

Optimum Processing Conditions And Shelf-life Of Smoked Striped Catfish(*Pangasius sutchi*)

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Abstract

Striped catfish (*Pangasius sutchi*) is a fatty fish which possesses a specific non-palatable flavour. Processing of this species into value-added smoked product so as to improve flavour and odour was therefore studied. The appropriate conditions for brining and dry curing were studied using 15, 20 and 26% brine for 10, 20 and 30 min, and salt to fish ratios of 1:3, 1:5 and 1:7 for 20, 30 and 40 min, respectively. Sample with the highest acceptability scores ($P \leq 0.05$) of each curing method was selected for further study on appropriate conditions of natural smoking using coconut hull. Smoking temperatures at 60, 70 and 80°C were studied for the smoking time of 2 and 3 hr at each temperature.

The proper conditions were found to be brining with 26% brine for 10 min, then smoking at 60°C for 3 hr or dry salting with salt to fish ratio of 1:7 for 20 min and smoking at 60°C for 2 hr.

Introduction

Smoked fish is a popular traditional product in Thailand, where it is known as *pla krob*. In general, it is made from freshwater fish such as butter catfish, sheat fish or minnow. *Pla krob* is crisp-dried to make it preservable at ambient temperature, whereas the Western style of hot-smoking fish produces a soft product with high moisture content, eg smoked salmon. Many species of freshwater and marine fish in Thailand have the potential to be used as raw material for hot smoking.

Striped catfish was one of the economical freshwater species suggested by the Department of Fisheries. In 1985, the total harvest of freshwater fish in Thailand was 75,254 mt of which 13,786 mt (18.3%) was striped catfish (Department of Fisheries, 1987). Because the supply for fresh consumption is much higher than the demand, the price of striped catfish is low. For this reason, it is necessary to process striped catfish in order to produce a ready-cooked item, such as smoked product, and thus add value to the raw material. Striped catfish is a fatty fish which possesses non-palatable flavour but it has bright yellow colour and soft flesh that should be suitable for hot smoking to improve its flavour and odour.

The objective of this study is to find the proper conditions for natural smoking of striped catfish with coconut hull.

Materials And Methods

Raw Material

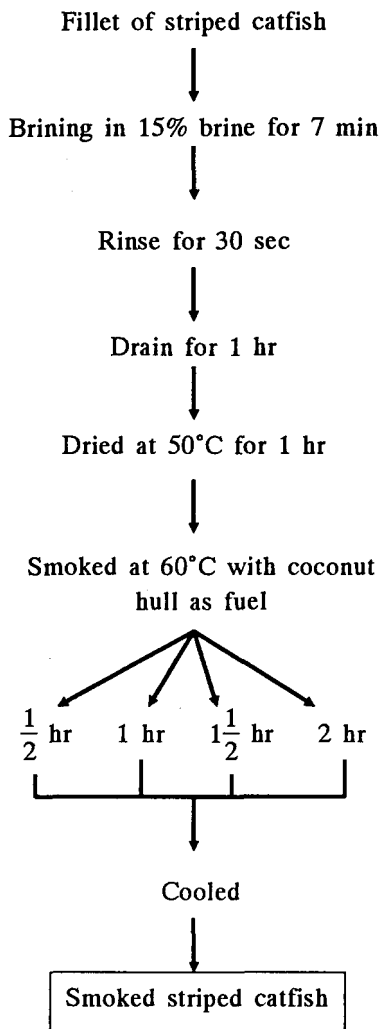
Striped catfish (*Pangasius sutchi*)

Methods

1. Quality Standard Of Acceptable Smoked Striped Catfish

At the present time, there is no quality standard for smoked fish; thus it is necessary to set up the acceptable quality to be used in further studies.

