

Original Research Article

<https://doi.org/10.20546/ijcmas.2017.610.024>

Effect of Different Drying Methods on the Quality Characteristics of *Pangasius hypophthalmus*

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ABSTRACT

Keywords

Sun drying, Salt drying, Kiln drying, Pangasius, Quality.

Article Info

Accepted:
04 September 2017
Available Online:
10 October 2017

The objective of the present study was to investigate the effect of sun drying, salt drying and kiln drying (50°C, 60°C, 70°C) on the quality of *Pangasius*. The changes in proximate composition, physico chemical, microbiological and sensory evaluation were analyzed. From the results, it was observed that salt dried *Pangasius* had the lowest pH (5.01). Highest TVBN values were recorded in unsalted sundried *Pangasius* (29.28 mgN/100 g). *Pangasius* mechanically dried at 70 °C had the lowest peroxide value (PV) (2.50 meq of O₂/kg of fat) and the highest was recorded in salted sundried *Pangasius* (4.53 meq of O₂/kg of fat). The total viable count (TVC) was higher in sun dried *Pangasius* (5.02 log cfu/g) and the lowest TVC was observed in mechanically dried *Pangasius* at 70 °C (2.53 log cfu/g). Based on the sensory scores, salt and mechanically dried *Pangasius* had superior quality whereas sun dried *Pangasius* was inferior in quality. Salt drying can be the most suitable and cost effective method for preserving the marketable size *Pangasius*.

Introduction

Fish is an important source of animal protein due to its high nutritional value, good quality proteins containing most of the essential amino acids and important minerals such as phosphorus, calcium, magnesium etc. (Chukwu, 2009; Jain and Pathare, 2007; Sarower-E-Mahfuj *et al.*, 2012) Fish is one of the most perishable foods because of its suitable medium for spoilage after harvest. High ambient temperature prevalent in tropics is responsible for faster spoilage and deterioration of tropical species. Hence quick preservation of fish is important which includes traditional methods like salting or

brining, sun drying, solar drying, air drying and smoking in smoking kilns (Mustapha *et al.*, 2014).

In India, most of the fishermen in villages use curing as a method of preservation. Among curing methods, fishermen use drying, salt curing, smoking or fermentation for the preservation of fish. Dried aquatic products are popular as one of the delicious and convenient food items (Rahman, 2006). Drying is one of the oldest methods of preservation of fish which improves the stability of fish by reducing the water and

microbial activity, minimizing physical and chemical changes during storage (Darvishi *et al.*, 2012) and brings a substantial reduction in weight and volume, minimizing packaging, storage and transportation costs (Vega-Gálvez *et al.*, 2009). Traditionally sun drying of fish was carried out under the open sun, a low-cost preservation technique used from days immemorial to preserve the fish (Jain and Pathare, 2007). The limitation to control weather conditions, drying process and parameter, high labor cost, insect infestation, the requirement of large drying area, mixing with dust and other foreign particles (Jain and Pathare, 2007) long processing time and poor hygiene of product have led to the development of kiln dryers or solar dryers. Hot air drying employs convection system with controlled air velocity and humidity, high temperatures but involves high energy consumption, bacterial contamination and possible quality change (Selmi *et al.*, 2010). Traditionally, fish products were immersed in concentrated solutions containing salt or other curing agents that can impregnate into the muscle (Valencia-Pérez *et al.*, 2008) and used as a pre-treatment before drying to achieve good quality product (Taiwo *et al.*, 2003). Salting as a pre-treatment enhances the capability of drying in reducing the water activity of the product within shorter time allowing microbial quality preservation and changing the sensorial quality of food (Chabbouh *et al.*, 2011).

