EVALUATION OF SUPERMARKET FOOD WASTE AS A PARTIAL REPLACEMENT OF COMMERCIAL FEED IN MOZAMBIQUE TILAPIA CULTURE

Technical report: Case Studies

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EXECUTIVE SUMMARY

Food waste (FW) is a pressing global issue, imposing substantial logistical and financial burdens on waste management systems and significant environmental impacts. With global FW estimated to cost around USD 1 trillion annually, addressing this issue is crucial. Despite the high stakes, detailed regional insights into FW within the retail sector are scarce. Understanding the characteristics of this sector's waste stream is essential to inform developing waste management strategies and promoting effective practices. FW has immediate economic and environmental consequences, contributing to global food systems' perpetual inefficiency and inequity. It wastes valuable monetary resources, labour, energy, and water invested in food production, exacerbating food insecurity, especially in underserved communities with limited access to nutritious food. The outcome of this study highlights the urgent need to reform food management strategies, encourage sustainable consumption, and increase accountability throughout the supply chain. The research focused on characterizing the FW from a supermarket (retail outlet), analyzing its composition and temporal variations to explore its potential as aquafeed. A comprehensive waste composition analysis was conducted at a major retail outlet, examining waste from the fruits, vegetables, and bakery departments. Samples of the discarded FW was collected weekly over 12 months and brought to the laboratory for analysis to generate the data for the study. The study found citrus fruits to be the most prevalent waste category year-round, with other waste types showing seasonal variations. A notable issue with the supermarkets was the lack of formal documentation for discarded waste, revealing significant gaps in tracking practices at the retail level. Approximately 95% of the waste was edible fruits and vegetables (FVs). After confirming the suitability and safety of using these waste fractions for animal feed, they were processed and used in a six-week fish-feeding trial. A diet consisting entirely of commercial feed (diet 1 - control) had the highest specific growth rate (1.54±0.12 units), outperforming diets with varying FW content (diet 3: 50% control: 50% FW, 0.86±0.57 units; diet 2: 75% control: 25% FW, 0.74±0.62 units). These findings suggest the feasibility of using fish feed meals from FW as a partial replacement for commercial tilapia. The outcome also highlights the potential benefits for sustainability, cost reduction, and environmental impact in raising tilapia by using supermarket food waste as an alternative feed. This is a promising area for further research, with future studies focusing on optimizing feed formulations and exploring innovative processing methods such as bioconversion and advanced fermentation.

Keywords: Food waste characterization, fruits and vegetable products, supermarket waste, alternative fish feed

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1. Introduction

Food waste (FW) is an environmental, societal, and nutritional problem (FAO, 2011) that researchers, academics, policymakers, and governments need urgent mitigation measures to address. FW is generated along the entire food supply chain (FSC) for several reasons, which vary depending on specific global geographical regions (Nicastro and Carillo, 2021). FW relates to the inefficient use of scarce resources such as water, land, and energy (Chen et al., 2020, Munesue and Masui, 2019). In addition to the negative environmental impacts, FW also imposes economic costs on all stakeholders of the FSC ((Thyberg and Tonjes, 2016). For example, FW is one of the main contributors to greenhouse gas (GHG) emissions (FAO, 2013). From the nutritional side, nearly 825 million people are estimated to suffer from hunger and malnutrition (Melikoglu, 2020) (Melikoglu et al., 2013). Thus, FW impacts the implementation of food security objectives.

The impacts of FW have prompted an increase in scientific inquiries and reports, including reports published by the Food and Agricultural Organization (FAO) highlighting FW in medium and high-income countries and the other for low and middle-income countries (FAO, 2011, 2013). Although FW has prompted numerous studies, publications, and reports, FW remains rampant, especially in low and middle-income countries, including South Africa. Similarly, the definitions of FW also vary depending on specific scientific inquiries. For example, FW definitions can vary based on the market, sector, and the methodology used for inquiry (Okuthe, 2024)

Over time, there have been various interpretations of FW. According to the United Nations Food and Agricultural Organization (FAO), food loss (FL) and food loss and waste (FLW), collectively known as wastage, pertain to the edible portions of plant or animal products that go unconsumed (FAO, 2016). In 2019, FAO revised these definitions, defining FL and FLW as the decline in the quantity and quality of food along the FSC. FL typically arises from unintended factors such as managerial or technical issues, leading to food damage during harvesting, transportation, or due to insufficient infrastructure like packaging (FAO, 2019). On the other hand, FLW involves intentional decisions to discard food, primarily occurring at the retail and consumer stages of the FSC. FAO's definitions exclude inedible food parts and those destined for upcycling for commercial purposes, such as industrial or animal feed. Alternative definitions, like Food Use for Social Innovation by Optimizing Waste Prevention Strategies (FUSIONS), encompass edible and inedible parts in FW EU FUSIONS. 2016. About FUSIONS. Available at. https://www.eu-fusions.org/index.php/about-fusions.

FUSIONS defines food waste as any food or inedible part removed from the FSC for recovery or disposal, including methods like composting, anaerobic digestion, and incineration (Östergren and Holtz, 2014). FUSIONS categorizes FW as part of foods diverted from the food supply chain (FSC) without distinguishing between FL and FLW, but it does differentiate between food surplus (FS) and FW. FS remains suitable for human consumption but could become FW without prevention or re-use strategies. Despite attempts by FAO and FUSIONS to align FL and FLW concepts, definitions continue to diverge based on stakeholder concerns and focus. FW may also include both the edible and non-edible parts of food (Buzby et al., 2014, Gascón et al., 2023, Östergren and Holtz, 2014), based on cultural and/or potential health risks (Ristaino et al., 2021). We adopt the term 'food waste' to represent all types of wastage along the FSC; therefore, the acronym 'FW' will represent fruit and vegetable waste.

The present technical report examines the disposal of FV waste within the secondary production phase (the retail level) of the FSC, which is significant within the current operational framework. We utilize the term 'food waste' to encompass all forms of wastage at the retail level, henceforth denoted by the acronym 'FW' for fruit and vegetable waste. The emphasis on FV waste streams arises from their substantial volume in South Africa, driven by escalated production to meet growing demand.

Given the above arguments, the United Nations' Sustainable Goals (SDGs) set targets in 2015 to halve FW by 2050 by optimizing FW along the FSC. Accordingly, many nations in Sub-Saharan Africa (SSA), including South Africa, are committed to meeting the target. Notwithstanding, FLW in SSA Africa remains prevalent, and to fast-track the objectives of optimizing FW along the FSC and to implement them, there is a need to know precisely the origin of the waste stream, how much is wasted and why there is so much it. Furthermore, it would be necessary to know which products form the bulk of the waste and why it is wasted. The paucity of data on FW in SSA is due to limited information in the literature or a lack of reliable data from the different provinces and district municipalities(Oelofse et al., 2021).

1.1 Statement of the problem

Approximately one-third (1.3 billion tons) of all food produced globally is lost or wasted each year, according to reports by the Food and Agricultural Organization of the United Nations (FAO 2011). On a global scale, 30– 40% of annual food production is wasted (Gu et al., 2020, Huang et al., 2021, Melikoglu, 2020). These wastages occur during the agricultural process, post-harvest handling and storage, processing, distribution, and consumption, with more than 40% loss occurring during post-harvest and processing levels in developing countries and at retail and consumer levels in developed countries (FAO, 2019). Increasing FW generation has put pressure on the environment. Currently, the technologies used to manage organic wastes include landfilling, incineration, anaerobic digestion and incineration. Food reuse programs are an economically feasible and reliable opportunity for FW recycling regardless of its technical flaws and social issues. Globally, efforts and initiatives are being implemented to address FW. In 2015, the United Nations defined the Sustainable Development Goal (SDG) 12 to "Ensure sustainable consumption and production patterns" within which target 12.3 refers to food waste: "By 2030, halve per capita global FW at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" (UN, 2015). Enormous quantities of FW, approximately 40% of municipal solid waste (MSW) generated, are currently mixed with the other waste streams and disposed of at landfills in most urban centers, creating negative environmental impacts (Sagar et al., 2024, Stenmarck et al., 2016)The current MSW management methods in South Africa include various waste management strategies, depending on the responsibility of a given local municipal authority.

In the past, MSW management was dominated by the private sector with selective methods of recycling resalable products, such as paper, cardboard, plastics, glass, and aluminium, among others (Karani and Jewasikiewitz, 2007). The bulk of the waste material, regardless of origin, is in landfills. Key issues include inadequate waste collection services for a large portion of the population, illegal dumping, unlicensed waste management activities, and a lack of legislation enforcement (Karani and Jewasikiewitz, 2007)These methods are unsustainable and promote environmental degradation by emitting greenhouse gases such as carbon dioxide (CO2) and methane (CH4), contributing to global warming. Apart from greenhouse gases, landfills harbour rodents and pests carrying diseases. FW is not only from environmental and economic points of view but also from some ethical and social ones. Furthermore, it represents a wasteful and inefficient use of the scarce resources used to produce it, such as land, water, and energy (FAO, 2013).

1.2 Background

In S. Africa, as in many African countries, managing urban FW is challenging, adding to the food loss already occurring during post-harvest and processing stages, attributed to poor processing infrastructure and preservation technologies. Nonetheless, current research shows that urban populations are beginning to show increased interest in 'FW reuse and recycling programs, which are local-level initiatives in the developed world to minimize wasted food each year (Malenica & Bhat 2020). In this regard, there has been renewed interest in the development of various valorization options for food wastes, such as anaerobic digestion (Zhang et al., 2016) (Zhang et al. 2016), composting (Kumar et al., 2010, Sundberg et al., 2013), biodiesel production (Antonopoulou et al., 2020, Kamusoko et al., 2021, Liakou et al., 2018, Poe et al., 2020, Ravi et al., 2020), animal feed production (Galanakis, 2020, San Martin et al., 2021, Tsai and Lin, 2021) (San Martin, Ramos, & Zufía 2016).

In the past ten years, the use of insects for the bioconversion of food waste in animal feed has become popular (Bosch et al., 2018, Gasco et al., 2020, Pinotti et al., 2019, Varelas, 2019). Currently, the use of FW generated from hotels and restaurants, housing estates (household), retail and wholesale sectors in animal feed has also attracted research interest (Ho and Chu, 2019, Malenica and Bhat, 2020, Truong et al., 2019, van Herpen et al., 2019).

The wholesale/warehouse sector has specialized sections specifically designed for consumer convenience (bakeries, delicatessens, butchers, fruits, and vegetables) and contributors of large amounts of food waste. Reasons for retail waste include product and packaging damage, temperature/storage in non-compliance with food safety regulations, blemishes on produce, and incorrect predictions of demand or spoilage due to power rationing, commonly called "load shedding" in S. Africa.

In most peri-urban and rural cities/ towns, FW is often not documented or quantified. A critical source are the grocery stores or supermarkets, the main intermediaries between producers and consumers living in peri-urban locations. Moving food from farms to consumers requires long transportation over long distances, especially in Mthatha (Eastern Cape Province), since most food items come from KwaZulu Natal (Durban), approximately 540 km or from East London, 250 km away and Qgeberha. As urbanization increases, the distance and process for providing the necessary food supply to dense populations will also increase. The increasing trend of multi-national grocery stores due to the increased global trade market is also putting more pressure on farmers to produce more than they did in the past, contributing to the potential of increased food loss.

As with wholesale, the food wasted in retail is due to damaged packaging, dented cans, and unsold blemished products (Parfitt et al. 2010). Another cause of many discarded food items is the sell-by date. These dates are on packages as the industry’s food quality measurements, not safety. Therefore, consumers tend to regard these dates as expiration dates. Outdated items are often removed from shelves or repackaged and resold to unsuspecting consumers, only to be discarded at the household level if they are deemed unsafe to eat (Tsiros and Heilman, 2005). This also leads to waste. This sector's waste contributes to the large volumes of decaying food in landfills and exacerbates greenhouse gas emissions. The increased production, coupled with poor handling and behaviour of retailers and consumers towards wastage, has led to huge quantities of loss and waste of vital agri-food commodities (Sagar et al., 2018). It is estimated that fruit and vegetable waste contributes nearly 60% of all FW (Fao, 2012).

