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Shelf life modelling of frozen shrimp at variable temperature conditions

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The objective of this study was to investigate the effect of variable storage conditions on shelf life and quality characteristics of frozen shrimp.

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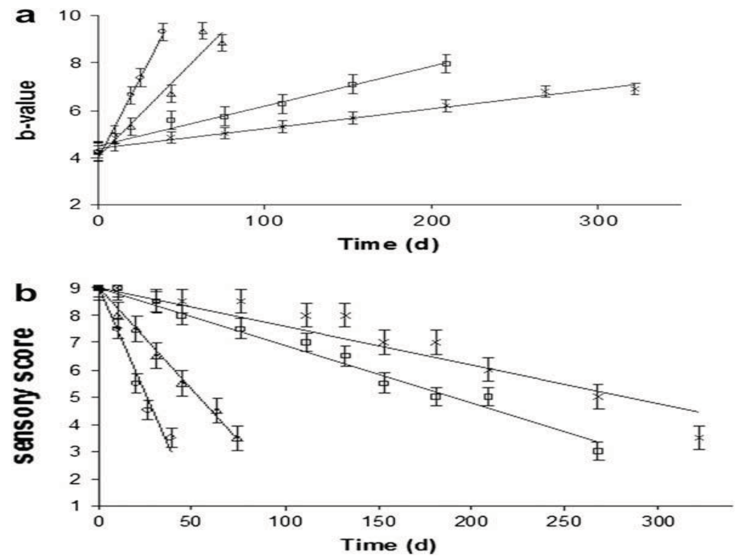

- Fig. 1. (a) Changes of colour (*b*-value) of thawed non-peeled frozen shrimp, (b) Sensory scores for colour of thawed non-peeled frozen shrimp during storage at ○: −5 °C, △: −8 °C, □: −12 °C and ⁎ : −15 °C. (Error bars indicate standard error of measurements of two different samples.)

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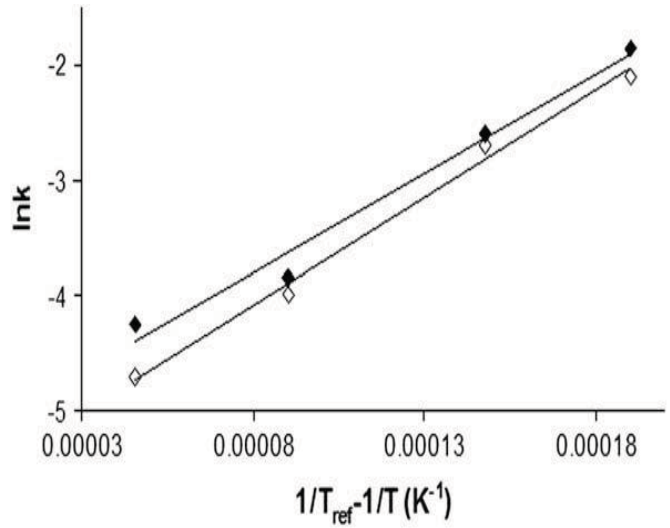

- Fig. 2. Effect of temperature on colour change rates of thawed non-peeled frozen shrimp, measured ◇ : instrumentally (*b*-value, *Ea* = 156 kJ/mol, Kref = 0.0037 day−1) and ♦: by sensory analysis (*Ea* = 143 kJ/mol, Kref = 0.0056 day−1), during storage.

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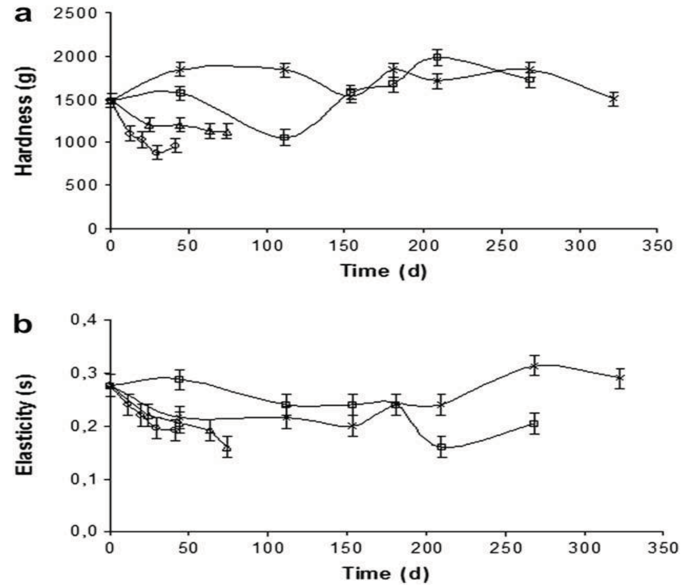
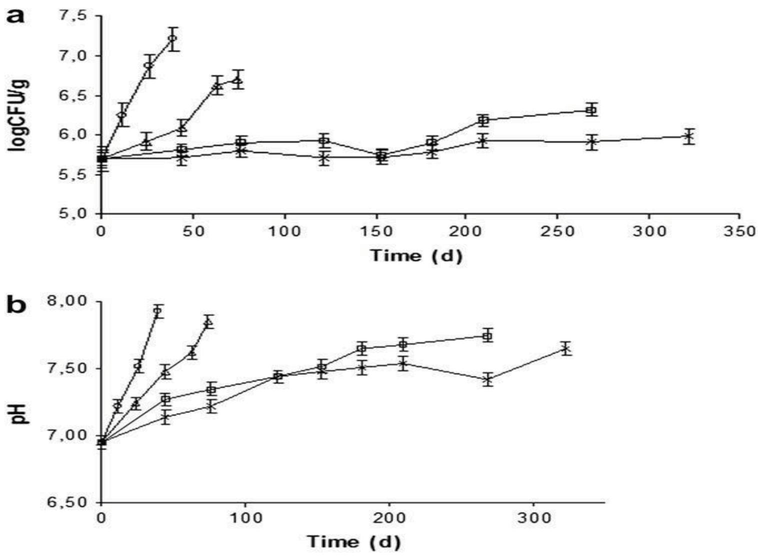
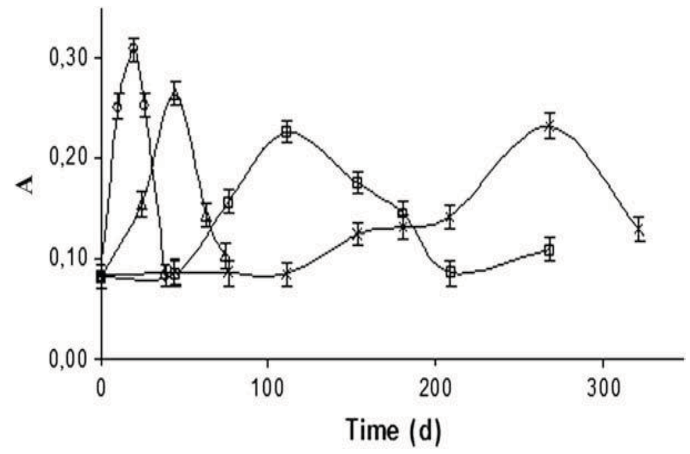


