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Process Development of Smoked Hybrid Clarias Catfish Fillets Using Fresh Lemon Grass Extract

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ABSTRACT

Crude lemon grass extract was prepared by blending fresh lemon grass in water (1:1 w/v), filtering and adding 5% NaCl (w/v). Soaking fresh catfish fillets in crude lemon grass extract for 45 minutes prior to drying at 50°C in a hot-air oven for 1 h before smoking for 1 h at 60°C and drying for 45 min at 60°C resulted in products with the highest consumer acceptability. The water activity (a_w) of the products was 0.932, color parameters L*, a* and b* were 44.41, 6.36 and 9.40, respectively while moisture, protein, fat, ash and carbohydrate contents were 62.1, 24.0, 10.3, 1.2 and 2.4%, respectively. Total count for bacteria was $3.25x10^2$ and for yeast and mold was <3 CFU/g. The acceptability of the products based on appearance, color, odor and flavor ranged from moderate to high. The shelf life of smoked, catfish fillets treated with lemon grass extract could be extended from two to nine days when packed in PA/LDPE bags under atmospheric conditions and stored at ambient temperature and extended from 9 to 36 days if stored at a chilled temperature (4±2°C). The shelf life of treated samples packed under a vacuum could be extended from 5 to 17 days at ambient temperature and from 15 to more than 60 days at 4-6°C.

Key words: smoked fish, hybrid Clarias catfish, shelf life, lemon grass extract

INTRODUCTION

Hybrid Clarias catfish is a cross breed of walking catfish (*Clarias macrocepalus*) and African catfish (*Clarias gariepinus*) and is called "Big Aui" in Thai. As it has a rapid growth rate, resistance to diseases and adapts readily to changes in its environment, it has been widely introduced and become popular among fish farmers. Production has increased rapidly causing an oversupply and a consequent lowering of the selling price. Production of the catfish accounted for 30-32% of the total value of freshwater aquaculture in Thailand during 2001-2004 (Department of Fisheries, 2007) and hybrid catfish accounts for over 90% of catfish production in Thailand (Poompuang and Na-Nakorn, 2004). Due to the delicious taste, versatility and year-round availability as well as its rather low price, hybrid Clarias catfish has achieved country-wide popularity. Apart from the variety of cooked dishes widely consumed, processed catfish is also commercially produced. One of the most popular and widely-acceptable, processed catfish products is smoked whole fish or smoked fillets.

Smoking of fish has a long tradition as a preservation method and is still widely used in fish processing. Smoked catfish has a pleasant odor

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and flavor. Hot smoking in mild conditions at a temperature not exceeding 65°C combined with a low concentration of salt does not neutralize all pathogens nor inhibit bacterial growth during storage (Sikorski and Kolodziejska, 2002). Typically, lightly-salted, mildly-heated, smoked fish contains a high moisture content ranging between 40-80% and a_w between 0.73-0.99, which are suitable conditions for microbial growth (Dodds *et al.*,1992). The shelf life of smoked, stripped catfish was reported to be 2-3 days at 5-10°C and about one week at 4°C (Kietkangwanklai, 1989). Products with a short shelf-life are limited to commercial marketing.

The use of herbs for curing is of interest, because it is believed that as herbs are 'natural' products, they are qualified as 'safe'. Some spices and herbs used today are valued for their antimicrobial activities and medicinal effects in addition to their flavor and fragrance qualities. The extracts of many plant species have become popular in recent years and attempts to characterize their bioactive principles have gained momentum for various pharmaceutical and food processing applications. The antimicrobial properties of plant extracts form the basis of many applications, including: raw and processed food preservation, pharmaceuticals, alternative medicines and natural therapies (Lis-Balchin and Deans, 1997). Some research has been done on the inhibitory effect of herbs on microorganisms that contaminate foods, including: basil, marjoram, sage, and thyme on yeast and *Yarrowia lipolytica* on raw chicken (Ismail *et al.*, 2001); and mustard essential oil, cinnamon, garlic and cloves on common fungi in bread (Nielsen and Rios, 2000). However, only limited studies on the application of herbs to fish products have been reported.