A major issue of FW recycling is the broad spectrum of sources and food types (Wong et al. 2016). With several waste conversion technologies available, there is little information regarding the composition of different food waste types and their potential as feedstocks for various technologies. In addition, the nutrient content of mixed FW is highly variable over time (Westendorf, 2000). Thus, it is essential to classify FW into different groups and understand its corresponding chemical composition characteristics to reduce the uncertainties during FW conversion and achieve effective management. FW in S. Africa is generally regulated as part of waste management, and no legislation obligates the recording of FW (Le Roux et al., 2018). As such, FW accounting is still at an early stage of development, and a consolidated framework for FW quantification is still a challenge. Furthermore, there is limited information in the literature on food wastage of specific vegetable crops. Notwithstanding, the costs of household FW have been studied in recent times (Nahman et al., 2012) and are estimated to be to the tune of R. 32.5 billion, including the household FW's actual value and disposal costs to landfill sites. In another study, it was reported that approximately 9 million tonnes of FW are generated annually in S. Africa (Oelofse and Nahman, 2013). So far, however, there is no information on the composition variability of FW with time and sources, which makes the feasibility and effectiveness of using FW data unclear.

For any FW to be used as direct animal feed or converted by insects, the nutrient content and undesirable substances present would be of great importance to the quality of the animal feed or insect biomass produced (Makkar et al., 2014, Makkar et al., 2015, Rumpold and Schlüter, 2013). Also, an essential aspect of designing efficient and effective policies to reduce FW is to know how much and where the food is being wasted and how it can be rescued at the macro scale level (e.g., regional, provincial, and national). Currently, there is no estimate on the amount of agri-food waste that is generated, mainly because of the absence of records and the fact that the harvest seasons may vary from one province to another and that currently, waste has no economic value since it does not have a place in any market.

1.3 Aim of study

This study aimed to characterise supermarket food waste (FW) and determine its composition and temporal variation as raw materials for making fish feed, with particular emphasis on FVs.

The study focused on reporting waste generated by five departments: fruits, vegetables, bakery, cereals, and flour. Data was collected once a week for 12 months. Every morning, retail staff removed waste products presumed to be unfit for human consumption or other reasons from shelves and transferred them to the supermarket's waste storage section, located not more than 20 meters from the product delivery entrance.

1.3.1 The Research Questions

- What are the FW fractions?
- What are the seasonal variations of the FW fractions?
- What are the proximal compositions of the FW fractions?
- Can FW flour partially substitute commercial feed in Mozambique tilapia culture?

1.3.2 The Scope of the Project

The scope of this project included:

- analyzing the FW streams from a typical retail (supermarket) store within King Sabata Dalindyebo Local Municipality in Mthatha, which belongs to one of the region's five major South African retailers. The study focused on waste generated by five departments: fruits, vegetables, bakery, cereals, and flour.
- collecting FW once a week for 12 months; every morning, retail staff remove waste products presumed to be unfit for human consumption or other reasons from shelves and transfer them to the supermarket's waste storage section, located not more than 20 meters from the produce delivery entrance.
- characterizing and evaluating the supermarket's seasonal variations of FW types.
- determining the proximate chemical composition properties of food waste.
- undertake a study to evaluate the effects of FW products as a partial substitute for commercial fish feed in tilapia farming.

Methods

2.1 The Study Area

The Oliver Reginald Tambo District Municipality (ORTDM), located in the Eastern part of the Eastern Cape Province along the Indian Ocean coast of South Africa, presents a compelling case for study. Bordered by the Alfred Nzo District to the north, Joe Gqabi District to the northwest, Chris Hani District to the west, and Amathole District to the south, ORTDM encompasses a critical geographical and socio-economic landscape (Fig. 1). The historical significance of the former Transkei region, now integrated into the ORTDM (IDP, 2020), adds further depth to its relevance. Strategically situated on the Wild Coast and bordered by the Amathole District to the west and KwaZulu-Natal to the northeast, ORTDM covers an extensive area of 15,947 km². The district's climate variability is influenced by altitude and proximity to the coast. The district comprises five local municipalities: King Sabata Dalindyebo (KSD), Nyandeni, Ngquza Hill, Mhlontlo, and Port St Johns.

ORTDM is one of the most densely populated districts in the province, with an average population of about 1.52 million and a population density of approximately 123 people per square kilometer (ORTDM, 2020). A category C2 Municipality (IDP, 2020), with 93% of its population residing in rural areas, underscores its predominantly rural character. This unique demographic profile makes ORTDM an optimal location for investigating rural development challenges and opportunities. The insights gained from this study will be instrumental in shaping effective policies and interventions to foster sustainable growth and development in similar rural contexts.

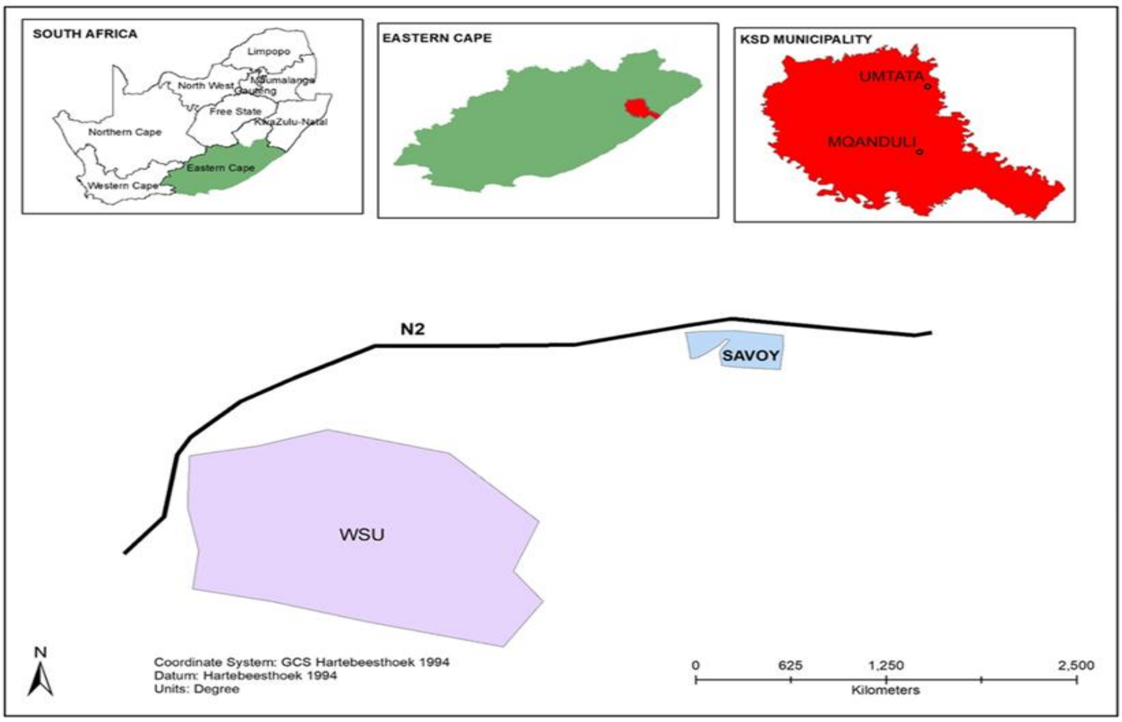

***Figure 1**:* Shows a map of the study site

2.2 The Supermarket store studied

Food waste samples were collected from a local retail facility (supermarket) located within the (King Sabata Dalindyebo Local Municipality (KSDLM) (Fig. 1.); (31° 45” 44” S/28° 40” 22” E), one of the five municipalities within ORTDM, as stated above. The retail store is one of the major supermarket chains in S. Africa, located near the Central Business District (CBD) of Mthatha Town. This retail store is strategically positioned less than 200 meters from Nelson Mandela Academic and Mthatha General Hospitals and less than 1.5 Km from an academic institution (university). The supermarket serves several eateries, hotels, and Bed and Breakfasts (B & B) within walking distance. It is also approximately a 10 -15 min drive from some of the affluent suburbs in Mthatha.

2.2.1 The General Flow of Produce in Retail Stores

Initially, interviews were conducted with managers of five stores in different locations of the local municipality to get an overview of how and where they source their produce and how often they receive, store and display their produce *(2.2.2 The* **supermarket store display logistics**

The fruit and vegetable aisles are at the retail store's main entrance. Various FV sections include a bulk display for fruits and vegetables (butternut, carrots, apples, onions, and potatoes); see

Figure 3 (A-C). In the grocery store's refrigerated section, fruits are packaged in cardboard boxes, plastic bags, or plastic containers see **Figure 4** Some vegetables are sold unpackaged. Cabbage heads are split and sold as halves, and pumpkins are sliced into small pieces. The refrigerated section is behind the loose vegetable display section, with direct access to the main entrance indicating higher storage temperatures above 18° C.

Figure 3: The supermarket's bulk (A) and loose and packed FV sections (B and C).

). Although only one retail chain store agreed to participate in the study, all the supermarkets have similar operational procedures regarding product sourcing, transportation, and management schedules, except for optimizing waste management strategies. Since no large commercial farms exist within the greater O.R. Tambo District Municipality (SAFL, 2022), most farm produce originates from neighbouring District Municipalities and Provinces. It is hypothesized that the supermarket is strategically located in a high-traffic area with consistent demand, which minimizes food wastage by ensuring a rapid inventory turnover. This optimal placement would allow the supermarket to sell products quickly, reducing the likelihood of food items reaching their expiration dates before being sold.

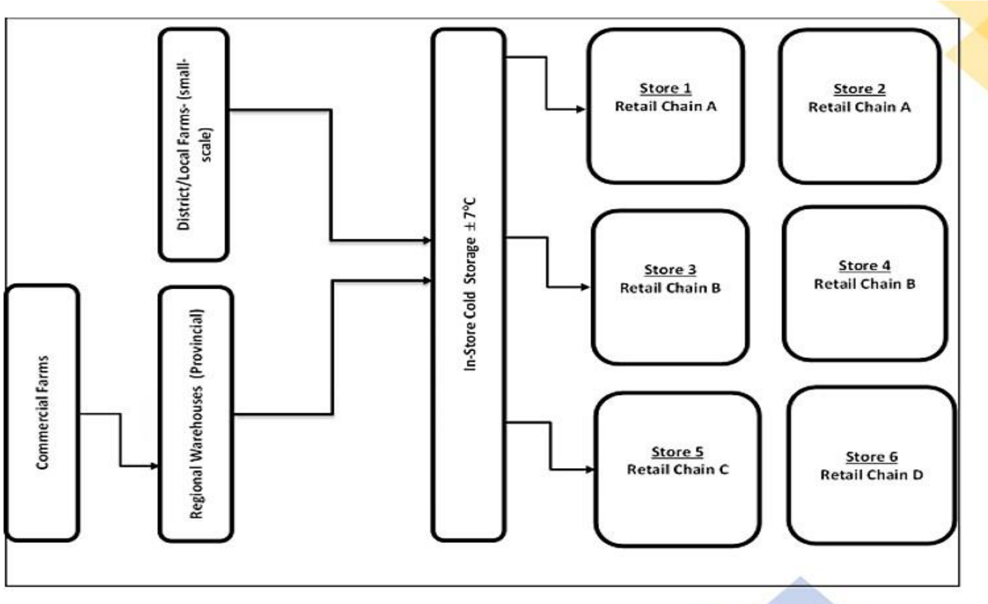

Figure 2*:* Fresh produce flow charts from various warehouses for the six retail stores (authors' data)

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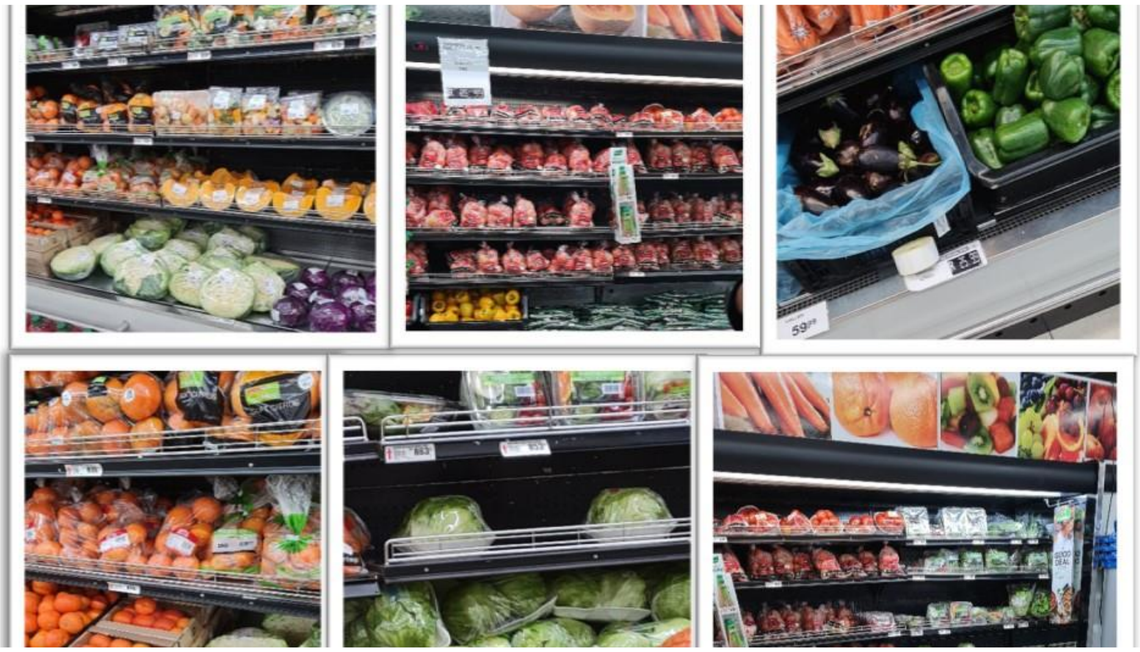
Figure 3: The supermarket's bulk (A) and loose and packed FV sections (B and C).