Fig. 3. Effect of temperature on texture parameters: (a) hardness and (b) elasticity of thawed peeled frozen shrimp, measured instrumentally during storage at ○: −5 °C, △: −8 °C, □: −12 °C and ⁎ : −15 °C. (Error bars indicate standard error of measurements of two different samples.)



- Fig. 4. (a) Growth of total viable count and (b) pH changes of frozen shrimp during storage at ○: −5 ˚C, △: −8 ˚C, □: −12 ˚C and ∗ : −15 ˚C. (Error bars indicate standard error of measurements of two different samples.)



- Fig. 5. Change of absorbance by TBARS method as a measure of lipid oxidation of frozen shrimp during storage at ○: −5 ˚C, △: −8 ˚C, □: −12 ˚C and ∗ : −15 ˚C. (Error bars indicate standard error of measurements of two different samples.)

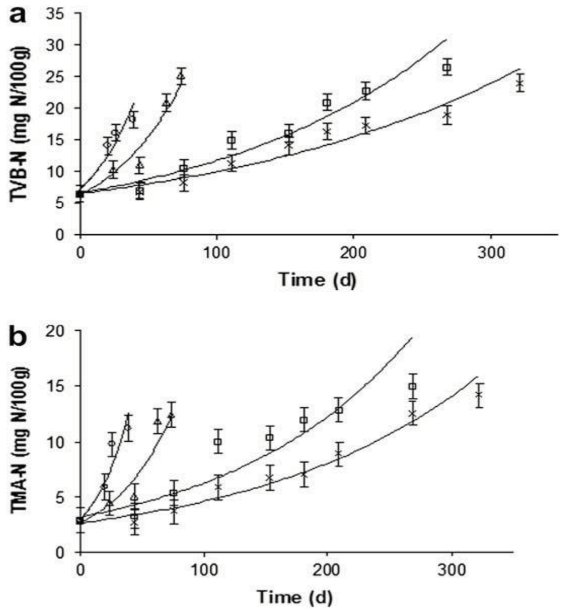
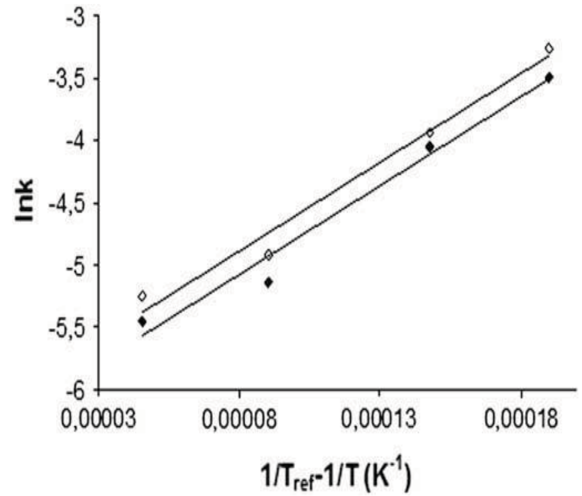


Fig. 6. Changes in (a) TVB-N and (b) in TMA-N of frozen shrimp during storage at ○: −5 ˚C, △: −8 ˚C, □: −12 ˚C and ∗ : −15 ˚C. (Error bars indicate standard error of measurements of two different samples.)



- Fig. 7. Effect of temperature on rates of ◆: TVB-N (*Ea* = 119 kJ/mol, *K*ref = 0.0020 day−1) and ◇: TMA-N (*Ea* = 118 kJ/mol, *K*ref = 0.0024 day−1) changes of frozen shrimp during storage.

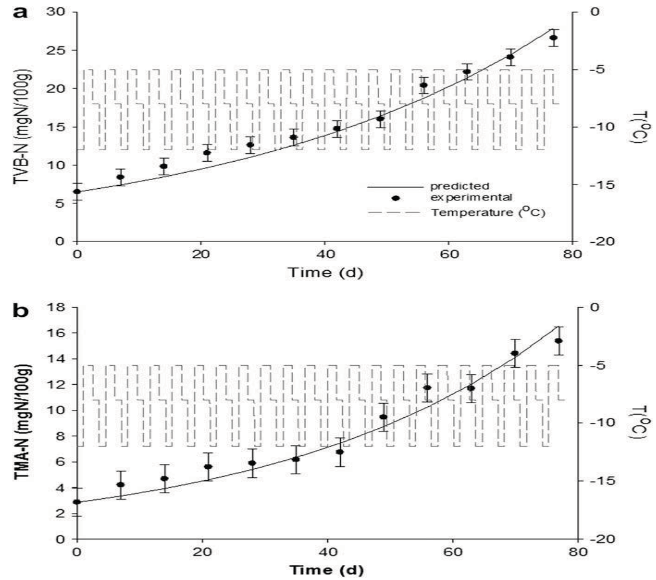


Fig. 8. Comparison of ●: experimental and ——: predicted changes in (a) TVB-N and (b) TMA-N of frozen shrimp at the temperature profile (— —) of the nonisothermal experiment (Teff = -7.3C). (Error bars indicate the standard error of the predicted y-value for each x in the regression.)

