ECONOMIC EVALUATION OF *DAGAA* SOLAR DRYING INNOVATION FOR POST-HARVEST LOSSES REDUCTION IN MWANZA, TANZANIA

SEBASTIAN FAUSTIN MHANGA

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN MANAGEMENT OF NATURAL RESOURCES FOR SUSTAINABLE AGRICULTURE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA

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ABSTRACT

Dagaa (Rastrineobola argentae) has been the major commercial fishery of Lake Victoria contributing 67.4% of total fish catch. In Tanzania it constitutes over 38% of the total fish landings from the lake. However, there is a high level of post-harvest loss of about 59%. To minimize the losses, various solar post-harvest innovations for *dagaa* processing have been developed but there is limited empirical evidence showing costs and benefits of these innovations to justify their adoption. The present study assessed the economic viability of three drying methods of *dagaa* namely, solar tent, bare sand and raised racks in Mwanza. A completely randomised experimental design, cost benefit analysis and trend analysis were employed to determine post-harvest losses, economic viability and future market of *dagaa* respectively. Data was collected by simple random sampling of *dagaa* from boats, key informant interviews and desk review of secondary data. Results showed that solar tent reduces post-harvest losses up to 24.9% compared to raised racks (14.9%) and bare sand (10%) drying methods. Solar tent achieved the highest Net Present Value (NPV) of Tsh. 68,069,703 at the Internal Rate of Return (IRR) of 341% and Benefit Cost Ratio (BCR) of 1.38 meaning that solar tent is economically viable. Market trend analysis augmented with key informant interviews indicated that domestic market for *dagaa* is rising. Based on the findings the study recommends solar tent innovation should be promoted to commercial scale to contribute in reducing *dagaa* post-harvest losses. The reduction of post-harvest losses implies more quantities of *dagaa* will be available for sale and employment opportunities will be created to enterprises in the fisheries industry. The promotion of the innovation can be done by various stakeholders including the government, private sector, researchers and development partners in forms of interventions to stimulate adoption and further research to upgrade the innovation.

DECLARATION

I, **Sebastian Faustin Mhanga**, do hereby declare to the SENATE of Sokoine University of Agriculture that this dissertation is my own original work and has neither been submitted nor concurrently being submitted in any other institution.

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Sebastian Faustin Mhanga **Date**

(MSc. Candidate)

The above declaration is confirmed by:

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Prof. Gerald C. Monela **Date**

(Supervisor 1)

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Dr. Augustine W. Mwandya **Date**

(Supervisor 2)

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LIST OF ABBREVIATIONS AND SYMBOLS

ADB	Asian Development Bank
ANOVA	Analysis of Variance
BCR	Benefit –Cost Ratio
BMUs	Beach Management Units
CBA	Cost- Benefit Analysis
CRD	Completely Randomised Design
CSC	Commonwealth Science Council
EMEDO	Environmental Management and Economic Development Organization
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GSARS	Global Strategy to improve Agricultural and Rural Statistics
IBAR	Inter-African Bureau for Animal Resources
ICFS	International Collective in Support of Fish Workers
IFLAM	Informal Fish Loss Assessment Method
IOP	Institute of Physics
IRR	Internal Rate of Return
LCSD	Low Cost Solar Dryer
LT	Load Tracking
LVFO	Lake Victoria Fisheries Organization
MBS	Malawi Bureau of Standards
MCC	Mwanza City Council
MITRE	The Mitre Corporation
Mk	Malawi Kwacha
NPV	Net Present Value
OABS	Optimal Agricultural Business Systems
PHFL	Post-Harvest Fish Losses

PHL	Post-Harvest Losses
PVC	Polyvinyl Chloride
QLAM	Questionnaire Loss Assessment Method
RBF	Rule Based Forecasting
SDC	Swiss Development Corporation
SPSS	Statistical Packages for Social Sciences
STFD	Solar Tent Fish Dryer
SUA	Sokoine University of Agriculture
TAFIRI	Tanzania Fisheries Research Institute
TRNSYS	Transient System Simulation
Tshs	Tanzanian Shillings
URT	United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The fisheries sector in Tanzania provides direct employment to about 183,800 fishermen (URT_a, 2016). In addition, more than 4 million people such as boat builders, fish processors, net and engine repairers are indirectly employed in the sector (URT$_a$, 2016). The sector also provides income to local people from foreign earnings, food for coastal and upcountry communities and also contributes to the national income (GDP) by 2.4% (URT, 2015; URT$_a$, 2016). In terms of food security fish contributes about 30% to the total protein intake in the country (Ibengwe, 2012).

In recent years, *dagaa (Rastrineobola argentae)* has been the major commercial fishery of Lake Victoria contributing 67.4% of total catch (LVFO, 2012; URT$_b$, 2017). In Tanzania *dagaa* constitutes over 38% of the total fish landings from Lake Victoria (Ibengwe, 2012; URT$_a$, 2016). However, the *dagaa* fishery is associated with a high level of post-harvest loss (physical and quality losses) of approximately 59% (Ibengwe, 2012). Post-Harvest Fish Losses (PHFL) refers to fish that is either discarded, wasted or sold at a relatively low price because of predators, quality deterioration or owing to market dynamics (FAO, 2011). In this study post-harvest loss focused on fish wasted during drying.

Post-harvest losses in fish are among the highest losses in comparison with all other commodities in the entire food production system (Abelt, 2016; Banda *et al*., 2017 Tesfy *et al.*, 2017). According to Tesfy *et al*. (2017) physical post-harvest losses are estimated to be 0-7.5%, 20-40% and 26-40% while the quality post-harvest losses are 1.5-18.9%, 20% and 2-5% in Kenya, Tanzania and Uganda respectively. Tanzania has the highest figures of post-harvest losses in terms of quantity and quality in the East African region. These losses have major implications for the availability of fish products and nutritional quality to local populations. Not only do losses constitute lost income to fishers, processors and traders but they also contribute to food insecurity (FAO, 2016). In an effort to reduce post-harvest losses, various solar post-harvest innovations for *dagaa* processing have been developed by various researchers. Such innovations include fish dryers of different models such as solar tent (CSC 1987; Zebib *et al*., 2017), open raised racks (Onyango *et al*., 2017), indirect cabinet solar dryer (Abdulmajid, 2015) and greenhouse solar dryer (Rhoda, *et al*., 2016). These innovations are acknowledged to give better shelf-life, than the traditional ones but it is hypothesized that the fishermen consider the opportunity cost of improved prolonged shelf-life to initial input cost of improved processing methods as insignificant (Onyango *et al*., 2017). Despite this claim there is limited empirical evidence showing costs and benefits of these innovations to justify their use or non-use. Therefore, this study assessed the economic viability of using solar tent drying method in comparison with the most common traditional methods of drying *dagaa* on bare sand and raised racks in Mwanza city Tanzania.

The Solar tent dryer is made up of a polythene sheet worn over a wooden framework (Olokor *et al*., 2009). It works through evaporative drying using the greenhouse principle. When set up in the sun, solar energy passes through the transparent polythene but gets trapped within it thereby raising the internal temperature. Cool air flowing in through an opening gets heated up and moves out moisture from fish laid on racks in the dryer. Solar dryer speeds up the drying process considerably, resulting in a high-quality product with extended shelf life (Sreekumar *et al*., 2015). Even under high humid conditions, solar dryers could have other advantages over the other two methods. Such advantages include the following: (i) it is rain-proof and hence can be kept in continuous operation even when it is raining. (ii) Drying in an enclosed environment protects the products from dust, dirt, attack by birds, rodents and insect infestation.

1.2 Problem statement

Inefficient drying techniques for *dagaa* by small scale fishermen contributes to high post-harvest losses of *dagaa* around Lake Victoria (FAO, 2016). Solar tent dryer is one of the simple and technically efficient innovations for drying *dagaa* (Mustapha *et al.*, 2014; IBAR, 2018). However, fishermen perceive it to be more costful than conventional methods of drying *dagaa* on bare sand or raised racks (Onyango *et al.*, 2017). This situation is a result of limited information regarding the costs and benefits between various innovative post-harvest techniques and the traditional techniques of drying small pelagic fish (Mustapha *et al.*, 2014; OABS, 2016). In line with this observation, assessments of costs and benefits of new post-harvest innovations in comparison with the traditional techniques in Tanzania are rare (Mutungi *et al.*, 2013).

The general observation under costs and benefits analysis literature is that there is a narrow coverage of analysis with regard to investment viability decision criteria such as NPV, IRR, BCR, sensitivity analysis and payback period of solar tent dryer. The main drawback is that sensitivity analysis of the drying projects using solar tent is hardly found in the literature. For example, Mbamba, (2018) did a study on cost-benefit analysis of *dagaa* drying tent but the study lacked sensitivity analysis. Lack of such information does not reflect the reality of market dynamics in prices, operational costs and other changes resulting from changes of macro-economic variables in the economy such as inflation and government spending. Another similar study conducted by Chiwaula, (2019) focused on NPV and sensitivity analysis but did not work out Benefit-Cost Ratio which is an important indicator of return on investment.

Further observation in connection to cost-benefit analysis of solar tent dryer is that most of the literatures reviewed with the exception of one paper presented by Chiwaula *et al.* (2017) have not shown the extent to which consumers demand for such products. Studies with such limitations include Mustapha *et al* (2014), Odoli,(2015) and Zebib *et al*, (2017). Information on estimated or actual quantity of *dagaa* demanded provides an indication of market response and it can therefore attract potential investors who could build interest to invest in solar tents for drying *dagaa*.

In addition to the shortcomings of cost-benefit analysis in previous studies, there are two general observations regarding the literature on operational performance of solar dryers. The first observation is that the literature hardly quantifies the extent to which the use of solar tents contributes in reducing post-harvest losses. The second observation is that the studies lack explanation on the implication of achieving low moisture content in fish when solar tent dryers are used. Studies with such drawbacks include Esmare *et al*, (2015) and Rhoda *et al*, (2016). How moisture content influences post-harvest losses is not clearly articulated in the literature reviewed despite its importance in influencing the longevity of *dagaa* shelf life.

1.3 Justification of the Study

There are few studies which have documented the economic viability of solar drying tent for fish in comparison with the conventional drying techniques (Mustapha *et al.*, 2014). Therefore, information from this study is expected to contribute in developing interest of fishers, traders and fish processors to adopt new post-harvest innovations in comparison with the conventional techniques of drying *dagaa.* The information is also expected to contribute in creating incentives for private sector to invest in sustainable *dagaa* processing enterprises. The study also contributes to inform the government and development partners in designing appropriate technological interventions for reduction of *dagaa* post-harvest losses.

1.4 Objectives of the Study

1.4.1 Overall objective

The main objective of this study is to assess the economic viability of drying *dagaa* by using solar tent, in comparison with bare sand and raised racks for reducing post-harvest losses.

1.4.2 Specific Objectives

i. To determine moisture content of *dagaa* dried by solar tent, raised racks and bare sand methods
ii. To quantify physical post-harvest losses of *dagaa* dried by solar tent, raised racks and bare sand methods.
iii. To estimate costs and benefits of solar tent, raised racks and bare sand methods of drying *dagaa*.
iv. To assess potential market demand for *dagaa* dried using solar tents.

1.5 Hypotheses and Research Questions

While each hypothesis or research question is related to one objective for the first objective up to the third objective, the last two research questions are associated with objective four.

1.5.1 Hypotheses

i. Drying *dagaa* in solar tent leads to significantly less moisture content compared to drying on raised racks and bare sand.
ii. Drying *dagaa* in solar tent cause significantly less physical post-harvest losses compared to drying on raised racks and bare sand.

1.5.2 Research questions

i. Which method of drying *dagaa* is more economic between using solar tent and the conventional methods of drying on sand or raised racks?

ii. What is the general market trend for dried *dagaa*?

iii. What is the market potential for *dagaa* dried by using solar tent?

1.6 Conceptual Framework of the Study

The conceptual framework (Figure 1) considers the whole post-harvest system to impart an understanding that post-harvest fish loss is a systemic issue and therefore it requires a systemic solution. The term system denotes logically interconnected functions within the *dagaa* post-harvest chain. In considering the system as a whole, losses can occur at harvest, handling before transportation, during transportation and distribution, at processing due to inefficient processing technology, at storage due to spillage, contaminations or pests.

The framework therefore associates post-harvest losses to activities and practices from the lake to the retail market and recognizes quantity and quality losses. The losses attract innovations whose usefulness in preventing or reducing them is governed by the type of innovations, their operational performance, cost-effectiveness, and market for the products. Marketability of the products is considered as the main incentive for users to acknowledge the innovations within their socio-economic context. Otherwise the innovations become abandoned and the loss mitigation cannot be achieved. For the purpose of this study only physical quantity post-harvest losses at processing point were considered in the framework. This is because processing point is a critical hot spot where *dagaa* post-harvest losses occur due to poor processing.

