenance cost		8,348	8,348	8,348	8,348	8,348
Total cost (capital & maintenance)		822,574	822,574	822,574	822,574	822,574
BENEFITS (USD)						
Benefit for drying on tents		844,383	844,383	844,383	844,383	844,383
Net benefit (USD)/revenues		21,809	21,809	21,809	21,809	21,809
Present value benefit/ discounted inflows		20,770	19,781	18,839	17,942	17,088
Present value benefits	94,420					
Initial investment	19,892					
Net present value	74,528					

Table 10: Five-year cost and benefit analysis for proposed solar tent dryers.

4.8.1 Payback period for proposed project

The findings show that the project will start generating profit after nine (9) months (Appendix 5). Therefore, it will take nine months for the project to reach its full potential. This shows that solar tent dryers have higher returns with a promise of quick inflow of cash. Since payback period is an effective measure of risk in investing projects, the findings revealed that proposed solar tent dryers have less risk. Chiwaula *et al.*, (2020) revealed a payback period of one to two years for solar tent dryers constructed along Lake Malawi. The difference in three (3) months between this study and the previous study might be due to the difference in price of dried product, as marine *dagaa* attain higher market prices compared to *dagaa* from the previous study.

5 CONCLUSION AND RECOMMENDATIONS

This study assessed the economic feasibility of a proposed solar tent dryer in reducing *dagaa* losses during the rainy season along the Tanzanian coastline. In addition, the study quantified marine *dagaa* physical and quality losses linked to poor drying conditions. Furthermore, the study collected information on the fish processors' community.

Six main research questions were set to meet the objectives of this study. The questions set were: Who are involved in processing of dried *dagaa* along Tanzanian coastline? What quantity of dried *dagaa* is lost due to spoilage, discarded or washed away during rainy season? How much income (money) is lost by processors due to spoilage or throwing away of processed *dagaa* during rainy season? Are the *dagaa* losses incurred by processors significant? What are the expected costs and benefits of using solar tent dryer? And finally: If investing in a proposed solar tent dryer is economically feasible?

This study revealed eight (8) key stages in marine *dagaa* processing including the main actors and their main roles. With the majority (59%%) of processors being women, the study further discovered three main categories of marine *dagaa* processors; owners of land based marine *dagaa* processing facilities, casual labourers and porters, as was revealed by Ibengwe *et al.*, (2022). Facility owners have responsibility for purchasing fresh *dagaa* from fishers, overseeing the processing activities, as well as wholesaling, and/or retailing. They employ casual labourers for grading, boiling *dagaa* in brine, drying, sieving, weighing, packaging and storing activities while porters are employed for carrying fresh *dagaa* (on their heads) to processing areas using plastic basins or baskets.

The findings further revealed that open sun drying of marine *dagaa* resulted in physical and quality loss of about 770 metric tons of marine *dagaa* which led to monetary loss of approximately one million USD. This loss does not only affect processors but the government also which experiences a reduction in fisheries revenue, food security and nutrition due to PHLs. It was revealed that LGAs lose approximately 33,000 USD annually through loss in revenue from local and national *dagaa* trade while MLF is anticipated to lose about 123,000 USD annually if the lost *dagaa* was to be exported to regional markets. This might be one of the reasons for the decline in fisheries sector contribution to Gross Domestic Product and foreign exchange earnings as was reported by studies conducted on Lake Victoria *dagaa* by Akande & Diei-Ouadi (2010).

It was found that quality losses contributed to approximately 90% of the total losses with discoloration being the main reason. The findings revealed that about 50% of downgraded dried marine *dagaa*, which sold at a lower price than the market value, was due to discolouration. Physical losses due to discarding were found to contribute about 9% only, while the amount of *dagaa* that was washed away by rain was found to be insignificant (1%). The findings show that there is a need to adopt improved methods of drying marine *dagaa* as discolouration is considered one of the signs of deterioration which is caused by drying oily fish (*dagaa*) under open sunlight making *dagaa* prone to lipid oxidation hence browning (Owaga et al., 2009); (CIFT, 2021).

From the analysis it was revealed that the number of processors who received training on fish handling and processing was insignificant (23%). This shows that processors do not receive extension services from fisheries officers, and this might be because of lack of knowledge and skills on fish handling and processing by fisheries officers who are expected to provide such services. This calls upon all stakeholders (LGAs, MLF, development partners, decision makers, local communities and other government agencies) to come together and act upon reducing marine *dagaa* losses. The study further shows a need for LGAs to empower fisheries extension officers in their districts to improve capacity building to marine *dagaa* processors in Tanzania.

