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IMPACT OF MODIFIED DRYING METHODS ON BIOCHEMICAL AND MICROBIOLOGICAL CHARACTERISTICS OF DRIED SMALLHEAD RIBBONFISH (*Lepturacanthus savala*)

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Abstract: The present study evaluated the effect of improved drying methods, namely solar tent drier (STD), raised bamboo platform (RBP), and black polythene sheet (BPS), on the biochemical and microbiological quality of smallhead ribbonfish (*Lepturacanthus savala*). The fresh fish contained 75.66% moisture, 17.66% crude protein, 2.08% crude fat, and 0.76% ash. The initial total plate count (TPC) of fresh ribbonfish was 2.90×10^4 cfu/g, while halophilic and pathogenic bacteria were absent.

Drying duration was recorded as 58 h, 82 h, and 130 h for STD, RBP, and BPS methods, respectively. The initial moisture content of dried samples was 17.85% (STD), 19.35% (RBP), and 19.95% (BPS), whereas the market sample (MS) showed a higher moisture content of 30.6%. Moisture content increased in all samples during 120 days of storage. Higher protein content (40–44%) was observed at the beginning of storage in all experimental samples except the market sample. Crude fat content varied in accordance with moisture changes during storage. The initial ash content was 15.55% in the market sample and slightly higher in experimentally dried samples, which declined by the end of storage.

A gradual increase was observed in trimethylamine nitrogen (TMA-N), total volatile base nitrogen (TVB-N), and peroxide value (PV) in all samples during storage. Variations in salt content were associated with differences in drying duration. The initial TPC of STD, RBP, BPS, and market samples was 2.96×10^3, 3.80×10^3, 1.12×10^4, and 2.30×10^4 cfu/g, respectively, which increased to 5.0×10^3, 6.30×10^3, 4.80×10^4, and 5.80×10^4 cfu/g after 120 days. The initial total halophilic count was 2.40×10^2, 2.44×10^2, 5.50×10^3, and 2.20×10^4 cfu/g, respectively, and increased to 4.0×10^2, 5.10×10^2, 2.0×10^4, and 1.4×10^5 cfu/g at the end of storage.

Fungal growth was absent in STD and RBP samples initially; however, total fungal count (TFC) reached 4.60×10^1 and 4.80×10^1 cfu/g, respectively, after four months. In BPS and market samples, the initial TFC was 0.9×10^2 and 1.2×10^3 cfu/g, which increased to 2.60×10^2 and 2.70×10^3 cfu/g, respectively. Samples dried using improved methods were free from total coliform organisms throughout the storage period, whereas coliforms were detected in market samples and increased during storage.

The findings indicate that improved drying methods, particularly solar tent drying, enhance the biochemical stability and microbiological safety of dried ribbonfish during extended storage.

Keywords: Smallhead ribbonfish, solar tent drier, raised bamboo platform, black polythene sheet, biochemical quality, microbiological quality, storage stability

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INTRODUCTION

Curing and drying are among the oldest and most economical methods of fish preservation. The choice of processing technique depends on the type, size, and condition of the raw material. However, improper handling and inadequate processing practices often lead to quality deterioration due to microbial spoilage, insect infestation, and environmental contamination. Product quality can be significantly improved through strict control of raw material quality, drying parameters, and hygienic handling practices (Anene et al., 1996; Muyonga et al., 2004).

Globally, approximately 1.4 million metric tonnes of fish, representing about 8% of the total world fish catch, are processed through curing methods. Major producers of cured fish include China, Japan, the former USSR, Indonesia, the Philippines, Ghana, Canada, and India (FAO, 2000; FAO, 2020). In India, nearly 14% of the total fish catch is utilized for curing, making it the second most important form of fish utilization after fresh consumption (FAO, 2000). Common species used for curing in India include Bombay duck, pink perch, croakers, mackerel, soles, seer fish, silver bellies, ribbonfish, and anchovies.