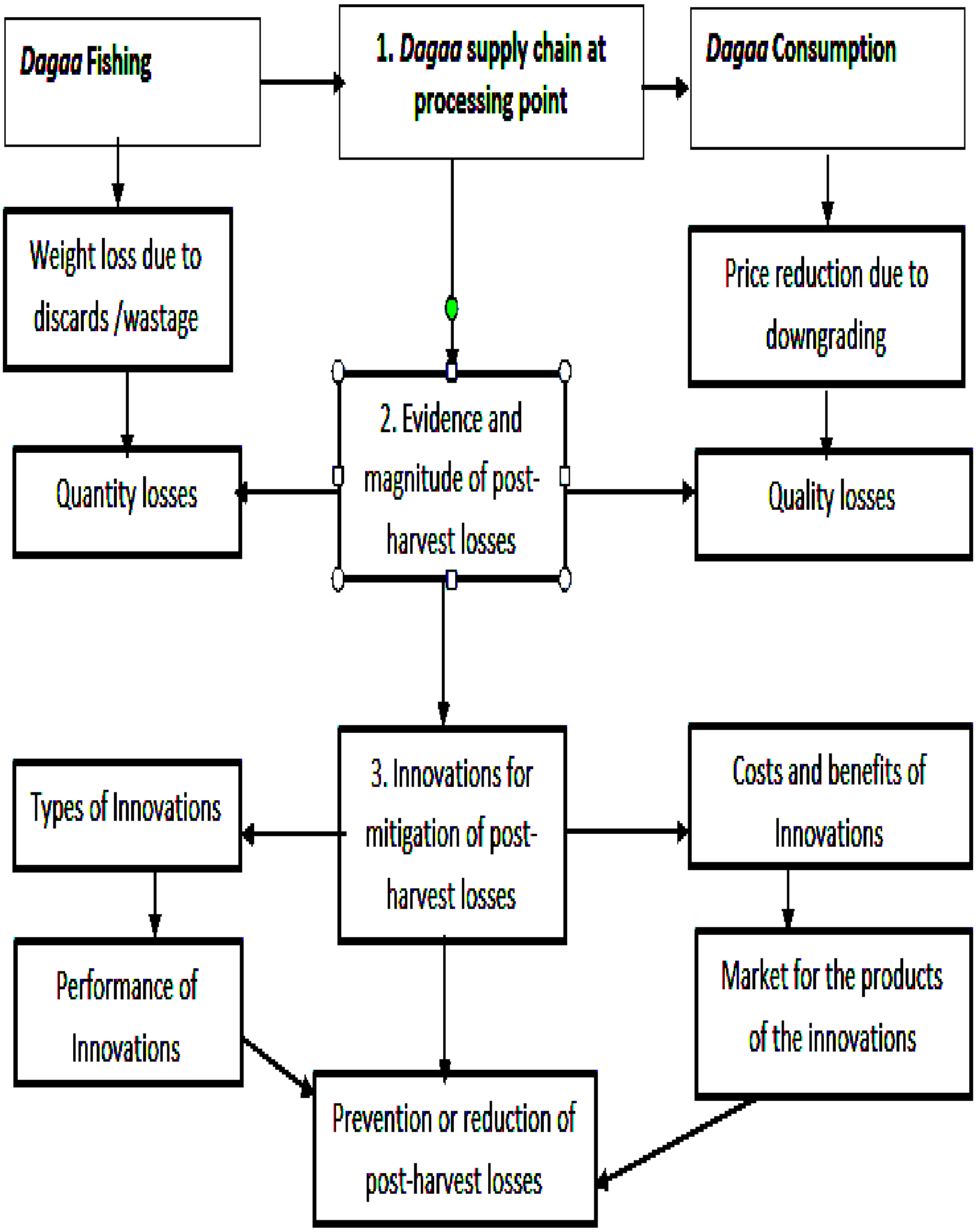

Figure 1. Conceptual Framework of the study
Adapted from Affognon *et al*. (2015)

CHAPTER TWO

2.0 LITERATURE REVIEW

The literature review is divided into two parts. The first part is a review of theories to which this study is based on. The theories covered include the framework for small scale fisheries post-harvest loss assessment, Cost-Benefit Analysis of investments and market demand forecasting techniques. The second part is the empirical literature review that focuses on past studies related to operational performance of solar based post-harvest innovations, costs and benefits of the innovations and consumer preferences on solar dried fish products. The empirical literature is reviewed from post-harvest loss management perspective.

2.1 Theoretical Literature Review

2.1.1 The framework for fish post-harvest loss assessment

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

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

2.1.1.1 The Informal Fish Loss Assessment Method (IFLAM)

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

2.1.1.2 The Questionnaire Loss Assessment Method (QLAM)

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

2.1.1.3 The Load Tracking (LT) Fish Loss Assessment Method

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

In summary, LT can be used for assessing how fish quality and/or quantity can change within a distribution chain; identifying why and where losses occur; estimating the value of losses in monetary terms; measuring the effect of interventions to reduce losses. The objective of LT can be derived from IFLAM findings and it must be desirable and achievable. For example: to quantify the physical and quality fish losses of fish species X along the distribution chain Y; to quantify the physical losses during packaging and transportation of sundried sardine; to measure the physical losses during the processing stage. However, in this study the Load Tracking method was used to assess the physical post-harvest losses of *dagaa* at the processing stage.

2.1.2 Cost-Benefit Analysis Project Appraisal Methods

Cost-Benefits Analysis (CBA) is the process of using theory, data, and models to examine products, trade-offs, and activities for assessing relevant objectives and alternative solutions in order to assist decision-makers in choosing the most appropriate alternative investment option (MITRE, 2014). The core of CBA is an evaluation (ex-ante or ex-post) of the project intertemporal socio-economic benefits and costs, all expressed in units of welfare, usually money in present value terms (Florio *et al.*, 2016). The net effect on society is finally computed by a quantitative performance indicator (the net present value, or the internal rate of return, or a benefit/cost ratio).

CBA is also a policy assessment method that quantifies the value to a given agency of public policy impacts and consequences in monetary terms" with the goal being "to help effective social decision making through efficient allocation of society's resources when markets fail (Belfield, 2012; ADB, 2013). The CBA is also a method that applies a systematic process for calculating and comparing benefits and costs of private or public investments. It is a widely used financial and economic approach for assessing whether the benefits of a particular action are greater than its costs. Thus, depending on whether a financial or economic analysis is requested, CBA is done from the view point of a project's individual beneficiary, a project partner, a private entity, a government agency or society as a whole (Jenkins *et al*., 2011; SDC, 2015).

CBA can be applied to any project that runs over several years, involves an investment and generates quantifiable benefits. In the fisheries sector for example, CBAs are used for projects such as aquaculture schemes or projects and corresponding processing facilities, e.g. fish processing factory. The basic idea is to find out if the investment in construction and equipment, as well as the yearly maintenance and operational costs of the project are justified in terms of higher production and income, i.e. benefits.

CBA has two main purposes: First is to determine whether a planned investment or decision can meet the viability criteria that are considered sufficient and thus whether or not it is justified and feasible. The second purpose is to provide a basis for comparing projects when different options are considered. The main result of a CBA is the benefit-cost ratio (BCR). However, two other important assessment criteria are generally used and calculated when doing a CBA: the net present value (NPV) and the internal rate of return (IRR). All three criteria take the influence of time into account, i.e. involve discounting. For a project to be accepted the NPV should be positive, the IRR should be greater than the discount rate and the BCR should be greater than one. After making choice of particular projects/project based on above mentioned indicators, analysts go further for risk assessment of the projects by carrying out sensitivity analysis.

A sensitivity analysis tests a chosen indicator with different assumptions to see how values change. It identifies critical values, in particular values that change the interpretation of an indicator. Thus, the results of a sensitivity analysis can be used in an investment or a credit proposal's risk assessment. Decision-makers are often interested in knowing how much values can change before a value that is acceptable for a certain criterion becomes unacceptable. For example, they may want to know how much costs can increase and/or how much benefits can decrease before a NPV drops below zero or the IRR drops below the accepted discount rate. Similarly, for projects producing negative NPVs or IRRs below the guiding rate, decision-makers may want to know how much costs would have to decrease, or benefits increase, in order to make the project acceptable. This is called a “break-even analysis” and provides useful information for decision making. The major weakness of CBA is that all costs and benefits have to be quantified into monetary value. The strength of the method lies in the sensitivity analysis where potential risks can be identified and planned for mitigation measures.

2.1.3 Market Demand Forecasting Methods

In the ever-changing world of business being able to accurately forecast customer demand is of utmost importance. Accurate forecasts are important for businesses and other organizations in making plans to meet demand for their goods and services (Mitsutaka *et al*., 2015; Armstrong *et al*., 2017). The need for accurate demand forecasts is particularly important when the information provided by market prices is distorted or absent, as when governments have a large role in the provision of a good (e.g., medicines), or service (e.g, national park visits.).

Without accurate forecasts companies essentially waste resources by carrying either too much (i.e. overstocks) or too little (i.e. stock outs) inventory (Nadler *et al*., 2007; Kedia *et al*., 2013; Bon *et al*., 2017). To remedy this problem companies, use many different methods of forecasting in an attempt to predict customer demand. Forecasting can be based on both quantitative and qualitative data (Daniel *et al*., 2014, Bon *et al*., 2017). Quantitative forecasting uses historical data to project demand and is a combination of extrapolation of previous studies consisting of statistical methods. Qualitative forecast technique requires a person’s idea and decisions collections which are related to future and present situation (Kocaoglu *et al*., 2014). The opinions of the experts are handled with subjective factors and experiences.

Qualitative techniques can be used during the inefficiency of numeric data and uncertain or changeable data excessiveness. Qualitative forecast technique’s inputs can be obtained from many sources. These sources can be clients, sales person, manager, craft or experts apart from companies. Qualitative technique, which is used in decision making process, can be classified as Delphi technique, expert groups’ opinion and sales force mixed. Despite handling with abstract and subjective experiences, qualitative techniques are generally concluded with low prediction performances due to bias and tendency (Nadler *et al*., 2007; Kocaoglu *et al*., 2014; Daniel *et al*., 2014).

To use ‘quantitative’ method, we have to reach quantitative data which is used in quantitative techniques. Fundamental assumption of the method is permanency of distinctive trends (Pereira da Veiga *et al.*, 2010; Kocaoglu *et al*., 2014). Even if this assumption is partly correct for the near future, as long as forecast horizon broaden, accuracy of quantitative methods is decreasing. As long as tendency is formed by forecast changes, their usage opportunity is also decreasing. To apply quantitative methods, three conditions should be completed: Information about the past, rendering information as data, and continuation of previous tendency in the future.

For a broader understanding of market forecasting a brief description from Amstrong *et al*. (2017) is provided hereunder narrating the qualitative and quantitative techniques.

2.1.3.1 Qualitative methods for market forecasting

Prediction markets also known as betting markets, information markets, and futures markets aim to attract experts who are motivated to use their knowledge to win money by making accurate predictions, thus being less likely to be biased. Markets have been long used for making forecasts. Prediction markets are especially useful when knowledge is dispersed and many motivated participants are trading. In addition, they rapidly revise forecasts when new information becomes available.

Judgmental bootstrapping was discovered in the early 1900s, when it was used to make forecasts of agricultural crops. The method uses regression analysis on the variables that experts use to make judgmental forecasts. The dependent variable is not the actual outcome, but rather the experts' predictions of the outcome given the values of the causal variables. As a consequence, the method can be used when one has no actual data on the dependent variable. The first step is to ask experts to identify causal variables based on their domain knowledge. Then ask them to make predictions for a set of hypothetical cases. For example, they could be asked to forecast the short-term effect of a promotion on demand given features such as price reduction, advertising, market share, and competitor response. By using hypothetical features for a variety of alternative promotions, the forecaster can ensure that the causal variables vary substantially and independently of one another. Regression analysis is then used to estimate the parameters of a model with which to make forecasts. In other words, judgmental bootstrapping is a method to develop a model of the experts' forecasting procedure.

Multiplicative decomposition involves dividing a forecasting problem into multiplicative parts. For example, forecasting sales for a brand, a firm might separately forecast total market sales and market share, and then multiply those components. Decomposition makes sense when forecasting the parts individually is easier than forecasting the entire problem, when different methods are appropriate for forecasting each individual part, and when relevant data can be obtained for some parts of the problem. Multiplicative decomposition is a general problem structuring method that should be used in conjunction with other evidence-based methods for forecasting the component parts.

Intentions surveys ask people how they plan to behave in specified situations. Data from intentions surveys can be used, for example, to predict how people would respond to major changes in the design of a product. Intentions surveys are especially useful when historical demand data are not available, such as for new products or in new markets. They are most likely to provide accurate forecasts when the forecast time horizon is short, and the behaviour is familiar and important to the respondent, such as with durable goods. Plans are less likely to change when they are for the near future.

Expert surveys (Key informant interviews) use written questions and instructions for the interviewers to ensure that each expert is questioned in the same way, thereby avoiding interviewers' biases. The written questions and instructions for the interviewers ensure that each expert is questioned in the same way, thereby avoiding interviewers' biases. The forecast is normally obtained from at least five experts. For more important forecasts, up to 20 experts are interviewed (Amstrong *et al.,* 2017). Delphi is an extension of the above expert survey approach whereby the survey is given in two or more rounds with anonymous summaries of the forecasts and reasons provided as feedback after each round. The process is repeated until forecasts change little between rounds; two or three rounds are usually sufficient. The median or mode of the experts' final-round forecasts is normally used as the Delphi forecast

Simulated interaction is a form of role-playing that can be used to forecast decisions by people who are interacting. For example, a manager might want to know how best to secure an exclusive distribution arrangement with a major supplier, how customers would respond to changes in the design of a product, or how a union would respond to a contract offer by a company.

The structured analogies method involves asking ten or so experts in a given field to suggest situations that were similar to that for which a forecast is required (the target situation). The experts are given a description of the situation and are asked to describe analogous situations, rate their similarity to the target situation, and to match the outcomes of their analogies with possible outcomes of the target situation. An administrator takes the target situation outcome implied by each expert's top-rated analogy and calculates the modal outcome as the structured analogies forecast.

Experimentation is widely used and is the most realistic method to determine which variables have an important effect on the thing being forecast. Experiments can be used to examine how people respond to factors such as changes in the design or marketing of a product. For example, how would people respond to changes in a firm's automatic answering systems used for telephone inquiries? Trials could be conducted in some regions, but not others, in order to estimate the effects. Alternatively, experimental subjects might be exposed to different answering systems in a laboratory setting. Laboratory experiments allow greater control than field experiments, and the testing of conditions in a controlled lab setting is usually easier and cheaper and avoids revealing sensitive information. A lab experiment might involve testing consumers' relative preferences by presenting a product in different packaging and recording their purchases in a mock retail environment. A field experiment might involve, using the different package in different geographical on a number of test markets that are representative.

Expert systems involve asking experts to describe their step-by-step process for making forecasts. The procedure should be explicitly defined and unambiguous, such that it could be implemented as software. Use empirical estimates of relationships from econometric studies and experiments when available in order to help ensure that the rules are valid. The expert system should result in a procedure that is simple, clear, and complete.

2.1.3.2 Quantitative methods for market forecasting

Quantitative methods require numerical data on or related to what is being forecast. However, these methods can also draw upon judgmental methods, such as decomposition. As well as numeric data, quantitative methods require structured judgmental inputs.

Extrapolation (time series) techniques use historical data only on the variable to be forecast. Such techniques include trend analysis, exponential smoothing and moving averages. The techniques are especially useful when little is known about the factors affecting the forecasted variable, or the causal variables are not expected to change much, or the causal factors cannot be forecast with much accuracy. Extrapolations are cost effective when many forecasts are needed, such as for production and inventory planning for many product lines.

Rule based forecasting (RBF) allows the use of causal knowledge in structured ways. To implement RBF, first identify the features of the series. There are 28 series features including the causal forces mentioned in the preceding section and factors such as the length of the forecast horizon, the amount of data available, and the existence of outliers. These features are identified by inspection, statistical analysis, and domain knowledge.

