Effects of Drying Methods on the Quality Characteristics of Oreochromis Niloticus in Benue State

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ABSTRACT

This study determined the effects of different drying methods (sun-drying, smoking and oven-drying) on the proximate and mineral composition of *Oreochromis niloticus* obtained from Oracle Farm, Makurdi, Benue State, Nigeria. Thirty fish samples were degutted, washed and subjected to the three drying treatments. Proximate composition was analysed according to AOAC (2010) procedures, while mineral composition (sodium, potassium, calcium, magnesium and zinc) was determined by spectrophotometry. Data were subjected to one-way analysis of variance (ANOVA) and significant means were separated at the 5% level. Significant differences ($p < 0.05$) were observed in all proximate and mineral parameters among the drying methods. Sun-dried samples recorded the highest crude protein (72.14 ± 0.25%) while smoked samples had the lowest (61.91 ± 0.35%). Lipid content was highest in smoked fish (6.81 ± 0.07%) and lowest in oven-dried samples (3.98 ± 0.19%). Oven-dried samples contained the highest ash (19.35 ± 0.17%) and were superior in all minerals examined: sodium (141.14 ± 1.37 mg/100 g), potassium (131.24 ± 1.42 mg/100 g), calcium (122.36 ± 4.44 mg/100 g), magnesium (135.32 ± 4.50 mg/100 g) and zinc (23.91 ± 0.77 mg/100 g). The results indicate that oven-drying better preserves mineral content while sun-drying maximises protein concentration. Oven-drying is therefore recommended as a suitable method for processing *O. niloticus* for improved nutritional quality.

Keywords: Oreochromis niloticus, drying methods, proximate composition, mineral composition, sun-drying, smoking, oven-drying

INTRODUCTION

Capture fisheries production, both inland and marine, has stagnated over the past two decades. Simultaneously, the increasing human population continues to exert pressure on the demand for fish, a demand that current capture production is unable to meet (FAO, 2018). The Food and Agriculture Organization (FAO, 2018) has identified aquaculture as the primary means of addressing the shortfall arising from declining capture fisheries. Globally, the contribution of aquaculture to the supply of fish and other aquatic organisms has increased steadily in recent years, and growth in overall fish production over the past decade has been attributed largely to aquaculture.

Oreochromis niloticus, commonly known as Nile tilapia, is a freshwater fish species belonging to the family Cichlidae. It is native to various freshwater habitats across Africa, including the Nile River and its tributaries, lakes and rivers in East Africa. Owing to its hardy nature, fast growth rate and adaptability to diverse environmental conditions, Nile tilapia has been extensively introduced and cultivated in many regions of the world (Albert et al., 2020). The species thrives in ponds, lakes, reservoirs and even brackish water. Combined

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with its omnivorous feeding habits and high reproductive capacity, these attributes make it an ideal candidate for aquaculture production (Costa-Pierce, 2015).

The economic significance of O. niloticus cannot be overstated. It serves as an important source of protein and income for many communities, particularly in developing countries. Its relatively low production cost and widespread availability have contributed to its popularity in the global market (Albert et al., 2020). In addition, its efficient conversion of feed to flesh and its ability to tolerate crowded conditions render it desirable for intensive aquaculture systems.

Knowledge of the proximate composition of fish is essential for estimating energy value and for planning appropriate industrial and commercial processing. Live weight of whole fish typically comprises 70–80% water, 20–30% protein and 2–12% lipid. Composition may, however, vary with environmental conditions and water quality. Information derived from studies such as the present one can therefore support the development of strategies for sustainable processing and utilisation of fishery resources.

Against this background, the aim of this study was to determine the effects of drying methods on the quality characteristics of Oreochromis niloticus in Benue State. The specific objectives were to determine the proximate composition and the mineral composition of O. niloticus dried under different drying methods.

MATERIALS AND METHODS

2.1 Description of Study Area

The research was conducted in Makurdi, Benue State, Nigeria. The state is bordered by Taraba State to the east, Nasarawa State to the north, Kogi State to the west, Enugu State to the southeast and Cross River State to the south. Geographically, the area lies between longitudes 8° and 9° East and latitudes 7° and 8° North, with an estimated population of approximately 600,000 (NPC, 2002). Makurdi is situated within the transitional zone between the equatorial rain belt of the south and the semi-arid regions of the north. The climate is strongly influenced by the River Benue. The area experiences two primary seasons: a rainy season that begins in April and ends in October, with peak rainfall in May and September, and a dry season for the remainder of the year.

2.2 Sample Collection and Preparation

Thirty (30) fresh Oreochromis niloticus were obtained from Oracle Farm in Makurdi and transported to the laboratory of the Department of Fisheries and Aquaculture, Joseph Sarwuan Tarka University, Makurdi. The fish were carefully cleaned, degutted and thoroughly rinsed under cold running water to remove residual debris or contaminants, following the procedures described by Motsara and Roy (2018). The samples were then divided equally among the three drying treatments.