This study aimed to develop a process for extending the shelf life of smoked catfish by using fresh lemon grass, a common Thai herb with a long history of use. A successful outcome was considered beneficial not only as an alternative for the consumer but was also expected to promote increased sales for the aquaculture sector.

MATERIALS AND METHODS

Fresh hybrid Clarias catfish samples with an average weight of 250 g each were purchased from a local market and transported to the laboratory within 2 h. Fresh lemon grass (*Cymbopogon citratus* (DC.) Stapf) stems were purchased from a local market, washed and cut into small pieces.

Crude extract preparation

A crude extract was prepared by mixing the crushed lemon grass with water using a ratio of 1:1 (w/v), in a blender (National: MK-5080M) for five minutes at a moderate speed and then another five minutes at a fast speed. After filtering with gauze, the crude extract was immediately used.

Smoked fish preparation

Whole catfish were cleaned, beheaded and filleted under controlled temperature conditions not exceeding 4°C. An untreated, control sample of fillets was soaked in 5% chilled brine, using a ratio of fish to brine of 1:1 (w/v) for 30 min. The treated samples were soaked in crude lemon grass extract with 5% salt under the same conditions. The fillets were drained, dried at 50° C for 1 h and then smoked at 60°C for 1 h in a gas/electric-automatic, controlled, hot-air, smoking chamber (King Co. Ltd., Thailand) using bagasse as the smoking source. The products were taken out of the smoker, left until they reached room temperature and then packed individually in PA/LDPE bags.

Process development for smoked catfish

Determination of a suitable crude extract concentration and soaking time

Two concentrations of crude extracts

were prepared as described above by varying the ratio of crushed lemon grass to water (1:1 and 1:2; w/v). Smoked catfish samples were prepared as described above with the different concentrations of the crude herb extract and soaking times of 30, 40 and 60 min. Thirty panelists selected from staff and graduate students in the Department of Fishery Products, Faculty of Fisheries, Kasetsart University evaluated samples using a sensory score based on a nine-point hedonic scale for appearance, color, odor, flavor, texture and overall liking of the product. The optimum concentration and soaking time that gave the highest scores were then used for the next stage.

Determination of drying conditions after smoking

Smoked catfish fillets treated with lemon grass extract were prepared under the optimum conditions determined described earlier. After smoking, samples were dried in a hot-air oven at a range of temperatures (60, 65, 70°C) and for a range of times (30, 45, 60 min). The moisture content, a_w, color parameters and nine-point hedonic sensory scores were evaluated. The optimum temperature and time that gave the lowest a_w with high sensory scores were identified.

Determination of the physical, chemical and sensory quality of treated catfish fillets

Proximate analysis was undertaken according to AOAC (2000), with a_w measured using a thermoconstanter (Novasina, Zurich, Switzerland) at 25°C and the color parameters (L* a* b*) measured with a chromameter (Minolta, Co., Ltd., Japan, Model CM-3500). Microbiological analysis involved measuring total plate counts (CFU/g) according to AOAC (2000) for: yeast and mold; *S. aureus; Salmonella sp.*; *C. perfringens*; *C. botulinum;* and *V. cholera;* and also for *E. coli* (MPN/g).

Shelf life of treated smoked catfish

Samples of smoked catfish fillets treated with lemon grass extract and processed under the optimum conditions determined according to the procedures described above were packed individually in PA/LDPE bags under either atmospheric or vacuum conditions and then kept at either ambient temperature (30±2°C) or a chilled temperature (4±2°C). Sensory evaluation by the 30 panelists who had judged the products during the process-development stage was carried out using a nine-point hedonic scale. Samples were warmed in a microwave oven at 850 watts for 30 seconds before evaluation. The total plate count of the samples was also determined according to AOAC (2000). Both sensory evaluation and microbial determination were carried out daily for the samples kept at ambient temperature and every three days for those samples kept at a chilled temperature until a sensory score of less than six or a total plate count of more than 10^6 CFU/g was reached.

