



Quality Attributes of Dried Fillets of Common Carp and African Catfish During Room Temperature Storage

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Abstract

This study evaluated the quality of dried fillets of common carp (*Cyprinus carpio*) and African catfish (*Clarias gariepinus*) pretreated with or without 3% salt, hot-air dried at 50 or 60 °C, vacuum-packed and stored at room temperature for four months. Gross chemical composition, moisture, salt content, hardness, total volatile basic nitrogen (TVBN), thiobarbituric acid (TBA), peroxide value (PV), colour, microbial counts and sensory attributes were determined. The dried fillets were rich in protein (64.98-69.94%) and low in moisture (6.78-11.06%), with salted catfish dried at 60 °C showing the lowest moisture. During storage, moisture increased only slightly, while hardness, TVBN, TBA and PV increased progressively. At the end of storage, TVBN (3.30-4.71 mg N/100 g) and PV (1.92-2.25 meq O₂/kg) were well below their permissible limits, and TBA (1.47-1.69 mg MDA/kg) remained within the permissible range. Salting combined with drying at 60 °C reduced TVBN in carp and gave the lowest TBA values in both species. Microbial counts decreased continuously during storage, with total viable bacterial count falling by 23-44% and the lowest counts recorded in the salted treatments. Carp pretreated with 3% salt and dried at 60 °C received the highest sensory scores. These results show that 3% salting combined with hot-air drying at 60 °C and vacuum packaging is an effective way to produce shelf-stable dried carp and catfish fillets.

Keywords: Common Carp; African Catfish; Hot-Air Drying; Salting; Storage Stability; Lipid Oxidation; TVBN; Microbial Quality

Introduction

Aquaculture is one of the fastest-growing food production sectors worldwide and is expected to play a crucial role in meeting the increasing demand for high-quality animal protein for the global population, which is projected to reach approximately 9 billion by 2050 [1]. In addition to population growth, increasing disposable income, urbanization, the growing number of working women, and changing consumer lifestyles have significantly increased the demand for convenient, ready-to-eat fish products [2,3].

Aquaculture in Egypt has rapidly grown, with production increased from 24,000 tonnes (15.4% of total fish production) in 1982 to 1,576,189 tonnes (78.7% of total fish production) in 2021 [4].

Fish is an excellent source of high-quality protein, essential amino acids, omega-3 fatty acids, vitamins, and minerals, including vitamins A and D, phosphorus, magnesium, selenium, and iodine [5]. Owing to its high nutritional value, fish is highly recommended for all age groups, particularly children, pregnant women, and breastfeeding mothers, as it contributes to healthy growth and development [6]. However, fresh fish contains approximately 80% moisture, making it one of the most perishable food products. Its high moisture content and water activity accelerate microbial growth, enzymatic activity, and biochemical deterioration, resulting in a very short shelf life if not properly preserved [7]. Consequently, substantial quantities of fresh fish may be lost when they are not consumed or processed promptly [8,9].

Among cultured freshwater fish, common carp (*Cyprinus carpio* L., 1758) is one of the most economically important species worldwide because of its rapid growth, adaptability to diverse environmental conditions, and wide consumer acceptance [10-12]. Likewise, African sharp tooth catfish (*Clarias gariepinus*) is one of the most widely distributed freshwater fish species in Africa and is well known for its tolerance to harsh environmental conditions and poor water quality [13]. In Egypt, *C. gariepinus* is successfully cultured under a wide range of farming conditions, although its market acceptance remains lower than that of other freshwater species despite its comparable nutritional value [14]. Moreover, the production of carps, catfish, barbels, and other cyprinids has substantially increased over recent decades, highlighting their growing importance in inland fisheries and aquaculture [15].

Dried fishes are low cost dietary protein source and used most frequently as a substitute of fish at the scarcity of fresh fish and are the most accessible type of processed fish for consumers matching with all income levels. The demand for these dried products is increasing day by day with the growing fisheries, aquaculture and increasing populations. In recent times, people are more health-conscious about the quality of food having good sensory and nutritional properties [16].

The most pronounced effect of drying is the reduction in moisture content, which may decrease from about 75-80% in fresh carp to 10-30% in dried products. This reduction is mainly due to water evaporation caused by heat and mass transfer during the drying process. Consequently, the decrease in water content leads to an apparent increase in dry matter components, such as protein, lipids, and minerals [17].

Protein content generally increases on a wet weight basis after drying due to moisture loss and concentration effects. For example, sun-dried carp has been reported to contain significantly higher protein levels compared to fresh samples. However, under high temperatures (e.g., smoking), partial protein denaturation and degradation may occur, leading to slight reductions in protein [18].

Drying affects other biochemical parameters such as total volatile basic nitrogen (TVBN) and thiobarbituric acid (TBA) values, which are indicators of protein degradation and lipid oxidation, respectively. These values tend to increase during drying and storage, reflecting quality deterioration if the process is not well controlled [19].

In carp fillets, drying methods such as oven drying and microwave drying significantly influence color parameters. Fresh fillets typically exhibit higher L^* values compared to dried samples, reflecting their brighter appearance. After drying, L^* decreases while a^* and b^* values may increase, indicating enhanced redness and yellowness due to lipid oxidation and protein denaturation. Additionally, microwave-dried carp fillets tend to show lower L^* values (more browning) compared to oven-dried samples, confirming the strong effect of drying technique on color deterioration [17].

Raut., *et al.* [20] reported that the kinetics of hardness growth during hot air drying are further distinguished by a clear spatial

variation, which is frequently related to the phenomena of “case hardening”. In the early and middle stages of hot air processing, surface evaporation exceeds internal moisture diffusion inside carp fillets. This imbalance results in a highly dried, crystalline crust on the fillet’s outer layers, while the interior stays comparatively wet. This solid surface crust alters the initial compression forces measured during texture profile analysis testing, resulting in abnormally high hardness readings. As the moisture equilibrium evolves during longer drying cycles, the localized crusting transforms into a homogenous, compact matrix, determining the ultimate textural quality and chewiness of the semi-dried or dried fish product.

So, the main goal of such manuscript is to study physico-chemical, microbiological and organoleptic characteristics of dried common carp (*Cyprinus carpio*) and african catfish (*Clarias gariepinus*) fillets during storage at room temperature.

Material and Methods

Materials

African Catfish and Common carp

Fresh African catfish (*Clarias gariepinus*) and common carp (*Cyprinus carpio* L, 1758) were purchased from El-Burullus Fish Market, Kafr El-Sheikh Governorate, Egypt. The fish were transported immediately to the laboratory in insulated polystyrene boxes containing crushed ice to maintain their freshness during transportation.

The salt was purchased from a local market at Mansoura city, Egypt.

Chemical, glasses and microbiological media

All chemical, glasses and microbiological media were purchased from El Arabia company for Chemicals and Pharmaceuticals in Mansoura city, Egypt.

Methods

Preparation of fish fillets

Upon arrival, the fish were thoroughly washed, and the heads, skin, and viscera were removed. The edible flesh was filleted and cut into uniform dimensions of 80 × 30 × 5 mm (length × width × thickness) to ensure consistent drying conditions. The fillets were rinsed with tap water to remove residual blood and surface

impurities, drained, and arranged in a single layer on stainless-steel wire mesh trays before the drying experiments.

Drying methods

Drying experiments were conducted using a laboratory-scale hot-air tray dryer (Officine Specializzate Garbuio, Treviso, Italy) located at the Department of Food Industries, Faculty of Agriculture, Mansoura University, Egypt. The dryer was equipped with an axial-flow fan that circulated air heated by electric heaters with a total power of 3.0 kW. The drying air temperature was automatically controlled using a digital thermostat. The heated air passed through the drying chamber containing perforated stainless-steel trays to ensure uniform air distribution around the fish fillets during drying. The drying process was carried out at 50 and 60 °C with 3% salt as a pretreatment. After drying, the fish fillets were vacuum-packed in airtight bags using a vacuum sealer.

Gross chemical composition of common carp and African catfish

Moisture, ash, crude protein and crude fat were determined as described by [21]. While, total carbohydrates was determined by difference as follows:

% carbohydrates = 100 - (% Moisture + % Protein + % Fat + % Ash).

