International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(3): 2052-2056

Received: 13-03-2018
Accepted: 17-04-2018

Kapil Deb Nath
Krishi Vigyan Kendra, Assam Agricultural University, Cachar, Assam, India

Parag Saikia
Krishi Vigyan Kendra, Assam Agricultural University, Kamrup, Assam, India

Nabadeep Saikia
Krishi Vigyan Kendra, Assam Agricultural University, Cachar, Assam, India

Pulakabha Chowdhury
Krishi Vigyan Kendra, Assam Agricultural University, Cachar, Assam, India

Ranendra Kumar Majumder
Department of Fish Processing Technology, College of Fisheries, Central Agricultural University, Lembucherra, Tripura, India

Correspondence
Kapil Deb Nath
Krishi Vigyan Kendra, Assam Agricultural University, Cachar, Assam, India

Influence of solar drying on the quality of three commercial valued fish species available in NE region

Kapil Deb Nath, Parag Saikia, Nabadeep Saikia, Pulakabha Chowdhury and Ranendra Kumar Majumder

Abstract
Solar drying is a common method of preserving the fish products. This study was carried out to investigate the influence of solar drying on quality of fish. To this consequence, some biochemical and microbial characteristics (moisture, ash, protein, lipid, TVB-N, PV, TBA, and APC) were determined for fresh and solar dried fish of three species (*Mystus gulio, Puntius sophore* and *Gudusia chapra*). Results showed that moisture content varied between 72.55 ± 1.03 to 74.76 ± 1.01 g/100g for fresh fish and between 9.84a ± 0.61 and 13.06a ± 0.65 g/100g for sun dried fish. With regard to protein contents, fresh had lower amount between 16.24% and 18.21% while sun dried fish products had the protein contents between 63.25% and 64.69%. The entire three fresh fish sample showed lower fat contents compared to that of sun dried fish sample. The microbiological quality i.e. aerobic plate count appeared to be of less than its cut off value.

Keywords: Fish, biochemical, microbial, solar dried fish

Introduction
Considerable quantities of dried fish are consumed in developing countries like India. Natural drying by exposure to sun and wind is widespread and is possibly the first method used for preserving seafood. This is still applied to a large extent to preserve fish and squid (Sikorski *et al.*, 1995) [1]. Conventional air drying at relatively higher temperature is detrimental to fish muscle, because, as a result of evaporation, more moisture and salts are diffused to the surface resulting in increase in salt concentration and changes in pH which affect solubility and water binding properties (Zyas, 1997) [2]. Extensive work on biochemical and nutritional changes during heating at higher temperature (100^0C and above) has been done by many workers and only a few reports are available on biochemical and nutritional changes during drying (Raghunath *et al.*, 1995) [3]

Materials and Methods
Fish Samples: The study focused on three commercial valued fish species namely *Mystus gulio, Puntius sophore* and *Gudusia chapra*. The fishes were bought from local fish market and transported to the laboratory in insulated ice boxes. For each species, fresh and solar dried fish were studied.

Biochemical Analyses
Moisture, ash, total lipid and crude protein analysis of all the fishes were carried out using standard procedures of AOAC (2000) [4]. Total volatile basic nitrogen (TVBN) was determined by using the Conway's micro-diffusion method (Conway, 1947) [5]. The peroxide value (PV) was determined on the chloroform extracts of tissues according to the methods suggested by Jacobs (1958) [6].

Thiobarbituric acid reactive substances (TBARS) were determined as described by Benjakul and Bauer (2001) [7]. The flesh (0.5 g) was dispersed in 2.5 ml of a solution containing 0.0375% thiobarbituric acid, 15% trichloroacetic acid and 0.25N HCl. The mixture was heated in boiling water for 10 min, followed by cooling in running tap water. The mixture was centrifuged at 8000 rpm for 20 min at room temperature.

The absorbance of supernatant was measured at 532 nm using a spectrophotometer (SHIMADZU, UV 2550). TBARS were calculated and expressed as mg malondialdehyde/kg fish meat.