Regression analysis can be useful for estimating the strength of relationships between the variable to be forecast and one or more *known* causal variables (Silva, 2014; Rusov *et al.*, 2017; Perraillon., 2017). Thus, regression analysis can be helpful in assessing the effects of various policies. In some situations, causal factors are obvious from logical relationships. In general, however, causal relationships are uncertain, and that is particularly the case with complex forecasting problems. If there are questions as to the validity of a proposed causal factor and its directional effect, one should consult published experimental research; especially meta-analyses of experimental findings

Segmentation involves breaking a problem into independent parts, using knowledge and data to make a forecast about each part, and then adding the forecasts of the parts. For example, to forecast air travel demand in ten years' time, the Port of New York Authority in 1955 broke down airline travellers into 290 segments, including 130 business traveller and 160 personal traveller segments. The personal travellers were split by age, occupation, income, and education, and the business travellers by occupation, then industry, then income.

Index models. Some forecasting problems are characterized by good knowledge of many causal variables. Consider for example, predicting which players will do well in football, who would make the best company executive, what a country should do to improve its economic growth, whether a new product will be successful. When there are many important causal variables, regression is not a valid way to identify the magnitudes (coefficients) of the causal relationships. Fortunately, Benjamin Franklin proposed a sensible solution that we refer to as the “Index Model”. The method is sometimes referred to as experience tables elsewhere. Index models require good prior knowledge about the direction of the effects of the variables. Use prior experimental evidence or domain knowledge to identify predictor variables and to assess each variable’s directional influence on the outcome. Index models with unit weights have been found to be more accurate than regression models with optimal weights estimated from historical data.

To wind up it is important to note that practitioners of forecasting typically use the method they are most familiar with, or the method that they believe to be the best for the problem to hand. Both are mistakes. Instead, forecasters should familiarize themselves with all of the valid forecasting methods and seek to use all that are feasible for the problem. Further, forecasters should obtain forecasts from several implementations of each method, and combine the forecasts (Nadler *et al*., 2007, Pilinkiene, 2008; Barbosa *et al*., 2015). At a minimum, Armstrong *et al*., (2017) suggest that forecasters should obtain forecasts from two variations of different methods in order to reduce the risk of extreme errors. Therefore, this study combined trend analysis and key informant (expert) interviews for increasing the precision of *dagaa* market demand forecast.

2.2 Empirical Literature review

2.2.1 Studies on Operational Performance of Solar Post-Harvest Innovations

As a quick note in this subsection, there are two general observations regarding the literature on operational performance of solar dryers. The first observation is that the literature hardly quantifies the extent to which the use of solar tents contributes in reducing post-harvest losses. The second observation is that the studies lack explanation on the implication of achieving low moisture content in fish when solar tents are used. How moisture content influences post-harvest losses is not clearly articulated in the literature reviewed despite its importance in influencing the longevity of *dagaa* shelf life.

2.2.1.1 An alternative to open-sun drying of (*Rastrineobola argentea*) fish

A study was conducted in Kenya by Abdulmajid, (2015) to evaluate performance of solar dryers for reducing post-harvest losses that ranged between 20% to 50%. A model of an indirect forced convection solar dryer was developed and tested for thin layer drying of *R. argentea* fish. The fish, in 10 kg batches were loaded onto the dryer and the moisture content reduced from an initial value of 73% (w. b.) to between 16 and 20% (w. b.) after 11 hours of drying at an average air flow rate of 0.017 kg/s, where open sun drying took 18 hours. The study did not quantify the amount of post-harvest losses avoided as a result of using the solar driers. This study also did not consider costs and benefits analysis of the innovation either.

2.2.1.2 Evaluation of drying efficiency and effectiveness of solar driers on fish

An evaluation of drying efficiency and effectiveness of five different types of improved low-cost solar driers in terms of moisture loss from *Clarias gariepinus* (African sharp tooth catfish) and *Oreochromis niloticus* (Nile tilapia) was done in Nigeria. The driers used were made from plastic, aluminium, glass, glass with black igneous stone, and mosquito net, with traditional direct open-sun drying as a control. A significant moisture loss was observed in the fish in all five driers with the highest performance occurring in the glass solar drier (Mustapha *et al*., 2017). The study recommended a wide use of the solar driers to reduce post-harvest losses and ensure food security. However, the study did not quantify the potential amount of fish losses that would be prevented as a result of using the improved solar driers. The study also did not show the costs and benefits of using the solar driers despite claiming that they are of low cost.

2.2.1.3 Shelf life of Solar Tent Dried and Open Sun Dried *Diplotaxodon limnothrissa*

Banda *et al*. (2017) evaluated changes in chemical, physical, microbial quality of solar tent dried and open sun dried *Diplotaxodon limnothrissa* fish species from Malembo landing site after 9 weeks of storage at ambient temperature. The shelf life of solar tent dried and open sun dried *Diplotaxodon limnothrissa* fish species was estimated at 7 and 3 weeks respectively. Spoilage indicators of Total Volatile Basic Nitrogen (g/100mg) and pH range were 15.45-17.31, 6.26-6.35 for solar tent dried fish and 15.74-20.56, 6.32- 6.41 for open sun dried fish. At the period of sensory rejection, total bacteria viable counts, Total Volatile Basic Nitrogen and pH were 5.7×106 cfu/g, 18.98 and 6.38, respectively, for open sun dried. On the other hand, solar tent dried fish registered 4.1×102 cfu/g total bacteria viable counts, 17.28 Total Volatile Basic Nitrogen and pH 6.33.

Relatively higher levels of *Esherichian coli, Salmonella, Vibrio* and *Micrococcus* bacteria were detected in open sun dried compared to the solar tent dried fish. Protein range for solar tent dried and open sun-dried samples were 63.3±0.15 - 61.09±0.07% and 63.3±0.34 - 58.19±0.21% respectively. Moisture content remained constant and significant (p= 0.001) at 8.3±0.12 and 17.0±0.01% for solar tent dried and open sun dried *Diplotaxodon limnothrissa* respectively. Visible fungal growth was observed from week 2 of storage in open sun-dried fish and the isolates of *Aspergillus* 3.3×101 and

Penicilium 3.3×101 were identified. The results confirmed the application of solar tent drying as an efficient technology for fish processing in Malawi. The study recommended the use of solar tent drying to increase shelf life and safeguarding markets for value addition of small fish products in Malawi.

2.2.1.4 Pre-Scaling Up of Solar Tent Fish Drier

Esmare *et al.* (2016) conducted a study to test solar tent fish drier (STFD) to reduce post-harvest losses, thereby ensuring continuous availability of cheap animal protein. This study aimed to: (1) minimize post harvest losses by improving the shelf life dried fish; (2) enhance technology multiplication and dissemination system; (3) create clear insight about the technology use. This study was carried out in the northern and north western part of Lake Tana from June 2014 to June, 2015.

Purposive sampling methods were used to select Dembiya, Alefa and Gondar zuriya districts with their respective locality. Transect walk, interview, focus group discussion, and stakeholder consultation were used to collect qualitative data. Quantitative data were collected from 38 sample households by preparing structured questionnaire. Likert scale scoring, descriptive statistics such as percentage, mean, and standard deviations were used for analysis. The age structure of the sample households shows an average of 33.97 years and 44.7% of the respondents were female. Sample household's average family size was 4.6 and the distance from home to the main road takes 63.89 minutes of walk.

The solar tent fish drier was prepared from readily available materials such as; wood, white and black plastic, nail, rope and mesh wire with a size of 2meter height and 1.7 meter length. For this activity, six tents were prepared for three districts and fish species selected for the activity was labeo barbus intermedius. The salt amount used was 60g iodine salt per liter in brine form.

The fish dried well in the third day; with total moisture losses of 60%. Drying fish by solar tent fish dryer enables to produce hygienic, high quality, organoleptically good dried fish with low cost. By drying quickly, it is possible to reduce post-harvest losses thereby ensuring continuous availability of cheap animal protein. Absence of better price for fish dried by solar tent is the main challenge for further adoption. Promotion and market linkage for the quality dried fish; continuous support and follow up are very important to sustain the technology. Despite a good narrative explanation about good performance of solar tent innovation for drying fish the paper does not disclose the extent to which the solar tent reduces post-harvest losses of fish.

2.2.1.5 A comparative study of fish smoking and solar drying

A study conducted by Kallon *et al*. (2017) in Sierra Leone to assess technical and economic efficiency of energy utilized along fish value chain reported that the use of a passive solar drier was unlikely to make a substantial contribution to fish processing in Sierra Leone in the immediate future. This is because they take too long (3 to 7 days) to dry the fish to acceptable moisture content and they can only be used for less than half a year. This is due to prevalence of long rainfall period associated with relatively low day temperatures. The study suggests the use of more efficient processing technologies. This study presents some useful economic information for comparisons of the innovations.

2.2.1.6 Green house solar drying and thin-layer drying of fresh Kapenta

A study conducted in Zambia (Rhoda, *et al*., 2016) to evaluate performance of Greenhouse Solar Dryer and thin-layer drying model for the fresh Kapenta and also to evaluate the nutritional constituents and quality of the Kapenta dried from the

Greenhouse solar dryer and the open sun showed that, the Greenhouse Solar Dryer gave the best final products in terms of low moisture content, highest protein, fibre and ash values. Therefore, it was concluded that Greenhouse Solar Dryer was better than the open sun drying due to the fact that it produced a final product that maintains its nutritional properties to a level that is valuable to consumers at the time of consumption. This paper also lacks information on contribution of the greenhouse solar dryer in reducing post-harvest losses, an important aspect of operational performance of the drying innovation.

2.2.1.7 Small scale fisheries in the context of traditional post-harvest practice

Ankintola *et al*. (2017) conducted a study in Nigeria in the form of a narrative review to expose post-harvest losses (PHL) practiced by small scale fisheries and discuss factors that prevent the adoption of locally available interventions in Nigeria. Findings of the study revealed that sun-drying and smoking are the major interventions practiced to mitigate PHL. Unfortunately, these methods of reducing PHL are constrained by gross under-capacity and improper handling during peak fishing periods. There are a handful of potential intervention mechanisms to address issues of PHL. However, general inertia and poor policy implementation hamper progress for reducing PHL. This study also has limited quantified information on the contribution of the proposed innovations in addressing post-harvest losses.

Chiwaula *et al*. (2017) conducted a study to design, test and promote solar tent dryers to reduce postharvest fish losses while increasing economic gains and reducing the use of forest resources. The project was implemented in Mangochi and Salima districts in Malawi from October 2014 to June 2017. A solar tent dryer that is able to dry *Usipa* (*Engraulicypris sardell*), *Utaka* (*copadichromis spp.)* and *Ndunduma (Diplotaxodon* *limnothrissa) was designed and tested*. Comparing with traditional open sun drying, the study findings show that that drying time for fish in solar tent dryers was similar, about 3 days 3 hours during the dry-cold season and about 1 day 15 hours during the rainy-warm season. The moisture content was (7.22% vs 16.31%), microbial load (more than three times better). The low moisture content and microbial load leads to longer shelf life than in open sun-dried fish. The highest losses are estimated at the fish processing node (8.90%) and the lowest is at the fish marketing node (5.49%). Economic losses during fish processing was estimated at 11.3% for open sun-dried fish and 0.8% for solar tent dried fish implying that solar tent drying is reducing postharvest losses at the fish processing node by 10% to fish processors.

2.2.2 Studies on Costs and Benefit of solar based Post-Harvest Innovations

The general observation under costs and benefits analysis literature is that there is limited coverage of analysis with regard to cost-benefit analysis decision criteria such as NPV, IRR, BCR, sensitivity analysis and payback period of solar tent fish dryers (Ibengwe, 2012; Mbamba, 2018; Chiwaula, 2019). For example, sensitivity analysis of the drying projects using solar tent is hardly found in the literature. Lack of such information does not reflect the reality of market dynamics in prices, operational costs and other changes resulting from changes of macro-economic variables in the economy such as inflation and government spending.

2.2.2.1 Profitability Analysis of Value Added Usipa (*Engraulicypris Sardella)*

A study by Mbamba *et al*, (2018) was conducted to determine the profitability of value addition of Usipa (*Engraulicypris sardella)* through packaging in Nkhotakota district, central Malawi. Samples (69Kg) of fresh *E. sardella* purchased and sundried in solar tent dryer, packaged (34.5Kg) in plastics papers while the other 34.5Kg was unpackaged. Sales data were analyzed using gross margin and net profit analysis. Benefit-cost ratio and rate of return on investment were used to determine the viability of small-scale *E. sardella* fish business. Results of Cost and Return Analysis of packaged *E. sardella* showed that the total revenue of packaged *E. sardella* was Malawian kwacha (Mk) 225 400 and total cost was Mk.40 350 while results for unpackaged *E. sardella* showed that the total revenue was Mk.104 144.92 and total cost was Mk.20 450. Results on Benefit cost ratio for packaged and unpackaged *E. sardella* were 5.09 and 5.58 respectively. The findings imply that packaged *E. sardella* was more profitable than unpackaged *E. sardella*. The rate of return for packaged and unpackaged *Engraulicypris sardella* was 4.58 and 4.09 respectively, implying that for every Mk.1.00 invested for Packaged *Engraulicypris sardella* there was a return of Mk4.58 and Mk.4.09 for unpackaged *Engraulicypris sardella.* The paper recommended that packaging should be encouraged to maximize profits from small scale fish business in Malawi. This paper gives the message that solar tent dryer is economically viable for drying usipa (*dagaa*) in Malawi.

2.2.2.2 A review on solar tunnel greenhouse drying system

Patil *et al*. (2015) reviewed research and development work on solar tunnel and green house type dryers operating in natural and forced convection mode by different researchers. The comprehensive explanation, basics and earlier work performed on solar tunnel greenhouse type dryers has been presented briefly. A technical and economical assessment shows that solar tunnel and greenhouse dryers appear the most attractive option for use in rural areas. Trials on solar tunnel and greenhouse type dryer show not only massive fuel savings but also great worth addition due to improved quality of dried product in terms of colour, aroma and taste. However, application of such dryers has not picked up due to higher capital investment, long payback period and lack of confidence in the technology. Nevertheless, incessant research and development work should be carried out to overcome these factors. It is hoped that this review work may be valuable and appropriate for further development work.

2.2.2.3 Low cost solar dryer for fish

Sengar *et al*. (2009) conducted a study to compare performance of low-cost solar dryer (LCSD) and open sun drying methods in drying Prawns (Kolambi). Time required for reducing the moisture content from 75 to 16% were observed in open sun drying and solar drying for its comparison. Salted fish inside the dryer required 8 h in order to dry prawns up to 16.15% while unsalted fish required 15 h to reach moisture content up to 15.15% in open condition.