The quality of sardine dried with fish rack, solar drier and traditional sun drying was evaluated and observed that fish rack assisted sundried and solar dried sardines to have better quality than sun dried sardines (Immaculate *et al.*, 2012). The influence of temperature, air velocity and thickness of tilapia fillets on moisture ratio and drying rate was studied and it was observed that drying took place only in falling rate period. Moisture ratio decreased and drying rate

increased with increase in drying temperature, drying velocity and decrease of fillet thickness (Guan *et al.*, 2013). The effect of drying methods (smoking kiln at 70-85° C and electric oven at 120° C) on nutritional properties of tilapia fish was evaluated and found that electric oven will improve protein quality in tilapia (Chukwu, 2009). The effects of drying conditions on drying kinetics at different temperatures (35, 40 and 50° C) and air velocities (0.5, 1.5 and 2 m/s) of lightly salted sardine were investigated and two falling rates were observed (Bellagha *et al.*, 2002).

Pangasius has become as one of the candidate species for aquaculture in India due to its high production rate. However, utilization of Pangasius in fresh form has got limitation and there is an urgent need to find out alternative ways of processing in the form of low-cost processing and curing is one of such method. The objective of the present study is to investigate the effect of different drying process on the quality of dried product produced from Pangasius. In this study, Pangasius was dried at 50, 60 and 70° C in kiln dryer along with the traditional sun drying and salt drying. The present investigation provides information on the changes that occur in these different drying conditions on the quality of marketable size Pangasius.

Materials and Methods

Raw material and processing

Fish was purchased from the fish market in Dadar, Mumbai, India, iced immediately and brought to the laboratory within 1 hour. The length and weight of Pangasius varied between 36–43 cm and 800–1100 grams respectively. Upon arrival to the laboratory, the fish were washed with chilled water to remove dirt and slime and were beheaded,

eviscerated and thereafter split open from the ventral side in butterfly style. Again the fish were washed thoroughly with chilled water to remove adhering blood and viscera. The butterfly style cut fish were used for drying. For salt drying, fishes were dry salted at 1:1 ratio (fish: salt) at room temperature (32° C) for 48 hours before drying. After 48 hours the fishes were taken out and excessive salt on the surface was rubbed off and was sundried.

Drying experiments

For sun drying, the fishes were dried under sunlight by hanging the fishes by using hooks to rope with the tail side up and for kiln drying the fishes were hanged with head side up. The average temperature for sun drying varied from 30° C (9 AM) to 42° C (12 PM). The kiln drying was carried out in the Accelerated mechanical dryer (Yarrow & Co Ltd, Glasgow, Scotland) at controlled temperatures of 50, 60 and 70°C ± 5° C with an air velocity of 2.0 ± 0.3 m/s maintained in each test.

The sampling was carried out by taking 4 fish (3 for biochemical and microbial analysis and 1 for sensory evaluation) and the muscle portion of all fishes was ground to fine powder, mixed, weighed, macerated in pestle and mortar and was used for analyses.

Proximate composition

Moisture, fat, protein and ash content were determined according to AOAC 2000. Differences in weight were recorded after drying the sample in hot air oven at 100 ± 5°C overnight to determine the moisture content. The crude protein content was measured by using the micro-Kjeldahl method using Kelplus equipment (Pelican instruments, Chennai, India). Ashing was done by incineration of the sample in a muffle furnace (CEM Corporation, USA) at 550 ± 50 °C until white ash was obtained.

Total lipid was estimated by Soxhlet extraction method with diethyl ether as solvent.

Biochemical quality parameters

Ten grams of fish was homogenized in 50 mL distilled water in a homogenizer (Polytron system PT 2100, Kinematica, AG, Germany) for 30 seconds and the pH was measured using the digital pH meter (Eutech tutor pH/°C meter, Eutech Instruments, Singapore). TVB-N was determined based on the method described by Vyncke (1996) using TCA with slight modifications. Peroxide value (PV) was expressed as meq of O₂/ kg of fat and determined according to the method of Jacobs (1958) and the content of free fatty acids (FFA) was determined from the chloroform extracts of muscles ground with anhydrous sodium sulphate according to AOAC, 2000. Thiobarbituric acid reactive substances (TBARS) were estimated by the method of Tarladgis *et al.*, (1960).