Traditional open sun drying is the simplest and most widely practiced method of fish preservation due to its low cost and minimal infrastructure requirements. However, it has several limitations. Drying duration is prolonged during cloudy or humid weather conditions, and achieving sufficiently low moisture levels becomes difficult in areas of high relative humidity. Moreover, open sun drying often results in inferior product quality due to slow dehydration, insect infestation, and contamination from airborne dust and debris (Akande et al., 2004; Oladimeji et al., 2008). These drawbacks necessitate the adoption of improved drying techniques to enhance product quality and safety (Curran and Trim, 1985).

Improvements in sun drying can be achieved by elevating fish above ground level using raised wooden or bamboo racks, which enhance air circulation around the product and facilitate uniform drying from both sides. This approach also disrupts insect breeding cycles (Alegbeleye et al., 2018). Waterman (1976) reported that drying fish on racks covered with mosquito netting improves exposure to air and wind while reducing contamination and insect infestation.

Solar tent dryers have been recommended as an efficient alternative to traditional sun drying. These systems collect and concentrate solar radiation, thereby generating elevated temperatures and accelerating moisture removal (Doe et al., 1977; Bala and Islam, 2001). The smallhead ribbonfish (*Lepturacanthus savala* Cuvier) is widely distributed along the Indian coastline and is particularly abundant along the Konkan coast. Its commercial importance as a dried fish product makes it a suitable candidate for drying studies.

Production of high-quality dried fish requires not only improved drying methods but also strict maintenance of hygiene throughout processing (Gopal et al., 2015). Therefore, the present investigation was undertaken to evaluate the effect of improved drying methods—solar tent dryer, raised bamboo platform, and black polythene sheet—on the quality characteristics of *Lepturacanthus savala* under hygienic processing conditions. The dried products were packed in trend packs and subjected to storage studies for a period of four months to assess biochemical and microbiological changes.

In addition, dried ribbonfish samples obtained from the local market were similarly packed and stored under identical conditions to enable comparison between products prepared using improved methods and those processed by traditional practices.

MATERIAL AND METODS

1. Fabrication of Drying Systems

1.1 Solar Tent Dryer (STD)

The solar tent dryer was constructed based on the design described by Doe et al. (1977) with slight modifications. In the original design, the sun-facing side was covered with transparent plastic and the opposite side with black polythene. In the present study, the sun-facing side was modified such that the upper half was covered with a transparent polyethylene sheet to permit solar radiation entry, while the lower half was covered with black polythene sheet. The remaining two sides were fully covered with black polythene sheet to enhance solar heat absorption. The internal heating generated natural convective air flow, thereby facilitating efficient moisture removal during drying.

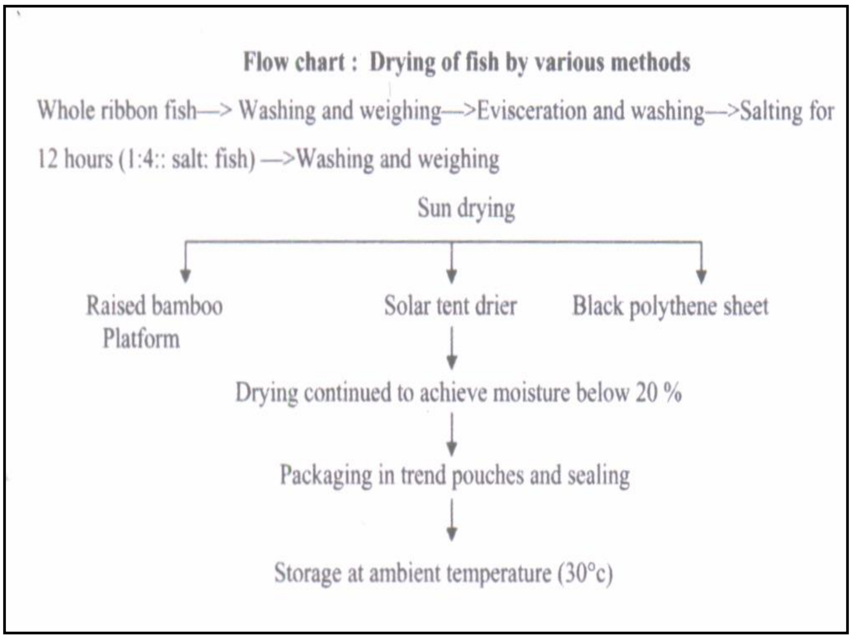
1.2 Raised Bamboo Platform (RBP)

