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COMPARATIVE EFFECT OF LEMON GRASS PRE-TREATMENT ON THE STORAGE QUALITY OF SUN AND SOLAR DRIED *BRYCINUS NURSE* FROM LAKE ALBERT, UGANDA

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ABSTRACT

Malnutrition is a serious problem that affects many people in Uganda (USAID, 2021). Increased consumption of fish, in addition to other foods, could reduce this problem because of its high protein and micronutrient composition. Large fish species are expensive, and the small pelagic fishery sector faces high post-harvest losses. The high fat content (14-20%) in *Brycinus nurse* increases its level of oxidation, thus increasing its spoilage rate, resulting in bad odour. Fish is then converted to animal consumption instead of human consumption. The effect of solar tent drying and lemongrass pre-treatment at 0-, 15-, and 30-minute soaking times on *Brycinus nurse* was evaluated. However, the open sun drying method used for processing is highly dependent on the prevailing weather conditions. Samples were analyzed for lipid hydrolysis and oxidation, as well as protein degradation, microbiological evaluation, and basic composition characteristics. There were significant differences in processing odour, water activity, and free fatty acids between the open sundried and solar dried groups ($p<0.05$). The lemongrass treatment (15 min) masked the bad odour of the fish after four weeks of storage. The microbial load decreased as water activity decreased. The water activity of the solar-dried groups was lower than 0.6, and TVC count was also lower for the solar-dried groups than for open-sun-dried groups. This trigger lowers FFA levels by reducing the quantity of inducers of lipid hydrolysis. Therefore, solar drying improved the quality parameters of the samples during storage compared to the open drying method, and lemongrass at 15 min in the solar drier soaking time yielded better processing odour compared to the other treatments.

Key words: Small pelagics, storage quality, lemongrass pre-treatment, sun and solar drying methods, Uganda

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1 INTRODUCTION

1.1 Background

1.1.1 Food security, nutrition status and fish consumption in Uganda

Food and nutrition insecurity remains a serious problem affecting a large population in sub-Saharan Africa (United Nations, 2019). According to the United States Agency for International Development, 2021, almost one-third of children under five years are stunted, 4% are wasted, and 11% are underweight in Uganda. In addition, 53% of 6-59 months old children and about 32% of women aged 15-49 were anaemic. Several factors contribute to food and nutrition insecurity in Uganda, including poverty, landlessness, increased population growth, natural disasters, inadequate dietary diversity, high food prices, and lack of education (United States Agency for International Development, 2021). The country falls within the top 20 countries with a high number of undernourished people (United Nations, 2019). The high malnutrition incidence in the region corresponds to a low quantity of fish consumed per capita, which was estimated at 5.3 kg (Obiero *et al*., 2019). The recognition of fish as a healthy food in fighting food and nutrition insecurity has led to growing interest in fisheries research in Uganda. Fish have high biological value for proteins, polyunsaturated fatty acids, minerals, and vitamins (Lawrence *et al*., 2017; Masette *et al*., 2014). However, its consumption has not yet been fully exploited to combat food insecurity and malnutrition in Uganda (Obiero *et al*., 2019). Large fish species are expensive and cannot be afforded by the majority, especially the rural poor.

1.1.2 Capture fish species in Uganda

Capture fisheries in Uganda account for approximately 450,000 tons annually (FAO, 2019). The type of fisheries in Ugandan water bodies is often characterized by irregular peaks. The fish landed (55%) mainly comprise of the large export species such as Nile perch (*Lates niloticus)*, Nile tilapia (*Oreochromis niloticus*), the cat fishes (*Bagrus docmak* and *Clarias gariepinus*). Small pelagic species make up 45.6% of the total fish landed (FAO, 2019). The main small pelagic fishes landed include silver cyprinid (*Rastrineobola argentea), Neobola bredoi* commonly known as muziri and tetra nurse (*Brycinus nurse*) locally known as ragoogi. Silver cyprinid is found in Lake Victoria and Kyoga, while the latter two are predominantly found in Lake Albert. More than 70% of the fish caught in lakes undergo processing, which varies with the type, nature, size, and condition of the fish (Masette, 2012).

1.1.3 Processing of Brycinus nurse and current post harvest losses

Brycinus nurse is a small pelagic fish that is predominantly caught in Lake Albert. The fish is usually landed in large quantities, with annual catches of approximately 121,000 tons, and approximately 95% of the landed fish is open sun-dried. Only a small portion is deep-fried for consumption around landing sites (Ministry of Agriculture, Animals and Fisheries. 2019).

Although the open sun-drying method is affordable for most processors, it is highly dependent on weather conditions. During the rainy season, postharvest losses may be as high as 90% of the total catch. Incomplete drying coupled with poor handling practices contributes substantially to high postharvest losses. Consequently, the high postharvest losses have severely undermined the utilization of this fish in Uganda, and thus, alternative processing techniques should be developed.

The proximate composition of fresh *Brycinus nurse* consists of 14.20% moisture, 28.08% crude protein, 24.29% fat, 13.44% ash and 19.98 % carbohydrates (Rabiu *et al*., 2016). The high fat, moisture, and protein contents create a big challenge to post-harvest processing. The extended drying time of fish during rainy or cloudy weather increases the rate of oxidation and protein degradation. Autolytic enzymes in fish also increase the rate of protein degradation, which in turn increases the spoilage rate. Open-air sun drying also exposes fish to dust, consumption by birds, and contamination. The fish commonly ends up being used for animal feed instead of human consumption (Masette *et al*., 2014). However, current research measures could help to reduce post-harvest losses. A solar tent dryer was produced under the NutriFish project in Uganda to improve the quality of small pelagic fish for human consumption. However, more research is needed to address the extent to which it could contribute to reducing quality losses in the sector. One of the factors that could ensure optimal results from the solar drier is the combination of drying and fish pre-treatment.

Some pretreatment methods, such as blanching, spicing, and brining, have been shown to reduce spoilage in fish during storage (Ayodele and Adesoji, 2012). Some spices such as rosemary, lemongrass, onions, garlic, and ginger, have been shown to possess antioxidant, bactericidal, and fungicidal activities, which help preserve food (Boeira and Natiéli, 2018). Lemon grass is a plant with antimicrobial and antioxidant properties that can increase the shelf life of fish (Omoruyi *et al*., 2019). It also imparts a good flavour to food products. Therefore, the present study sought to evaluate the effects of lemon grass pretreatment on the chemical and sensory properties of open sundried and solar-dried *Brycinus nurse* from Lake Albert, Uganda.