Total aerobic plate counts

To determine the total number of viable microorganisms in the fish muscle, 10 g of representative sample was added to 90 ml of sterile physiological saline (0.85% NaCl) and mixed thoroughly in stomacher (Stomacher 80, Seward, UK) and further dilutions were carried out in the same diluent (APHA, 2001)[8]. Pour plating method was followed using plate count agar for enumerating the bacteria. The plates were incubated at 37^0 C for 48 h and counts taken. All the constituents of the media used were acquired from Hi Media Laboratories Pvt. Limited, Mumbai, India.

Sensory Analyses

Sensory characteristics and overall acceptability of fresh *Mystus gulio, Puntius sophore and Gudusia chapra* were assessed by a panel of six members on the basis of ten point suggested by Sukumar *et al*. (2007) [9]. Sensory characteristics study included general appearance, odour and texture of fish. Scale employed for evaluating sensory quality of fresh fish is given in Annexure-I. The scores were given in the decreasing order scale with 10 – 9 for excellent, 8 – 7 for good, 6 – 5 for fair and acceptable, 4 – 3 for poor and 2 – 1 for very poor. The mean of the scores given by the panel represented the overall sensory quality. A score below 5 was considered unacceptable.

Sensory characteristics and overall acceptability of sun dried fish was assessed by a panel of six members on the basis of 5 point scale suggested by Ninan *et.al.*, (2008) [10] and given in Annexure-II. Sensory characteristic study included general appearance, colour, odour and texture. The score were given in the decreasing order scale with 5 for excellent, 4 for very good, 3 for good, 2 for poor and 1 for unacceptable. The mean of the score given by the panel represented the overall sensory quality. A score of below 3 was considered as unacceptable.

Statistical Analyses

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, version 11.0 for Windows). The tests for differences were done by using Duncan's Multiple Comparison Test. Significance of differences was defined at $p<0.05$.

Results and Discussion

The biochemical composition of fresh and sun dried fish a sample of analyzed fish sample is presented in Table 1.

Table 1: Biochemical composition of fresh and sun dried fish

Species	Treatment	Moisture %	Ash (%)	Protein (%)	Total lipid (%)
Mystus gulio	Fresh	74.76 ± 1.01	1.58 ± 0.03	16.87 ± 1.15	5.69 ± 0.03
	Sun dried	13.06 ± 0.65	5.42 ± 0.17	64.69 ± 1.39	15.10 ± 0.50
Puntius sophore	Fresh	72.55 ± 1.03	1.72 ± 0.17	18.21 ± 0.16	4.49 ± 0.20
	Sun dried	10.34 ± 0.28	4.39 ± 0.26	63.25 ± 4.00	13.91 ± 1.53
Gudusia chapra	Fresh	73.18 ± 0.15	1.77 ± 0.27	16.24 ± 0.24	4.43 ± 0.13
	Sun dried	9.84± 0.61	4.41 ± 0.26	63.69 ± 3.67	13.96 ± 1.49

Moisture and ash content

The moisture content of all three fishes studied were relatively high and were not significantly different ($p>0.05$). The values were 74.76 ± 1.01, 72.55 ± 1.03 and 73.18 ± 0.15 respectively for *Mystus gulio, Puntius sophore* and *Gudusia chapra*. Drying or dehydration reduced moisture contents to values < 15% (Ali *et al.*, 2011) [11].

The sun dried fish products *Mystus gulio, Puntius sophore* and *Gudusia chapra* registered residual moisture contents of 13.06a ± 0.65, 10.34a ± 0.28 and 9.84a ± 0.61 respectively. The fewer amounts of residual moisture contents in sun dried fish products compared to that of fresh fish. This could be explained by the fact that during drying the fish flesh losses its water holding capacity due to the progress of protein denaturation which resulting increase of evaporation of moisture during drying. Thippeswamy *et al.* (2001) [12] observed reduction of moisture content from 73.6% in wet fish to 25.8% in the dried milk fish (*Chanos chanos*), when dried for 24 h in hot air oven at 60^0C. The ash content of the three species were found to be more after drying than that of fresh one and this may be due to reduction of moisture content.