To reduce losses that processors incur, this study assessed all the costs and benefits of implementing solar tent dryers in four pilot coastal districts of Tanga City, Kinondoni, Mafia and Kilwa. The project aimed to construct eight (8) solar tents in total, two in each district. The estimated cost of constructing eight dryers was 19,800 USD with an estimated annual maintenance cost 8,000 USD. The overall financial net benefits of using solar tents were found to be about 21,800 USD annually in all pilot districts.

To make an investment decision on whether adopting the proposed solar tents was feasible, the study further computed the NPV to be 74,528 USD which revealed the project to be economically feasible, therefore likely to succeed. The study further analysed the payback period of the project to determine the length of time until the proposed project could start generating a profit. It was found that the proposed project will start generating profit after nine (9) months. This shows that there is low risk in investing to solar tent dryers as the returns are anticipated to be high. This is because the shorter time the money is tied up in a project the more opportunity there is to invest in the same project in other coastal districts.

For this project to be implemented and operate successfully, the following suggestions and recommendations are made based on the study.

There is a need for the MLF, who is the custodian in fisheries matters, and LGAs to work together in preparing a training need assessment for fisheries extension officers in fish handling and processing. Provision of training to extension officers will improve extension services and lead to a reduction in *dagaa* losses. Training should also be extended to all stakeholders in fisheries including government officials, policy makers, village officials and coastal communities at large.

Processors should also be trained on general management skills including management of dryers and record keeping as this study revealed (observation from questionnaires) that most of *dagaa* processors, especially women, do not keep records of their financials due to lack of managerial skills. Training influences the increased performance and financial skills of women processors who mostly lack knowledge. Women processors or entrepreneurs who underwent training on managing their businesses were reported to have changed in attitude in terms of managing their businesses and improving their income as was shown by Mtani and Nyangarika (2020).

Apart from capacity building on fish handling and processing, detailed research is needed on marine *dagaa* quality losses during rainy season as the study revealed that about 90% of losses is due to quality deterioration. The research should specifically assess the causes for discolouration in boiled sun dried *dagaa* as several reasons such as metal traces, rancidity or salt impurities were mentioned to contribute to discolouration.

Due to higher initial investment cost of this project, LGAs may support registered groups of women processors with a 4% loan to construct solar tent dryers, since LGA is mandated by Local Government finance Act of 1982 CAP 290 (Amended in 2019) section 37A to empower women registered groups with loans to improve their businesses. Since the majority of women are involved in processing, there is a need for fisheries extension officers to sensitize women processors to register into groups through community development officers and apply for women´s loans through Districts Executive Directors.

There is a need for the Ministry of Fisheries and Livestock to develop a National Fisheries Post Harvest Loss Management Strategy since the current NPHLMS that was developed by the Ministry of Agriculture does not address fisheries issues. This might be the reason why Tanzanian fisheries matters are not well addressed in AU-PHLMS.

In conclusion, reducing marine *dagaa* post-harvest loss is crucial to coastal communities as well as the government. Adopting solar tent dryers is important in reducing losses as it was revealed to be economically feasible with a very short payback period.

ACKNOWLEDGEMENTS

I am grateful to Almighty God who kept me safe and healthy throughout my stay in Iceland. I would like to give my sincere appreciation and gratitude to my supervisors Arnheiður Eyþórsdóttir and Guðrún Arndís Jónsdóttir from the University of Akureyri for their professional and technical guidance throughout my study. I am truly thankful for the time, constructive comments and guidance they gave.

I would also like to thank Hreiðar Þór Valtýsson as head of Fisheries Policy and Management line specialization. He was so welcoming and ready to solve any matters that arose despite a tight schedule.

I am especially grateful to the GRÓ FTP team for providing the opportunity to participate in this fellowship. Special appreciation to the Director of the GRÓ Fisheries Training Programme Mr. Thor Asgeirsson, Deputy Director Mary Frances Davidson, Julie Ingham, Stefán Þ. Úlfarsson, Dr. Tumi Tómasson and Agnes Eydal.

I would also like to thank my employer, the Director of Tanga City Council for granting me study leave to attend this program. My special gratitude goes to the Ministry of Livestock and Fisheries for nominating me. A big thank you to all fisheries officers who were involved in data collection at the study sites, your work is appreciated.