Microbiological quality parameters

The microbiological parameters such as Total Viable Count (TVC) and *Escherichia coli* were carried out as per APHA (2001). 10 grams of the sample was aseptically weighed and transferred to a sterile stomacher bag and 90 ml of sterile physiological saline (NaCl 0.85% w/v) was added and the mixture was homogenized using stomacher (Lab Blender 400, Seward Medical, UK). For the enumeration of total plate count, 0.1 ml of the serial dilution of homogenate was spread on Plate count agar (Himedia, India) and incubated at 37 °C for 2 days. Enumeration of *Escherichia coli* was done by MPN method with initial inoculation of the sample at different volumes by 3-tube method in Lauryl tryptose broth (Lauryl sulphate broth) (Himedia, India) for coliforms for 24 hours and then positive tubes were re-inoculated in EC broth with 24 hours incubation at 37 °C.

Sensory evaluation

The sensory evaluation for overall acceptability was carried out after cooking the selected fish and it was done by 10 trained panellists using 9 point hedonic scales viz., Like extremely (9), Like very much (8), Like moderately (7), Like slightly (6), Neither like nor dislike (5), Dislike slightly (4), Dislike moderately (3), Dislike very much (2), Dislike extremely (1).

Statistical analysis

All analyses were carried out in triplicates and subjected to tests. Analysis of variance was performed by one-way ANOVA procedures with the application of Duncan's multiple range tests and descriptive statistics using SPSS 16 (SPSS, 2010). The least significant difference (LSD) was used to test for difference between means and significance was defined at $P < 0.05$. Results are reported as mean values of determinations \pm Standard Deviation.

Results and Discussion

Higher moisture content will make the product susceptible to microbial and enzymatic spoilage. Pangasius having a moisture content of 78% is susceptible to spoilage if it is not preserved properly. Though modern preservation techniques are available, they are costly for farmers and fishermen. So curing of fish, which is a low-cost preservation technique and easily adaptable can be used as a method of preservation of Pangasius. Higher temperature will lead to faster drying rate and shorter drying time (Guan *et al.*, 2013).

Changes in proximate composition

The fresh Pangasius consisted of moisture 79.32 ± 0.87 %, protein 16.96 ± 0.31 %, fat

2.02 ± 0.06 % and ash 1.44 ± 0.18 %. The moisture content has decreased during mechanical drying of Pangasius from 78.14% (fresh) to 16.67, 13.50 and 14.53% at temperatures 50, 60 and 70 °C respectively (Table 1). During sun drying of salted and unsalted Pangasius, a decrease in moisture was observed with values of 15.36% and 14.59% respectively. The decrease in moisture content may be due to the loss of free water present in muscle due to ingress of heat and salt. During drying, the water activity will decrease but the fat, protein and carbohydrate contents increase with water loss, pH changes, increase in free amino acids and fatty acids was reported (Collignan *et al.*, 2008). Moisture content decreased in kiln dried and electric oven dried tilapia from 70.15% to 20.12 and 17.13% respectively (Chukwu, 2009). Immaculate *et al.*, (2012) reported a decrease in moisture from 11.60, 8.31 and 4.0% in sun dried, rack dried and solar dried sardine.

The protein content increased during mechanical drying of Pangasius from 18.23% (fresh) to 62.77, 65.16 and 63.98% at temperatures of 50, 60 and 70 °C respectively (Table 2). The protein content of salted and unsalted sundried Pangasius was reported to be 55.53% and 63.39% respectively. An increase in protein content was due to aggregation of proteins after the removal of water molecules present between proteins during drying (Ninawe and Ratnakumar, 2008). The increase in drying time and loss of moisture leads to denaturation of the protein (Begum *et al.*, 2013). Protein was not lost during kiln and electric oven drying of cat fish (*Clarias gariepinus*) (Chukwu and Shaba, 2009). Protein content has increased in sardine during rack drying, solar drying and traditional drying (Immaculate *et al.*, 2012). Protein content increased from 23.06% to 63.64 and 64.10% in kiln dried and electric oven dried Tilapia (Chukwu, 2009).