1.2 Problem statement

With the rapidly growing population of Uganda, there is a need to increase the availability and accessibility of cheap and nutritious foods. Small pelagic fish are one of the cheapest and most affordable nutritious foods in Uganda. *Brycinus nurse* is a very abundant small pelagic fish species found in Lake Albert. However, the small pelagic fisheries sector still faces a significant challenge at the landing sites as far as post-harvest losses (40–90%) are concerned (Tinyiro, *et al*., 2016). The open sun-drying method for processing fish is highly dependent on the prevailing weather, exposing fish to dust, rain, and consumption by domestic birds. On the other hand, high fat and moisture content results in extended drying time of the fish during cool and wet days (Masette *et al*., 2014). This increases the rate of oxidation and autolytic enzymatic and bacterial activities in fish. A combination of all these factors in one way or the other contributes to the deterioration and loss of fish quality. Because of these factors, most fish species have been designated for animal consumption. There is a need to improve the quality of fish so that it is suitable for human consumption. This study analyzed the effect of lemon grass pre-treatment and solar tent drying on improving the quality of dried *Brycinus nurse*.

1.3 Objectives

The overall objective of this study was to ascertain the role of lemon grass pretreatment in improving the quality of sun- and solar-dried *Brycinus nurse* in Lake Albert, Uganda. This was achieved through the following objectives:

- Evaluation of the effect of lemon grass pre-treatment on the oxidative and sensory properties of solar and sundried *Brycinus nurse*

- Evaluation of the effect of lemon grass pre-treatment on the chemical and microbial properties of solar and sundried *Brycinus nurse*

1.4 Goal of the project

The overall goal of the project was to reduce post-harvest losses in *Brycinus nurse*, a commercial small pelagic fish in Lake Albert, Uganda, as a measure to improve food security.

1.5 Rationale of the project

Uganda is one of the fastest growing nations economically in sub-Saharan Africa and is in socio-economic transition. The country aims to become a middle-income country by 2040, with zero hunger, a major share of earnings coming from the non-farming sector (Second National Development Plan, 2015) of which the fisheries sector is part. In addition, micronutrient and macronutrient malnutrition is recognized by the Ugandan government as a potential threat to the general health and welfare of the entire population; therefore, food fortification and the inclusion of highly nutritious food items are recommended. Quality assurance, improvement, and diversification of fish and fish-based products are also recognized in Uganda’s National Development Plan (NDP) as some of the primary growth needs for the fish sub-sector (Icelandic International Development Agency, 2014). This study aimed to reduce the post-harvest losses of small pelagic fish, thereby reducing food insecurity and contributing to the United Nations Sustainable Development Goals 2 and 3 of zero hunger and good health and well-being, respectively, by 2030.

2 LITERATURE REVIEW

2.1 Overview of *Brycinus nurse* and its proximate composition

Brycinus nurse is a sardine-colored silver bluish-gray pelagic fish species belonging to the Alestidae family (Figure 1).

Figure 1: Picture of Brycinus nurse

The fish is found in freshwater systems in Africa, thriving well in both lacustrine and riverine conditions. The size of adult fish ranges from 15-23 cm (Saliu, 2002). The major constituents of *Brycinus nurses* are moisture, protein, and fat, along with trace amounts of minerals (Dhanapal et al., 2011). A study carried out by Bello and Oyelese (2016) reported variations in the proximate composition of the fresh fish. These compositions vary depending on the season. In their study, the highest fat content was observed in the Hammatan periods (between November and mid-March (40%) while high protein content ranged from 14% to 56% depending on the season. The dry fish in Uganda contains 66.99% protein, 14.55% fat, 15.35% moisture, and 1.70% ash (Masette *et al*., 2012).

2.2 Factors contributing to spoilage of dried fish

Protein degradation, fat oxidation, and microbial activity are the main factors responsible for the spoilage of fish. These are dependent on the initial composition of the fish and storage conditions after landing (Ghaly *et al*., 2010).

2.2.1 Protein degradation

The muscle and viscera of fish contain several proteolytic enzymes that are responsible for post-mortem degradation, resulting in quality changes (Aubourg *et al*., 2007). These changes occur during the processing and storage stages. Degradation of fish muscle proteins results in the production of peptides and free amino acids (Aoki *et al*., 2004). When conditions are inappropriate, autolysis of nucleotides and nitrogenous compounds occurs, and the extent of autolysis increases with prolonged storage (Aubourg *et al*., 2007).

2.2.2 Oxidation of fish

Lipid oxidation in muscle foods can be initiated by both non-enzymatic and enzymatic reactions. Oxidation of fish lipids leads to an off flavour (Ghaly *et al*., 2010). This occurs because of microbial decarboxylation of amino acids which is also dependent on the level of decarboxylase activity and the amino acid substrate available. Oxidation of lipids is associated with a decrease in triacyglycerols and phospholids and an increase in free fatty acids (Beltran and Moral, 1989) which often results in a product with off flavors (rancid) which may not be appealing to many consumers. Lipid oxidation has been deeply studied in recent decades, and its complex mechanisms, kinetics and products are now to a large degree well established. As reported by Schaich (1992), the mechanisms frequently proposed are based on kinetics, usually a prerequisite of either oxygen consumption or appearance of peroxides (indicated as peroxide value, PV), malondialdehyde (MDA, expressed as thiobarbituric acid reactive substances, TBARS), free fatty acids (FFAs), and/or volatile compounds, assuming standard radical chain reaction sequences.

2.3 Drying and pre-treatment as a processing and preservation method

Pretreatments are intentional unit operations performed to modify food substrates prior to further processing. Among these pre-treatment techniques is blanching, a unit operation mostly performed prior to other processing operations, in which food items are briefly heated to modify texture and other sensory characteristics (Taiwo & Baik, 2007).
Drying is a commonly accepted method of fish preservation, with sun-drying being the most widely practiced method worldwide. In this process, water is removed from the food by evaporation or

sublimation, thus reducing the water available for chemical, enzymatic, or microbial degradation (Raquel, 2018). Drying takes approximately 3-5 days depending on the weather and surface area of the fish in question. After the process, the products are collected from the drying yards and stored in a storage room for packaging.

2.3.1 Sun drying of fish

In the sun-drying method of fish processing and preservation, the products are exposed to open air. This process is very cost effective because no fuel or appliance costs are incurred by the processor. However, the quality of dried products is compromised as a result of varying temperature levels, poor hygienic conditions, and contamination of products with dust.