Salt (NaCl)

The sodium chloride content was determined according to the [21]. Approximately 5 g of homogenized fish sample was weighed and mixed with 50 mL distilled water. The mixture was filtered, and 10 mL of the filtrate was transferred into a conical flask. Then, 1 mL potassium chromate indicator (5%) was added and the solution was titrated with 0.1 N silver nitrate (AgNO₃) until the appearance of a permanent brick-red color. The sodium chloride percentage was calculated using the following equation:

$$\% \text{ Salt} = \frac{(V \times N \times 58.5 \times 100)}{1000 \times W}$$

Thiobarbituric acid (TBA) content of dried fish fillets

TBA value was determined using trichloroacetic acid calorimetrically at a wavelength of 538 nm using ultra violet visible scanner spectrophotometer (LKB 4054 combridge, England) according to [22].

Total volatile basic nitrogen (TVBN) content of dried fish fillets:

Total volatile basic nitrogen (TVBN) was determined as described by [23].

$$\text{TVBN (mg/100 g sample)} = \frac{(V_1 - V_0) \times 0.14 \times 2 \times 100}{M}$$

Where: V_1 is the valume of titration of sample (ml of 0.1 N NaOH), V_0 is valume of titration of blank (withiout sample), M: Weight of fish sample (10 g).

PV content of dried fish fillets

Chloroform (100 mL) was added to 20 g of fish samples, after homogenizing and filtration, 20 mL of water was added to filterate. Then the mixture was decanted and chloroform phase was collected.

$$\text{PV (meq oxygen/kg of fish sample)} = \frac{V \times N \times 1000 \times \text{dilution factor}}{W}$$

V = ml of $\text{Na}_2\text{S}_2\text{O}_4$ used in titration.

N = normality of $\text{Na}_2\text{S}_2\text{O}_7$.

W: weight of sample (20 g).

Colour

Colour parameters were carried out for dried fish samples as described by [24], CIE L^* , a^* , b^* parameters were evaluated using a Hunter colourimeter (Hunter Lab Scan XE, USA). Where C^* : Chroma and WI: whitening index was calculated from CIE parameters using the equations as follows:

$$C^* = \sqrt{a^{*2} + b^{*2}}$$

$$WI = \sqrt{a + b + (100 - L)^2}$$

Texture profile analysis of dried fish fillets

All texture parameters of the fish samples fillets were determined by a conical probe (texture analyzer, TAHD Plus, Stable Micro System, Godalming, UK) with a compression force of 55 mm and a speed of 1 mm/s, according to [24].

Microbiological assay

Total bacterial count (TBC) was determined using nutrient agar according to the method described by [25]. Molds and yeasts

were enumerated using Potato Dextrose Agar (PDA, Oxoid, UK) supplemented with chloramphenicol to inhibit bacterial growth, following the standard method [26]. Serial decimal dilutions of dried fish samples were prepared in sterile buffered peptone water.

Sensory evaluation of fish fillets

The sensory attributes of dried common carp and catfish fillets were estimated using a panel taste by 20 persons at Food Industries department, Faculty of Agriculture, Mansoura University. The evaluation parameters included, colour, odor, texture, appearance, infestation and overall acceptability according to [27].

Statistical analysis

The obtained results were statistically analyzed using one way analysis of variance (ANOVA) in [28] version 17 program for windows and comparisons were done using Duncan's test at $P < 0.05$ level of significance.

Results and Discussion

Gross chemical composition at zero time

Data in Table (1) show the gross chemical composition of the dried carp and catfish fillets at zero time. For carp, raising the drying temperature from 50 to 60 °C lowered the final moisture content from 11.06 to 8.68% in the unsalted fillets and from 10.77 to 9.24% in the salted fillets, reflecting the greater driving force for water removal at the higher air temperature. The same rise in temperature slightly reduced crude protein (from 69.57 to 67.88% and from 69.94 to 65.37% in unsalted and salted fillets, respectively) and increased crude oil (from 7.79 to 8.64% and from 8.71 to 9.63%), while total carbohydrates, calculated by difference, increased accordingly. Regarding the salt pretreatment, 3% salt raised the ash content of carp at both temperatures (from 4.32 to 5.60% at 50 °C and from 3.98 to 6.36% at 60 °C), as expected from the uptake of sodium chloride into the muscle, and was associated with slightly higher oil contents (8.71 vs 7.79% at 50 °C and 9.63 vs 8.64% at 60 °C). The effect of salt on protein depended on the drying temperature: it was negligible at 50 °C (69.94 vs 69.57%) but lowered protein at 60 °C (65.37 vs 67.88%), which may be related to the leaching of salt-soluble proteins during salting and drying.

For catfish, the effect of drying temperature depended on salting. In the unsalted fillets, moisture was almost identical at 50

and 60 °C (8.15 vs 8.13%), whereas protein and crude oil decreased (from 67.56 to 65.35% and from 8.59 to 7.89%, respectively) and ash increased (from 4.63 to 6.35%). In the salted fillets, drying at 60 °C gave the lowest moisture content of all treatments (6.78 vs 8.91% at 50 °C) together with a higher protein content (69.48 vs 64.98%) and crude oil content (10.08 vs 9.34%) but a lower ash content (4.37 vs 6.52%). Salting at 50 °C increased moisture (from 8.15 to 8.91%) and ash (from 4.63 to 6.52%) and decreased protein (from 67.56 to 64.98%), whereas at 60 °C the salted fillets had lower moisture (6.78 vs 8.13%) and ash (4.37 vs 6.35%) but higher

crude oil (10.08 vs 7.89%) and protein (69.48 vs 65.35%) than their unsalted counterparts. Consequently, total carbohydrates, calculated by difference, increased with drying temperature in the unsalted fillets (from 11.05 to 12.28%) but decreased in the salted fillets (from 10.23 to 9.29%).

Generally, the data demonstrated that both dried carp and catfish fillets have high nutritional value, especially due to their high protein content and relatively low moisture levels, which makes them suitable for long-term storage and human consumption. These results are in agreement with Fitri., *et al.* [17].

Table 1: Gross chemical composition of studied dried carp and catfish fillets at zero time.

Dried fish treatments		Approximate chemical components (%)				
		Moisture	Crude Protein	Crude oil	Crude ash	Total carbohydrates
Dried Carp Fillets	0% salt, 50°C	11.06 ^d ± 0.32	69.57 ^{bc} ± 0.99	7.79 ^a ± 0.19	4.32 ^{ab} ± 0.01	7.24 ^{ab} ± 0.84
	3% salt, 50°C	10.77 ^d ± 0.7	69.94 ^c ± 0.12	8.71 ^{bc} ± 0.2	5.6 ^c ± 0.46	4.97 ^a ± 1.47
	0% salt, 60°C	8.68 ^{bc} ± 0.43	67.88 ^{bc} ± 0.07	8.64 ^b ± 0.35	3.98 ^a ± 0.19	10.81 ^c ± 1.06
	3% salt, 60°C	9.24 ^c ± 0.07	65.37 ^a ± 1.09	9.63 ^{de} ± 0.52	6.36 ^d ± 0.044	9.38 ^{bc} ± 0.89
Dried Catfish Fillets	0% salt, 50°C	8.15 ^b ± 0.08	67.56 ^b ± 0.88	8.59 ^b ± 0.12	4.63 ^b ± 0.18	11.05 ^c ± 1.09
	3% salt, 50°C	8.91 ^{bc} ± 0.08	64.98 ^a ± 0.35	9.34 ^{cd} ± 0.15	6.52 ^d ± 0.036	10.23 ^{bc} ± 0.19
	0% salt, 60°C	8.13 ^b ± 0.11	65.35 ^a ± 0.07	7.89 ^a ± 0.17	6.35 ^d ± 0.03	12.28 ^c ± 0.28
	3% salt, 60°C	6.78 ^a ± 0.10	69.48 ^{bc} ± 0.8	10.08 ^e ± 0.13	4.37 ^{ab} ± 0.1	9.29 ^{bc} ± 0.84
Mean values ± standard error (n = 3). Means of sample having the same letter(s) within a column are not significantly different (p < 0.05).						

