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Article

Biochemical, Microbiological, and Sensory Properties of Dried Silver Carp (*Hypophthalmichthys molitrix*) Influenced by Various Drying Methods

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Abstract: An experiment was performed to evaluate the effects of different drying methods with different pre-treatments on the physico-chemical, microbiological, and sensory properties of the silver carp, *Hypophthalmichthys molitrix*. In order to achieve this objective, the collected fresh fish were dried using traditional (without any pre-treatment), improved (fish soaked in a 5% salt solution for 10 min and then treated with chili powder (0.3%) and turmeric powder (0.3%)), and solar tunnel (fish soaked in a 5% salt solution for 10 min) drying methods. The results showed that the dried fish produced by the solar tunnel drying method were rehydrated more rapidly than the products produced by the traditional and improved drying methods. The moisture content of the dried *H. molitrix* was varied from 18.24 to 25.43% on a fresh matter basis. There was no significant ($p > 0.05$) difference found regarding the protein, lipid, and ash content among the different drying methods on a dry matter basis. The total volatile base nitrogen (TVB-N) contents ranged between 37.58 and 45.03 mg/100 g, and significantly ($p < 0.05$) the lowest TVB-N was observed in dried fish produced by the solar tunnel drying method. Moreover, the highest peroxide and acid values were found in the traditionally produced dried fish as compared with the fish dried by the improved and solar tunnel drying methods. The aerobic plate count of dried fish ranged from 4.52 to 7.51 log CFU/g. The sensory evaluation results revealed that the solar-dried products showed superior quality than the products produced by the traditional and improved drying methods. The results revealed that the dried fish produced by the solar tunnel drying method provided the best product in terms of physico-chemical, microbiological, and sensory aspects.

Keywords: drying methods; chemical composition; silver carp; sensory properties

1. Introduction

Low-cost fish preservation, such as sun drying, is a popular technique not only used in Bangladesh but also all over the world. Dried fish is one of the most important sources of animal protein and other essential nutrients for the maintenance of a healthy body [1]. Moreover, Bangladeshi people from northeastern, central, and coastal areas highly prefer this dried fish due to its characteristic taste and flavor. On a per unit weight basis, dried fish retains comparatively higher amounts of essential nutrients compared with fresh fish. In Bangladesh, the sun drying of fish has been practiced since time immemorial. The activity of the muscle enzymes and the microorganisms are halted by reducing the moisture content of fish [2]. However, the physical and sensory qualities of many traditional sun-dried fishery products available in the local market are not satisfactory for human consumption. Insect infestation by blow fly and beetle larvae in fish is one of the major problems related to traditional sun drying. Netting and neem (*Azadirachta indica*) leaves are generally used to minimize this problem. Moreover, chili powder and turmeric powder are also used to protect fish from insects during drying [3]. Another major problem of dried fish products is microbial and fungal growth, which can be reduced by maintaining proper drying and packaging of the product.

Nowadays, dried fish processors usually use insecticides to keep insects away during the drying and storage of the products, which creates serious human health complications. As a result, the biochemical properties of the dried fish are changed greatly due to such drying practices. Thus, traditionally produced dried fish are not safe for human consumption due to the random use of different kinds of pesticides and the extreme level of insect infestation [4]. To eliminate quality loss of dried fish products, different kinds of drying methods with different pre-treatments of fish have been established [5,6]. Solar tunnel drying is one such method, and it is easy to accomplish with locally available materials and does not require any power from an electrical grid [7].

The silver carp (*Hypophthalmichthys molitrix*) is one of the most widely cultivated species of fish all over the world due to its high yielding potentiality, ease of cultivation, efficient utilization of supplementary feed, and the fact that it contains essential nutrients for human health. In 2016–2017, the total fish production of Bangladesh was 4,134,434 metric tons; among this, silver carp production was 226,175 metric tons [8]. However, the taste of cooked silver carp is comparatively less palatable than the other major Indian carps. For this reason, consumers do not prefer to eat it as a regular dish; although, the price is found to be reasonable. Due to its relatively lower price, dried fish products can be made to add value to obtain more commercial benefits from this species. Thus, there is an opportunity to develop a dried product of this species that might improve the quality, taste, and consumer acceptability of this fish. Moreover, it is important to develop quality dried fishery products for export earning. Therefore, this study was aimed to evaluate the effects of different drying methods with different pre-treatments on the quality and sensory properties of dried silver carp (*H. molitrix*).