2.3.2 Solar drying of fish

The need to use solar radiation/energy for fish drying has become more than necessary at the present time because of the huge competitive demand for fuelwood for fish smoking. Solar drying is an improved sun drying method. This minimizes or stops some of the limitations of open-sun drying. It differs from open sun drying in that a structure, often very simple in construction, is used to enhance the effect of the insulation because a solar tent dryer (Figure 2) is an enclosed structure that traps heat inside the tent and makes effective use of the heat that is stored inside the tent both during the day and night with the help of a black body to absorb heat (Ojutiku *et al*., 2009).

Figure 2: Picture of solar tent drier

2.4 Pre-treatment in fish processing

In recent years, there have been several advances in drying technology, including pre-*treatments*, techniques, and equipment, that influence the quality of the final products. Pre-treatments, for example, are used to accelerate the drying process, enhance quality, and improve the safety of foodstuffs. Other pre-treatments include the addition of spices that contain compounds with preservation effects on food products.

2.4.1 Use of plant extracts to reduce oxidation in food products

Fish have a high spoilage rate, which begins as soon as they die. Fish flesh contains deposits of fat, which makes lipid oxidation a major cause of quality deterioration in its muscles. Lipid oxidation in fish can be reduced by incorporating antioxidants. The incorporation of antioxidants not only prevents quality loss but also improves the sensory attributes of fish and fish products (Meltem and Elvan, 2005). The most used antioxidants in the food industry are butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA). However, they are highly volatile and easily decompose at high processing temperatures, in addition to being synthetic chemicals (Meltem and Evans, 2005).

Recently, there has been growing interest in using natural antioxidant substances to replace synthetic additives. Natural antioxidants play functional and biochemical roles in the inhibition of oxidative damage induced by free radicals. Many plant tissues are good sources of phytochemicals, particularly phenolic compounds and flavonoids (Gorinstein *et al*., 2005). Several studies have reported on the use of plant materials as antioxidants in fish and fish products. The antioxidant properties of spices and herbs are attributed to their phenolic contents. The antioxidant effects of rosemary and onion in sardines have been previously reported (Pier *et al*., 2012). Lemongrass contains compounds with antibacterial, antioxidant, and anti-hyper-ammonia-producing ruminal bacterial activities. Its role in the reduction of oxidation in fish and meat products has been studied in a study conducted by Amer et al. (2021). According to a study conducted by Hayam et al. (2013). lemongrass inhibited oxidation in chicken patties after nine days of storage (Hayam et al., 2013). However, its antioxidant role in other food products needs to be explored.

3 METHODOLOGY

3.1 Experimental design

This study was conducted in 2 areas. Fish were processed at the Dei landing site in Lake Albert, Uganda (Figure 3), and the processed samples were shipped to Matis, Iceland, for laboratory analysis. Eighteen kilograms of freshly caught fish were caught on 10th of December in the morning, when the temperatures were low using beach nets, kept at normal temperatures (18°C) on board, and directly transported in a basin to the processing site (200 meters from the landing site) at room temperature to imitate the routine processing temperature. Fish were divided according to their respective treatments.

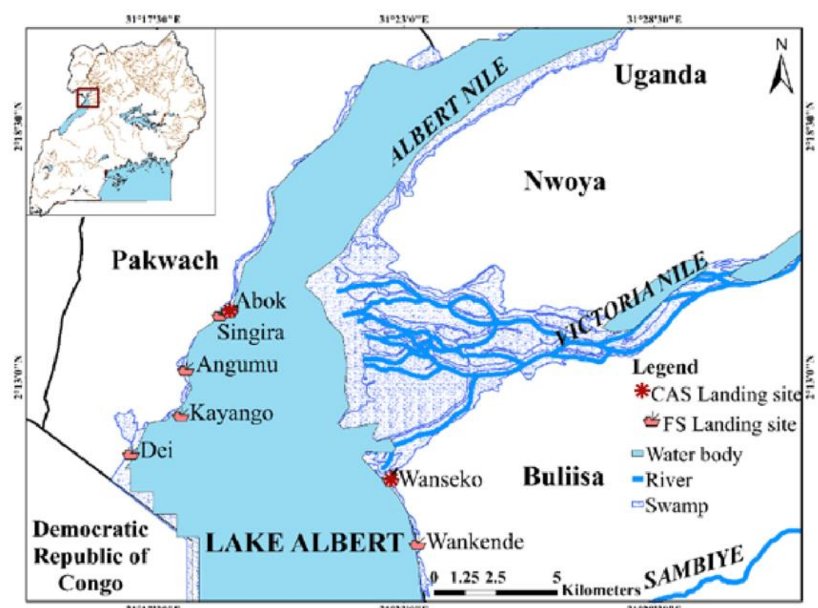

Figure 3: Map of Uganda showing location of Lake Albert

3.2 Purchase and preparation of materials

3.2.1 Lemongrass

Twelve kilograms of fresh lemongrass were purchased from a lemongrass farmer in the Pakwach district, Uganda. Eighteen kilograms of fresh *Brycinus nurse* fish was purchased from fishermen at Dei landing site, L. Albert. The fish were taken to the processing site and washed with tap water until they were clean to remove other foreign matter such as weeds and dirt (Figures 4 and 5).

The experiments were performed in triplicate. For each soaking time under solar drying conditions, 3 kg of fresh lemongrass was used, with one kilogram per replicate of the experiment. One kg of fresh lemongrass was crushed, soaked in 5 litres cold water for 3 hours, and sieved (approximately 0.1 cm size) using a muslin cloth to obtain a filtrate without solid particles. In each replicate of soaking time, 1 kg of fish was used per replicate and then placed under the solar drier. The same steps were repeated for fish exposed to open-sun drying (Figure 6).

A control that was not pre-treated with lemongrass consisted of fish washed with clean water and subjected to each drying condition.