Physio-chemical properties of dried fillets during storage

Results in Table (2) show the changes in moisture content, salt content and hardness of dried carp and catfish fillets during four months of storage at room temperature. For carp, drying temperature was the main factor controlling moisture: fillets dried at 60 °C retained markedly lower moisture than those dried at 50 °C throughout storage (8.68-8.92% vs 11.06-11.24% for unsalted fillets and 9.24-9.39% vs 10.77-11.19% for salted fillets). The 3% salt pretreatment had only a minor effect, slightly lowering moisture at 50 °C (10.77 vs 11.06% at zero time) and slightly raising it at 60 °C (9.24 vs 8.68%). During storage, moisture increased gradually but only slightly in all carp treatments (by 0.15-0.42 percentage points, i.e. 2-4% of the initial value), the largest gain being recorded in the salted fillets dried at 50 °C (from 10.77 to 11.19%). This slight

gain reflects the hygroscopic nature of the dried muscle matrix and the release of bound water during the slow breakdown of proteins Zhang., *et al.* [29], while its small magnitude indicates that vacuum packaging largely protected the fillets from moisture uptake.

For catfish, the effect of drying temperature on moisture depended on salting. Unsalted fillets had nearly identical moisture at 50 and 60 °C (8.15 vs 8.13% at zero time), whereas salted fillets dried at 60 °C had the lowest moisture of all treatments throughout storage (6.78-6.94%) compared with 8.91-9.08% for salted fillets dried at 50 °C. Accordingly, salting increased moisture at 50 °C (8.91 vs 8.15%) but decreased it at 60 °C (6.78 vs 8.13%), suggesting that at the higher temperature salt-induced protein denaturation facilitated the release of water from the muscle. During storage, all

catfish treatments showed small and parallel increases of about 0.16-0.17 percentage points ($\approx 2\%$) over the four months, and the ranking of treatments remained unchanged. Such low and steady moisture contents are necessary to restrict microbial growth and enzymatic activity and thus to extend the shelf life of dried fish Chen., *et al.* [30].

As expected, the 3% salt pretreatment increased the salt content of carp fillets at both drying temperatures (0.36 vs 0.12% at 50 °C and 0.21 vs 0.14% at 60 °C at zero time). Regarding drying temperature, salted carp dried at 60 °C contained less salt than those dried at 50 °C throughout storage (0.21-0.26% vs 0.34-0.41%), while the unsalted controls had similar low values at both temperatures (0.12-0.21% and 0.12-0.15%). During storage, salt content of carp changed only within a narrow range; the salted fillets dried at 50 °C showed a slight peak at the third month (0.41%) before returning to 0.35% at the fourth month, whereas the salted fillets dried at 60 °C increased slightly from 0.21 to 0.26%. Slight changes are associated with the movement and concentration of solutes in the desiccated muscle during storage Birie., *et al.* [31].

In catfish, salting similarly increased salt content at both temperatures (0.50 vs 0.20% at 50 °C and 0.33 vs 0.22% at 60 °C at zero time). Salted fillets dried at 60 °C initially contained less salt than those dried at 50 °C (0.33 vs 0.50%), although both reached the same value (0.37%) by the fourth month. During storage, the salt content of the salted catfish dried at 50 °C decreased from 0.50 to 0.37%, mainly between the first and second months, whereas the other catfish treatments showed slight increases (from 0.20 to 0.26%, 0.22 to 0.25% and 0.33 to 0.37% for 0% salt, 50 °C, 0% salt, 60 °C and salted 60 °C, respectively). The 3% salted treatments remained more stable than the 0% salt, groups, supporting the findings of Fitri., *et al.* [17] investigated the role of salt in maintaining muscle structure.

Hardness of carp fillets was affected by both processing factors. At zero time, drying at 60 °C produced softer fillets than drying at 50 °C (0.94 vs 1.12 N for unsalted and 0.97 vs 1.27 N for salted fillets), while salting increased hardness, particularly at 50 °C (1.27 vs 1.12 N). During storage, hardness increased in all carp treatments, reaching 1.48-1.73 N at the fourth month. The increase was greatest in the unsalted fillets dried at 60 °C (+76%, from 0.94 to 1.65 N) and smallest in the fillets dried at 50 °C (+36% for both unsalted and salted fillets), whereas salting moderated hardening at 60 °C (+53%, from 0.97 to 1.48 N), giving the lowest final hardness among carp treatments. This progressive hardening is mainly attributed to the denaturation and aggregation of myofibrillar proteins, which produce a more compact and rigid muscle matrix (Chen., *et al.* [30], Peng., *et al.* [32]).

For catfish, drying at 60 °C initially produced softer unsalted fillets than drying at 50 °C (0.83 vs 1.17 N), while the salted fillets had similar hardness at both temperatures (0.95 vs 0.98 N). Salting lowered the initial hardness at 50 °C (0.98 vs 1.17 N) and slightly raised it at 60 °C (0.95 vs 0.83 N). During storage, hardness increased in all catfish treatments, and fillets dried at 60 °C hardened most: the unsalted fillets increased from 0.83 to 1.83 N (+120%, the highest final value in the study) and the salted ones from 0.95 to 1.72 N (+81%), compared with increases from 1.17 to 1.62 N (+38%) and from 0.98 to 1.49 N (+52%) for the unsalted and salted fillets dried at 50 °C. At the end of storage, salted catfish fillets were softer than their controls at both temperatures (1.49 vs 1.62 N at 50 °C and 1.72 vs 1.83 N at 60 °C), indicating that the initial salt-protein interaction helps stabilize the fibrous network against excessive toughening during storage Akhtar and Borah [33].

Table 2: Effect of storage period of dried carp fish and catfish fillets samples on some physical properties (Moisture, Salt and Hardness).

Studied Properties	Time/ month	Dried fish treatments							
		Carp				Catfish			
		0% salt, 50°C	3% salt, 50°C	0% salt, 60°C	3% salt, 60°C	0% salt, 50°C	3% salt, 50°C	0% salt, 60°C	3% salt, 60°C
Moisture (%)	0	11.06 ^{bc} ± 0.32	10.77 ^d ± 0.7	8.68 ^{bc} ± 0.43	9.24 ^c ± 0.07	8.15 ^b ± 0.08	8.91 ^{bc} ± 0.08	8.13 ^b ± 0.11	6.78 ^a ± 0.10
	1	11.14 ^d ± 0.32	11.09 ^d ± 0.64	8.82 ^{bc} ± 0.42	9.29 ^c ± 0.42	8.22 ^b ± 0.07	8.98 ^{bc} ± 0.08	8.20 ^b ± 0.10	6.84 ^a ± 0.10
	2	11.17 ^d ± 0.32	11.12 ^d ± 0.64	8.85 ^{bc} ± 0.42	9.32 ^c ± 0.07	8.25 ^b ± 0.07	9.01 ^{bc} ± 0.08	8.23 ^b ± 0.10	6.87 ^a ± 0.10
	3	11.21 ^d ± 0.32	11.16 ^d ± 0.64	8.89 ^{bc} ± 0.42	9.36 ^c ± 0.07	8.29 ^b ± 0.07	9.05 ^{bc} ± 0.08	8.27 ^b ± 0.10	6.91 ^a ± 0.10
	4	11.24 ^d ± 0.32	11.19 ^d ± 0.64	8.92 ^{bc} ± 0.42	9.39 ^c ± 0.07	8.32 ^b ± 0.07	9.08 ^{bc} ± 0.08	8.30 ^b ± 0.10	6.94 ^a ± 0.10