Overall collection efficiency was found as 70.97%. Average drying efficiency for salted fish was 14% and unsalted fish was 11% whereas pickup efficiency for salted and unsalted fish was found to be 10 and 9% respectively. Salted prawns were found most liked for its colour and texture than unsalted solar dried sample in sensory evaluation. Unsalted prawns sample dried in solar dryer was overall accepted, while traditionally open sun-dried sample was least liked for its colour and texture. The value of F was calculated as 1.98 during the sensory evaluation.

The economic cost of solar dryer was compared with mechanical drying for beneficial to local fishermen. The cost of LCSD in Rs. 1700/- is affordable to poor fisherman comparing to another costly mechanical dryer. Local fisherman could recover solar dryer cost within the period of 0.19 years by adopting solar drying technology. This paper gives the message that solar tent dryer is economically viable for small scale fisheries, however it does not provide information on risk assessment in terms of sensitivity analysis.

2.2.2.4 Technical and financial evaluation of a solar dryer

Chilli is the most important spice crop, for both sale and consumption Fuller *et al*. (2005). As the chilli harvest season coincides with the monsoon, it is not always possible to dry chilli. It has therefore become a common feature in Bhutan to see chilli flooding the local market for a relatively short period and then disappearing until the next season. This problem could be reduced if chilli could be dried when it is available abundantly. Solar drying may be a feasible option and therefore the technical and financial performance of a proven commercial-scale solar crop dryer has been evaluated for Bhutan.

The performance of the complete dryer system has been predicted to dry chilli and beef strips using the solar simulation program (TRNSYS). From the technical evaluation, the average collector, pick-up and system efficiencies were found to be 30%, 23% and 14.5% respectively for chilli. The solar contribution to the load is approximately 24.4%. Similar performance figures were predicted for drying beef.

From the business point of view, however, the current dryer design is financially not viable in Bhutan. The total investment cost for a solar dryer was US$2 343, but operating costs exceed the benefits. A negative NPV and a benefit cost ratio of less than one is unlikely to attract private investors. The favourable technical performance suggests that the financial performance might be improved if the design was optimised to minimise drying costs, particularly by increasing solar collector area to better suit the climatic and financial situation in Bhutan.

2.2.2.5 Design of a solar energy dryer under specific climatic condition

Al-Busoul, (2017) conducted a study on drying apples in solar tent to reduce wastage of the apples during peak harvesting periods in Jordan. Apples are popular fruits in the world market because of their unique and attractive flavor, color and nutritional value. During the harvest season there is a large quantity of this fruit and it has a relatively low price. Drying might be an interesting method in order to keep the price of this fruit in the accessible range and prevent fresh fruit deterioration. There is a spoilage of fruits and vegetables that could be preserved using drying techniques in Jordan.

Large quantities of small apples that are not demanded in the market could be used in solar energy drying. It is therefore, envisaged that the design of a simple solar dryer could contribute greatly to solving this problem. In this paper, a new solar dryer was designed taking into account the local climatic conditions of Jordan. The designed dryer with a collector area of 18.9 m2 was expected to dry 100 kg of fresh apple, with moisture content from about 84.9% to less than 10% by weight, within two days under ambient conditions during the harvesting period, i.e July-September.

Based on the estimated costs and preliminary economic analysis, it was predicted that the payback period of such system would be around 3-4 years depending on the used materials and its prices in construction in the local market. It is deemed that such solar dryer will help poor farmers to secure a sustainable income due to higher selling prices of dried apples. The paper does not tell much about the economic viability of the solar dryers based on investment worthiness indicators such as the Net Present Value, Internal Rate of Return and the Benefit –Cost Ratio. In addition, the paper does not provide information on risk assessment of the investment in apple drying by using the solar tent in Jordan.

2.2.2.6 Cost benefit analysis for reduction of *dagaa* post-harvest losses

Ibengwe, (2012) conducted a study to propose cost effective management strategy to reduce *dagaa* post-harvest loss in Tanzania. To meet this objective a cost and benefit analysis was done, to determine whether adopting drying *dagaa* on racks will reduce post-harvest loss and hold positive public value in the future. Two categories of analysis were set i.e. private (individual) and public (Government) for a pilot district (500 fishers), the analyses were divided into five parts: (i) Assessment of all possible *dagaa* post-harvest losses, (ii) Assessment of the cost of reducing the losses, (iii) Assessment of the anticipated benefits associated with reducing the losses, (iv) Evaluation of costs and benefits to determine net benefit and NPV, (v) A sensitivity analysis.

From the analysis it was found that, drying racks has positive NPV therefore it is worthwhile to be implemented in Tanzania to reduce *dagaa* post-harvest loss. Also sensitivity analysis indicated that NPV is sensitive and is likely to be affected by changes in sales price, while changes in investment and implementation cost were found to have no impact on NPV. By using drying racks productivity will be increased and provide sustainable livelihood to fishers and as well as increase regional trade and foreign exchange earnings to the government. The study provides a good analysis of costs and benefits of using raised racks as an innovation for reducing *dagaa*-post harvest losses however it does not quantify the extent to which the innovation reduces post-harvest losses and the extent to which the NPV is sensitive to selling prices.

2.2.3 Consumer studies of fish dried by using solar innovations

With regard to literature reviewed on consumer studies it was observed that fish dried in solar tents are highly preferred by potential consumers compared to other methods of drying (Mustapha *et al.*, 2014; Odoli, 2015; Zebib *et al.*, 2017). However, most of the literature reviewed with the exception of one paper presented by Chiwaula *et al.* (2017) have not shown the extent to which consumers are willing to pay or are actually paying for such products. Actual payment or an expression of willingness to pay provides an indication of market response and it can therefore attract potential investors who could build interest to invest in such kind of investment.

2.2.3.1 Drying and smoking of capelin and sardine and their influence to consumers

The effects of blanching, drying and smoking methods on fish quality around Lake Victoria in Kenya revealed that drying under controlled conditions improved quality of the fish (Odoli, 2015), demonstrating the need for developing a commercial solar drier for processing of small fish. Solar dried and smoked capelin and sardine were found to be rich in essential polyunsaturated fatty acids. Improved solar dried sardine and capelin received significantly high acceptability ratings at a probability level of $P<0.05$. The rating was evidenced by their willingness to buy the improved dried *dagaa* at an average price of US$1 per kg. The rating was done by using a Likert scale ranking ranging from 1= which means very unlikely to buy to 9= very likely to buy. However, the study did estimate quantity demanded for this product.

2.2.3.2 Improved Processing and Marketing of Healthy Fish Products

According to a study conducted by Chiwaula *et al*. (2017) to design, test and promote solar tent dryers to reduce postharvest fish losses found out that solar tent dried fish was found to be of significantly higher quality than open sun dried fish in terms of ash content (21.97% vs 14.48%), moisture content (7.22% vs 16.31%), microbial load (more than three times better), and similar quality in terms of crude protein and fat content. The low moisture content and microbial load leads to longer shelf life than in open sun-dried fish. As a result of these superior qualities, the Malawi Bureau of Standards (MBS) certified solar tent drying and solar tent dried fish as safe for human consumption.

Consumer preference analysis showed higher level of acceptability for cooked and uncooked solar tent dried fish than open sun-dried fish. Before cooking, consumers' overall quality score for dried *Usipa* (4.35 vs 3.81) and *Ndunduma* (4.25 vs 3.55) were significantly higher than the scores for open sun-dried fish. After cooking, preferences remained higher for solar dried *Usipa* (4.19 vs 3.67) and *Ndunduma* (4.17 vs 3.43) than open sun-dried fish.

Fish processors were willing to pay US$132 as a contribution to a group owned solar dryer. Women are willing to pay US$132 while men were willing to pay US$ 151. The proportion of fish processors that were willing to pay reduced between the baseline survey and the end line survey but the amount of money fish processors were willing to pay increased because of the improvements in the information about the costs and benefits of a solar tent dryer. While women are more likely to pay for solar tent dryers, the average amount of money they are likely to pay is lower than what men are likely to pay. Economic assessment of the solar tent drier showed a net present value of Mk.6 014 489 with an internal rate of return of 57% and a payback period of 1.8 years. A risk analysis on the investment on solar tent dryers shows that when uncertainty is factored, solar tent dryers have an 80% probability of being profitable. With these results, it is shown that solar tent dryers are economically viable.

2.2.3.3 Evaluation of solar dryers on salted tilapia fillets to consumers

Zebib *et al.* (2017) evaluated solar dryers potential in Ethiopia to reduce fish post - harvest losses and evaluation of consumer tastes and preferences on dried tilapia using raised rack tent, solar tent and family tent, and salting methods (dry salted and brined) showed significantly lowest moisture content values in fish products dried in raised rack tent (10.17%) using dry salted method than other dryers. The raised rack tent fish dryer was found to produce acceptable sensory dried products and need to be demonstrated and popularized in high temperature areas.

2.2.3.4 Comparative study between Open Sun Rack and Solar Tent Drying of Fish

Comparative studies between an open sun rack and solar tent drier in Eritrea for their drying effectiveness on the quality of Anchovy (*Stelophorus heterolobus),* showed that the quality of fish products dried in the solar tent drier was superior compared to that of open sun rack-dried products (Abraha *et al*., 2017). It took only three days for the fish to be dried in the solar tent drier compared with the open sun rack dried fish products which took five days to dry.

2.2.3.5 Solar drying and organoleptic characteristics of fish

Mustapha *et al.* (2014) conducted a study of drying two commercially important tropical African fish species *Clarias gariepinus* (African sharp tooth catfish) and *Oreochromis niloticus* (Nile tilapia) using different improved low-cost solar driers. The aim was to evaluate the performance, efficiency, and effectiveness of these improved low-cost solar driers in terms of moisture loss and organoleptic characteristics of the dried products. Organoleptic assessment by the volunteers who evaluated the dried samples from the driers and the control revealed that the control had lowest acceptability, while samples from the glass drier containing black stone had a very high acceptability in terms of the taste, flavor, appearance, texture, odour, palatability, and shelf-life

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of the study area

The study was conducted at New Igombe beach located in Mwanza city on the Southern shores of Lake Victoria. Mwanza city has a population of 363,452 people growing at a natural growth rate of 3% per annum (MCC, 2016). The city lies at an altitude of 1,140 metres above the sea level with mean temperature ranges between 25.7ºC and 30.2ºC in hot season and 15.4ºC and 18.6ºC in the cooler months. The city also experiences the average annual rainfalls between 700mm and 1000mm (MCC, 2016). The majority of the residents (64.8%) in Mwanza region are informally employed in Agriculture sector.

The *dagaa* drying experiment was conducted at New Igombe landing site which is located in Bugogwa ward of Ilemela municipality (Figure 2) in the city. The landing site is about 17.2 km away from Mwanza city centre towards the North. The location of the experiment was randomly selected from the two major *dagaa* landing sites of Kayenze and New Igombe (Promarconsulting, 2011; Luomba, 2013; Kashindye, 2015) also using information from literature and reconnaissance survey. Other *dagaa* landing sites in Mwanza city include Kabangaja, Bwiru, Nyegezi and Miama. The selection was done by first writing names of the landing sites on pieces of paper, thereafter the pieces of paper were folded and mixed up, and finally one folded piece of paper was picked up and unfolded to read what appeared on it and was picked as a study landing site.

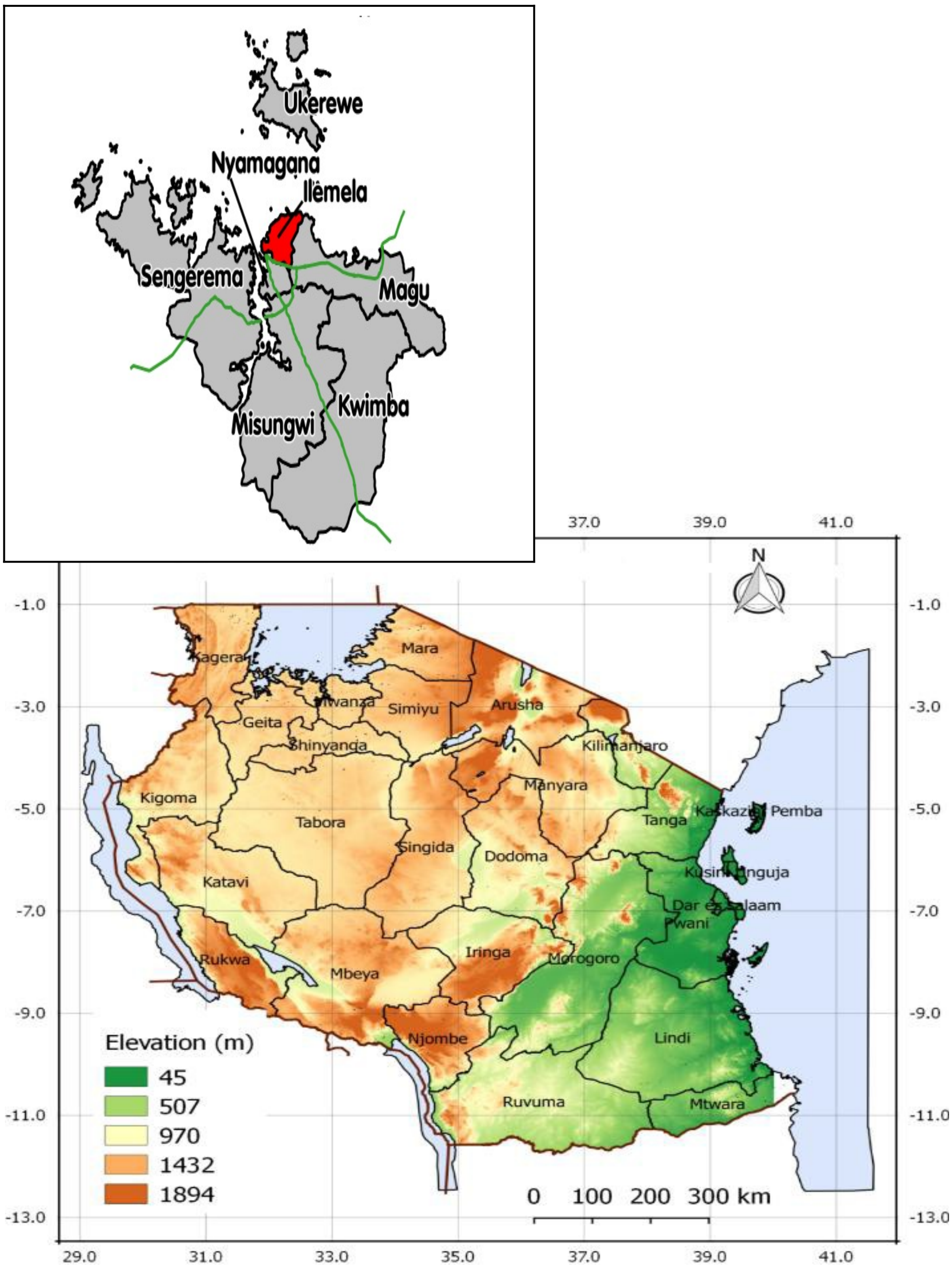

Figure 2. The map of Tanzania showing location of Ilemela municipality
Source: URT_b (2017)

3.2 Research Design

A completely randomized (CRD) experimental design (Casella, 2008; Bowerman *et al.*, 2011; GSARS, 2018;) and key informant interviews were employed (Kedia *et al.*, 2013; Daniel *et al.*, 2014; Bon *et al.*, 2017; Young *et al.*, 2017). The CRD experimental design was represented by the model given by $Y_{ij} = \mu + T_i + e_{ij}$, where:

Y_{ij} = observation *j* for treatment *i*,

μ = The overall mean,

T_i = The treatment effect, and

e_{ij} = The error term.

