DEVELOPMENT OF EFFECTIVE DRYING TECHNOLOGY FOR QUALITY ENHANCEMENT OF WHITINGS FISH (*MERLANGIUS MERLANGIUS)*

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ABSTRACT

*A cost effective, affordable and environmental friendly solar tent dryer was developed for production of stockfish from Whitings fish (*Merlangius merlangius*) that is stable and free of contamination from air borne dust and insects. The dryer was constructed of locally available materials; basically steel and polythene. It was able to record an average differential temperature of 12 °C when compared with the ambient condition. The tent dried fresh samples of Whitings of 25 kg with average moisture content of 80.10% (wet basis) to a final weight of 5.42 kg with average moisture content of 10.13% (wet basis) in four days. Over 75 % overall acceptance was recorded when the stockfish was subjected to sensory analysis. The drying technology reduced the bacterial and fungal count of the fish sample used from initial value of 6.8 CFU/g x 10^2 and 3.6 CFU/g x 10^5 to 3.9 CFU/g x 10^2 and 2.7 CFU/g x 10^5 respectively. This is below the acceptable safe limit and what is obtainable in stockfish sold in the market. The output could be a good alternative to the imported stockfish in terms of food safety and sensory quality. Most importantly, it would reduce the huge amount of money being spent on importation of stockfish, and more job and wealth will be created for the teeming populace while the lovers of stockfish now have access to freshly processed products that would not endanger their life.*

Keywords : *Stockfish, dryer, sensory, solar, quality*

RESUME

DEVELOPPEMENT D'UNE TECHNOLOGIE DE SECHAGE EFFICACE POUR L'AMELIORATION DE QUALITE DU POISSON MERLAN (MERLANGIUS MERLANGIUS)

Un séchoir à énergie solaire rentable, abordable et écologique a été développé pour la production de Merlan séché (Merlangius merlangius), stable et exempt de toute contamination par l'air la poussière et les insectes. Le séchoir a été construit avec des matériaux disponibles localement; essentiellement en acier et en polyéthylène. Il est capable d'enregistrer une température différentielle moyenne de 12°C par rapport à la condition ambiante. Le séchoir sèche des échantillons de Merlan frais de 25 kg avec une teneur en humidité moyenne de 80,10% (sur une base humide) à un poids final de 5,42 kg avec une teneur en humidité moyenne de 10,13% (en conditions humides) en quatre jours. Plus de 75% de l'ensemble des personnes soumises à l'analyse sensorielle du poisson séché l'ont approuvé. La technologie de séchage réduit la charge bactérienne et fongique de l'échantillon de poisson utilisé avec la valeur initiale de 6,8 UFC / g × 102 et 3,6 UFC / g x 105 à 3,9 UFC / g x 102 et 2,7 UFC / g x 105 respectivement. Ceci est en dessous de la limite acceptable de sécurité et de ce qui est disponible dans les stocks de poisson vendu sur le marché. La valeur ajoutée pourrait être une bonne alternative à l'importation de poissons séchés, en termes de sécurité alimentaire et de qualité sensorielle. Plus important encore, cela réduirait d'énorme quantité d'argent dépensé sur l'importation de poisson, en plus du travail et de richesse seront créés avec l'approvisionnement de la population. Les amateurs de poisson séché auront maintenant accès à des produits fraîchement transformés qui ne mettent pas en danger leur vie.

Mots clés : *Poissons séché, séchoir, sensoriel, solaire, qualité*

INTRODUCTION

Fish is an important food and one of the major sources of protein in the Tropics. It is highly nutritious, provides not only high value protein but also represents an important source of a wide range of essential micro nutrients and fatty acids (FAO 2008). Fish supplies a good balance of proteins, vitamins and minerals. It has 10% calories content and hence plays a great role in nutrition supply and balanced diet (Akande and Tobor 1992). Fish and fish products constitute more than 60% of the total protein intake in adults especially in the rural areas (Adeleye 1992). Fish flesh is tender due to bundles of muscle fibres which are held together by fibrous material when heated (Fagade 1992). It is better digested than beef or other types of protein (Adebayo-Tayo *et al.,* 2008).

Whitings fish (stockfish) *Merlangius merlangius* called *Okporoko* and *Panla* among Southern and Western Nigerians respectively, is not only a tasty delicacy but also a costly soup material. It is a healthy, fresh commodity chemically free from artificial additives, created almost from «fresh air and love» alone. The production process is resource friendly and beyond all doubt the least energy-demanding food manufacturing procedure in the world. Most of the fresh fish nutrients remain in the dried fish, only the water is removed during the processing (Kurlansky 1997). Stockfish is usually processed from Cod which boasts remarkable nutritional properties: it contains over 18% proteins, besides being an excellent low-calorie source of protein (a four-ounce serving of cod provides 52.1% of the daily need for protein for only 119 calories).