Figure 4: soaking of lemongrass in water

Figure 5: Lemongrass filtrate

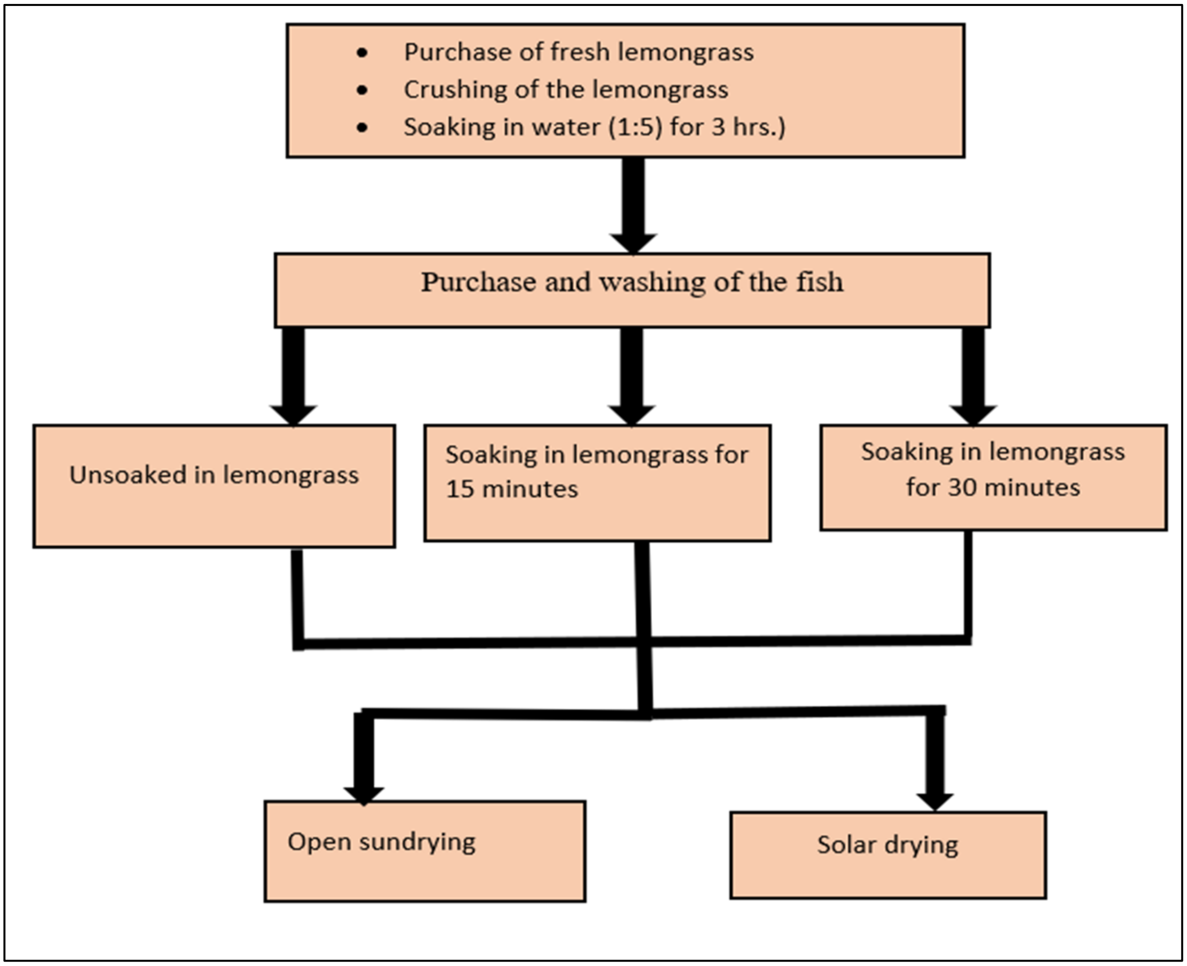

Figure 6: Flow chart for processing of the samples

Table 1: Codes for the dry samples

CODE	MEANING
COSD	Control open sundried
OSD 15	Open sundried in lemongrass for 15 minutes
OSD 30	Open sundried soaked in lemongrass for 30 minutes
CSD	Control solar dried
SD 15	Solar dried soaked in lemongrass for 15 mins
SD 30	Solar dried soaked in lemongrass for 30 minutes

Figure 7: Freshly purchased fish

Figure 8: Fresh fish soaked in lemongrass water

For each soaking time, the fish were subjected to two drying conditions. One batch of fish was placed on the rack in a solar tent drier (41°C), and another batch of fish was spread out for sun-drying (28^0C-30^0C) using a tray placed on the floor as shown in figure 10 for solar drying, and the drying surface was one meter above the floor. The open sundried fish took four days to dry, while the fish under the solar-tent drier took two days to dry. The fish were weighed until their weights became constant. The final dry weight under the different treatments reduced from 1 kg to 315 g - 318 g. The experiment was carried out in triplicate, and the results are shown (Table 1).

Figure 7:Solar used in drying of the fish

Figure 8: Fish being open sun-dried

Figure 9: Dried fish packed in ziplock bags

Dry samples removed from the two drying conditions were allowed to cool and were packed in Ziplock bags (Figure 11). The samples were stored at room temperature to imitate local storage conditions and then shipped to Iceland for further laboratory analysis. The time gap between the removal and packing of dried fish in Uganda and their arrival in Iceland was 14 days for sun-dried fish and 16 days for sun-dried fish.

3.3 Laboratory analyses

3.3.1 Total Volatile Bases Nitrogen
The steam distillation method, as described by Malle and Poumeyrol (1989), was used to analyze TVBN in the samples as an indication of the breakdown of proteins.

3.3.2 Peroxide value
The peroxide value was determined using the method described in the protocol by Matis to indicate the degree of primary oxidation (Santha & Decker 1994).

3.3.3 Thiobarbituric acid reactive substances (TBARs)
TBARs in the samples were determined using the methods described by Lemon (1975) to indicate the degree of secondary oxidation.

3.3.4 Microbial analysis
Total viable cell counts were determined using the standard method (NMKL 86 5TH EDITION).

3.3.5 Free fatty acids
Free fatty acids were determined using standard methods at Matis. Lipids were extracted according to the method described by Bligh and Dyer (1959).

3.3.6 Water activity
The water activity was measured using an Aqualab activity meter.

3.3.7 Sensory evaluation
Sensory evaluation was carried out using the five panelists at Matís for selected attributes for processing odour and rancid odour, as described in the table below. A fish meal (silage) odour was used to describe the processing odour. The evaluation was performed on a 15 cm linear scale with 1 denoting none and 15 denoting much processed odour. A general linear model was used to correct the panelists' use of the scale.

3.4 Statistical analysis

The data were subjected to one- and two-way analysis of variance using GenStat 14th edition to determine significant differences during storage. For the sensory evaluation, analysis of variance (ANOVA) was used to correct the panelists' use of the scale. Tuckey's post hoc test was used to compare the means between treatments, the a-b-c-d letters indicate significant differences.

