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Effect of Phosphate Treatment on Yield and Quality of Canned Tuna

by

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인삼염처리가 다랑어 통조림의 수율과 품질에 미치는 影響

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(1976년 12월 15일 수리)

Abstract

A 7~10% aqueous phosphate solution comprised of 85% sodium tripolyphosphate and 15% sodium hexametaphosphate was injected into tuna flesh prior to precook until the fish weight increased approximately 4~10%. The experiments were conducted at a commercial tuna processing plant using Yellowfin tuna (*Thunnus albacares*) of 45~68kg and 7.3~10.5kg sizes, and Skipjack tuna (*Euthynnus pelamis*) of 4.5~5.0kg size. The experimental results showed that the phosphate treatment resulted in:

1. Approximately 5~8% increase in yield and somewhat more moist meat with the large Yellowfin.
2. Approximately 3~8% increase in yield with the smaller Yellowfin.
3. Approximately 1~4% increase in yield with the Skipjack.
4. Minimal improvement in color and flavor.

Introduction

Much information has been compiled concerning the application of phosphate to seafood to improve moisture retention and texture of the processed meat. Love and Abel[1] reported on the effect of the polyphosphate in reducing drip loss and preventing dehydration of the fish muscle. Akiba and co-workers[2] reported that mixtures of approximately 5% of sugars and alkaline phosphates at approximately 5% of the fish meat were effective in maintaining high-quality frozen, raw, ground muscle. Meyer[3] reported that adding a polymeric phosphate to the brine in which herrings were preserved greatly improved the color of the fish. Mahon[4] patented the use of dips containing polyphosphates and salt to prevent drip-loss upon thawing and to reduce loss of yield upon cooking frozen fish filets. He claimed the treatment of fish with a combination of 12% sodium tripolyphosphate and 4% salt inhibited development of rancidity in the fish and, therefore, improved flaver and odor. However, Dyer and co-workers[5] demonstrated no effect on lipid hydrolysis due to dipping fish filets in a sodium tripolyphosphate solution

prior to freezing with subsequent thawing. Swartz[6] reported that pumping a solution of molecularly dehydrated phosphate into tuna flesh prior to cooking improves yield, flavor and texture of the meat. However, the yield data reported were based on the meat cooked in an autoclave to internal temperatures of 75 to 88°C. and consequently may not be directly applicable to canned tuna. Since at present a large portion of tuna harvested is canned, we attempted in this investigation to determine the effect of phosphate treatment on the yield and quality of canned tuna.

Experiment

I. Preparation of Samples

The following three samples were prepared at a commercial tuna processing plant from Yellowfin tuna (*Thunnus albacares*) of 45~68kg size, from Yellowfin of 7.3~10.5kg size and from Skipjack tuna (*Euthynnus pelamis*) of 4.5~5.0kg size:

a. Canned tuna prepared from the fish injected with a 7~10% aqueous phosphate solution comprised of 85% sodium tripolyphosphate and 15% sodium hexametaphosphate with and without sodium chloride added.

b. Canned tuna prepared from the fish injected with fresh water.

c. Canned tuna prepared in the same manner as for the regular plant pack from the fish which received no additional treatment.

A. Yellowfin of 45~68kg size(Sample Code X/A~X/J)

Ten thawed Yellowfin of approximately 45~68kg size were eviscerated and rinsed with fresh water. Each fish was coded as A,B,C,... I and J; then each fish was cut longitudinally into two similar portions which were assigned subcodes 1 and 2. Each piece was weighed and treated as follows:

1. The flesh of all of the fish bearing subcode 1, namely: A1, B1, C1,...I1 and J1, was injected at 1.4kg/cm^2 pressure with an aqueous solution containing 10% of the phosphate mixture and 10% sodium chloride using 4 stainless needles (Presto Model SNA 15.3cm in length, 0.48cm in outside diameter with 16 cross drilled holes) attached to a pumping unit(Presto Model SS-35-1/3T) manufactured by Presto Precision Products, Inc., Franklin Square, L.I., N.Y.; and each piece of the fish was weighed.

2. The fish coded as A2, B2, C2, D2 and E2 were injected with fresh water in the same manner as for injection of the phosphate solution, and each piece of the injected fish was weighed.

3. The fish coded as F2, G2, H2, I2 and J2 received no additional treatment.

All of the fish were precooked in a steam chamber at 103°C. until the center temperature reached approximately 55°C. The precooked fish were cooled overnight at the ambient temperature and each piece was weighed individually; then the fish were cleaned on the table in the usual manner and the cleaned meats including loins, blood meat and grated meat from each piece were weighed separately. The cleaned loins from each piece of the fish were chunked; filled into 307×113(8.731cm in diameter×4.604 cm in height) tuna cans; salt, vegetable broth and soy oil were added; and steam-flow closed using the lids marked as X/A1, X/A2,... X/B1, X/B2, X/J1 and X/J2, respectively. Fill weight was about 187 g per can consisting of approximately 142 g of chunked loins, 35 g of soy oil, 10g of vegetable broth and 0~1.12g of salt to attain 1.0~1.5% level of salt in the finished product. The closed cans were retorted 80 minutes at 117°C.

B. Yellowfin of 10~10.5kg size (Sample code X/Lot 1-X/Lot 3)

Twenty-four thawed Yellowfin of approximately 10~10.5kg size were eviscerated and divided into three lots, each lot consisting of 8 fish, and coded as Lots 1, 2 and 3. Each lot of fish was weighed and treated as follows:

1. The flesh of Lot 1 fish was injected at 1.4 kg/cm^2 pressure with an aqueous solution containing 10% of the phosphate mixture and 10% sodium chloride using the stitch pumping apparatus previously described and weighed.

2. Lot 2 fish were injected with fresh water in the same manner as for injection of the phosphate solution and weighed.

3. Lot 3 fish received no additional treatment.

All of the three lots of fish were precooked and cooled in the same manner as for those of the large Yellowfin. Each lot of the precooked fish was weighed

and cleaned on the table. The cleaned meats including loins, blood meat and grated meat from each lot were weighed separately. Each lot of the cleaned loins was chunked; filled into 307×113 tuna cans; salt, vegetable broth and soy oil were added; and steam-flow closed using the lids marked as X/Lot 1, X/Lot 2 and X/Lot 3, respectively. The fill weight and process used for these samples were identical with those of X/A thru X/J samples.