2. Results

2.1. Water Reconstitution of Sun-Dried Fish

The water reconstitution of sun-dried fish produced by the different drying methods is shown in Figure 1. The results showed that the traditionally produced dried silver carp held 41.43% moisture after 60 min at room temperature, whereas better moisture-holding capacity was observed in the dried fish produced by the improved (49.21%) and the solar tunnel (54.94%) drying methods. A similar trend was also observed when dried fish were soaked at 40 °C and 60 °C for 60 min.

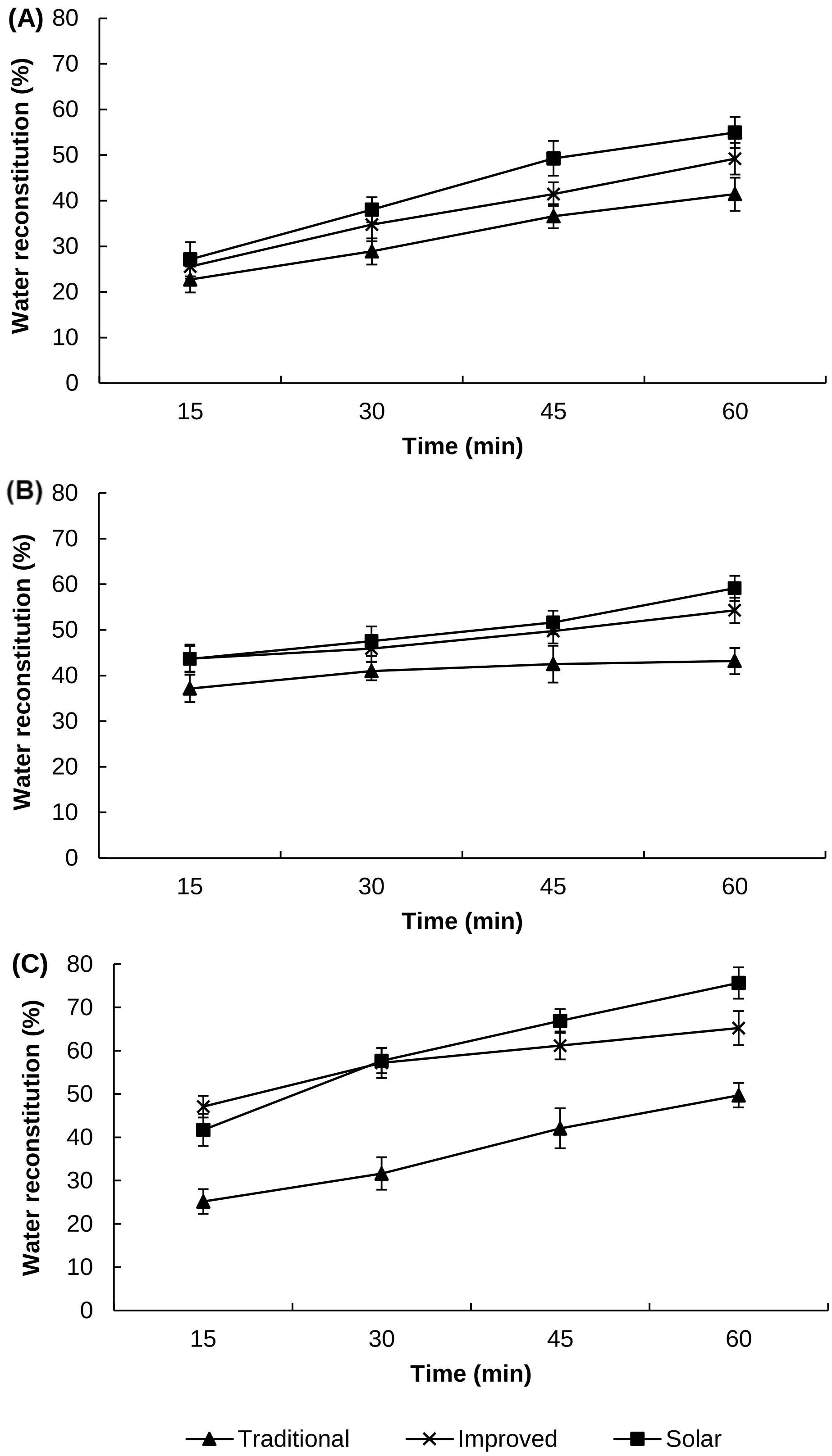

Figure 1. Water reconstitution of *Hypophthalmichthys molitrix* at (**A**) room temperature, (**B**) 40 °C and (**C**) 60 °C for the different drying methods.