Fish is an extremely perishable food. It begins to spoil as soon as it is caught perhaps even before it is taken out of the water. Spoilage proceeds as a series of complex enzymatic, bacteria and chemical changes that begin as soon as the fish dies. This is why the fish become soft and the smell becomes more noticeable (Carruthers, 1986). Because of the perishable nature of fish, it requires proper handling and preservation to increase its shelf life and retain its quality and nutritional attributes. In Nigeria, fish is eaten fresh, preserved or processed (Adebayo – Tayo *et al.*, 2008). Fish processing and preservation is carried out to slow down or prevent the enzymatic, bacteria and chemical deterioration to maintain the fish flesh (Carruthers, 1986).

Food preservation can be achieved by the removal of water from the food items since microbial organisms require moisture for active growth including enzymatic hydrolysis of the food components (Ogbonna, 1987). Water occurs naturally in the fish's body and so drying is one of the simplest ways to preserve fish. It works by removing water from the fish which prevents the growth of micro-organisms and decay. Drying food using the sun and wind to prevent spoilage has been known since ancient times, water is usually removed by evaporation (air drying, sun drying or smoking). Drying also creates a hard outer layer helping to stop micro-organisms from entering the food (Wikipedia, 2009a). In other to prevent spoilage, the moisture content needs to be reduced to 25% or less. The percentage will depend on the oiliness of the fish or whether it has been salted (Facts, 2004). Stockfish is unsalted fish especially cod dried by sun and wind on wooden racks on the foreshore called «Flakes» or in special drying houses (Wikipedia, 2009b).

For centuries, it was preserved by drying as stockfish and clip fish and traded as a world commodity. During the drying, about 80% of the water in the fish disappears. The stockfish retained most of the nutrients of the fresh fish only concentrated. It is best known to be one of the richest sources of protein with the important B vitamin, Iron and calcium. Cod is moist and flaky when cooked and is white in colour. It has a mild flavour, low fat content and a dense white flesh that flakes easily (Kurlansky, 1997). In Nigeria, especially the Sothern part, stockfish is a delicacy usually eaten by the rich because of it high cost. Nigeria, Italy and Croatia are reported as the biggest importers of stockfish (whitings) *Merlangius merlangius* in the world. Nigeria has been importing large quantities of high grade stockfish not available locally from all over the world in the last few decades (Junaid *et al.,* 2010). Nigeria has the resource capacity (12 million ha inland water and aquaculture) to produce 2.4 million MT of fish every year, with an estimated demand at 1.4 million MT which currently exceeds supply. However, despite this great potential Nigeria is still a major importer of fish (about 648,000 MT of fish imported annually) with domestic fish production estimated at only 496,700 MT from all sources (Abba, 2007).

Furthermore, the literature revealed that little technology is available for its production as the country depends on imported product. Olokor and Omojowo (2009) carried out a comparative study on the use of Doe's dryer and Kanji Solar Tent Dryer (KSTD). The two dryers which have different designs were made of wood and polythene with black pvc and stone as heat enhancement materials for Doe's dryer and KSTD respectively. It was used to dry *Bagrus bayad.* The amount of money being spent on importation of stockfish could be diverted into other economic sector of the country if local fish species available within Nigerian territorial water is fully harnessed into stockfish production. In order to achieve this, technology input is required to develop a good quality stockfish product that is widely acceptable. NSPRI has indentified some fish that could be processed into stockfish using standard protocols. Cost benefit analysis of the technology has shown that an investor of the venture when fully developed would make 35% profit margin and can breakeven within 12 to 15 weeks of production.

This project was aimed at developing high quality stockfish that will command high acceptability with reduce price especially in supermarkets and fish markets in Nigeria. Specifically, the study was targeted at development of a simple and affordable drying technology for non-fatty fish dehydration. If the technology is fully developed to commercial level, it will drastically reduce stockfish importation, increase consumption and empower local producers.

MATERIALS AND METHODS

STUDY AREA

This study was carried out in the premises of Nigerian Stored Products Research Institute (NSPRI) headquarters in Ilorin, North Central zone of Nigeria. The study was carried out in November 2014. The average ambient temperature and relative humidity of the location at the period of the experiment ranged from 22.43 (min.) to 33.16 °C (max.) and 47.14 (min.) to 84% (max.) respectively (NSPRI Agro-meteorological Station).