2.3 Drying Methods

Three drying methods were evaluated: sun-drying, oven-drying and smoke-drying.

2.3.1 Sun-drying

Sun-drying is a traditional method widely practised in many regions. It involves exposing fish to direct sunlight so that solar energy and natural air circulation remove moisture. Fish samples were arranged evenly on drying racks or trays with adequate spacing to ensure uniform exposure to sunlight and free air circulation throughout the drying process (Akande et al., 2014).

2.3.2 Oven-drying

Oven-drying is a controlled laboratory method that employs a drying oven to dehydrate fish at elevated but regulated temperatures. Samples were placed on trays inside the oven, which was maintained at 60 °C to facilitate

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moisture removal while minimising thermal degradation and flavour loss (Sathivel, 2015). Drying duration was monitored and adjusted until the desired moisture content and texture were achieved.

2.3.3 Smoke-drying

Smoke-drying (also known as smoke-curing) combines drying and smoking to prolong shelf life and enhance flavour. Fresh fish were placed on racks in a smoking kiln. Smoke was generated from charcoal fires maintained at temperatures between 65 °C and 85 °C to ensure even heat distribution (Oladapo et al., 2020). The smoke contains antimicrobial compounds such as formaldehyde and phenols that inhibit the growth of spoilage microorganisms and pathogens.

2.4 Analysis of Quality Characteristics

After drying, samples from each treatment were analysed for proximate and mineral composition. Proximate composition was determined according to the official methods of the Association of Official Analytical Chemists (AOAC, 2010) as described by Oladapo et al. (2020). Mineral contents (sodium, potassium, calcium, magnesium and zinc) were determined by spectrophotometry using a Jenway digital spectrophotometer following the method of Jame (1995).

2.5 Statistical Analysis

Data were subjected to one-way analysis of variance (ANOVA) in a completely randomised design using the SPSS statistical package. Significant differences among means were separated at the 5% significance level using the least significant difference (LSD) procedure. Results are presented as mean ± standard error (SE).

RESULTS

The mean proximate composition of Oreochromis niloticus dried by the three methods is presented in Table 1. Significant differences ($p < 0.05$) were observed among treatments for all proximate components except crude fibre, which was not detected in any sample (0.00 ± 0.00%). Sun-dried fish recorded the highest crude protein (72.14 ± 0.25%), while smoked samples had the lowest (61.91 ± 0.35%). Lipid content was highest in the smoked samples (6.81 ± 0.07%) and lowest in the oven-dried samples (3.98 ± 0.19%). Oven-dried samples contained the highest ash (19.35 ± 0.17%). Moisture content did not differ significantly among the three methods ($p > 0.05$). Nitrogen-free extract (NFE) was highest in smoked fish (8.07 ± 0.35%).

Table 1: Mean proximate composition (%) of *Oreochromis niloticus* dried under different drying methods

Proximate component	Sun-dried	Smoked	Oven-dried	LSD
Crude protein	72.14 ± 0.25^{a}	61.91 ± 0.35^{c}	65.53 ± 0.28^{b}	**0.00***
Lipids	5.37 ± 0.08^{b}	6.81 ± 0.07^{a}	3.98 ± 0.19^{c}	**0.00***
Crude fibre	**0.00 ± 0.00**	**0.00 ± 0.00**	**0.00 ± 0.00**	**—**
Ash	14.65 ± 0.24^{c}	16.00 ± 0.11^{b}	19.35 ± 0.17^{a}	**0.00***
Moisture	6.24 ± 0.05^{a}	7.22 ± 0.87^{a}	7.42 ± 0.93^{a}	0.55
NFE	1.61 ± 0.35^{b}	8.07 ± 0.35^{a}	3.74 ± 0.86^{b}	0.01

*LSD values of 0.00 indicate highly significant differences ($p < 0.001$). Values are mean ± standard error (SE). Means in the same row with different superscripts differ significantly ($p < 0.05$). Crude fibre was not detected in any of the samples.

The mean mineral composition is presented in Table 2. Significant differences ($p < 0.05$) were observed for all minerals examined. Oven-dried samples recorded the highest concentrations of sodium, potassium, calcium, magnesium and zinc. Sun-dried samples generally had the lowest mineral levels, except for potassium, for which the smoked samples recorded the lowest value.