2.2. Changes in pH Value

The pH values of the dried fish produced by the different drying methods are shown in Figure 2. The pH values of dried silver carp ranged from 6.33 to 6.65. Significantly ($p < 0.05$) the highest pH value was observed in the traditionally produced dried fish, while the lowest value (6.33) was found in dried fish produced by the solar tunnel drying method.

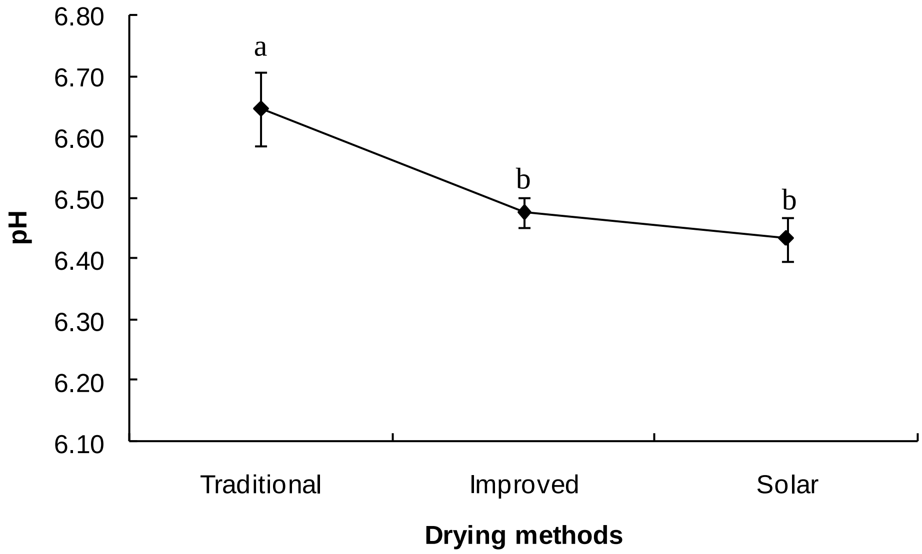

Figure 2. Changes in pH value of *H. molitrix* in various drying methods.

2.3. Proximate Composition of Dried Silver Carp

The moisture content of the dried *H. molitrix* ranged from 18.24% to 25.43% on a fresh matter basis (Table 1). Comparatively higher moisture content was found in the traditionally produced dried fish when compared with the dried fish produced by the improved and solar tunnel drying methods. However, the highest protein content was observed in the dried fish (83.68%) produced by the solar tunnel drying method, and the lowest protein content was found in the dried fish (82.49%) produced traditionally. The lipid content of dried fish ranged between 8.32% and 8.77% on a dry matter basis. The ash content of dried fish ranged from 7.51% to 9.11% on a dry matter basis.

Table 1. Effect of drying methods on the proximate composition (%) of *H. molitrix*. Each value is expressed as a mean ± standard deviation (SD) (n = 3). Means with different superscripts (a,b: fresh matter; d: dry matter) within a column are significantly different ($p < 0.05$). * Figures in parenthesis indicate values on a dry matter basis.

DRYING METHODS	Moisture	Protein	Lipid	Ash
Traditional	25.43 ± 1.07^{a}	61.51 ± 1.11^{b} (82.49 ± 1.48^{d}) *	6.21 ± 0.93^{a} (8.32 ± 1.25^{d})	6.79 ± 1.11^{a} (9.11 ± 1.48^{d})
Improved	19.83 ± 0.47^{b}	65.44 ± 1.02^{a} (82.88 ± 1.27^{d})	6.81 ± 0.72^{a} (8.75 ± 0.93^{d})	6.49 ± 1.29^{a} (8.34 ± 1.66^{d})
Solar	18.24 ± 0.16^{b}	68.41 ± 0.61^{a} (83.68 ± 0.75^{d})	7.04 ± 1.58^{a} (8.77 ± 1.97^{d})	6.03 ± 1.01^{b} (7.51 ± 1.26^{d})

2.4. Changes of Total Volatile Base Nitrogen Value

The total volatile base nitrogen (TVB-N) values of the dried silver carp produced by the different drying methods are shown in Figure 3. The TVB-N values of the solar, improved, and traditionally produced dried silver carp were 37.58 mg/100 g, 40.05 mg/100 g, and 45.03 mg/100 g of muscle, respectively. Significantly ($p < 0.05$), the highest TVB-N value was observed in the dried fish produced by the traditional drying method, while the lowest value was found in the dried fish produced by the solar tunnel drying method.