4 RESULTS

This chapter summarises the results from the water activity, water content, sensory, oxidation, chemical, and microbial quality analyses from the samples.

There were significant differences in the sensory scores for processing odour between the open sundried and solar dried groups ($p<0.05$) (Figure 12). However, there were no significant differences between treatments in each group.

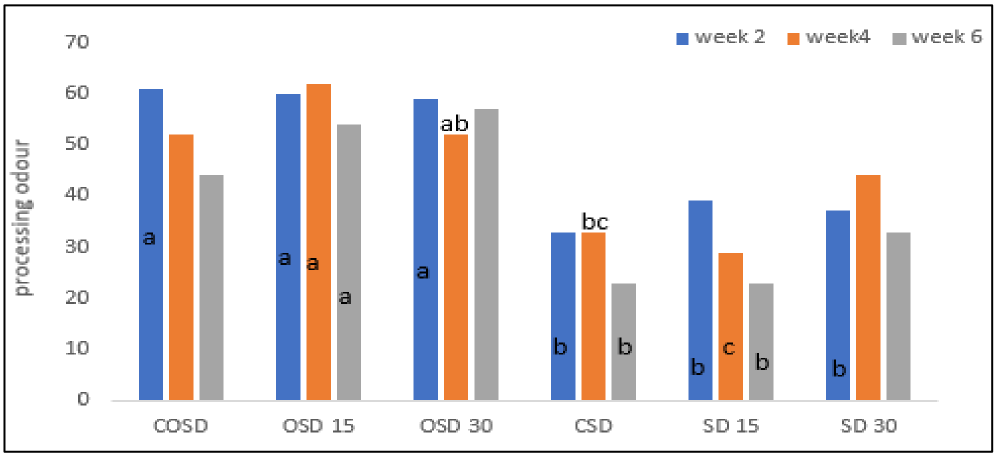

Figure 10: Processing odour of the fish samples

The microbial load of the solar-dried samples was lower than that of the open-sundried samples (Figure 13). The low microbial load in the solar-dried samples corresponded to low water activity, which could not favour rapid growth of the microorganisms. Regarding the lemongrass pre-treated samples, soaking for 30 minutes increased the microbial load, probably because the long soaking time could have exposed the samples to microbes in water.

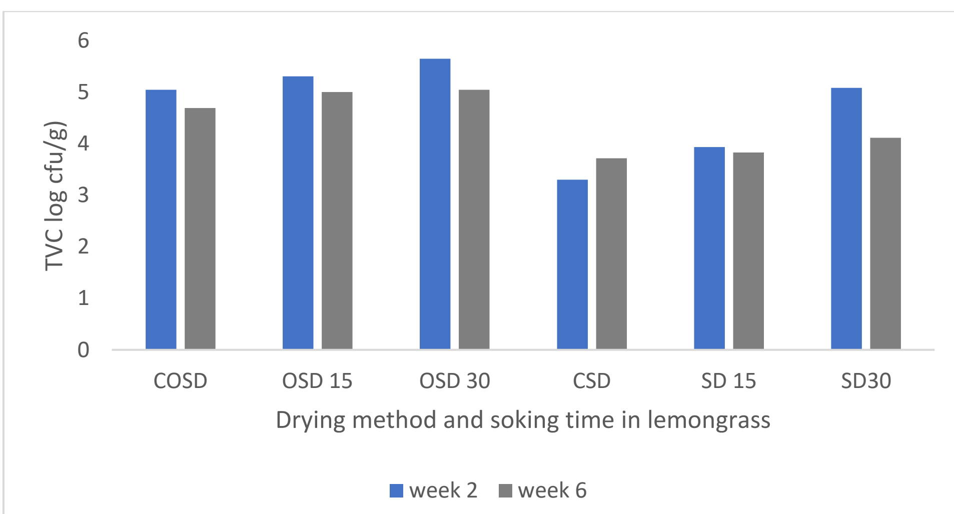

Figure 11:Total Viable counts in the samples

The solar-dried samples had lower TVBN values than the open-dried samples (Figure 14). The total volatile base nitrogen content was higher in the open sun-dried samples than in the solar-dried samples. Degradation of proteins occurs often when the temperature is not stable and when the drying takes a longer time (which explains why the open sundried samples had higher values (Enamul Haque et al., 2013).

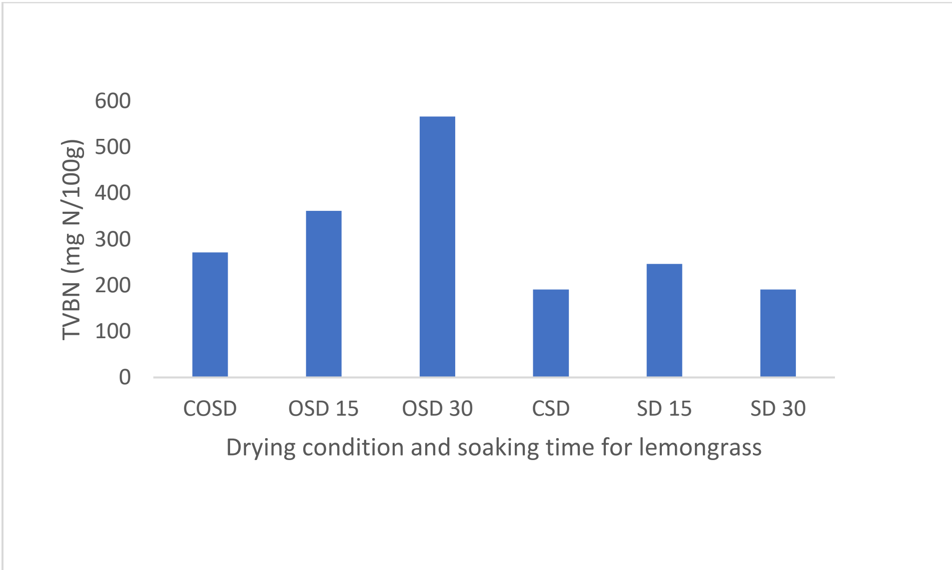

Figure 12: Total Bases Nitrogen in the fish samples in week 2

The moisture content of the open dried samples was higher than that of the solar-dried samples, except for the control solar-dried samples and samples that were soaked in lemongrass for 30 min. Moisture content ranged from 6% to-12%. The high value of the samples soaked for 30 min and solar drying could be because the soaking time increased the water in the fish (Figure 15).