I would like to thank my colleagues from 2021/22 GRÓ FTP fellowship for the moments we shared together in Iceland. Special thanks to Fisheries Policy fellows for the encouragement, knowledge, skills and experience shared together as a family. Special thanks to James Banda from Malawi Fisheries Research Institute for sharing his experience, skills and knowledge on solar tent dryers.

Lastly, to my family who have been supportive since I was offered this fellowship. I would like to thank my husband Philip, my son John and my sister Josephine for their patience, encouragement, support and understanding during my absence from home. I would also like to extend special thanks to my parents and siblings (Veronica, Herieth and Gibson) for their encouraging messages throughout the study period. Thank you and may God bless you all.

REFERENCES

Abraha, B., Samuel, M., Mohammud, A., Habte-Tsion, H., Admassu, H., & Al-Hajj, N. (2017). A Comparative Study on Quality of Dried Anchovy (Stelophorus heterolobus) Using Open Sun Rack and Solar Tent Drying Methods. *Turkish Journal of Fisheries and Aquatic Sciences, 17*, 1107-1115.

Akande, G., & Diei-Ouadi, Y. (2010). *Post-harvest losses in small-scale fisheries: Case studies in five sub-Saharan African countries.* Rome: FAO of United Nations.

Anam, R., & Mostarda, E. (2012). Field identification guide to the living marine resources of Kenya. 422.

Anderson, J., & Samoilys, M. (2016). The Small pelagic fisheries of Tanzania. In J. Anderson, & T. Andrew, *Case studies on climate change and Agrican coastal fisheries: A vulnerability analysis and recommendations for adaptation options* (Circular No.1113 ed., p. 188). Rome: FAO.

AU. (2018). *African Union Post-Harvest Loss Management Strategy-PHLMS.* Addis Ababa, Ethiopia: African Union Commission.

Bank of Tanzania. (2020, December 31). *Economic statistics publication*. Retrieved February 15, 2022, from www.bot.go.tz: https://www.bot.go.tz/Publications/Filter/13

Bianchi, G. (1985). *FAO species identification sheets for fishery purposes. Field Guide to the Commercial Marine and Brackish-water Species of Tanzania.* FAO. Rome: Prepared and published with the support of TCP/URT/4406 and FAO (FIRM) Regular Programme.

Boardman, A. E., Greenberg, D. H., Vining, A. R., & Weimer, D. L. (2018). *Cost Benefit Analysis: Concepts and Practice* (Fifth ed.). University of British Columbia, Vancouver, United Kingdom: Cambridge University Press,.

BoT. (2020, May 8). *Press release*. Retrieved 01 04, 2022, from https://www.bot.go.tz/: https://www.bot.go.tz/Adverts/PressRelease/en/20200610213039114.pdf

Bradford, K., & Katikiro, R. E. (2019). Fighting the tides: A review of gender and fisheries in Tanzania. *Fisheries Research, 216*, 79-88.

Breuil, C., & Bodiguel, C. (2015). *Report of the Meeting on Marine Small Pelagic Fishery in the United Republic of Tanzania.* FAO.

Chiwaula, L. S., Chirwa, G. C., Binauli, L. S., Banda, J., & Nagoli, J. (2018). Gender differences in willingness to pay for capital-intensive agricultural technologies: the case of fish solar tent dryers in Malawi. *Agricultural and food economics, 6*(1), 15.

Chiwaula, L. S., Kawiya, C., & Patrick, S. (2020). Evaluating Economic Viability of Large Fish Solar Tent Dryers. *Agricultural Resources, 9*(20), 270-276.

Chiwaula, L. S., Nagoli, J., Kanyerere, G., & Chisale , E. (2017). *Guide to solar tent fish dryer (Samva Nyengo) construction and use module.* Malawi: Processing section, Fisheries Research Unit.

Chiwaula, L., Jamu , D., Chaweza , R., & Nagoli , L. (2012). *The structure and margins of the Lake Chilwa fisheries in Malawi: a value chain analysis.* Penang: WorldFish.

Chiweza, A. L. (2005). Women's inheritance rights in Malawi: the role of district assemblies. *Development in Practice, 15,* 83–89.

Chou, S. K., & Chua, K. J. (2001). New hybrid drying technologies for heat sensitive foodstuffs. *Trends in Food Science and Technology, 12*(10), 359-369.

CIFT. (2021, 10 12). *Central Institute of Fisheries Technology; (Cochin); Knowledge base*. Retrieved 02 22, 2022, from https://www.cift.res.in/: https://www.cift.res.in/uploads/userfiles/SPOILAGE%20OF%20FISH%20PRODUCTS.pdf

Coastal Resources Center. (2016). *Value chain and fish postharvest loss assessment of four small pelagic lake fisheries in Malawi.* Graduate School of Oceanography, University of Rhode Island, Fisheries. Narragansett: Coastal Resources Center.