FVs are packaged in three categories: loose, small quantities, and for bulk purchases. Within the retail store, each section (retail department) has a manager and one or two responsible personnel for handling produce within an aisle (e.g., the fruit and vegetable section). These personnel constantly check and replenish shelves and check for damaged products as part of quality control.

Through this process, damaged fruits and vegetables are repackaged and sold at half the original price per/kg or a reduced price a few days from the sell-by date. Once deemed unfit for human consumption or spoilt, the fruits and vegetables are removed from the shelves every evening and packaged in plastic bags for disposal the following morning in a designated area for waste disposal outside the store. Fruits and vegetables deemed unfit for human consumption are mainly due to consumer handling (for example, picking them up and leaving them at the till for various reasons, damage due to "load shedding", among other factors). Once left at the till, designated personnel collect and return the FV to the shelves. While at the till, they may be out of the refrigerated sections for at least 5 to 15 minutes, depending on the time of the month. For grains, cereals, and floors, damaged products due to transportation and handling at the store are often recorded and stored at a designated section within the warehouse for later return to manufacturers, according to the previously assigned return policies.

Figure 4*:* Shows the refrigerator section for fresh FVs, including sliced produce and ready-to-eat salads.

In the store, produce is sold according to the exact weight in kilograms or as individual units. Vegetables like lettuce, kale, collard greens, celery, spinach, parsley, garlic, and cucumber are sold by the unit. Larger vegetables like pumpkins, butternut squash, and cabbage are sold whole or halved and wrapped in plastic. Ready-to-eat salads are packaged in small plastic containers, while spinach can be bought loose, packaged, or shredded and packaged.



2.3 Laboratory Experiments

2.3.1 FW collection, sorting and weighing

This study evaluated the feasibility of FW from a supermarket as a sustainable feed ingredient for Mozambique tilapia. FW from five departments (fruits, vegetables, cereals, bread, bakery, and grains) was collected daily and analyzed for nutritional composition. FW samples were processed into a fine powder and incorporated into experimental diets at varying levels, as outlined below in **Figures 5 - 10.**

Briefly, a comprehensive study was conducted in the King Sabatha Dalindyebo (KSD) Local Municipality to investigate the potential of FW from a supermarket as a sustainable feed source. Five distinct departments within supermarkets were identified as primary sources of FW: fruits, vegetables, cereals, bread/bakery, and grains. Collections were made once a week for twelve months from these departments, with samples carefully sorted and stored for analysis (Figs 6-8). Collected FW samples underwent rigorous laboratory analysis to determine their suitability as fish feed. Moisture content, nutrient composition, and energy density were assessed.

Additionally, the samples were processed to a fine powder for easier incorporation into fish feed **(Fig 10).**

Figure 5. Shows the steps used in FW collection, sampling, sorting and processing (Vundisa, 2004)

Figure 6. Shows selected sample images of the laboratory cleaning and sorting of FV waste.

Figure 7. Shows selected sample images of the shredding of FV waste in preparation for drying.

Figure 8. Shows selected sample images of FV waste in drying ovens.

Figure 9. Shows milled FW flour and feed formulation

2.3.2 Fish Feeding Trials

2.3.2.1 Experimental fish and feeding trial

Mozambique tilapia (*Oreochromis mossambicus*) fingerlings were raised in controlled tanks and fed these diets for eight weeks. Growth performance, feed conversion efficiency, and survival rates were monitored. Faculty of Natural Science animal care approval was obtained before the experiment (FNS-AREC/2021/11/03/A20. O. mossambicus (Red Tilapia) fingerlings were obtained from a local supplier (Aquaculture Innovations, Grahamstown, South Africa). They were transported in large cooler boxes. The fish were then offered the commercial diet twice daily until the beginning of the experiments. Water was aerated using a regenerative blower and submerged air diffusers. Temperature was maintained at 28 ± 1 °C using submerged heating elements. Daily temperature and dissolved oxygen measurements were performed using a Hanna portable Model HI198198 dissolved oxygen (DO) meter (Hanna Instruments). Total ammonia nitrogen (TAN), nitrite nitrogen and pH were measured weekly using a Freshwater Aquaculture Test Kit (Hanna Instruments). Photoperiod was maintained at 14:10 h (light: dark), and 30% of the water in each system was replaced weekly to maintain optimal water quality. A total of 270 fish (all male) were used in feeding trials. Fish were size-sorted by hand and randomly stocked into each of the 15 tanks. Fish in each experimental tank were offered one of three feed regimens with three replicate tanks per treatment as follows: (i) T1: 100% commercial feed (CF); (ii) T2: 50% CF, 50% FW and (iii) T3: 75%CF, 25% FW. In all experiments, fish were fed at 4% of total body weight divided over four portions per day divided over 12 hours (7:00 h, 7 11:00 h, 15:00 h and 19:00 h), six days a week. Fish were group-weighed bi-weekly after a day of fasting, and the ration was adjusted accordingly to 5 % of the average total biomass of the largest treatment. Dead fish were removed immediately and recorded. Uneaten feed was siphoned out after 1 hour of feeding, and tanks were scrubbed once a week to minimize algal and fungal growth. Experiments were terminated after six weeks.

At the end of the feeding trial, fish were starved for 24 hours before harvest and data collection. Sixty fish /feeding regimes were anaesthetized (MS222, Sigma Aldridge MO, USA), individually weighed (± 0.1 g), focal lengths (± 1.0 mm) measured, and fish were allowed to recover in aerated water before returning to experimental tanks. Fulton's condition factor (K) was calculated using K = (WL−3) 100, where W is body weight (g) and L is fork length (cm). Weight data was used to calculate the specific growth rate (SGRwt) and feed conversion rate (FCR) for each sampling period where SGRwt was calculated as (eg-1) × 100, where g = (ln(Wf) − ln(Wi)) × (t2 − t1) -1. Relative Weight gain (RWG) was calculated as (Wf-Wi)/Wi x 100. FCR was calculated as F / (Bf − Bi + Bm) −1 where F is the feed fed (kg), Bf is the final biomass (kg), Bi is the initial biomass (kg), and Bm is the mortality biomass for the period (kg). Further, 24 fish/feeding regimes were euthanized, and viscera (intestines and associated fat deposits without liver or gonad) and livers dissected individually weighed to calculate viscerosomatic (VSI, %) and hepatosomatic (HSI, %) indices, where VSI was calculated as viscera weight / (body weight – viscera weight) x 100; and HSI as liver weight / (body weight – liver weight) x 100.

Figure 10. Shows experimental and holding tanks

2.3.2.2 Proximate composition of diets

The proximate composition of feeds and fish was performed as described by Nasser et al. (2018). This included the measurement of moisture, total nitrogen, crude protein, fiber, ash, carbohydrate, lipid, carbohydrate-to-lipid ratio, energy, protein-to-energy ratio and protein solubility. Following the proximate analysis, the feed's digestible energy was calculated as 16.72, 17.62 and 37.62 kJ/g for protein, carbohydrate and lipid, respectively (Garling Jr and Wilson 1976). Dry matter was analysed by drying the samples to constant weight at 105 °C. Crude protein was determined using the Kjeldahl method (AOAC,1996) and crude protein content was estimated by multiplying nitrogen by 6.25; crude lipid by acid hydrolysis with a Sotex System HT 1047 Hydrolyxing Unit (Tecator Application Note 92/87), followed by Soxhlet extraction using a Soxtex system 2055; gross energy in an adiabatic bomb calorimeter (Parr Instruments, Moline, IL); ash was analysed by combustion in a muffle furnace at 550 °C for 16 h. There were three replicates for each analysis.

3.0 Results and Discussions

3.1 Food waste categories in studied supermarket

Based on the data collected during the study, the following food items were identified as the most common food waste in the supermarket. Within the vegetable category, tubers/roots, cruciferous vegetables, and marrows comprise more food waste (FW) than leafy vegetables, alliums, and other vegetable types (**Figures 12 to 14)**. Among fruits, tropical varieties such as bananas and citrus contribute the most to FW, surpassing pomes and pineapple fruits. **Figure 14** illustrates the types and proportions of FVs lost or wasted during the study period. Vegetables account for the highest proportion of waste, followed by fruits and grains.

Several of these FVs produce ethylene gas, influencing their ripening and spoilage rates. These include the following:

- Tomatoes: Known for high ethylene production, tomatoes can significantly impact the ripening of other ethylene-sensitive produce (López-Gómez et al., 2023, Yu et al., 2024).
- Avocados also produce a considerable amount of ethylene, especially as they ripen (Anagnostopoulou et al., 2024, Hunter et al., 2024)
- Peppers: Bell peppers and other varieties produce ethylene (Gu et al., 2024, Li et al., 2024) at lower levels than fruits like tomatoes.
- Eggplants: They release ethylene, particularly when they start to ripen (Alkan et al., 2023, Campos et al., 2024).
- Potatoes: Both sweet potatoes and regular potatoes produce ethylene, especially as they sprout (Kou et al., 2023, Li et al., 2024).
- Carrots: Produce ethylene, but to a lesser extent (Ferrante, 2023, Hamieh et al., 2023).

Figure 11: Shows sample images of selected *FV* waste from the retail supermarket store

Figure 12: Shows sample images of selected *FV* waste from the retail store

***Figure 13:* Shows** FW fractions within the studied supermarket

3.2 Seasonal variation of FW

Figures 15 and 16 show the seasonal variation in food waste (FW). As depicted in Figure 15, the findings highlight the unparalleled dominance of vegetables across all seasons, displaying percentages of 45% in autumn, 54.8% in summer, 58% in winter, and a staggering 65.7% in spring. Following closely, fruits emerge as the next substantial category, showing significant proportions of 34% in autumn, 30% in winter, 26.2% in summer, and 18.1% in spring. Conversely, bakeries emerge as the least impactful contributors throughout the seasons, registering modest figures of 12% in winter, 15.2% in spring, 16.7% in summer, and 21% in autumn. Notably, grains only appear during spring and summer, with scant percentages of 1.0% and 2.4%, respectively. The Seasonal dynamics of individual FW fractions are shown in Figure 16.