The crude fat of *Pangasius* has increased from 2.29% (fresh) to 15.45, 15.31 and 14.48 % during mechanical drying at temperatures of 50, 60 and 70 °C respectively (Table 1). An increase in fat content was also observed in salted and unsalted *Pangasius* during sun drying with values of 9.32 % and 15.17 % respectively. The fat content increases with a decrease in water content as the lipid plus water content of fish flesh equal to 80% (Bligh *et al.*, 1988). According to Chukwu and Saha (2009) fat may exude with moisture evaporation and extended heat treatment may lead to the removal of lipids in smoking kiln than in electric oven. An increase in fat was observed from 12.85% to 28.03% and 20.25% respectively in kiln dried and electric oven dried tilapia (Chukwu, 2009).

The ash content has increased from 1.44% (fresh) to 3.63, 4.38 and 4.88 % during mechanical drying of *Pangasius* at temperatures of 50, 60 and 70 °C respectively (Table 1). Ash content of salted and unsalted sundried *Pangasius* was recorded as 18.72% and 5.22 % respectively. The highest ash content was observed in the salt dried *Pangasius* (18.72%) which may be due to the penetration of salt followed by unsalted sun dried *Pangasius* due to the accumulation of dust or other foreign bodies. During incineration, organic matter is removed and inorganic material will remain as ash (Clucas and Ward, 1996). Sun drying in open space allows the settling of wind-borne dust, insect and bird infestation and increases inorganic content may be a probable reason for the increase in ash content (Immaculate *et al.*, 2012). The higher ash content was due to the substantial loss of moisture (Mustapha *et al.*, 2014). An increase in ash content was observed in kiln dried and electric oven dried catfish (*Clarias gariepinus*) from 3.06% to 3.92% and 3.62% (Chukwu and Saha, 2009). Ash content of 15 dried market samples of Assam ranged from 9.28% to 28.72% (Vijayan and Surendran, 2012).

Changes in physico-chemical parameters

From the results, it was observed that pH values were lowest in salt dried *Pangasius* (5.01) (Table 2). The pH values of fish dried at 50 °C, 60 °C and 70 °C of kiln drying were recorded as 6.34, 6.12, and 6.33 respectively. The decrease in pH may be due to the fact that true lactic acid fermentation does not occur during drying. Chabbouh *et al.*, (2011) reported a decrease in pH of dried salted beef samples from 5.57 to 5.40. The pH values of unsalted sundried *Pangasius* were 6.86 and that of salted sundried *Pangasius* was 5.01. The increase in pH of unsalted and sundried fish may be due to production of nitrogenous compounds during drying. Addition of salt to fish decreases the pH of fish due to increase in acidic compounds (Farid *et al.*, 2014). The reduction in the pH of the salt washed dagaa fish was due to the leaching of the salt soluble proteins (Owaga *et al.*, 2009).

TVBN has decreased with the increase in temperature of kiln drying with the values ranging from 28.53, 25.33 and 15.61 mg N /100g at temperatures of 50°C, 60°C, 70°C respectively (Table 2). The TVBN value of unsalted sun-dried *Pangasius* was 29.28 mg N/100g and the TVBN value of salted sun-dried *Pangasius* was 19.58 mg N/100g. According to Nooralabettu (2008) the autolytic enzyme activity in fish flesh can be reduced by addition of sodium chloride to fish.

The TVBN value was higher in the preparation of Layú a Chinese cured product when compared to other drying methods (sun drying, drying at 5, 15 and 45°C and intermittent drying). The higher TVBN value during the preparation of Layú indicated the effect of the curing process on the increase of TVBN levels (Zhang *et al.*, 2013). Deng *et al.*, (2014) reported that TVBN value has increased in hot air dried squid samples. The endogenous proteases and microbial

contamination are the main sources causing the increase in TVB-N value during the preservation and processing of fish and fish products (Lenfant *et al.*, 2013).