Salt (%)	0	0.12 ^a ± 0.01	0.36 ^{bc} ± 0.01	0.14 ^a ± 0.01	0.21 ^{ab} ± 0.05	0.2 ^{ab} ± 0.05	0.50 ^c ± 0.05	0.22 ^{ab} ± 0.06	0.33 ^b ± 0.08
	1	0.13 ^a ± 0.01	0.34 ^b ± 0.01	0.12 ^a ± 0.08	0.24 ^{ab} ± 0.05	0.22 ^{ab} ± 0.05	0.49 ^c ± 0.09	0.23 ^{ab} ± 0.05	0.33 ^b ± 0.03
	2	0.19 ^{ab} ± 0.11	0.39 ^c ± 0.01	0.14 ^a ± 0.01	0.24 ^{abc} ± 0.05	0.22 ^{abc} ± 0.05	0.35 ^{bc} ± 0.09	0.25 ^{abc} ± 0.04	0.34 ^{bc} ± 0.08
	3	0.21 ^{ab} ± 0.17	0.41 ^c ± 0.01	0.15 ^a ± 0.01	0.26 ^{abc} ± 0.05	0.21 ^{ab} ± 0.09	0.36 ^{bc} ± 0.07	0.27 ^{abc} ± 0.05	0.34 ^{bc} ± 0.05
	4	0.15 ^a ± 0.01	0.35 ^b ± 0.01	0.13 ^a ± 0.01	0.26 ^{ab} ± 0.07	0.26 ^{ab} ± 0.05	0.37 ^b ± 0.04	0.25 ^{ab} ± 0.05	0.37 ^b ± 0.07
Hardness (Newton)	0	1.12 ^d ± 0.01	1.27 ^f ± 0.02	0.94 ^b ± 0.01	0.97 ^c ± 0.01	1.17 ^e ± 0.01	0.98 ^c ± 0.01	0.83 ^a ± 0.01	0.95 ^{bc} ± 0.00
	1	1.07 ^b ± 0.01	1.36 ^e ± 0.01	1.15 ^c ± 0.00	1.27 ^d ± 0.01	0.9 ^a ± 0.05	1.25 ^d ± 0.01	1.14 ^c ± 0.01	1.16 ^c ± 0.01
	2	1.35 ^e ± 0.01	1.43 ^f ± 0.01	1.23 ^b ± 0.01	1.37 ^g ± 0.01	0.99 ^a ± 0.01	1.33 ^d ± 0.01	1.28 ^c ± 0.01	1.22 ^b ± 0.01
	3	1.43 ^g ± 0.01	1.32 ^b ± 0.01	1.34 ^c ± 0.01	1.39 ^e ± 0.01	1.18 ^a ± 0.01	1.41 ^f ± 0.01	1.38 ^{de} ± 0.01	1.37 ^d ± 0.01
	4	1.52 ^b ± 0.01	1.73 ^e ± 0.01	1.65 ^d ± 0.01	1.48 ^a ± 0.01	1.62 ^c ± 0.01	1.49 ^a ± 0.01	1.83 ^f ± 0.01	1.72 ^e ± 0.01

Mean values ± standard error (n = 3). Means of sample having the same letter(s) within a row are not significantly different ($p < 0.05$).

Chemical quality indices (TVBN, TBA and PV)

Table (3) and Figures (1-3) show the changes in TVBN, TBA and PV of dried fillets during storage in comparison with their permissible limits. Drying temperature had an effect on TVBN in carp (Figure 1) depending on salting. Drying at 60 °C resulted in higher TVBN than drying at 50 °C in the unsalted fillets both in the beginning (2.51 vs 1.39 mg N/100 g) and in the fourth month (4.71 vs 4.14 mg N/100 g). The salted fillets dried at 60 °C had lower TVBN than those dried at 50 °C (1.46 vs 1.87 mg N/100 g in the beginning and 3.44 vs 4.05 mg N/100 g in the fourth month). Salting had no significant effect at 50 °C at the end of storage (4.05 vs 4.14 mg N/100 g) but reduced TVBN clearly at 60 °C (3.44 vs 4.71 mg N/100 g). The salted carp dried at 60 °C had the lowest value. In all carp treatments, TVBN increased progressively (1.9- to 3.0-fold) during storage, with a sharp rise between the third and fourth months. The rise of TVBN results from the degradation of proteins and non-protein nitrogenous compounds by endogenous enzymes and residual microbial activity to volatile bases such as

ammonia, trimethylamine, and dimethylamine Sun., *et al.* [34]. The highest recorded value (4.71 mg N/100 g) was, however, far below the permissible limit of 15-20 mg N/100 g and thus protein degradation was well controlled in all.

In catfish, neither drying temperature nor salting markedly affected TVBN (Figure 1); values ranged from 1.16 to 1.30 mg N/100 g at zero time and from 3.30 to 3.43 mg N/100 g at the fourth month, and most treatments did not differ significantly from each other. The salted fillets dried at 50 °C showed the numerically lowest value at the end of storage (3.30 mg N/100 g). During storage, TVBN of catfish increased 2.6- to 2.9-fold, following the same pattern observed in carp. The generally lower TVBN of catfish compared with carp may be related to the lower moisture content of the catfish fillets (Table 2), which restricts enzymatic and microbial activity. All catfish values remained well below the permissible limit of 15-20 mg N/100 g throughout storage.

For TBA (Figure 2), carp fillets dried at 60 °C without salt showed higher values than those dried at 50 °C throughout storage (0.35 vs 0.16 mg MDA/kg initially and 1.69 vs 1.59 mg MDA/kg at the fourth month), consistent with thermally accelerated lipid oxidation, whereas salted fillets dried at 60 °C had lower values than those dried at 50 °C (0.23 vs 0.28 and 1.48 vs 1.63 mg MDA/kg, respectively). The effect of salt also depended on temperature: at 50 °C, salting slightly increased TBA (0.28 vs 0.16 mg MDA/kg initially and 1.63 vs 1.59 mg MDA/kg at the fourth month), in line with the known pro-oxidant action of sodium chloride, while at 60 °C salting reduced TBA (1.48 vs 1.69 mg MDA/kg), giving the lowest value among carp treatments. During storage, TBA increased sharply in all carp treatments (4.8- to 9.9-fold), particularly after the second month. By the fourth month, all carp samples exceeded 1 mg MDA/kg (the lower bound of the permissible range) but remained below the upper limit of 2 mg MDA/kg; the unsalted carp dried at 60 °C was the first to exceed 1 mg MDA/kg (1.05 mg MDA/kg at the third month).

In catfish, the unsalted fillets dried at 60 °C again showed higher TBA (Figure 2) than those dried at 50 °C at the end of storage (1.69 vs 1.59 mg MDA/kg), whereas the salted fillets dried at 60 °C showed lower values than those dried at 50 °C (1.47 vs 1.55 mg MDA/kg). Salting reduced TBA at both temperatures at the fourth month, although the difference was significant only at 60 °C (1.47 vs 1.69 mg MDA/kg). During storage, TBA of catfish increased 6.5-

to 10.3-fold; values remained below 1 mg MDA/kg up to the third month (0.84-0.97 mg MDA/kg) and reached 1.47-1.69 mg MDA/kg at the fourth month, i.e. within the permissible range of 1-2 mg MDA/kg. The salted catfish dried at 60 °C (1.47 mg MDA/kg) and the salted carp dried at 60 °C (1.48 mg MDA/kg) showed the highest oxidative stability among all treatments. These findings agree with the literature indicating that drying may accelerate lipid degradation in fatty fish fillets, and that the choice of pretreatment and drying conditions largely determines the chemical shelf-life of the product Fitri., *et al.* [17].

Peroxide values of carp fillets (Figure 3) were low at zero time (0.40-0.68 meq O₂/kg). At the fourth month, the unsalted carp showed similar PV at both drying temperatures (2.25 vs 2.22 meq O₂/kg at 50 and 60 °C), whereas the salted carp dried at 60 °C showed a higher PV than that dried at 50 °C (2.09 vs 1.92 meq O₂/kg). Salting lowered PV at both temperatures by the end of storage (1.92 vs 2.25 meq O₂/kg at 50 °C and 2.09 vs 2.22 meq O₂/kg at 60 °C), the salted carp dried at 50 °C showing the lowest value. During storage, PV increased 3.1- to 5.0-fold in all carp treatments, with a marked rise after the third month; however, the highest value (2.25 meq O₂/kg) remained well below the permissible limit of 4-5 meq O₂/kg. The low PV together with a sharp increase in TBA indicates the continuous decomposition of primary hydroperoxides into secondary oxidation products such as malondialdehyde, a typical behaviour for dried fish products Wang., *et al.* [35].