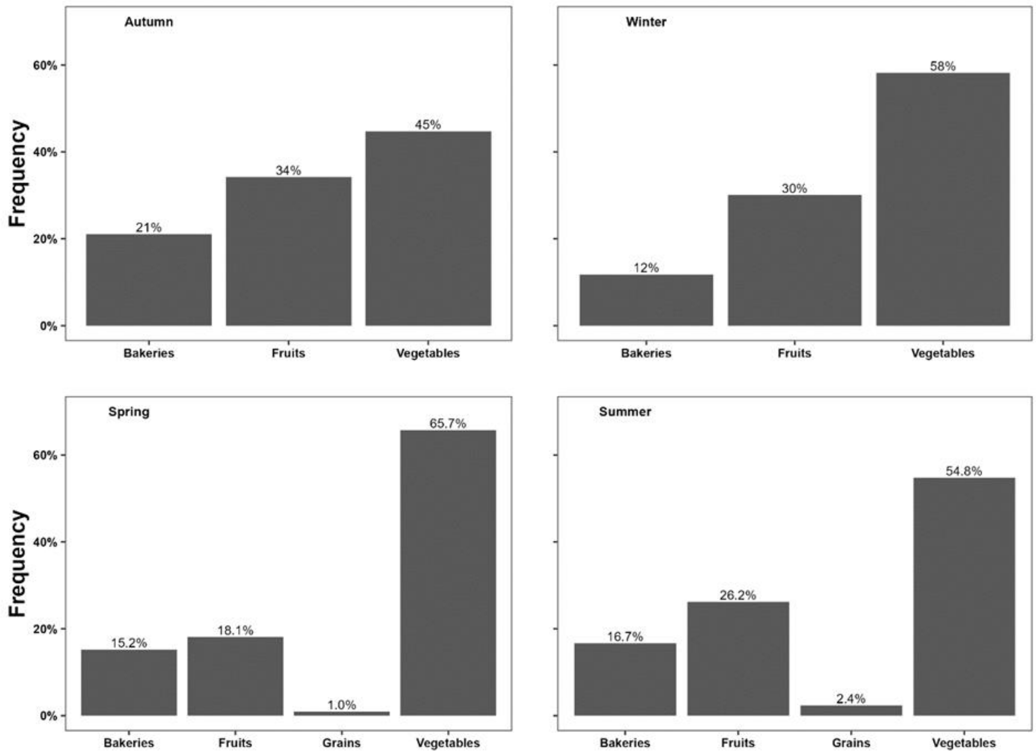


Figure 14: Annual frequencies of FW fractions per season, (Vundisa, 2024)

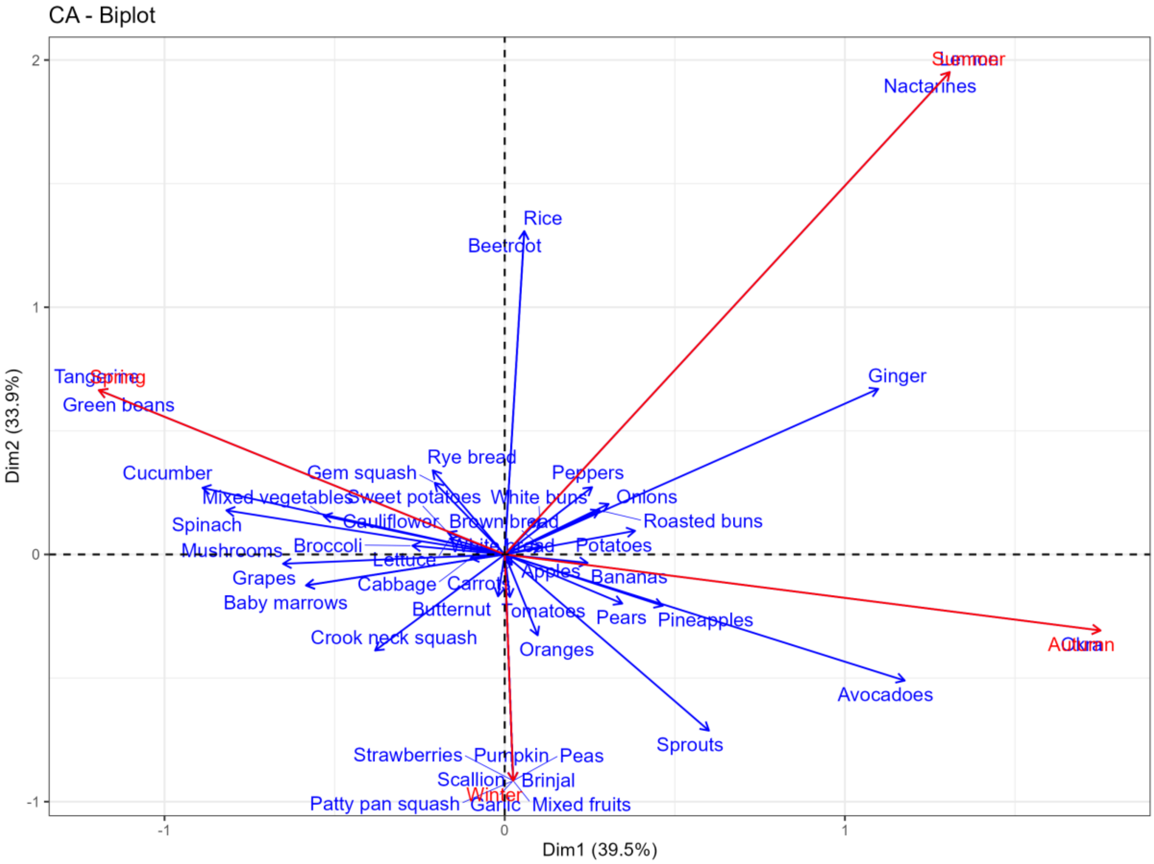


Figure 15: The Seasonal dynamics of individual FW fractions (Vundisa, 2024)

3.3 Root causes of wastage at a store with a high purchase power

3.3.1 Long-distance overhaul of produce from neighbouring provinces and District Municipalities

The retail store sources fresh produce from KwaZulu-Natal (KZN), approximately 540 km away, or from East London, 250 km away, and Qgeberha (483 Km) by road. A small proportion of produce is sourced locally, mainly leafy vegetables (spinach), cruciferous (cabbages) and marrows. The transition of food from farms to warehouses to retail stores has significant implications for produce quality and its eventual spoilage. Long-distance transportation of produce significantly impacts food quality due to several factors: spoilage during transit, extended storage periods, and multiple stages of handling and packaging that increase the risk of damage. Fresh produce is highly perishable and susceptible to spoilage during long journeys. Some spoilage can occur even with refrigeration due to delays, temperature fluctuations, and handling issues. Poor road conditions, delays, and other logistical challenges can exacerbate this issue.

Delays during transit, common especially on the N2 Highway, for example, include routine road closures due to maintenance, accidents, and industrial actions in peri-urban towns along the highways. Furthermore, produce often needs to be harvested earlier to accommodate transportation to their destination, affecting shelf life and quality.

Additionally, multiple stages of handling and packaging are involved in long-distance transportation, increasing the chances of damage. During handling, bruising, crushing, and other physical damage can lead to wastage. The product is often rejected and wasted at the retail store if it arrives with imperfections due to the journey. Inadequate packaging, as shown in Figures 5 and 6, can fail to protect produce from physical damage due to handling during heavy traffic. While most produce is packaged differently and transported in refrigerated trucks, separating ethylene-producing fruits like apples and bananas away from leafy greens can prevent the latter from ripening in transit or storage. Continuous monitoring systems play a crucial role in promptly detecting and addressing these issues, reassuring that solutions are available.

3.3.2 The inefficiency of front-of-store produce display

During the study period, it was observed that the retail store displays fresh produce towards the main entrance, and the highly perishable refrigerated section did not have glass doors. Displaying produce by the main entrance with the door open daily for more than 12 hours can exacerbate the spoilage rate due to several factors:

Temperature fluctuations: Open doors allow external weather conditions to influence the temperature inside the store. This is exacerbated by load shedding/power rationing. The refrigerated display area is meant to be cool, so open doors can cause the area to lose its environment, leading to faster spoilage. Having a glass door in the refrigerated section can also help the retail industry reduce food wastage with significant energy savings (de Frias et al., 2020). Doors can also improve spatial and temporal temperature uniformity in whole and fresh-cut vegetable cases (Xie et al., 2021). Retailers can be encouraged to retrofit open displays with doors or purchase closed displays. The decreased overall temperature uniformity in closed displays, including better produce quality and potential energy savings, may reduce greenhouse gas emissions at landfills.

Humidity changes: High humidity levels can promote mould growth and bacterial proliferation, causing FVs to spoil quickly. Decreased humidity levels can lead to dehydration and wilting. During heavy winds, open doors allow dirt, dust, and other vehicular fumes from the gas station less than 20 meters and N2 highway approximately 50 meters from the main entrance into the store.

Exposure to light: Artificial light can affect some produce's quality and shelf life. Research indicates that the type and intensity of artificial lighting can significantly impact the spoilage rate of produce. LED lights, commonly used in supermarkets, can alter the biochemical processes in FVs, accelerating ripening and senescence, which leads to quicker spoilage. For instance, low-intensity light cycles have been found to improve the quality of some vegetables, like lamb's lettuce, during storage, but improper light conditions can have the opposite effect (Nassarawa et al., 2021). Similarly, other studies have shown that the variability in light exposure in different supermarket sections can lead to inconsistent shelf life and produce quality. This inconsistency causes premature spoilage in many cases. For example, a study by Zest Labs found significant variation in the freshness and shelf life of strawberries, romaine lettuce, and salad mixes across different supermarket chains and even within individual stores. Some retailers are leveraging technology to mitigate these issues. Walmart, for instance, has developed AI technology named Eden, which inspects fresh produce for defects and spoilage, helping to predict shelf life more accurately and reduce waste https://www.foodprocessing-technology.com/news/walmarts-eden-artificial-intelligence-technology-inspect-fresh-food-spoilage/. Overall, while artificial lighting is necessary for product display and customer experience, its management is crucial to minimize the adverse effects on produce shelf life. Adjusting light quality, intensity, and advanced monitoring technologies can help retailers better manage spoilage rates. Although this technology may be out of reach for franchisees, placing produce displays further from the entrance can reduce exposure to external conditions.

Increased handling and Traffic: The prominent placement of fresh produce at the main entrance of the retail store may lead to increased handling by customers, which can further bruise and damage delicate produce and most likely contribute to contamination.

3.3.3. Handling/Touching of loose/ “naked” produce on display

Physical Damage and Microbial Contamination: As mentioned in **Section 3.2.2**, handling fragile produce by multiple consumers can lead to bruising, crushing, and other forms of physical damage. Multiple customers often handle produce in the retail store (pers. Obs.), which can lead to cross-contamination. Such damaged areas may be prone to microbial infection and spoilage. This applies to fragile FVs like tomatoes, bell papers, brinjals, pawpaw and leafy greens. Research indicates frequent touching and inadequate hand hygiene can transfer pathogens from customers to produce. This repeated handling increases the risk of contamination by bacteria such as *E. coli* and *Salmonella* (Nassarawa et al., 2021, Young et al., 2020). Factors such as temperature fluctuations, humidity, and the cleanliness of display areas play significant roles. Studies have shown that consumers' hands can transfer bacteria, viruses, other pathogens, and foodborne illnesses. Frequent handling can also lead to natural protective coatings of FVs accelerating spoilage. Human hands can also transfer sweat and oils, creating conditions favourable for microbial growth.

Mitigation Strategies:

- Consumer education: Educate consumers with signs encouraging minimal handling of produce and using gloves when handling.
- Adequate packaging options: Offering pre-packed produce, as was done during the COVID-19 pandemic, could reduce the need to handle produce by hand.
- Hand sanitizing stations: Hand sanitizing stations are at this supermarket's main entrance, but hand sanitizing is not enforced. Signs encouraging hand sanitization at these display stations could help reduce the handling of produce.

By implementing these strategies, retailers can help reduce the impact of multiple consumers handling naked produce.

3.3.4. Slicing vegetables and wrapping them with plastic film

Providing pre-sliced vegetables in peri-urban areas, such as the study area, offers several benefits. Balancing these advantages with cost considerations, food safety, and broader economic impacts is crucial. Slicing vegetables like cabbage and pumpkins in retail stores and wrapping them in plastic film can be justified in poverty-stricken regions for the following reasons:

Affordability: Pre-sliced vegetables can be sold in smaller quantities, making them more affordable for individuals or families with limited budgets. This allows people to buy only what they need, reducing waste and expense.

Convenience: Pre-sliced vegetables save time and effort for consumers who juggle multiple jobs, work late hours, or have limited kitchen facilities. They are also helpful for those with physical limitations that make food preparation difficult.

Waste Reduction: Whole vegetables often spoil before they are entirely used. Pre-slicing helps reduce waste by allowing consumers to purchase the exact amount they need, ensuring fresher consumption and less food thrown away.

However, wrapping sliced vegetables in plastic film can have drawbacks, such as increased microbial growth, as mentioned in **Section 3.2.3**. Similarly, as discussed in **Section 1**, some products contain ethylene gas, which can speed up ripening and spoilage if the plastic film does not allow adequate gas exchange. This accumulation can hasten spoilage. Additionally, certain nutrients in vegetables, such as vitamins, can degrade faster when exposed to light and fluctuating temperatures, which can still occur under plastic wrap. This can impart off-flavours to the vegetables, affecting their taste and overall quality.

Mitigation Strategies:

Here, following best practices such as appropriate film selection, temperature control, sanitation, and labelling could reduce the adverse effects of slicing and wrapping vegetables, helping maintain freshness, safety, and quality for an extended period. Managing Ethylene-producing vegetables is also vital. This can be achieved by separating the storage of sensitive vegetables from ethylene, producing proper ventilation to reduce ethylene buildup, and applying ethylene absorbers or scrubbers (Almenar, 2020, Deshwal et al., 2021, Gaikwad et al., 2020, Gorris and Peppelenbos, 2020, Kölgesiz, 2023).

