Correlation between Electrical Conductivity and Salt Content in Tuna Meat

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Abstract: In tuna industry, salt content in tuna meat is necessary to be determined for quality control by traditional method, in which some chemicals are expensive and not environmental friendly. Therefore, applications of simple analytical methodologies that ensure quality are in demand. This research studied the ability of electrical conductivity (EC) value to predict the salt content in a flesh of skipjack tuna meat compared with the traditional method which used automatic titration. Tuna samples sampling from different sizes (all 8 sizes ranged from 0.10-0.99 to 6.10-9.00 kg) and three different sources were determined chemical composition, salt content and EC value. Salt content and EC value varied depending on tuna size (P<0.05) and sources (P<0.05). Prediction model was built with a total of 170 tuna samples. As per the result, the Pearson correlation (r) showed the relationship of salt content and EC value as 0.92 with P<0.05. This result indicated that EC value had a high correlation with salt content in flesh of tuna meat in a positive direction with statistically significant (P<0.01). The coefficient of determination (R^2) of the prediction model was obtained at 0.85; the linear regression model had a good fit. Comparison of actual and predicted salt content with paired samples t-test indicated that two variables had a high correlation with a positive direction (r=0.91) with non-significant difference ($P\geq$0.05). In conclusion, EC is really promising for application to predict salt content in tuna meat.

1 INTRODUCTION

Skipjack tuna (*Katsuwonus pelamis*) is the species most commonly used in canned tuna. Canned tuna processing industries in Thailand has imported frozen raw tuna approximately 90% of the total (National Food Institute, 2016). Tuna freezing has occurred aboard vessels after catching for preserves the quality of fish. The preservation technique is brine immersion freezing, which involves storing fish in brine (water-saturated or nearly saturated with salt, usually, sodium chloride) and reducing the temperature of the brine until the fishes are frozen.

The main risk of this preservation method is the penetration of salt into fish meat. A high concentration of salt in tuna would affect the meat quality and might reduce its commercial value. The factors influencing salt penetration are the rise of brine temperature, the concentration of brine, and the storage duration. These parameters investigated by tuna industries are controlled aboard vessels to avoid any fish deterioration. Also, some biological factors such as fish species, fish size, muscle type, and muscle composition are affecting salt penetration (Bodin *et al.,* 2014).

The salt content in tuna is one of the tuna trade requirements according to the guideline quality standard for frozen raw tuna as recognized by all members of the Thai Tuna Industry Association (TTIA) (Thai Tuna Industry Association, 2016). The quality control laboratory of the industry measures the salt content of tuna by traditional method in which the salt content is titrated using auto-titrator, where sodium chloride is a calibration substance and silver nitrate is a titrant, in which some chemicals are expensive and not environmental friendly. Therefore, applications of simple analytical methodologies that ensure quality are in demand.

Electrical conductivity (EC) of any solution is depended on the total ion concentration in the solution. The EC is an ability of the material to pass an electric current, which is carried by cations and anions in the solution. A solution that contains many ions (strong electrolyte solution), will conduct electricity better than a low-ion solution (weak electrolyte solution). Salts are ionic compounds

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which consist of positive sodium ions (Na^+) and negative chloride ions (Cl^-). Previous research reported that the EC of a NaCl salt solution increased with increasing salt concentration (Kaewthong *et al.*, 2017). Kaewthong and Wattanachant (2017) reported that the EC of breast meat marinated with salt solutions was significantly increased in correlation with increasing concentration of the salt solution. Thus, It's was probable that EC value can be used to determine salt content. Therefore, this work aimed to determine the correlations between the EC and the salt content in tuna meat. The feasibility of predicting the salt content in tuna meat using EC was evaluated.

2 MATERIALS AND METHODS

2.1 Sampling

Tuna meat samples from skipjack tuna (*Katsuwonus pelamis*) with the weight of 0.10 to 9.00 kg were obtained from Chotiwat Manufacturing Co., Ltd., Thailand.

