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Brining parameters for the processing of smoked river carp (*Leptobarbus hoevenii*)

[Parameter penggaraman untuk pemprosesan ikan jelawat (*Leptobarbus hoevenii*) salai]

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Keywords: fishery product, smoked fish, brine concentration, brining time, smoking procedure

Abstract

The effect of brine concentrations and brining times on the quality of smoked river carp was studied using 10% and 20% brines. The mean water-phase salt content in smoked fillets brined in 20% salt solution was significantly higher (p <0.05) than those brined in 10% salt solution especially at pre-rigor stage. However, 5 min brining time in both brine concentrations was insufficient to produce a safe smoked river carp fillets of a minimum 3.5% water-phase salt content. Brine concentration at 20% and 20 min brining time produced a significant curvilinear relationship (p <0.01). The water-phase salt contents in smoked fillets from both rigor stages increased significantly (p <0.01) with the increase in brining time until the point of saturation. The critical water-phase salt content of ≥3.5% in pre-rigor and post-rigor smoked fillets was obtained after 5.9 and 5.4 min brining respectively. No significant difference (p >0.05) in the mean scores for colour, taste and overall acceptability for all smoked fillets with different salt contents. The result from the validation experiment confirmed that river carp fillets brined for 10 min in 20% salt solution before smoking produced a smoked product with 5.2% water-phase salt content (i.e. more than the critical 3.5% in the final product).

Introduction

Fish may be smoked by cold, hot or a combination of both smoking techniques. Hot smoked fish is more popular in the Asian and African countries where fish of any suitable species is treated with smoke generated from burning or smouldering wood at a temperature which will cause complete coagulation of the fish flesh. Fish is normally salted before smoking. Different salting methods are being practised by the smoked fish industry in different parts of the world (Espe et al. 2001; Jittinandana et al. 2002). Fish may be subjected to dry salting, wet salting, brine salting or injection salting prior to smoking.

Outbreaks of botulism and listeriosis associated with smoked fish consumptions have been reported by many researchers (Dillon and Patel 1993; Heinitz and Johnson 1998). Sunen et al. (2003) found that smoke wood condensates from four types

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of wood causes a reduction in viable counts of *Listeria monocytogenes,* but not able to reduce the total viable cells to undetectable levels. Outgrowth of the pathogenic organisms may be due to insufficient salt and temperature abuse during processing, storage and distribution.

United States Food and Drug Administration had specified that water-phase salt in vacuum-packed, hot smoked-fish must be at least 3.5% when no nitrite is added to prevent the growth of *Clostridium botulinum* type E (USFDA 1998). However, it is difficult to achieve uniform salt distribution in fish flesh during brining operations. Factors such as fish species, size, muscle thickness, fat content, salting methods and ratio between fish and salt affect the salt uptake during brining (Hyytia et al. 1999; Cardinal et al. 2001; Jittinandana et al. 2002).

Various brining techniques had been reported by researchers working on different fish species. Hassan (1988) had recommended brine concentrations of 15% and 24% (w/v) salt with brining time of 48 h followed by desalting process to achieve a water-phase salt of more than 3.5% for common carp. Smoked carp brined in 15% salt solution is more preferred in terms of taste and texture (Hassan 1988). Yanar et al. (2006) reported that 5% brine was optimal for prevention of lipid oxidation during storage of hot-smoked tilapia at 4 °C but this product had a water-phase salt content of only 2.09%. They also reported that other fish products that had been subjected to 1 hour brining time in 10% and 15% brine had water-phase salt of more than 3.5% and longer shelf life in terms of the formation of total volatile bases (TVB-N).

Smoked Atlantic salmon had been salted by different techniques including dry-salting technique, injection with 21% brine, immersion in 20% brine solution and immersion in saturated brine solution (Wang et al. 1998; Hyytia et al. 1999; Wang et al. 2000; Cardinal et al. 2001). Kosak and Toledo (1981) recommended a two-stage brining procedure, 15 h in 10% brine followed by 24–48 h in 2% brine, to minimize differences in water-phase salt between thin and thick section of fish after hot smoking. This procedure, although efficient, requires a low temperature brining room to overcome the problem of microbial growth during the long brining process especially under hot tropical condition. Hence, a better technique with short brining time is seen as more appropriate under tropical conditions.