Table.1 Changes in proximate composition (%) of *Pangasius hypophthalmus* at Different drying conditions

Conditions	Moisture	Protein (N x 6.25)	Crude fat	Ash
Fresh	78.14 ± 0.45 ^e	18.23 ± 0.04 ^a	2.29 ± 0.36 ^a	1.44 ± 0.85 ^a
MD 50°C	16.67 ± 0.11 ^d	62.77 ± 0.31 ^c	15.45 ± 0.32 ^d	3.63 ± 0.04 ^b
MD 60°C	13.50 ± 0.11 ^a	65.16 ± 0.63 ^e	15.31 ± 0.21 ^d	4.38 ± 0.14 ^c
MD 70°C	14.53 ± 0.11 ^b	63.98 ± 0.34 ^d	14.48 ± 0.06 ^c	4.88 ± 0.11 ^d
Unsalted and Sun drying	14.59 ± 0.18 ^b	63.39 ± 0.18 ^{cd}	15.17 ± 0.11 ^d	5.22 ± 0.27 ^d
Salted and sun drying	15.36 ± 0.38 ^c	55.53 ± 0.30 ^b	9.32 ± 0.35 ^b	18.72 ± 0.49 ^e

* Each value is represented as arithmetic mean ± SD (n =3).

Different superscripts in the same column indicate the values are significantly different (p≤0.05), (MD-Kiln drying)

Table.2 Changes in physico-chemical parameters of *Pangasius hypophthalmus* at different drying conditions

Conditions	pH	TVBN (mg N/100g)	PV (meq of O ₂ /kg of fat)	FFA (% oleic acid)	TBARS (mg malonaldehyde /kg)	Water activity
Fresh	6.75 ± 0.05 ^e	4.95 ± 0.18 ^a	0.07 ± 0.01 ^a	0.26 ± 0.03 ^a	0.04 ± 0.00 ^a	0.93 ± 0.00 ^d
MD 50°C	6.34 ± 0.02 ^c	28.53 ± 0.40 ^e	2.99 ± 0.05 ^d	0.66 ± 0.04 ^c	0.54 ± 0.01 ^d	0.72 ± 0.01 ^c
MD 60°C	6.12 ± 0.02 ^b	25.33 ± 0.20 ^d	2.90 ± 0.04 ^c	0.52 ± 0.00 ^b	0.35 ± 0.01 ^c	0.74 ± 0.01 ^c
MD 70°C	6.33 ± 0.02 ^c	15.61 ± 0.36 ^b	2.50 ± 0.28 ^b	0.46 ± 0.02 ^b	0.29 ± 0.01 ^b	0.72 ± 0.01 ^{ab}
Unsalted and Sun drying	6.86 ± 0.04 ^d	29.28 ± 0.11 ^f	3.89 ± 0.02 ^e	1.51 ± 0.23 ^d	0.56 ± 0.01 ^e	0.73 ± 0.00 ^b
Salted and sun drying	5.01 ± 0.05 ^a	19.58 ± 0.43 ^c	4.53 ± 0.14 ^f	2.04 ± 0.10 ^e	0.82 ± 0.01 ^f	0.72 ± 0.00 ^a

* Each value is represented as arithmetic mean ± SD (n =3).

Different superscripts in the same column mean that the values are significantly different (p≤0.05) (KD-Kiln drying)

Table.3 Microbiological changes of *Pangasius hypophthalmus* at different drying conditions

Conditions	TVC (log cfu/g)	<i>E. coli</i> (MPN/g)	<i>Staphylococcus</i> spp. (log cfu/g)	Total fungal count (log cfu/g)
Fresh	4.69	<3.0	2.55	<1
MD 50°C	3.84	<3.0	1.04	1.20
MD 60°C	3.61	<3.0	<1	1.11
MD 70°C	2.53	<3.0	<1	1.04
Unsalted and Sun drying	5.02	27	3.54	1.82
Salted and sun drying	4.98	<3	2.84	1.18

* Each value is represented as arithmetic mean of 2 estimates.

cfu = colony forming units; MPN = most probable number; MD = Mechanical drying

Table.4 Sensory changes of *Pangasius hypophthalmus* at different drying conditions