A total of 270 skipjack tuna samples (n=270) was used in this study. The sample was divided into 3 sets; *(1)* 80 skipjack tuna samples were obtained from Western Pacific for study of effect of size tuna on proximate composition, salt content and EC of the tuna meat samples, in this part, the tuna samples were divided into 8 sizes, 10 tuna samples per sizes, *(2)* 90 skipjack tuna samples were obtained from three sources, Western Pacific, Western Pacific (MSC) and Indian Ocean, for study of effect of source of tuna on proximate composition, salt content and EC of the tuna meat samples, In this part, the 90 tuna samples were divided by source of tuna by the following 30 tuna samples were obtained from the Western Pacific which fishing during December 2018, 30 tuna samples were obtained from the Western Pacific which fishing during October 2018 and carrying the blue MSC label and 30 tuna samples were obtained from the Indian Ocean which fishing during September to November 2018. In each source, tuna samples were divided into 3 sizes, 10 tuna samples per size and *(3)* 100 skipjack tuna samples for verification of a prediction equation.

A shoulder (Dorsal Loin) meat of frozen flesh tuna was taken following the sampling procedure of the guideline (figure 1A.). Each tuna meat sample was kept in a tightly sealed plastic bag (nylon/LLDPE) (figure 1C.) after that the sample was thawed and blended with the blender (Kenwood, CH500) for 1 minute. Then, the EC, pH, proximate composition and salt content of the tuna meat samples were determined.

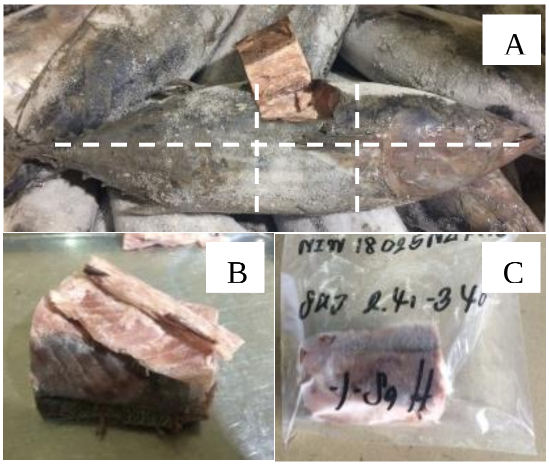

Figure 1: Sampling position of tuna carcass.

2.2 Proximate Composition

Moisture, ash and lipid were determined by the method of the AOAC (1999). Nitrogen was determined by the Kjeldahl method. Protein was then obtained by multiplying the nitrogen by a factor of 6.25. The moisture content of each sample was analyzed according to oven drying method (at 105°C until it obtained a constant weight). The oven dried samples were further used to determine the fat content and protein content.

2.3 Electrical Conductivity

The EC of tuna meat was analyzed using an EC meter (Mettler Toledo, SevenGo, Switzerland). The EC of tuna ground meat was directly measured at the tuna temperature range between 17.83±7.23℃ (adapted from Kaewthong and Wattanachant, 2017).

2.4 pH Value

The pH value of tuna meat was analyzed using a pH meter (Mettler Toledo, SevenGo SG2-FK2, Switzerland). The pH value of tuna ground meat was directly measured.

2.5 Salt Content

The salt concentration of tuna meat was determined by 2 methods using auto-titrator and manual titration method. The salt content was determined in duplicate for auto-titration method (Potentiometric

Method) (Mettler Toledo, G20, Switzerland) and triplicate for manual titration method (AOAC official method 937.09) (AOAC, 2000).

2.6 Statistical Analysis

A completely randomized design (CRD) was applied to determine the effect of size and source tuna on the EC, pH, proximate composition and salt content of the tuna meat samples. The coefficient of determination (R^2) between salt content and EC of the tuna meat was determined by the linear regression model. Furthermore, Pearson correlation coefficients (r) between salt content and EC of the tuna meat were generated by using the Pearson's Correlation Coefficient option of the SPSS computer program. Pairwise t-tests were performed for evaluating the differences in actual and predicted salt content. Significant differences among the results of different treatments' means were analyzed by Duncan's multiple range tests using the SPSS computer program (SPSS program, SPSS Inc., Chicago, IL).

