Effects of Dipotassium Phosphates on the Texture of Frozen Whitefish and Burbot Muscles

Soon-Sil CHUN · Mu-Nam KIM* and Kang-Ho LEE**
Department of Food and Nutrition Suncheon National University, Suncheon 540-070, Korea
**Department of Food and Nutrition Pusan Women's University, Pusan 607-080, Korea*
***Department of Food Science and Technology National Fisheries University of Pusan Pusan 608-737, Korea*

인산염 처리가 Whitefish와 Burbot의 Texture에 미치는 영향

전순실 · 김무남* · 이강호**
순천대학교 식품영양학과
*부산여자대학 식품영양학과
**부산수산대학교 식품공학과

Whitefish(*Coregonus clupeaformis*) and Burbot(*Lota lota*) muscle was filleted, treated with dipotassium phosphate(pH 8.0) by means of high pressure injection method, and finally stored at -12℃ for 3 months. Factors, the pH, moisture content, and total amount of collagen were analyzed on the samples before and after the frozen storage.

The pH of the sample showed substantially higher values in the phosphate treated muscles than the controls and decreased after 3 months storage in all of the whitefish and burbot samples, there was no significant differences in the moisture content between the control and treated but some reduction occurred during frozen storage.

The amount of total collagen in the tail sections of burbot was significantly high comparing with head sections and hardness of the tail section also showed high values which indicated that total collagen might be related to the texture of fish muscle. However, in the case of whitefish the effect was not apparent.

The effects of these factors on the hardness determined by Instron texturometer were analyzed through standardized multiple regression. A specific factor was not apparent to the texture of white fish while pH showed the highest correlation to the hardness of the burbot muscle.

Introduction

Freezing has long been considered as one of the best methods to preserve fish. However, several undesirable changes still occur in the frozen stored meats, such as dehydration, oxidative off-flavors, protein denaturation, serious browning and toughening of texture(Hultin, 1985; Shenouda, 1980).

Furthermore, when the thawed meat is cooked, the succulence and water holding capacity is decreased resulting in toughness, coarseness, and dryness. Some attempts have been made to reduce these problems and to extend its storage life during frozen storage(Josephson et al., 1985).

Sweet(1973) suggested that a proper distribution of phenolic antioxidants might substantilly increase the shelf-life of frozen freshwater fish.

These studies included an calculation of the relative quality of fillet sections, phosphate treatments for limiting toughening and moisture loss from frozen fillets, and the inhibition of a serious browning defect that develops in refrigerated burbot fillets.

Shimizu et al(1960) and Shiorski(1984) reported that the muscle collagen contributed to the toughness of the raw fish meat.

However, Dunajski(1979) and Love et al(1974) stated that the actual content of collagen had little or no effect on the texture of fish.

Thus, the importance of the collagen to the texture of fish is still in doubt.

Attention was given to two freshwater species of fish, whitefish and burbot to determine; why changes in their textural properties differ from so greatly during frozen storage; burbot toughens and whitefish exhibits undesirable fragility, and to develop effective means for stabilizing or improving the texture of both species during frozen storage.

In the present study, the relationships between the textural change and such factors as pH, moisture content, and total collagen content of two different fish fillets(whitefish and burbot) were investigated. In addition, the pH of fish was controlled by injecting phosphate buffer solution to improve texture during frozen storage and the effect was studied.

Materials and Methods

Fish

Whitefish(*Coregonus clupeaformis*) and Burbot (*Lota lota*) were obtained from a commercial distribution(lake Michigan, Hickey Bothers Fisheries) during the first week of December, 1985. They were gutted, washed, iced and delivered promptly laboratory. The round fish were filleted and skinned. Each fillet was cut in half crosswise to yield a head section and a tail section.