C. Yellowfin of 7.3~8.2kg Size(Sample code X/Lot 4-X/Lot 6)

Duplicate samples of X/Lot 1, X/Lot 2 and X/Lot 3 were prepared from 33 Yellowfin of approximately 7.3~8.2kg size. The fish were eviscerated and divided into three lots; each lot consisting of 11 fish coded as Lots 4, 5 and 6. Each lot of fish was weighed and treated as follows:

1. The flesh of Lot 4 fish was injected at 1.4kg/cm² pressure with an aqueous solution containing 10% of the phosphate mixture and 10% sodium chloride using the stitch pumping apparatus and weighed.

2. Lot 5 fish were injected with fresh water in the same manner as for injection of the phosphate solution and weighed.

3. Lot 6 fish received no additional treatment.

All of the three lots of fish were precooked, cooled, weighed and cleaned in same manner as for those of Lot 1~Lot 3 fish. The clean meats including loins, blood meat and grated meat from each lot were weighed separately. Canned samples of X/Lot 4, X/Lot 5 and X/Lot 6 were prepared from Lots 4, 5 and 6 fish, respectively, in the same manner as for preparation of X/Lot 1-X/Lot 3 samples.

D. Skipjack of 4.5~5.0 kg size (Sample Code M/Lot 7-M/Lot 9)

Forty-five thawed Skipjack of approximately 4.5~5.0 kg size were eviscerated and divided into three lots, each lot consisting of 15 fish; and coded as Lot 7, 8 and 9. Each lot of fish was weighed and treated as follows:

1. The flesh of Lot 7 fish was injected at 1.4kg/cm² pressure with an aqueous solution containing 7% of the phosphate mixture using the stitch pumping apparatus and the treated fish were weighed.

2. Lot 8 fish were injected with fresh water in the same manner as for injection of the phosphate solution and weighed.

3. Lot 9 fish received no additional treatment.

All of the three lots of fish were precooked, cooled, weighed, and cleaned in the same manner as for those of Lot 1-Lot 6 fish. The clean meats including loins, blood meat and grated meat from each lot were weighed separately. Canned samples of M/Lot 7, M/Lot 8 and M/Lot 9 were prepared from Lots 7, 8 and 9 fish, respectively, in the same manner as for preparation of X/Lot 1-X/Lot 6 samples.

II. Examination of Sample

A. Weights of Pressed Cakes

The pressed cake weight was determined by placing the drained content of a can of tuna in a steel cylinder, inserting a plunger, and slowly exerting increasing pressure upon the tuna meat, following the procedure described under Section 37.3 of U.S.A. Code of Federal Regulations Title 21. By increasing the pressure to 27 kg/cm² of the plunger face, free liquid was pressed out, and the pressed cake remaining in the cylinder was recovered and weighed.

The pressed cake weights of the samples XX/A thru X/J were determined using 12 cans each of the samples, the net weights of which were in the range of 184~192 g. The pressed cake weights of the samples X/Lot 1 thru X/Lot 6 and M/Lot7 thru M/Lot 9 were determined using 24 cans each of the samples, the net weights of which were in the range of 184~194 g.

B. Analyses for pH, Phosphorus and Moisture Contents

Phosphorus content and pH of the samples were determined by analyzing 1 can each of the samples X/A thru X/J and 3 cans each of the samples X/Lot 1 thru X/Lot 6 and M/Lot 7 thru M/Lot 9. Moisture contents of the pressed cakes were determined by analyzing two pressed cakes each of the samples X/A thru X/J and six pressed cakes each of the samples X/Lot 1 thru X/Lot 6 and M/Lot 7 thru M/Lot 9.

C. Organoleptic Evaluation

The samples were divided into the following 13 sets and each set of the samples was evaluated by a panel of 40 judges.

1. Phosphate treated vs. Water treated (5 sets)
X/A1 vs. X/A2; X/B1 vs. X/B2; X/C1 vs. X/C2; X/

D1 vs. X/D2; and X/E1 vs. X/E2.

2. Phosphate treated vs. Untreated(5 sets) X/F1vs. X/F2; X/G1 vs. X/G2; X/H1 vs. X/H2; X/I1 vs. X/I2; and X/J1 vs. X/J2.

3. Phosphate treated vs. Water treated vs. Untreated (2 sets) X/Lot 1 vs.X/Lot 2 vs. X/Lot 3 and X/Lot 4 vs. X/Lot 5 vs. X/Lot 6.

4. Phosphate treated vs. Water treated vs. Untreated (1 set) M/Lot 7 vs. M/Lot8 vs. M/Lot9.

In each evaluation, the judges were asked to rate the color, flavor and texture of each sample on a five step scale from "excellent" to "poor". The judges were also asked to indicate which sample was lighter and which sample they preferred for each dimension of texture, flavor and color.

Results

I. Yellowfin of 45~68 kg Size

The weights of individual pieces of the two groups of fish (one for phosphate treated vs. water treated and the other for phosphate treated vs. untreated) at different stages of the process, namely: eviscerated, phosphate or water treated, precooked and cleaned, are presented in Tables 1 and 4, respectively. The net weight and pressed cake weight averages of 12 cans, together with pressed cake weight adjusted to 187 g net weight, pH, phosphorus contents, moisture contents of pressed cakes, theoretical yield based on loin recovery and tuna fill weight, and relative yield based on moisture contents of pressed cakes of the two groups of samples (one for phosphate treated vs. water treated and the other for phosphate treated vs. untreated) are presented in Tables 2 and 5, respectively. The results of the panel evaluation of the two groups of samples, one for phosphate treated vs. water treated and the other for phosphate treated vs. untreated, are presented in Tables 3 and 6, respectively.

A. Phosphate treated vs. Water treated

Average of the test results on the five pairs of fish, X/A1 vs. X/A2 thru X/E1 vs. X/E2, showed that:

1. The clean loins recovered (approximately 90% of the entire clean meats) were 45.2% and 42.1% of the eviscerated fish weight for phosphate treated and water treated, respectively; while the entire meats recovered were 48.7% and 48.1% of the eviscerated fish weight for phosphate treated and water treated, respectively, as shown in Table 1.