Table 3: Effect of storage period of dried carp fish and catfish fillets on TVBN, TBA and PV.

Studied Properties	Time/month	Dried fish treatments							
		Carp 0% salt, 50°C	Carp 3% salt, 50°C	Carp 0% salt, 60°C	Carp 3% salt, 60°C	Catfish 0% salt, 50°C	Catfish 3% salt, 50°C	Catfish 0% salt, 60°C	Catfish 3% salt, 60°C
TVBN (mg N/100g)	0	1.39 ^b ± 0.01	1.87 ^c ± 0.02	2.51 ^d ± 0.12	1.46 ^b ± 0.09	1.19 ^a ± 0.01	1.16 ^a ± 0.01	1.3 ^{ab} ± 0.01	1.22 ^a ± 0.01
	1	1.78 ^b ± 0.09	2.18 ^c ± 0.02	2.92 ^d ± 0.02	1.72 ^b ± 0.02	1.61 ^a ± 0.01	1.5 ^a ± 0.01	1.54 ^a ± 0.02	1.49 ^a ± 0.01
	2	2.01 ^b ± 0.18	2.3 ^c ± 0.01	3 ^d ± 0.046	1.73 ^a ± 0.02	1.7 ^a ± 0.011	1.53 ^a ± 0.01	1.6 ^a ± 0.01	1.56 ^a ± 0.01
	3	2.78 ^d ± 0.07	2.9 ^e ± 0.02	3.57 ^f ± 0.04	2.31 ^c ± 0.003	2.29 ^{bc} ± 0.02	2.14 ^a ± 0.02	2.2 ^{bc} ± 0.01	2.18 ^{ab} ± 0.02
	4	4.14 ^b ± 0.11	4.05 ^b ± 0.04	4.71 ^c ± 0.01	3.44 ^a ± 0.01	3.43 ^a ± 0.01	3.3 ^a ± 0.01	3.32 ^a ± 0.02	3.37 ^a ± 0.02

TBA (mg MDA/kg)	0	0.16 ^a ± 0.01	0.28 ^e ± 0.01	0.35 ^f ± 0.01	0.23 ^{cd} ± 0.01	0.19 ^b ± 0.01	0.15 ^a ± 0.01	0.26 ^{de} ± 0.01	0.22 ^{bc} ± 0.01
	1	0.4 ^c ± 0.001	0.44 ^d ± 0.00	0.52 ^e ± 0.01	0.33 ^a ± 0.01	0.43 ^d ± 0.01	0.37 ^b ± 0.01	0.38 ^{bc} ± 0.01	0.31 ^a ± 0.01
	2	0.5 ^{cd} ± 0.01	0.50 ^e ± 0.01	0.57 ^f ± 0.01	0.38 ^a ± 0.01	0.5 ^{de} ± 0.02	0.41 ^b ± 0.01	0.46 ^c ± 0.01	0.38 ^a ± 0.01
	3	0.95 ^{cd} ± 0.01	0.99 ^d ± 0.02	1.05 ^e ± 0.01	0.86 ^a ± 0.01	0.97 ^d ± 0.01	0.9 ^{bc} ± 0.01	0.96 ^d ± 0.01	0.84 ^a ± 0.01
	4	1.59 ± 0.01 ^b	1.63 ^c ± 0.01	1.69 ^d ± 0.02	1.48 ^a ± 0.01	1.59 ^b ± 0.02	1.55 ^b ± 0.01	1.69 ^d ± 0.01	1.47 ^a ± 0.01
PV (meq o ₂ /kg)	0	0.45 ^c ± 0.01	0.40 ^a ± 0.01	0.55 ^d ± 0.01	0.68 ^e ± 0.01	0.5 ^c ± 0.01	0.43 ^{ab} ± 0.01	0.56 ^d ± 0.01	0.45 ^b ± 0.02
	1	0.63 ^b ± 0.01	0.56 ^a ± 0.01	0.69 ^c ± 0.0	0.56 ^a ± 0.01	0.69 ^c ± 0.01	0.63 ^b ± 0.01	0.6 ^{ab} ± 0.02	0.56 ^a ± 0.01
	2	0.77 ^c ± 0.01	0.62 ^a ± 0.01	0.78 ^c ± 0.01	0.62 ^a ± 0.01	0.77 ^c ± 0.01	0.71 ^b ± 0.01	0.69 ^b ± 0.01	0.63 ^a ± 0.01
	3	1.29 ^d ± 0.03	1.09 ^a ± 0.01	1.3 ^d ± 0.01	1.14 ^a ± 0.01	1.19 ^b ± 0.02	1.2 ^c ± 0.01	1.2 ^c ± 0.02	1.14 ^a ± 0.01
	4	2.25 ^e ± 0.01	1.92 ^a ± 0.04	2.22 ^d ± 0.02	2.09 ^b ± 0.01	2.25 ^e ± 0.01	2.15 ^c ± 0.01	2.07 ^b ± 0.01	2.19 ^c ± 0.01
Permissible limit		TVBN (mg N/100 g)				15 - 20			
	TBA (mg MDA/kg)				1 - 2				
	PV (meq O ₂ /kg)				4 - 5				
Mean values ± standard error (n = 3). Means of sample having the same letter(s) within a row are not significantly different (<i>p</i> < 0.05). Permissible limits of TVBN, TBA and PV are according to ISO.									

In catfish, the unsalted fillets dried at 60 °C had a lower PV (Figure 3) at the fourth month than those dried at 50 °C (2.07 vs 2.25 meq O₂/kg), whereas the salted fillets had similar values at both temperatures (2.19 vs 2.15 meq O₂/kg). Salting reduced PV at 50 °C (2.15 vs 2.25 meq O₂/kg) but slightly increased it at 60 °C (2.19 vs 2.07 meq O₂/kg). During storage, PV of catfish increased 3.7- to 5.0-fold, from 0.43-0.56 to 2.07-2.25 meq O₂/kg, yet all values remained below the permissible limit of 4-5 meq O₂/kg, reflecting the acceptable oxidative stability of the lipid fraction under the investigated storage conditions.

Colour parameters

The colour parameters of dried carp fillets during storage are presented in Table (4). Regarding drying temperature, unsalted carp dried at 60 °C showed markedly higher redness and yellowness

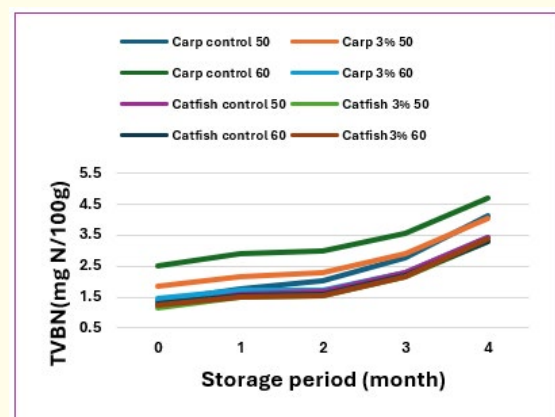


Figure 1: Effect of storage period of dried carp fish and catfish fillets on TVBN.

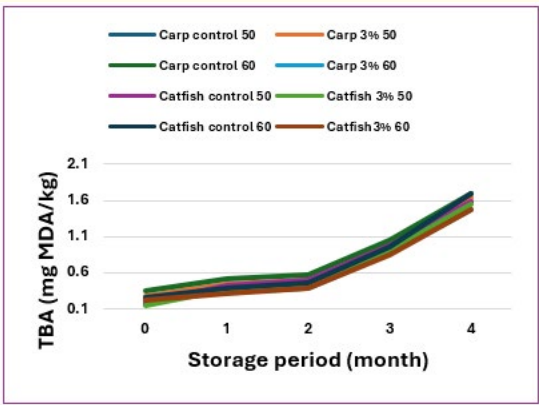


Figure 2: Effect of storage period of dried carp fish and catfish fillets on TBA.