Diei-Ouadi, Y., & Mgawe, Y. (2011). *Post-harvest fish loss assessment in small-scale fisheries: A guide for the extension Officer.* Rome: FAO of the United Nations.

Doe, P. E., Ahmed, M., Muslemuddin, & Sachithanathan, K. (1977). A polyethylene tent dryer for improved Sun drying of fish. *Food technology in Australia*, *29*, 437 – 441.

El-Sebaii, A. A., & Shalaby, S. M. (2012). Solar drying of agricultural products: A review. *Renewable and Sustainable Energy Reviews, 16,* 37-43.

FRU. (2017). *Samva Nyengo Solar Tent Fish Dryer:Construction and Operation.* Monkey-Bay Mangochi, Malawi: Fisheries Research Unit. Retrieved January 02, 2022, from http://www.malawifisheries.org/: http://www.malawifisheries.org/bitstream/handle/20.500.12364/1194/Samva%20Nyengo%20Solar%20Tent%20Fish%20Dryer-%20Construction%20and%20Operation.pdf?sequence=1&isAllowed=y

Galo, A. (2014, November 19). A Refresher on Net Present Value. (J. Knight, Interviewer) Havard University.

Garrido, S., & van der Lingen. (2014). Feeding biology and ecology. In K. Ganias, *Biology and Ecology of Sardines and Anchovies* (pp. 122 - 189). Alaska, USA: CRC Press. doi:10.1201/b16682

Ibengwe, L. (2010). *Reducing post-harvest losses of the artisanal dagaa (Rastrineobola argentea) fishery in Lake Victoria, Tanzania: A cost-benefit analysis.* Reykjavik, Iceland: UNU-FTP.

Ibengwe, L. J., Onyango, P. o., Hepelwa, A. S., & Chegere, M. J. (2022). Regional trade integration and its relation to income and inequalities among Tanzanian marine *dagaa* fishers, processors and traders. *Marine Policy,* 137.

IDRC-CRDI. (2020, April 1). *International Development Research Centre*. Retrieved January 2, 2021, from https://www.idrc.ca/: https://www.idrc.ca/en/research-in-action/gender-inclusive-financing-scale-fish-processing-technologies#:~:text=Using%20the%20solar%20tent%20technology%20can%20reduce%20product,1.9%25%2C%20and%20quality%20losses%20from%209.2%25%20to%201.4%25.

Immaculate, J., Sinduja, P., & Jamila, P. (2012). Biochemical and microbial qualities of Sardinella fimbriata sun dried in different methods. *International Food Research Journal, 19*, 1699–1703.

Isaacs, M. (2016). The humble sardine (small pelagics): fish as food or fodder. *Agriculture & Food Security, 5*(27), 14.

Jebri, F., Jacobs, Z., Raitsos, D. E., Srokosz, M., Popova, E., Painter, S. C., . . . Wishgott, J. (2020). *Interannual monsoon winds variability as a key driver of East African small pelagics.* Natureresearch. doi:https://doi.org/10.1038/s41598-020-70275-9

Jiddawi, N. S., & Öhman, M. C. (2002, December). Marine fisheries in Tanzania. *Ambio, 31*(7-8).

Kawiya , C. (2017). *Economic Assessment of the fish solar tent dryers in Malawi.* Department of economics. Zomba: University of Malawi.

Leon, M. A., Kumar, S., & Bhattacharya, S. C. (2002). A comprehensive procedure for performance evaluation of solar food dryers. *Renewable and Sustainable Energy Reviews, 6*(4), 367-393.

Losse, G. F. (1964). A purse seine fishery in East African coastal waters: In Anderson J, Andrew T (eds) Case studies on climate change and African coastal fisheries: a vulnerability analysis and recommendations for adaptation options. FAO Fisheries and Aquaculture, C 1113. *Proc. E. Afri. Acad, 2*, 88-91.

MALF. (2016). *The Tanzanian Fisheries sector: Challenges and Opportunities.* Dar es Salaam: Ministry of Agriculture, Livestock and Fisheries.

Mayala, P. (2016). *Assessment of social economic value of the small pelagic fishery in Mafia island, Tanzania.* Reykjavik, Iceland: UNU-FTP. Retrieved December 28, 2021

Medard, M. (2012). Relations between People, Relations about Things: Gendered Investment and the Case of the Lake Victoria Fishery, Tanzania. *Journal of women in culture and society, 37*(3).