3 RESULTS AND DISCUSSION

3.1 Effect of Size Tuna on Proximate Composition, Salt Content and EC of the Tuna Meat Samples

The effects of tuna size on the proximate composition are shown in Table 1. It was found that the size of tuna affected the chemical composition, including moisture content, ash, fat and protein in tuna meat ($P<0.05$). In general, moisture content of tuna fish was reported in the range of 60 - 80%. The amount of ash content was found in wide range between 0.4 - 1.5%. The fat content was varied in the range from 0.2 to 1% and the protein content was in the range of 16 - 25%. The amount of chemical composition of the fish could varied according to the species, nutritional status and growth stage of the fish (Mahaliyana *et al.*, 2015).

The results of the salt content in tuna meat, both using the auto titration and the manual titration method are shown in Table 2. It was found that the salt content of tuna in different size was significantly different ($P<0.05$). Balogun and Talabi (1985) reported that salt was not a normal constituent of marine fish species. The salt content of tuna related to the absorption of salt into the tissue during brine preservation on board rather than to changes in oceanographic conditions of salinity (Balogun *et al.*, 1985). From the result, the amount of salt in tuna tended to be inversely to the size of the fish. The fish size is one of the factors influencing salt penetration (Bodin *et al.*, 2014). Small tunas are more sensitive than large tunas. Small tunas are more sensitive to salt penetration due to a larger surface area to volume ratio. The amount of salt which analyzed by manual titration method was higher than that using auto-titrator at approximately 15% (average salt content in tuna which analyzed by manual titration method and using auto-titrator were 1.63 and 1.42, respectively).

The manual method, the concentrated HNO_3 must be applied to hydrolyze the tuna meat during boiling. The strong acidic environment gives advantage for halide (such as chloride ion) analysis (L. D. Michaud, 2016). The protons from nitric acid can release the silver ions that adsorbed. This will increase the silver ion interaction with chloride ion result in more precipitates (Shing, 2014). However,

Table 1: Proximate composition (%) of the flesh from different size of skipjack tuna.

Size (kg)	Moisture	Ash	Fat	Protein
0.10-0.99	71.35 ± 0.27^{c}	2.91 ± 0.08^{ef}	1.16 ± 0.06^{e}	22.06 ± 0.19^{a}
1.00-1.40	71.22 ± 0.15^{bc}	2.51 ± 0.09^{cd}	2.03 ± 0.07^{f}	22.54 ± 0.55^{a}
1.41-1.80	70.41 ± 0.31^{ab}	2.68 ± 0.22^{de}	1.15 ± 0.06^{e}	22.73 ± 0.42^{a}
1.81-2.40	69.89 ± 0.54^{a}	3.00 ± 0.18^{f}	0.98 ± 0.06^{d}	23.79 ± 0.93^{b}
2.41-3.40	71.48 ± 0.13^{c}	2.31 ± 0.37^{bc}	0.41 ± 0.16^{c}	22.52 ± 0.01^{a}
3.41-4.50	70.81 ± 0.13^{bc}	2.11 ± 0.06^{ab}	0.32 ± 0.07^{bc}	23.73 ± 0.20^{b}
4.51-6.00	72.29 ± 0.17^{d}	1.80 ± 0.01^{a}	0.07 ± 0.01^{a}	24.05 ± 0.12^{b}
6.10-9.00	73.06 ± 0.80^{e}	1.96 ± 0.02^{a}	0.23 ± 0.01^{b}	22.54 ± 0.55^{a}
Sig.	0.00	0.00	0.00	0.00
Total Mean	71.38 ± 1.16	2.41 ± 0.44	0.81 ± 0.67	22.98 ± 0.80

$^{a–f}$ Means ± SD, different small letters within the same column indicate a significant difference ($P < 0.05$).
8 treatments x 3 replication (n=24).

Table 2: Electrical conductivity and salt content of the flesh of skipjack tuna.