Treatment of Phosphate Buffer

Fish samples were treated at the Utilization Researcher Division, Northwest and Alaska Fisheries Center, US Marine Fisheries Service in Seattle, Washington. A pilot plant sized high-pressure injection Machine(Intermediate Technology Manufacturing, Inc.) was employed to inject the sample solution into fish muscle(Fig. 1). K_2HPO_4, potassium phosphate dibasic(Mallinckrodt) was dissolved in distilled water to obtain 1.8 *m* solution. The pH of this solution was adjusted to 8.0 with concentrated phosphoric acid.

For each of the 16 sample types, three one-pound sample of each section were analyzed duplicately.

Three grams of fish muscle and 30 *ml* of distilled water were homogenized(Osterizer; high speed) for 10 seconds and the pH was measured with a digital ion analyzer (Model 701 A, ORION Research, Cambridge).

Moisture content was determined by AOAC method(1980)

The amount of total collagen in whitefish and burbot muscle was determined by the method of Culler et al(1978). Values were converted to *mg* collagen assuming a hydroxyproline content of 7% (Bacgason, 1984).

The textural properties of the fish fillets were determined by peak height on the recording chart of an Instron Universal Testing Machine(Model 1132) equipped with a Kramer shear cell(Cat. No. CS-1, Food Technology Corp., Rockville, Maryland). The operating conditions is listed on Table 1.

Results were reported as peak hight/50*g* sample

Table 1. Operating conditions of texture measurement of whitefish and burbot muscle

Crosshead speed	200mm/min
Load	10*kg*
% deformation	80%
Sensibility	500*g*
Sample size	1×1×1*cm*

in the units of *kg*-force.

Hardness of the fish muscle was calculated with peak height of texturometer curve.

SPSS primer and SPSS UPDATE 7-9 were used to obtain results of statistical analysis by standardzed multiple regression.

Results and Discussion

Changes in pH of Whitefish and Burbot Muscle during the Frozen Storage

As shown in Table 2, the pH values of treated whitefish and burbot muscle samples exhibited much greater values than corresonding controls(not injected). Within a given fish species and a given treatment(control or injected), the tail section usually exhibited more or less lower pH values than the head section.

For each type of sample, three months of storage at -12℃ caused a significant reduction in pH compared to the values at beginning of storage. Generally, whitefish showed slightly higher values than burbot for the every corresponding sample.

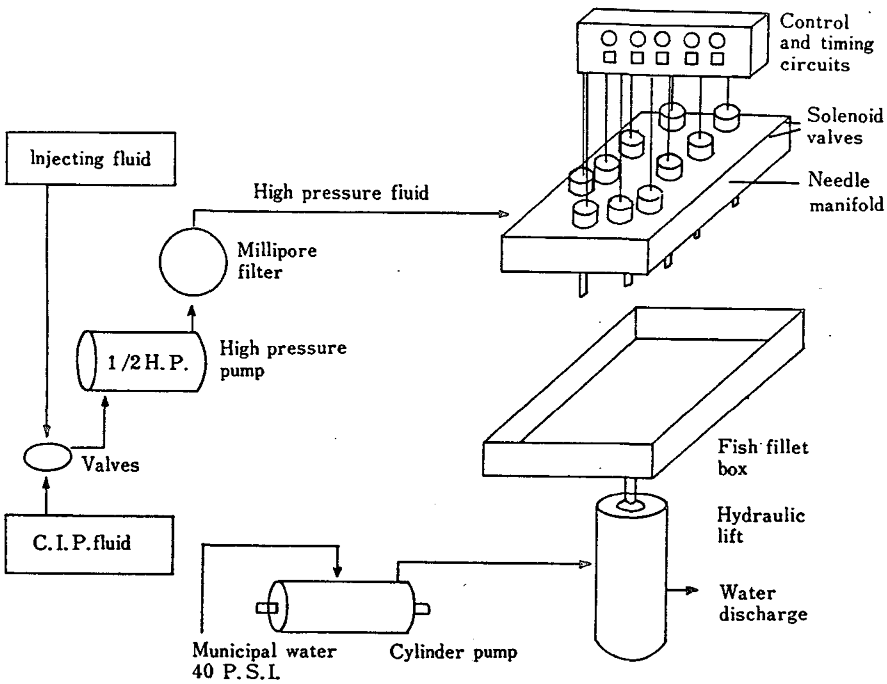

Fig. 1. High pressure injection machine.