A raised bamboo platform of dimensions 2.0 m × 1.0 m was fabricated using split bamboo strips. The platform was elevated 0.5 m above ground level using a plywood stand to allow adequate air circulation from both sides of the fish during drying.

2. Preparation of Fish for Drying

Fresh smallhead ribbonfish (*Lepturacanthus savala*) were washed thoroughly with potable water, weighed, eviscerated, and cleaned. The fish were salted at a ratio of 1:4 (salt:fish, w/w) and kept overnight for uniform salt penetration. After salting, the fish were washed to remove excess salt and divided into three batches of 10 kg each. Each batch was dried separately using solar tent dryer (STD), raised bamboo platform (RBP), and black polythene sheet (BPS).

Drying was carried out for approximately 10 h per day until the moisture content was reduced below 20%.



3. Biochemical Analysis

Proximate composition of dried ribbonfish samples was determined following standard methods of AOAC (2019).

- Moisture content was determined by hot air oven drying method at 105°C to constant weight.
- Crude fat was estimated using Soxhlet extraction with petroleum ether as solvent.
- Crude protein was determined by the Micro-Kjeldahl method (nitrogen × 6.25).
- Ash content was measured by incineration in a muffle furnace at 550°C.
- Acid insoluble ash was determined after treating total ash with hydrochloric acid and drying at 135°C.
- Salt content was determined according to AOAC (2019) standard procedures.

Trimethylamine nitrogen (TMA-N) and Total volatile base nitrogen (TVB-N) were estimated using the Conway micro-diffusion technique and expressed as mg N/100 g fish muscle (Beatty and Gibbons, 1937; FAO, 2011).

Peroxide value (PV) was determined by the iodometric titration method as described in AOAC (2019).

4. Microbiological Analysis

Microbiological evaluation included:

- Total Plate Count (TPC)
- Total Halophilic Count (THC)
- Total Fungal Count (TFC)
- Total Coliform Count (TC)
- Detection of pathogenic bacteria including *Escherichia coli*, *Staphylococcus spp.*, *Streptococcus spp.*, *Salmonella spp.*, and *Vibrio spp.*

All microbiological analyses were performed according to standard methods recommended by APHA (2015) and ICMSF (2011). Results were expressed as colony forming units per gram (cfu/g).

5. Organoleptic Evaluation

Sensory evaluation was conducted during storage using a panel of ten trained assessors. Attributes such as colour, odour, taste, texture, and overall acceptability were evaluated using a ten-point hedonic scale.

6. Statistical Analysis

Statistical analysis was performed following the procedures described by Snedecor and Cochran (1989). Results were expressed as mean values, and significance was tested at $P < 0.05$ and $P < 0.01$ levels.

Results and Discussion

1. Quality Characteristics of Fresh Ribbonfish

The fresh smallhead ribbonfish (*Lepturacanthus savala*) used in the present study contained 75.66% moisture, 17.66% crude protein, 2.08% crude fat, and 0.76% ash (Fig. 1). The initial total plate count (TPC) was 2.90×10^4 cfu/g. These values are comparable to earlier reports on ribbonfish composition (Ramachandran and Solanki, 1988), indicating that the raw material used in the study was of acceptable quality.