2. As shown in Table 2, the pressed cake weights adjusted to 187 g net weight from the pressed cake weight averages of 60 cans were 114.8 g for phosphate treated and 115.1g for water treated. Tuna fill weights required to obtain 113.4 g pressed cake weight, calculated on the basis of the pressed cake weights and fill weight of 35 g oil and 10 g vegetable broth,were 139.8g. for phosphate treated and 139.4 g for water treated. Theoretical yield calculated from the loin recovery and tuna fill weight showed 7% higher yield for phosphate treated over water treated. However,the relative yield calculated on the basis of moisture contents of the samples pressed, 61.0% for phosphate treated and 60.2% for water treated, showed 2.0% higher yield for phosphate treated over water treated.

Phosphorus contents and pH of the samples were 0.79%(P_2O_5) and 5.95 for phosphate treated and 0.40%(P_2O_5) and 5.86 for water treated, respectively.

3. The results of the panel evaluation of the samples presented in Table 3 showed that:

a. There was no difference in lightness, but a trend toward preferring the color of the water treated to that of the phosphate treated.

b. There was a trend toward preferring the texture and flavor of the phosphate treated to those of the water treated.

B. Phosphate treated vs. Untreated

Average of the test results on the five pairs of fish, X/F1 vs. X/2 thru X/J1 vs. X/J2, showed that:

1. The clean loins recovered (approximately 90% of the entire clean meats) were 51.3% and 46.5% of the eviscerated fish weight for phosphate treated and untreated, respectively; while the entire meats recovered were 56.8% and 51.4% of the eviscerated fish weight for phosphate treated and untreated, respectively, as shown in Table 4.

2. As shown in Table 5, the pressed cake weights adjusted to 187 g net weight from the pressed cake weight averages of 60 cans were 113.9 g for phosphate treated and 113.3 g for untreated. Tuna fill weights required to obtain 113.4 g pressed cake weight were

Weights of Individual Fish Pieces From Yellowfin of 45–68kg Size After Eviscerated, Phosphate or Water Treated, Precooked and Cleaned

Fish code	Treatment	Number of fish	Weight of Fish					Weight of Cleaned Meat							
			Eviscerated Kg	Treated		Precooked		Loins		Blood Meat		Grated Meat		Total	
				Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated
A1	Phosphate & Salt	1/2	38.1	42.0	110.1	30.0	78.6	19.3	50.6	1.8	4.8	0.0	0.0	21.1	55.4
A2	Water	1/2	24.3	26.1	107.5	18.1	74.8	10.9	44.9	1.1	4.7	0.2	0.9	12.2	50.5
B1	Phosphate & Salt	1/2	34.2	36.3	106.0	24.5	71.5	15.4	45.0	1.1	3.3	0.2	0.7	16.8	49.0
B2	Water	1/2	20.9	22.5	107.6	14.5	69.6	8.8	42.4	1.4	6.5	0.0	0.0	10.2	48.9
C1	Phosphate & Salt	1/2	40.8	43.3	106.1	29.3	71.7	16.1	39.5	1.1	2.8	0.2	0.6	17.5	42.8
C2	Water	1/2	25.9	27.9	107.9	15.6	60.5	10.9	42.1	1.4	5.3	0.2	0.9	12.5	48.3
D1	Phosphate & Salt	1/2	31.3	33.1	105.8	22.2	71.0	14.1	44.9	0.7	2.2	0.0	0.0	14.7	47.1
D2	Water	1/2	16.1	16.8	104.2	10.7	66.2	5.7	35.2	1.4	8.5	0.5	2.8	7.5	46.5
E1	Phosphate & Salt	1/2	40.3	42.6	105.9	30.7	76.3	18.6	46.2	1.1	2.8	0.2	0.6	20.0	49.6
E2	Water	1/2	22.7	24.0	106.0	16.3	72.0	10.0	44.0	0.2	1.0	0.2	1.0	10.4	46.0
Average															
A1-E1	Phosphate & Salt	1/2	37.0	39.5	106.8	27.3	73.8	16.7	45.2	1.2	3.2	0.1	0.4	18.0	48.7
A2-E2	Water	1/2	22.0	23.5	106.6	15.1	68.6	9.3	42.1	1.1	5.2	0.2	1.1	10.6	48.1

Net Weight, Pressed Cake Weight, pH, Phosphorus and Moisture Contents, and Theoretical Yield of Canned Chunk Tuna FromYellowfin of 45–68 Kg Size (Phosphate Treated vs. Water Treated)

Sample Code	Treatment	Analysis of One Can		Net Wt. (Avg. of 12 Cans) gram	Pressed Cake Wt.		Tuna Fill Wt.* Required to Obtain 113.4g Pressed Cake Wt. gram	Theoretical Yield**		% Moisture of Pressed Cake (Avg. of 2 Cans)	Relative Yield Based on % Moisture of Pressed Cake
		pH	Phosphorus % P_2O_5		Avg. of 12 Cans gram	Adjusted to 187g Net Wt. gram		No. of Cans from 453.6 Kg of Eviscerated Fish	Relative Yield Based on Loin Recovery and Tuna Fill Wt.		
X/A1	Phosphate & Salt	6.10	.80	186.3	120.4	121.0	130.0	1764	107	61.2	101.8
X/A2	Water	5.95	.44	190.0	127.4	125.5	123.7	1646	100	60.5	100.0
X/B1	Phosphate & Salt	6.05	.87	190.0	111.5	109.9	147.8	1381	103	61.4	102.1
X/B2	Water	5.88	.39	189.4	113.3	111.9	144.2	1333	100	60.6	100.0
X/C1	Phosphate & Salt	5.92	.66	189.7	115.4	113.9	141.0	1271	98	61.9	101.6
X/C2	Water	5.87	.39	191.4	112.6	110.1	147.3	1296	100	61.3	100.0
X/D1	Phosphate & Salt	5.85	.80	189.4	118.9	117.5	135.3	1505	130	60.8	103.3
X/D2	Water	5.88	.39	187.7	115.7	115.3	138.7	1151	100	59.5	100.0
X/E1	Phosphate & Salt	5.85	.80	188.5	112.4	111.6	144.8	1447	103	59.5	100.7
X/E2	Water	5.75	.37	191.4	115.1	112.5	143.1	1394	100	59.2	100.0
Average											
X/A1—X/E1	Phosphate & Salt	5.95	.79	188.8	115.8	114.8	139.8	1473	107	61.0	102.0
X/A2—X/E2	Water	5.86	.40	190.0	116.8	115.1	139.4	1364	100	60.2	100.0

* Tuna Fill Weight was calculated by subtracting 45g (35g oil and 10g broth) from the calculated Net Weight which should give 113.4g Pressed Cake Weight. ** Theoretical Yield is determined by dividing Weight of cleaned loins with Tuna Fill Weight.