Size (kg)	*Electrical conductivity (mS/cm)	Salt content (%)	
		*By auto titration	**By manual titration
0.10-0.99	20.33 ± 4.65^{bc}	1.71 ± 0.62^{b}	2.03 ± 0.03^{d}
1.00-1.40	16.31 ± 1.79^{ab}	1.44 ± 0.26^{ab}	1.62 ± 0.05^{c}
1.41-1.80	18.28 ± 5.63^{ab}	1.56 ± 0.72^{ab}	1.73 ± 0.03^{c}
1.81-2.40	24.42 ± 8.93^{c}	1.74 ± 0.96^{b}	2.25 ± 0.08^{e}
2.41-3.40	15.82 ± 3.18^{ab}	1.44 ± 0.51^{ab}	1.93 ± 0.01^{d}
3.41-4.50	15.48 ± 1.62^{a}	1.32 ± 0.26^{ab}	1.36 ± 0.03^{b}
4.51-6.00	15.25 ± 2.64^{a}	1.02 ± 0.38^{a}	1.12 ± 0.17^{a}
6.10-9.00	15.46 ± 2.26^{a}	1.05 ± 0.47^{a}	1.14 ± 0.17^{a}
Sig.	0.00	0.05	0.00
Total Mean	17.38 ± 4.86	1.42 ± 0.60	1.63 ± 0.44

$^{a–e}$ Means ± SD, different small letters within the same column indicate a significant difference (P<0.05), pH value as 5.71 ± 0.13.
*8 treatments x 10 replication (n=80) **8 treatments x 3 replication (n=24).

in auto-titration systems, chloride ions in sample are directly titrated with silver nitrate without acidic condition adjusted and then automatically control endpoint detection. The titrator determines the endpoint by directly measuring changes in mV potential (Hanna Instruments, 2016) of chloride ion in the system.

Electrical conductivity is an electrical property, which is measured by the concentration and movement of ions (Shi *et al.*, 2014). It was found that the electrical conductivity value of tuna in different size was significantly different (P<0.05) (Table 2).

3.2 Effect of Source of Tuna on Proximate Composition, Salt Content and EC of the Tuna Meat Samples

The results of the composition analysis are shown in Table 3. It was found that the source of tuna influenced the chemical composition, including moisture content, ash, fat and protein in tuna meat (P<0.05). The environment and seasonal are some of the factors which affect the chemical composition of the fish (Mahaliyana *et al.*, 2015).

The results of the salt content analysis, both using the auto titration method and the manual titration method of tuna sample are shown in Table 4. It was found that the salt content of tuna in difference source was significantly different (P<0.05). The salt content of tuna related to the brine preservation on board (Bodin *et al.*, 2014). Different sources, it is possible to have different rigidity of controlled aboard vessels which affecting salt penetration. The electrical conductivity value of tuna in difference source was significantly different (P<0.05) (Table 4).

The Pearson correlation (r) between the salt content which analyzed by auto titration and proximate composition on EC value are shown in Table 5. From the results, it was found that the salt content and ash content of meat tuna have a high correlation in positive direction with EC value (P<0.01). The ash content is a measure of the total amount of minerals present within a food, whereas the mineral content is a measure of the amount of specific inorganic components present within a food, such as Ca, Na, K and Cl. The results were in agreement with Kaewthong and Wattanachant (2017) who found that the EC of salt solutions increased with increasing concentration and the EC of salted meat increased with increasing concentration of salt solutions. The higher number of NaCl molecules provides more ionic strength in the solution, leading to a higher EC. The high mobility of the chloride ion (Cl^-) and sodium ion (Na^+) also enhance the ability of NaCl solutions to conduct electric current (Kaewthong and Wattanachant, 2017).

Table 3: Proximate composition (%) of the flesh of skipjack tuna from different sources.