EXPERIMENTAL MATERIALS AND PROCEDURES

Dryer

A solar tent dryer was developed for the purpose of the study. The dryer has capacity to hold 25 kg fresh fish per batch. It was mainly fabricated of steel and polythene sheet. The tent dryer has dimension of 245 x 184 x 160 cm (L x B x H). The frame was constructed of galvanized pipe of 2.54 cm diameter while the rack was made of 37.5 x 37.5 mm angle iron. The dryer has two sets of trays with an interspacing of 82.5 cm. The first sets has two (2) trays of dimension 120 x 109 cm situated 77 cm from the floor while the second set consists of two trays of dimension 120 x 45 cm positioned 42 cm from the top of the dryer. The frame was covered with 0.25 mm thick polyethylene sheet. It is collapsible for ease and comfort of transportation. Openings which are underlay with a thin pvc mesh (mosquito nets) were provided at the base end for fresh air intake and at the angular top sides of the dryer for moisture laden air exit. The pictorial view of the dryer is presented as Figure 1.

Figure 1 : Pictorial view of the solar tent dryer.

Vue picturale du séchoir à tente solaire

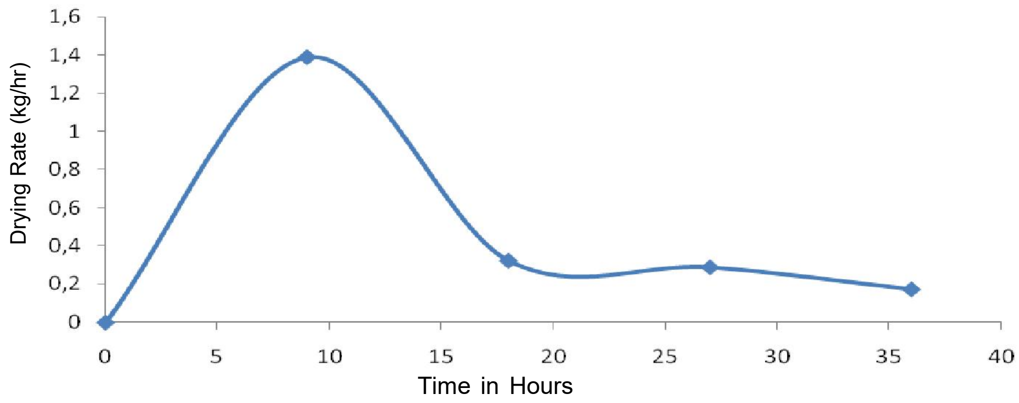

Figure 2 : Drying rate curve of the fish dried in the solar tent dryer.

Courbe de taux de séchage du poisson séché dans le séchoir à tente solaire

Fish

Whitings fish (*Merlangius merlangius*) was used for the experiment. The fish was sourced from a reliable fish marketer located within Ilorin metropolis and transported to the processing centre of Nigerian Stored Products Research Institute. The average weight of fish used for the experiment is 180g.

Fish Preparation and Drying

The fish was gutted and thoroughly washed. Thereafter, the washed fish was brined (200 grams of salt to 5 litres of water) to give the stockfish good taste. The fish was allowed to drain before it was arranged on the drying trays. Positioning of loaded trays in the dryer and covering of the dryer with polythene followed immediately. The dryer was situated in location where there was no possible obstruction of sun energy. The drying operation commenced immediately after the covering of the dryer.

Sampling Procedures

Samples were taken prior the drying for initial moisture content and microbial load. Initial weight of loaded fish was taken and recorded. Moisture content of the stockfish samples was determined by oven drying method as described by Adebayo-Tayo *et al.* (2008). Weight of the fish was also taken every day throughout the experiment. This was accomplished using a digital weighing balance with an accuracy of 0.01 g (Avery Berkel- Averyweigh-Tromix HL122). The drying temperature of the dryer was monitored using a data logger (Tinytag^{TM}TV-4104). The rate of moisture removal (drying rate) was calculated from the data recorded during drying. The drying rate was calculated using equation 1.

where ; $$R = \left(\frac{dM}{dt}\right) = \frac{m_i - m_f}{t}$$

R is the drying rate in g/hr, *dM* is the change in mass (g), *dt* is the change in time (hr) and t is the total time (hr). m_i and m_f are the initial and final mass of fish samples respectively in gram.

Figure 3 : Sample of stockfish Produced.

Échantillon de poisson séché produit.