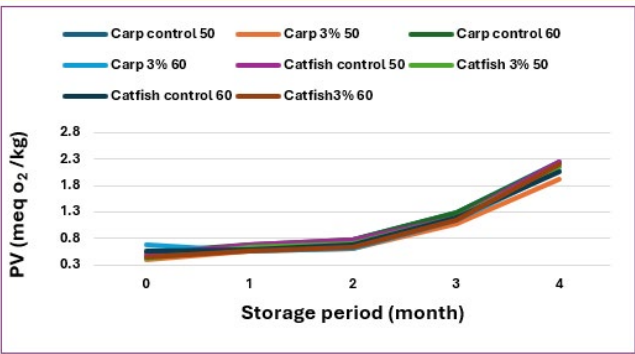


Figure 3: Effect of storage period of dried carp fish and catfish fillets on PV.

than those dried at 50 °C at zero time (a^* 14.24 vs 10.55; b^* 22.16 vs 15.70), with similar lightness (L^* 31.69 vs 31.25), whereas in the salted fillets drying at 60 °C increased L^* (32.88 vs 30.31) and a^* (13.91 vs 11.16) but slightly lowered b^* (14.41 vs 15.35). The more intense colour at 60 °C can be attributed to the acceleration of Maillard-type browning and heme pigment changes at the higher drying temperature. Regarding salting, 3% salt slightly lowered L^* and b^* at 50 °C (30.31 vs 31.25 and 15.35 vs 15.70), while at 60 °C it markedly reduced yellowness (14.41 vs 22.16). Moreover, salted fillets kept lower redness than their controls throughout storage (a^* at the fourth month 11.3 and 10.8 vs 14.2 and 14.6 at 50 and 60 °C, respectively).

All carp treatments lightness (L^*) decreased during storage by the fourth month (31.25 to 30.5, 30.31 to 28.1, 31.69 to 29.4 and 32.88 to 28.9 for 0% salt, 50 °C, salted 50 °C, 0% salt, 60 °C and salted 60 °C respectively) with the highest decrease in salted fillets dried at 60 °C. Redness increased in the unsalted fillets dried at 50 °C (from 10.55 to 14.2), remained almost stable in the salted fillets dried at 50 °C and unsalted fillets dried at 60 °C and decreased in the salted fillets dried at 60 °C (from 13.91 to 10.8), mostly during the first month. Yellowness was almost constant after the first month in all treatments, except for a decrease in the unsalted fillets dried at 50 °C (from 15.7 to 14.2). The progressive browning during storage is due to non-enzymatic browning, the formation of melanoidins by the Maillard reaction and the reaction of lipid oxidation products with amino groups of muscle proteins Zeng, *et al.* [36].

Table 4: Effect of storage period on color parameters of dried carp fish fillets.

Dried fish treatments				Storage period (month)				
				0	1	2	3	4
Carp	0% salt, 50°C	L^*	31.25 ^b ± 0.02	31.8 ^d ± 0.05	32.5 ^d ± 0.05	32.1 ^b ± 0.05	30.5 ^d ± 0.05	
		a^*	10.55 ^e ± 0.02	13.5 ^e ± 0.05	14.4 ^e ± 0.05	13.9 ^f ± 0.05	14.2 ^g ± 0.05	
		b^*	15.7 ^c ± 0.05	14.36 ^a ± 0.06	14.3 ^a ± 0.05	14.2 ^a ± 0.05	14.2 ^a ± 0.05	
	3% salt, 50°C	L^*	30.31 ^a ± 0.1	30.4 ^a ± 0.05	30.15 ^a ± 0.005	30.7 ^a ± 0.05	28.1 ^a ± 0.05	
		a^*	11.16 ^f ± 0.01	11 ^d ± 0.05	11.5 ^d ± 0.57	11 ^e ± 0.57	11.3 ^f ± 0.05	
		b^*	15.35 ^b ± 0.02	15.3 ^b ± 0.05	15.1 ^b ± 0.05	15.3 ^b ± 0.05	15.1 ^b ± 0.05	
	0% salt, 60°C	L^*	31.69 ^c ± 0.01	31.6 ^c ± 0.05	31.45 ^c ± 0.01	33.8 ^c ± 0.05	29.4 ^c ± 0.05	
		a^*	14.24 ^h ± 0.02	13.5 ^e ± 0.05	14.8 ^e ± 0.05	14.5 ^f ± 0.05	14.6 ^h ± 0.05	
		b^*	22.16 ^h ± 0.037	23.5 ^h ± 0.05	21.9 ^e ± 0.05	22.8 ^e ± 0.05	21.9 ^e ± 0.05	
	3% salt, 60°C	L^*	32.88 ^d ± 0.1	31.2 ^b ± 0.05	30.95 ^b ± 0.01	31.2 ^a ± 0.05	28.9 ^b ± 0.05	
		a^*	13.91 ^g ± 0.03	10.3 ^c ± 0.05	11 ^{cd} ± 0.57	10.9 ^{de} ± 0.05	10.8 ^e ± 0.05	
		b^*	14.41 ^a ± 0.01	15.6 ^c ± 0.05	15.4 ^b ± 0.05	15.6 ^b ± 0.05	15.4 ^b ± 0.05	
Mean values ± standard error (n = 3). Means of sample having the same letter(s) within a column are not significantly different ($p < 0.05$).								

The colour profile of dried catfish fillets during storage is shown in Table (5). Regarding drying temperature, unsalted catfish dried at 60 °C showed higher lightness (L^* 40.68 vs 38.21), lower redness (a^* 8.15 vs 10.11) and similar yellowness (b^* 19.20 vs 18.46) compared with those dried at 50 °C at zero time, whereas the salted fillets had similar lightness at both temperatures (43.71 vs 44.52), with higher redness (7.25 vs 5.46) and lower yellowness (18.67 vs

21.22) at 60 °C. Importantly, fillets dried at 60 °C retained higher lightness at the end of storage (L^* 41.4 vs 38.4 for unsalted and 41.9 vs 35.9 for salted fillets). Regarding salting, 3% salt increased the initial lightness at both temperatures (44.52 vs 38.21 at 50 °C and 43.71 vs 40.68 at 60 °C) and reduced redness (5.46 vs 10.11 and 7.25 vs 8.15), and at 60 °C the salted fillets kept the lowest redness throughout storage (5.4-5.9).

Table 5: Effect of storage period on color parameters of dried catfish fillets.

Dried fish treatments			Storage period (month)				
			0	1	2	3	4
Catfish	0% salt, 50°C	<i>L</i> [*]	38.21 ^e ± 0.01	40.7 ^f ± 0.05	40.45 ^f ± 0.01	40 ^e ± 0.57	38.4 ^f ± 0.05
		<i>a</i> [*]	10.11 ^d ± 0.06	7.8 ^b ± 0.05	8.5 ^b ± 0.05	8.2 ^c ± 0.05	8.3 ^c ± 0.05
		<i>b</i> [*]	18.46 ^d ± 0.04	19.5 ^f ± 0.05	18.8 ^c ± 0.05	19 ^c ± 0.57	18.8 ^c ± 0.05
	3% salt, 50°C	<i>L</i> [*]	44.52 ^h ± 0.28	38.6 ^e ± 0.05	37.95 ^e ± 0.01	38 ^d ± 0.57	35.9 ^e ± 0.05
		<i>a</i> [*]	5.46 ^a ± 0.04	10.6 ^{cd} ± 0.05	10.5 ^c ± 0.05	10.3 ^d ± 0.05	10.3 ^d ± 0.05
		<i>b</i> [*]	21.22 ^g ± 0.01	18.7 ^d ± 0.05	18.2 ^c ± 0.05	18.4 ^c ± 0.05	18.2 ^c ± 0.05
	0% salt, 60°C	<i>L</i> [*]	40.68 ^f ± 0.07	42.4 ^g ± 0.05	43.45 ^g ± 0.01	40.5 ^e ± 0.05	41.4 ^g ± 0.05
		<i>a</i> [*]	8.15 ^c ± 0.07	7.4 ^b ± 0.05	7.7 ^b ± 0.05	7.2 ^b ± 0.05	7.5 ^b ± 0.05
		<i>b</i> [*]	19.2 ^f ± 0.1	18.9 ^e ± 0.05	18.4 ^c ± 0.05	18.5 ^c ± 0.05	18.4 ^c ± 0.05
	3% salt, 60 °C	<i>L</i> [*]	43.71 ^g ± 0.04	44.2 ^f ± 0.05	43.95 ^h ± 0.01	44.2 ^f ± 0.05	41.9 ^h ± 0.05
		<i>a</i> [*]	7.25 ^b ± 0.02	5.4 ^a ± 0.05	5.9 ^a ± 0.05	5.9 ^a ± 0.05	5.7 ^a ± 0.05
		<i>b</i> [*]	18.67 ^e ± 0.04	21.2 ^g ± 0.05	21 ^d ± 0.57	21.7 ^d ± 0.05	21 ^d ± 0.57
Mean values ± standard error (n = 3). Means of sample having the same letter(s) within a column are not significantly different (<i>p</i> < 0.05).							