The preparation of smoked striped catfish was as follows:



Sensory evaluation of product was carried out by a panel of 12 persons familiar with the product. The panel judged the raw product for colour and appearance, and the cooked product for flavour, saltiness, texture and overall acceptability using a 9-point hedonic scale. The smoked fillet was trimmed to 1.6 cm² (0.5 in²), skinned and microwave cooked for 1 min before serving to the judges. The result was statistically analyzed using

completely randomized design (CRD). The moisture content was also determined (AOAC, 1980).

2. Preparation And Quality Analysis Of Raw Material

Striped catfish was sampled for quality analysis, ie freshness, K-value (Uchiyama, 1978), proximate composition (AOAC, 1980).

3. Appropriate Conditions Of Salting And Smoking

Two salting methods were used, wet and dry salting. The brine concentrations, ratio of fish to salt and salting time were varied to get a product with at least 3% water phase salt (WPS) which is enough in inhibit the germination and toxin production of *Clostridium botulinum* type E while the flavour of the product is still acceptable (Christiansen *et al*, 1968).

3.1. Proper Salting Condition

Striped catfish was headed, gutted, washed and filleted. Fat was trimmed off. The fillet was divided into 2 parts and salted as follows.

3.1.1. Brine Salting

The fish was soaked in brine at a fish to brine ratio of 1:1 (wt/wt). The brine concentrations were 15, 20 and 26%. The soaking times were 10, 20 and 30 min for each concentration.

3.1.2. Dry Salting.

The second stage consisted of dry salting with salt-to-fish ratio of 1:3, 1:5 and 1:7 (wt/wt) for 20, 30 and 40 min for each ratio. Both salted fillet from 3.1.1 and 3.1.2 were smoked as follows:

Results

Acceptability Of Smoked Striped Catfish

See Table 1.

Preparation And Analysis Of Quality Of Raw Materials

The striped catfish used was very fresh with clear eyes, red gill, bright skin, fresh odour and elastic texture. Weight of the fillet ranged from 180 - 200 g, thickness ranged from 1.6 - 1.8 cm. The colour of the flesh was yellowish orange with layer of fat (Table 2).

3.2.1. Appropriate Conditions Of Salting

3.2.1.1. Wet Salting

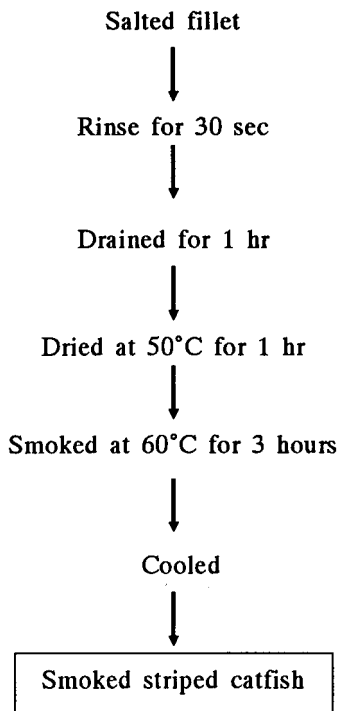
It was found that brine concentration and salting time have no effect on colour and texture but that they significantly affected appearance ($P \leq 0.05$) and that there was interaction effect between brine concentration and salting time on saltiness, flavour and overall acceptability ($P \leq 0.01$) (Tables 3 and 4).

Statistical analysis of the average of WPS and moisture content showed that brine concentration and salting time had significant effects on WPS and moisture content respectively (Table 5).

Appropriate Condition Of Dry Salting

It appeared that fish : salt ratios and salting time had no effect on colour, appearance and texture of smoked product but significantly affect flavour ($P \leq 0.01$). Both salting time and fish to salt ratios had interacting effects on saltiness and overall acceptability (Table 6).

Statistical analysis of WPS and moisture content showed that fish : salt ratio and salting time had significant effects on WPS and moisture content.