Source	Size	Moisture	Ash	Fat	Protein
WP	S	70.90 ± 0.07^{ab}	2.68 ± 0.08^{f}	0.22 ± 0.01^{a}	24.02 ± 0.65^{bc}
	M	71.88 ± 0.19^{c}	2.37 ± 0.05^{e}	0.26 ± 0.03^{a}	24.51 ± 0.06^{bc}
	L	70.58 ± 1.03^{a}	2.06 ± 0.09^{cd}	0.41 ± 0.00^{b}	25.60 ± 0.22^{de}
$WP_{(MSC)}$	S	70.80 ± 0.11^{ab}	2.44 ± 0.35^{ef}	1.47 ± 0.04^{h}	22.54 ± 0.70^{a}
	M	71.78 ± 0.42^{c}	2.30 ± 0.17^{de}	1.21 ± 0.03^{e}	23.43 ± 0.66^{ab}
	L	71.39 ± 0.16^{bc}	1.94 ± 0.07^{c}	1.28 ± 0.03^{f}	24.07 ± 0.37^{bc}
IO	S	71.83 ± 0.24^{c}	1.80 ± 0.18^{bc}	0.88 ± 0.03^{c}	24.23 ± 0.38^{b}
	M	71.46 ± 0.33^{bc}	1.51 ± 0.05^{a}	1.36 ± 0.03^{g}	24.65 ± 0.06^{cd}
	L	71.92 ± 0.11^{c}	1.56 ± 0.05^{ab}	0.97 ± 0.02^{d}	25.72 ± 0.29^{e}
Sig.		0.01	0.00	0.00	0.00
Total Mean		71.43 ± 0.61	2.07 ± 0.41	0.87 ± 0.46	24.31 ± 1.01
Sources of skipjack tuna	WP	71.15 ± 0.84^{x}	2.37 ± 0.28^{y}	0.28 ± 0.08^{x}	24.71 ± 0.78^{y}
	$WP_{(MSC)}$	71.73 ± 0.30^{y}	2.23 ± 0.30^{y}	1.30 ± 0.11^{z}	23.35 ± 0.83^{x}
	IO	71.39 ± 0.51^{xy}	1.63 ± 0.17^{x}	1.03 ± 0.21^{y}	24.86 ± 0.72^{y}
	Sig.	0.03	0.00	0.00	0.00

$^{a–h,\ x–z}$ Means ± SD, different small letters within the same column indicate a significant difference (*P*<0.05).
WP: Western Pacific, IO: Indian Ocean and MSC: Tuna carrying the blue Marine Stewardship Council (MSC) label.
Size: S; the skipjack tuna with a weight of 1.4 to 1.8 kg, M; 1.8 to 2.4 kg and L; 4.51 – 6.0 kg. 9 treatments x 3 replication (n=27).

Table 4: Electrical conductivity and salt content of the flesh of skipjack tuna.

Sources of tunas	Sizes of tunas	*Electrical conductivity (mS/cm)	Salt content (%)	
			*By auto titration	**By manual method
WP	S	18.75 ± 2.42^{d}	1.72 ± 0.30^{e}	2.44 ± 0.13^{c}
	M	15.57 ± 1.68^{c}	1.42 ± 0.27^{d}	2.36 ± 0.06^{c}
	L	12.02 ± 0.35^{a}	0.94 ± 0.17^{c}	1.41 ± 0.11^{b}
$WP_{(MSC)}$	S	18.23 ± 3.23^{d}	1.52 ± 0.52^{de}	2.38 ± 0.08^{c}
	M	17.42 ± 1.75^{d}	1.40 ± 0.31^{d}	1.98 ± 0.11^{c}
	L	13.80 ± 2.14^{b}	0.81 ± 0.25^{bc}	1.30 ± 0.56^{b}
IO	S	11.90 ± 1.71^{a}	0.60 ± 0.20^{ab}	0.67 ± 0.02^{a}
	M	10.53 ± 0.82^{a}	0.43 ± 0.10^{a}	0.77 ± 0.05^{a}
	L	10.77 ± 1.22^{a}	0.43 ± 0.14^{a}	0.81 ± 0.05^{a}
Sig.		0.01	0.00	0.00
Total Mean		14.34 ± 3.57	1.03 ± 0.54	1.57 ± 0.73
Sources of skipjack tuna	WP	15.57 ± 3.19^{z}	1.38 ± 0.41^{z}	2.07 ± 0.52^{z}
	$WP_{(MSC)}$	16.49 ± 3.08^{z}	1.24 ± 0.48^{z}	1.88 ± 0.55^{z}
	IO	11.07 ± 1.39^{y}	0.49 ± 0.17^{y}	0.75 ± 0.07^{y}
	Sig.	0.00	0.00	0.00