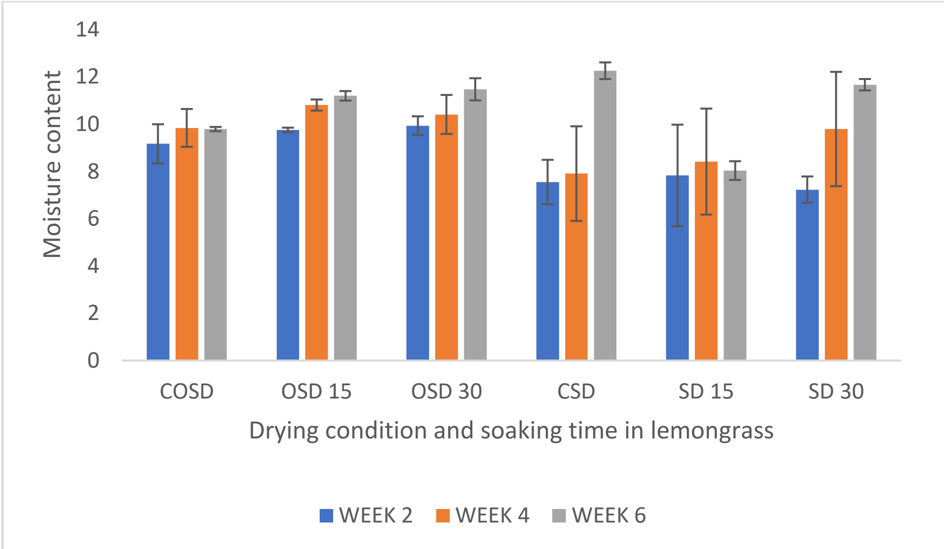

Figure 13: Water content of the samples

There were significant differences in the water activity of the fish samples ($p<0.05$). The solar-dried samples had lower values of water activity, indicating the effectiveness of the solar tent drier in the drying of fish compared with the open sun drying conditions (Figure 16). The high temperature in the solar tent dries the fish both during the daytime and at night.

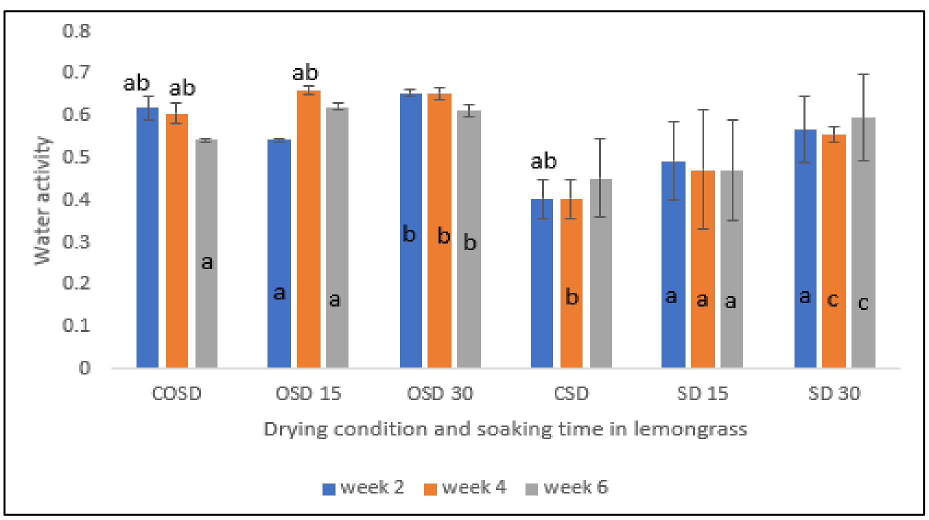

Figure 14: Water activity values in the fish samples

The fat content of the samples was between 10% and 20 % (Figure 17). These results were in agreement with those reported by Massette et al. (2012). The samples with higher fat content could probably be due to the low moisture content and rate of formation of lipid oxidation products such as FFA and aldehydes such as TBARs (Huss, 1995).

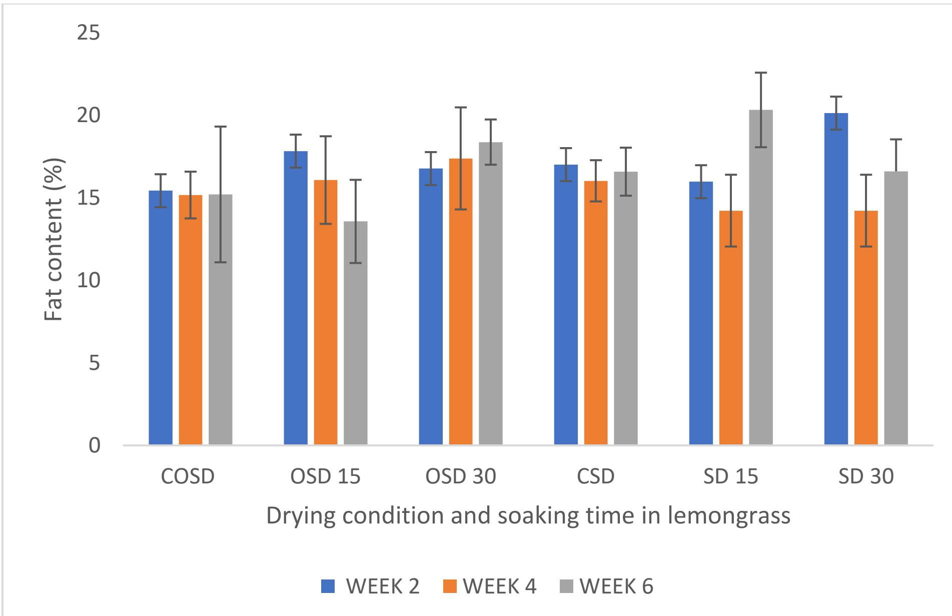

Figure 15: Fat content of the samples

The solar-dried samples had higher peroxide values (Figure 18). Peroxide values increased during storage. The higher value in the solar-dried samples is probably due to the constant high temperature in the solar tent drier during the drying process as opposed to lower temperatures in the open sun-drying conditions. The values in the samples were very low compared to those of the other dried fish, probably because the results could have had a problem.