Smoked striped catfish were analyzed for WPS, using the following formula :

$$WPS (\%) = \frac{\% NaCl}{\% NaCl + \frac{\% Moisture}{content}} \times 100$$

(Weckel and Wosje, 1966; Mill, n.d.). Moisture contents and sensory evaluation for colour, appearance, saltiness, flavour, texture and overall acceptability were also recorded.

The results were statistically analyzed by Symmetric Factorial Experiment 3 x 3 and Duncan's New Multiple Range Test.

3.2. Appropriate Conditions For Smoking

From 3.1. we selected the best salting conditions. Smoking was carried out in a Torry Kiln using coconut hull as fuel. The temperatures studied were 60, 70 and 80°C for 2 and 3 hr.

Table 1. Sensory evaluation score and moisture content of smoked striped catfish at 60°C for 30, 60, 90 and 120 min.

Smoking Time (min)	Moisture Content (%)	Average Sensory Score \pm SD			
		Colour ¹	Appearance ¹	Texture ¹	Overall ¹ Acceptability
30	76.62 \pm 0.75	3.00 \pm 0.93	2.88 \pm 0.83	3.50 \pm 0.53	3.38 \pm 0.52
60	74.62 \pm 1.07	3.63 \pm 1.41	4.00 \pm 0.93	4.63 \pm 0.92	4.25 \pm 0.71
90	72.83 \pm 0.60	4.75 \pm 1.16	4.50 \pm 1.07	5.25 \pm 0.46	4.50 \pm 0.53
120	71.28 \pm 0.48	7.50 \pm 0.53	7.88 \pm 0.83	7.63 \pm 0.74	7.75 \pm 0.46

¹ Significantly different ($P \leq 0.05$)

Table 2. Proximate composition and freshness index of raw striped catfish.

	Average value ¹ \pm S.D.
K-value (%)	10.77 \pm 1.61
Protein (%)	16.89 \pm 0.79
Fat (%)	2.23 \pm 0.47
Moisture content (%)	79.22 \pm 1.05
Ash (%)	1.35 \pm 0.05

¹ Average of 4 determinations.

Appropriate Smoking Condition

Appropriate Smoking Condition Of Striped Catfish Prepared By Wet Salting At 26% Brine For 10 Min

It appeared that smoking time did not affect all characters tested but smoking temperature significantly affected saltiness and texture (Table 9). Both smoking time and temperature had interacting effects on colour, appearance and overall acceptability (Table 10).

Statistical analysis of WPS and moisture content showed that smoking temperature and time had interacting effects on WPS and moisture content respectively.

Appropriate Smoking Condition Of Striped Catfish Dry Salting At Salt : Fish Ratio Of 1:7 For 20 Min

It appeared that smoking time had no effect on sensory evaluation scores but that smoking temperature affected colour, appearance, flavour, texture and overall acceptability of the product ($P \leq 0.01$). There was no interacting effect of smoking time and temperature on sensory score.

Statistical analysis of WPS and moisture content showed that smoking temperature affected WPS but that smoking time had no effect ($P \leq 0.05$). Interaction of smoking temperature and time significantly affected moisture content ($P \leq 0.01$).

Discussion

Quality Standard Quality Standard Of Acceptable Smoked Striped Catfish

Smoked striped catfish was prepared according to the procedure of the Fishery Technological Development Division. The smoked product was tested for colour, appearance, texture and overall acceptability as well as moisture content. As Table 1 indicates, the product smoked for two hours with a moisture content of 71.28% was the most preferred sample. Samples with moisture content between 76.62 - 72.83 % had a lower acceptability score ($P \leq 0.05$). The most acceptable product was

Table 3. Sensory evaluation score of smoked striped catfish prepared at different brine concentration and salting times of 10, 20 and 30 min.