Prior to the experiment a reconnaissance survey was conducted to collect information from various stakeholders in the city for understanding *dagaa* processors's environment, goals, constraints, opportunities and *dagaa* drying management practices. These stakeholders included *dagaa* processors at Landing sites, alliances of fish traders, the Kirumba International Fish Market administration. Others were the National Fish Quality control laboratory for Lake Zone, Municipal Fisheries Office and Beach Management Units at landing sites in Ilemela municipal. The reconnaissance survey provided information that helped to select the *dagaa* landing site for setting up the experiment, to identify appropriate sources for collection of secondary data, particularly data on *dagaa* market information and identification of appropriate key informants for interviews.

3.3 Materials used in the Experiment

The experimental unit was a batch of 2kg of fresh *dagaa* with individual lengths ranging from 3.6 cm to 5.8 cm with belly depth measuring between 0.8cm to 1.4cm. Measurements were taken by using a common 30 cm plastic ruler. The experimental set up comprised of three treatments/drying methods namely; solar tent (Plate 1), raised racks (Plate 2) and bare sand (Plate 3). Each treatment was replicated into nine replicates. The bare sand drying method was the control treatment.

Plate 1a: The general structure of the solar tent (Front view)
Source: Field data (2018)

Plate 1b: The general structure of the solar tent (Rear view)

Plate 1c: Drying *dagaa* in solar tent
Source: Field data (2018)

Plate 2: Drying *dagaa* on open raised racks
Source: Field data (2018)

Plate 3: Drying *dagaa* on bare sand
Source: Field data (2018)

The dimensions of the drying racks used in the solar tent (Plate 1c) were 1m x 0.5m x 1.5m (length x width x height). The dimensions of drying racks used outside the tent were 1.5m x 1m x 0.9 m (length x width x height). Lastly the dimensions of the drying sand plots were 1.5m x 1m (length x width). The solar tent dryer (Plate 1a and 1b) consisted of a transparent plastic polyethene sheet with a thickness of 200µm stretched over a wooden house-like frame work with the dimensions (1.5 m wide by 3.5 m long by 2. m high on sides and 2.4m high at the apexes). Two plastic meshed air inlets at the base from the in-blowing wind side of the tent were made with dimensions 10cm x 50cm each. On each side of the top most sides of the tent (the apex) one plastic meshed vent was made with a common size of 800cm^2 for releasing moisture from *dagaa* as adapted from Abrahah *et al*. (2017).

A 25kg spring balance Salter weighing scale of Model 235 with a resolution of 100g was used to weigh *dagaa* before and after drying and a digital camera was used for taking photos. Other materials included two pairs of plastic cushioned gloves, a black PVC carpet of size 3m x 1.5m for collecting heat from the sun inside the solar tent, 2 plastic crates with a loading capacity of 30kg for carrying *dagaa*, a plastic bucket, a plastic dish, a plastic bowl and water for washing *dagaa*, a plastic ruler, digital thermometer Model HI 98509-1 which was correct to ±0.1^{o}C, measuring a maximum of 100^{o}C. Another material was fresh *dagaa* amounting to a total weight of 60 kg and a note book with a pen for recording. For the purpose of ensuring validity of measurements the thermometer and the weighing scales were calibrated before using them for taking measurements. The thermometer was calibrated by measuring water temperature at 100^{o}C to cross-check that it measures correctly. The weighing scale was calibrated by weighing five 1kg packets of sugar to check its correctness. Both the thermometer and the weighing scale were found to correctly measure temperature and weight respectively.

3.4 Data collection

3.4.1 *Dagaa* sampling

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

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

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

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

3.4.2 Data collection from experiment

Dagaa for all the three drying methods were dried for eleven hours that is from 11.00 am to 6.00 pm for day 1 and from 8.00 am to 12.00 noon on the second day. The data collected in the experiment were: the initial weights of 27 samples of fresh *dagaa* bought, weight of *dagaa after* drying, number of hours taken to dry *dagaa* for each drying method and temperature value inside the solar tent and outside the tent taken on an hourly basis (Appendix 2a, 2b and 2c). Other variables for economic analysis of each drying method were; investment costs, operational costs which are detailed as labour, purchase of fresh *dagaa*, maintenance, storage, packaging materials, and transport (Appendix 1c). After field experiment 250g of *dagaa* was sub-sampled from each treatment and packed in plastic bags for moisture content testing. The samples were submitted to the National Fish Quality Control Laboratory of Mwanza.

3.4.3 Key informant interviews

A questionnaire (Appendix 3) was used as an aid to conduct key informant interviews to collect data for forecasting market demand (Nadler *et al.*, 2007; Armstrong *et al.*, 2017; Bon *et al.*, 2017) of *dagaa* dried in solar tent. The questionnaire was pre-tested before use to ascertain its validity. The key informants were selected by carrying out a reconnaissance survey where knowledgeable stakeholders in *dagaa* subsector were first identified prior to the interviews. The key informant interviews were conducted to informed *dagaa* market stakeholders in Mwanza city to obtain data on the type of buyers and their trading destinations, the level of competition in the market, the current market dynamics and future outlook of *dagaa* market. Participants in the interviews included one processor of *dagaa* from New Igombe *dagaa* landing site, the manager of Kirumba international fish market, the chairperson of Mwaloni Fish Traders Cooperative Society, the chief inspector of the National Fish Quality Control Laboratory of Lake Zone, the Fisheries officer for Ilemela municipal council and the chairperson of New Igombe Beach Management Unit.

3.4.4 Secondary data collection

Secondary data on production and trade of *dagaa* were obtained on print and on-line sources from the Ministry of Livestock Development and Fisheries, Lake Victoria Fisheries Organization, Tanzania Fisheries Research Institute and Kirumba International Fish Market.

3.5 Limitations of the Study

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

In order to eliminate the effect of season on economic analysis, the investment estimations/projections for drying *dagaa* in solar tent was prepared for a dry period only which covers 7 months running from June to December. In order to control humidity levels inside the solar tent fog was observed on inner walls of the tent to detect excessive humidity levels. When fog was observed more air-flow inside the tent was allowed at the air-inlet control points until the fog disappeared.

3.6 Data analysis

3.6.1 Descriptive statistics

Descriptive statistics that includes arithmetic means and percentages of moisture content in dried *dagaa* were computed. The purpose was to check whether it could achieve the recommended moisture content level of not more than 12% as stipulated by the East African Community Standard for *dagaa* trade (LVFO, 2016). This standard moisture content for *dagaa* limits the activity of harmful microbial organisms that cause *dagaa* post-harvest losses. The analysis was done by using SPSS software.

3.6.2 Analysis of variance for moisture content and post-harvest losses

Prior to conducting One-way Analysis of Variance (ANOVA), Levene's test of homogeneity of variance (Gastrwith *et al.*, 2009; Nordstokke *et al.*, 2010; Para, 2013; Kim *et al.*, 2018) was conducted as a pre-condition for analysis of variance. After the homogeneity testing, ANOVA test was conducted to evaluate the significance of using solar tent drying method for reducing *dagaa* moisture content to the optimum level.

An F-Statistic was employed to test the hypothesis that "Drying *dagaa* in solar tent leads to significantly less than 12% moisture content than drying on raised racks or bare sand". The hypothesis was tested at a probability level of $p<0.05$. Finally, Tukey's post-hoc analysis (Gastrwith *et al.*, 2009; Kim *et al.*, 2018) was conducted to identify the actual source of differences among the various pairs of means of moisture content. However, Kruskal-Wallis, a non-parametric test was used to test the hypothesis that "Drying *dagaa* in solar tent creates significantly less physical post-harvest losses than drying on raised racks or bare sand." The non-parametric test was used because the mean variances for post-harvest losses were found to be heterogeneous after Levene's test even after square root transformation of the original data. The test was also done at a probability level of $p<0.05$. Thereafter Games Howell post-hoc test was conducted to identify the pair of means that makes a difference among the various means of *dagaa* post-harvest losses. The analysis was done by using SPSS software.

3.6.3 Cost –Benefit Analysis of the drying methods

Cost Benefit Analysis (CBA) method was used to estimate investment requirements, operating costs, profitability and economic viability of solar tent drying method in comparison with open sun drying of *dagaa* in raised racks and open sun drying on bare sand covering a period of four years. Net Present Value, Internal Rate of Return and

Benefit- Cost Ratio were computed (Table 3) for comparing the economic viability of the drying methods by using the following formulas:

(i) $. NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+r)^t}$

Where:

NPV = Net Present Value,

B_t= Benefits at time t,

C_t = Costs at time t,

t = specific year,

r = the discount rate,

n = Number of years the dryer will last.

(ii) $IRR = \sum_{t=0}^{n} [(B_t - C_t)/(1+r)^t] = 0$

Where:

IRR=Internal Rate of Return,

B = Benefits, C=Costs,

t = specific year,

n = number of years the dryer will last,

$(1+r)^t$ = The discount factor.

(iii) $BCR = \frac{\sum B_t}{\sum C_t}$

Where:

BCR= Benefit Cost Ratio,

B_t= Discounted Benefits for specific year,

C_t= Discounted Costs for specific year (Jenkins *et al*., 2011).

A discount rate of 20% was applied for discounting streams of cash flows based on the prime lending rate of banks during the time of the study. After working out the investment viability indicators sensitivity analysis was carried out against the Net Present Value by making percentage changes on fresh *dagaa* purchase price by increasing it to 23%, selling price of dried *dagaa* by reducing it down to 17% and increasing operational costs by 17%. These variables were assumed to be as the key driving factors that could affect the profit of the business based on past experiences of changes of these variables. The analysis was done by using MS-Excel software.

3.6.4 *Dagaa* Market demand forecast

Demand forecasting means an estimate of most likely future demand for a product under given conditions (Bon *et al.*, 2017). Knowledge of how demand will fluctuate enables the supplier to keep the right amount of stock on hand. Total market demand for *dagaa* was forecasted by using trend analysis technique in combination with content analysis of information from key informant interviews. Trend analysis as expounded by Nadler *et al.* (2007) was done by using historical data of *dagaa* market demand in terms of volumes of domestic *dagaa* consumption, *dagaa* exports, *dagaa* production and general fish imports from abroad. Based on Kedia *et al*. (2013) and Rusov *et al.* (2017) the trend analysis was conducted by fitting a trend line to a mathematical equation

$Y_i = ax_i + b$

where:

Y_{i} = is the dependent variable (i.e. projected *dagaa* sales in future years),

a = is the rate of change of *dagaa* sales in past years,

x_{i}= is the independent variable (that is the quantity of *dagaa* sold in the past years) and

b= is a constant.

Therefore, future quantities of *dagaa* demanded were projected by means of this equation. Correlation coefficients were computed to determine the strength of the relationship between past demands and the projected future demands. The trend analysis was augmented by content analysis method, a qualitative data analysis approach as expounded by White *et al*. (2006), Erlingsson *et al*. (2013), Demirok *et al*. (2015), Bengtsson, (2016), Erlingsson *et al*. (2017) and Castleberry *et al*. (2018). Content analysis of data from key informant interviews provided a detailed explanation about the future prospects of *dagaa* market beyond the projected numbers in trend analysis as expounded by Armstrong *et al.* (2017). The information from the key informant interviews included the type of buyers and their trading destinations, the level of competition in the market, the current market dynamics and future outlook of *dagaa* business.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Objective 1: Moisture content of dried *dagaa*

The minimum and maximum temperatures observed during the drying period were 35ºC and 42ºC inside the solar tent, 25ºC and 38ºC on raised racks and 33ºC and 41ºC on bare sand. The results showed that *dagaa* dried in solar tent had the least average moisture content (8.3%), followed by that dried on open raised racks (9.7%) and highest values was recorded in *dagaa* dried on bare sand (11.1%), (Table 1). There was a significant difference in moisture content among the three drying methods (F- Statistical test values $p < 0.05$) =). Post-hoc comparison (Tukey's test) revealed the difference between solar tent and raised racks and between solar tent and bare sand. However, there was no significant difference in moisture contents between raised racks and bare sand drying methods.

The highest moisture content in *dagaa* dried on bare sand could be caused by soil particles and other contaminations from sand. These results are similar to the study conducted by Banda *et al*. (2017) around lake Nyasa in Malawi who found that moisture content was significant at ($P = 0.001$) at 8.3±0.12% and 17.0±0.01% for solar tent dried and open sun dried *Diplotaxodon limnothrissa* respectively. Another study by Chiwaula *et al*. (2017) also found similar trend of 7.22% moisture content for longer shelf life (from time span of 3 - 7weeks; to 7 - 16 weeks) of dried *dagaa* (*Engraulicypris sardell)*.

Table 1: Moisture content in *dagaa* based on drying method

Dagaa Drying Methods	Solar tent	Raised racks	Sand bed
Average Moisture in %	8.3	9.7	11.1

Test Statistics	F-test at $p < 0.05$	Tukey's post hoc test at $p<0.05$		
		Solar tent Vs Raised Racks	Solar tent Vs Sand	Raised Racks Vs Sand
Significance level	0.00	0.00	0.00	0.00

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

4.2 Objective 2: Physical Post-Harvest losses of *dagaa*

The results showed lower post-harvest loss of 0.7 % for *dagaa* dried in solar tent compared to *dagaa* dried on raised racks (16 %) and those dried on bare sand (26%) (Table 2). There was a significant difference in physical post-harvest loss among the three drying methods ($p<0.05$). The differences were noted between solar tent and raised racks ($p<0.05$) and between solar tent and bare sand ($p<0.05$). However, there was no significant difference in post-harvest loss between raised racks and bare sand ($p<0.05$).