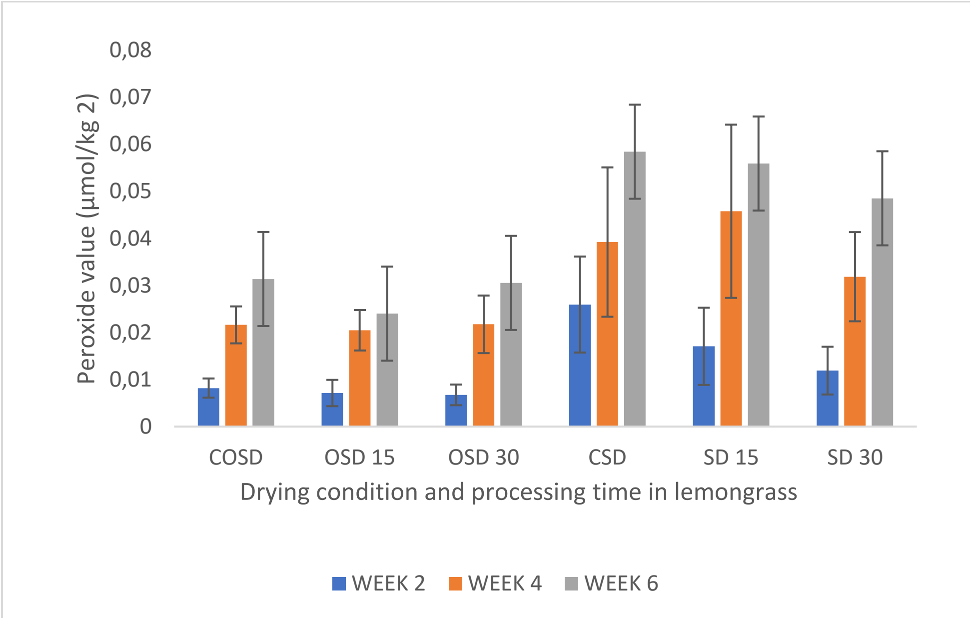

Figure 16: Peroxide values in the fish samples

The TBARS values indicate the quantity of the secondary products of oxidation (Figure 19). Throughout storage, the open sun-dried groups, both with and without lemongrass pre-treatment, had similar values (no significant differences). The quantity of secondary products of oxidation in these groups increased between two and four weeks of storage. After 6 weeks of storage, the quantity of secondary products of oxidation was lower than that after 2 weeks of storage, which could be explained by a breakdown of those secondary products into tertiary or further products of oxidation.

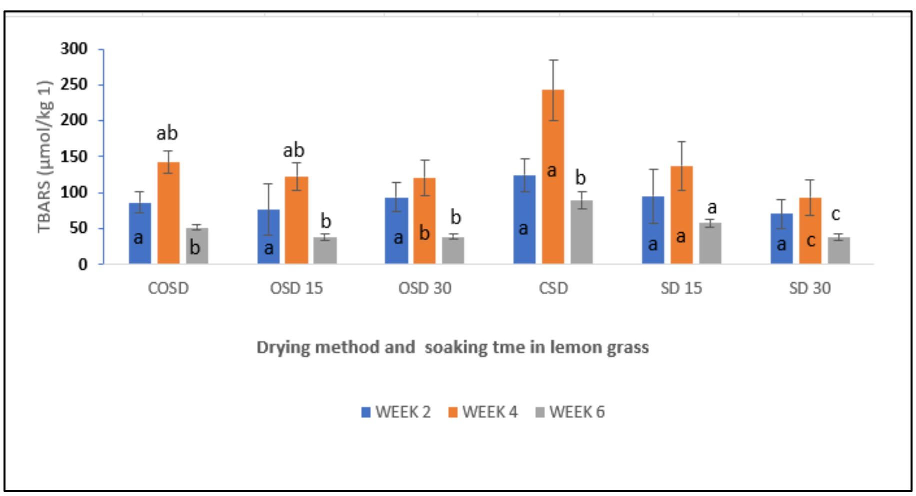

Figure 17: Values of TBARS in the samples during storage

For the solar-dried groups, lemongrass pretreatment had an effect. TBARS followed the same trend as in the open sun-dried groups, with an increase followed by a decrease after 6 weeks. However, the groups that were treated with lemon grass showed lower amounts of TBARS from week 4 for the 30 min treated group and then for 6 weeks the control solar-dried group was significantly higher than the 15 min lemon grass treated group, which was also significantly higher than the 30 million treated lemon grass group. This shows that the lemongrass treatment has an effect in reducing the formation of secondary oxidation products, and that a longer application has a greater effect.

The samples that were open sundried had higher values of free fatty acids compared to those that were solar-dried (Figure 20). In contrast, treatment of the samples with lemongrass did not affect the free fatty acid content of the dry fish.

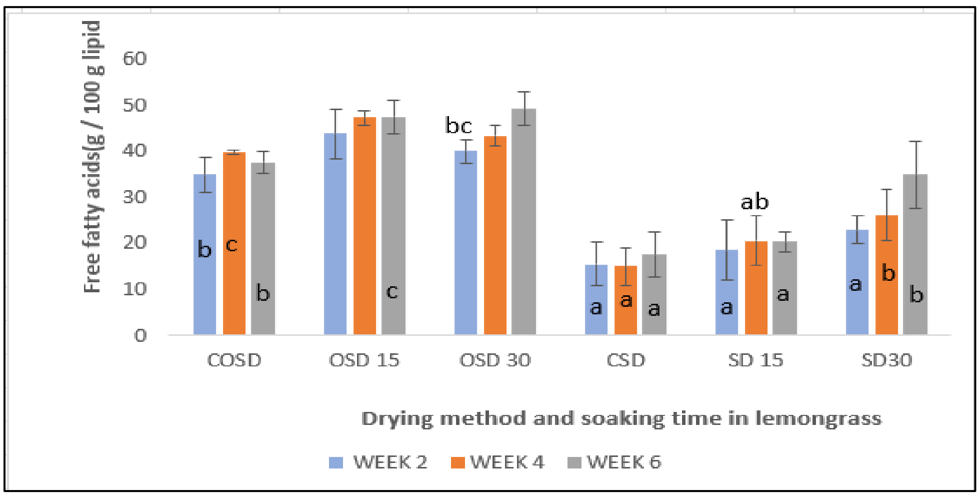

Figure 18: Free fatty acid value in the fish samples

5 DISCUSSION

5.1 Water activity

Water activity is related to moisture content in a non-linear relationship, known as a moisture sorption isotherm curve. Every microorganism has minimum, optimum, and maximum water activities for growth. However, 0.6 is considered a safe cut-off level for pathogen growth. In the present study, the water activity of all samples was below 0.6 (Abbas *et al*., 2009). As water activity decreased, the microbial load also decreased. Water activity in the solar dried groups was lower than 0.6; therefore, the TVC count was also lower for the solar dried than the open sun-dried black surface in the solar drier, which absorbs heat during the day and continues drying at night (Mustapha et al., 2014), which continues to dry fish. This lowers FFA levels by reducing the quantity of inducers of lipid hydrolysis.