Mitigation Strategies:

Here, following best practices such as appropriate film selection, temperature control, sanitation, and labelling could reduce the adverse effects of slicing and wrapping vegetables, helping maintain freshness, safety, and quality for an extended period. Managing Ethylene-producing vegetables is also vital. This can be achieved by separating the storage of sensitive vegetables from ethylene, producing proper ventilation to reduce ethylene buildup, and applying ethylene absorbers or scrubbers (Almenar, 2020, Deshwal et al., 2021, Gaikwad et al., 2020, Gorris and Peppelenbos, 2020, Kölgesiz, 2023).

3.3.5 Retail Store Management

High management turnover brought different approaches that could have contributed to the waste. During the study period, the retail store experienced frequent changes in senior management, with three different managers overseeing operations. This high turnover can result in inconsistent management practices, including fluctuating store policies and procedures. Each new manager may introduce varying approaches to inventory management, ordering, and food handling, which can lead to inefficiencies among staff.

Inconsistent management practices often result in issues such as overstocking or improper product rotation, heightening the risk of food spoilage and waste. Adequate inventory and waste management typically rely on stable, long-term strategies, but frequent leadership changes can disrupt these strategies, causing poor planning and forecasting.

New managers also require time to familiarize themselves with the store’s operations and to train their staff accordingly. During these transition periods, there may be lapses in training and communication, leading to mistakes in managing perishable goods and further contributing to waste.

Additionally, high turnover at the senior management level can negatively impact staff morale. Employees may become uncertain about their roles and responsibilities or struggle to adapt to new processes, while others may cling to outdated practices. This decline in morale and productivity can lead to food handling and stocking errors, exacerbating waste issues. Frequent management changes can strain relationships with suppliers. Managers are crucial for negotiating terms and adjusting delivery schedules based on inventory needs. High turnover can disrupt these relationships, leading to challenges such as receiving excess stock that cannot be sold before it spoils, thereby complicating supply chain management.

3.4. The potential of FW flour for partial replacement of commercial tilapia feed

The aquaculture industry is rapidly expanding, propelled by the escalating global demand for cost-effective and nutritionally dense animal protein sources. This growth has intensified the need for sustainable and innovative aquafeed ingredients to support this booming sector. The prohibitive costs associated with conventional feed ingredients like fish and soybean meals have spurred the exploration of alternative sources. In this context, the by-products, such as FV waste, often considered environmental hazards, have emerged as an up-and-coming resource due to their exceptional nutritional profile. Packed with bioactive compounds such as polyphenols, flavonoids, vitamins, minerals, polysaccharides, and peptides, these by-products serve as potent functional feed additives. Furthermore, as the aquaculture industry grapples with the urgent need to reduce antimicrobial use and combat the rising threat of antimicrobial resistance, using dietary feed additives derived from FV by-products stands out as a cutting-edge, eco-friendly solution poised to revolutionize sustainable aquaculture practices.

Section 1 of this report states that millions of tonnes of agricultural waste are generated worldwide, which, despite sharing similar profiles with primary agricultural products, are of lower quality. Managing these wastes is costly and requires stringent regulations to minimize their environmental impact. Valorizing these agricultural by-products for industrial applications, such as alternative resources for aquafeed, fertilizers, antimicrobial agents, and immunostimulatory enhancers, offers a sustainable solution. This approach reduces reliance on traditional feed ingredients like fish and soybean meals and addresses pressing environmental and economic challenges. Fruits, vegetables, and bakery products dominate food waste statistics, representing the highest tonnage of waste, according to Gustavsson et al. (2011). In Italy, for example, these categories alone contribute to two-thirds of the total FW generated in retail stores, as shown by Cicatiello et al. (2017). This pattern is consistent across the EU, where fruits and vegetables are the leading contributors to FW within the supply chain (Caldeira et al., 2019). However, these findings primarily reflect trends in high-income countries.

In contrast, in rural peri-urban cities in Sub-Saharan Africa, quantifying FW in retail operations remains a critical data gap in the literature and has been historically overlooked. Chaboud (2017) highlights this neglect, pointing out the persistent knowledge and methodological gaps in quantifying FW in Sab-Saharan Africa, a concern echoed by Kitinoja and Kader (2015). Consequently, transforming agricultural waste into valuable products is essential for sustaining the agricultural sector, minimizing environmental harm, and benefiting the aquaculture industry stakeholders. The current study also summarizes the nutritional content of major FW (amino acid and broader proximal chemical composition of major FW fractions, **Figures 17 and 18,** respectively. According to the current study's findings, using flour made from FW as a partial replacement for commercial tilapia feed is possible and is grounded in several scientific principles and research findings, as discussed below.

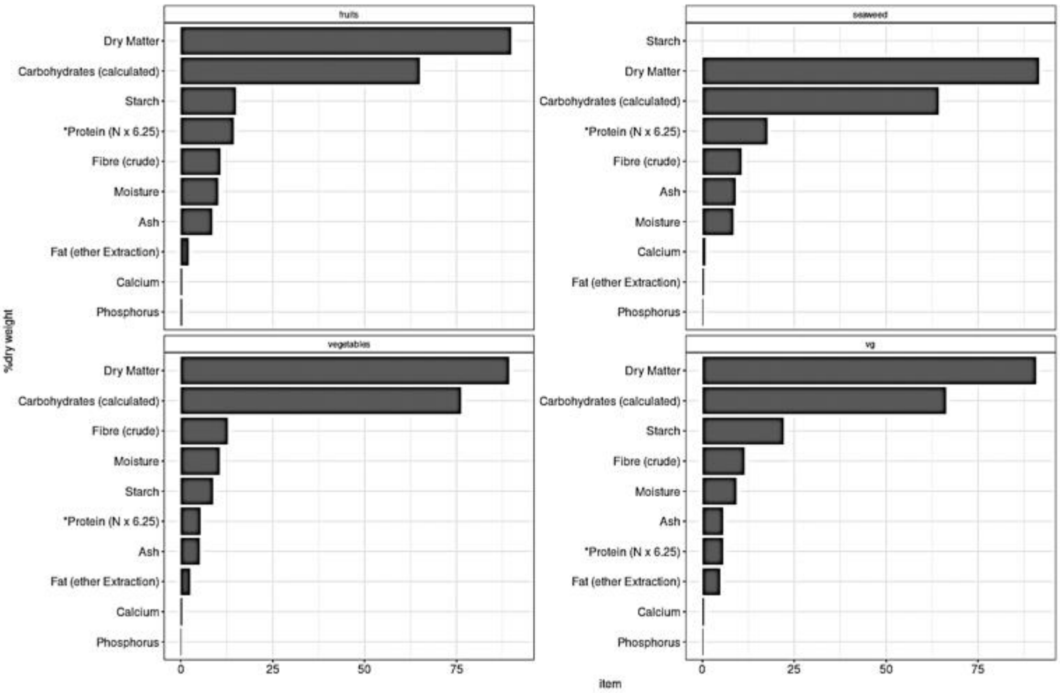


***Figure 16**:* Amino acid profiles of FW Fractions

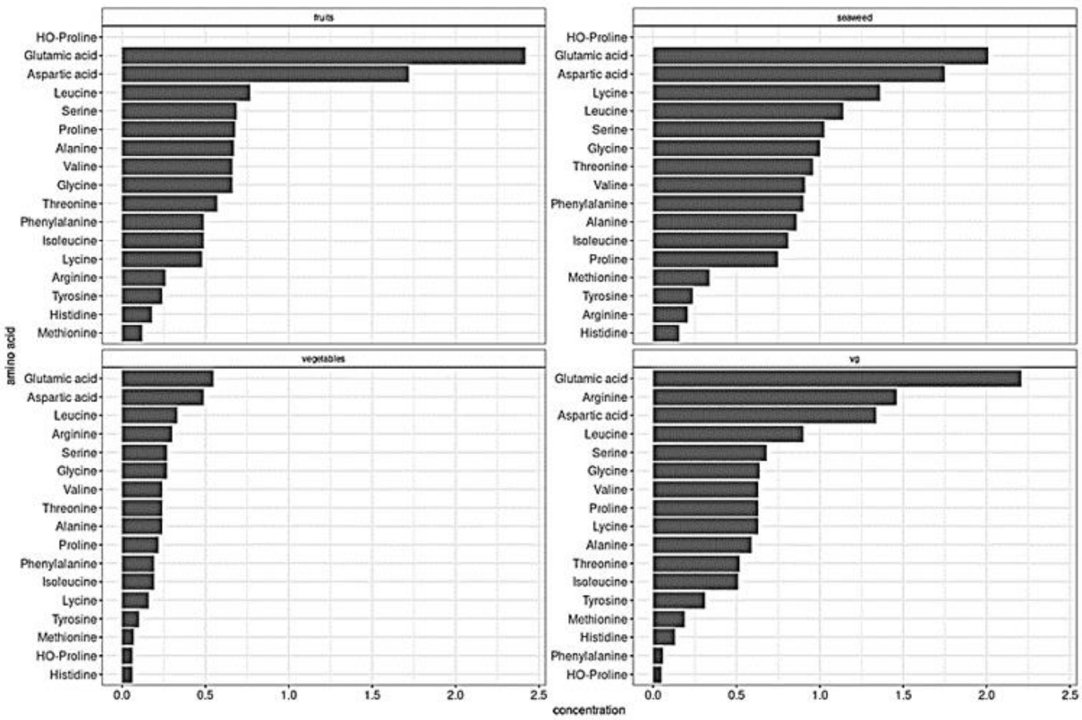


Figure 17: Proximal Chemical Composition of the FW Fractions.

Nutritional Composition of Fruit and Vegetable Waste: Fruit and vegetable wastes are often rich in essential nutrients that can benefit tilapia growth.

- **Carbohydrates**: Many FV wastes contain significant amounts of carbohydrates, which can serve as an energy source for tilapia (Table 1, Fig. 19).
- **Vitamins and Minerals**: These wastes are typically high in vitamins (such as Vitamin C, A, and B-complex) and minerals (like potassium, calcium, and magnesium) that benefit fish health and immunity.
- **Dietary Fiber**: While tilapia may be limited in digesting fiber, moderate levels can aid digestion and gut health.

For example, a study by Ortiz et al. (2014) demonstrated that FV wastes like banana peels, carrot tops, and tomato pulp could be processed into flour that retains high levels of vitamins and antioxidants, which could support the dietary needs of farmed fish.

Protein Content and Quality: Protein content and quality are critical considerations in tilapia feed. FV wastes are typically lower in protein (Table 1). Here, results show that the commercials tilapia feed (control) exhibited the lowest levels of carbohydrates, crude fiber, moisture content, and fat as expected. In contrast, experimental diet 3 had the highest carbohydrates, natural fiber, and moisture content concentrations. High levels of crude protein and ash characterized diet 1. Diet 2 contained the highest amounts of ash and fat among all diets. While FV wastes are typically lower in protein compared to animal-based feed (this study), certain types can still contribute significantly:

- *Leguminous Wastes*: Pea pods, bean husks, and other legume-related wastes can be rich in protein.

- *Enzymatic Treatment and Fermentation*: Techniques such as fermentation can enhance vegetable waste's protein content and digestibility, making them more suitable as feed ingredients. For example, it is reported that fermentation of certain vegetable wastes could increase the bioavailability of essential amino acids, improving their potential as a protein source in aquaculture feeds (Adebo et al., 2022, Faria et al., 2023, Ibarruri et al., 2021, Kiczorowski et al., 2022, Sadh et al., 2018, Yafetto et al., 2023).

Figure 18*: Selected Samples of Flour made from FW*

Table 1: Proximate nutritional composition of two formulated diets and commercial tilapia feed (used as control in the current study)

Diet	Diet 1 (Commercial tilapia feed-control)	Diet 2	Diet 3
Crude Protein	33	25.19	21.54
Carbohydrates	46.95	52.66	58.79
Crude Fibre	2.14	4.55	6.97
Ash	7.01	5.75	4.7
Moisture	8.25	10.92	11.48
Fat	4.94	8.73	8.32

Even though many plant-based materials contain anti-nutritional factors (ANFs) such as tannins, phytates, and oxalates that can interfere with nutrient absorption, techniques such as heat treatment, soaking, and fermentation can reduce or eliminate ANFs, making the waste more suitable for fish feed (Kheto et al., 2024, Lan et al., 2023, Rifna et al., 2023, Sadh et al., 2018). Furthermore, specific enzymes can break down ANFs and improve nutrient bioavailability. Olvera-Novoa et al. (1990) demonstrated that detoxification processes such as boiling and sun-drying significantly reduced the levels of ANFs in vegetable wastes, making them more suitable for use in tilapia feed.