Results of Panel Evaluation of Canned Chunk Tuna Prepared From Yellowfin of 45—68Kg Size (phosphate Treated vs. Water Treated)

Sample Code	Treatment	Color				Texture				Flavor			
		Ranking (Lightness)		Quality		Ranking		Quality		Ranking		Quality	
		Rank*	Significant Difference?	Score**	Significant Difference?	Rank*	Significant Difference?	Score**	Significant Difference?	Rank*	Significant Difference?	Score**	Significant Difference?
X/A1	Phosphate & Salt	1.72	Yes, @ 1% level	2.6	Yes, @0.1% level	1.43	No, @ 5% level	2.8	No, @ 5% level	1.57	No, @ 5% level	3.2	No, @ 5% level
X/A2	Water	1.28		3.6		1.57		2.8		1.43		3.0	
X/B1	Phosphate & Salt	1.48	No, @ 5% level	3.0	No, @ 5% level	1.37	No, @ 5% level	3.0	No, @ 5% level	1.45	No, @ 5% level	3.2	No, @ 5% level
X/B2	Water	1.52		3.3		1.63		2.8		1.55		3.0	
X/C1	Phosphate & Salt	1.43	No, @ 5% level	2.0	No, @ 5% level	1.41	No, @ 5% level	2.5	No, @ 5% level	1.42	No, @ 5% level	2.4	No, @ 5% level
X/C2	Water	1.57		2.2		1.59		2.2		1.58		2.3	
X/D1	Phosphate & Salt	1.47	No, @ 5% level	2.4	No, @ 5% level	1.70	No, @ 5% level	3.0	Yes, @ 5% level	1.57	No, @ 5% level	2.9	Yes, @ 5% level
X/D2	Water	1.53		2.7		1.30		2.4		1.43		2.5	
X/E1	Phosphate & Salt	1.39	No, @ 5% level	2.9	No, @ 5% level	1.45	No, @ 5% level	3.1	Yes, @0.1% level	1.32	Yes, @ 5% level	3.2	Yes, @0.1% level
X/E2	Water	1.61		3.0		1.55		2.5		1.68		2.6	
Average													
X/A1—X/E1	Phosphate & Salt	1.50		2.6		1.47		2.9		1.47		3.0	
X/A2—X/E2	Water	1.50		3.0		1.53		2.6		1.53		2.7	

* Average Rank—based on range of 1—2 (1=best; 2—worst). An average rank of 1 would be the best possible average rank.
** Average Score—based on range of 1—5 (5=excellent; 1—poor). An average score of 5 would be the best possible average score.

Weights of Individual Fish Pieces From Yellowfin of 45—68Kg Size After Eviscerated, Phosphate Treated, Precooked and Cleaned

Fish Code	Treatment	Number of Fish	Weight of Eviscerated Fish Kg	Weight of Fish				Weight of Cleaned Meat							
				Phosphate treated		Precooked		Loins		Blood Meat		Grated Meat		Total	
				Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated
F1	Phosphate & Salt	1/2	29.3	32.0	109.3	23.8	81.4	15.0	51.2	0.9	3.1	0.2	0.8	16.1	55.0
F2	None	1/2	29.9	—	—	22.7	75.8	13.2	43.9	1.1	3.8	0.2	0.8	14.5	48.5
G1	Phosphate & Salt	1/2	22.2	25.6	115.3	18.1	81.6	12.7	57.1	1.4	6.1	0.2	1.0	14.3	64.3
G2	None	1/2	23.1	—	—	22.7	98.0	11.3	49.0	1.1	4.9	0.2	1.0	12.7	54.9
H1	Phosphate & Salt	1/2	17.5	20.6	118.2	13.6	77.9	9.3	53.2	1.1	6.5	0.2	1.3	10.7	61.0
H2	None	1/2	23.1	—	—	18.4	79.4	10.4	45.1	0.9	3.9	0.0	0.0	11.3	49.0
I1	Phosphate & Salt	1/2	24.5	26.5	108.3	18.4	75.0	12.2	50.0	0.9	3.7	0.2	0.9	13.4	54.6
I2	None	1/2	29.0	—	—	21.3	73.4	14.3	49.2	1.6	5.5	0.2	0.8	16.1	55.5
J1	Phosphate & Salt	1/2	21.5	24.3	112.6	16.6	76.8	9.8	45.3	0.9	4.2	0.2	1.1	10.9	50.5
J2	None	1/2	33.3	—	—	24.9	74.8	15.2	45.6	1.1	3.4	0.2	0.7	16.6	49.7
Average															
F1—J1	Phosphate & Salt	1/2	23.0	25.8	112.7	18.1	78.7	11.8	51.3	1.0	4.5	0.2	1.0	13.1	56.8
F2—J2	None	1/2	27.7	—	—	22.0	79.4	12.9	46.5	1.2	4.3	0.2	0.7	14.2	51.4

Net Weight, Pressed Cake Weight, pH, Phosphorus and Moisture Contents, and Theoretical Yield of Canned Chunk Tuna From Yellowfin of 45—68 Kg Size (Phosphate Treated vs. Untreated)