The salted catfish dried at 50 °C showed the highest colour change during storage, where L^* decreased from 44.52 to 35.9, a^* increased from 5.46 to 10.3 and b^* decreased from 21.22 to 18.2, suggesting increment in darkening and reddening. However, the salted fillets dried at 60 °C were the most stable in lightness (from 43.71 to 41.9), while the redness decreased (from 7.25 to 5.7) and yellowness increased (from 18.67 to 21.0). The unsalted fillets showed an increase in L^* during the first two months followed by a return to near initial values at the fourth month (38.21 to 38.4 at 50 °C and 40.68 to 41.4 at 60 °C), with slight decreases in a^* and b^* . These changes are due to non-enzymatic browning and the reactions between lipid oxidation products and muscle proteins Smith and Hole [37], and indicate that combining salting with drying at 60 °C is the most effective treatment for colour stability of dried catfish.

Microbiological quality

The microbiological quality of dried carp fillets during storage is presented in Table (6). Regarding drying temperature, carp fillets dried at 60 °C had slightly higher initial counts than those dried at 50 °C, both for total viable bacterial count (TVBC; 33 vs 30 $\times 10^7$ CFU/g for unsalted and 25 vs 22 $\times 10^7$ CFU/g for salted fillets) and for molds and yeasts (20 vs 17 $\times 10^7$ and 13 vs 7 $\times 10^7$ CFU/g, respectively). However, by the fourth month the salted fillets dried at 60 °C had the lowest TVBC among carp treatments (14 $\times 10^7$ CFU/g vs 17 $\times 10^7$ CFU/g at 50 °C). Regarding salting, 3% salt reduced the initial TVBC by 24-27% (22 vs 30 $\times 10^7$ CFU/g at 50 °C and 25 vs 33 $\times 10^7$ CFU/g at 60 °C) and molds and yeasts by 35-59% (7 vs 17 $\times 10^7$ and 13 vs 20 $\times 10^7$ CFU/g), and the salted fillets

dried at 50 °C had the lowest mold and yeast counts throughout storage (3×10^7 CFU/g at the fourth month). During storage, microbial counts decreased continuously in all carp treatments: TVBC declined by 23% in both treatments dried at 50 °C, by 27%

in the unsalted fillets dried at 60 °C and by 44% in the salted fillets dried at 60 °C, while molds and yeasts declined by 35, 57, 30 and 15% for 0% salt, 50 °C, salted 50 °C, 0% salt, 60 °C and salted 60 °C, respectively Indio., *et al.* [38].

Table 6: Effect of storage period on microbiological examinations (CFU/g) of dried carp fish fillets.

Dried fish treatments		Storage period (month)				
		0	1	2	3	4
0% salt, 50°C	TVBC	30×10^7	27×10^7	26×10^7	24×10^7	23×10^7
	Mold and yeasts	17×10^7	15×10^7	14×10^7	13×10^7	11×10^7
3% salt, 50°C	TVBC	22×10^7	20×10^7	19×10^7	19×10^7	17×10^7
	Mold and yeasts	7×10^7	6×10^7	6×10^7	5×10^7	3×10^7
0% salt, 60°C	TVBC	33×10^7	28×10^7	28×10^7	26×10^7	24×10^7
	Mold and yeasts	20×10^7	20×10^7	19×10^7	15×10^7	14×10^7
3% salt, 60°C	TVBC	25×10^7	18×10^7	17×10^7	15×10^7	14×10^7
	Mold and yeasts	13×10^7	12×10^7	12×10^7	11×10^7	11×10^7
Maximum permissible	TVBC	10^7 to 10^8				
Limit in fish fillets	Mold and yeasts	10^8				

The microbiological quality of dried catfish fillets during storage is shown in Table (7). Regarding drying temperature, catfish dried at 60 °C had higher TVBC than those dried at 50 °C both initially (35 vs 24×10^7 CFU/g for unsalted and 28 vs 19×10^7 CFU/g for salted fillets) and at the fourth month (25 vs 16×10^7 and 19 vs 11×10^7 CFU/g). Molds and yeasts were initially lower at 60 °C (13 vs 18×10^7 and 9 vs 11×10^7 CFU/g) but increased sharply during the first month of storage (to 20 and 17×10^7 CFU/g), so that at the fourth month the salted fillets dried at 60 °C had higher mold and yeast counts than those dried at 50 °C (15 vs 6×10^7 CFU/g). Regarding salting, 3% salt reduced the initial TVBC by about 20% at both temperatures (19 vs 24×10^7 and 28 vs 35×10^7 CFU/g) and reduced molds and yeasts (11 vs 18×10^7 and 9 vs 13×10^7 CFU/g), and the salted fillets dried at 50 °C had the lowest microbial load at the end of storage (TVBC 11×10^7 and molds and yeasts 6×10^7 CFU/g). During storage, TVBC decreased by 33, 42, 29 and 32% for 0% salt, 50 °C, salted 50 °C, 0% salt, 60 °C and salted 60 °C, respectively; molds and yeasts decreased by 28 and 45% in the fillets dried at 50 °C, whereas in the fillets dried at 60 °C they

increased during the first month and then declined, ending at the initial level in the unsalted fillets and above it in the salted fillets (from 9 to 15×10^7 CFU/g) Indio., *et al.* [38].

The gradual decrease of microbial counts of both species during storage, despite slight increases in moisture, TVBN and indices of lipid oxidation, could be due to the combined effect of several preservation hurdles Ali and Ibrahim [39]. The first and the most important barrier is the low water activity of the dried fillets. The water activity of desiccated fish at the moisture percentages reported in this research (6.78 – 11.24%) is most probably much lower than the threshold of about 0.85 for the growth of most bacteria [31]. Foods with low moisture content do not allow the growth of microorganisms; however, some species can survive for a long time Acuff., *et al.* [40]. The other cells are in a metabolically active state, trying to restore their internal equilibrium via osmoregulation and repair processes. These mechanisms consume energy, but as there is no proliferation cells slowly consume their energy resources and die, this is termed as metabolic exhaustion Ali and Ibrahim [39]. It explains the slow decline in amounts with storage instead of a steady state.

Table 7: Effect of storage period on microbiological examinations (CFU/g) of dried catfish fillets.