3.5. Feeding trial using FW flour for partial replacement of commercial tilapia feed

Our studies were conducted to determine the proximal chemical composition of three diets (Table 1): Diet 1, 100% commercial diet (control); Diet 2 (75% control: 25% food waste); and Diet 3 (50% control: 50% food waste). Safety analyses were evaluated (see Annex …), and feed was meticulously formulated. Subsequently, the efficacy of the formulated feed was rigorously assessed in a six-week feeding trial, a crucial part of our research process.

Among the diets, diet 1 exhibited the highest overall specific growth rate (Fig. 20), reaching 1.54±0.12, surpassing diet 3 (0.86±0.57) and diet 2 (0.74±0.62).

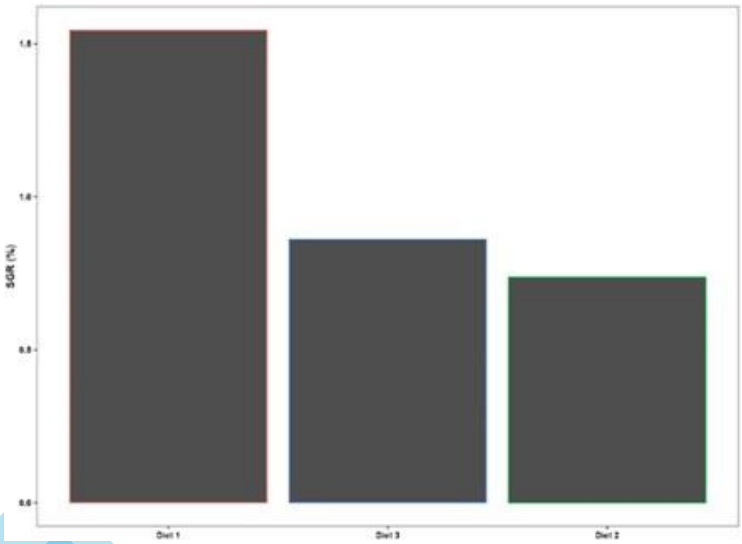


***Figure 19**:* Shows variation in the growth rate (SGR) variation in *O. mossambicus* fed different diets for six weeks (Vundisa, 2004)

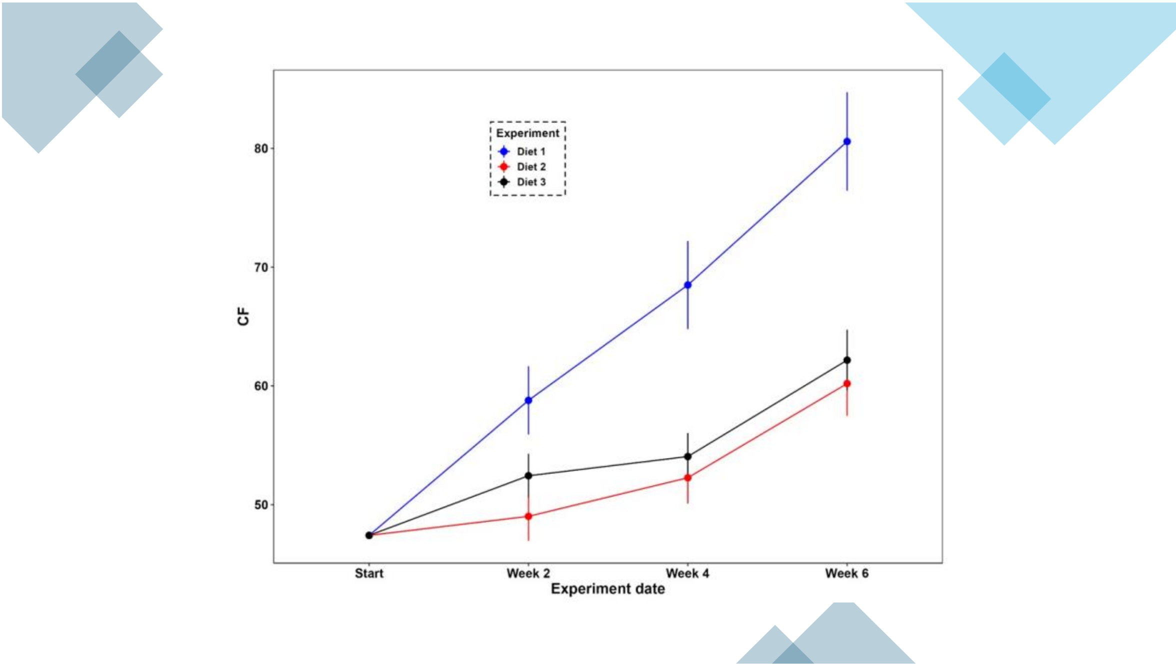


Figure 20: Shows Variations in condition factor in *O. mossambicus* fed different diets for six weeks (Vundisa, 2004)

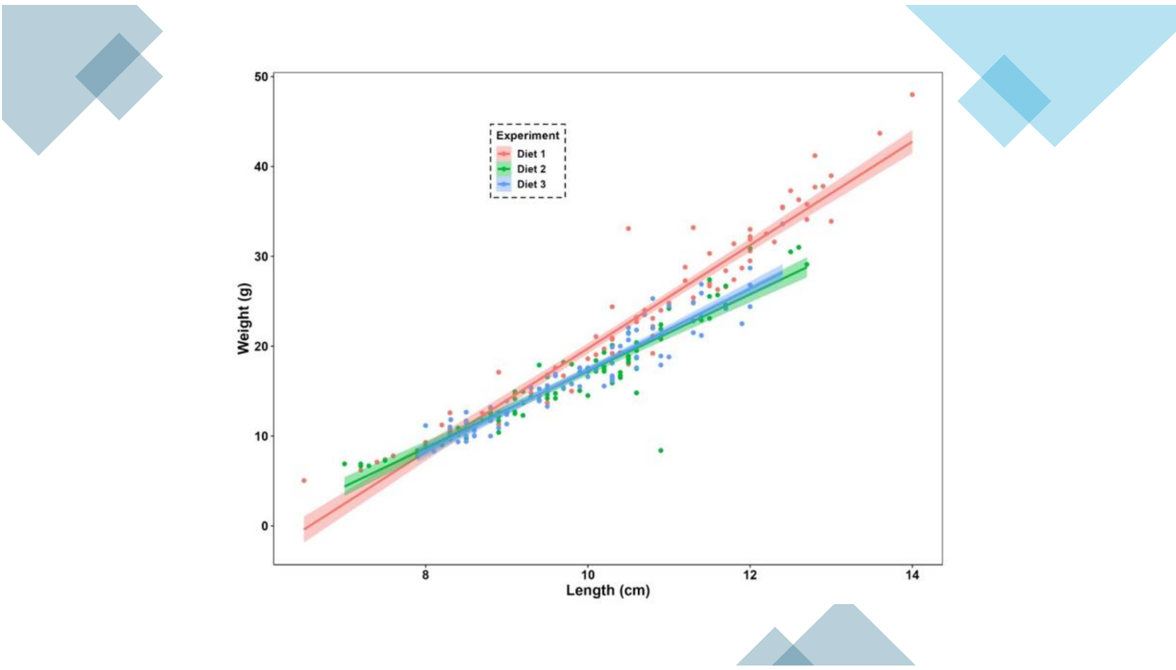


Figure 21: Regression analysis relating body weight as a function of body length in *O. mossambicus* fed different diets for six weeks (Vundisa, 2004)

This pilot feeding trial demonstrates the potential of FW as a partial substitute for commercial fish feed. While fish readily accepted the FW-formulated feed, their growth rates were slightly lower than those fed a commercial diet. Although the FW-based feed contained essential nutrients, protein supplementation may be necessary to optimize fish growth. Alternative protein sources should be carefully selected to reduce the cost of fish feed without competing with human food supplies. Proximal composition analysis confirmed the presence of certain nutrients in the FW-based feed, but it did not fully meet the fish's nutritional requirements. Further adjustments, such as optimizing the formulation or supplementing with additional nutrients, may be needed to achieve optimal growth and performance. Overall, this research suggests that FW can be a valuable component of fish feed, but careful formulation and supplementation are essential to ensure that the fish's nutritional needs are met.

4.0 Conclusions

Using FW in tilapia feed is a nutritional consideration and a step towards sustainable aquaculture. The aquaculture industry can significantly reduce its environmental impact by valorising FW into fish feed, contributing to a circular economy. Moreover, utilizing local and abundant waste materials can lower feed costs, which is one of the most significant expenses in tilapia farming. A study by Naylor et al. (2009) highlighted the importance of finding alternative feed sources in aquaculture to reduce dependency on wild fish stocks and lower the industry's overall environmental footprint. The ultimate test of any feed is its impact on growth performance and FCR in tilapia. Research has shown that replacing 20-30% of commercial feed with fruit and vegetable waste-derived flour can maintain growth rates and FCRs comparable to standard feeds. Tilapia has shown good acceptance of feeds containing fruit and vegetable waste, although gradual introduction is recommended. Abdel-Tawwab et al. (2010) found that tilapia fed with diets containing 25% fruit and vegetable waste exhibited similar growth performance and FCR to those fed with standard commercial feeds, suggesting that such replacements are viable.

In conclusion, this study demonstrates the potential of FW as a sustainable and cost-effective feed ingredient for tilapia. By incorporating FW-derived flour into their diets, aquaculture producers can reduce their reliance on commercial feeds, lower production costs, and contribute to a more circular economy. While further research is needed to optimize the formulation and processing of FW-based feeds, this study's results suggest that it is a viable alternative or supplement to traditional feed. Future studies should focus on identifying the optimal inclusion rates of FW, addressing potential safety concerns, and exploring novel processing techniques to enhance its nutritional value and digestibility. Overall, this research's findings highlight the potential of FW to play a significant role in sustainable aquaculture. FW offers a promising solution for the industry's growing demand for feed while minimizing environmental impact. While promising, using FW as a partial replacement for tilapia feed presents challenges and areas where further research is needed. These include the following:

4.1 The Study Limitations

- The quantity of produce received, amount sold, and amount lost were unavailable to the research team.

- Some FW fractions had not reached their sell-by date and were adequately sealed and in perfect condition. However, they happened to have been discarded. This could not be explained.
- During the study period, the retail store experienced frequent changes in senior management, with three different managers overseeing operations.

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ANNEXURE 1

PROXIMATE CHEMICAL COMPOSITION AND AMINO ACIDS PROFILES OF FW FRACTIONS

Analysis	Method Number	Unit	Sample Number 1: Fruits (FR)	Sample Number 2: Seaweed (SW)	Sample Number 3: Vegetables (VG)	Sample Number 4: FR+VG (Mix-Ready to eat salads)
Dry matter	**ASM 013**	**%**	89.91	91.60	89.35	90.82
Moisture	**ASM 013**	**%**	10.09	8.40	10.65	9.18
Ash	**ASM 048**	**%**	8.48	9.06	5.13	5.65
***Protein (N x 6.25)**	**ASM 078**	**%**	14.41	17.78	5.45	14.06
Fat (ether extraction)	**ASM 044**	**%**	2.06	0.40	2.50	4.77
Carbohydrates (calculated)	**ASM 075**	**%**	64.96	64.37	76.27	66.34
Calcium	**ASM 042**	**%**	0.43	0.85	0.30	0.37
Phosphorous	**ASM 045**	**%**	0.28	0.16	0.12	0.24
Fibre (crude)	**ASM 059**	**%**	10.73	10.70	12.84	11.53
Starch	**ASM 043**	**%**	15.09	**ND	8.82	22.14
Arginine	**ASM 021**	**g/100g**	0.26	0.21	0.30	1.46
Serine	**ASM 021**	**g/100g**	0.69	1.03	0.27	0.68
Aspartic acid	**ASM 021**	**g/100g**	1.72	1.75	0.49	1.34
Glutamic acid	**ASM 021**	**g/100g**	2.42	2.01	0.55	2.21
Glycine	**ASM 021**	**g/100g**	0.66	1.00	0.27	0.64
Threonine	**ASM 021**	**g/100g**	0.57	0.96	0.24	0.52
Alanine	**ASM 021**	**g/100g**	0.67	0.86	0.25	0.59
Tyrosine	**ASM 021**	**g/100g**	0.24	0.24	0.10	0.31
Proline	**ASM 021**	**g/100g**	0.68	0.75	0.22	0.63
HO-Proline	**ASM 021**	**g/100g**	**ND	**ND	0.06	0.05
Methionine	**ASM 021**	**g/100g**	0.12	0.34	0.07	0.19
Valine	**ASM 021**	**g/100g**	0.66	0.91	0.24	0.63
Phenylalanine	**ASM 021**	**g/100g**	0.49	0.90	0.19	0.06
Isoleucine	**ASM 021**	**g/100g**	0.49	0.81	0.19	0.51
Leucine	**ASM 021**	**g/100g**	0.77	1.14	0.33	0.90
Histidine	**ASM 021**	**g/100g**	0.18	0.16	0.06	0.13
Lysine	**ASM 021**	**g/100g**	0.48	1.36	0.16	0.63

ANNEXURE 2

SAFETY ANALYSIS OF FISH FEED INGREDIENT MADE FROM FRUIT AND VEGETABLE WASTE FRACTIONS – (Emphasis on pathogenic bacteria).