Conditions	Colour	Appearance	Odour	Taste	Texture	Overall acceptability
Fresh	8.52 ± 0.19 ^e	8.64 ± 0.14 ^e	8.60 ± 0.07 ^e	8.44 ± 0.11 ^d	8.65 ± 0.70 ^d	8.58 ± 0.08 ^c
MD 50°C	7.62 ± 0.18 ^b	7.74 ± 0.18 ^b	7.62 ± 0.16 ^b	7.92 ± 0.08 ^a	7.54 ± 0.11 ^b	7.58 ± 0.15 ^b
MD 60°C	8.12 ± 0.11 ^c	8.24 ± 0.05 ^{cd}	8.20 ± 0.23 ^d	8.08 ± 0.08 ^{ab}	8.08 ± 0.08 ^c	8.14 ± 0.17 ^{cd}
MD 70 °C	8.48 ± 0.13 ^d	8.41 ± 0.06 ^d	8.42 ± 0.04 ^e	8.08 ± 0.08 ^{ab}	8.08 ± 0.08 ^c	8.30 ± 0.16 ^d
Unsalted and Sun drying	5.4 ± 0.812 ^a	4.86 ± 0.22 ^a	4.58 ± 0.16 ^a	NA	5.20 ± 0.20 ^a	5.08 ± 0.08 ^a
Salted and sun drying	8.18 ± 0.20 ^c	8.18 ± 0.21 ^c	7.92 ± 0.08 ^c	8.12 ± 0.22 ^c	7.12 ± 0.13 ^b	7.92 ± 0.33 ^c

* Each value is represented as arithmetic mean ± SD (n =10).

Different superscripts in the same column mean that the values are significantly different (p≤0.05)

MD-Mechanical drying; NA- Not analysed

Peroxide value defines the initial stage of the oxidative changes. It was observed that the peroxide value of Pangasius decreased with the increase in temperature from 2.99 to 2.50 meq of O₂/ kg of fat at temperatures of 50 to 70 °C respectively (Table 2). The data indicated that hydrolytic and oxidative degradations have occurred during drying. High temperatures accompanying drying processes could speed up the breakdown of peroxides into their carbonyl components (Wu and Mao, 2008). This is a clear indication of the rapid decomposition of hydroperoxides into secondary oxidation products at high temperatures. Because hydroperoxides are unstable and decompose via fission, dehydration and the formation of free radicals, to form a variety of chemical products, such as alcohols, aldehydes, ketones, acids, dimers, trimers, polymers, and cyclic compounds at elevated temperatures (Fritsch, 1981; Tan *et al.*, 2002).

According to Wu and Mao (2008), peroxide value was a poor indicator for heated samples while drying of grass carp fillets at hot air drying and micro wave drying. The increase in peroxide value in unsalted sun dried (3.89 meq of O₂/ kg of fat) and salted sun dried Pangasius (4.53 meq of O₂/ kg of fat) may be due the increased exposure of fish to oxygen. Prolonged exposure to light and air during initial drying has resulted in oxidation of fatty acids (Relekar *et al.*, 2014). The Peroxide value of salted sun dried Pangasius (4.53 meq of O₂/ kg of fat) was highest of all drying methods. The cause of such lipid oxidation may be the pro-oxidant effect of sodium chloride (Sachithanathan, 1976). PV is not a good index of rancidity during storage of dried anchovy but TBA gave a better correlation with overall quality (Bligh *et al.*, 1988; Inoue, 1970). PV of salt cured choodai ranged from 1.2 to 21.4 meq O₂/kg with different salt and nitrate treatments (Pillai and Nayar, 1957). A peroxide value of 10-15 meq/Kg of lipids indicates rancidity (Connell,

1995). The peroxide value of the mechanically dried and sundried Pangasius was within the acceptable limit indicating that the product is of good quality.