Microbial Analysis

1 gram of fish sample was put in 10 ml of phosphate buffered saline (PBS). The aliquant from the PBS was stored overnight at 4°C until microbiological analyses were performed. This was done for the fresh and dried samples. Enterobacteriaceae, enumerated by duplicate plating of 1 ml aliquots of whitings fish, were put on Violet red bile glucose agar (VRBG). Plates were poured with an overlay of VRBG to assist in the recovery of injured organisms. Plates were incubated overnight at 37°C and observed for colony formation. Dark red to purple colonies with red-purple haloes were counted and converted to log_{10} CFU/ml samples. Up to five isolates for each positive sample were randomly selected for further analysis. A numbered circular grid (10 cm diameter with 1 cm^2 divisions) and random number tables were used to select isolates from plates with greater than 20 colonies. Each selected isolate was streaked for purity on plate count agar plates (PCA) and incubated overnight at 37°C. Slants were then stored at 4°C. Using an isolated colony the procedure was repeated twice to ensure purity. An isolate from the third streak plate was saved on brain-heart infusion agar slants at 37°C and protect beads (Technical Service Consultants Ltd., The Ropewalk, Schofield St., Heywood, Lancashire OL10 1DS) at -20°C until further identification analyses.

Total mould count on the fish samples was estimated on dichloran rose bengal chloramphenicol agar (Difco- DRBC) and the plates were then incubated at 25°C for 7 to 10 days. For *Salmonella* isolation, whitings fish samples were enriched in Rappaport-Vassilidis broth (RV, Oxoid, UK), followed by recovery on xylose lysine dextrose agar (XLD - Scharlau, Barcelona, Spain). For *Listeria* isolation, two stage enrichment procedures were done using *Listeria* enrichment broth (LEB - Oxoid) followed by isolation on palcam agar plates (Oxoid). For *E. coli* O157:H7, tryptone soya broth (TSB, Difco, Detroit, MI, USA) supplemented with 20 mg/L novobiocin (Sigma, Germany) were used. Isolation was done on MacConkey sorbitol agar plates. Thermophilic *Campylobacter* were isolated directly or after enrichment on Karmali media at 42°C (BK + BS, Biokar Diagnostic, Beauvais Cedex - France).

The methods used were of the Association of Official Analytical Chemists (AOAC 1995) and in the compendium of methods for the microbiological examination of foods (Downes and Ito 2001). Identification of Enterobacteriaceae and other species was made by commercially available biochemical tests, while taxonomic identification of the different genera and species was made according to microscopic criteria in accordance with appropriate keys (Pitt and Hocking 1997).

Sensory Evaluation

The following food sensory quality parameters were employed to assess the quality of the dried fish samples: appearance, colour, texture, taste, flavour and aroma. The sensory analysis was carried out using a palatability test template with a hedonic scale of 9 points. The template gave the panellists opportunity to choose from a range of options, which covered 'like extremely' to 'dislike extremely'. The options include; like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much and dislike extremely; and they were allocated 9, 8, 7, 6, 5, 4, 3, 2 and 1 mark (s) respectively. The team of panellists was constituted of ten (10) members. Each of the panellists was given 3 test templates; one per sample. After the test, the result was extracted by collating the allocated point for each option chosen by the panellists.

RESULTS

PERFORMANCE EVALUATION OF THE SOLAR TENT DRYER

The dryer was able to record an average differential temperature of 12 °C when data recorded by the data logger was compared with the ambient temperature. Result of the first day of drying revealed that fish of 25 kg loaded in dryer was reduced to 12.5 kg. Reduction in weight after the second and third day drying was gradual. The weight was 9.58 kg and 6.98 kg after the second and third day respectively. The drying operation was completed after four days with a final weight of 5.42 kg (Table 1). The dryer dried fresh samples of Whitings (*Merlangius merlangius*) of 25 kg from average moisture content of 80.10 % (wet basis) to a final weight of 5.42 kg with average moisture content of 10.13% (wet basis) for four days.

Table 1 : Result of performance evaluation of the solar tent dryer.

Résultat de l'évaluation des performances du séchoir à tente solaire

Day	1	2	3	4	Average
Drying Rate (Kg/hr)	1.39	0.32	0.29	0.17	0.54
Moisture Loss (kg/day)	12.50	2.92	2.60	1.56	4.90

MICROBIAL ANALYSIS OF THE FISH DRIED IN THE TENT

The result of the microbial analysis carried out on both fresh and dried samples recorded a reduction in bacteria count from 6.8 to 3.9 CFU x 10^2. There was also reduction in fungi count from initial 3.6 to 2.7 CFU x 10^5 (Table 2).

Table 2 : Microbial Load of fish dried in the solar tent dryer.