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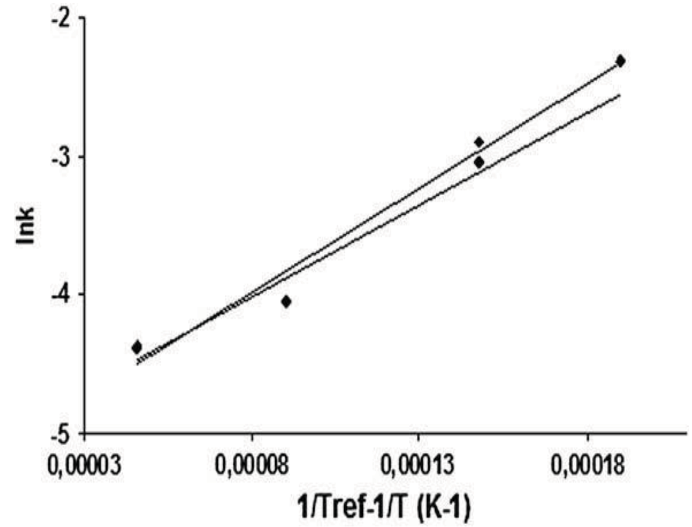

Fig. 9. Effect of temperature on ◆: taste (Ea = 124 kJ/mol, Kref(Tref18C) = 0.0056 day $^{-1}$) and ◇: overall acceptability (Ea =111 kJ/mol, Kref(Tref18C) = 0.0062 day $^{-1}$) of frozen shrimp determined by sensory evaluation during storage.

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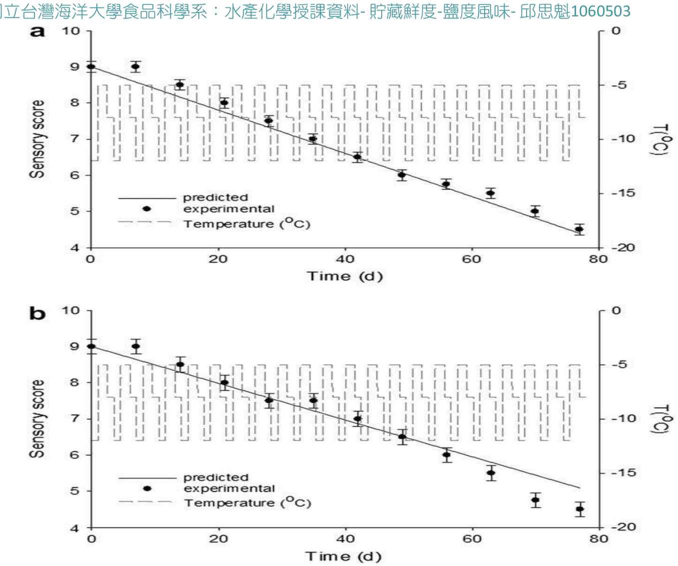

- Fig. 10. Comparison of ●: experimental and ——: predicted scores of (a) taste and
- (b) overall acceptability of frozen shrimp at the temperature profile (— —) of the
- non-isothermal experiment (Teff = -7.3C). (Error bars indicate the standard error of
- the predicted y-value for each x in the regression.)

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Table 1

Shelf life of frozen shrimp stored at −5, −8, −12, −15 and −18 °C

Storage temperature (°C)	Shelf life of frozen shrimp (days)	
	Sensory scoring (limit = 5)	TVB-N (limit = 25 mgN/100 g)
−5	51	45
−8	90	82
−12	194	187
−15	351	353
−18	644[a]	677[a]

[a] Calculated using the models developed.

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Freshness decay and shelf life predictive modelling of European sea bass (*Dicentrarchus labrax*) applying chemical methods and electronic nose

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Abstract

Colour change measured both instrumentally and visually was modelled by apparent zero order equations and showed high dependence on temperature.

TVB-N and TMA values increased with storage time and were modelled with apparent first order equations.

Taste and overall acceptability scores of frozen shrimp had high correlation with TVB-N and TMA values.

The temperature dependence of quality deterioration was adequately modelled by the Arrhenius equation and activation energy ranged from 118 to 156 kJ/mol for the different indices measured.

The developed models were validated in fluctuating time–temperature conditions in order to establish their applicability in the real cold chain.

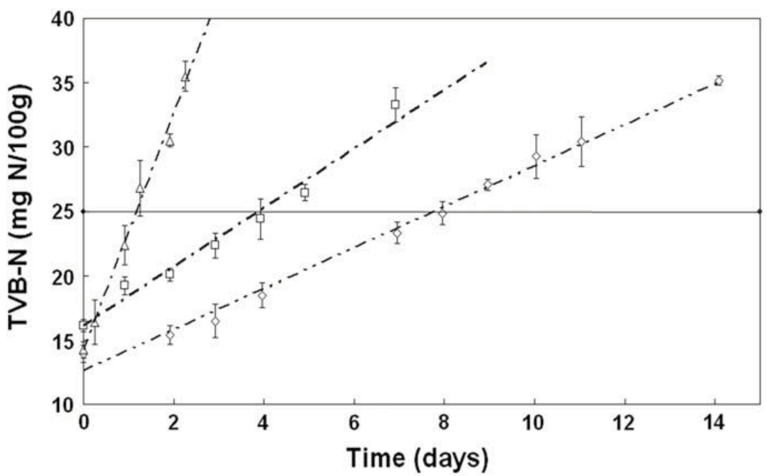

Fig. 1. Trend of TVB index in fresh European sea bass stored at different temperatures: (△) samples stored at 16.5 C, (□) samples stored at 4.8 C and (◇) samples stored at -0.5 C.

- From the kinetic model: 7.4 days for the storage at -0.5 C; 3.7 days at 4.8 C and 1.1 days at 16.5 C

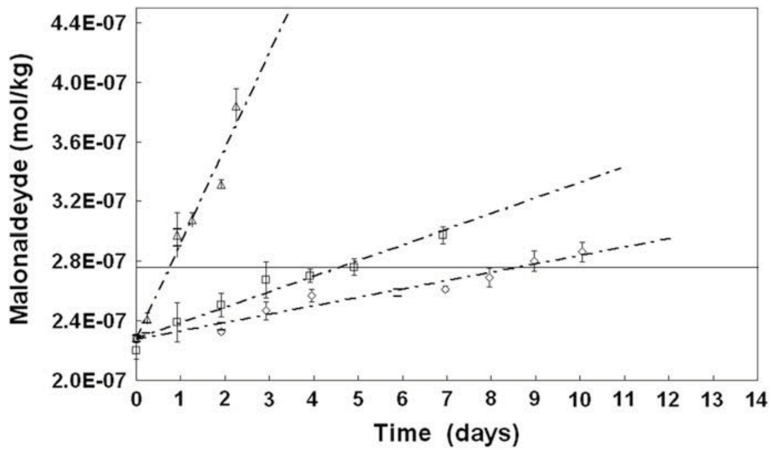

Fig. 2. Trend of TBA index (expressed as malonaldeyde) in fresh European sea bass stored at different temperatures: (△) samples stored at 16.5 C, (□) samples stored at 4.8 C and (◇) samples stored at -0.5 C