Secondary lipid oxidation compounds formed during drying were measured by the thiobarbituric acid reactive substances, (TBARS). There was an increase in the TBARS at all temperatures when compared to fresh fish (0.04 mg MDA/kg). TBARS value decreased with increase in drying temperature from 50°C (0.54 mg MDA/kg) to 70 °C (0.29 mg MDA/kg) (Table 2), which may be due to the effect of temperature and exposure time. The formation of secondary oxidation compounds has proved to be an interesting tool to assess the chemical changes produced as a result of the drying process (Ortiz *et al.*, 2013). Ali *et al.*, (2011) observed an increase in TBARS value for smoked-dried and sun-dried flesh of two fish species (*Silurus glanis* and *Arius parkii*). Ortiz *et al.*, (2013), reported that exposure time during drying would have a greater effect on formation of secondary lipid oxidation compounds in the dried fish samples from 40 to 60 °C. In the unsalted sundried Pangasius, it was observed that TBARS value was higher (0.56 mg MDA/kg) than fresh sample (0.04 mg MDA/kg). According to Cakli *et al.*, (2006), TBARS vales greater than 3–4 mg MDA/kg indicates a loss of product quality. In the present study, the TBARS values of dried Pangasius were within the limit of acceptability. Ali *et al.*, (2011) has observed that TBARS value of sundried fish was greater than smoked dried and fresh sample in all three species (*Tilapia niloticus*, *Silurus glanis* and *Arius parkii*).

Free fatty acid (FFA) has increased with increase in temperature as compared with fresh Pangasius (Table 2). The FFA content of Pangasius dried in mechanical dryer at temperatures of 50, 60 and 70 °C were 0.66, 0.52 and 0.46 % oleic acid respectively (Table

2). The decrease in FFA during kiln drying at 70 °C may be due to combined effect of hot air and reduction in water activity thereby reducing hydrolysis of lipids. The FFA value of salted and unsalted dried Pangasius was 2.04 and 1.51 % oleic acid respectively. Huss (1998) suggested that high level of FFA is an indication of microbial spoilage activity. The increase of FFA during drying and salt drying may be due to the extended time taken for drying during which the lipolytic enzymes may hydrolyse the lipids. Lipid hydrolysis is more rapid at high temperature and the increase of free fatty acid is an indication of microbial spoilage activity (Jeyasanta *et al.*, 2016). Lipid hydrolysis is catalyzed by lipases which cleave fatty acids from glycerol backbone of both triglycerides and phospholipids (Hardy, 1980). Most fat acidity begins to be noticeable to the palate when the FFA value calculated as Oleic acid is about 0.5 -1.5 % (Pearson, 1976). From the results it was observed that mechanically dried Pangasius was within the limit but in both the sundried pangas the values were a little higher than the limit.

There was not much variation in water activity of dried Pangasius as the water activity in all dried Pangasius samples varied from 0.72 to 0.74 (Table 2). The decrease in water activity may be due to removal of water from fish during drying. According to FSSAI (2016), the a_w of dried product should be less than 0.78. In the present study the values of a_w were lower than 0.78 indicating that the product was stable and of good quality. Chabbouh *et al.*, (2011) reported a decrease in water activity of salted and dried kaddid from 0.90 to 0.66 and opined that the decrease may be due to bounding of water molecules with NaCl and water evaporation.

Microbial changes

Among all the drying conditions, highest total viable count were observed in unsalted and

sun dried Pangasius (5.02 log cfu/g) followed by salt dried Pangasius (4.98 log cfu/g) (Table 3). The probable reason for the decrease of TVC in salted sundried Pangasius may be due to the preservative action of salt. During the mechanical drying of Pangasius it was observed that the TVC decreased with the increase in the drying temperature from 50 °C to 70 °C with TVC ranging from 3.84 log cfu/g to 2.53 log cfu/g. An increase in total viable count (TVC) during sun drying of *Scomberoides tol* was observed (Patterson and Ranjitha, 2009). According to FSSAI (2017) the maximum limit of TVC in dried fish product is 5 log (cfu/g). The counts of TVC were within the limit of acceptability indicating that the product was of good quality except unsalted and sun dried Pangasius in which the TVC was recorded as 5.02 log (cfu/g) indicating the product has a chance of early spoilage. The *E. coli* count was higher in unsalted sun dried Pangasius (27 MPN/g) where as in other drying methods the *E. coli* content is below the determinant levels. According to FSSAI (2017), the maximum limit of *E. coli* is 20 MPN/g in dried seafood. In the present study, the counts of *E. coli* of mechanically dried Pangasius and salted sundried Pangasius were lower than the acceptable limit whereas the unsalted sundried Pangasius had higher *E. coli* counts indicating that the product was unacceptable for consumption. This increase in *E. coli* in the unsalted sun dried Pangasius may be due to contamination of water used for ice preparation in the market or improper hygiene of the market area. *E. coli* has decreased during sun drying (Patterson and Ranjitha, 2009). The decrease in the *Staphylococcus spp.* in all the samples dried by mechanical drying may be due to effect of temperature.