Nitrogenous compounds

The crude protein (TN% x 6.25) content in all the three fishes was not significantly different from one species to another. The values obtained from *Mystus gulio, Puntius sophore* and *Gudusia chapra* were 16.87%, 18.21% and 16.24% respectively. These values are similar with Ali *et al.*, 2011 [11], who obtained an average of 18.81, 19.83 and 21.23% crude protein content for the fish species namely *Arius parkii, Tilapia nilotica* and *Silurus glanis* respectively. Product dehydration increased the protein contents and in case of sun dried fish it was found 64.69, 63.25 and 63.69% respectively for *Mystus gulio, Puntius sophore* and *Gudusia chapra*. The increase in protein contents may be due to product dehydration which concentrated the proteins and thus increasing the nutritional value of dried fishes (Thot and Pothast, 1984) [13].

TVB-N is a term that includes measurement of trimethylamine, dimethylamine, ammonia and other compounds associated with seafood spoilage, which increases as spoilage progresses. For several fish species, TVB-N values were reported to increase curvilinearly or linearly with time, and a level of 30 mg muscle TVB-N/100g has been considered the upper limit above which some fishing products are considered spoiled and unfit for human consumption (Gokodlu *et al.*, 1998) [14]. In this study the average values of TVB-N content of fresh fish were found to be not significant among the species and values are like 14.0^a ± 0.12, 13.07^a ± 1.23 and 12.27^a ± 0.33 respectively for *M. gulio, P. sophore* and *G. chapra* (Table 2). The FAO has indicated that samples with less than 25 mg TVB-N /100 g flesh are 'perfect quality', whereas, samples with up to 30 mg TVB-N/100 g flesh are 'good quality', samples with up to 35 mg TVB-N/100g flesh are 'marketable quality' and the samples with more than 35 mg TVB-N/100g flesh are indicated as 'spoiled' (Schormuller, 1968) [15]. The TVB-N content of the dried products produced was about 11 mg/100g in all the three fishes. Such a low content of TVB-N in dried fishes compared

to fresh fish could be explained by evaporation of volatile compound during drying. Sen *et al.* (1961) [16] reported that TVB-N value of the sun dried fish product varied from 32.5 to 41.0 mg/100g.

Table 2: Biochemical and microbial quality indexes of fresh and sun dried fish

Species	Treatment	TVB-N	PV	TBA	APC
Mystus gulio	Fresh	14.0 ± 0.12	3.55 ± 0.27	0.68 ± 0.02	3.51 ± 0.01
	Sun dried	11.67 ± 0.46	3.78 ± 0.11	0.70 ± 0.02	3.51 ± 0.04
Puntius sophore	Fresh	13.07 ± 1.23	2.61 ± 0.45	0.87 ± 0.03	4.36 ± 0.02
	Sun dried	11.73 ± 0.44	4.14 ± 0.13	0.72 ± 0.02	3.59 ± 0.06
Gudusia chapra	Fresh	12.27 ± 0.33	2.60 ± 0.35	0.66 ± 0.04	3.47 ± 0.01
	Sun dried	11.27 ± 0.66	3.85 ± 0.09	0.69 ± 0.01	3.50 ± 0.02

Lipid and lipid degraded compounds

Fresh fish appeared to be relatively low in lipid contents. The values were 5.69 ± 0.03, 4.49 ± 0.20 and 4.43 ± 0.13% for *M. gulio*, *P. sophore* and *G. chapra* respectively. In view of their lipid content the three species studied could be considered as semi fatty fish. These values are raised by sun drying of fish. After sun drying of fish the greatest increase of lipid content was observed in *Mystus gulio* (15.10 ± 0.50%) followed by *G. chapra* (13.96 ± 1.49) and *P. sophore* (13.91 ± 1.53). Total lipid contents increased due to reduction of moisture contents. Akinneye *et al.* (2010) [17] observed lower fat content in the sun-dried fish than that of smoke-dried fish. The lower fat content observed in sun-dried fish could be associated with the oxidation of fat during the period of sun drying (McGill *et al.*, 1974) [18].