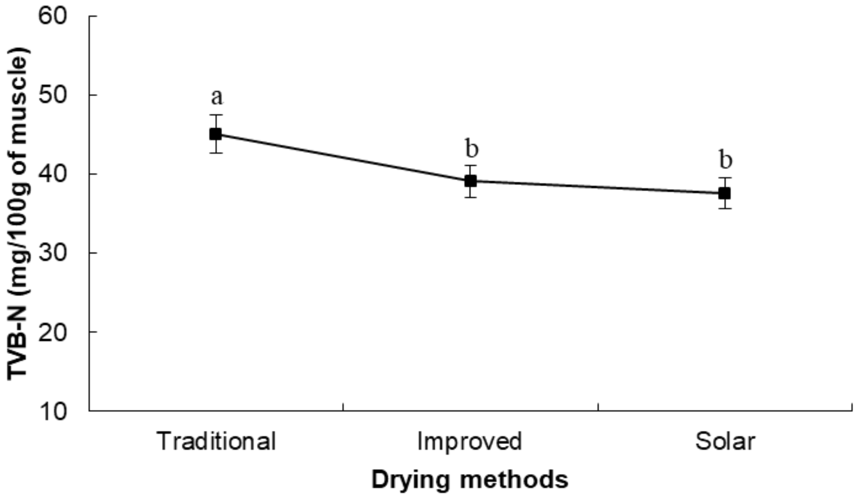

Figure 3. Total volatile base nitrogen (TVB-N) of *H. molitrix* in different drying methods.

2.5. Lipid Oxidation

The peroxide value and acid value were determined to measure the degree of lipid oxidation in the dried fish. The peroxide value of the dried fish ranged from 9.16 to 15.50 meq/kg lipid (Table 2). The acid values of dried *H. molitrix* ranged from 7.85 to 18.87 mg KOH/g of lipid.

Table 2. Effect of the drying methods on the peroxide value and acid value of *H. molitrix*. Each value is expressed as a mean ± SD (n = 3). Means with different superscripts within a column are significantly different ($p < 0.05$).

Drying Methods	Peroxide Value (meq/kg of Lipid)	Acid Value (mg KOH/g of Lipid)
Traditional	15.50 ± 0.93^{a}	18.87 ± 0.85^{a}
Improved	11.68 ± 1.23^{b}	12.20 ± 1.05^{b}
Solar	9.16 ± 0.96^{c}	7.85 ± 0.45^{c}

2.6. Microbiological Load of Dried Fish Products

The aerobic plate count (APC) of dried silver carp varied between 4.52 and 7.51 log CFU/g (Table 3). Comparatively higher APC was found in the traditionally produced dried fish as compared with the dried fish produced by the improved and solar tunnel drying methods.

Table 3. Effect of the drying methods on microbial load (aerobic plate count (APC)) of *H. molitrix*.

Drying Methods	Aerobic Plate Count (log CFU/g)
Traditional	7.51
Improved	5.15
Solar	4.52

2.7. Sensory Characteristics of Dried Fish Products

Significantly the highest values of color, odor, texture, and insect infestation were found in the traditionally produced dried fish when compared with the dried fish produced by the improved and solar tunnel drying methods (Table 4). The dried fish produced by the solar tunnel drying method was excellent in quality according to the sensory properties, such as color, odor, texture, and insect infestation. On the other hand, the dried fish produced by the improved drying method was also found to be of good quality, whereas the traditionally produced dried *H. molitrix* had decreased in quality.

Table 4. Effect of the drying methods on the sensory properties of *H. molitrix*. Each value is expressed as a mean (1–10 scoring) ± SD (n = 3). Means with different superscripts within a column are significantly different ($p < 0.05$).