- A maximum acceptability time for each storage temperature was computed from the kinetic model as follows: 8.5 days for the storage at -0.5 C; 4.6 days at 4.8 C and 0.8 days at 16.5 C

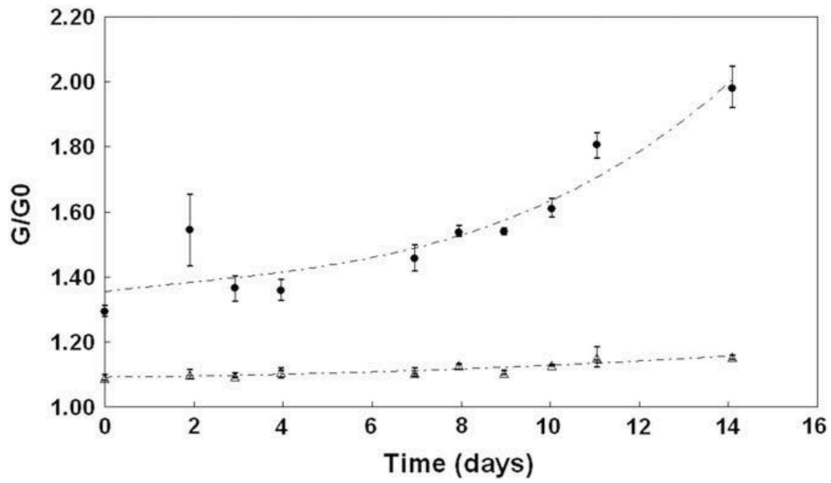

Fig. 3. Raw responses of two sensors of e-nose device during storage: (●) W2S sensor responses and (△) W6S sensor responses.

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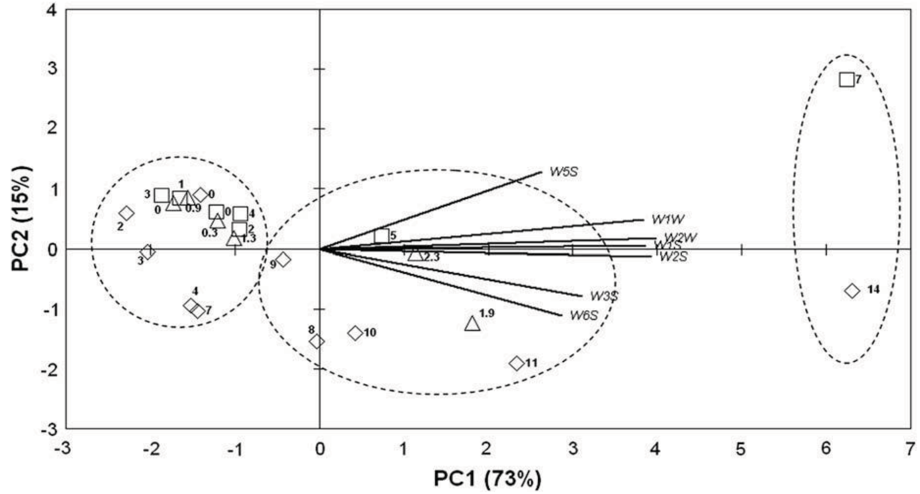

- Fig. 4. Biplot of sensor responses and samples scores during storage of fresh European sea bass at different temperatures: (△) samples stored at 16.5 C, (□) samples stored at 4.8 C and (◇) samples stored at -0.5 C

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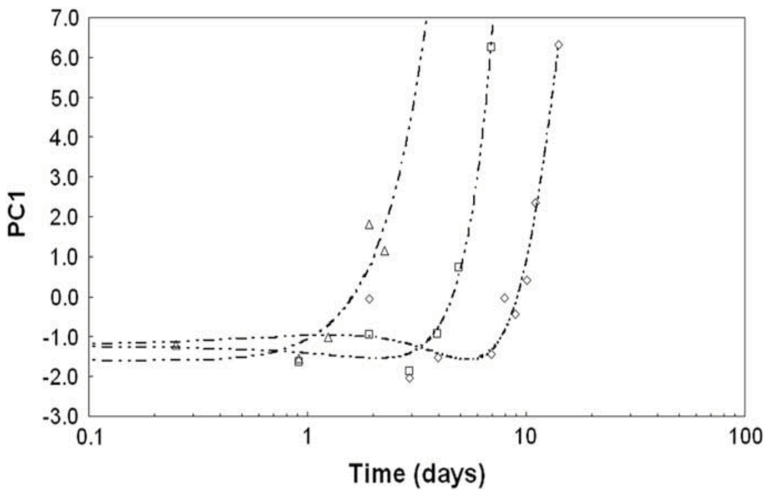

Fig. 5. PC1 trend versus storage time at different temperatures: (△) samples stored at 16.5 C, (□) samples stored at 4.8 C and (◇) samples stored at -0.5 C

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Table 1
Maximum stability times for the considered indexes.

Maximum stability time (days)				
Temperature (°C)	TVB	TBA	E-nose	Average
−0.5	7.4	8.5	9.0	8.3
4.8	3.7	4.6	4.3	4.2
16.5	1.1	0.8	1.2	1.04
Q_{10}	2.97	4.17	3.23	3.45

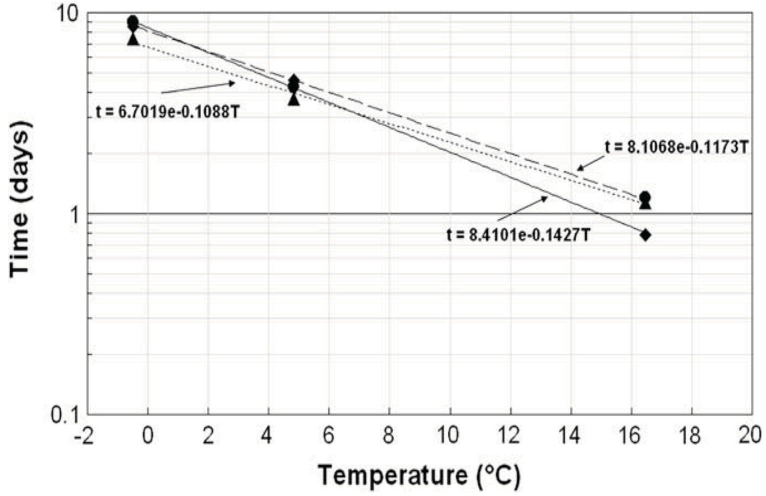

Fig. 6. Time–Temperature Tolerance chart of fresh sea bass: (▲) TVB stability times, (◆) TBA stability times, (●) electronic nose stability time.