Statistical analysis

The results were subjected to analysis of variance (ANOVA) and Duncan's new multiple range test (DMRT). Differences among the means were determined at $p \leq 0.05$. Experiments were performed in duplicate using a completely randomized design (CRD) and a completely randomized block design (RCBD) during process development. Analyses were run in triplicate.

RESULTS AND DISCUSSION

Optimum crude extract concentration and soaking time

The sensory scores for appearance, color, odor, flavor, texture, and overall liking of the samples treated with different lemon-grass extract concentrations (crushed herb to water ratios of 1:1 and 1:2) and soaking times (30, 45, 60 min) are shown in Table 1. It was found that concentration and soaking time did not affect the odor and texture attributes ($p>0.05$). Samples treated with a 1:2 ratio

Table 1 Mean sensory scores of lemon grass-extract-treated, smoked, catfish fillets prepared by varying the concentration of extract and soaking time.

Condition[x]	Sensory attributes					
	Appearance*	Color*	Odor[ns]	Flavor*	Texture[ns]	Overall liking*
1:1/30	7.20±0.96^{abc}	7.26±1.17^{ab}	7.00±1.53	7.45±1.32^{ab}	7.50±1.00	7.45±0.89^{ab}
1:1/45	7.43±0.81^{ab}	7.53±1.04^{a}	7.46±0.97	7.78±0.88^{a}	7.51±0.93	7.71±0.58^{a}
1:1/60	6.83±1.11^{c}	6.93±1.20^{b}	7.30±1.08	7.85±0.93^{a}	7.36±1.03	7.38±0.97^{ab}
1:2/30	7.03±1.06^{bc}	7.20±1.24^{ab}	7.20±1.21	7.48±1.10^{ab}	7.36±1.06	7.43±1.07^{ab}
1:2/45	7.21±0.90^{abc}	7.20±1.09^{ab}	7.03±1.27	7.10±1.24^{b}	7.13±1.25	7.15±1.26^{b}
1:2/60	6.90±1.29^{c}	6.86±1.56^{b}	6.96±1.24	7.05±1.52^{b}	7.43±0.89	7.00±1.21^{b}
Control[1]	7.60±0.77^{a}	7.60±1.07^{a}	6.80±1.24	7.55±1.16^{ab}	7.50±1.00	7.36±0.88^{ab}

a,...,c Means within a column followed by different superscript letters are significantly different ($P \leq 0.05$)

* significantly different($P \leq 0.05$) ns non significant ($P > 0.05$)

x ratio of herbs: water / soaking time in min

[1] control sample, soaked in 5% chilled brine for 30 min

extract had a lower score for all attributes than the samples treated with 1:1 ratio extract. A soaking time of 60 min produced the lowest scores, followed by soaking for 30 min, while soaking for 45 min had the highest scores for every attribute. Treating the smoked catfish with lemon grass extract seemed to have little effect on the appearance and color with only slightly lower scores than the control. The results from this study indicated that the optimum lemon grass extract concentration was crushed herb to water with a ratio of 1:1 (w/v) and a soaking time of 45 min. Treatment under these conditions produced samples with the highest sensory scores for all attributes.

Conditions for reducing the retained moisture after smoking

After smoking, the products had quite high moisture retention. An experiment was conducted with the aim of reducing the retained moisture before packing for storage. During the storage period, product stability mainly depended on the a_w value of the final products. However, excessive moisture reduction was considered to have an adverse effect on the products' texture. Sensory scores (Table 2) showed that increasing the drying temperature to 60°C also increased the sensory score for texture, whereas at 65°C and 70° C the texture acceptability tended to decrease with increased drying time. Varying the drying conditions did not affect the flavor of samples ($p>0.05$), but slightly affected color and odor ($p\leq0.01$). Drying at 70°C for 60 min obtained the highest overall liking scores (7.98), with high scores for appearance (7.46), color (7.56) and texture (7.88), but a low score for odor (6.91) as the sample was considered to be too smoky. Along with the sensory characteristics, the effect of drying condition on the moisture content and a_w value were also investigated and the results are presented in Table 3. The moisture content and a_w value of all treatments ranged between 56-64% and 0.93-0.98, respectively. Taking both sensory and physical characteristics into account, the optimum conditions were drying at 60°C for 45 min. Under these conditions, the samples had almost the lowest a_w value (0.932) with high acceptable sensory scores.