Drying Methods	Color	Odor	Texture	Insect Infestation	Overall Acceptability
Traditional	2.81 ± 0.33^{a}	2.38 ± 0.40^{a}	3.27 ± 0.20^{a}	4.96 ± 0.16^{a}	13.42 ± 0.46^{a}
Improved	1.93 ± 0.25^{b}	1.56 ± 0.53^{b}	2.18 ± 0.16^{b}	1.20 ± 0.18^{b}	6.87 ± 0.27^{b}
Solar	1.69 ± 0.20^{c}	1.22 ± 0.20^{b}	1.93 ± 0.15^{b}	1.03 ± 0.06^{b}	5.87 ± 0.31^{b}

3. Discussion

Dried fish is a very popular processed food item, not only among consumers of Bangladesh but also in many other countries of the world. Dried fish are usually prepared by various drying methods with different pre-treatments, which play a vital role in the biochemical, microbiological, and sensory properties of the dried fish. Generally, the water-holding capacity of dried fish is increased with the increase of water temperature and soaking time. Overall, the dried fish produced by the solar tunnel drying method was rehydrated more rapidly than the dried fish produced by the improved or traditional drying methods. It has been reported that increased water temperature may open the internal structure of the fish muscle, which accelerates the rate of water absorption [9,10]. Reza et al. [11] also reported that rehydration ability is positively influenced by the physical properties of dried fish. Moreover, the water absorption capacity of dried fish depends on the variation of species in addition to time and temperature [10,12].

The determination of pH in fish muscle is an important index for quality assessment. In this study, pH values varied with the drying methods. However, no significant variation was observed in pH values between the dried fish produced by the improved and solar tunnel drying methods. The lowest pH values of dried fish produced by the solar tunnel drying method may inhibit microbial growth and extended the shelf life by reducing the activity of the endogenous enzyme. Moreover, the quality of dried fish improved when the pH value was decreased [13].

In this study, the moisture content was 25.43%, 19.83%, and 18.24% in the dried fish produced by the traditional, improved, and solar tunnel drying methods, respectively. The variation of moisture content in the dried fish might be the effect of the different drying methods. Comparatively lower amounts of moisture content were observed in the improved and solar-dried products, where fish was soaked in a salt solution that helped to reduce the water activity of the fish more rapidly. Generally, higher moisture content may enhance mold/fungal growth in the traditionally produced dried fish. Hasan et al. [14] reported that the moisture contents of traditional and solar-dried products of some small indigenous species ranged from 26.02% to 27.33% and 13.71% to 19.30%, respectively. After drying, the protein content was 61.51%, 65.44%, and 68.41% in the dried fish produced by the traditional, improved, and solar tunnel drying methods, respectively. Protein content was increased in the dried fish due to the dehydration of water molecules present between the proteins, causing the aggregation of protein [15]. But, there was no significant ($p > 0.05$) difference observed in the protein, lipid, or ash content in the dried fish produced by the various drying methods on a dry matter basis. The lowest lipid content was observed in the dried fish produced by the traditional drying method, which might be due to comparatively higher oxidation of lipids than the other drying methods. The highest amount of ash was found in the traditionally produced dried fish, which might be associated with contamination by sands and dirt during drying. It has been reported that the biochemical composition, such as moisture, ash and free fatty acid content, was lower in the dried fish produced by the solar tunnel drying method, whereas the values of protein and lipid were higher in the dried fish produced by the improved and traditional drying methods [16].

A number of volatile base nitrogenous compound, such as ammonia, dimethylamine, and trimethylamine, are released in fish during decomposition by bacteria. The TVB-N values of the dried silver carp ranged between 37.58 mg/100 g and 45.03 mg/100 g of muscle, which is much lower than the recommended value (100–200 mg/100 g of muscle) for different dried and salted fish products [17]. It has been reported that the TVB-N value of dried tilapia fillets ranged between 44.27 and 64.39 mg/100 g of muscle [18].