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

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

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

The post-harvest losses that occurred in raised racks and on bare sand methods of drying were due to *dagaa* being mainly consumed by birds during drying. A number of birds were observed during the drying process and had to be scared to avoid the losses. For the sand dried *dagaa* another potential loss could be attributed to left overs during collecting after drying. Picking *dagaa* from bare sand was difficult and more tedious and some were left on sand. The negligible percentage of post-harvest loss for *dagaa* dried in solar tent is due to the closed nature of the solar tent prohibiting birds to get in the tent to eat the *dagaa*, hence causing the losses. Based on these results it means that solar tent is the best dryer as it reduces post-harvest losses by 14.9% and 24.9% compared to drying *dagaa* on raised racks and on bare sand respectively.

4.3 Objective 3: Cost-Benefit Analysis of *dagaa* drying methods

The results showed that drying *dagaa* in solar tent, raised racks and on bare sand achieved NPV of Tshs 68 069 703/=, 25 939 470/=, 8 056 681/=; at IRR of 341%, 323%, 1070% and BCR of 1.38, 2.19, 1.47 respectively (Table 3). The highest value of NPV for the solar tent implies that drying *dagaa* in solar tent is the most economically viable method than drying on raised racks and on bare sand. Based on the IRR findings alone, drying *dagaa* on bare sand sounds to be more economically viable compared to the other two drying methods. The IRR of 1070% means that it is a discount rate at which the NPV will be reduced to zero (a breakeven point). In terms of BCR, the *dagaa* dried on raised racks sounds to be the most economically viable. The BCR of 2.19 means that the project's discounted benefits are 2.19 times the discounted costs of the project. In other words, one Tanzanian shilling invested generates a return of two shillings and nineteen cents. However, the overall assessment criteria of having the highest NPV, IRR higher than the discount rate, BCR greater than one, improved quality of *dagaa* and the highest recovery of post-harvest losses rank solar tent to be the most economically viable option for drying *dagaa* compared to the conventional drying methods.

Sensitivity analysis was conducted on three key variables that were conceived likely to affect business prospects if they change over time based on past experience as reported by key informants. The variables included a decline of *dagaa* selling price by 17%, a rise of price of fresh *dagaa* by 23% and a rise of other operational costs by 17%. The results of the sensitivity analysis showed that for the solar tent dryer, more sensitive variables were the selling price of *dagaa* and purchase price of fresh *dagaa*. The decline of selling price and the rise in purchase price reduced NPV from Tshs 68 069 703 to Tshs 24 689 809 and from Tshs 68 069 703 to Tshs 31 016 335 respectively (Table 3). This means that a 17% decline in selling price accounts for 64% decline in the NPV and the rise of price of fresh *dagaa* by 23% causes NPV to decline by 54%. The results of this study are similar to findings from a study by Chiwaula *et al.* (2017) in Malawi who found that drying *dagaa* by using a solar tent is economically viable with a positive NPV at an IRR of 57% and a payback period of 1.8 Years.

Table 3: Cost-Benefit Analysis of three *dagaa* drying methods

A	**DRYING *DAGAA* IN SOLAR TENT**	**Project Economic Viability Indicators**		
	Sensitivity Analysis Assumptions	**NPV (Tsh)**	**IRR**	**BCR**
1	Base scenario	**68 069 703**	**341%**	**1.38**
2	*Dagaa* selling price/kg (Tshs 6,250) declines by 17%	24 689 809	147%	1.15
3	Fresh *dagaa* purchase price/kg (Tshs 1,000) rises by 23%	58 597 562	319%	1.31
4	Operational costs rise by 17%	31 299 335	171%	1.15
B	**DRYING *DAGAA* ON RAISED RACKS**	**Project Economic Viability Indicators**		
	Sensitivity Analysis Assumptions	**NPV (Tsh)**	**IRR**	**BCR**
1	Base scenario	**25 939 470**	**323%**	**2.19**
2	*Dagaa* selling price/kg (Tshs 5,000) declines by 17%	17 545 477	233%	1.82
3	Fresh *dagaa* purchase price/kg (Tshs 1000) rises by 23%	23 659 263	298%	1.99
4	Operational costs rise by 17%	20 980 666	295%	1.76
C	**DRYING *DAGAA* ON BARE SAND**	**Project Economic Viability Indicators**		
	Sensitivity Analysis Assumptions	**NPV (Tsh)**	**IRR**	**BCR**
1	Base scenario	**8 056 681**	**1070%**	**1.47**
2	*Dagaa* selling price/kg (Tshs 3,000) declines by 17%	3 775 745	584%	1.23
3	Fresh *dagaa* purchase price/kg (Tshs 1,000) rises by 23%	5 776 474	778%	1.30
4	Operational costs rise by 17%	4 802 219	900%	1.22

Source: Field data (2018)

Although the rise in selling price has a substantial reducing effect on NPV for using solar tent it could be mitigated by improving the quality of *dagaa* dried in solar tent as there is an increasing interest of consumers for high quality *dagaa* based on market analysis. In addition, the selling price used in the cost-benefit analysis of Tsh. 6250/= for solar tent was the highest market price charged for *dagaa* dried on raised racks at landing sites. This price was used because so far there are no *dagaa* processors who use solar tent. So, the price was considered to be a reasonable initial estimate for higher quality *dagaa* dried in solar tent. There is potential to increase price for *dagaa* dried in solar tent upon further in-depth market research for the new product in the future. The purchase price of fresh *dagaa* also had a big reducing effect on NPV. However, the price for fresh *dagaa* usually falls during the high catch season covering the months of August to December (Figure 3). Figure 3 indicates that from August to November which is also a dry season is the high catch season for *dagaa* in the study area, i.e. Lake Victoria.

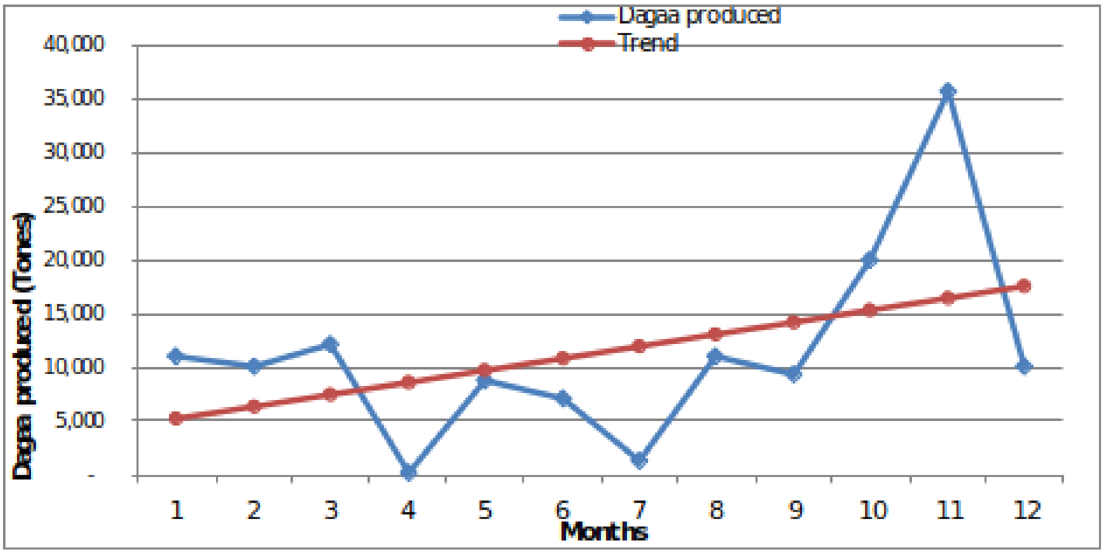

Figure 3: Monthly *dagaa* production trend in Lake Victoria
Source: URT_b (2016)

Therefore, the price of fresh *dagaa* is expected to be higher for a period of two months only based on the planning framework of seven months for all the projects under consideration in this study. The rise in other operational costs indicated limited reducing effect on the NPV for the solar tent dryer. The rise of 17% of other operational costs led to a decline of NPV from Tsh. 68 069 703 to Tshs 36 299 025 (Table 3). This means that a 17% increase in operational costs results into a fall of NPV by 13.9%. However, in this study the initial capital outlay (Total cost in year zero) required for drying *dagaa* in solar tent was found to be the highest of all. While solar tent requires an estimated initial investment of Tsh. 9 872 640/=, the raised racks and bare sand methods requires Tsh 4 073 000/= and Tsh.353 480/= respectively. This means that solar tent initial investment is higher by (59%) and 96% compared to raised racks and bare sand drying methods respectively (Appendix 1a, 1b and 1c).

Despite the challenge of high initial capital, the use of solar tent makes more *dagaa* to be available for consumption to the general public but also making more money to processors and create more employment opportunities to other enterprises related to the fisheries industry. Furthermore, the use of solar tent reduces the problem of limited space of land for drying *dagaa* as reported by EMEDO, (2017) especially during high catch periods. It also ensures high quality of *dagaa* by limiting contamination with dust, insects and animals such as cats and dogs. Findings from this analysis suggests promotion of solar tent drying method which gives benefits to processors and the Tanzania society in general. However, further research is needed to find out the efficiency of solar tent drying method during the rainy season.

4.4 Objective 4: Total Market demand forecast for *dagaa*

Market analysis was done by using trend analysis complemented with content analysis of qualitative data from key informant interviews. The assumption behind trend analysis is that the economic behaviour of market participants in *dagaa* subsector will almost not change.

The key informants' interviews were carried out to knowledgeable and experienced people in *dagaa* subsector. With regards to market demand for *dagaa*, there was no disaggregated quantitative secondary data available on consumption of *dagaa* dried on raised racks and on bare sand. More important is that, there was no historical data at all for *dagaa* dried in solar tent because it is a new innovation in Tanzania. Therefore, various aggregate time series data related to *dagaa* and fish market was analysed to forecast the general market demand trend of *dagaa* in particular and fish in general. The data used in the analysis includes domestic consumption and exports data from Lake Victoria for the years 2010 to 2015, Tanzania fish exports and Import data for the years 2010 to 2016. Similarly, *dagaa* supply trend analysis was conducted based on historical production data in Lake Victoria for the years 2010 to -2015, and fresh water fish production data was analysed for the periods 2007 to 2016. The trend analysis results for domestic *dagaa* consumption showed that there is a promising market for *dagaa* dried in the solar tent (Figure4).

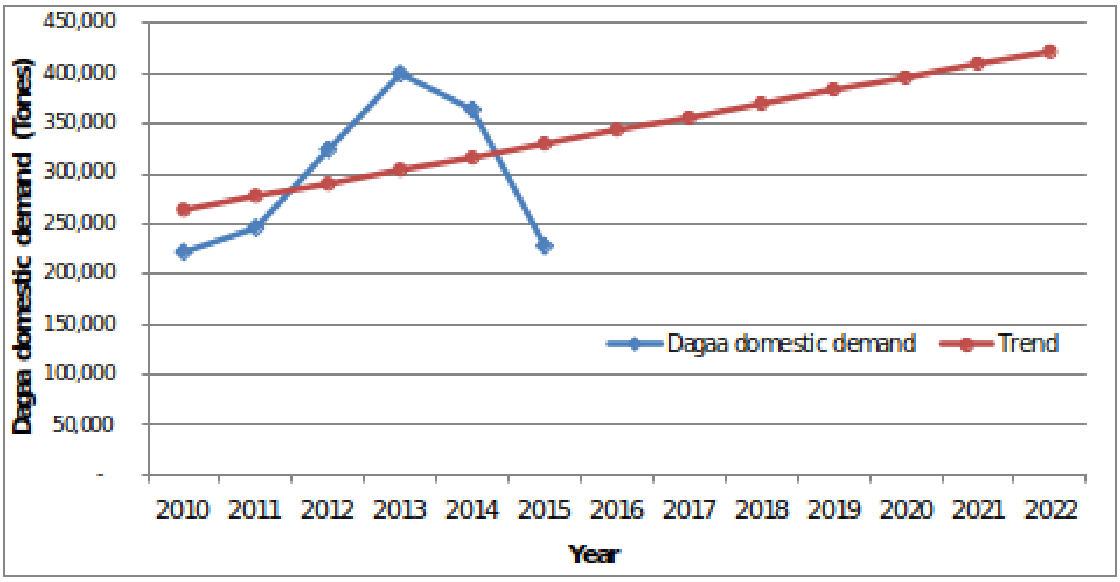

Figure 4: *Dagaa* consumption trend in Tanzania for years 2010-2015

Source: LVFO (2016)

From Figure 4 above it can be verified that domestic *dagaa* market shows a positive trend. The trend line achieved a Pearson correlation coefficient of 0.32 which is positive although it shows that there is weak linear relationship between past consumption of *dagaa* and the future possible consumption. However, the positive correlation means that the market is promising a lucrative future in *dagaa* trade. On the other hand, *dagaa* export trade showed a declining trend (Figure 5) despite the increasing trend of *dagaa* supply (Figure 6) from Lake Victoria in Tanzania. From correlation analysis the export trend achieved a negative Pearson correlation coefficient of -0.98. This means that there is a strong negative linear relationship between past exports of *dagaa* and future projected exports. As past exports of *dagaa* decrease the future projected exports of *dagaa* will also be declining. The declining trend (Figure 5) of *dagaa* exports could be caused by low quality of *dagaa* being exported which is mainly (80%) used for fish meal for animals or an increasing domestic consumption. However, further market research is required to find out the driving factors for this phenomenon.