Physical, chemical and microbiological quality of lemon-grass-treated catfish fillets

Catfish fillets treated with lemon grass extract (herb to water ratio = 1:1) for 45 min, first dried at 50°C for 1 h, smoked at 60°C for 1 h and final dried at 60°C for 45 min were analyzed for

Table 2 Mean sensory scores of lemon grass-treated, smoked, catfish fillets by varying drying temperature and time after smoking.

Condition[x]	Sensory attributes					
	Appearance*	Color**	Odor**	Flavor[ns]	Texture[ns]	Overall liking*
60/30	7.81±0.49[c]	7.81±0.67[ab]	7.63±0.61[a]	7.70±0.65	7.16±0.64[f]	7.73±0.59[ab]
60/45	7.61±0.73[ab]	7.58±0.78[bc]	7.63±0.85[a]	7.70±0.74	7.53±0.77[de]	7.70±0.81[ab]
60/60	7.30±0.98[bc]	7.20±0.99[d]	7.50±0.86[ab]	7.66±0.75	7.56±0.77[ef]	7.53±0.78[b]
65/30	7.58±0.72[ab]	7.56±0.81[bcd]	7.43±0.93[ab]	7.58±0.96	8.16±1.08[ab]	7.56±0.80[b]
65/45	7.56±0.72[ab]	7.60±0.67[bc]	7.50±0.90[ab]	7.68±0.85	7.70±0.65[cde]	7.60±0.75[b]
65/60	7.40±0.72[bc]	7.45±0.69[bcd]	7.20±0.66[bc]	7.63±0.71	7.43±0.80[ef]	7.58±0.69[b]
70/30	7.30±0.88[bc]	7.33±0.88[cd]	7.60±0.81[a]	7.63±0.66	8.00±1.11[bc]	7.95±1.22[a]
70/45	7.30±0.95[bc]	7.40±0.96[cd]	7.60±0.72[a]	7.63±0.71	7.10±0.84[f]	7.51±0.67[b]
70/60	7.46±0.86[abc]	7.56±0.77[bcd]	6.91±0.91[c]	7.60±1.02	7.88±1.31[bcd]	7.98±1.21[a]
Control[1]	7.15±0.92[c]	8.13±1.22[a]	7.66±0.60[a]	7.80±0.53	8.36±0.71[a]	7.81±0.72[ab]

a,...,d Means within a column followed by different superscript letters are significantly different ($P \leq 0.05$)

* significantly different ($P \leq 0.05$) ** highly significantly different ($P \leq 0.01$) ns non significant ($P > 0.05$)

x Drying Conditions: Temperature in °C / Time in min

[1] Control sample with no treatment after smoking at 60°C for 1 h

Table 3 Moisture content and a_w value of lemon grass-treated, smoked catfish by varying drying temperature and time after smoking.

Condition[x]	Moisture content**	a_w**
60/30	64.98±0.20[a]	0.984±0.0005[a]
60/45	62.00±0.62[abc]	0.932±0.0005[h]
60/60	59.12±0.67[cde]	0.934±0.001[g]
65/30	64.85±2.95[a]	0.983±0.0005[b]
65/45	62.19±0.97[abc]	0.940±0.0005[e]
65/60	58.37±2.74[de]	0.935±0.0005[f]
70/30	63.66±0.35[ab]	0.974±0.0005[c]
70/45	60.35±2.66[bcd]	0.956±0.0005[d]
70/60	56.60±1.00[c]	0.930±0.001[i]
Control[1]	64.72±2.17[b]	0.984±0.0005[a]

a,…,i Means within a column followed by different superscript letters are significantly different ($P \leq 0.05$)

** highly significantly different ($P \leq 0.01$)

x Drying conditions: Temperature in °C / Time in min

[1] Control sample with no treatment after smoking at 60°C for 1 h

moisture content, a_w, color parameters (L*,a*, b*), proximate composition and microbiological quality. The results indicated that samples containing a high protein content (24%) and not contaminated with pathogenic bacteria were safe for consumption (Table 4). However, these products still contained quite a high moisture content (62.1%) and a_w value (0.932) which may limit their storage period.