Fresh fish is highly perishable, and during peak landing seasons surplus catches are traditionally preserved by salting and drying for use during lean periods. However, conventional drying methods often lack hygienic control, resulting in poor product quality characterized by discoloration, off-odour, sand contamination, insect infestation, tissue disintegration, and elevated microbial load (Thomas and Balachandran, 1989; Alegbeleye et al., 2018). Therefore, improved drying systems were evaluated in the present study.

2. Drying Time under Different Methods

Drying duration varied significantly among the three methods. Fish dried in the solar tent dryer (STD) required 58 h, whereas those dried on raised bamboo platform (RBP) and black polythene sheet (BPS) required 82 h and 130 h, respectively.

The shorter drying time in STD may be attributed to enhanced internal temperature and improved convective airflow within the enclosed structure. In contrast, RBP drying was conducted under open conditions without heat entrapment, leading to a longer drying period. The longest drying time observed in BPS could be due to moisture accumulation on the polythene surface and possible reabsorption by the fish.

Similar observations on reduced drying time in solar drying systems have been reported by Bala and Islam (2001) and more recently by Bala et al. (2019), who demonstrated improved efficiency of solar-assisted drying technologies compared to open sun drying.

3. Biochemical Changes During Storage

3.1 Moisture Content

Initial moisture content of market sample (MS) was 30.6%, significantly higher than STD (17.85%), RBP (19.35%), and BPS (19.95%). Although within the maximum permissible limit of 35% specified by MPEDA (2003), higher moisture is known to reduce storage stability.

Moisture increased gradually during 120 days of storage in all samples. Moisture content is a critical determinant of shelf life, as higher levels favour microbial growth and biochemical deterioration (Antony and Govindan, 1983; Ghaly et al., 2010).

3.2 Crude Protein

Fish dried in STD recorded the highest initial protein content (44.13%), followed by RBP (42.22%) and BPS (41.35%), whereas market sample showed lower protein (32.48%). The higher protein levels in experimentally dried samples may be attributed to more effective moisture removal.

An inverse relationship between moisture and protein during storage has been widely reported (Khuntia et al., 1990; Kumar et al., 1997). Similar findings have also been observed in dried seafood products during ambient storage (Aremu et al., 2013).

3.3 Crude Fat

Crude fat content fluctuated during storage and generally showed a decreasing trend. This reduction may be associated with lipid oxidation and moisture gain. Polyunsaturated fatty acids in fish are highly susceptible to oxidative degradation during storage (Rao and Bandyopadhyay, 1983; Shahidi and Zhong, 2010).

3.4 Ash and Acid Insoluble Ash

Ash content was slightly higher in STD (16.67%), RBP (16.73%), and BPS (16.70%) compared to MS (15.35%), likely due to controlled salting. A strong positive correlation between ash and salt content has been previously reported (Khuntia et al., 1990).

Acid insoluble ash values were lowest in STD (1.17%) and highest in MS (4.5%), indicating greater contamination in market samples. Solar tent drying provided better protection from dust and environmental contaminants. Similar protective effects of solar drying systems have been reported (Bala and Islam, 2001; Basu et al., 1989).

3.5 Salt Content

Initial salt content was higher in STD (15.85%), RBP (15.5%), and BPS (15.8%) compared to MS (12.6%), suggesting better salting control. Inadequate salting in traditional practices may contribute to reduced stability and higher microbial load (Prasad, 1995).

3.6 TMA-N and TVB-N

TMA-N increased gradually in all samples during storage. Lower TMA-N levels were observed in STD and RBP samples compared to BPS and MS. Connell (1975) suggested 10–15 mg N/100 g as a general spoilage limit; however, in the present study, samples remained organoleptically acceptable beyond this value, consistent with observations by Khuntia (1990).