- From the average values, shelf life was about 8 days for fish preserved in melting ice (-0.5 C), 4 days at 4.8 C and about 1 day at 16.5 C.

Table 2
Time–Temperature reference data in the commercial chain.

Step	Time (days)		Temperature (°C)	
	$p = 50\%$	$p = 90\%$	$p = 50\%$	$p = 90\%$
1. Storage at the retailer	0.268	0.311	0.24	0.94
2. Rest in the truck (before transport)	0.015	0.022	0.08	0.59
3. Delivery	0.018	0.024	0.10	0.59
4. Storage at the sale points	1.133	2.068	0.18	0.76
5. Rest on the exposure bench	0.094	0.141	4.51	8.18
Cumulative	1.53	2.57	0.46	1.19

Table 3
Remaining shelf life for TBA, TVB and e-nose indexes during commercialization of fresh sea bass.

	Temperature (°C)	Time (days)	Remaining Shelf life (%)		
	$p = 90\%$	$p = 90\%$	TBA	TVB	e-nose
Storage at the retailer	0.94	0.311	95.8	94.8	95.7
Rest in the truck (before transport)	0.59	0.022	95.5	94.5	95.4
Delivery	0.59	0.024	95.2	94.1	95.1
Storage at the sale points	0.76	2.068	67.8	60.6	67.2
Rest on the exposure bench	8.18	0.141	62.4	55.5	62.7

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Assessment of European cuttlefish (*Sepia officinalis*, L.) nutritional value and freshness under ice storage using a developed Quality Index Method (QIM) and biochemical methods

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The aim of this study was to determine the nutritional value of adult commercial cuttlefish, to develop a Quality Index Method (QIM) scheme, and to evaluate the application of some biochemical methods commonly used for freshness assessment of fish under ice storage. Additionally, shelf-life was to be determined based on both QIM and suitable biochemical methods.

Table 1
29 demerit point QIM scheme for cuttlefish (*S. officinalis*) freshness evaluation

Parameters		Characteristics	Demerit points
Superficial appearance	Dorsal face	Brownish with bright pigmentation; indistinct shell	0
		Still brownish, with pink tones; more distinct shell	1
		Brown to dark pink; perfectly distinct shell	2
	Ventral face	Iridescent bright white; flat mantle	0
		White with less iridescence; slightly sunken mantle, with few stretch marks	1
		Pink without iridescence; sunken mantle with stretch marks	2
	Skin	Well adherent to the flesh, resistant	0
		Slightly fragile but still adherent	1
		Fragile, without adhesion	2
	Odour	Seaweedy, fresh	0
		Metallic or neutral	1
		Musty or grassy	2
		Ammoniacal, sour or rotten	3
Eyes	Colour	Black	0
		Purple	1
		Lilac	2
		White, milky	3
	Eyelid	Clear, transparent	0
		Opalescent, foggy	1
		Milky, opaque	2
Head	Suckers	Well adherent, resistant	0
		Slightly detachable (3–5 per tentacle)	1
		Detachable, removable (>5 per tentacle)	2
	Tentacles	Resistant, doesn't break when pulled away	0
		Still resistant, break when pulled away	1
		Not resistant, break easily when pulled away	2
	Shape	Firm head, well defined ocular globe	0
		Head and ocular globe slightly sunken	1
		Head and ocular globe sunken and liquefied	2
Mantle cavity	Odour	Seaweedy, fresh	0
		Metallic or neutral	1
		Musty our slightly sour	2
		Ammoniacal or rotten	3
	Flesh colour	Mother-of-pearl or pearly-white	0
		Yellowish, ivory-white	1
		Greyish, translucent	2
	Gills	Well defined, creamy colour	0
		Slightly liquefied, black (from the ink)	1
		Liquefied, with only its filaments left	2
	Ink sac	Well defined, liquid ink	0
		Hard, thick ink	1
		Soft, waxy or gummy ink	2
		Total (0–29)	

Table 2
Average scores for each quality parameter assessed with the QIM scheme, for cuttlefish stored in ice and the correlation to days in ice

Parameter/days in ice	1	2	3	4	6	7	8	9	Correlation (R)
Dorsal face	0.20	0.60	0.80	1.00	0.67	1.40	1.40	1.80	0.903
Ventral face	0.60	0.60	1.00	0.80	1.00	1.40	2.00	1.80	0.917
Skin	0.00	0.20	0.80	1.00	1.33	1.20	1.40	2.00	0.951
Superficial odour	0.40	0.40	0.80	0.80	1.67	1.20	1.60	1.80	0.940
Eye colour	0.20	0.40	0.80	1.00	1.33	2.00	2.20	2.60	0.990
Eyelid	0.20	0.40	0.60	0.80	1.00	1.20	1.60	1.40	0.976
Suckers	0.20	0.00	0.40	0.40	1.00	1.60	1.80	1.80	0.965
Tentacles 0.20	0.40	0.40	0.40	0.67	1.40	1.20	1.20	0.913	
Head shape	0.20	0.40	0.80	1.00	1.00	1.80	1.60	2.00	0.960
Mantle cavity odour	0.60	0.20	0.60	1.20	2.00	1.80	2.40	2.20	0.943
Flesh colour	0.20	0.00	0.20	0.20	1.33	1.20	1.80	1.40	0.917
Gills	0.20	0.00	0.20	0.40	1.00	1.20	1.20	1.00	0.920
Ink sac	0.00	0.00	0.20	0.60	1.00	1.60	1.60	1.60	0.975