Sample Code	Treatment	Analysis of One Can		Net Wt. (Avg. of 12 Cans) gram	Pressed Cake Wt.		Tuna Fill Wt* Required to Obtain 113.4g Pressed Cake Wt. gram	Theoretical Yield**		% Moisture of Pressed Cake (Avg. of 2 Cans)	Relative Yield Based on % Moisture of Pressed Cake
		pH	Phosphorus % P_2O_5		Avg. of 12 Cans gram	Adjusted to 187g Net Wt. gram		No. of Cans from 453.6 Kg of Eviscerated Fish	Relative Yield Based on Loin Recovery and Tuna Fill Wt.		
X/F1	Phosphate & Salt	6.13	.84	188.5	116.1	115.2	138.8	1673	113	57.5	105.9
X/F2	None	5.98	.48	188.0	117.9	117.3	135.5	1469	100	59.1	100.0
X/G1	Phosphate & Salt	6.02	.96	187.7	113.2	112.8	142.7	1814	117	60.6	108.1
X/G2	None	5.90	.48	187.4	112.6	112.4	143.4	1550	100	57.4	100.0
X/H1	Phosphate & Salt	6.02	1.03	188.2	115.2	114.6	139.9	1725	123	60.0	102.3
X/H2	None	5.75	.46	188.2	111.3	110.6	146.5	1396	100	59.1	100.0
X/I1	Phosphate & Salt	5.95	.73	190.0	115.9	114.0	140.7	1612	103	59.0	104.9
X/I2	None	5.75	.46	188.0	113.5	112.9	142.5	1566	100	57.0	100.0
X/J1	Phosphate & Salt	6.05	.89	189.4	114.1	112.7	142.8	1438	99	59.1	105.6
X/J2	None	5.85	.44	190.0	114.9	113.2	142.1	1455	100	56.8	100.0
Average											
X/F1—X/J1	Phosphate & Salt	6.03	.89	188.8	114.9	113.9	141.0	1652	111	59.6	105.3
X/F2—X/J2	None	5.84	.46	188.2	114.0	113.3	142.0	1487	100	57.5	100.0

* Tuna **Fill** Weight was calculated by subtracting 45g (35g oil and 10g broth) from the calculated Net Weight which should give 113.4g Pressed Cake Weight. ** Theoretical Yield is determined by dividing weight of cleaned loins with Tuna Fill Weight.

Results of Panel Evaluation of Canned Chunk Tuna Prepared From Yellowfin of 45—68Kg Size (Phosphate Treated vs. Untreated)

Sample Code	Treatment	Color				Texture				Flavor			
		Ranking(Lightness)		Quality		Ranking		Quality		Ranking		Quality	
		Rank*	Significant Difference?	Score**	Significant Difference?	Rank*	Significant Difference?	Score**	Significant Difference?	Rank*	Significant Difference?	Score**	Significant Difference?
X/F1	Phosphate & Salt	1.2	Yes, @ 1% level	3.2	No, @ 5% level	1.38	No, @ 5% level	3.3	No, @ 5% level	1.24	Yes, @ 1%level	3.3	Yes, @ 5% level
X/F2	None	1.7		3.2		1.62		3.1		1.76		3.0	
X/G1	Phosphate & Salt	1.2	Yes, @0.1%level	3.2	No, @ 5% level	1.33	No, @ 5% level	3.2	No, @ 5% level	1.45	No, @ 5% level	3.2	No, @ 5% level
X/G2	None	1.7		3.3		1.67		3.0		1.55		3.1	
X/H1	Phosphate & Salt	1.3	No, @ 5% level	3.3	No, @ 5% level	1.42	No, @ 5% level	3.4	No, @ 5% level	1.53	No, @ 5% level	3.2	No, @ 5% level
X/H2	None	1.6		3.4		1.58		3.1		1.47		3.1	
X/I1	Phosphate & Salt	1.2	Yes, @ 5% level	3.1	No, @ 5% level	1.22	Yes,@0.1% level	3.1	Yes, @ 1% level	1.42	No, @ 5% level	3.2	Yes, @ 5% level
X/I2	None	1.7		3.2		1.78		2.6		1.58		2.8	
X/J1	Phosphate & Salt	1.2	Yes, @ 1% level	2.6	No, @ 5% level	1.39	No, @ 5% level	3.2	No, @ 5% level	1.35	No, @ 5% level	3.2	No, @ 5% level
X/J2	None	1.74		2.5		1.61		2.8		1.65		2.9	
Average													
X/F1—X/J1	Phosphate & Salt	1.28		3.1		1.35		3.2		1.40		3.2	
X/F2—X/J2	None	1.72		3.1		1.65		2.9		1.60		3.0	

* Average Rank—based on range of 1—2 (1=best; 2=worst). An average rank of 1 would be the best possible average rank.

** Average Score—based on range of 1—5 (5=excellent; 1=poor). An average score of 5 would be the best possible average score.

Weight of Each Lot of Fish from Yellowfin of 10—10.5 Kg Size (Lots 1, 2 and 3) and 7.3—8.2Kg Size (Lots 4,5 and 6) and Skipjack of 4.5—5.0 Kg Size (Lots 7,8 and 9) After Eviscerated, Phosphate or Water Treated, Precooked and Cleaned