MLF. (2015). *National Fisheries Policy of 2015.* Dar es Salaam: Ministry of Livestock and Fisheries.

MLF. (2016). *The humble sardine (small pelagics): fish as food or fodder.* Dar es Salaam: Ministry of Livestock and Fisheries.

MLF. (2018). *Fisheries (Amendment) regulations* . Dodoma: Gazette of the United Republic of Tanzania, No. 34, Vol. 99.

MLF. (2018). *Marine fisheries frame survey report: Mainland Tanzania.* Dodoma: Ministry of Livestock and Fisheries.

MLF. (2018). *MARINE FISHERIES FRAME SURVEY: MAINLAND TANZANIA.* Statistics. Dodoma, Tanzania: Ministry of Livestock and Fisheries.

MLF. (2019). *Annual Fisheries statistics report.* Fisheries Department. Dodoma: Ministry of Livestock and Fisheries.

MLF. (2019). *THE ANNUAL FISHERIES STATISTICS REPORT (JANUARY- DECEMBER).* Statistics Department. Dodoma, Tanzania: Ministry of Livestock and Fisheries.

MLF. (2020). *Annual fisheries ststistics report (January-December)* . Dodoma: Ministry of Livestock and Fisheries.

MLF. (2020). *Implementation status and key challenges for the Artisanal small and medium pelagic fishery Management Plan in Tanzania.* Dodoma: Ministry of Livestock and Fisheries.

MLFD. (2013). *Management plan for the Tanzanian artisanal fishery for the small and medium pelagic fish species.* Dar es Salaam: Ministry of Livestock and Fisheries Development.

MOA. (2019). *National Postharvest Management Strategy--NPHMS 2019-2029.* Dodoma, Tanzania: Ministry of Agriculture.

MOF. (2016). *National Five year development plan 2016/17-2020/21: Nurturing Industrialization for Economic Transformation.* Dar es Salaam: Ministry of Finance and Planning.

MOF. (2019). *The Local Government Finance Act.* Dodoma: Ministry of Finance and Planning.

MoFEA. (2010). *National strategy for Growth and Reduction of Poverty (NSGRP II).* Dar es Salaam: Ministry of Finance and Economic Affairs.

Mtani, M., & Nyangarika , A. (2020). Constraints of Empowering Women's Entrepreneur's and its Impact in Community Welfare in Tanzania. *International Journal of Advanced Research and Innovative Ideas in Education, 6,* 2395-4396.

Muhando, C. A., & Rumisha, C. K. (2008). *Distribution and status of coastal habitats and Resources in Tanzania.* Dar es Salaam: WWF. Retrieved November 21, 2021, from https://www.cbd.int/doc/meetings/mar/ebsa-sio-01/other/ebsa-sio-01-urtanzania-02-en.pdf

Mulyila, E. J., Matsuoka, T., & Anraku , K. (2012, June 20). Sustainability of fishers' communities in tropical island fisheries from the perspectives of resource use and management: a comparative study of Pohnpei (Micronesia), Mafia (Tanzania), and Guimaras (Philippines). *Fisheries science, 78*, 947–964.

Mwaipopo, R., & Mahongo, S. B. (2020). Adaptive capacity of small pelagic fishing communities in coastal Tanga (Tanzania) to changes in climate-related phenomena. *WIO Journal of Marine Sciences*, 127-144.

Nagoli, J., Chiwaula, L., Kanyerere, G., & Banda, J. (2017). Reducing fish postharvest losses by use of solar tent dryers. *The 1st all Africa Post Harvest Congress & Exhibition, Reducing food losses and waste: sustainable solutions for Africa* (pp. 78-80). Nairobi, Kenya: WorldFish. Retrieved January 03, 2022, from https://www.cabdirect.org/cabdirect/abstract/20183238024

Ngwira, N. (2001). *Study on women's property and inheritance rights in Malawi.* Gender studies unit. Zomba: Chancellor College.

Nyandwi, N. (2013). The effects of monsoons on the East African Coastal Current through the Zanzibar Channel, Tanzania. *The Journal of Ocean Technology, 8*, 65–74.

Nyandwi, N. (2013). The effects of monsoons on the east African coastal currents through the Zanzibar channel, Tanzania. *Journal of Ocean Technology, 8*(4), 65-74.