The pre-treatments used before filleting was reported to affect the fillet quality in terms of fillet colour, pH, incidence of gaping after storage and final yield after processing (Skjervold et al. 2001). They found that the incidence of gaping in Atlantic salmon was significantly reduced and the visual colour was better by pre-rigor filleting. The distribution of salt in different sections of a smoked Atlantic salmon fillet was not uniform because the fillet is thick at the upper part and tapers down to the tail end (Wang et al. 2000; Rora et al. 2004).

Salt uptake involved both mechanical and biochemical aspects of the muscle. During salting, salt and other curing compounds penetrated into the fish muscle, while water and soluble components were leached out, thus reducing the water activity of the product. The most uniform distribution of salt within each salmon fillet was obtained in the injection-salting (Rora et al. 2004). They found large variation in salt content between the middle and lower layers of dry-salted fillets. Therefore, a suitable processing practice must be developed for a particular species of fish to ensure the production of safe and quality product.

Farmed river carp, locally known as 'jelawat', is a popular cultured species in Asia. Other than being consumed as table fish, its utilization in the downstream processing is very limited. Che Rohani and Mat Arup (1997) reported that river carp can be used as a raw material for smoked fish. No study has been reported on the brining parameters for the production of smoked river carp, therefore this study was conducted to determine appropriate processing and brining parameters for the production of safe and acceptable smoked river carp.

Materials and methods

Raw materials

Farmed river carp (*Leptobarbus hoevenii*) of the same age group, weighing 0.9–1.2 kg each were obtained from fish farms in Perak. At each harvest, the fish was divided into two lots and weighed, each with a minimum of 50 fish.

One of the lots was randomly selected and immediately bled, gutted and filleted by cutting the fish muscles as close as possible to the backbone and rib bones from the head to the tail part. The fillets were cleaned, soaked in 5% salt solution for 15 min to remove surface slime and dipped into 0.1% polyphosphate solution for 30 s before being weighed, iced and transported to the processing laboratory at MARDI Kuala Terengganu.

The rest of the fish were allowed to reach full development of body stiffening before being gutted and packed in ice and transported to the processing laboratory. Filleting was done in the laboratory after the fish body stiffening was resolved and its full movement of the muscle was regained (post-rigor stage). The fish regained their muscle flexibility after 72–80 h in ice.

Brining process

In the first experiment, two brining solutions, each containing 10% and 20% (w/w) sodium chloride (NaCl), were prepared to determine the appropriate brining parameters for river carp. Iced fillets from pre-rigor and post-rigor filleting were rinsed in clean water and divided into four lots each. Each lot was assigned at random to each of the four treatments group; treatment combinations are 10% and 20% brining solution for 2 and 5 min brining times, at ambient temperature. The experiment was replicated four times at different time of harvest.

In the second experiment, iced fillets from pre-rigor and post-rigor filleting were brined in 20% brine solution and also divided into four lots each. Each lot was assigned at random to each of the brining time of 2, 5, 10 and 20 min to study the relationship between salt uptake and brining time for both rigor stages. This experiment was replicated three times. Brown sugar (2%, w/v), garlic and turmeric powder (0.1% and 0.2% each, w/v) were also added to all brine solutions to give a better flavour and colour to the smoked products.

The third experiment was conducted to validate the optimum processing conditions using pre-rigor filleting and brining in 20% brine solution for 10 min.

In all experiments, a minimum of 25 skin-on fillets were used in each treatment combination. A fillet-to-brine ratio of 1:2 (w/v) was used and fillet was submerged throughout the brining period. After brining, the fillets were placed on racks and drained overnight in a walk-in chiller (1–2 °C) to allow brine equilibration and facilitate pellicle formation during smoking.