Shelf life of lemon grass-treated, smoked catfish stored under air or vacuum at ambient or chilled temperature

The treated samples were prepared using the optimum conditions described above, packed in PA/LDPE bags and stored at ambient (30±2°C)

Table 4 Physical, chemical and microbiological properties of lemon-grass-treated, catfish fillets.

Physical property	a_w	0.932
	Color parameters L*, a*, b*	44.41, 6.36, 9.40
Chemical composition	Moisture (%)	62.1
Protein (%)		24.0
Fat (%)		10.3
Ash (%)		1.2
Carbohydrate (%)		2.4
Microbiological analysis	Total plate count (CFU/g)	3.5×10^2
	Yeast and mold (CFU/g)	<10
	E. coli (MPN/g)	<3
	S. aureus (CFU/g)	not detected
	Salmonella sp. (CFU/g)	not detected
	C. perfringens (CFU/g)	not detected
	C. botulinum (CFU/g)	not detected
	V. cholerae (CFU/g)	not detected

or chilled (4±2°C) temperatures. The shelf life of the samples was judged based on either the sensory scores (overall acceptability score) being more than 6 or the total plate count less than 10^6 CFU/g (Department of Medical Science, 2001). The data are shown in tables 5 and 6. The sensory scores showed a decreasing trend with increasing storage time, but they were still acceptable (score more than 6) at the time the total plate count reached the acceptable limit. Smoked catfish fillets treated with lemon grass extract could have their shelf life extended from two to nine days and from 9 to 36 days when packed in PA/LDPE bags under atmospheric condition and stored at ambient and chilled temperatures, respectively. Samples packed under a vacuum could have their shelf life extended from 5 to 17 days and from 15 to more than 60 days at ambient and chilled temperatures, respectively. Due to the high value of a_w (0.932), samples were considered to be susceptible to microbial growth. The shortest shelf life of the control sample in this study was only two days, when packed under atmospheric conditions and stored at ambient temperature. In addition to imparting characteristic flavors, certain spices and herbs can prolong the storage life of samples by preventing a rancid taste through their antioxidant activity or through bacteriostatic or bactericidal activity (Beuchat and Golden, 1989). Chemicals found in lemon grass essential oil, such as citral, citronellol, geraneol and cineole have been reported to exhibit an antimicrobial effect against selected bacterial strains and fungi (Pattnaik *et al.*, 1996). This may have been the reason for the extended shelf life of smoked catfish in this study. Spices and herbs and their constituents are generally recognized to be safe for human consumption. Being natural foodstuffs, spices and herbs appeal to many consumers who question the safety of synthetic food additives. Thus, applying lemon grass to the catfish fillets not only enhanced the flavor using an acceptable, safe, natural additive but also had the benefit of prolonging the product shelf life by more than three times that of the untreated product.

Smoked catfish fillets with a longer shelf life and higher overall acceptability may provide an alternative product for the consumers. This study could thus be expected to promote the catfish-processing sector and consequently boost the interest in catfish culture.

Table 5 Mean sensory scores and total plate count of lemon grass-treated samples during storage at ambient temperature (30±2°C).