TVB-N increased from:

- 30.5 to 73.23 mg N/100 g (STD)
- 46 to 82.2 mg N/100 g (RBP)
- 89.5 to 247.5 mg N/100 g (BPS)
- 70.6 to 211.56 mg N/100 g (MS)

Increase in volatile bases is associated with microbial and enzymatic activity leading to odour deterioration (Kalakowski, 1986; Huss, 1995).

3.7 Peroxide Value (PV)

Peroxide value increased during storage but remained within moderate limits. Higher PV in BPS samples may be due to prolonged exposure to light and air. Sodium chloride may also exhibit pro-oxidant effects (Rao and Bandyopadhyay, 1983; Shahidi and Zhong, 2010).

4. Microbiological Changes During Storage

4.1 Total Plate Count (TPC)

Initial TPC values were lowest in STD (2.96×10^3 cfu/g) and RBP (3.80×10^3 cfu/g), and highest in MS (2.30×10^4 cfu/g). The permissible limit for dried fish is 1×10^5 cfu/g (IS, 2001; FSSAI, 2016).

TPC increased during storage in all samples, likely due to moisture uptake. Similar trends have been reported in dried fishery products during storage (Silva et al., 2002; Abraham et al., 1993).

4.2 Total Halophilic Count (THC)

Initial THC was lowest in STD (2.40×10^2 cfu/g) and RBP (2.44×10^2 cfu/g), and highest in MS (2.20×10^4 cfu/g). Increased THC during storage may be attributed to moisture absorption and salt-tolerant bacterial proliferation.

Halophilic bacteria can grow at water activity levels as low as 0.75 (FAO, 1981). Use of good quality salt and proper salting ratio reduces halophilic contamination (Prasad, 1995).

4.3 Coliforms and Pathogens

Fish dried under improved methods were free from total coliforms throughout storage, indicating good hygienic practices. Market samples showed increasing coliform counts during storage, suggesting poor handling.

Samples dried using improved methods were free from *E. coli*, *Staphylococcus spp.*, *Salmonella spp.*, and *Streptococcus spp.* throughout storage. Presence of these organisms in market samples indicates unhygienic handling and environmental contamination (Basu et al., 1989; FAO, 2011).

5. Organoleptic Changes During Storage

All samples showed gradual decline in sensory attributes over 120 days. STD samples maintained highest sensory scores and remained acceptable after 120 days. RBP samples showed moderate decline but remained acceptable. BPS samples became unacceptable after 90 days. Market samples showed marked quality deterioration by 120 days.

Reduction in sensory scores during storage has been attributed to microbial growth, lipid oxidation, and enzymatic proteolysis (Nair et al., 1994; Khuntia, 1990; Ghaly et al., 2010).

CONCLUSION

Traditional open drying of ribbonfish, though widely practiced, is associated with several limitations including higher residual moisture, inadequate salting, contamination with sand and dust, and overall inferior product quality. These shortcomings directly affect biochemical stability, microbiological safety, and storage life of the dried product.

The findings of the present study demonstrate that adoption of improved drying techniques, particularly the solar tent dryer (STD), significantly enhances product quality. The STD facilitated faster moisture removal, resulting in lower final moisture content and improved shelf stability. The enclosed structure provided effective protection against environmental contaminants such as dust and wind-blown particles, as reflected by the lower acid insoluble ash content.

Biochemical deterioration indices (TMA-N, TVB-N, and peroxide value) and microbiological parameters increased during storage in all samples; however, the magnitude of change was comparatively lower in STD-treated samples. Solar tent dried ribbonfish maintained superior microbiological quality and showed better retention of sensory attributes throughout 120 days of storage. The raised bamboo platform (RBP) also produced acceptable quality product, though with slightly lower performance compared to STD.

Overall, the results indicate that solar tent drying, followed by raised bamboo platform drying, can be recommended as effective and hygienic improved methods for drying smallhead ribbonfish (*Lepturacanthus savala*). Adoption of these improved systems, along with good manufacturing practices, can substantially enhance the quality, safety, and storage stability of dried fish products.

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