Brine Concentration (%)	Average Values \pm S.D.								
	Saltiness			Flavour			Overall Acceptability		
	10min	20min	30min	10min	20min	30min	10min	20min	30min
	aA	aA	aA	aA	aA	aA	aA	aA	aA
15	7.33 \pm 0.75	7.42 \pm 0.95	7.50 \pm 0.76	7.50 \pm 0.76	7.33 \pm 0.85	7.08 \pm 0.64	7.17 \pm 0.69	7.33 \pm 0.75	7.25 \pm 0.60
	aA	bA	cB	aA	aA	aB	aB	aA	bB
20	7.67 \pm 0.85	7.17 \pm 0.80	4.67 \pm 1.03	7.58 \pm 0.86	7.50 \pm 0.96	5.25 \pm 0.83	7.67 \pm 0.75	7.50 \pm 0.96	4.67 \pm 0.75
	aA	bB	cC	aA	bB	cC	aB	bB	cC
26	7.75 \pm 0.72	4.92 \pm 1.62	3.33 \pm 1.03	7.67 \pm 0.85	5.92 \pm 0.64	4.00 \pm 1.15	7.87 \pm 0.55	5.25 \pm 0.72	3.17 \pm 0.80

a,b,c values in the same line followed by different letter are significantly different ($P \leq 0.05$)

A,B,C values in the same column followed by different letter are significantly different ($P \leq 0.05$)

Table 4. Sensory evaluation score of appearance of striped catfish prepared at different brine concentration and salting time.

Brine concentration (%)	Average score \pm S.D.
15	8.03 ^a \pm 0.25
20	7.81 ^{ab} \pm 0.13
26	7.72 ^b \pm 0.05

a,b values followed by different letter in column are significantly different ($P \leq 0.05$).

Table 6. Sensory evaluation score of smoked striped catfish prepared at different ratio of fish : salt and salting time.

Salting time (min)	Average \pm S.D.
20	7.83 ^a \pm 0.09
30	6.53 ^b \pm 0.50
40	6.31 ^b \pm 0.13

a,b values followed by different letter are significantly different ($P \leq 0.05$).

Table 5. WPS and moisture content of smoked striped catfish prepared at different brine concentration and salting times of 10, 20 and 30 min.

Brine concentration (%)	Average \pm SD					
	WPS (%)			Moisture Content (%)		
	10min	20min	30min	10min	20min	30min
15	aA	bA	cA	aA	aA	bA
	1.96 \pm 0.03	2.53 \pm 0.18	2.84 \pm 0.07	69.50 \pm 0.28	69.70 \pm 0.13	68.51 \pm 0.13
	aB	bB	cB	aA	aA	bB
20	2.21 \pm 0.13	2.85 \pm 0.09	3.85 \pm 0.09	69.37 \pm 0.34	69.18 \pm 0.14	67.23 \pm 0.23
	aC	bC	cC	aA	aB	bB
	26	3.39 \pm 0.13	4.02 \pm 0.13	5.26 \pm 0.13	69.30 \pm 0.20	69.02 \pm 0.11

a,b,c values in the same line followed by different letter are significantly different ($P \leq 0.05$).

A,B,C values in the same column followed by different letter are significantly different ($P \leq 0.05$).

Table 7. Sensory evaluation score of saltiness and overall acceptability prepared at different fish : salt ratios and salting times of 20, 30 and 40 min.

Salt : Fish ratio	Average \pm SD					
	Saltiness			Overall Acceptability		
	20min	30min	40min	20min	30min	40min
	aA	bA	bA	aA	bA	bA
1:3	7.33 \pm 0.94	3.75 \pm 1.23	3.26 \pm 1.14	7.75 \pm 0.43	3.75 \pm 0.92	3.33 \pm 1.03
	aA	bA	bB	aA	bB	bB
1:5	7.50 \pm 0.96	4.25 \pm 0.72	4.25 \pm 1.01	7.83 \pm 0.69	4.92 \pm 0.76	4.42 \pm 1.04
	aA	bB	cB	aA	bC	bC
1:7	7.67 \pm 0.75	6.58 \pm 0.95	5.00 \pm 0.82	8.00 \pm 0.71	6.67 \pm 1.05	6.00 \pm 0.71

a,b,c values in the same line followed by different letter are significantly different ($P \leq 0.05$).