Storage (day)	Control sample[1]				Treated sample			
	Air packing		Vacuum packing		Air packing		Vacuum packing	
	Overall acceptability**	TPC (CFU/g)	Overall acceptability	TPC (CFU/g)	Overall acceptability**	TPC (CFU/g)	Overall acceptability**	TPC (CFU/g)
0	7.23±0.56^{a}	2.40×10^{3}	7.23±0.56^{a}	2.40×10^{3}	8.15±0.60^{a}	3.25×10^{2}	8.15±0.60^{a}	3.25×10^{2}
1	6.33±0.56^{b}	4.72×10^{4}	6.85±0.37^{b}	3.86×10^{3}	8.03±0.49^{ab}	4.82×10^{2}	7.91±0.59^{ab}	3.10×10^{2}
2	6.25±0.41^{b}	1.0×10^{6}	6.50±0.45^{c}	7.20×10^{3}	7.98±0.54^{ab}	4.64×10^{2}	7.98±0.59^{ab}	3.24×10^{2}
3	5.85±0.39^{c}	>10^{6}	6.21±0.31^{d}	2.61×10^{4}	8.06±0.50^{a}	5.10×10^{2}	7.66±0.60^{bcd}	3.72×10^{2}
4			6.20±0.40^{d}	4.70×10^{5}	7.95±0.51^{ab}	7.43×10^{2}	7.78±0.66^{bc}	3.36×10^{2}
5			5.90±0.57^{e}	6.92×10^{6}	7.76±0.50^{bc}	5.30×10^{2}	7.53±0.50^{cde}	4.20×10^{2}
6			5.40±0.55^{c}	>10^{6}	7.35±0.51^{d}	7.20×10^{2}	7.53±0.57^{cde}	4.87×10^{2}
7					7.65±0.52^{c}	9.41×10^{2}	7.76±0.56^{bc}	4.13×10^{2}
8					7.30±0.42^{d}	9.85×10^{2}	7.73±0.61^{bcd}	4.64×10^{2}
9					7.15±0.48^{d}	4.47×10^{3}	7.55±0.62^{cde}	5.13×10^{2}
10					7.32±0.42^{d}	>10^{6}	7.55±0.59^{cde}	7.24×10^{2}
11							7.66±0.49^{bcd}	4.30×10^{2}
12							7.41±0.49^{def}	6.72×10^{2}
13							7.40±0.60^{def}	8.54×10^{2}
14							7.26±0.55^{efg}	7.13×10^{2}
15							7.21±0.61^{efg}	9.80×10^{2}
16							7.13±0.49^{fg}	3.02×10^{3}
17							7.00±0.62^{g}	5.35×10^{3}
18							5.50±0.45^{h}	>10^{6}

a,...,h Means within a column followed by different superscript letters are significantly different ($P \leq 0.01$)
ns non significant ($P > 0.05$)
[1] control sample, soaked in 5% chilled brine, following the same processing conditions as the treated samples.

Table 6 Mean sensory scores and total plate count of lemon grass-treated samples during storage at ambient temperature (4±2°C).

Storage (days)	Control sample[1]				Treated sample			
	Air packing		Vacuum packing		Air packing		Vacuum packing	
	Overall acceptability*	TPC (CFU/g)	Overall acceptability**	TPC (CFU/g)	Overall acceptability^{ns}	TPC (CFU/g)	Overall acceptability**	TPC (CFU/g)
0	7.23±0.56^{a}	2.40×10^{3}	7.33±0.56^{a}	2.40×10^{3}	8.15±0.60	3.25×10^{2}	8.15±0.60^{a}	3.25×10^{2}
3	6.63±0.54^{b}	3.62×10^{3}	6.83±0.55^{b}	3.24×10^{3}	8.21±0.50	3.10×10^{2}	7.98±0.56^{ab}	3.06×10^{2}
6	6.60±0.54^{b}	1.83×10^{4}	6.81±0.59^{bc}	7.84×10^{3}	8.05±0.57	4.20×102	8.05±0.44^{ab}	3.10×10^{2}
9	5.81±0.60^{c}	1.0×10^{6}	6.65±0.80^{bc}	3.61×10^{4}	8.03±0.49	3.40×10^{2}	8.13±0.45^{a}	3.24×10^{2}
12		>10^{6}	6.50±0.62^{c}	4.10×10^{5}	8.06±0.50	4.35×10^{2}	8.11±0.53^{a}	3.20×10^{2}
15			5.66±0.71^{d}	1.0×10^{6}	7.96±0.57	4.80×10^{2}	7.93±0.58^{abc}	3.41×10^{2}
18				>10^{6}	8.15±0.49	5.33×10^{2}	8.05±0.59^{ab}	3.45×10^{2}
21					7.96±0.66	4.31×10^{2}	8.08±0.49^{a}	2.98×10^{2}
24					8.08±0.54	4.77×10^{2}	8.05±0.51^{ab}	2.86×10^{2}
27					8.08±0.56	5.53×10^{2}	7.93±0.58^{abc}	3.15×10^{2}
30					8.05±0.64	4.92×10^{2}	8.21±0.46^{a}	3.07×10^{2}
33					7.91±0.60	6.42×10^{2}	7.98±0.62^{ab}	3.34×10^{2}
36					7.83±0.42	6.75×10^{2}	8.06±0.59^{a}	3.20×10^{2}
39					7.93±0.42	>10^{6}	8.06±0.41^{a}	3.17×10^{2}
42							7.95±0.51^{abc}	3.12×10^{2}
45							7.75±0.43^{bcd}	2.97×10^{2}
48							7.63±0.43^{d}	2.93×10^{2}
51							7.55±0.46^{d}	2.91×10^{2}
54							7.56±0.40^{d}	2.84×10^{2}
57							7.60±0.44^{d}	2.82×10^{2}
60							7.68±0.44^{cd}	2.78×10^{2}