$^{a–h,\ y–z}$ Means ± SD, different small letters within the same column indicate a significant difference (*P*<0.05). pH value as 5.71 ± 0.13.
WP: Western Pacific, IO: Indian Ocean and MSC: Tuna carrying the blue Marine Stewardship Council (MSC) label.
Size: S; the skipjack tuna with a weight of 1.4 to 1.8 kg, M; 1.8 to 2.4 kg and L; 4.51 – 6.0 kg.
*9 treatments x 10 replication (n=90) **9 treatments x 3 replication (n=27).

Table 5: The Pearson correlation (r) between salt content and proximate composition on EC value in tuna meat.

Composition (%)	EC value	
	Pearson Correlation (r)	Sig. (2-tailed)
Salt content	0.90**	0.00
Moisture content	-0.46	0.07
Ash content	0.92**	0.00
Fat content	0.07	0.78
Protein content	-0.59*	0.01

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

3.3 Correlation between EC and Salt Content of the Tuna Meat Samples

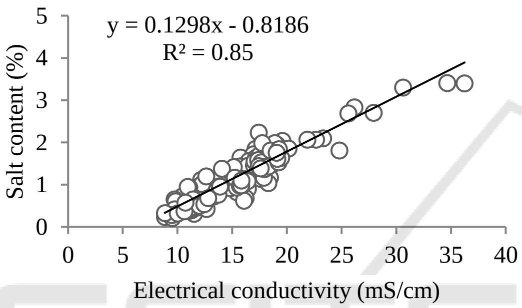

Figure 2: The regression equation for variables used in the prediction of the salt content of the flesh of skipjack tuna.

The data (n=170) from the two of the previous part were studied regression analysis.

The relationship between EC and salt content are shown in Figure 2 which is provided the following prediction equation:

$$Y = 0.1298X - 0.8129 \quad (1)$$

which Y as salt content and X as EC value. The R-Square value of the regression model is 0.85 which is high. The higher the R-square meant the better the model fits. Thus the regression model obtained a good fit.

Table 6: The Pearson correlation (r) between EC and the salt content was analyzed by auto titration.

		EC
Pearson correlation	Salt (auto titration)	0.92**
	Sig. (2-tailed)	0.00

**. Correlation is significant at the 0.01 level (2-tailed).

The Pearson correlation (r) between the salt content which analyzed by auto titration and EC as 0.923 which indicated the EC values of tuna meat had a high correlation in a positive direction with salt content (P<0.01) as shown in Table 6.

3.4 Verification of a Prediction Equation

A total of 100 skipjack tuna samples were used to verification of a prediction equation by substituting EC value in the previous equation.

Then, the difference between actual and predicted salt content was evaluated. The significant level was obtained at 0.27 which was higher than chosen significance level α=0.05. It could be concluded that the average actual and predicted salt content was non-significantly different (Table 7).

Table 7: Actual and predicted salt content of the flesh of skipjack tuna.

n	Actual	Predicted	% Dev.	Correlation (r)	Sig. (2-tailed)
100	1.52 ± 0.70	1.55 ± 0.61	1.92	0.91	0.27^ns

n; number of tuna sample, ^ns Non-significant

Figure 3 shows the accuracy of the predicted salt content of Skipjack tuna which estimated by EC value of the tuna sample. The R-Square value of the model is 0.83 which indicated that the actual and predicted salt content have a high correlation in positive direction