Table 2. pH values of whitefish and burbot muscle before and after the frozen storage at -12℃

Storage time	Whitefish				Burbot			
	Control		Treated[1]		Control		Treated[1]	
	Head	Tail	Head	Tail	Head	Tail	Head	Tail
0 month	6.50 ±0.04	6.35 ±0.04	7.00 ±0.01	6.95 ±0.05	6.35 ±0.00	6.35 ±0.06	6.63 ±0.05	6.66 ±0.03
3 month	6.35 ±0.04	6.26 ±0.01	6.91 ±0.02	6.75 ±0.03	6.21 ±0.01	6.07 ±0.00	6.42 ±0.04	6.36 ±0.04

[1]Potassium phosphate buffer(pH 8.0) was injected to elevate pH of the fish muscle. All pH values at 3 months differ significantly($P<0.001$) from corresponding value at 1 month.

Van den Berg(1966) carried out measurements on the frozen state and observed decreases in pH during frozen storage. Also, Bito(1978) reported that skipjack decreased in pH during frozen storage.

Changes in Moisture Contents of Whitefish and Burbot Muscle before and after the Frozen Storage

Changes in moisture contents of whitefish and burbot muscle during frozen storage are shown in Table 3.

In most instances the phosphate buffered materials contained more water than corresponding control samples, within exception being for whitefish sample at zero time. The reason why the whitefish samples at zero time behave in this manner is not clearly known and has not been expected. Differences in the moisture contents of head and tail sections within a given fish species and treatment were often not significant and if any differences occurred they were relatively too small to clarify any complete pattern and, therefore, were probably of little importances.

In most cases of the eight sample columns three month's storage at -12℃ was found to have some effects on the reduction in moisture content. Also treatment of samples with phosphate buffer proved to decrease the loss of moisture during storage in both cases of head and tail sections of two species. This result is agreed with the fact that the treatment of phosphates is known to lesson thaw-exuate in fish muscle.

Total Collagen

Some investigators examined the effect of maturity on various muscle constituents and texture. Maturation and starvation have been related to increased collagen content in certain species of fish (Love, 1974; Creach, 1972), however, the importance of collagen to the texture of fish is still in doubt. Shown in Table 4 are the total collagen contents of whitefish and burbot muscle. The collagen contents of whitefish muscle ranged from 2.87 to 4.02 *mg/g* of muscle. A comparison of appropriate samples within a given treatment and location indicated that in all cases of such comparison burbot contained considerably more collagen than whitefish. Within same species and a given treatment the tail sections, in all instances contained even more collagen than the corresponding head sections.

The amount of the total collagen appeared to decrease with storage time in both whitefish and burbot. The phosphate treatment usually proved to have no significant effect on the total collagen content of whitefish while in burbot the same treatment was generally associated with a reduction in total collagen content. Bacgason(1984) reported that collagen values were 2.60, 2.24 and 2.29 *mg/g* of muscle in cancary, yellow tail, and widowfish(a kind of rockfish species), respectively. Feinstein (1984) showed that the amounts of collagen of cusk were 3.53 *mg/g* in head section and 6.30 *mg/g* in tail section while those of yellow tail floulder 4.

Table 3. Moisture content of whitefish and burbot muscle before and after the frozen storage at -12℃

Storage time	Moisture content(%)							
	Control		Treated[1]		Control		Treated[1]	
	Head	Tail	Head	Tail	Head	Tail	Head	Tail
0 month	76.47 ±0.73	77.76 ±0.95	76.62 ±0.50	76.08 ±0.41	80.34 ±1.32	80.60 ±0.93	81.67 ±0.30	80.32 ±0.50
3 month	74.41 ±1.17 **[2]	75.76 ±1.08 **[2]	75.80 ±0.71 **[2]	75.84 ±0.97 N. S.[2]	78.35 ±0.81 *[2]	78.06 ±0.16 **[2]	80.36 ±1.13 **[2]	79.17 ±0.81 **[2]

[1]Potassium phosphate buffer(pH 8.0) was injected to elevate pH of the fish muscle(see Table 2).
[2]Significance of difference in moisture content with storage time;
*: P<0.05, **: P<0.01 and N. S. non-significant.