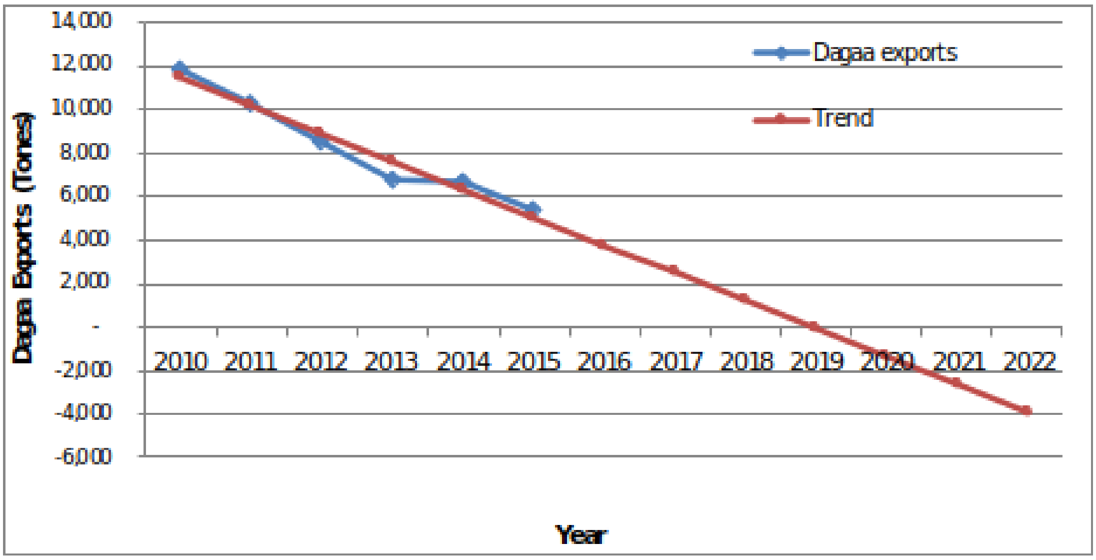

Figure 5: *Dagaa* export trend in Tanzania for years 2010-2015
Source: URT_b (2016)

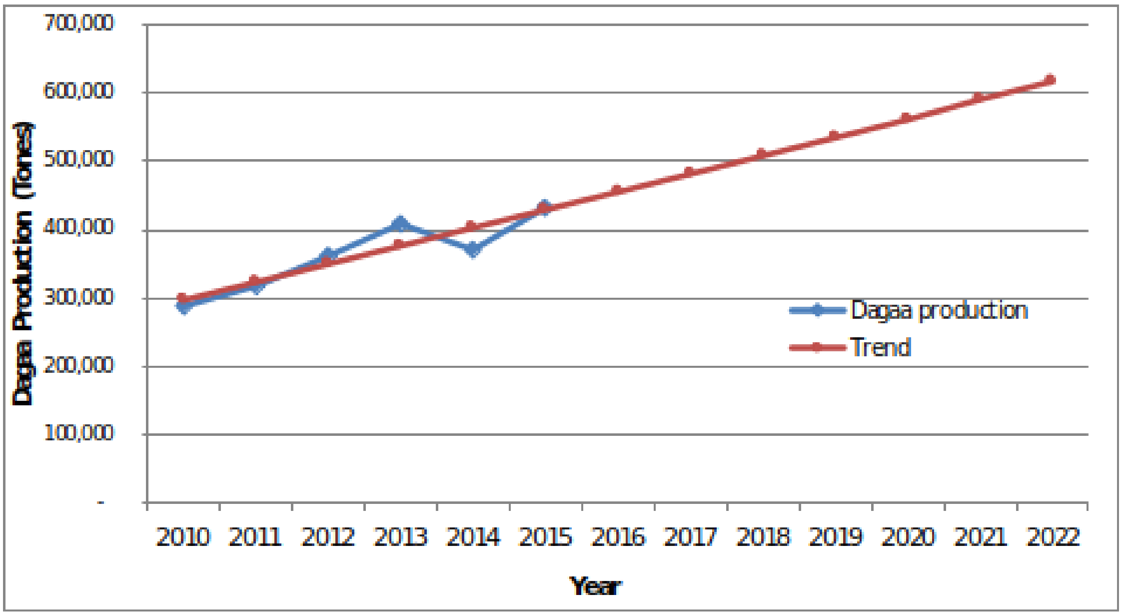

Figure 6: *Dagaa* production trend in Tanzania for years 2010-2015

Source: URT$_b$ (2016)

The rising *dagaa* production trend with a strong positive correlation coefficient of 0.44 also gives an indication that *dagaa* trade for domestic supply will be available for a long foreseeable future.

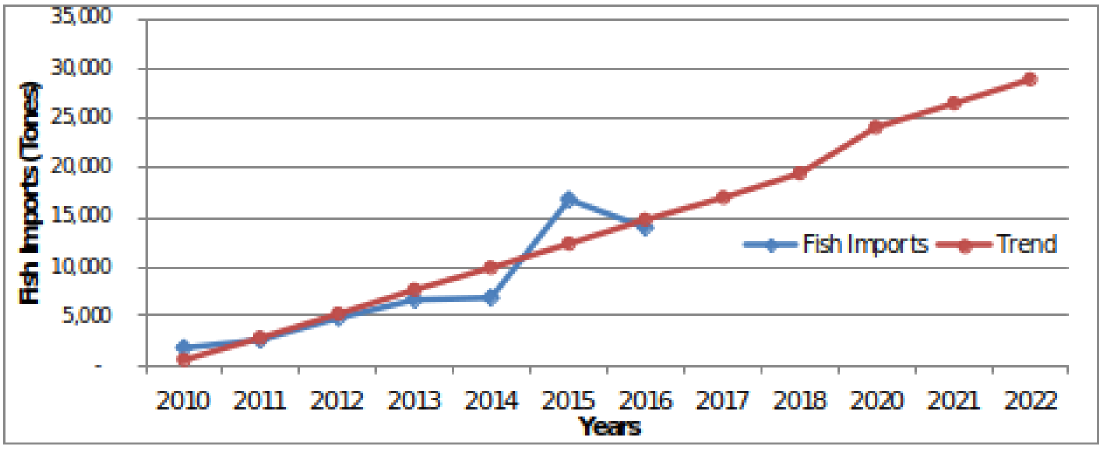

Figure 7: Fish imports trend in Tanzania for years 2010-2016

Source: URT$_b$ (2016)

Similarly, the general fish market for imports (Figure 7) showed a positive trend with a strong linear relationship indicated by a Pearson correlation coefficient of 0.91. An increasing imports trend of fish in Tanzania is a reflection of shortage of fish supplies in the country. This situation has the potential to create lucrative market for *dagaa* dried in solar tent as a substitute to other fish types given its desirable quality aspects of good taste and free from contaminations that can amount into health hazards to consumers.

Results of the content analysis of data from key informant interviews showed that market for *dagaa* is growing and customers of *dagaa* are shifting to high quality products. There is a rising trend for consumers to demand *dagaa* without sand contaminations. On the part of processors there is also a shift gaining momentum to dry *dagaa* by using old fishing nets which are no longer used for fishing in order to reduce sand contamination. Key informants in *dagaa* subsector claimed that most *dagaa* processors (more than 50%) are in a move to meet the new emerging customer need for uncontaminated *dagaa*. The key informants also reported that market opportunities for improved *dagaa* products are limitless; the main challenge for the industry at the moment is limited access to financing for establishment of commercial processing facilities which will guarantee quality of *dagaa*.

Dagaa has a wide domestic market as well as the East Africa region market. Findings from the demand projections and content analysis of data from key informant interviews are similar to the studies conducted by Mustapha *et al*. (2014), Odoli, (2015), Zebib *et al*. (2017), Abraha *et al*. (2017) and Chiwaula *et al*. (2017) who tested consumer preferences on *dagaa* dried on raised racks and in solar tent. Findings from these studies showed that consumers most preferred *dagaa* dried in solar tent because of their good taste and cleanliness. Based on these findings it implies that the use of solar tent for drying *dagaa* should be promoted around Lake Victoria because there is potential market for the new product in the next coming decade.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Moisture content in *dagaa*

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

5.1.2 Post-harvest losses of *dagaa*

Based on the findings, the hypothesis postulated on post-harvest losses can be concluded that drying *dagaa* in solar tent creates significantly less physical post-harvest losses than drying on raised racks and bare sand. Drying *dagaa* in solar tent reduced post-harvest losses by 14.9% and 24.9% compared to drying on raised racks and bare sand respectively. The reduction in post-harvest losses has an implication on availability of *dagaa* to consumers, more income to traders and more employment opportunities to fisheries related economic activities.

5.1.3 Cost-Benefit Analysis of *dagaa* drying methods

From this study it can be concluded that drying *dagaa* by using solar tent is more economically viable compared to the use of raised racks or drying on bare sand. Drying *dagaa* by using solar tent achieved the highest Net Present Value (NPV) of Tsh. 68 069 703 at the Internal Rate of Return (IRR) of 230% and Benefit-Cost Ratio (BCR) of 1.22. Sensitivity analysis indicated that the investment of drying *dagaa* by using solar tent is more sensitive to decrease in selling price of dry *dagaa* and increased purchase price of fresh *dagaa*. However, based on market analysis, the sensitivity can be mitigated by the rising trend of consumers preference to high quality *dagaa* which is likely to stabilize the price of *dagaa* dried in solar tent. In the case of price of fresh *dagaa*, low prices persist longer during high catch periods of about five months and the high prices exist only for a short period of two months within the planning framework of this investment analysis. Despite being expensive, solar drying method should be promoted because of the good quality obtained and the losses that it reduces which contributes to a sustainable fish resources management.

5.1.4 Market demand prospects for *dagaa*

Based on market forecast from historical data and results of content analysis of data from key informant interviews, it is concluded that there is a promising market potential for *dagaa* dried in solar tent. The market analysis showed a positive trend of rising demand for *dagaa* and fish market in general. Also correlations coefficients showed that there was a strong relationship between the demands of *dagaa* in the past and the projected forecasts of demand. The key informant interviews also indicated that *dagaa* market is promising lucrative future business prospects. The interviews also showed that there is limited competition in the market and the future market is promising increased demand. The demand is growing, and consumers prefer higher quality products to the low quality ones. More importantly *dagaa* production trend shows that the *dagaa* production is increasing over the years so it guarantees availability of *dagaa* for doing business. In addition, the general fish market shows that there is an increasing trend of fish imports from abroad which means that more fish is needed in the domestic market.

5.2 Recommendations

5.2.1 Upscaling the solar tent drying innovation

Based on the findings of the study and conclusions it is recommended that solar tent should be promoted for drying *dagaa* at large scale due to its high initial capital requirement which would not be feasible for small scale *dagaa* processors. This will highly contribute to reduction of post-harvest losses of *dagaa* and ensure sustainable *dagaa* harvesting in Lake Victoria. In addition to reduction of post-harvest losses the use of solar tent reduces the problem of limited space of land at lake shores. This has also been recommended by other previous studies such as EMEDO, (2017). Drying by solar tent also ensures high quality of the product *dagaa* by limiting possible contaminations by dust, insects and animals such as cats and dogs.

Promotion of the solar tent drying innovation could be done by various stakeholders who have interest in *dagaa* subsector and can capitalize on information from this study to address post-harvest losses in the fisheries industry. Such stakeholders include the national and local governments, the private sector which includes the business community in general and banking financial institutions in particular for financing, international and local development partners to trigger and facilitate interventions for adoption of the innovation. This will in turn make more *dagaa* available for consumption to the people of Tanzania and for export. It will also enable fish processors and other related businesses in the fishing industry benefit in terms of increasing their incomes and employment.

5.2.2 Further research to upgrade solar drying innovation

Further research should be conducted especially for experimenting the efficiency of solar tent in drying *dagaa* during the rainy season because this is the period when post-harvest losses of *dagaa* is at peak. This is due to lack of physical cover of the *dagaa* dried on open ground to protect it from rainfall, but also the sunlight intensity during this period is low because of cloud cover. In addition, studies to assess the level of humidity in the solar tent, the wind flow rate to the tent and determination of the amount of microbial counts in *dagaa* to ascertain the quality of *dagaa* dried in the solar tent are important. Furthermore, detailed market research that involves a sensory taste of *dagaa* should be conducted in order to widen an understanding of the extent of the market preferences for *dagaa* dried in solar tent.

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APPENDICES

Appendix 1a: Discounted Cash flow for drying *dagaa* in solar tent

YEAR	0	1	2	3	4
Total Additional Costs	**9 872 640**	**92 834 993**	**94 828 418**	**96 866 496**	**98 950 289**
Land acquisition- 150 square meters	2 000 000				
Solar tents -5 Units	3 240 000				
Drying racks (65)	2 015 000				
Water Sieving racks (5 Units)	180 000				
A weighing scale	65 000				
Dagaa carrying crates (910)	150 000				
Transport Costs		700 000	724 500	749 858	776 103
Wages		5 950 000	6 158 250	6 373 789	6 596 871
Maintenance and Repair		2 002 993	2 073 098	2 145 656	2 220 754
Packaging materials		252 000	260 820	269 949	279 397
Storage rent		210 000	217 350	224 957	232 831
Purchase of fresh *dagaa*		83 720 000	85 394 400	87 102 288	88 844 334
Working Capital	2 222 640				
Total Additional Benefits	**-**	**111 132 000**	**113 354 640**	**115 621 733**	**122 470 911**
Sales of dried *dagaa*	-	111 132 000	113 354 640	115 621 733	117 934 167
Residual Value of Investment					2 314 103
Recovery of Working Capital					2 222 640
Net Additional Cashflow	**(9 872 640)**	**18 297 007**	**18 526 222**	**18 755 236**	**23 520 621**

Appendix 1 b: Discounted cashflow for drying *dagaa* on raised racks

YEAR	**0**	**1**	**2**	**3**	**4**
Total Additional Costs	**4 073 000**	**9 251 838**	**9 508 452**	**9 772 704**	**10 044 834**
Land acquisition- 150 square meters	2 000 000				
Raised racks (5 units)	1 500 000				
A weighing scale	65 000				
Dagaa carrying crates (4 Units)	60 000				
Transport Costs		210 000	217 350	224 957	232 831
Wages		2 800 000	2 898 000	2 999 430	3 104 410
Maintenance and Repair		1 607 838	1 664 112	1 722 356	1 782 639
Packaging materials		84 000	86 940	89 983	93 132
Storage rent		70 000	72 450	74 986	77 610
Purchase of fresh *dagaa*		4 480 000	4 569 600	4 660 992	4 754 212
Working Capital	448 000				
Total Additional Benefits	**-**	**22 400 000**	**22 848 000**	**23 304 960**	**24 868 630**
Sales of dried *dagaa*	-	22 400 000	22 848 000	23 304 960	23 771 059
Residual Value of Investment					649 571
Recovery of Working Capital					448 000
Net Additional Cashflow	**(4 073 000)**	**13 148 162**	**13 339 548**	**13 532 256**	**14 823 796**

Appendix 1 c: Discounted cashflow for *dagaa* drying project on bare sand

YEAR	0	1	2	3	4
Total Additional Costs	**353 480**	**7 644 000**	**7 844 340**	**8 050 348**	**8 262 195**
Land acquisition (public land used for free)	-				
A weighing scale	65 000				
Dagaa carrying crates (910)	60 000				
Transport Costs		210 000	217 350	224 957	232 831
Wages		2 800 000	2 898 000	2 999 430	3 104 410
Packaging materials		84 000	86 940	89 983	93 132
Storage rent		70 000	72 450	74 986	77 610
Purchase of fresh *dagaa*		4 480 000	4 569 600	4 660 992	4 754 212
Working Capital	228 480				
Total Additional Benefits	**-**	**11 424 000**	**11 652 480**	**11 885 530**	**12 424 993**
Sales of dried *dagaa*	-	11 424 000	11 652 480	11 885 530	12 123 240
Residual Value of Investment					73 273
Recovery of Working Capital					228 480
Net Additional Cashflow	**(353 480)**	**3 780 000**	**3 808 140**	**3 835 182**	**4 162 798**