Charge microbienne de poisson séché dans le séchoir à tente solaire

Wet		Dried	
Bacteria CFU × 10^2	Fungi CFU × 10^5	Bacteria CFU × 10^2	Fungi CFU × 10^5
6.8	3.6	3.9	2.7

SENSORY EVALUATION OF DRIED FISH

The result of the sensory attributes of the fish samples dried in the solar tent dryer was presented in Table 3. The appearance attribute of the fish was scored the highest point of 8.6, followed by taste with 8.4 ; while the least score of 6.8 was recorded against flavour. The overall acceptability of the product was 7.7.

Table 3 : Result of sensory evaluation of dried fish.

Résultat de l'évaluation sensorielle du poisson séché.

	Appearance	Colour	Texture	Taste	Flavour	Aroma	Overall Acceptability
Average	8.6	8.3	7.0	8.4	6.8	7.0	7.7
Maximum	9.0	8.8	7.5	8.6	7.3	7.3	8.1
Minimum	7.8	7.0	6.2	7.7	6.0	6.5	6.9

DISCUSSION

DRYING RATE CURVE FOR STOCKFISH DRIED IN THE SOLAR TENT DRYER

Fifty (50) % of the total weight of the fish was lost after the first day of drying. This might be due to the initial high moisture in the fish and the drying air conditions in the dryer. There was a rapid drying rate during the first 10 hours of drying (that is throughout the first day of drying). This was due to the condition of the drying air (air temperature, relative humidity and the air velocity) which was the predominant factors influencing drying during this period. As the drying progresses the drying rate fell drastically after the 10^{th} hour of drying. This is because at this point, the internal movement of water is the predominant factor influencing drying. The drying rate as expected is lower than that of the artificial or mechanical dryers due to the fact that the maximum temperature obtainable in the solar dryer is lower compare to temperature output of mechanical dryer. This is in line with the results of Babarinsa *et al.* (2011). However, the solar tent is able to provide the needed drying conditions to produce the stockfish of the desired quality. It maintains a differential temperature of 12^0C with the ambient. It is a good result when compared with findings of Olokor and Omojowo (2009) that reported a differential temperature of 6.2^0C and 12.1^0C for Doe's tent and KSTD respectively. Despite that there was no heat enhancement provided for the dryer developed, heat available is highly comparable with the two former that were provided with heat enhancement.

EFFECTS OF THE DRYING PROCESS ON THE MICROBIAL LOAD OF THE FISH DRIED

The initial microbial load from the fresh fish sample for the total viable count was 6.8×10^2 CFU/g while that of the total fungal count was 3.6×10^5 CFU/g. The final total bacteria count obtained from the fish dried in the solar tent was 3.9×10^2 CFU/g while that of fungal count obtained for the dried stockfish was 2.7×10^5 CFU/g. The temperature attained in the solar tent dryer was responsible for the reduction in microbial load (Assefa *et al.,* 2013).

The result obtained showed that the microbial load of the samples dried with the dryer were below the acceptable limit of 6.0 $\log_{10}$ CFU/g as recommended by the International Commission on the Microbiological Specifications for Food (ICMSF 1998). The safety of the product (stockfish) from the microbial results is encouraging as Adebayo – Tayo *et al.* (2008**)** observed higher presence of fungi above the recommended levels in imported stockfish sold in majority of markets in Nigeria. This proves that the production process the stockfish went through was able to keep the fungi level in the stockfish below the safe limit and hence safe for consumption.

EFFECT OF DRYING ON THE SENSORY ATTRIBUTES OF THE STOCKFISH

The result of the sensory evaluation as in Table 3 depicts the average, maximum and minimum responses of the panellists. All the sensory parameters considered were scored high because of the quality of stockfish produced from this exercise. The colour was appealing together with its irresistible taste and aroma. The average score for overall acceptance of the product is evidenced in people's demand for more whenever they have opportunity to eat the stockfish. The analyses carried out so far prove that the stockfish is safe to take without further processing unlike the imported stockfish that lack most of these qualities, and is also highly contaminated as reported by Junaid *et al.* (2010).

CONCLUSION

The technology is capable of producing stockfish of good quality that could command higher economic value. The output (stockfish) of the solar tent can compete favourably with the imported stockfish in terms of food safety, nutritional and sensory qualities even if not better. This process has the potential to reduce the huge amount of money been spent on importation of stockfish if not totally replacing it. The low production cost will enable stockfish presently seen as the food of the rich to get to the commoners and masses. It is also another means of job and wealth creation for the active population while the lovers of stockfish now have access to freshly processed products of better quality.

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