68 and 5.03 *mg/g*, respectively.

Hardness of the Raw Shitefish and Burbot Muscle

Shown in Table 5 are the hardness(*kg*-force) values that were determined to estimate the texture of raw whitefish and burbot muscle. A comparison of appropriate sample pairs within the same species and location indicated that the phosphate treatment considerably decreased the hardness of all burbot samples but had no such significant effect on the those of the whitefish samples. The different response of phosphate treatment to the texture of the whitefish and burbot samples different texture. Burbot muscle, being very firm, would potentially be more susceptible to tenderizing treatments than would whitefish muscle which is inherently tender.

In every instance, the burbot sample is significantly and substantially firmer than the whitefish sample. Different firmness of raw muscle of the head and tail sections can be assessed by comparing eight appropriate sample pairs of same species and treatment.

In case of whitefish, the values of the head and tail sections did not significantly differ from each other while, the tail sections of burbots exhibited much greater values in all instances. The results with burbot might be explainable in part by the fact that the tail sections of burbot contained more collagen than the head sections as seen in Table 4.

This differs from the results of whitefish in that the phosphate treatment does not have a significant effect on the hardness of whitefish muscle in all the raw comparisons was significantly and substantially firmer than whitefish muscle.

Factors Affecting the Hardness of the Fish Muscle

The effects of these factors on the hardness determined by Instron texturometer were analyzed thorugh standardized multiple regression.

Various factors have been studied in an attempt to explain textural difference among various spe-

Table 4. Total collagen content of whitefish and burbot muscle before and after the frozen storage at -12℃

Storage time	Total collagen content(*mg/g* muscle)							
	Control		Treated[1]		Control		Treated[1]	
	Head	Tail	Head	Tail	Head	Tail	Head	Tail
0 month	3.16 ±0.06	3.77 ±0.26	3.19 ±0.03	3.39 ±0.36	4.03 ±0.39	6.04 ±0.22	3.65 ±0.37	4.46 ±0.28
3 month	3.06 ±0.14	4.02 ±0.10	2.87 ±0.11	3.22 ±0.16	3.69 ±0.29	5.33 ±0.21	3.49 ±0.40	4.40 ±0.61
	**[2]	**[2]	**[2]	N. S.[2]	**[2]	**[2]	*[2]	N. S.[2]

[1]Potassium phosphate buffer(pH 8.0) was injected to elevate pH of the fish muscle(see Table 2).
[2]Significance of difference in moisture content with storage time;
*: P<0.05, **: P<0.01 and N. S. non-significant.

Table 5. Hardness of the raw whitefish and burbot muscle before and after the frozen storage -12℃

Storage time	Raw texture(*kg*-force)							
	Control		Treated[1]		Control		Treated[1]	
	Head	Tail	Head	Tail	Head	Tail	Head	Tail
0 month	31.78 ±2.79	31.66 ±2.50	29.40 ±0.71	27.40 ±2.20	106.70 ±10.34	151.53 ±8.64	86.05 ±5.76	131.95 ±6.85
3 month	36.73 ±1.51	34.52 ±1.52	35.05 ±4.96	33.00 ±3.93	128.71 ±4.29	203.63 ±12.78	109.14 ±3.51	184.25 ±9.06

[1]Potassium phosphate buffer(pH 8.0) was injected to elevate pH of the fish muscle(see Table 2).

cies of fish. Several workers reported that as pH decreased, toughness of fish muscle increased(Cowie and Little, 1966; Kelley et al., 1966; Connell and Howgate, 1968; Love et al., 1974). A low pH causes an increase in cooking llosses and, thus, increases the concentration of myofibrillar proteins in the muscles.