The oxidation of lipids in fish muscle usually develops off-flavor and off-odor that ultimately affect the storage time [19]. The highest peroxide value and acid value were determined in the dried fish produced by the traditional method, and the lowest values were observed in the dried fish produced by the solar tunnel drying method. The peroxide values (PV) observed in this study were lower than the recommended value (PV $\leq$ 20 meq/kg fish lipid) [17]. It has been reported that the peroxide value of herring (*Clupea pallasii*) lipids (5.52–11.86 meq/kg) increased significantly during the drying period [20]. Generally, lower acid values indicate better quality of a product. In this study, the acid values ranged from 7.85 to 18.87 mg KOH/g of lipid, which is more or less similar with the results reported by Majumdar et al. [21]. The formation of free fatty acid is one of the important factors that increases the acid value in the dried fish. Moreover, these free fatty acids were further oxidized and produced secondary oxidation products, which generated characteristic taste and off-odor of fish and fishery products [22].

Quantitative microbiological analysis helps to evaluate the quality of dried fish. The APC were 7.51, 5.15, and 4.52 log CFU/g in the dried fish produced by the traditional, improved, and solar tunnel drying methods, respectively. It has been reported that the acceptable limit of total plate count for fresh fish is 7 log CFU/g [23]. The APC of some marine dried fish range between 3.27 and 4.49 log CFU/g [24]. Mansur et al. [25] reported that the total bacterial count of some sun-dried fishes range between 1.84 and 5.3 log CFU/g.

Sensory analysis such as color, odor, texture, and insect infestation of dried fish were evaluated to estimate quality using panel members' senses. The overall acceptability was 13.42, 6.87, and 5.87 in the dried fish produced by the traditional, improved, and solar tunnel drying methods, respectively. It has been suggested that a lower sensory score of a dried fish indicates better quality of the products and vice versa [26]. The traditionally produced sun-dried fish showed objectionable color, odor, and texture, whereas the dried fish produced by the solar tunnel drying method showed comparatively better quality in every aspect [27]. Our results suggested that the dried fish produced by the solar tunnel drying method showed comparatively better quality than the dried fish produced by the traditional and improved drying methods.

4. Material and Methods

4.1. Collection of Samples

Fresh silver carp (*H. molitrix*) (weight 405.47 $\pm$ 41.13 g and length 28.4 $\pm$ 4.03 cm) were purchased from a local market situated at Gazipur, Bangladesh (23°99′17″ N, 90°41′96″ E). The fish were transported for drying to the laboratory in the Department of Fisheries Technology, Faculty of Fisheries, Bangabandhu Sheikh Mujibur Rahman Agricultural University, in an insulated ice box. The fish were dried for about six days, until moisture content was reduced to approximately 20% in the final product, during the month of February.

4.2. Traditional Sun Drying Method

In the traditional sun drying method, the collected fish were dressed and spread on bamboo mats without any pre-treatment, such as icing, salting, and cleaning for sun drying. The dried fish were stored in a freezer at −20 °C for further use.

4.3. Improved Sun Drying Method

According to the method of Immaculate et al. [16], in the improved sun drying method, the fish were properly gutted, washed, and soaked in a salt solution (5% per body weight) for 10 min and then treated with chili powder (0.3%) and turmeric powder (0.3%). The treated fish were hung on a rack. The sun-dried fish were stored in a freezer at −20 °C for further use.

4.4. Solar Tunnel Drying Method

In the solar tunnel drying method, the fish were dried following the method described by Nowsad [3]. Briefly, the fish were properly gutted, washed, and soaked in a brine solution (5% salt) for 10 min, and then, the treated fish were hung in a dryer. The dried fishes were stored in a freezer at −20 °C for subsequent analysis.

4.5. Determination of Water Reconstitution

Water reconstitution behavior was investigated following the method described by Hasan et al. [28] with slight modification. Briefly, about 8–10 g of the sample was weighed and submerged into water at room temperature (26–28 °C), 40 °C, and 60 °C for 60 min. The soaked dried fish was taken out from the water at 15 min intervals and reweighed. The water reconstitution percentage was calculated using the following formula:

$$\text{Water reconstitution } (\%) = \frac{W_r - W_i}{W_i} \times 100 \tag{1}$$

where W_i is the initial weight of the dried fish and W_r is the final weight of the rehydrated dried fish.

4.6. Measurement of pH Value

The dried fish (10 g) was homogenized with 100 mL of distilled water, and the pH was directly determined using a pH meter (MeterLab PHM 310, Beijing, China).

4.7. Analysis of Proximate Composition

The proximate composition such as moisture, crude protein, crude lipid and ash content were analyzed according to standard procedure given in Association of Official Analytical Chemists (AOAC) methods [29].