Fish Code	Treatment	No. of Fish & Average Weight No Kg		Weight of Fish					Weight of Cleaned Meat							
				Eviscerated Fish Kg	Treated		Precooked		Loins		Blood Meat		Grated Meat		Total	
		No	Kg		Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated	Kg	% of Eviscerated
Yellowfin																
Lot 1	Phosphate & Salt	8	10.0	72.8	81.2	111.5	61.0	83.8	31.8	43.6	4.3	5.9	0.2	0.3	36.3	49.8
Lot 2	Water	8	10.0	76.9	81.4	105.8	58.7	76.4	31.1	40.4	3.4	4.4	0.5	0.6	34.9	45.4
Lot 3	None	8	10.0	74.4	—	—	58.5	78.6	27.0	36.3	3.6	4.9	0.7	0.9	31.3	42.1
Lot 4	Phosphate & Salt	11	8.0	74.4	78.9	106.1	61.0	82.0	32.7	43.9	3.9	5.2	0.5	0.6	37.0	49.7
Lot 5	Water	11	8.0	77.6	82.6	106.4	62.1	80.1	30.8	39.8	3.9	5.0	0.2	0.3	34.9	45.0
Lot 6	None	11	8.0	85.1	—	—	69.4	81.6	34.2	40.3	3.4	4.0	0.9	1.1	38.6	45.3
Yellowfin Average (or Total)																
Lots 1 & 4	Phosphate & Salt	19	8.8	147.2	160.1	108.8	122.0	82.9	64.4	43.7	8.2	5.5	0.7	0.5	73.3	49.8
Lots 2 & 5	Water	19	8.8	154.5	164.0	106.1	120.9	78.2	61.9	40.1	7.3	4.7	0.7	0.4	69.9	45.2
Lots 3 & 6	None	19	8.8	159.4	—	—	127.9	80.2	61.2	38.4	7.0	4.4	1.6	1.0	69.9	43.8
Skipjack																
Lot 7	Phosphate	15	4.7	68.6	70.8	103.1	55.3	80.6	26.5	38.7	4.5	6.6	0.5	0.7	31.5	45.9
Lot 8	Water	15	4.7	65.5	70.4	107.6	51.7	79.0	22.0	33.6	4.8	7.3	0.7	1.0	27.4	41.9
Lot 9	None	15	4.7	65.5	—	—	52.6	80.3	23.1	35.3	3.4	5.2	0.5	0.7	27.0	41.2

Net Weight, Pressed Cake Weight, pH, Phosphorus and Moisture Contents, and Theoretical Yield of Canned Chunk Tuna from Yellowfin of 10—10.5 Kg Size (X/Lot 1—3) and 7.3—8.2 Kg Size (X/Lot 4—6) and Skipjack of 4.5—5.0 Kg Size(M/Lot 7—9)

Sample Code	Treatment	pH (Avg. of 3 cans)	Phosphorus % P_2O_5 (Avg. of 3 Cans)	Net Wt. (Avg. of 24 cans) gram	Pressed Cake Wt.		Tuna Fill Wt.*required to obtain 113.4g Pressed Cake Wt. gram	Theoretical Yield**		% Moisture of Pressed Cake (Avg. of 6 cans)	Relatve Yield Based on % Moisture of Pressed Cake
					Avg. of 24 cans gram	Adjusted to 187g Net Wt. gram		No of Cans from 453.6 Kg of Eviscerated fish	Relative Yield Based on Loin Recovery and Tuna Fill Wt.		
Yellowfin											
X/Lot 1	Phosphate & Salt	5.98	.80	191.9	105.0	102.3	162.0	1221	117	62.7	102.9
X/Lot 2	Water	6.07	.51	188.0	103.4	102.9	160.7	1140	109	62.9	103.5
X/Lot 3	None	5.98	.50	188.5	105.0	104.2	158.0	1041	100	61.6	100.0
X/Lot 4	Phosphate & Salt	5.99	.81	186.3	114.0	114.5	139.9	1423	112	63.1	104.3
X/Lot 5	Water	5.88	.46	191.6	116.7	113.9	140.8	1282	101	62.8	103.5
X/Lot 6	None	5.80	.49	188.8	112.6	111.6	144.7	1263	100	61.5	100.0
Yellowfin Average											
X/Lots 1 & 4	Phosphate & Salt	5.99	.81	189.1	109.5	108.4	150.9	1322	114	62.9	103.7
X/Lots 2 & 5	Water	5.98	.49	190.0	110.0	108.4	150.7	1211	105	62.8	103.5
X/Lots 3 & 6	None	5.89	.50	188.8	108.8	107.9	151.4	1152	100	61.5	100.0
Skipjack											
M/Lot 7	Phosphate	5.86	.68	188.5	118.9	118.0	134.5	1305	107	63.5	101.6
M/Lot 8	Water	5.80	.47	190.0	124.7	122.9	127.3	1197	99	63.8	102.5
M/Lot 9	None	5.83	.48	188.8	120.5	119.4	132.3	1210	100	62.9	100.0

* Tuna Fill Weight was calculated by subtracting 45g (35g oil and 10g broth) from the calculated Net Weight which should give 113.4g Pressed Cake Weight.

** Theoretical Yield is determined by dividing Weight of cleaned loins with Tuna Fill Weight.

Results of Panel Evaluation of Canned Chunk Tuna Prepared From Yellowfin of 10—10.5 Kg Size (X/Lot 1—3) and 7.3—8.2Kg Size (X/Lot 4—6) and Skipjack of 4.5—5.0 Kg Size (M/Lot 7—9)

Sample Code	Treatment	Color				Texture				Flavor			
		Ranking(Lightness)		Quality		Ranking		Quality		Ranking		Quality	
		Rank*	Significant Difference?	Score**	Significant Difference?	Rank*	Significant Difference?	Score**	Significant Difference?	Rank*	Significant Difference?	Score**	Significant Difference?
Yellowfin													
X/Lot 1	Phosphate & Salt	1.6	Yes, @ 1% level	2.9	Yes, @ 1% level	2.0	No, @ 5% level	3.1	No, @ 5% level	1.8	No, @ 5% level	3.2	No, @ 5% level
X/Lot 2	Water	1.7	between lot 3 &	3.1	between lot 2 &3	1.9		3.1		2.1		2.8	
X/Lot 3	None	2.6	1 or lot 3 & 2	2.4		2.1		2.9		2.1		2.8	
X/Lot 4	Phosphate & Salt	2.3	No, @ 5% level	2.6	Yes, @ 1% level	2.1	No, @ 5% level	3.2	No, @ 5% lovel	2.1	Yes, @ 1% level	3.0	No, @ 5% level
X/Lot 5	Water	1.8		3.2	between lot 4 &	2.1		3.0		2.3	between lot 6 & 4	3.0	
X/Lot 6	None	2.0		3.3	5 or lot 4 & 6	1.8		3.2		1.6	or lot 6 & 5	3.6	
Yellowfin Average													
X/Lots 1 & 4	Phosphate & Salt	2.0		2.8		2.1		3.2		1.9		3.1	
X/Lots 2 & 5	Water	1.8		3.2		2.0		3.1		2.2		2.9	
X/Lots 3 & 6	None	2.3		2.9		2.0		3.1		1.9		3.2	
Skipjack													
M/Lot 7	Phosphate	1.7	Yes, @ 1% level	2.8	No, @ 5% level	1.8	No, @ 5% level	3.0	No, @ 5% level	1.8	No, @ 5% level	2.9	No, @5% leve
M/Lot 8	Water	2.4	between lot 8 &	2.9		2.3		3.0		2.3		2.9	
M/Lot 9	None	1.9	7 or Lot 8 & 9	3.0		1.9		3.0		1.9		3.0	

* Average Rank—based on range of 1—3 (1=best; 3=worst). An average rank of 1 would be the best possible average rank.