Smoking procedure

A smoke-kiln (AFOS, Hull, UK) was used for smoking using smoke generated from ‘meranti’ sawdust. Brined fillets were hung on smoking hooks and smoked for 1 h at 40 °C followed by 2 h at 60 °C and cooked at 85 °C to reach the internal temperature of 66 °C and held at 85 °C for another 30 min. This procedure was in accordance to FDA guidelines for hot smoked fish that requires internal temperature of the fish to be maintained at or above 63 °C for at least 30 min.

Three thermocouple probes (Ellab, Denmark) attached to a digital Fo meter were inserted into the thickest part of three separate fillets places at the top, middle and bottom part of the smoking chamber to monitor the final core temperature of the fillet during smoking. Smoked fillets were cooled at ambient temperature, packed in polyethylene bags and stored at 1 °C for evaluation.

Yield measurement

Fillet yield after filleting at different rigor stages and smoking was calculated on fresh fish weight basis.

Chemical analysis and colour measurement

The moisture, ash, protein and fat contents were determined using AOAC procedures (AOAC 1990). Samples from the first and second experiments were analysed only for moisture, fat and salt contents. The raw and smoked fillets were randomly selected from the third experiment for proximate composition analysis and colour measurement since the smoked sample in this experiment was prepared under optimum brining condition.

The colour of the raw and smoked fillets was measured at the anterior, median and posterior parts of fillet using a Minolta Chromameter CR-300 (Japan) for CIE 1976 L* a* b* colour space with standard illuminant D_{65} according to manufacturer's guidelines. The L* values represent lightness, positive and negative a* represent redness and greenness respectively and positive and negative b* represent yellowness and blueness respectively.

Sensory evaluation

The sensory responses of the samples were evaluated by a trained panel (n = 10) using a 9-point hedonic scale (Larmond 1970).The attributes evaluated were colour, taste and overall acceptability (1 = dislike very much, 9 = like very much).

Salt uptake

Salt content was determined by the Mohr method. Salt was extracted by water from the pre-weighed sample and after precipitation of the proteins; the chloride concentration was determined by titrating an aliquot of the solution with a standardized silver nitrate solution and calculated as sodium chloride. Percentage of water-phase salt content was calculated as (percentage of sodium chloride x 100)/(percentage of sodium chloride + percentage of moisture) (Heinitz and Johnson 1998).

Experimental design

In experiment 1, a 2*2 factorial trial at two levels of brine concentration and brine time were arranged in a randomized complete block design with four replicates for pre-rigor and post-rigor stages. Analytical data and sensory evaluation data were analysed statistically using the software program package SAS version 8.1 (SAS Inst. 1985). Data were subjected to analysis of variance (ANOVA) by using the general linear model procedure. A combined analysis of variance on the whole data set was also conducted to detect any statistical differences among the rigor stages. If significant differences among treatment means were noted for a measurement, the comparison of means were determined using the Duncan Multiple Range Test.

In experiment 2, regression analysis was used to detect the relationship between salt uptake and brining time.

Data for proximate analysis, colour measurement and yield was analysed using independent samples t-test to compare the two treatment means of the raw and smoked fillets.

Results and discussion

Two-way analysis of variance showed that the water-phase salt in the smoked fillets showed a significant interaction between rigor stages, brine concentration and brining time (p <0.05). The water-phase salt in the smoked fillets increased significantly (p <0.05) with the increased in brining time and brine concentration except for the pre-rigor fillet brined in 10% brine solution (*Table 1*). None of the brining conditions gave a product with a water-phase salt content higher than 3.5% as required to prevent survival and outgrowth of *Clostridium botulinum* Type E spores.