Ojutiku, R. O., Kolo, R. J., & Mohammed,, M. L. (2009). Comparative Study of Sun Drying and Solar Tent Drying of Hyperopisus bebe occidentalis. *Pakistan Journal of Nutrition, 8*, 955-957.

Olokor, Oghenekaro, J., Omojowo, & Samuel, F. (2009). Adaptation And Improvement Of A simple Solar Tent Dryer to enhance fish drying. *Nature and Science, 7*(10), 8.

Onyango, D. M., Sifuna, A. W., Otuya, P., Owigar, R., Kowenje, C., Lung'ayia, H. B., & Oduor, A. O. (2017). Evaluation of Fish Processing and Preservation Systems along the Shores of Lake Victoria towards Enhancement of Sun Drying Technology. *International Journal of Food Science and Nutrition Engineering, 7*(5), 111-118.

Owaga, E. E., Onyango, C. A., & Njoroge, C. K. (2009). Effect of selected washing treatments and drying temperatures on biochemical and microbiological quality of *dagaa* (Rastrineobola argentea). *African journal of food, agriculture, nutrition and development*, 830-845.

Sahdev, R. K. (2014, March). Open Sun and Greenhouse Drying of Agricultural and Food Products: A Review. *International Journal of Engineering Research & Technology (IJERT), 3*(3), 14.

Sekadende, B., Scott, L., Anderson, J., Aswani, S., Francis, J., Jacobs, Z., . . . Kelly, S. (2020). The small pelagic fishery of the Pemba Channel, Tanzania: What we know and what we need to know for management under climate change. *Ocean and Coastal Management, 197*, 19.

Silas, M. O., Mgeleka, S. S., Polte, P., Skold, M., Lindborg, R., de la Torre-Castro, M., & Gullström, M. (2020). Adaptive capacity and coping strategies of small-scale coastal fisheries to declining fish catches: Insights from Tanzanian communities. *Environmental Science and Policy, 108*, 67-76.

Sreekumar, A., Manikantan, P. E., & Vijayakumar, K. P. (2008). Perfomance of indirect solar cabinet dryer. *ScienceDirect, 49*, 1388-1395.

SWIOFP. (2012). *Mainstreaming biodiversity in fisheries management: a retrospective analysis of existing data on vulnerable organisms in the South West Indian Ocean.* Durban, South Africa: Southwest Indian Ocean Fisheries Project.

Szulmaye, W. (1971). From sun drying to solar dehydration I. Methods and equipment. *Food Technology in Australia, 23*, 440–443.

TAFIRI. (2019). *Research on the Tanzania mainland small pelagic fishery.* Tanzania Fisheries Research Institute. Dar es Salaam,Tanzania: MLF.

Tessem, A., Demssie, S., & Goshu, G. (2013). Evaluation of solar tent and drying rack methods for the production of quality dried fish used in Lake Tana area. *Journal of fisheries International, 8*(1), 7-12.

Visavale, G. L. (2012). Principles, Classification and Selection of Solar Dryers. In *Solar Drying: Fundamentals, Applications and Innovations* (pp. 1-50). Singapore.

Wanyinyi, I. N., Wamukota, A., Tuda, P., & Mwakha, V. A. (2016). Migrant fishers of Pemba: Drivers, impacts and mediating factors. *Marine Policy, 71*, 242-255.

Ward, A. R., & Jeffries, D. J. (2000). *A manual for assessing post-harvest fisheries losses.* Chatham, UK: Natural Resources Institute.

Wong, I. L., Eames, P. C., & Perera, R. S. (2007). A review of transparent insulation systems and the evaluation of payback period for building applications. *ScienceDirect, 81*, 1058–1071.

WorldFish. (2017, June 21). *Improving livelihoods and gender relations in the Barotse floodplain fishery, Zambia*. Retrieved January 03, 2022, from https://www.worldfishcenter.org/: https://www.worldfishcenter.org/pages/improving-fisher-livelihoods-gender-relations-rural-zambia/

APPENDICES

Appendix 1: Structured questionnaire for marine *dagaa* processors

Name of landing site: ____________________ District: ________________

Date: ____________

Introduction:

The researcher is conducting feasibility study on cost effective solar tent dryer that will reduce *dagaa* losses along Tanzania coastline. The researcher is collecting data about physical and economic losses that occur during processing of *dagaa*. You will be asked questions regarding processing of *dagaa;* and your answers will be completely confidential. These questions will take around 15 minutes to complete and your participation is voluntary. Other people at this landing station will also be interviewed. Do you have any question about the study or what I have said?