Rancidity development was measured by means of primary (PV) and secondary (TBARS) lipid oxidation compound formation. The peroxide value (mmoles of O_2/Kg fat), indicative of primary oxidative products (Balachandran, 2001) [19], was observed in fresh sample of *Mystus gulio* – 3.55, *Puntius sophore* – 2.61 and *Gudusia chapra* – 2.60 those registered a significant ($p < 0.05$) difference between Species to species (Table 2). Many workers suggested that peroxide value gives a measure of the first stages of oxidative rancidity which does not necessarily correlate well with the sensory assessment of fish. Connell (1995) [20] suggested peroxide value10 – 20 as limiting value in case of fresh fish. The PV of dried *Mystus, Puntius* and *Gudusia* were found to be 3.78, 4.14 and 3.85 respectively. The higher PV of dried fish products might be attributed to the oxidation of lipids during the drying process (Aitken and Connell, 1979) [21]. The PV is not related to actual sensory quality of products, which may indicate a potential for a later formation of objectionable compounds. The oxidation of fat during drying may lead to rancid flavour (Tsuchiya, 1961) [22].

TBA index is a widely used indicator for the assessment of degree of lipid oxidation (Nishimoto *et al.*, 1985) [23]. TBA concentration proved to be most sensitive to variations over the storage time of fish fillets in ice (Hernandez *et al*., 2009) [24]. Thiobarbituric acid reactive substances (TBARS) in muscle of all the three fish species were in the range of 0.66 to 0.87 mg malonaldehyde/Kg meat, where the lowest value was attributed in *Gudusia chapra* and highest value was attributed in *Puntius sophore* (Table 2). The differences in lipid oxidation possibly resulted from different initial fat content and from the different fatty acid compositions (Benjakul *et al.*, 2005) [25]. Sundried fish flesh of *M. gulio, P. sophore* and *G. chapra* contained the TBARS value of 0.70, 0.72 and 0.69 mg malonaldehyde/Kg meat respectively. On a nutritional point of view, a food product is considered acceptable if its TBARS index is < 1 mg malonaldehyde/Kg meat of this product (Kezban and Nuray, 2003) [26]. The increase in extent of lipid oxidation is a general phenomenon of aerobically stored, dehydrated fishery products (Horner, 1992[27]; Jeevanandam *et al.*, 2001) [28].

Changes in microbial load (APC)

The parameters that proved to be most sensitive to variations over storage time were TBA concentration, aerobic mesophilic, psychrophilic, enterobacteria and coliform counts, and all attributes related to the sensory analysis (Hernandez *et al*., 2009) [24]. The evolution of microbial growth in *M. gulio, G. chapra* and *P. sophore* is shown in Table 2. The bacterial count (log *cfu* g^{-1} meat) of fresh fishes was observed in the range of 3.47 to 4.36, where the least value was attributed to *G. chapra* and highest value was attributed to *P. sophore*. Fish flesh starts visibly to spoil when bacterial level rises above 10^7 *cfu* g^{-1} (Lakshmanan, 2005) [29]. Total viable count (TVC) value of 7 log *cfu* g^{-1} is considered as the upper acceptability limit for fresh water and marine species as defined by ICMSF (2002) [30]. The dried products of different fish species produced from the Day-1 fish had APC (log *cfu* g^{-1} meat) ranging from 3.50 to 3.59 with the lowest in *G. chapra* and highest in *P. sophore*. The dried products had a microbial load of around 5 log *cfu* g^{-1}. ICMSF (1986) [31] suggested acceptable limit of bacterial load in dry fish as < 5 log *cfu* g^{-1}. Abraham *et al.* (1993) [32] and Basu *et al*. (1989) [33] reported microbial load of around 5 log *cfu* g^{-1} in dried marine fishes.

Sensory Evaluation

When evaluating fish quality, freshness is one of the most important attributes. The freshness and quality of the end-product depend on different biological and processing factors that have an influence on the fish changes that occur post mortem (Huss, 1995) [34]. The organoleptic characteristics of fresh fish was graded using the scores from 1-10. On the basis of the score, all the fishes exhibited excellent quality. The fishes were very fresh with natural flavour and odour and had characteristics of freshly caught fish (Table 3).

The initial sensory quality of the dry fish depends on the quality of the raw materials. Karthikeyan *et al.* (2007) [35] observed sensory score in the range of 5.7-7.3 (on 10-Point hedonic scale) of dried fish collected from the markets of Tripura. The organoleptic characteristics of dried fish products such as general appearance, colour, odour and texture were judged using the scores from 1-5. Excellent quality of dried products having bright shining surface, attractive colour and characteristic odour with firm texture were obtained (Table 3).