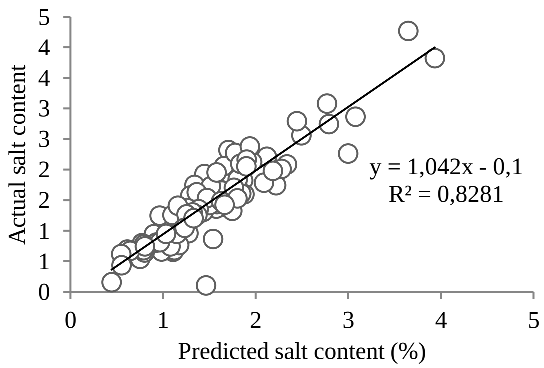

Figure 3: Accuracy in predicted salt content of Skipjack tuna by electrical conductivity.

4 CONCLUSIONS

The size of tuna affected the chemical composition, including moisture content, ash, fat and protein in tuna meat. The salt content of tuna in different size was significantly different. Small tunas are more sensitive than large tunas. It has to because small tunas are more sensitive to salt penetration due to a larger surface area to volume ratio. The electrical conductivity value of tuna in different size was significantly different.

The source of tuna affected the chemical composition, including moisture content, ash, fat and protein in tuna meat. The environment and seasonal are some of the factors which affect the chemical composition of the fish. The salt content and electrical conductivity value of tuna from different source was significantly different. The Pearson correlation (r) between the salt content had a high correlation in positive direction with EC value.

The high R-Square value of the regression model was obtained at 0.85. The Pearson correlation (r) between the salt content which analyzed by auto titration and EC have a high correlation in a positive direction with salt content. The averages actual and predicted salt content was non-significantly different. Therefore, it was a possibility to use the EC value to predict salt content in tuna meat.

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REFERENCES

AOAC. 1999. Official Methods of Analysis. 16th Ed., Association of Official Analytical Chemists, Washington, DC

AOAC. 2000. Official Methods of Analysis. 17th Ed., Association of Official Analytical Chemists, Washington, DC

Balogun, A. M. and Talabi, S. O. 1985. Proximate analysis of the flesh and anatomical weight composition of skipjack tuna (*Katsuwonus pelamis*). Food chemistry. 17(2): 117-123.

Bodin, N., Lucas V., Dewals, P., Adeline M., Esparon, J., and Chassot E. 2014. Effect of brine immersion freezing on the determination of ecological tracers in fish. European Food Research and Technology. 238: 1057–1062.

Hanna Instruments. 2016. The Complete Guide to Salt in Food (online). Available from: https://blog.hannainst.com/determining-salt-in-food/ #3methods (25 August 2019)

Kaewthong, P., and Wattanachant, S. 2017. Optimizing the electrical conductivity of marinade solution for water-holding capacity of broiler breast meat. Poultry science. 97: 701-708.

L. D. Michaud. 2016. Volhard's method (online). Available from: https://www.911me-tallurgist.com/blog/volhards-silver-determination-argentometry (25 August 2019)

Mahaliyana, A. S., Jinadasa, B. K. K. K., Liyanage, N. P. P., Jayasinghe, G. D. T. M. and Jayamanne, S. C. 2015. Nutritional al of Skipjack Tuna (*Katsuwonus pelamis*) Caught from the Oceanic Waters around Sri Lankae. American Journal of Food and Nutrition. *3*(4): 106-111.

National Food Institute. 2016. Tuna industry (online). Available from: http://fic.nfi.or-.th/ foodsectordatabank-detail.php?id=14 (10 November 2017)

Shi, C., Lu, H., Cui, J., Shen, H. and Luo, Y. 2014. Study on the predictive models of the quality of silver carp (*Hypophthalmichthys molitrix*) fillets stored under variable temperature conditions. J. Food Process. Pres. 38: 356-363.

Shing, G, Y. 2014. Comparison of three methods used for determining chloride in acid copper sulfate plating bath. Master of Science. University of Malaya.

Thai Tuna Industry Association. 2016. Guideline quality standard for frozen raw tuna (online). Available from: http://www.thaituna.org/ho-me/guidelinequality-stan-dard.php (25 August 2019)