Table 1. The mean (n = 8) salt and fat contents in smoked river carp subjected to different brining parameters

Treatment	Brining parameters		Water-phase salt content (g/100 g) (*)	Fat content (g/100 g) (**)
	Brine concentrations (%, w/w)	Brining time (min)		
Pre-rigor filleting	10	2	1.69 ± 0.15e	13.00 ± 0.49d
	10	5	1.98 ± 0.32ed	11.45 ± 0.66e
	20	2	2.55 ± 0.35c	11.50 ± 0.47e
	20	5	3.29 ± 0.36ab	14.73 ± 2.92cb
Post-rigor filleting	10	2	2.11 ± 0.17d	14.05 ± 0.79c
	10	5	3.00 ± 0.40b	15.50 ± 0.38b
	20	2	3.05 ± 0.37b	18.45 ± 0.89a
	20	5	3.48 ± 0.17a	14.81 ± 0.54cb

Mean values within the same column followed by same letter are not significantly different *(p >0.01)*
**Significant at p <0.01; *Significant at p <0.05

Under a short brining time of 5 min used in this study, the salt uptake by pre-rigor fillets in both brine concentrations was lower than the uptake in post-rigor fillets (*Table 1*). Similar finding was reported by Lauritzsen et al. (2004) working with salted cod and prolonged salting up to 28 days at low temperature. The salt uptake during the initial stage of brining was lower in pre-rigor fillet compared to post-rigor fillet. They concluded that the lower salt uptake was influenced by the high amount of adenosine triphosphate (ATP) present in the pre-rigor fish muscle at salting that lead to higher resistance to influx of sodium chloride during salting.

Both pre-rigor and post-rigor smoked fillets brined in 20% brine for 5 min had significantly the highest water-phase salt content of 3.3% and 3.4% respectively. There was also a significant 3-factor interaction (p <0.01) in the fat contents of smoked fillets used in this study, however, there was no specific trend shown. This was probably attributable to the variation in fat content of the fish used in this study even though the fish was from the same age group and farm. Lipid content in fish muscle had been shown to be affected by the many factors including the fish age, dietary oil and natural variation (Robb et al. 2002). The fat content affects the salt uptake by fish fillets during brining. Salt uptake is higher in leaner and smaller Atlantic salmon than in fish with high fat content (Cardinal et al. 2001).

The state of fish rigor-mortis has been reported to affect the fillet quality. Most studies had been conducted with temperate fish. Pre-rigor filleting significantly improves the quality attributes such as gaping, texture and colour of the fillets (Skjervold et al. 2001; Taylor et al. 2002). The amount of fillet gaping in temperate marine fishes due to the breakdown of the tubular junction between the ends of muscle cells and the myocommata is reduced by filleting at pre-rigor stage (Fletcher et al. 1997; Skjervold et al. 2001; Lauritzsen et al. 2004).

In this study, no significant difference (p >0.05) in the fresh fillet yield was obtained by filleting at pre-rigor or post-rigor state. However, the yield after processing of smoked river carp was significantly higher (p <0.05) when fish was filleted at pre-rigor stage compared to filleting at post-rigor (*Table 2*). The process yield obtained by filleting at pre-rigor and post-rigor states was 38.3% and 34.0% respectively. Higher process yield obtained in pre-rigor smoked river carp was expected to be related to the amount of gaping. Gaping exposed more surface area for moisture loss during smoking. Pre-rigor fillet has less gaping and more intact cell structure that prevent moisture loss (Roth et al. 2009).

It was observed that the number of river carp fillet with substantial gaping was higher in post-rigor fillet than in pre-rigor fillet. This finding was in agreement with other studies on temperate fish. Roth et al. (2009) recently reported higher gaping in post-rigor salmon fillet than in pre-rigor fillet. These post-rigor fillet had higher drip loss that lead to lower process yield of salted smoked salmon. Lauritzsen et al. (2004) also found that pre-rigor salting resulted in higher weight loss after 25 days of salting, hence lower yield of heavily salted cured cod compared to fish salted post-rigor or after freezing. However, Rora et al. (2004) reported that the process yield of dry salted Atlantic salmon fillet was not affected by filleting pre- rigor or post-rigor.