Table 3: Sensory quality aspects of fresh fish and solar tent dried fish products

Treatment	General appearance	Colour	Odour	Texture	Overall quality
Fresh	Eye fresh, red gills	Bright red gills	Natural muddy odour	Moderately firm and elastic	Excellent
Sun dried	Bright and shining surface	Slight browning	Characteristic of dry fish odour	Flexible and firm	Excellent

Conclusion

On the basis of organoleptic characteristics, biochemical and microbial evaluation, all the three commercial valued freshwater fish species such as *Mystus gulio*, *Puntius sophore* and *Gudusia chapra* can produced good quality dried fish products under solar tent dryer. The dried products produced, possess the characteristic fish odour with flexible texture and ultimately help the dry fish producers to get higher market price for their products.

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Annexure I: Scale employed for sensory evaluation of freshwater fish stored in ice

General appearance	Texture	Odour	Score
Bright opalescent sheen, cornea transparent, eyes perfectly fresh, convex black pupil, bright red gills, slime transparent, no bleaching	Very firm, elastic to finger touch, fish not yet in rigor, scale very firmly attached to skin	Muddy odour	10
Eye fresh, slightly convex, black pupil, red gills, slime translucent, cornea translucent	Moderately firm, elastic, fish in pre rigor	Muddy odour	9
Eyes flat, very slight gray pupil, dull red gills, slightly translucent cornea	Firm, moderately elastic, scale firmly attached to skin, fish in rigor	Slightly muddy odour, no off odour	8
Slime translucent, eyes flat, slight gray pupil, loss in red colour of gills	Slightly firm, slightly elastic, fish in rigor	Odour of seaweed and mud	7
Eyes slightly, gray pupil, slight opalescent cornea, discoloration of gills, some mucus, outer slime slightly opaqu	Slight soft, some grittiness near tail, fish passing out of rigor	No off odour	6
Eyes sunken, pale pupil, opaque cornea, slime opaque, some mucus, light brown gills	Moderately soft, moderate grittiness, slightly loose scales, fish in post rigor	Slight decayed odour of weed	5
Eyes completely sunken, milky white pupil, opaque cornea, brown gills	Soft, definite grittiness, slightly loose flesh, scale easily removable	Decayed odour of weed	4
Eyes completely concave, head sunken with thick slime, gills exhibit bleaching and dark brown discoloration	Very soft, marked grittiness, loosened flesh, scales, easily rubbed off the skin	Stale cabbage, phosphine like odour	3
Eyes completely concave, sunken head and body, cornea and pupil milky white, body covered with yellowish mucus or slime	Very soft flabby, slight retaining of finger indentation, flesh easily torn	Ammoniacal with strong odour	2
Eyes loose and completely concave, body and head sunken and discoloured, bloom completely gone, thick yellowish slime or mucus	Extremely soft and flabby, strong retention of marks, flesh very easily torn	Indole, faecal, H_2S, strong ammoniacal and putrid odours	1

Annexure II: (5 point) Scale employed for sensory evaluation of dried fish

Quality attribute	Characteristics	Sensory scores	Quality
General Appearance	Bright and shining surface	5	Excellent
	Slight dullness with shining surface	4	Very good
	Dull with surface	3	Good
	Definite dullness with surface	2	Poor
	Dry fish like, loss of weight, fungal growth	1	Rejected
Colour	Like as fresh fish	5	Excellent
	Slight browning	4	Very good
	Brownish	3	Good
	Dark brown	2	Poor
	Gray yellowish	1	Rejected
Odour	Strong characteristic of dry fish odour	5	Excellent
	Light characteristic of dry fish odour	4	Very good
	Slight off odour	3	Good
	Slight rancid	2	Poor
	Rancid	1	Rejected
Texture	Flexible and firm	5	Excellent
	Slightly soft	4	Very good
	Limp and flaccid muscle	3	Good
	Slightly fibrous	2	Poor
	Fibrous	1	Rejected