** Average Score—based on rang of 1—5 (5=excellent; 1=poor). An average score of 5 would be the best possible average score.

141g for phosphate treated and 142 g for untreated. Theoretical yield calculated from the loin recovery and tuna fill weight showed 11% higher yield for phosphate treated over untreated. However, the relative yield calculated on the basis of moisture contents of the samples pressed, 59.6% for the phosphate treated 57.5% for untreated showed 5.3% higher yield for phosphate treated over untreated.

Phosphorus contents and pH of the samples were 0.89% (P_2O_5) and 6.03 for phosphate treated and 0.46 %(P_2O_5) and 5.84 for untreated, respectively.

3. The results of the panel evaluation of the samples presented in Table 6 showed that:

a. Phosphate treated was significantly lighter than untreated but there was no preference in color of the samples.

b. There was a trend toward preferring the texture and flavor of the phosphate treated to those of the untreated.

II. Yellowfin of 10~10.5 kg and 7.3~8.2 kg Sizes and Skipjack of 4.5~5.0 kg Size

The weights of individual lots of the six lots of Yellowfin (Lot 1 thru Lot 6) and three lots of Skipjack (Lot 7 thru Lot 9) at different stages of the process, namely: eviscerated, phosphate or water treated, precooked and cleaned,are presented in Table 7. The net weight and pressed cake weight averages of 24 cans, together with pressed cake weight adjusted to 187 g net weight, pH, phosphorus contents, moisture contents of pressed cakes, theoretical yield based on loin recovery and tuna fill weight, and relative yield based on moisture contents of pressed cakes are presented in Table 8. The results of the panel evaluation of the samples are presented in Table 9.

A. Yellowfin(Phosphate treated vs. Water treated vs. Untreated)

Averages of the test results of the two runs, X/Lots 1 and 4 vs. X/Lots 2 and 5 vs. X/Lots 3 and6, showed that:

1. The clean loins recovered(approximately 88% of the entire clean meats) were 43.7%, 40.1% and 38.4 % of the eviscerated fish weight for phosphate treated, water treated and untreated, respectively; while the recoveries of the entire meats were 49.8%, 45.2 % and 43.8% of the eviscerated fish weight for phosphate treated, water treated, and untreated, respectively, as shown in Table 7. The difference in loin recovery between Lot 1 and Lot 3, phosphate treated and untreated with Yellowfin of 10~10,5kg size was 7.3%, while the difference between Lot 4 and Lot 6, phosphate treated and untreated with Yellowfin of 7.3~8.2 kg size was 3.6%.

2. As shown in Table 8, the pressed cake weights adjusted to 187 g net weight from the pressed cake weight averages of 48 cans were 108.4 g for both the phosphate treated and water treated and 107.9 g for untreated. Theoretical yield calculated from the loin recovery and tuna fill weight showed 14% and 5% higher yields for phosphate treated and water treated, respectively, over untreated. However, the relative yield calculated on the basis of moisture contents of the samples pressed, 62.9%, 62.8% and 61.5% for phosphate treated, water treated and untreated, respectively showed 3.7% and 3.5% higher yields for phosphate treated and water treated, respectively, over untreated.

Phosphorus contents and pH of the samples were 0.81% (P_2O_5) and 5.99 for phosphate treated, 0.49% (P_2O_5) and 5.98 for water treated, and 0.50%(P_2O_5) and 5.89 for untreated, respectively.

3. Results of the panel evaluation of the samples presented in Table 9 showed that there were no significant differences in lightness, texture and flavor between the samples of phosphate treated, water treated and untreated, although there was a slight trend toward preferring the color of the water treated.

B. Skipjack (Phosphate treated vs. Water treated vs. Untreated)

The results of the test on three lots of Skipjack, M/Lot 7 vs. M/Lot 8 vs. M/Lot 9, showed that:

1. The clean loins recovered (approximately 80~86 % of the entire clean meats) were 38.7%, 33.6% and 35.3% of the eviscerated fish weight for phosphated, water treated and untreated, respectively; while recoveries of the entire meats were 45.9%, 41.9% and 41.2% of the eviscerated fish weight for phosphate treated, water treated and untreated, respectively, as shown in Table 7.

2. As shown in Table 8, the pressed cake weights adjusted to 187g net weight from the pressed cake

weight averages of 24 cans were 118 g, 122.9 g and 119.4 g for phosphate treated, water treated and untreated, respectively. Theoretical yield calculated from the loin recovery and tuna fill weight showed that yield for phosphate treated was 7% higher than untreated, while yield for water treated was 1% lower than untreated. However, the relative yield calculated on the basis of moisture contents of the samples pressed, 63.5%, 63.8% and 62.9% for phosphate treated, water treated and untreated, respectively, showed 1.6 % and 2.5% higher yield for phosphate treated and water treated, respectively, over untereated.

Phosphorus contents and pH of the samples were 0.67% (P_2O_5) and 5.86 for phosphate treated, 0.47% (P_2O_5) and 5.80 for water treated, and 0.48% (P_2O_5) and 5.83 for untreated.

3. Results of the panel evaluation of the samples presented in Table 9 showed that phosphate treated sample was lightest and water treated sample was darkest, while there were no significant preferences in color, texture and flavor of the samples.

Discussion

The test results showed that phosphate treatment raised the pH value of tuna meat, improved moisture retention of the processed meat, and somewhat lightened color of the meat. The effect of phosphate treatment on retention of the meat moisture was shown both in recovery of the clean meats and in moisture contents of the pressed cakes, particularly in the results of the test on large Yellowfin where the interfering variables were minimized. The color lightening effect of phosphate treatment might have been partly due to washing out of blood from the flesh during injection of the solution into tuna.