Table 2. Effect of rigor-mortis on the yield of raw and smoked river carp fillet

Treatment	Yield (wholefish basis) (%)	
	Raw fillet (ns)	Smoked fillet (*)
Pre-rigor filleting	46.02a (±1.51)	38.28a (±2.15)
Post-rigor filleting	43.07a (±2.90)	33.96b (±1.33)

Mean values within the same column followed by same letter are not significantly different (p <0.01)
*Significant at p <0.05

Table 3. Mean scores of smoked river carp sensory attributes at different parameters

	Colour	Taste	Overall acceptability
Brine conc. (%,w/v)			
10	7.28a	7.04a	7.07a
20	7.26a	6.97a	6.98a
Brining time (min)			
2	7.34a	7.01a	7.01a
5	7.20a	7.00a	7.03a
Rigor stage			
Pre-rigor filleting	7.26a	6.87a	6.92a
Post-rigor filleting	7.27a	7.14a	7.13a

Means (column wise) with the same letter are not significantly different (p >0.05)

The treatment means of smoked river carp sensory attributes for colour, taste and overall acceptability were not significantly different (p >0.05) from each other for all the three factors studied (*Table 3*). The rigor status during filleting, the brine concentrations and the brining time used in the first experiment did not have any significant effect on the sensory attributes of the products. The results indicated that the products were well accepted by the taste panel regardless of their water-phase salt contents which ranged from 1.7% to 3.4%. The mean score for all attributes was about 7.0. Goulas and Kontominas (2005) also found that the taste, colour and texture of smoked chub mackerel were not affected by the salting and smoking method. Hassan (1988) reported that the organoleptic acceptability of smoked carp was not affected by the salt content.

Therefore, a higher brine solution with longer brining time was chosen for the next stage of the experiment. The increase in salt content in smoked fillets brined in 20% brine solution has a curvilinear relationship with respect to the brining times (*Figure 1*). The regression model describing their relationship could be expressed as below where Y is the water-phase salt content and X is the brining time:

Pre-rigor: $Y = 1.5960 + 0.3839*X - 0.0098*X*X$
Post-rigor: $Y = 2.5809 + 0.1930*X - 0.0040*X*X$

The coefficient of determination (R^2) for the pre-rigor was 0.9366 and for post-rigor was 0.7362 respectively.

The above equations indicate that both the intercept and the slope are significant (p <0.01) for the two rigor stages. The trends showed that the increase of salt content was faster in pre-rigor fillets even though it was comparatively low during the initial period of brining. This may be contradictory with the results of other researchers working with Atlantic salmon and much longer salting

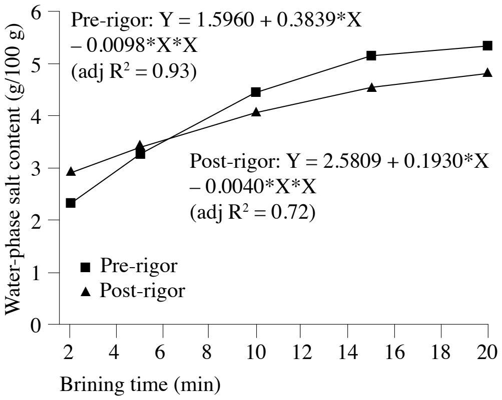

Figure 1. Relationship between salt content and brining time of pre-and post-rigor smoked river carp fillets brined in 20% brine solution

period (Wang et al. 1998; Wang et al. 2000). Wang et al. (1998) reported that the salt uptake in post-rigor Atlantic salmon slices soaked in 20% salt solution for a period of 6–48 h was higher than in pre-rigor muscle.

However in this study, a different species of fish farmed in a tropical habitat and a very short brining time compared to that used in temperate fish, may contribute to this contradictory results. The exact rigor-stage at the time of brining and smoking of the pre-rigor fillet used in this study was unknown since these fillets had been kept in ice during transportation from the farm to the processing laboratory for the brining and smoking processes.