Demographic characteristics (*Mark only one box*)

1. Age of respondent.

   ☐ 18-25 ☐ 26-33 ☐ 34-40 ☐ Above 40

2. Gender of respondent

   ☐ Female ☐ Male

3. Marital status of respondent

   ☐ Married ☐ Divorced ☐ Widowed ☐ Separated ☐ Single

4. Residence of respondent

   ☐ Local ☐ Immigrant

5. Education level of respondent

   ☐ None ☐ Primary Education ☐ Secondary Education ☐ Higher level

6. How long have you been processing boiled dried *dagaa*?

   ☐ Less than 1 year ☐ 1-3 years ☐ 4-6 years ☐ Above 6 years

***Dagaa* Post- Harvest Losses in different periods**

7. How much *dagaa* did you purchase, per day, for processing on high season (Northeast monsoon, NEM) and on low season (Southeast Monsoon, SEM) in 2020? (In kg of fresh *dagaa*)

   a) High season__________________

   b) Low season_________________

8. How much *dagaa* did you process, per day, on high season and on low season in 2020? (Dry weight)

   a) High season: _______________________

   b) Low season: ________________________

9. How much did you purchase for processing during rainy periods in comparison to sunny periods in 2020? (Fresh weight in kg/day)

   a) Sunny days: _______________________kg

   b) Rainy days: ________________________kg

10. How much processed products did you deliver to customers during rainy season in comparison to sunny days in 2020? (Dry weight in kg/day)

   a) Sunny days: _________________kg

   b) Rainy days: __________________kg

11. How long does it take to dry *dagaa* during sunny periods in comparison to rainy periods? (In hours)

   a) Sunny days: ___________________hours

   b) Rainy days: ____________________ hours

12. What method of drying do you use during rainy season?

13. How many people did you employ in 2020?

   a) Part time: ____________________

   b) Full time: _________________

14. Mention the people you employed according to their roles and their numbers (e.g., *dagaa* carriers (1), helpers in boiling (3), drying (3), guards… etc.)

---

15. Did you sell *dagaa* at lower price than expected because of spoilage/downgrading in year 2020?
Yes ☐ No ☐

If yes, how much did you sell? (In kilograms) __________ and at what price? (T.sh/kg) ______________

a) What was the market price for a good quality dried *dagaa* per kilogram? (T.sh): ___________

16. What were the reasons for spoilage? Please estimate the quantity.

☐ Improper drying of fish due to rain (fish did not dry properly):________kg

☐ Breakage: ___________________________kg

☐ Purchase low quality fresh *dagaa*: ________________________kg

☐ Improper packaging and storage: ______________________kg

☐ Other: _____________________________________kg

17. Did you throw away deteriorated *dagaa* that has been rained on in 2020?

☐ Yes ☐ No

If yes, how much (kg): ___________________________________

18. Did any of your *dagaa* washed away by rainfall in 2020?

☐ Yes No ☐

If yes, how much (kg): _____________________________

Tick all that applies

19. What method of drying boiled dried *dagaa* are you using?

☐ Open sundry on the ground

☐ Nylon sheets laid on ground

- ☐ Used fishing nets laid on ground
- ☐ Raised racks
- ☐ Others (mention)………………………………………………………

20. Did you encounter the following problems with your dried *dagaa* after storage?
    - ☐ Mould
    - ☐ Change in colour
    - ☐ Odour
    - ☐ Presence of maggots
    - ☐ Others (mention)……………………………………………………….

21. What adaptive mechanism do you use while drying *dagaa* during rainy season?
    - ☐ Cover with nylon sheets
    - ☐ Purchase small amount of *dagaa* to process
    - ☐ Change into other sources of livelihood until sunny day
    - ☐ Others (mention)………………………………………………………….

22. Do you have other sources of livelihood other than processing *dagaa*?

    Yes ☐ No ☐

If yes, please mention: ____

23. If answer from question 22 is "no", how do you meet your needs or family needs when prolonged rainfall becomes a challenge on drying *dagaa* under open sunlight?
    - ☐ I use savings from selling *dagaa* during sunny periods
    - ☐ I borrow money
    - ☐ I reduce my expenditure
    - ☐ Others (explain): ____

On a scale of 1 to 5, tick only one answer that applies to you

24. Please rank on a scale of 1 to 5 and mark only one answer that applies to.

How satisfied are you with *dagaa* drying method (racks, nylon sheets or old fishing nets) that you are currently using?					
	1=Very satisfied	**2=Moderately satisfied**	**3=neutral**	**4=Moderately dissatisfied**	**5=Very dissatisfied**
Operating during rainy season					
Shelf-life of dried product					
Labour costs					
Space for drying					
Economic gain (profit)					

Post-Harvest fish handling awareness

25. Have you obtained any training on fish handling and processing?

☐ Yes ☐ No

26. If yes, when and from whom?

____

27. Do you know any other fish drying methods than the one you are currently using?

☐ Yes ☐ No

28. If yes, which method(s)?

29. Have you obtained governmental support or from other partners?

☐ Yes ☐ No

30. If yes, what kind of support?

31. Please mention if there are other challenges you face during drying *dagaa*.

Thank you very much for your time.