Averages of the pressed cake weights of 12~24 cans presented in Tables 2, 5 and 8 showed that:

(1) There was no significant difference in pressed cake weight between the samples of phosphate treated, water treated and untreated prepared from Yellowfin.

(2) There was only a slight difference in pressed cake weight between the samples of phosphate treated, water treated and untreated prepared from Skipjack.

The pressed cake weight comparison showing no significant difference between the samples of phosphate treated and untreated seems to indicate that phosphate treatment does not require adjustment of tuna fill weight. However, the loin recovery data presented in Tables 1, 4 and 7 and the moisture contents of pressed cakes presented in Tables 2, 5 and 8 showed that only a portion of the additional moisture retained in the cleaned loins of phosphate treated fish remained in the cakes. This seems to indicate that tuna fill weight should be increased to meet the pressed cake weight requirement when the fish is treated with phosphate. The discrepancy between the two calculations of theoretical yield,one based on the loin recovery and tuna fill weight and the other on moisture contents of the pressed cakes, is probably due to the following factors:

1. Moisture content of meat is not the only factor determining pressed cake weight. Pressed cake weights of the samples of similar net weights ranging 184~194g fluctuated in the range of 93~140.9 g. Pressed cake weights of the samples of similar net weights ranging 184~192 g prepared from the same fish also fluctuated in the ragne of 106.9~134.1 g. This indicates that pressed cake weight is affected not only by moisture content of the meat, but also to a certain extent by physical condition, such as shape, size and number of pieces constituting the chunks.

2. Variation of tuna fill weight: Tuna meat was filled by volume and consequently, the fill weight varied somewhat.

3. Moisture contents of the pressed cakes varied depending upon not only the treatment, but also the characteristics, such as species and size of the fish from which the samples were prepared.

Considering the magnitude of the aforementioned interfering variables, the number of samples we analyzed was too small to determine the representative averages of weights and moisture contents of pressed cakes applicable to calculation of the exact tuna fill weight. However, the results of analysis for moisture contents of the pressed samples showing higher moisture contents for phosphate treated over untreated for all sizes and species of tuna clearly indicate that phosphate treatment resulted in higher yield. The results of the panel evaluation showing a trend toward

preference for texture of the phosphate treated samples over that of the water treated and untreated samples also suggest that the former was more moist than the latter. From the foregoing discussion, it appears that the theoretical yield of phosphate treated tuna calculated on the basis of:

(1) The loin recovery and the calculated tuna fill weight based on the pressed cake weight averages of 12~24 cans is probably too high, since the release from the meat during processing and pressing of some of the additional moisture retained in the loins of the phosphate treated fish should appear on pressed cake weight average when a larger number of cans is examined.

(2) Moisture contents of the pressed cakes is probably a little too low, since no consideration is given in this calculation to the effect of physical conditions, such as size and shape of pieces of meat chunks on pressed cake weight.

With the limited data obtained from the test, it is reasonable to assume that an average of the above two theoretical yields is probably a better guide for evaluating the effect of phosphate treatment on yield of chunk style canned tuna.

It should be noted that the effect of phosphate treatment on yield,texture and color of the canned meat was more prominent in the samples prepared from the large Yellowfin and somewhat obscure in the samples prepared from the small fish. It is also interesting to note that injection of water into the large Yellowfin resulted in about 3% increase in yield, while the effect of water injection into the small fish was negligible. The moisture contents of pressed cakes of the samples prepared from the large Yellowfin were lowest (average 57.5% for untreated and 59.6% for phosphate treated) and those of the samples prepared from Skipjack were highest (average 62.9% for untreated and 63.5% for phosphate treated), while the increase in moisture contents of the pressed cakes resulting from the phosphate treatment was largest in the samples prepared from the large Yellowfin(average 2.1%) and smallest in the samples prepared from Skipjack (average 0.6%). This indicates that the increase in yield and improvement in texture of meat through the phosphate and salt treatment was primarily the result of increased hydration of meat, and that the small fish we used for the test had initial moisture and salt contents so high that the phosphate treatment did not increase hydration of the meat of such fish as much as that of the large Yellowfin.

The following may be concluded from the test results.

1. Approximately 5~8% increase in yield, some improvement in meat texture and a little lightening of meat color of chunk style canned tuna may be expected from injection of an aqueous solution containing 10% sodium chloride 10% phosphate comprised of 85% sodium tripolyphate and 15% sodium hexametaphosphate into the flesh of large Yellowfin of 45~68 kg size prior to precook until the fish weight increases 7~12%.

2. Approximately 3~8% increase in yield of chunk style canned tuna may be expected from injection of an aqueous solution containing 10% sodium chloride and 10% phosphate comprised of 85% sodium tripolyphosphate and 15% sodium hexametaphosphate into the flesh of Yellowfin of 7.3~10.5 kg size prior to precook until the fish weight increases 7~12%.

3. Approximately 1~4% increase in yield of chunk style canned tuna may be expected from injection of an aqueous solution containing 7% phosphate comprised of 85% sodium tripolyphosphate and 15% sodium hexametaphosphate into the flesh of Skipjack of 4.5~5.0 kg size until the fish weight increases 3~4%.

요 약

85% 나트륨 tripolyphosphate와 15%나트륨 hexametaphosphate로 조성된 7~10% 인산수용액을 미리 조리하기 전에 어체의 무게가 약 4~10% 증가될 때까지 다랑어육질에 주입하였다. 이실험은 45~68kg과 7.3~0.5kg 크기의 황다랭이(*Thunnus albacares*)와 4.5~5.0kg 크기의 가다랭이(*Euthynnus pelamis*)를이용하여 산업규모의 다랑어 가공공장에서 처리하였는데 이 實驗에서 나타나는 燐酸鹽處理 결과는 다음과 같았다.

1. 큰 황다랭이는 수율이 약 5~8% 증가하였고 다소 수분함량이 높았다.

2. 조그만 황다랭이는 수율이 약 3~8% 증가하였다.

3. 가다랭이는 수율이 1~4% 증가하였다.

4. 생산품의 색과 맛은 극히 조금 좋아졌다.

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