Dried fish treatments		Storage period (month)				
		0	1	2	3	4
0% salt, 50°C	TVBC	24 x10 ⁷	20 x10 ⁷	20 x10 ⁷	18 x10 ⁷	16 x10 ⁷
	Mold and yeasts	18 x10 ⁷	15 x10 ⁷	14 x10 ⁷	13 x10 ⁷	13 x10 ⁷
3% salt, 50°C	TVBC	19 x10 ⁷	15 x10 ⁷	13 x10 ⁷	12 x10 ⁷	11 x10 ⁷
	Mold and yeasts	11 x10 ⁷	9 x10 ⁷	9 x10 ⁷	8 x10 ⁷	6 x10 ⁷
0% salt, 60°C	TVBC	35 x10 ⁷	30 x10 ⁷	28 x10 ⁷	27 x10 ⁷	25 x10 ⁷
	Mold and yeasts	13 x10 ⁷	20 x10 ⁷	17 x10 ⁷	14 x10 ⁷	13 x10 ⁷
3% salt, 60°C	TVBC	28 x10 ⁷	23 x10 ⁷	22 x10 ⁷	20 x10 ⁷	19 x10 ⁷
	Mold and yeasts	9 x10 ⁷	17 x10 ⁷	16 x10 ⁷	16 x10 ⁷	15 x10 ⁷
Maximum permissible Limit in fish fillets	TVBC	10 ⁷ to 10 ⁸				
	Mold and yeasts	10 ⁸				

The second hurdle is sodium chloride. Because salt is dissolved in the small amount of water remaining in the dried muscle, its concentration in the water phase is much higher than the total salt content suggests; it can be estimated at approximately 2–5% in the salted fillets compared with 1–2.6% in the controls. This imposes osmotic stress that forces microbial cells to accumulate protective compatible solutes such as trehalose, proline and betaine at a high energy cost Oliveira, *et al.* [41]. Salting has likewise been shown to reduce the microbial load of dried fish by lowering moisture and water activity Birie, *et al.* [31]. This explains the lower initial counts of the salted fillets and the fastest declines recorded in the salted treatments, such as the salted carp dried at 60 °C (44% reduction in TVBC) and the salted catfish dried at 50 °C (42% reduction in TVBC and 45% in molds and yeasts). Third, many of the microbial cells that survived hot-air drying at 50–60 °C are expected to be sublethally injured. In an arid, saline and nutrient-deficient background, such cells are unable to repair the damage and die off slowly or lose their ability to form colonies on plating media Shao, *et al.* [42]. Some cells can enter a viable but non-culturable (VBNC) state, where cells are metabolically active but do not form colonies that can be detected microscopically by conventional culture techniques Zhang, *et al.* [43].

Fourth, vacuum packaging removes oxygen from the package, preventing the growth of aerobic spoilage microorganisms

Siddiqui, *et al.* [44], such as moulds, which require oxygen to grow. Moreover, the secondary lipid oxidation products that built up during storage, as evidenced by the increasing PV and TBA values (Table 3), may impose additional stress on the surviving microflora. The only exception to this general trend is the transient increase in moulds and yeasts observed in catfish dried at 60 °C during the first month. This could be due to xerophilic and osmotolerant fungi which are better adapted to low water activity and high salt concentrations than bacteria or due to germination of fungal spores which survived drying followed by decline which suggests that these hurdles finally limited their survival too. These results confirm that, in general, the combination of low water activity, salting, drying injury and vacuum packaging creates an environment in which microorganisms can only temporarily survive but not grow, resulting in a progressive decrease in microbial load during storage.

Sensory evaluation

The sensory evaluation of dried carp and catfish fillets is presented in Table (8). Odor, texture and infestation scores did not differ significantly among the eight treatments ($p > 0.05$), indicating that the characteristic aroma and texture of the dried fillets were not affected by drying temperature or salting. For carp, the effect of drying temperature depended on salting: in the unsalted fillets,

drying at 60 °C significantly lowered colour (12.25 vs 13.87), general appearance (12.81 vs 13.93), overall acceptability (12.93 vs 14.12) and the total score (79.12 vs 83.73), consistent with the more intense redness and yellowness of this treatment (Table 4), whereas in the salted fillets drying at 60 °C slightly improved colour (14.37 vs 14.06), appearance (14.25 vs 13.62) and overall acceptability (14.68 vs 13.93). Regarding salting, 3% salt had no significant effect at 50 °C, but at 60 °C it markedly improved colour

(14.37 vs 12.25), general appearance (14.25 vs 12.81), overall acceptability (14.68 vs 12.93) and the total score (85.06 vs 79.12). Thus, carp pretreated with 3% salt and dried at 60 °C achieved the highest sensory scores in the study, which may be attributed to the controlled surface browning and the more stable colour of this treatment.

Table 8: Sensory evaluation of studied dried fish fillets.

Dried fish treatments	Color (15)	Odor (15)	Texture (15)	General appearance (15)	Infestation (15)	Overall acceptability (15)	Total (90)
Carp 0% salt, 50°C	13.87 ^c ± 0.25	13.75 ^a ± 0.31	13.81 ^a ± 0.26	13.93 ^c ± 0.26	14.25 ^a ± 0.33	14.12 ^b ± 0.22	83.73 ^{bc} ± 2.87
Carp 3% salt, 50°C	14.06 ^c ± 0.17	13.87 ^a ± 0.25	13.93 ^a ± 0.27	13.62 ^{bc} ± 0.41	14.25 ^a ± 0.31	13.93 ^b ± 0.29	83.68 ^{bc} ± 1.26
Carp 0% salt, 60°C	12.25 ^{ab} ± 0.26	13.12 ^a ± 0.3	13.87 ^a ± 0.32	12.81 ^{ab} ± 0.34	14.12 ^a ± 0.31	12.93 ^a ± 0.31	79.12 ^{ab} ± 1.45
Carp 3% salt, 60°C	14.37 ^c ± 0.17	13.81 ^a ± 0.29	13.75 ^a ± 0.29	14.25 ^c ± 0.25	14.18 ^a ± 0.34	14.68 ^b ± 0.11	85.06 ^c ± 0.99
Catfish 0% salt, 50°C	12.18 ^{ab} ± 0.34	13.12 ^a ± 0.31	13.18 ^a ± 0.42	12.25 ^a ± 0.42	13.93 ^a ± 0.41	12.75 ^a ± 0.44	77.43 ^a ± 1.85
Catfish 3% salt, 50°C	12.62 ^b ± 0.3	13.31 ^a ± 0.26	13.31 ^a ± 0.42	12.62 ^{ab} ± 0.41	13.93 ^a ± 0.37	12.75 ^a ± 0.43	78.56 ^{ab} ± 1.58
Catfish 0% salt, 60°C	12.18 ^{ab} ± 0.31	13.37 ^a ± 0.31	13.18 ^a ± 0.37	12 ^a ± 0.42	13.43 ^a ± 0.44	12.37 ^a ± 0.39	76.56 ^a ± 1.54
Catfish 3% salt, 60°C	11.62 ^a ± 0.31	13.12 ^a ± 0.32	13.12 ^a ± 0.41	11.93 ^a ± 0.44	14 ^a ± 0.35	11.87 ^a ± 0.41	75.68 ^a ± 1.68
Mean values ± standard error (n = 20). Means of sample having the same letter(s) within a column are not significantly different ($p < 0.05$).							

Catfish fillets generally received lower sensory scores than carp fillets (total scores 75.68-78.56 vs 79.12-85.06 for carp). Regarding drying temperature, the unsalted catfish showed similar scores at 50 and 60 °C (total 77.43 vs 76.56), while in the salted fillets drying at 60 °C lowered colour (11.62 vs 12.62) and overall acceptability (11.87 vs 12.75). Regarding salting, 3% salt caused only small and non-significant changes at both temperatures (total 78.56 vs 77.43

at 50 °C and 75.68 vs 76.56 at 60 °C). The lower sensory scores of catfish compared with carp may be related to species-specific differences in muscle pigmentation and lipid composition, which influence the colour and surface appearance of the dried product Al Banna, *et al.* [27].

Conclusion

Drying is a cheap method of fish preservation but the quality of the final product depends largely on processing conditions. Hot-air dried carp and catfish fillets, vacuum packed and stored at room temperature, maintained acceptable chemical quality for four months, with TVBN and PV below and TBA within the permissible limits. However, total viable bacterial counts in all treatments and mould and yeast counts in most treatments exceeded the permissible limit of 10^8 CFU/g, the lowest mould and yeast counts being recorded in the salted fillets dried at 50 °C. Salting combined with drying at 60 °C gave the best chemical and sensory quality of carp and the lowest TBA and most stable colour of catfish, whereas the sensory scores of catfish did not differ significantly among treatments. Therefore, 3% salt pretreatment followed by vacuum packaging is recommended for both species, with drying at 60 °C favouring chemical and sensory quality and drying at 50 °C favouring microbial quality. Further studies on hygienic handling, salt concentration, drying time and natural antimicrobials and antioxidants are needed to reduce the microbial load and extend the shelf life.

Conflicts of Interest

There are no conflicts to declare.

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