5.2 Lipid stability during storage.

Lipid oxidation products reduce the palatability and nutritive value of dried fish (Wasowicz et al., 2004); hence, fishery products must be protected against oxidative changes.

In this study, the TBARS values increased in the first four weeks and declined in the 6th week. The trend of increase in TBARS content in the fish samples during the first four weeks of storage may be due to greater formation of malonaldehyde compared to the 6th week. A similar trend has been reported by Tinyiro et al. (2016) The production of substantial quantities of TBA-reactive substances can also be linked to fatty acids with a high degree of unsaturation (Fennema, 1996). Solar-dried samples treated with lemon grass had fewer secondary oxidation products. This could be due to the presence of polyphenols in lemongrass, which scavenge free radicals responsible for secondary oxidation products. Therefore, applying lemongrass for a longer time would help reduce the quantity of secondary products of oxidation (Alzobaay, 2021). The higher FFA content in the open sun-dried samples could be due to the high-water activity, which increased the level of microbial load and hence increased the number of lipid hydrolyses.

6 CONCLUSION

Based on the results of this study, it can be concluded that solar drying improved the quality parameters of the samples during storage compared to the open drying method. Soaking in lemongrass for 15 minutes improved the processing odour. The group soaked in lemongrass for 15 minutes and solar-dried could be sold to the market for human consumption.

7 RECOMMENDATIONS

Fish processors should be trained on good handling practices of fish during processing to reduce microbiological contamination. More solar-tent driers should be constructed, and the frequent utilization of solar tent driers should be encouraged. Training of the processors on how to use lemongrass in pre-treatment before drying. Farmers should also be encouraged to increase the cultivation of lemongrass to increase its availability for use in fish processing.

REFERENCES

Ayodele, M.O., Adesoji ,M.O. (2012). Effects of Pre-treatments and drying temperatures on drying rate and quality of African catfish (Clarias gariepinus). *Biology, Agriculture and Healthcare*, ISSN 2224-3208.

Boeira, C.P ., Natiéli, P. (2018). Extraction of bioactive compounds of lemongrass, antioxidant activity and evaluation of. *Food Technology*, 1678-4596.

Omoruyi, K., Nneli, A.E., Benjamin O.G. (2019). Effect of Natural Preservatives (Lemon Grass and Bay Leaf Marinade on the Microbial Load and Shelf of Smoke-dried Clarias gariepinus. *Asian Food Science Journal*, 1-10.

Amer, Alzobaay., Baidaa, H. K., Rawaa, M. A. (2021). Antioxidant properties of Lemongrass leaves aqueous extract and its effect on fish balls oxidative stability during refrigerated storage. *Pure and Applied Science*, 120-126.

Aoki, H., Ahsan, M. N., Matsuo, K., Hagiwara, T., & Watabe, S. (2004). Partial purification of prtoteases that are generated by processing of the Northern shrimp Pandalus borealis and which can tenderize beef. *Intenational Journal of Food Sciece and Technology*, 471-480.

Aubourg, S. P., Quitral, V., Angélica Larraín, M., Rodríguez, A., Gómez, J., Maier, L. (2007). Autolytic degradation and microbiological activity in farmed Coho Salmon (Oncorhynchus kisutch) during chilled storage. *Food Chemistry*, 369-375.

Aubourg, S. P., Quitral, V., Angélica Larraín, M., Rodríguez, A., Gómez, J., Maier, L., & . (2007). Autolytic degradation and microbiological activity in farmed. *Food Chemistry*, 369-375.

Bello, M. M and Oyelese, O. A. (2016). Seasonal variations in the proximate composition of nurse tetra (Brycinus nurse) from Alau Lake Maiduguri, Nigeria. *Animal Research International*, 2470-2474.

Ghaly, A.E., Deepika, D., Budge, S., Brooks, M.S. (2010). Fish Spoilage Mechanisms and Preservation Techniques: Review. *American Journal of Applied Science*, 859-877.

Gorinstein, S., Drzewiecki, J., Leontowickz, H.,Leontowickz, M., Najman, K. (2005). Comparison of the bioactive compounds and antioxidant potentials of fresh and cooked Polish, Ukrainian, and Israeli garlic. *Agriculture and Food Chemistry*, 2726-2732.

Hayam, M. I., Ferial, M. A.S. (2013). Effect of Adding Lemongrass and Lime Peel Extracts on Chicken Patties Quality. *Journal of Applied Sciences Research* , 5035-504.

Meltem S, and Elvan F. (2005). Effects of using rosemary extract and onion juice on oxidative stability of sardine (Sardina pilchardus) mince. *Food Quality*, 109–120.

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

Pier, G.P., Francesco, G., Marco, O., Riccardo, A., Claudio, M. (2012). Effects of Rosemary Oil (Rosmarinus officinalis) on the Shelf-Life of Minced Rainbow Trout (Oncorhynchus mykiss). *Foods* , 28-38 ; doi:10.3390/foods1010028.

Rabiu ,A., Auta, J., Jatau, A. (2016). Comparative proximate composition of Clarias gariepinus (buchell,1822), Oreochromis niloticus (linnaeus, 1754) and Brycinus nurse (J.P Muller and Troichel, 1846) caught from bakori dam in Katdina state. *Arts and Science*, ISSN: 1118-5953 .

Raquel. (2018). The Drying of Foods and Its Effect on the physicochemical, sensorial and nutritional properties. *International Journal of Food Engineering*, 93-100.

Saliu, J. (2002). Observations on the age and growth of Brycinus nurse. (Paugy 1986) - Pisces: Characidae in Asa Reservoir, Ilorin, Nigeria. *African journals Online,* https://doi.org/10.4314/tfb.v11i1.20866.

Sriket, C. (2014). Proteases in fish and shellfish: Role on muscle softening and prevention. *Intenational Food Research Journal*, 433-445.

(2016). *Uganda Demographic and Health Survey.* Kampala: Uganda Bureau of Statistics .

United Nations. (2019). *World Economic Situation and prospects.* New York: United Nations.

United States Agency for International Development. (2021). *Uganda Nutrition Profile.* Washington, DC: : USAID.