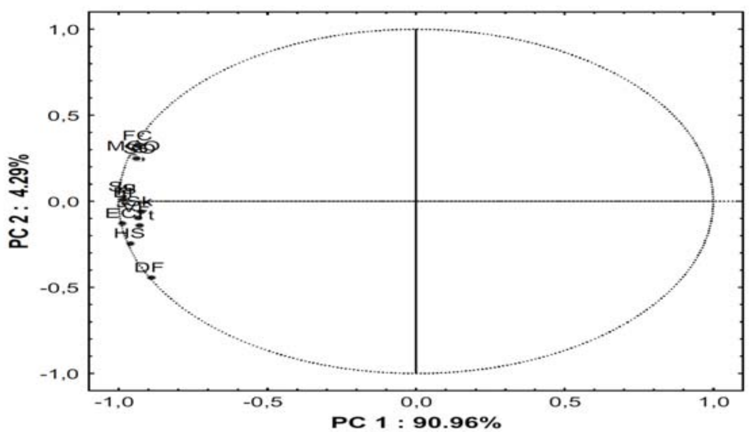

Fig. 3. PCA multivariate analysis of all quality parameter used in the 29 demerit points QIM scheme and ice storage time. DF – dorsal face; EI – eyelid; EC – eye colour; FC – flesh colour; G – gills; HS – head shape; IS – ink sac; MCO – mantle cavity odour; Sk – skin; Su – suckers; SO – superficial odour; T – time (days in ice); Tt – tentacles; VF – ventral face.

Most important parameters (r >0.98) for PC1 were, in descendant order, storage time (T), eye colour (EC), ink sac (IS) and eyelid (EI).
For PC2, dorsal face (DF), flesh colour (FC), mantle cavityodour (MCO) and gills (G) were the most important parameters (r = 0.25-0.44).

Table 3
Eigenvalues of correlation matrix, and related statistics (PCA)

PC	Eigenvalue	% Total variance	Cumulative eigenvalue	Cumulative %
1	12.73447	90.96048	12.73447	90.9605
2	0.60062	4.29017	13.33509	95.2507
3	0.37217	2.65837	13.70726	97.9090
4	0.17729	1.26637	13.88456	99.1754
5	0.06465	0.46178	13.94920	99.6372
6	0.03524	0.25169	13.98444	99.8889
7	0.01556	0.11114	14.00000	100.0000

PC – principal component.

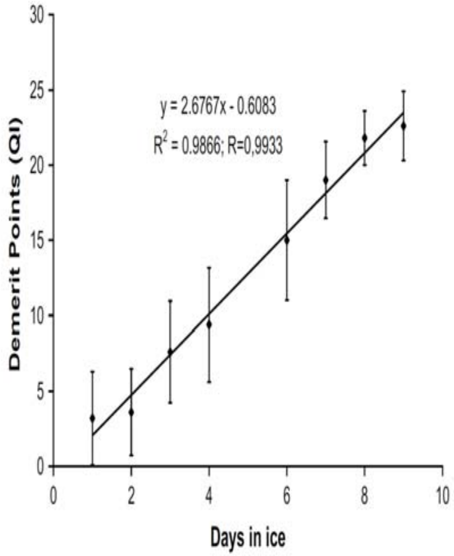

Fig. 1. QI linear correlation with ice storage days of the 29 demerit points QIM scheme developed for the cuttlefish. Bars represent daily standard deviation.

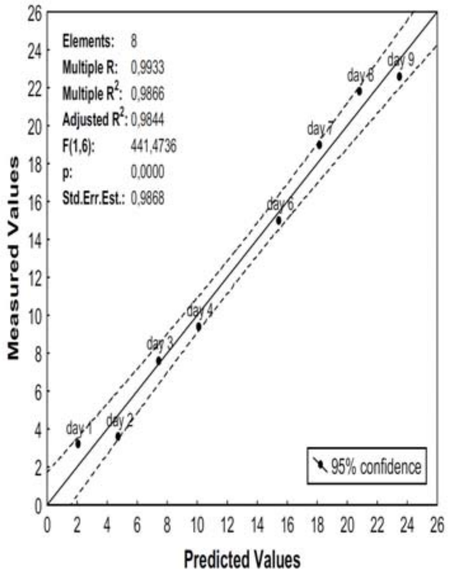

Fig. 2. PLS regression model of the 29 demerit points QIM scheme measured vs. predicted values. Traced lines represent 95% confidence limits of the regression.

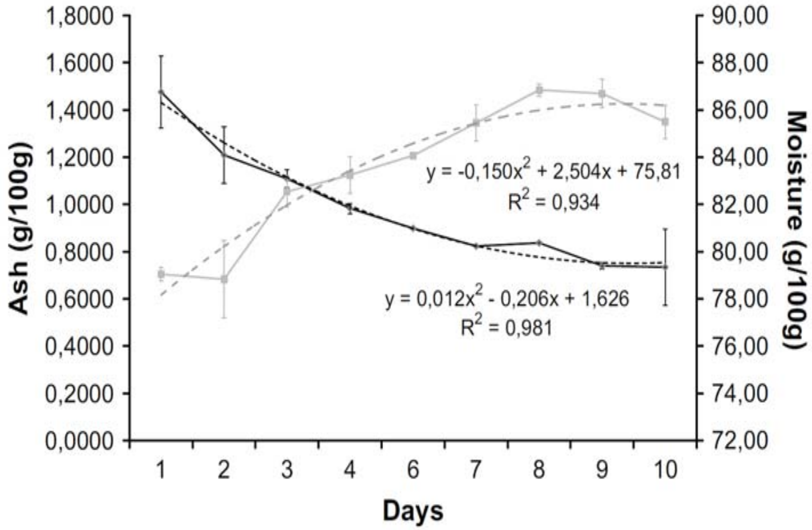

Fig. 4. Moisture (grey) and Ash (black) (both in g/100 g of sample tissue) polynomial evolution during time of storage. Vertical bars represent daily standard deviations.

Table 4

Proximate composition of cuttlefish (*S. officinalis*) (g/100 g)

Day	First day		Thirteenth day	
	Wet weight	Dry weight	Wet weight	Dry weight
Moisture*	79.55 ± 0.14	–	87.04 ± 0.13	–
Protein*	16.60 ± 0.10	81.17 ± 0.49	11.90 ± 0.28	91.82 ± 2.16
Fat	0.09 ± 0.01	0.44 ± 0.05	0.17 ± 0.09	1.31 ± 0.69
Ash*	1.39 ± 0.03	6.80 ± 0.15	0.52 ± 0.01	4.01 ± 0.08
NPN	0.99 ± 0.04	4.84 ± 0.20	0.98 ± 0.02	7.56 ± 0.15
Total	98.62 ± 0.32	93.25 ± 1.56	100.61 ± 0.53	104.71 ± 4.09
Solids	20.45 ± 0.18	100.00 ± 0.88	12.96 ± 0.40	100.00 ± 3.09

*Represent statistical differences at $p < 0.001$ for the wet weight fraction.