A,B,C values in the same column followed by different letter are significantly different ($P \leq 0.05$).

Table 8. WPS and moisture content of smoked striped catfish prepared at different fish : salt ratios and salting times of 20, 30 and 40 min.

Salt : Fish Ratio	Average \pm SD					
	WPS (%)			Moisture content (%)		
	20min	30min	40min	20min	30min	40min
	aA	bA	bA	aA	bA	cA
1:3	3.78 \pm 0.23	5.00 \pm 0.12	5.17 \pm 0.07	68.66 \pm 0.26	66.79 \pm 0.30	67.36 \pm 1.10
	aA	bB	cB	aB	aB	bB
1:5	3.72 \pm 0.30	4.25 \pm 0.15	4.79 \pm 0.12	68.28 \pm 0.08	68.45 \pm 0.01	66.99 \pm 0.24
	aA	bC	cB	aB	bC	aC
1:7	3.62 \pm 0.03	3.89 \pm 0.04	4.62 \pm 0.02	68.13 \pm 0.14	69.47 \pm 0.04	68.37 \pm 0.03

a,b,c values in the same line followed by different letter are significantly different ($P \leq 0.05$).

A,B,C values in the same column followed by different letter are significantly different ($P \leq 0.05$).

Table 9. Sensory evaluation score of saltiness, flavour and texture of smoked striped catfish prepared by wet salting and smoked at different smoking time and temperature.

Smoking Temperature (°C)	Average \pm SD		
	Saltiness	Flavour	Texture
60	7.92 ^a \pm 0.12	8.09 ^a \pm 0.12	8.19 ^a \pm 0.33
70	7.50 ^b \pm 0.10	7.54 ^b \pm 0.06	7.13 ^b \pm 0.59
80	7.65 ^{ab} \pm 0.09	7.29 ^b \pm 0.06	5.94 ^c \pm 0.21

a, b, c values in the same column followed by different letter are significantly different ($P \leq 0.05$).

Table 10. Sensory evaluation score of colour, appearance and overall acceptability of smoked striped catfish prepared by wet salting at different temperatures and times of 2 and 3 hr.

Smoking Temperature (°C)	Average \pm SD					
	Colour		Appearance		Overall	
	2hr	3hr	2hr	3hr	2hr	3hr
	aA	bA	aA	bA	aA	bA
60	7.58 \pm 0.49	8.33 \pm 0.62	7.63 \pm 0.46	8.33 \pm 0.62	8.08 \pm 0.49	8.50 \pm 0.50
	aA	bB	aA	bB	aB	bB
70	7.67 \pm 1.03	6.21 \pm 0.75	7.42 \pm 0.64	6.17 \pm 0.80	7.46 \pm 0.63	6.67 \pm 0.94
	aB	aC	aB	aC	aC	bC
80	4.83 \pm 0.69	4.92 \pm 0.76	4.54 \pm 0.95	4.50 \pm 0.87	5.67 \pm 0.85	5.17 \pm 0.99

a,b,c values in the same line followed by different letter are significantly different ($P \leq 0.05$).

A,B,C values in the same column followed by different letter are significantly different ($P \leq 0.05$).

Table 11. WPS and moisture content of smoked striped catfish prepared by wet salting and smoked at different temperatures and times of 2 and 3 hr.

Smoking Temperature (°C)	Average \pm SD			
	WPS (%)		Moisture Content (%)	
	2hr	3hr	2hr	3hr
	aA	bA	aA	bA
60	3.33 \pm 0.49	3.62 \pm 0.04	71.70 \pm 0.18	69.61 \pm 0.11
	aA	bA	aB	bB
70	3.27 \pm 0.09	3.58 \pm 0.03	69.91 \pm 0.01	68.14 \pm 0.11
	aB	aA	aC	bC
80	3.58 \pm 0.06	3.55 \pm 0.06	67.07 \pm 0.10	66.15 \pm 0.23

a,b,c values in the same line followed by different letter are significantly different ($P \leq 0.05$).