Appendix 2: Structured questionnaire for KII

Name of interviewer: ______________________________ District: _______________

Position: ____Date: _________________

Introduction:

The researcher is conducting feasibility study on cost effective solar tent dryer that will reduce *dagaa* losses along Tanzania coastline, especially during rainy periods. You will be asked questions regarding processing of *dagaa* in your District and your answers will be completely confidential. These questions will take around 10 minutes.

Dagaa processing facilities

1. How many *dagaa* processors are available in your district based on their gender?
   Female: ________________
   Male: __________________

2. Have processors experienced *dagaa* loss due to external conditions in 2020?
   ☐ Yes ☐ No

   If yes, what were the reasons for *dagaa* losses:
   ____
   ____

3. How do the processors of boiled dried *dagaa* operate? (Cooperative, individual…etc.)

4. Please describe how boiled dried *dagaa* processing system operate in your district as well as people involved in the chain from when *dagaa* is landed to when it reaches consumer.

5. Does your organization provide support to *dagaa* processors?

   Yes ☐ No ☐

If yes, what type (s) of support?

6. What actions are taken by your organization to reduce *dagaa* losses?

---

7. How much does processors pay per kg as fish levies for dried product?

---

8. In your own opinion, what do you think should be done to improve drying *dagaa* during rainy periods?

---

9. Have you ever heard of solar tent dryers?

   Yes ☐ No ☐

   If the answer is yes, in your own view, do you think that introducing solar tent dryers could reduce *dagaa* losses?

---

10. What are the challenges facing your organization in reducing *dagaa* losses?

Thank you

Appendix 3: Total revenue gained by using solar tent dryers in pilot districts.

	Capacity of solar tent/ drying cycle	Amount processed / month (kg)-20 days	Amount processed for 6 months-full capacity (kg)	Amount processed for 6 months -70% capacity (kg)	Total available to process (kg)	Eq. dry weight(35%)-kg	Amount loss by solar tent(20%)-kg	Amount remain for selling (kg) (80%)	Revenue (Tsh.)	Revenue (USD)
Total benefits from implementing solar tents		20	6	70%		35%	20%	80%	5,000	2,300
1 solar tent capacity per cycle	850	17,000	102,000	71,400	173,400	60,690	12,138	48,552	242,760,000	105,548
8 solar tents in pilot districts	6,800	136,000	816,000	571,200	1,387,200	485,520	97,104	388,416	1,942,080,000	844,383

Capital cost for purchasing fresh *dagaa*, T.sh.	1,872,720,000 (1.8B)
Capital cost for purchasing fresh *dagaa* (USD)	814,226
Selling price for fresh *dagaa* (T.sh.)	1,350
Selling price for dried *dagaa* (T.sh)	5,000
1USD=T.sh	2,300

Appendix 4: Percentage government revenue saved by using solar tent dryers

Government charges for export (0.16USD per kg)			0.16
The government charges 3% of the revenue for national and local trade			3%
	Est. government revenue from solar tent dryer	Est. revenue lost by government through open sun dry (USD)	% Revenue saved by solar tent dryer
Government revenue at national and local trade-USD	25,331	32,738	77%
Government revenue (export regional trade)-USD	62,147	123,360	50%
Revenue lost=quality loss + physical loss			
Lost due to physical loss (USD)	170,000		
Lost due to quality loss (USD)	921,261		
Total revenue loss	1,091,261		
Total *dagaa* loss in kg	771,000		
Est. dried *dagaa* for selling (kg)	388,416		

Appendix 5: Payback period of proposed solar tent dryer

Year	**0**	**1**	**2**	**3**	**4**	**5**
Investment (USD)	(19,892)					
Cashflow (USD)		21,809	21,809	21,809	21,809	21,809
Cumulative cash flows (USD)	(19,892)	1,917	23,725	45,534	67,343	89,151
Investment decision						
Payback period	0.9					