The low counts of *Staphylococcus spp.* also indicate that the product was prepared hygienically. The increase in *Staphylococcus spp.* during sun drying of salted and unsalted Pangasius may be due to the microbes, dirt

and dust falling on the product when they are dried for 4-6 days. The total fungal counts varied with temperature from 1.20, 1.11 and 1.04 log cfu/g during drying of Pangasius at temperatures of 50 °C, 60 °C and 70 °C respectively. The total fungal count of unsalted sundried Pangasius was 1.82 log cfu/g and that of salted and sundried Pangasius was 1.18 log cfu/g (Table 4). According to FSSAI (2017), the maximum limit of moulds in dried fishery products is 500 cfu/g (2.7 log cfu/g). In the present study it was observed that Pangasius dried in different conditions had fungal counts lower than 500cfu/g (2.7 log cfu/g).

Sensory changes

The sensory scores of Pangasius dried at different temperatures are given in table 4. The overall sensory scores of Pangasius had shown a significant difference. Highest overall scores were observed for mechanically dried Pangasius at 70 °C (8.30) but lower overall sensory scores were observed for unsalted sundried Pangasius (5.08). Among the sensory parameters like appearance, color, odor, texture and overall acceptability were lowest for unsalted sun dried Pangasius but the texture of salted sun dried Pangasius was lower than unsalted sun dried Pangasius. In salt drying, the salt penetration is accompanied by the removal of moisture and as the salt content increases there are chances of crust formation making moisture removal difficult. Crust formation was formed on the surface of fish due to combined effect of heat and salt at 50 °C in lightly salted sardine (Bellagha *et al.*, 2002). From the above results it was observed that the sensory scores of mechanically dried Pangasius were high at all the three temperatures indicating the high acceptance of mechanically dried Pangasius due its good colour, fishy odour and texture. Among the different temperature of mechanical drying, Pangasius dried at 70°C

had high scores indicating high acceptance than other dried products. The unsalted sundried Pangasius had lower scores near to the rejection point indicating that the product was not acceptable which may be due to the off odour and the fish was spoiled by maggots and some remains of maggots were found after drying making the fish unacceptable. The higher sensory scores of salted sundried Pangasius might be due to the good texture, flavor and taste indicating that salted sundried Pangasius was highly acceptable. Among salted and unsalted sundried pangas, salted sundried Pangasius was more acceptable. Based on the sensory scores, mechanically dried and salted sundried Pangasius was acceptable among the different drying conditions.

From the results of the present investigation, the quality of Pangasius dried at 50, 60 and 70° C was superior to sun drying and salt drying and the products were produced hygienically. Among the sun drying and salt drying of Pangasius, the quality of salt dried Pangasius was superior. Though the quality of kiln dried Pangasius is more acceptable than sun dried and salt dried Pangasius, the cost involved in their production and other difficulties in using kiln drier makes it unfavorable for using by village farmers and fishermen in India. Hence salt drying which takes less time to dry and produces a good quality product can be used as an effective method of preservation for marketable size Pangasius.

Acknowledgements

The first author is thankful to Indian Council of Agricultural Research (ICAR) and Director, ICAR-Central Institute of Fisheries Education, Mumbai for providing necessary facilities for conducting this study. The first author also remains grateful to University Grants Commission (UGC) for providing

financial assistance in the form of fellowship (RGNF).

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How to cite this article:

Gonugodugu Praveen Kumar, K.A. Martin Xavier, Binaya Bhusan Nayak, H. Sanath Kumar, Gudipati Venkateshwarlu and Amjad K. Balange. 2017. Effect of Different Drying Methods on the Quality Characteristics of *Pangasius hypophthalmus*. *Int.J.Curr.Microbiol.App.Sci.* 6(10): 184-195. doi: <https://doi.org/10.20546/ijcmas.2017.610.024>