Appendix 2a: Data collection sheet for an experiment of drying *dagaa* in solar tent

No.	**DATA TO BE COLLECTED**												
1	Solar tent investment costs (Tshs)												
2	Labour costs (Tshs)												
3	Temperature record hourly (^{0}C)												
4	Fresh *dagaa* weight (Kg)												
5	Weight of dried *dagaa* (Kg)												
6	Time taken to to dry *dagaa* (Hours)												
7	Moisture content of dried *dagaa* % w/w												
8	*Dagaa* post-harvest losses (Kg)												

Appendix 2b: Data collection sheet for an experiment of drying *dagaa* on raised racks

No.	**DATA TO BE COLLECTED**												
1	Investment costs of raised racks (Tshs)												
2	Labour costs (Tshs)												

3	Temperature record hourly (^{0}C)												
4	Fresh *dagaa* weight (Kg)												
5	Weight of dried *dagaa* (Kg)												
6	Time taken to dry *dagaa* (Hours)												
7	Moisture content of dried *dagaa* % w/w												
8	*Dagaa* post-harvest losses (Kg)												

Appendix 2c: Data collection sheet for an experiment of drying *dagaa* on bare sand

No.	**DATA TO BE COLLECTED**												
1	Investment costs (Tshs)												
2	Labour costs (Tshs)												
3	Temperature record hourly (^{0}C)												
4	Fresh *dagaa* weight (Kg)												
5	Weight of dried *dagaa* (Kg)												
6	Time taken to to dry *dagaa* (Hours)												
7	Moisture content of dried *dagaa* % w/w												
8	*Dagaa* post-harvest losses (Kg)												

Appendix 3: A Questionnaire for Key informant interviews to supplement market data

	Name of Respondent	
	Age	
	Occupation	
	Organization	
	Location	
	Contacts	
	Date of Interview	

QUESTIONS:

1. Who are the main players in *dagaa* market?

____
____
____
____
____

2 What are the main distribution channels of *dagaa*?

____
____
____
____
____

3 What are the key elements of *dagaa* value chain?

4 What regulations govern the *dagaa* market?

5 Who are main customers of *dagaa* in Mwanza?

6 What are the drivers of demand for *dagaa* ?

7 What are the strengths of key players in the market?

8 What are the weaknesses of the key players in the market?

9 What is the business model for *dagaa* processors?

10 What are barriers to entry for new entrepreneurs ?

11 What is the level of competition in the market?

c

12 What are the current market dynamics of *dagaa*?

13 How does the future of *dagaa* market look like?

14 What are the main challenges facing *dagaa* dealers ?

15 What are the key potential risks in *dagaa* market?

16 What opportunities do you see in *dagaa* market?

17 Do you have any other information you think that it is important I know as regards *dagaa* market?

Appendix 4: Key assumptions and parameters used in the data analysis per objective

	OBJECTIVES		ASSUMPTIONS AND PARAMETERS
1	To determine moisture content of dried *dagaa*	a	Standard maximum moisture content of dried *dagaa* is 12%
		b	Temperature in the Solar tent is homogeneous at any specific time
2	To assess physical post-harvest losses of *dagaa*	a	The experimental unit is 2kg of fresh *dagaa*
		b	Post-harvest losses occur at processing point
		c	*Dagaa* drying conversion ratio is 1kg of fresh *dagaa* yields 0.25kg of dried *dagaa*
3	To assess economic viability of *dagaa* drying methods	a	The discount rate for cash flow discounting is 20% and the prime lending rate in banking financial institutions ranges from 17 to 20%
		b	The investment analysis period covers 4 years
		c	Depreciation rate used for solar tent and raised racks is 20% and for plastic carrying crates is 12.5% both on reducing balance
		d	Land plot size for *dagaa* drying investment is 150m^2
		e	Land acquisition cost for the plot size of 150m^2 is Tsh. 2 million
		f	Fresh *dagaa* market price is Tsh. 1000/= per kg
		g	Selling market price of *dagaa* dried in solar tent is 6,250/= per kg
		h	Selling market price of *dagaa* dried in raised racks is Tsh.5000/=
		i	Selling market price for *dagaa* dried on bare sand is Tsh 3000/=
		j	The manager's wage per day is Tsh, 10,000/= and attendants wage is Tsh. 5000/= per day
		k	5 units of solar tent will dry 520kg of fresh *dagaa* for one drying cycle. One solar tent unit with the capacity of drying 104 kg of fresh *dagaa*
		l	*Dagaa* drying operations will take place for 7 months only; June to December
		m	Post-harvest losses factored in are 25.6%, 15.6% and 0.7% for drying on bare sand, raised racks and solar tent respectively
		n	For sensitivity analysis, the potential risk for *dagaa* selling price to fall was factored as 17%, the potential for fresh *dagaa* price to rise was 23% and the potential for other operational costs to rise was 17%
		o	Maintanance and repair costs for solar tent is 2.2% of operational cost
		p	Gunny bags of 70 kg to be used for packaging which costs at Tsh. 600/= per piece
		q	*Dagaa* processors are not charged taxes if they sell at processing point

4	To assess market potential of *dagaa* dried in solar tent	a	The rising domestic demand trend for *dagaa* will continue in the next four years
		b	The highest market price of *dagaa* dried on raised rack (Tsh. 6250/= per kg) is used as the initial price for *dagaa* dried in solar tent.
		c	There is a potential to increase selling price of *dagaa* dried in solar tent over time

Appendix 5: Questionnaire for reconnaissance survey

RECONNAISANCE SURVEY FOR DESIGNING AN EXPERIMENTAL STUDY LEADING TO AN ECONOMIC EVALUATION OF *DAGAA* SOLAR DRYING INNOVATION AND ITS PROSPECTS FOR REDUCING POST-HARVEST LOSSES AROUND LAKE VICTORIA IN MWANZA CITY, TANZANIA.

INTRODUCTION

This survey intends to capture background information about *dagaa* drying innovations for reducing post-harvest losses initiated by various stakeholders in Mwanza city. These stakeholders include *dagaa* processors, Fisheries department of the city council, Lake Victoria Fisheries Organization, Tanzania Fisheries Research Institute and Fish Markets Authorities. The data will provide a basis for understanding the processors' objectives, constraints, opportunities and post-harvest loss management practices. The understanding will provide a basis for setting up *dagaa* drying experiment for reducing post-harvest losses by using a solar tent dryer appropriate to the socio-economic conditions of the processors. Specifically, the information will allow the researcher to describe the existing *dagaa* processing system and understand why processors have arrived at it; identify both the problems it presents and the opportunities it offers. Ultimately match the compatibility of the proposed experimental research design with the existing processing system geared to address processors' constraints.

SECTION 1: IDENTIFICATION PARTICULARS

Municipality:	
Division:	
Ward:	
Street:	
Name of respondent and/ or organization:	
Sex	1=Male 2=Female
Age in complete years	
Education level reached	0= None 1= Primary 2= Secondary 3= Tertiary
Respondent’s phone number	

Name of interviewer:……………………………………………………………………...

Date of Interview:………………………………………………………………………………

SECTION 2: DATA COLLECTION FROM *DAGAA* PROCESSORS

Subsection 2.1. Establishment and Investment requirements for *dagaa* drying business

No	Question	Response/Data to be collected				
1	What is the process to obtain a drying site for *dagaa*?					
2	Do you need licensing to be allocated the site?	Yes		No		
3	How much do you pay for licensing per year?	Tsh				
4	Do you pay fees/ rent for the drying site? How much?	Yes		No	Tshs	
5	What method of drying *dagaa* do you use?	Rack		Sand		
6	What are investment costs for the open sun drying rack?	Tshs				
7	What is the size of your *dagaa* drying area on sand?		M^2			
8	What is the holding capacity of the area for 1 drying cycle?		Kg			
9	What is the holding capacity of your raised rack in 1 cycle?		Kg			
10	What are investment costs for the sand drying method?	Tshs				

Subsection 2.2. *Dagaa* drying objectives, constraints and opportunities

No	Question	Response/Data to be collected				
11	What are your objectives for *dagaa* drying?	Business	Subsistence	Other		
12	What constraints do you face in *dagaa* drying	Market		Finance		Other
13	What opportunities exist in *dagaa* drying?	Market	Technology	Gov. Support	NGO suppor t	Other

Subsection 2.3. Existing *dagaa* drying and post-harvest loss management practices

No	Question	Response/Data to be collected				
14	Where do you source fresh *dagaa* for drying?	Fishermen	Wholesalers	Other		
15	How much *dagaa* do you dry in 1 cycle?		Kg			
16	What is labour required in 1 drying cycle?		Persons			
17	What is your source of labour for *dagaa* drying?	Family		Other		
18	How much is labour cost in 1 drying cycle?	Tshs				
19	How many hours does it take to dry in 1 cycle?		Hours			
20	How do you control predators?					
21	How much *dagaa* is spoiled when drying in racks?		Kg/cycle			
22	How much *dagaa* is spoiled when drying on sand?		Kg/cycle			
23	What is the transport cost for 1 drying	Ths.				

	cycle?					
24	What materials do you use to pack dried *dagaa*?	Sacks	Boxes	Other		
25	In how many units do you pack *dagaa* in 1 cycle?		Units			
26	What is the price of 1 unit of packaging material?	Tshs				
27	Where do you store *dagaa* after drying?	Rented		Home		
28	If rented store how much do you pay per month?	Tshs.				
29	How much is maintenance cost of drying racks?	Tshs/year				
30	What is normally done to maintain the racks?					
31	What other costs do you incur in 1 drying cycle?	Tshs				
32	Do you have access to support services?	Yes		No		
33	What kind of support services do you get?	Technology	Finance	Other		
34	Who provides the support services?					
35	How do you determine your *dagaa* prices?	Market	Drying cost	Other		
36	How do you get market information for *dagaa*?	Friends	Gov.	Other		

Subsection 2.4. Respondents opinions on how the constraints could be addressed

No	**Question**	**Response/Data to be collected**
37	In what ways do you think the constraints could be addressed?	

SECTION 3: CHECK LIST FOR DATA COLLECTION IN VARIOUS INSTITUTIONS

	INSTITUTIONS	**DATA TO BE COLLECTED**			
		1	2	3	4
1	Mwanza City Council (Fisheries department)	Services provided to *dagaa* processors	Regulations for *dagaa* fishermen and processors		
2	Tanzania Fisheries Research Institute (TAFIRI)	Past research experiences in *dagaa* drying methods	Identification and accessibility to suitable experimental sites		
3	Lake Victoria Fisheries Organization (LVFO)	Technological interventions for *dagaa* processing to reduce post-harvest losses	Capacity building interventions related to *dagaa* processing for reducing post-harvest losses		

4	Lake Shore Fish Markets	Compliance requirements for *dagaa* processors to do business in the market	Volumes of dried *dagaa* sold domestically for the past 5 years by product type	Volumes of dried *dagaa* exported for the past 5 years by product type	Domestic and Export prices of *dagaa* for the past 5 years by product type.
5	Tanzania Meteorological Agency (TMA)	Temperature and relative humidity trends for the past 5 years	Rainfall trend for the past 5 years	Wind flow trend for the past 5 years	Sunshine trend for the past 5 years

Appendix 6: Monthly *dagaa* production trend in Lake Victoria for year 2015

Months		Production (Tones)	Trend	Absolute error
January	1	11 116	5 209	5 907
January	2	10 113	6 336	3 776
January	3	12 156	7 464	4 693
January	4	125	8 591	8 465
January	5	8 722	9 718	996
January	6	7 052	10 845	3 793
January	7	1 257	11 972	10 716
January	8	11 094	13 100	2 005
January	9	9 349	14 227	4 878
January	10	20 121	15 354	4 767
January	11	35 659	16 481	19 177
January	12	10 141	17 608	7 467
	Mean absolute error			**6 387**

Appendix 7: *Dagaa* consumption trend in Tanzania for years 2010 to 2015

Years	Domestic demand (Tones)	Trend	Absolute error
2010	221 578	264 720	43 142
2011	246 858	277 939	31 081
2012	324 223	291 158	33 065
2013	401 588	304 377	97 211
2014	364 007	317 596	46 411
2015	228 349	330 815	102 466
2016		344 034	344 034
2017		357 253	357 253
2018		370 472	370 472
2019		383 691	383 691
2020		396 910	396 910
2021		410 129	410 129
2022		423 348	423 348
Mean absolute error			**233 785.6**

Appendix 8: *Dagaa* Export Trend in Tanzania for the year 2010 to 2015

years	Exports (Tones)	Trend	Absolute error
2010	11 904	11 505	399
2011	10 314	10 216	98
2012	8 569	8 928	359
2013	6 824	7 639	815
2014	6 673	6 351	322
2015	5 417	5 062	355
2016		3 773	3 773
2017		2 485	2 485
2018		1 196	1 196
2019		- 93	93
2020		- 1 381	1 381
2021		- 2 670	2 670
2022		- 3 959	3 959
Mean absolute error			**1 377**

Appendix 9: *Dagaa* Production Trend in Tanzania for for years 2010 to 2015

Years	Production (Tones)	Trend	Absolute error
2010	289 873	297 257	7 384
2011	316 350	323 841	7 491
2012	362 472	350 426	12 046
2013	408 593	377 011	31 582
2014	371 177	403 595	32 418
2015	433 845	430 180	3 665
2016		456 765	456 765
2017		483 349	483 349
2018		509 934	509 934
2019		536 518	536 518
2020		563 103	563 103
2021		589 688	589 688
2022		616 272	616 272
Mean absolute error			**296 170**

Appendix 10: Fish imports trend in Tanzania for the years 2010-2016

Years	Imports (Tones)	Trend	Absolute error
2010	1 920	573	1 347
2011	2 659	2 932	273
2012	4 886	5 292	406
2013	6 642	7 652	1 009
2014	6 792	10 011	3 219
2015	16 744	12 371	4 373
2016	13 918	14 730	813
2017		17 090	17 090
2018		19 450	19 450
2020		24 169	24 169
2021		26 529	26 529
2022		28 888	28 888
Mean absolute error			**10 630**