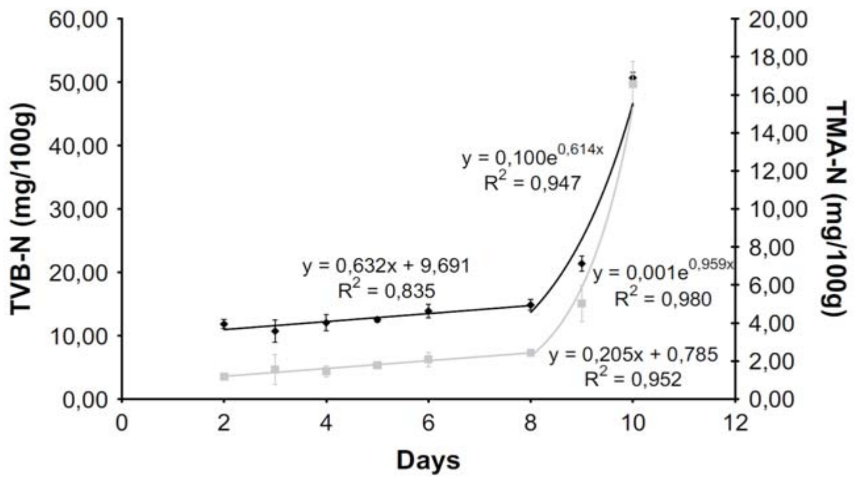

Fig. 5. TVB-N (grey) and TMA-N (black) (both in mg/100 g of sample tissue) trends during the time of storage. In both trends, the first 8 days were linear while from the 8th to the 10th days their evolution was exponential. Vertical bars represent daily standard deviations.

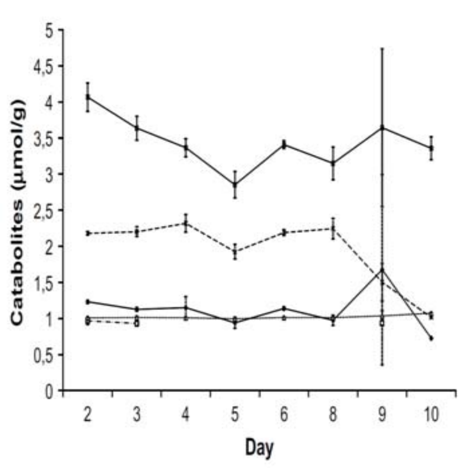

Fig. 7. Nucleotide catabolites (ATP, ADP, AMP, Hx and IMP) (µmol/g) trend during ice storage. Vertical bars represent daily standard deviations. ◆ – IMP; □ – ATP; △ – ADP; × – AMP; ■ – Hx.

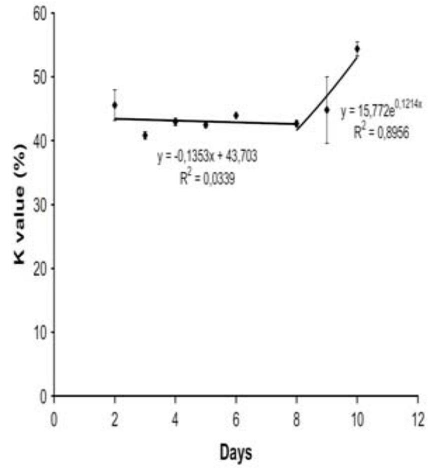

Fig. 6. K value (%) evolution during ice storage. Vertical bars represent daily standard deviations.

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- Results seem to indicate that there is impregnation of the iced water into the mantle tissue promoting protein leaching with the melting ice.

- TVB-N and TMA-N displayed a similar increasing tendency, peaking beyond EEC regulations proposed maximum between the 9th and 10th days. The developed QIM scheme for cuttlefish was composed of 29 demerit points, divided into 4 attributes and 13 parameters. The calculated quality index (QI) evolved linearly with storage time in ice (QI = 2.68 x days in ice - 0.61, R^2 = 0.9866). Storage time could be estimated with an accuracy of 1 day, if five cuttlefish from each sample were included in the QIM assessment. The shelf-life was determined as 8 ± 1 days by both type of methods (QIM and biochemical). However, the suitability of some biochemical methods to assess freshness need to be more thoroughly researched.

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Comparison of flavor components in shrimp *Litopenaeus vannamei* cultured in sea water and low salinity water

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Table 1 Chemical composition of muscle extracts from the shrimp *Litopenaeus vannamei* cultured in sea water and low salinity water†

Muscle composition	Shrimp cultured in sea water (n = 10)	Shrimp cultured in low salinity water (n = 10)
Moisture (%)	74.72 ± 3.56^b	80.78 ± 4.25^a
Crude protein (%)	22.48 ± 1.43^a	18.00 ± 2.12^b
Crude lipid (%)	0.78 ± 0.12^a	0.85 ± 0.17^a
Ash (%)	1.59 ± 0.67^a	1.67 ± 0.72^a
pH	7.57 ± 0.12^a	7.01 ± 0.17^b

†Values are mean (±SD) of three analyses.
Means within a row having different superscripts are significantly different (P < 0.05).