Analysis	***Enterobacteriaceae* count**	**Coliform count**	***E. coli* count**	***E. coli* detection**	***Clostridium perfringens* count**
Method Number	**ASM 031**	**ASM 037**	**ASM 037**	**ASM 037**	**ASM 077**
Unit	**CFU / g**	**CFU / g**	**CFU / g**	**/ g**	**CFU / g**
Sample No.					
1: - FR	840000	815000	<10	Negative	<10
3: - VG	10	10	<10	Negative	<10
4: FR+VG Mix	735000	640000	<10	Negative	<10

Analysis	***Enterobacteriaceae* count**	**Coliform count**	***E. coli* count**	***E. coli* detection**	***Clostridium perfringens* presumptive count**	***Clostridium perfringens* count (confirmed)**
Method No.	**ASM 031**	**ASM 037**	**ASM 037**	**ASM 037**	**ASM 077**	**ASM 077**
Unit	**CFU / g**	**CFU / g**	**CFU / g**	**/ g**	**CFU / g**	**CFU / g**
Sample No.						
2: SW	220	220	<10	Negative	40	40

Analysis	****Salmonella spp.* detection**	****Listeria mono-Cytogenes* detection**	**Total aerobic count**	**Yeast & moulds count**	***Staphylococcus aureus* count**	***Bacillus cereus* count**
Method Number	**ASM 009**	**ASM 014**	**ASM 018**	**ASM 020**	**ASM 024**	**ASM 030**
Unit	**/ 5 g**	**/ 1 g**	**CFU / g**	**CFU / g**	**CFU / g**	**CFU / g**
Sample No.						
1: - FR	Negative	Negative	88000000	13000	<10	<10
2: - SW	Negative	Negative	31900000	335	<10	<10
3:- VG	Negative	Negative	87000000	2300	<10	<10
4: - Mix	Negative	Negative	1145000	1200	<10	<10

ANNEXURE 3

SAFETY ANALYSIS OF FISH FEED INGREDIENT MADE FROM FRUIT AND VEGETABLE WASTE FRACTIONS – (Emphasis on Trace heavy metals (THMs).

	B	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As
	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
LOQ	**753,17**	**184,67**	**2,83**	**15,55**	**13,58**	**83,81**	**5,19**	**16,50**	**134,82**	**39,73**	**9,86**
% Accuracy on internal QC	**101,8**	**118,5**	**101,6**	**105,1**	**112,5**	**113,8**	**115,3**	**113,3**	**115,5**	**114,4**	**113,8**
% Recovery on certified reference material	**119,6**	**91,8**	**87,6**	**94,0**	**110,1**	**104,7**	**103,8**	**106,7**	**115,5**	**104,1**	**118,1**
CAR -TM	33110,6	65000,3	140,8	939,5	23144,9	62508,6	206,4	1967,9	8413,1	31999,6	<LOQ
CAR -TM	32265,3	74047,9	100,2	733,5	22642,4	55920,8	215,0	1863,1	8768,1	31290,3	<LOQ
CAR -TM	34012,8	121552,4	154,1	778,6	22725,0	58271,4	191,3	1822,5	7988,1	30674,2	<LOQ
BR -TM	39338,2	20892,2	36,2	321,9	33209,2	63979,1	117,4	707,1	10786,3	44505,1	24,6
BR -TM	44445,9	22226,8	39,2	356,9	33848,1	65157,4	138,6	731,0	11017,6	33434,4	29,3
BR -TM	42997,6	20342,8	36,6	290,6	34355,6	60874,9	120,9	699,7	10996,9	34063,0	35,6
GGR -TM	12699,5	320595,8	405,4	9744,8	239846,4	237962,5	254,1	2264,0	10726,1	42844,3	36,7
GGR -TM	12676,7	304918,0	383,2	9411,1	240248,6	222705,5	285,2	2140,8	10471,9	40042,6	41,6
GGR -TM	63690,6	294319,1	356,3	8849,0	218763,4	218317,1	229,7	1899,4	10202,2	36972,4	123,3
P -TM	33278,8	87933,0	115,4	426,6	68185,0	136130,3	483,4	6906,0	11184,8	39349,6	<LOQ
P -TM	36413,2	83564,0	127,0	433,3	67833,1	134980,3	501,8	7067,2	11604,3	40478,0	<LOQ
P -TM	35143,9	91779,3	121,1	512,7	70222,1	137486,0	472,2	7343,2	11777,7	40994,1	<LOQ
P -TM	36078,8	97836,0	124,2	408,6	73042,7	148386,8	486,9	7365,9	12196,6	41925,5	<LOQ
CA -TM	37475,6	212954,1	282,6	1751,4	101870,0	163473,5	524,3	2060,4	5229,1	27476,2	30,8
CA -TM	36821,8	215231,7	267,9	1754,0	100884,9	147604,8	523,0	2049,8	4702,6	28172,1	24,5
CA -TM	38160,2	204223,3	271,9	1675,9	96366,6	147096,6	479,9	1947,0	4608,5	26617,6	25,9
BN-TM	28403,6	123203,0	48,3	3370,8	27797,9	66554,6	62,4	2112,2	3765,5	24903,8	<LOQ
BN-TM	29153,4	117754,8	46,0	3317,8	26276,7	66010,7	61,2	2054,3	3559,3	24044,2	<LOQ
BN-TM	28073,1	108092,6	41,1	3138,6	25791,2	63956,6	56,8	1968,1	3379,9	23228,4	<LOQ

ON-TM	21100,1	64530,0	39,1	264,3	19804,8	43094,2	82,2	1555,0	4973,4	28829,8	<LOQ
ON-TM	19545,6	115382,7	43,9	332,2	20562,3	42161,7	82,1	1681,9	4924,5	29995,4	<LOQ
ON-TM	22086,2	99256,7	62,5	618,9	20883,0	47302,2	96,5	1598,3	5133,2	31689,8	<LOQ
PPR-TM	21783,0	212129,1	79,3	288,3	19603,5	70574,9	646,7	4143,3	11686,8	23600,5	<LOQ
PPR-TM	19748,9	194814,7	78,3	357,7	18201,3	86312,9	614,7	3831,9	10783,9	21458,2	<LOQ
PPR-TM	19248,9	193099,4	72,1	207,1	18387,8	67153,9	597,1	3799,6	10598,7	27972,6	<LOQ
AVS-TM	30684,2	19142,0	32,7	1556,8	10503,2	39835,5	101,6	2671,2	9657,0	21989,0	<LOQ
AVS-TM	29784,6	40701,0	32,5	1564,5	9330,5	34827,9	90,2	2098,3	9308,3	19388,0	<LOQ
AVS-TM	25401,6	33865,1	30,8	1511,2	9323,7	34409,9	84,2	2241,8	8984,8	18289,1	<LOQ
CP-TM	33271,5	36670,7	36,4	1569,6	6456,9	64749,6	33,4	1117,6	3382,8	18086,8	<LOQ
CP-TM	35086,9	31183,7	37,4	1391,9	6457,9	29933,4	44,2	1004,4	3430,6	8405,5	<LOQ
CP-TM	33840,7	34881,7	36,2	1251,5	6521,8	29839,3	60,6	958,0	3634,9	8747,7	<LOQ
ST-TM	9956,9	13701,6	27,7	890,9	14784,0	81720,2	127,7	2952,8	10274,9	43757,7	<LOQ
ST-TM	10342,5	10392,3	31,9	1901,6	15719,8	94891,9	133,9	3296,7	9934,8	46772,0	<LOQ
ST-TM	11118,4	14643,8	29,5	1104,7	15205,0	89523,6	127,6	3157,2	9727,5	45588,4	<LOQ
PT-TM	8919,1	159192,5	64,3	1161,7	9308,5	47173,6	306,6	1130,4	3955,0	32418,2	<LOQ
PT-TM	8637,7	144857,5	61,8	1315,1	9303,9	48210,9	305,4	1190,8	4103,1	31557,9	<LOQ
PT-TM	9480,8	172387,4	70,5	1274,5	9408,8	51583,8	305,2	982,8	4061,9	31788,9	<LOQ
OK-TM	2511,1	24282,6	56,2	1548,7	35651,5	47017,7	185,9	1015,8	2240,2	21730,8	<LOQ
OK-TM	1988,8	26061,6	52,8	1524,3	35549,1	45085,6	176,3	1018,1	2229,2	21355,7	<LOQ
OK-TM	2233,5	23440,9	52,0	1516,2	35087,0	44396,5	176,5	981,2	2233,5	21267,9	<LOQ
PA-TM	13177,0	22720,4	52,4	2760,6	244692,5	47734,3	779,5	3824,1	2472,9	10739,6	<LOQ
PA-TM	15274,7	19191,7	51,9	2784,1	239545,3	46152,1	780,5	3763,5	2511,4	10322,6	<LOQ
PA-TM	14815,7	22394,7	52,6	2908,0	245273,9	46413,1	862,1	3842,5	2577,3	10342,4	<LOQ
SPIN-TM	48626,0	590510,9	634,0	2151,4	336631,0	328440,0	635,8	2302,0	14603,3	74724,7	59,1
SPIN-TM	48070,4	565453,9	597,2	2214,4	311721,1	312566,0	617,1	2246,9	14171,7	72524,6	44,4
SPIN-TM	49000,5	633148,8	619,7	2204,0	336175,4	337596,6	647,4	2340,0	14357,0	75201,2	48,0
APP-TM	35642,7	118535,3	110,9	1228,3	27303,1	36278,6	100,3	504,8	3240,9	6373,4	<LOQ
APP-TM	32132,6	106176,4	100,4	786,9	25640,6	34974,6	90,5	468,4	3107,1	5797,6	<LOQ

APP-TM	30788,7	151340,4	151,9	592,5	29639,7	38682,0	106,1	554,3	3290,7	6240,8	<LOQ
BS-TM	13619,2	11405,2	28,3	262,7	44523,2	100562,1	198,8	3869,2	12851,9	78430,7	<LOQ
BS-TM	15104,8	16850,3	33,1	286,7	47079,7	104151,7	232,7	3861,1	13307,9	81530,7	<LOQ
BS-TM	14452,7	15099,9	25,2	249,5	44776,2	96205,7	219,9	3817,4	12743,8	78292,5	<LOQ
MF-TM	24219,2	67395,2	111,6	590,1	21693,1	83489,8	284,2	2576,1	9200,5	37765,8	<LOQ
MF-TM	23385,8	58742,1	93,5	477,8	21562,9	74068,0	250,1	2372,8	9354,1	35366,5	<LOQ
MF-TM	22545,2	58467,6	96,4	435,4	21918,1	76388,2	254,6	2301,4	8577,6	35104,7	<LOQ
MV-TM	25245,3	129278,0	173,2	2121,7	58085,9	106956,3	443,5	2395,9	7483,0	36702,6	<LOQ
MV-TM	26257,8	124474,8	148,8	2105,1	57850,9	103816,2	458,8	2339,1	8121,4	36376,9	<LOQ
MV-TM	27476,7	141684,0	165,0	2209,6	59324,1	106682,7	473,2	3310,6	7749,5	37582,3	<LOQ
BUTN-TM	33028,1	34652,3	51,9	1119,4	23830,8	56479,5	607,0	4991,6	8725,0	29092,7	<LOQ
BUTN-TM	32907,1	42251,1	54,0	1408,0	24497,9	60799,4	623,0	5257,7	9855,2	31247,1	<LOQ
BUTN-TM	32176,1	31834,0	55,0	1196,0	24057,1	52581,5	597,6	4854,5	9178,4	28756,2	<LOQ
MIX -NV	22462,1	73358,9	96,9	1043,2	49452,9	80158,7	237,7	1898,9	7020,4	30455,4	<LOQ
MIX -NV	19508,0	89969,3	101,0	1483,8	52917,7	92360,1	275,4	2058,4	6771,7	30477,0	<LOQ
MIX -NV	20190,9	80349,7	107,8	1057,2	48228,1	82816,2	229,3	2066,4	7001,6	31516,3	<LOQ
SW -NV	228908,9	245644,7	2740,1	3458,6	29501,0	176087,9	2514,8	4632,2	3255,5	76916,7	7018,3
SW -NV	231350,7	303297,3	2884,5	2437,6	31788,8	251226,7	2626,3	6124,5	3667,6	66733,3	7414,8
SW -NV	238552,1	311771,4	3054,9	2670,0	32250,3	258278,9	2690,5	6475,6	3660,4	64179,1	7570,3

SAFETY ANALYSIS OF FISH FEED INGREDIENT MADE FROM FRUIT AND VEGETABLE WASTE FRACTIONS – (Emphasis on Trace heavy metals (THMs) CONT'.