A,B,C values in the same column followed by different letter are significantly different ($P \leq 0.05$).

Table 12. Sensory evaluation score of colour, appearance, flavour, texture and overall acceptability of smoked striped catfish prepared by dry salting and smoked at different temperature and time.

Smoking Temperature (°C)	Average \pm SD				
	Colour	Appearance	Flavour	Texture	Overall Acceptability
60	7.75 ^a \pm 0.47	7.83 ^a \pm 0.35	7.87 ^a \pm 0.23	8.08 ^a \pm 0.42	7.83 ^a \pm 0.42
70	6.25 ^b \pm 0.24	5.96 ^b \pm 0.06	7.52 ^b \pm 0.03	6.58 ^b \pm 0.06	6.62 ^b \pm 0.12
80	5.50 ^c \pm 0.00	5.12 ^c \pm 0.06	7.44 ^b \pm 0.03	5.91 ^c \pm 0.12	6.21 ^c \pm 0.06

a, b, c values in the same column followed by different letter are significantly different ($P \leq 0.05$).

Table 13. WPS of smoked striped catfish prepared by dry salting and smoked at different smoking times and temperatures.

Smoking Temperature (°C)	WPS (%) ± S.D.
60	3.54 ^a ± 0.03
70	3.13 ^b ± 0.13
80	3.49 ^a ± 0.17

a, b values followed by different letter are significantly different ($P \leq 0.05$).

yellowish-brown or golden-brown, smooth and soft in glossy texture. Other samples with higher moisture content had lighter colour and soggy texture. It could be concluded that the product smoked for two hours was the most acceptable. It was similar to smoked chubs with 61.19 - 72.65% moisture content (Graham, Hamilton and Pierson, 1986). Thus, moisture content around 71% or lower was selected as a standard for using in further studies.

Preparation And Quality Analysis Of Raw Material

The striped catfish used in the experiment was alive so its K-value was very low (10.77%). In general, fish with K-value lower than 20% was judged very fresh and can be eaten raw since its protein were not denatured (Uchiyama, 1978).

The proximate composition showed that striped catfish had more than 2% fat content (Cole and Greenwood-Barton, 1965). This fish with inter-muscular fat is suitable for smoking because the finished product will have soft texture.

Appropriate Conditions Of Salting And Smoking

Appropriate Salting Condition

1. Wet Salting

The appropriate brine concentration and bringing time were 26% for 10 min, respectively with WPS higher than 3% required for inhibition of toxin production of *Clostridium botulinum* (Christiansen *et al*, 1968). As seen in Table 4, the highest appearance score (8.03) was obtained at 15% brine,

Table 14. Moisture content of smoked striped catfish prepared by salting and smoked at different temperatures and times of 2 and 3 hr.

Smoking Temperature (°C)	Average Moisture Content ± S.D.	
	2hr	3hr
60	70.26 ^{aA} ± 0.03	69.50 ^{bA} ± 0.06
70	69.19 ^{aB} ± 0.03	67.28 ^{bB} ± 0.13
80	68.54 ^{aC} ± 0.01	65.48 ^{bc} ± 0.01

a,b,c values in the same line followed by different letter are significantly different ($P \leq 0.05$).

A,B,C values in the same column followed by different letter are significantly different ($P \leq 0.05$).

but at 15% brine salting time had no effect on saltiness (Table 3). At 20 and 26% brine concentration, the fish salted for 20 and 30 min had a lower saltiness score than the fish salted for 10 min ($P \leq 0.05$). Thus 10 min was selected as an appropriate salting time. Brine concentration, together with brining time, affected the moisture content of the finished product. At a higher salt content the moisture content tended to be lower. This may be due to the fact that high salt denatured protein and decreased the water-holding capacity of the muscle protein (Dell Valle and Ganzalez Inigo, 1968).