Table 2 Free amino acid composition in muscle extracts from *Litopenaeus vannamei* cultured in sea water and low salinity water (mg/100 g)[†]

Amino acids	*Litopenaeus vannamei* cultured in sea water	*Litopenaeus vannamei* cultured in low salinity water
Aspartic acid	8.45 ± 1.05^{a}	9.91 ± 2.12^{a}
Threonine	14.84 ± 0.80^{b}	19.52 ± 1.05^{a}
Serine	21.64 ± 1.52^{a}	19.57 ± 2.36^{a}
Glutamate	34.46 ± 1.72^{a}	28.17 ± 1.80^{b}
Glycine	333.67 ± 2.50^{a}	300.98 ± 1.52^{b}
Alanine	97.82 ± 2.33^{b}	177.39 ± 3.06^{a}
Valine	32.01 ± 0.76^{b}	41.86 ± 0.65^{a}
Methionine	15.12 ± 3.07^{a}	11.77 ± 2.12^{b}
Isoleucine	16.43 ± 1.16^{b}	25.70 ± 2.01^{a}
Leucine	27.37 ± 0.74^{b}	45.43 ± 1.19^{a}
Tyrosine	16.80 ± 0.78^{b}	24.94 ± 1.03^{a}
Phenylalanine	20.47 ± 2.11^{a}	23.94 ± 1.12^{a}
Lysine	23.24 ± 1.87^{b}	32.27 ± 2.18^{a}
Histidine	16.45 ± 0.55^{a}	11.22 ± 0.87^{b}
Arginine	244.45 ± 8.23^{a}	136.58 ± 2.27^{b}
Proline	74.57 ± 1.15^{a}	69.35 ± 0.95^{b}
Taurine	22.41 ± 1.37^{b}	25.32 ± 2.06^{a}
Total amino acids	1020.20 ± 10.85^{a}	1003.92 ± 11.59^{b}

[†]Values are mean (±SD) of three analyses.
Means within a row having different superscripts are significantly different ($P < 0.05$).

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Table 3 The amino acid composition of peptides (including oligopeptides) in muscle extracts from *Litopenaeus vannamei* cultured in sea water and low salinity water (mg/100 g)[†]

Amino acids	*Litopenaeus vannamei* cultured in sea water	*Litopenaeus vannamei* cultured in low salinity water
Aspartic acid	42.31 ± 1.32^{b}	66.80 ± 0.28^{a}
Threonine	50.11 ± 2.09^{b}	58.40 ± 1.86^{a}
Serine	62.54 ± 1.77^{b}	72.85 ± 3.65^{a}
Glutamate	390.83 ± 2.78^{a}	356.00 ± 3.84^{b}
Glycine	939.09 ± 11.25^{a}	1002.58 ± 22.87^{a}
Alanine	313.05 ± 3.35^{b}	327.27 ± 2.91^{a}
Valine	252.97 ± 1.42^{a}	247.29 ± 1.54^{b}
Methionine	96.24 ± 4.12^{b}	88.37 ± 0.58^{a}
Isoleucine	88.81 ± 1.55^{a}	87.83 ± 1.32^{a}
Leucine	144.66 ± 2.55^{b}	152.86 ± 1.89^{a}
Tyrosine	84.56 ± 0.59^{a}	77.62 ± 0.78^{b}
Phenylalanine	70.65 ± 1.23^{a}	64.91 ± 1.08^{b}
Lysine	113.10 ± 3.42^{b}	137.95 ± 4.56^{a}
Histidine	39.14 ± 0.65^{a}	35.29 ± 0.53^{b}
Arginine	448.22 ± 8.08^{b}	514.46 ± 10.05^{a}
Proline	609.81 ± 3.54^{a}	519.02 ± 6.83^{b}
Total amino acids	3746.13 ± 17.67^{b}	3809.48 ± 22.13^{a}

[†]Values are mean (±SD) of three analyses.
Means within a row having different superscripts are significantly different ($P < 0.05$).

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Table 4 The contents of nucleotide compounds, trimethylamine oxide, and betaine in muscle extracts from *Litopenaeus vannamei* cultured in sea water and low salinity water (mg/100 g)[†]

Nucleotides	*Litopenaeus vannamei* cultured in sea water	*Litopenaeus vannamei* cultured in low salinity water
ATP	0.20 ± 0.01^{b}	0.89 ± 0.03^{a}
ADP	7.77 ± 0.22^{a}	7.67 ± 0.36^{a}
AMP	60.26 ± 1.02^{a}	24.86 ± 0.89^{b}
IMP	80.91 ± 0.55^{a}	64.71 ± 1.26^{b}
HxR	19.97 ± 0.05^{b}	31.25 ± 1.01^{a}
Hx	2.32 ± 0.03^{b}	4.85 ± 0.18^{a}
CMP	3.69 ± 0.15^{b}	7.59 ± 0.24^{a}
GMP	5.70 ± 0.56^{a}	2.03 ± 0.27^{b}
Trimethylamine oxide	4.52 ± 0.73^{a}	4.23 ± 0.69^{a}
Betaine	268 ± 5.52^{a}	179 ± 6.78^{b}

ADP, adenosine diphosphate; AMP, adenosine monophosphate; ATP, adenosine triphosphate; CMP, cytidylic acid; GMP, guanosine monophosphate; Hx, hypoxanthine; HxR, inosine; IMP, inosine monophosphate.
[†]Values are mean (±SD) of three analyses.
Means within a row having different superscripts are significantly different ($P < 0.05$).

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Table 5 The organic acid content of muscle extracts from *Litopenaeus vannamei* cultured in sea water and low salinity water (mg/100 g)[†]

Components	*Litopenaeus vannamei* cultured in sea water	*Litopenaeus vannamei* cultured in low salinity water
Acetic acid	59.20 ± 2.13^{b}	320.80 ± 4.65^{a}
Formic acid	ND	0.32 ± 0.00
Malic acid	16.80 ± 0.78^{a}	16.00 ± 0.43^{a}
Oxalic acid	0.80 ± 0.02^{b}	2.40 ± 0.27^{a}
Citric acid	ND	0.56 ± 0.01
Succinic acid	1.5 ± 0.03	ND
Total	78.30 ± 3.12^{b}	340.08 ± 6.25^{a}

ND, not detected.
[†]Values are mean (±SD) of three analyses.
Means within a row having different superscripts are significantly different ($P < 0.05$).

Table 6 Sensory evaluation of muscle extracts from *Litopenaeus vannamei* cultured in sea water and low salinity water†

Sensory attributes	*Litopenaeus vannamei* cultured in sea water	*Litopenaeus vannamei* cultured in low salinity water
Umami	6.92 ± 0.90^{a}	5.50 ± 0.80^{b}
Aftertaste	4.91 ± 0.79^{a}	4.16 ± 0.72^{a}
Sweetness	3.08 ± 0.79^{a}	0.42 ± 0.51^{b}
Earthy-musty taste	0.00 ± 0.00^{b}	5.58 ± 0.90^{a}
Overall flavor	7.33 ± 0.65^{a}	3.83 ± 0.94^{b}

Note: †Values are mean (±SD) of three evaluation.
Means within a row having different superscripts are significantly different ($P < 0.05$).