A comparison of appropriate samples with a given treatment and location indicated that in all cases of such comparison burbot considerably more collagen than whitefish. The tail sections, in all instances contained even more collagen than the corresponding head sections. In every instance, the burbot muscle was significantly and substantially firmer than whitefish muscle(Table 5). In the cases of burbot muscle collagen content was very high and the texture of raw meat was very tough. These results indicate that there is a certain degree of correlation between the collagen content and the toughness of the raw fish meat.

However, some workers suggested that the total amount of collagen might be less related to the texture of muscle(Love et al., 1974; Dunajski, 1979; Feinstein et al., 1984).

The phosphate treatment usually proved to have no significant effect on the total collagen of whitefish whereas in burbot same treatment was generally associated with a reduction in collagen content. However, Hatae et al.(1986) showed that the difference in physical properties of the sliced raw meat among five species was caused by the difference in the muscle structure rather than the composition of constituent proteins.

Table 6 showed that standardized multiple regression coefficients of the factors affecting the hardness of whitefish and burbot muscle. From the table, pH was the most important factors influencing the hardness of burbot.

Table 6. Standrdized multiple regression coefficients of the factors affecting the hardness of whitefish and burbot muscle

	Factor	Whitefish	Burbot
	pH	-0.1263	-0.7676
Raw	Moisture content	-0.1848	-0.0961
	Total collagen	-0.0425	-0.1850

Summary and Conclusion

The texture of the fishes, whitefish and burbot evaluated by hardness using Instron texturometer was investigated. Both are fresh water fishes and have quite different properties of the muscle that whitefish is fragile while burbot is tough and hard which decide their acceptabilities on the market.

In the present work, therefore, several factors which might affect the textural properties of the fish muscle were studied.

Fish muscle was filleted, treated with dipotassium phosphate(pH 8.0) by means of high pressure injection method, and finally stored at -12℃ for 3 months. Factors, the pH, moisture content, and total amount of collagen were analyzed on the samples before and after the frozen storage.

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전순실 · 김무남* · 이강호**
순천대학교 식품영양학과
*부산여자대학 식품영양학과
**부산수산대학교 식품공학과

Whitefish와 Burbot는 북미지역, 유럽등지에서 비교적 널리 이용되고 있는 담수어종이지만 Whitefish는 조직이 연하여 가공중 부스러지기 쉽다는 점이 문제가 되고 있으며, 이와는 대조적으로 Burbot육은 끈적한 점액이 어피를 둘러싸고 있어 이용이 제한되고 있는 외에 가공저장중에 조직이 tough해지는 결점이 있다. 따라서 본 실험에서는 이들의 조직상의 제 문제를 개선함으로써 두 어종의 가공성을 높이고 나아가 상품적 가치를 제고할 목적으로 이들의 texture에 영향을 미친다고 생각되는 각종 인자들을 살펴보았다. 두 어종의 어육을 fillet로 하여 대조군과 인산염 완충용액을 high pressure injection법으로 처리한 군의 pH, 수분 함량, Total collagen량의 차이를 검토하였고 아울러 -12℃에서 3개월간 저장한 후의 이들의 변화를 살펴보았으며, 이들 제 인자들이 Instron texturometer로써 측정한 texture와 어떻게 관련되어 지는지를 다중 회귀방정식을 이용하여 분석하였다. pH는 인산염 처리구가 대조구보다 다소 높았다. 3개월 저장으로 두 어종 모두 pH와 수분함량이 감소하였다. Instron texturometer으로 측정한 texture의 값과 이들 제 인자들 사이의 상관관계는 조직이 약한 whitefish에서는 상관계수가 낮아 특정인자가 두드러진 영향을 미친다고 보기는 어려웠으나 조직이 단단한 burbot육은 이들 인자중 pH가 비교적 상관계수가 높게 나타났다.