4.8. Determination of Total Volatile Basic Nitrogen

The TVB-N was determined following the method of Antonacopoulos and Vyncke [30]. The value was expressed as mg/100 g of muscle.

4.9. Extraction of Lipids

The total lipids were extracted from the dried fish with a solvent combination of chloroform:methanol:distilled water according to the method of Bligh and Dyer [31], with slight modification making those final ratios 10:5:3, $v/v/v$. The extracted lipids were stored in chloroform at −20 °C until further analysis.

4.10. Measurement of Peroxide Value

The peroxide value was measured according to AOAC methods [29]. About 0.5 g of total lipids were added to a glacial acetic acid:chloroform solution (3:2, v/v) in a conical flask. Saturated potassium iodide (0.5 mL) was added to the mixture and kept in the dark for 10 min. Then, distilled water (30 mL) and freshly prepared 1% starch solution (0.5 mL) were added to the mixture. The solution was shaken and titrated with 0.01 mol/L sodium thiosulfate. The result was expressed as meq/kg of lipid.

4.11. Determination of Acid Value

To measure acid value, 0.5 g of the total lipids were mixed with an ethanol:diethyl ether solution (1:1, v/v), and phenolphthalein was added to it. The mixture was then titrated with 0.01 mol/L potassium hydroxide. The result was expressed as mg KOH/g lipid [29].

4.12. Microbiological Analysis

The microbial load of the dried fish was estimated using the aerobic plate count method. Physiological saline solution (0.85% NaCl) and plate count agar (Hi media, Mumbai, India) were prepared according to the methods given in Cowan and Steel's manual [32].

4.13. Sensory Characteristics

Color, odor, texture, and insect infestation of the dried fish produced by the different drying methods with different pre-treatments were examined by sensory analysis according to the method described by Roy [26], which is shown in Table 5.

Table 5. Characteristic score for determining the sensory quality of dried fish.

Sensory Characteristics	Description	Score	Comment on Quality
Color	Characteristic color for every treatment	1–2.99	Excellent
	Slightly brownish/whitish/yellowish	3–5.99	Average
	Brownish/Faded	6–7.99	Moderately unacceptable
	Darkish color	8–10	Highly unacceptable
Odor	Characteristic fishy odor	1–2.99	Excellent
	Slight decrease of dry fish odor	3–5.99	Good
	Slightly rancid	6–7.99	Average
	Prominence of herbal odor/absence of dry fish/rancid	8–10	Poor in quality and unacceptable
Texture	Firm and flexible	1–2.99	Excellent
	Some loss of firmness and elasticity	3–5.99	Average
	Soft in texture	6–7.99	Poor in quality and unacceptable
	Fragile/Fragmented	8–10	Unacceptable
Insect infestation	No infestation	1–2.99	Excellent
	Few insect infestation	3–5.99	Average
	Moderate insect infestation	6–7.99	Poor in quality and unacceptable
	Heavy insect infestation	8–10	Unacceptable

4.14. Statistical Analysis

All the analyses were carried out by one-way analysis of variance (ANOVA). All the data are expressed as mean ± standard deviation (SD). Duncan's multiple range test was performed to compare the means at a 5% level of significance. All analyses were performed using statistical software, Statgraphics (StatPoint Inc., Herndon, VA, USA) version 7.0.

5. Conclusions

The results of this study revealed that different drying methods with different pre-treatments have a significant role on the physico-chemical, microbiological, and sensory properties of the dried silver carp. Water reconstitution, pH, and sensory characteristics were highly acceptable for the solar dried fish products, where fish were pre-treated with salt solution only. The traditionally produced dried fish were of comparatively poor quality in terms of proximate composition, TVB-N, peroxide value, acid value, and aerobic plate count when compared with the improved and solar dried fish products. Our results indicate that the dried fish produced by the solar tunnel drying method showed comparatively better quality than the dried fish produced by the improved and traditional drying methods.

Author Contributions: M.G.R. and A.K.M.A.S. conceived of and designed the study. B.C.M. and F.A. performed the experiments, while M.A.J.B. analyzed the data. M.G.R. and A.K.M.A.S contributed reagents/materials/analysis tools. M.G.R led the writing of the manuscript with contributions from all authors.

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Conflicts of Interest: The authors declare no conflict of interest.

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