	Se	Sr	Mo	Cd	Sn	Sb	Ba	Hg	Pb	Ca	K	Mg	Na	P	Si
	ug/kg	**ug/kg**	**ug/kg**	**ug/kg**	**ug/kg**	**ug/kg**	**ug/kg**	**ug/kg**	**ug/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
LOQ	**20,28**	**3,03**	**3,72**	**0,96**	**4,26**	**6,49**	**2,35**	**2,25**	**2,83**	**15,00**	**15,00**	**15,00**	**15,00**	**15,00**	**15,00**
% Accuracy on internal QC	**104,4**	**107,1**	**99,0**	**110,1**	**107,0**	**101,0**	**109,3**	**94,7**	**98,3**	**109,6**	**101,9**	**105,9**	**92,37**	**99,53**	**104,3**
% Recovery on certified reference material	**119,2**	**92,0**	**94,4**	**93,5**	**NA**	**95,3**	**91,8**	**82,2**	**85,4**	**101,4**	**91,4**	**97,4**	**93,0**	**95,9**	**NA**
CAR -TM	30,2	27315,7	315,7	45,3	128,9	<LOQ	19990,5	<LOQ	83,9						
CAR -TM	24,6	26606,2	278,1	39,5	136,7	<LOQ	19663,3	<LOQ	66,1						
CAR -TM	20,9	25327,5	262,4	43,3	113,6	<LOQ	18533,7	<LOQ	114,9						
BR -TM	159,2	7283,5	870,6	19,6	4,7	<LOQ	9631,7	<LOQ	41,9						
BR -TM	148,7	7598,7	903,6	16,8	6,3	<LOQ	9105,8	<LOQ	34,9						
BR -TM	136,0	7637,9	888,6	16,2	5,2	<LOQ	8880,3	<LOQ	34,5						
GGR -TM	49,1	12780,6	439,7	94,5	23,2	17,2	34827,4	<LOQ	481,7						
GGR -TM	35,9	12172,0	280,5	88,9	19,5	7,9	33806,4	<LOQ	474,9						
GGR -TM	21,9	12165,3	277,7	85,2	18,7	8,5	32111,8	<LOQ	427,0						
P -TM	109,9	46546,3	2865,4	11,8	11,0	<LOQ	24673,1	<LOQ	52,6						
P -TM	102,2	44376,8	2813,7	12,9	14,1	<LOQ	23073,0	<LOQ	47,5						
P -TM	118,6	46387,8	2956,1	13,0	43,4	<LOQ	23916,8	<LOQ	355,8						
P -TM	131,2	49090,6	3028,4	9,1	8,2	<LOQ	25086,2	<LOQ	41,1						
CA -TM	73,2	207742,4	956,8	51,4	13,9	<LOQ	110616,4	<LOQ	109,2						
CA -TM	76,4	203117,2	961,6	44,3	10,6	<LOQ	109142,7	<LOQ	97,7						
CA -TM	97,3	203691,9	940,9	48,6	12,4	<LOQ	108665,1	<LOQ	105,1						
BN-TM	<LOQ	10752,6	160,8	11,5	<LOQ	<LOQ	7768,9	<LOQ	39,7						
BN-TM	<LOQ	10204,0	170,9	12,2	<LOQ	<LOQ	7346,2	<LOQ	35,9						
BN-TM	<LOQ	10034,1	166,2	10,1	<LOQ	<LOQ	7570,3	<LOQ	32,0						
ON-TM	<LOQ	17055,9	246,6	46,7	<LOQ	<LOQ	3363,1	<LOQ	29,4						
ON-TM	<LOQ	16748,9	252,6	49,1	<LOQ	<LOQ	3238,1	<LOQ	29,4						
ON-TM	<LOQ	17426,1	266,5	51,1	<LOQ	<LOQ	3999,8	<LOQ	35,1						

PPR-TM	<LOQ	7280,1	890,1	16,3	<LOQ	<LOQ	5093,8	<LOQ	36,4
PPR-TM	<LOQ	6631,0	805,6	21,3	<LOQ	<LOQ	4497,3	<LOQ	34,1
PPR-TM	<LOQ	6606,4	781,3	18,8	<LOQ	<LOQ	4541,5	<LOQ	36,6
AVS-TM	50,1	3893,6	357,3	10,3	11,6	<LOQ	2066,0	<LOQ	37,4
AVS-TM	44,3	3463,2	264,1	8,3	9,9	<LOQ	1770,8	<LOQ	17,9
AVS-TM	39,7	3402,3	265,4	8,3	7,9	<LOQ	2162,9	<LOQ	16,6
CP-TM	<LOQ	56365,7	96,3	4,1	<LOQ	235,3	13332,3	<LOQ	62,2
CP-TM	<LOQ	60609,3	99,1	4,8	<LOQ	249,1	13437,1	<LOQ	41,9
CP-TM	<LOQ	58484,7	98,7	5,7	<LOQ	247,4	13407,4	<LOQ	49,2
ST-TM	170,6	6349,0	2694,3	8,4	10,9	<LOQ	4425,1	<LOQ	16,0
ST-TM	172,8	6826,6	2942,0	7,5	11,0	<LOQ	4816,4	<LOQ	13,2
ST-TM	171,8	6841,1	2817,8	9,5	9,5	<LOQ	4727,2	<LOQ	30,1
PT-TM	27,2	4026,8	288,8	33,0	18,1	<LOQ	1590,1	<LOQ	94,4
PT-TM	19,0	4318,4	284,1	36,9	15,5	<LOQ	1597,9	<LOQ	106,6
PT-TM	39,9	4170,5	289,5	37,0	16,5	<LOQ	1637,6	<LOQ	94,4
OK-TM	<LOQ	9161,4	287,2	10,7	14,0	8,5	7055,2	<LOQ	31,5
OK-TM	<LOQ	9050,5	289,0	9,7	13,4	6,6	7030,4	<LOQ	43,8
OK-TM	<LOQ	9084,5	282,0	11,1	15,9	8,9	6951,3	<LOQ	29,4
PA-TM	<LOQ	2150,2	137,8	7,3	<LOQ	<LOQ	1379,3	<LOQ	25,8
PA-TM	<LOQ	2169,2	131,4	7,1	<LOQ	<LOQ	1472,4	<LOQ	25,4
PA-TM	<LOQ	2206,3	131,2	4,8	<LOQ	<LOQ	1483,9	<LOQ	26,6
SPIN-TM	55,5	47616,8	334,8	45,8	22,9	13,7	46742,4	<LOQ	175,6
SPIN-TM	45,7	45121,4	316,9	44,9	27,6	15,5	44739,0	<LOQ	162,2
SPIN-TM	65,1	45478,5	316,3	42,2	21,4	12,5	43997,6	<LOQ	161,0
APP-TM	<LOQ	2145,8	56,2	15,5	9,2	<LOQ	1407,2	<LOQ	61,9
APP-TM	<LOQ	2473,5	52,0	15,2	6,1	<LOQ	1479,6	<LOQ	63,0
APP-TM	<LOQ	2170,7	61,7	17,9	6,1	<LOQ	1552,8	<LOQ	77,1
BS-TM	229,4	4247,3	3194,3	5,8	<LOQ	<LOQ	2218,9	<LOQ	14,7
BS-TM	217,7	4774,7	3137,6	6,5	<LOQ	<LOQ	2659,1	<LOQ	21,7

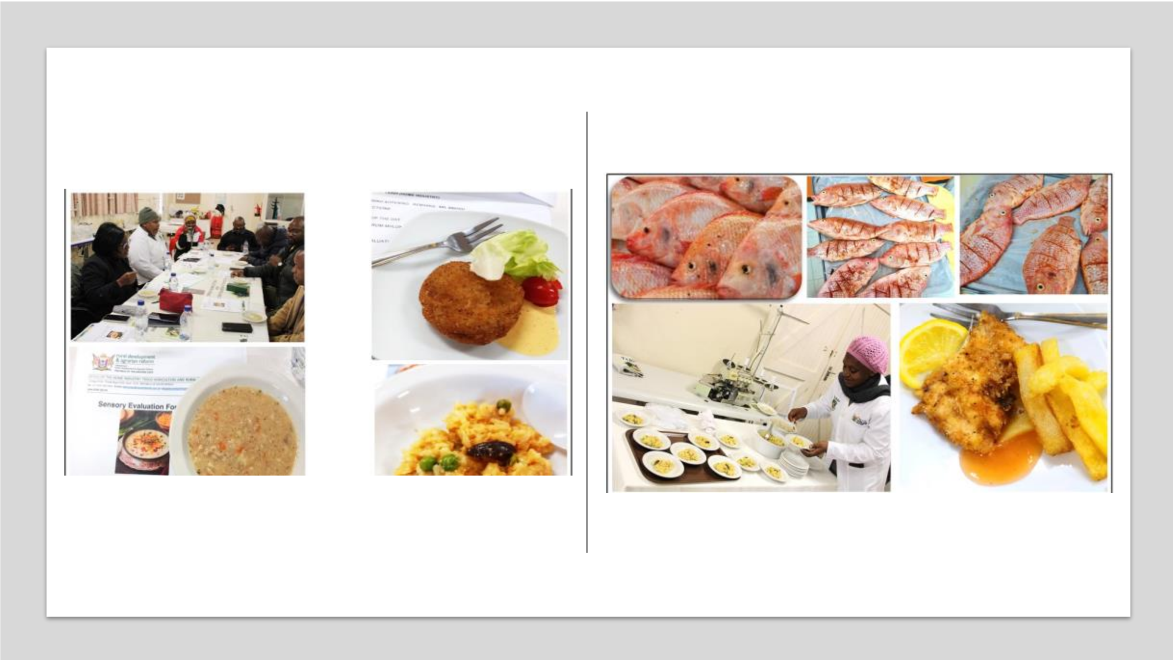
BS-TM	238,4	4484,3	3179,0	7,5	<LOQ	<LOQ	2406,9	<LOQ	12,5						
MF-TM	35,0	14684,0	506,7	32,2	<LOQ	<LOQ	11732,7	<LOQ	81,4						
MF-TM	22,0	13694,7	474,5	28,5	<LOQ	<LOQ	11522,2	<LOQ	69,7						
MF-TM	28,5	13963,5	483,8	26,6	<LOQ	<LOQ	11407,7	<LOQ	78,0						
MV-TM	38,2	55665,3	557,9	64,5	20,0	<LOQ	29998,0	<LOQ	170,1						
MV-TM	28,4	54665,6	551,4	68,9	15,8	<LOQ	30147,5	<LOQ	280,3						
MV-TM	40,1	56872,1	598,1	74,4	23,7	<LOQ	30969,5	<LOQ	118,4						
BUTN-TM	66,4	18756,7	373,1	33,1	20,7	<LOQ	10113,5	<LOQ	30,5						
BUTN-TM	65,5	19797,2	394,9	31,2	21,8	<LOQ	10683,1	<LOQ	30,1						
BUTN-TM	57,8	19267,2	358,8	26,4	31,2	<LOQ	10014,4	<LOQ	27,4						
MIX -NV	120,4	21067,1	717,4	42,5	11,9	14,8	12683,7	<LOQ	56,8	3409	18363	2059	2304	3169	331
MIX -NV	97,8	20691,2	718,5	42,0	17,5	16,3	12694,8	<LOQ	84,6	3395	19438	2149	2451	3281	286
MIX -NV	84,7	20068,5	726,1	46,4	12,6	10,9	12137,9	<LOQ	60,0	3207	17803	2142	2313	3359	329
SW -NV	41,0	62082,5	425,2	2510,6	7,4	13,1	2972,5	2,9	7529,4	9565	8471	2526	5687	1784	288
SW -NV	52,7	108840,9	463,8	2753,8	12,2	12,8	1951,4	2,1	428,5	9972	8507	2792	5808	1921	357
SW -NV	62,7	98866,9	475,3	2802,4	9,1	14,0	2440,0	3,8	2434,9	10586	8896	2916	6135	1961	364

ANNEXURE 4

EXPERIMENTAL AND GROW-OUT TANKS

ANNEXURE 5

END PRODUCTS (HARVESTED FISH AFTER EIGHT MONTHS:- FISH TASTING DAY @ TARDI



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