Rigor-mortis is a complex process that affects the quality of processed fish including salted and smoked fish. It is associated with the breakdown of adenosine triphosphate (ATP) in dead fish. It starts when permanent actin and myosin linkages are formed and the fish develops a full body stiffening (Wang et al. 1998). Rigor-mortis is resolved after some time. Cultivated Atlantic salmon went into rigor-mortis 8 h after death and resolved fully after 60–70 h (Wang et al. 1998). The different source of oils used in the fish diet had been shown to affect the rate of rigor-mortis in Atlantic cod. Dietary inclusion of soybean oil in fish feed resulted in faster rigor contraction, firmer texture immediately after slaughter and paler fillets colour (Morkore 2006).

The treatment means sensory score for colour, taste and overall acceptability of smoked river carp brined in 20% brine solution were not significantly different (p >0.05) from all the variables regardless of their brining times from 2–20 min and rigor status used in this study (*Table 4*). Smoked fish samples with about 2–6 % salt in the water-phase were equally acceptable to the panellists.

The regression equations for salt uptake in pre-rigor and post-rigor fillets may be used to calculate the salt uptake during brining in 20% brine solution (*Figure 1*). The critical water-phase salt content of ≥3.5% in pre-rigor and post-rigor smoked fillets can be obtained after 5.9 and 5.4 min brining respectively. If 10 min brining is used, the final water-phase salt content in smoked river carp is expected to be 4.4% in pre-rigor fillet and 4.1% in post-rigor fillet.

To validate this calculated water-phase salt in smoked river carp, a third experiment was conducted using pre-rigor fillet. The results in *Table 5* confirmed that a safe water-phase salt of more than 3.5% was obtained with 10 min brining time in 20% salt solution used in the validation experiment. The water-phase salt in the smoked product was 5.2%, slightly higher than the calculated 4.4% from the regression equation.

The mean moisture, protein and fat contents in raw fillet were 67.1, 18.1 and 14.1% respectively. The mean moisture content decreased significantly (p <0.01) in smoked fillets, while the protein and ash contents (on wet weight basis) increased significantly (p <0.01) due to moisture loss during brining and smoking (*Table 5*). However, the fat content remained unchanged. Similar increase in protein content on wet weight basis was reported by other researchers working with temperate fish (Espe et al. 2001; Yanar et al. 2006). Jittinandana et al. (2002) found that increasing the brine concentration

Table 4. Duncan Multiple Range Test (DMRT) for comparing smoked river carp fillet sensory attributes at each brining time in 20% brine solution

Rigor status	Brining time (min)	Sensory attributes		
		Colour	Taste	Overall acceptability
Pre-rigor fillet	2	7.3a	6.9a	6.9a
	5	7.1a	7.0a	7.0a
	10	7.4a	7.0a	7.0a
	20	7.6a	7.3a	7.1a
Post-rigor fillet	2	7.4a	7.0a	7.0a
	5	7.2a	7.0a	7.0a
	10	7.5a	7.4a	7.3a
	20	7.5a	7.4a	7.2a

Means (column wise) with the same letter are not significantly different (p >0.05)

Table 5. Proximate composition and colour readings of raw and smoked river carp fillets

Sample	Proximate composition (g/100 g flesh) (values in parentheses indicate dry weight basis)					Colour readings		
	Moisture (**)	Protein (**)	Fat	Ash (**)	Salt (**) (water-phase in bracket)	L (**)	a (**)	b (**)
Raw fillet	67.1a	18.1b (55.0)	14.1a (42.8)	1.0b	0.1b [0.3]	56.17a	–1.59b	2.08b
Smoked fillet	61.7b	20.4a (53.3)	14.5a (37.8)	4.4a	3.4a [5.2]	43.89b	16.18a	24.58a

Mean values within the same column followed by same letter are not significant (p >0.01)
**Significant at p <0.01; *Significant at p <0.05

from 8.7% to 17.4% had increased the fillet weight loss both after brining and smoking.