Table 2: Mean mineral composition (mg/100 g) of *Oreochromis niloticus* dried under different drying methods

Mineral	Sun-dried	Smoked	Oven-dried	LSD
Sodium	118.95 ± 0.73^{c}	132.65 ± 0.37^{b}	141.14 ± 1.37^{a}	**0.00***
Potassium	123.38 ± 0.32^{b}	107.86 ± 1.84^{c}	131.24 ± 1.42^{a}	**0.00***
Calcium	91.35 ± 1.66^{b}	116.81 ± 0.19^{a}	122.36 ± 4.44^{a}	0.01
Magnesium	105.65 ± 4.36^{b}	124.46 ± 1.55^{a}	135.32 ± 4.50^{a}	0.03
Zinc	9.11 ± 0.13^{c}	13.63 ± 1.37^{b}	23.91 ± 0.77^{a}	**0.00***

*LSD values of 0.00 indicate highly significant differences ($p < 0.001$). Values are mean ± standard error (SE) and are expressed in mg/100 g. Means in the same row with different superscripts differ significantly ($p < 0.05$).

DISCUSSION

Significant differences were observed in the mineral content of O. niloticus among the three drying methods, indicating that processing technique influences the retention of essential minerals. Calcium concentration was significantly lower in sun-dried samples (91.35 ± 1.66 mg/100 g) than in smoked (116.81 ± 0.19 mg/100 g) and oven-dried (122.36 ± 4.44 mg/100 g) samples ($p < 0.05$). This pattern is consistent with the findings of Otitoloju et al. (2015), who reported that calcium in seafood is relatively resilient to many processing conditions, although absolute levels can still vary with the intensity and duration of heat exposure.

Potassium content was highest in oven-dried samples (131.24 ± 1.42 mg/100 g) and lowest in smoked samples (107.86 ± 1.84 mg/100 g). The superior retention of potassium under controlled oven-drying conditions aligns with the observations of Kawo et al. (2018), who suggested that regulated heating minimizes mineral loss compared with traditional smoking. Sodium followed a similar trend, with oven-dried fish containing the highest level (141.14 ± 1.37 mg/100 g) and sun-dried fish the lowest (118.95 ± 0.73 mg/100 g). Concentration effects associated with progressive moisture removal under controlled temperature may contribute to the higher sodium values recorded after oven-drying (Jagtap et al., 2016).

Magnesium and zinc were also significantly higher in oven-dried samples (135.32 ± 4.50 mg/100 g and 23.91 ± 0.77 mg/100 g, respectively) than in the other treatments. Adewuyi et al. (2020) and Eke et al. (2017) similarly reported better preservation of magnesium and zinc under oven-drying, attributing the advantage to reduced leaching and limited oxidative losses that can occur during prolonged sun exposure or the higher and more variable temperatures of smoking. Overall, the controlled thermal environment of the oven appears to favour mineral retention relative to the more variable conditions of sun-drying and traditional smoking.

With respect to proximate composition, sun-dried O. niloticus recorded the highest crude protein content (72.14 ± 0.25%), followed by oven-dried (65.53 ± 0.28%) and smoked samples (61.91 ± 0.35%). Dehydration concentrates protein on a dry-matter basis; the particularly high value obtained under sun-drying may reflect more complete moisture removal under prolonged solar exposure (Idodo-Umeh, 2003; Arason, 2003). Lipid content was highest in smoked fish (6.81 ± 0.07%) and lowest in oven-dried fish (3.98 ± 0.19%). This observation agrees with Ayeloja et al. (2020), who noted that smoking does not reduce lipid content as thoroughly as oven-drying.

Ash content was highest in oven-dried samples (19.35 ± 0.17%), consistent with the elevated mineral levels already discussed. Moisture content did not differ significantly among treatments, indicating that all three methods achieved comparable levels of dehydration under the conditions employed. Nitrogen-free extract was highest in the smoked product, possibly reflecting residual carbohydrate or other non-protein, non-lipid material that remains after smoking. Crude fibre was not detected in any of the samples, which is expected for fish muscle that contains negligible structural carbohydrate.

CONCLUSION

The present study demonstrates that the method of drying exerts a significant influence on both the proximate and mineral composition of Oreochromis niloticus. Sun-drying produced the highest crude-protein

concentration, making it advantageous when protein density is the primary nutritional objective. In contrast, oven-drying consistently yielded the highest ash and mineral contents (sodium, potassium, calcium, magnesium and zinc), indicating superior retention of inorganic nutrients under controlled thermal conditions. Smoking resulted in the highest lipid content but the lowest protein and, for several minerals, intermediate or lower values.

These findings have practical implications for small-scale processors and households in Benue State and similar tropical regions. Where the goal is to maximize protein delivery per unit weight of dried fish, sun-drying remains a low-cost and effective option. Where mineral nutrition is of particular concern, for example, in programmes aimed at addressing micronutrient deficiencies,oven-drying offers a clear advantage. Processors may therefore select the drying method that best matches the intended nutritional use of the final product.

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