a,...,d Means within a column followed by different superscript letters are significantly different ($P \leq 0.01$)
ns non significant ($P > 0.05$)
[1] control sample, soaked in 5% chilled brine, following the same processing conditions as the treated samples.

A smoking process for hybrid Clarias catfish fillets treated with crude lemon grass extract was developed. Soaking fresh catfish fillets in crude lemongrass extract (1:1 w/v) with added 5% salt for 45 min before 1 h drying at 50°C, 1 h smoking at 60°C and 45 min drying at 60°C gave products with the highest acceptability. Treatment with lemon grass extract could extend the shelf life by approximately three times at ambient temperature storage and four times at chilled storage.

LITERATURE CITED

AOAC. 2000. **Official Methods of Analysis.** 16th ed., Association of Official Analytical Chemists, Arlington, Virginia. 1043 p.

Beuchat, L.R. and D.A. Golden.1989. Antimicrobials occurring naturally in foods. **Food Technol.** 43: 134–142.

Department of Fisheries. 2007. **Yield from freshwater culture by species** (1985-2004) [online, available: http://fishco.fisheries.go.th/fishery3/doc/fish_water.htm]

Department of Medical Science. 2001. **Knowing of Chemical Substants and Microbs in Food.** Ministry of Public Healt. 13 p.

Dodds, K.L., M.H. Brodsky and D.W. Warburton.1992. A retail survey of smoked ready-to-eat fish to determine their microbiological quality. **J. Food Prot.** 55 (3): 208–210.

Ismail, S.A.S., T. Deak , H.A. Abd El-Rahman , M.A.M. Yassien and L.R. Beuchat. 2001. Effectiveness of immersion treatments with acids, trisodium phosphate, and herb decoctions in reducing populations of *Yarrowia lipolytica* and naturally occurring aerobic microorganisms on raw chicken. **Inter. J. Food Microbiol.** 64: 13–19.

Kietkangwanklai, P. 1989. **Process Development and Shelf Life of Smoked Stripped Catfish (*Pangasius sutchi*)**. M.S. Thesis. Chulalongkorn University. Bangkok.

Lis-Balchin, M. and S.G. Deans. 1997. Bioactivity of selected plant essential oils against *Listeria monocytogenes*. **App. Microbiol.** 82: 759–762.

Nielsen, P.V. and R. Rios. 2000. Inhibition of fungal growth on bread by volatile components from spices and herbs, and the possible application in active packaging, with special emphasis on mustard essential oil. **Inter. J. Food Microbiol.** 60: 219–229.

Pattnaik S, V.R. Subramanyam and C. Kole. 1996. Antibacterial and antifungal activity of ten essential oils *in vitro*. **Microbiol.** 86(349): 237-46.

Poompuang, S and U. Na-Nakorn. 2004. A preliminary genetic map of walking catfish (*Clarias macrocephalus*). **Aquaculture** 232: 195-203.

Sikorski, Z.E. and I. Kolodziejska. 2002. Microbial risks in mild hot smoking of fish. **Critical Reviews in Food Sci. Nutrit.** 42 (1): 35-51.