Comparing both the fat and protein contents on dry weight basis before and after smoking, the results in *Table 5* shows that both fat and protein contents had actually decreased slightly from 42.8% to 37.8% and from 55% to 53.3% respectively. Similar findings were reported by Espe et al. (2001) and Yanar et al. (2006) who worked on smoked tilapia and Atlantic salmon respectively. Espe et al. (2001) reported a decrease in total fat content in smoked Atlantic salmon and they observed higher fat losses in fish salted by brine salting than in fish salted by dry salting.

Birkeland and Bjerkeng (2004) found that salt-soluble proteins were extracted into the brines during processing regardless of the NaCl-concentration but the highest protein losses during brining occurred at pH 6–7. Both actin and myosin heavy chain were realeased in pH 6.5 brines after immersion of the fish (Martinez-Alvarez and Gomez-Guillen 2005).

Smoked river carp fillet had an attractive light red-yellow colour as indicated by the increase in the a* (redness) and b* (yellowness) values (*Table 5*). River carp fish is a fatty fish with a fat content of 14.1% (*Table 5*), hence produced a good quality smoked fillet with a glossy and attractive appearance. Fish with high fat content has been reported to give a better yield after processing and an attractive product (Cardinal et al 2001).

Robb et al. (2002) had conclusively showed that the increase in muscle lipid content of smoked Atlantic salmon had significantly increased the overall flavour and overall liking of the product by the taste panel. They recommended that fish for smoking should be properly graded according to the lipid content to minimize variation in the eating quality of the smoked product.

Conclusion

Farmed river carp fish produced a good smoked fillet with good colour, taste and texture. A short time brining protocol in 20% sodium chloride solution for a minimum of 10 min was sufficient to produce a smoked product that was well accepted by the trained taste panellists and met the safety requirement in terms of critical salt content.

Fish may be filleted at pre-rigor or post-rigor stage and brined in 20% brining solution for a minimum of 10 min before smoking at 40–85 °C for a total of 4 h to reach a final core temperature of 66 °C and water-phase salt content of 5.2%. Pre-rigor filleting will give a higher process yield and a more attractive smoke fillet with less occurrence of gaping. The final water-phase salt content in the smoked river carp fillet can be calculated using the regression models derived in this study which was validated to be slightly higher than the calculated value.

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Abstrak

Kesan kepekatan garam dan tempoh proses penggaraman terhadap mutu ikan jelawat salai dikaji menggunakan 10% dan 20% larutan garam. Kandungan purata garam fasa-air di dalam ikan salai yang menggunakan 20% larutan garam adalah lebih tinggi (p <0.05) berbanding dengan yang menggunakan 10% larutan garam terutamanya bagi filet sebelum rigor. Walau bagaimanapun, tempoh penggaraman selama 5 minit dalam 10% dan 20% larutan garam tidak menghasilkan filet jelawat salai yang dapat memenuhi keperluan kandungan garam fasa-air minimum sebanyak 3.5%. Penggunaan 20% larutan garam dengan tempoh penggaraman 20 minit meningkatkan penyerapan garam secara selanjar melengkong yang signifikan (p <0.01). Kandungan garam fasa-air di dalam kedua-dua jenis filet sebelum dan selepas rigor meningkat secara signifikan (p <0.01) dengan meningkatnya tempoh penggaraman sehinggalah ia menghampiri titik penepuan. Kandungan garam fasa-air kritikal sebanyak ≥3.5% dapat dicapai dalam 5.9 minit bagi filet sebelum rigor dan 5.4 minit bagi filet selepas rigor. Tiada perbezaan signifikan (p >0.05) dalam warna, rasa dan penerimaan keseluruhan bagi kesemua filet ikan salai. Kajian penentusahan membuktikan filet jelawat yang direndam selama 10 minit di dalam 20% larutan garam sebelum disalai telah menghasilkan produk dengan kandungan garam fasa-air sebanyak 5.2% iaitu melebihi nilai kritikal 3.5%.

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