2. *Dry Salting*

From Table 7 we see that salting time between 20 and 30 min and ratio of salt : fish affected saltiness of the product significantly. The smoked product salted for 20 min, had the highest acceptable score for flavour and WPS was also higher than 3%. Fish : salt ratios had shown antagonism effects with salting time on moisture content of the product.

At a salt to fish ratio of 1:3, moisture content was decreased, when salted for 20-30 min - more than that of the sample salted at salt : fish ratio of 1:5, and salted for 40 min.

At salt : fish ratio of 1 : 7 moisture content was slightly changed. Moisture content of samples salted at salt : fish ratio of 1 : 5 and 1 : 7 were not significantly different and were lower than the set standard of 71%.

From sensory evaluation scores, WPS and moisture content, dry salting at a salt fish ratio of 1:7 for 20 min was selected as the best condition. Shorter processing time is required because it will provide a better control of contamination (Ragulin, 1985).

Appropriate Smoking Condition

1. *Fish Prepared By Wet Salting At 26% Brine For 10 Min.*

It appeared that smoking at 60°C yielded a product with higher sensory score for saltiness,

flavour, and texture than those smoked at 70 and 80°C. Smoking at 80°C yielded a product which was too dry, probably due to the denaturation of skinned fillet by heating and moisture loss (Suryanarayama Rao and Khabada, 1968; Deng, Toledo and Lillard, 1974).

Smoking time at 80°C had no effect on colour and appearance but both had sensory scores lower than 5, which was the borderline, and could have been due to the melting of intramuscular fat between skin and flesh and denaturation of the tissue which connect skin and muscle protein (Suzuki, 1981). High temperature will catalyse the Maillard reaction at the skin of the product which will darken the colour of the product (Ruiter, 1979). Statistical analysis of WPS and moisture content (Table 11) showed that at 70°C for 2 hr and 60°C for 3 hr the latter had higher WPS with 69.61% moisture content which was acceptable. This sample also had highest sensory evaluation score. Thus smoking at 60°C for 3 hr was selected.

2. *Appropriate Smoking Condition Of The Fish Prepared By Dry Salting With Salt : Fish Ratio Of 1:7 For 20 Min.*

Smoking time had no effect on all sensory evaluation scores, but smoking temperature did affect the sensory scores. Smoking at 60°C for 2 hr appeared to produce the highest score for acceptable samples which also have acceptable WPS and moisture content.

Thus smoking at 60°C for 2 hr was selected for striped catfish dry-salting at salt to fish ratio of 1:7 for 20 min.

Conclusion

1. Acceptable smoked striped catfish should have not more than 71% moisture content, 3-4% WPS.
2. The appropriate conditions of natural smoking using coconut hull were:
 - 2.1 Wet salting at 26% brine for 10 min and smoking at 60°C for 3 hr.
 - 2.2 Dry salting at salt to fish ratio of 1:7 for 20 min and smoking at 60°C for 2 hr.

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Discussion

Since smoked fish is a semi-dried product and susceptible to mould growth, a participant asked why analysis for mould was not included in the study. Miss Kiatkungwalkrai said this has not been a storage study but one aimed at developing a processing technique. In any case, the product has about 69% moisture and must be kept chilled.

Clarifying the price breakdown in producing this product, Miss Kiatkungwankrai replied that fresh catfish costs ₪ 8-10/kg, while the yield was of the final product is 26%. This works out to be between ₪ 30 to ₪ 40/kg cost price.

Asked whether there was any commercial production of smoked striped catfish in Thailand, she replied that there is no commercial production at the moment. On the subject of product quality, she noted that while traditional smoked products from other kinds of catfish were dry and quite hard, this new type of product is moist and soft.

Regarding the storage life of the product, she replied under 5-7°C, two months storage was possible. If kept frozen, the period was six months.