KOREAN J. FOOD SCI. TECHNOL.
Vol. 11, *No.* 4 (1979)

Conditions for Processing of Meaty Textured Fish Protein Concentrate from Filefish and Sardine

Eung Ho Lee, Sudibjono* and Se Kwon Kim
Department of Food Science and Technology, National Fisheries University of Busan
(Received July 30, 1979)

畜肉 組織과 類似한 말쥐치 및 정어리의 組織 蛋白質 濃縮物의 加工 條件에 관한 硏究

李 應 昊·수디버노*·金 世 權
釜山 水産 大學, 食品 工學科
(1979년 7월 30일 수리)

Abstract

For the effective utilization of the fish resource in coastal regions, an investigation on optimum processing conditions and meat quality textured fish protein concentrate (FPC) was carried out with the fish meat of filefish and sardine.

Optimum pH and sodium chloride content of fish meat were 7.5 and 1.0 %, respectively. The most effective soaking conditions were as follows: soaking time, 30 min ; temperature of ethanol, 5 to 20°C ; amount of added ethanol, 3 times the weight of the fishmeat paste ; repeated number of soaking in ethanol for filefish and sardine, 2 and 4, respectively.

The ethanol remaining in meaty textured FPC could be removed effectively by forced-air drying. Yields of the product to the minced meat weight and the contents of protein lipid in meaty textured from filefish were 21.1, 77.6 and 0.2 % and those from sardine were 24.3, 75.8 and 3.6 %, respectively.

Contents of essential amino acids in meaty textured FPC of filefish and sardine were not inferior to those of beef, textured soybean protein and FAO pattern. Beef meat could be substituted with the meaty textured FPC up to 50 % in the processing of typical meat balls and hamburger without any significant loss in its taste, odor and texture.

Introduction

The potential shortage of future food supplies, particularly that of protein, for the increasing world population has been pointed out by many investigators and proteins from several resources have been developed for human nutrition[1].

Fish is the main source of dietary protein in many developing coastal countries, and fish protein has a favorable balance of amino acid which is almost equal to those of beef and chicken meat.

* *Department of Fisheries, University of Diponegoro, Indonesia*

As food material, however, fish has a serious defect. It is very susceptible to physical and chemical influences and can be easily deteriorated. It is, therefore, of great importance to stabilize the fish and fish protein for storing and consequent transporting them to the wider area of the world[2]. Fish protein concentrate (FPC), prepared by hot solvent extraction of ground fish, is considered a reasonable protein source of high nutritive value for that purpose. However, it is a denatured product with poor functional properties. It is not readily soluble or dispersible. Moreover, it has poor wetting, swelling and foaming characteristics. It generally takes form of a bland odorless powder, and when tasted either dry or after rehydration it shows a dry gritty feel. In general, incorporation of FPC into food products with the maintenance of desirable characteristics has met limited success[3,4].

Several efforts have been made to improve the functional properties of FPC. Tannenbaum *et al.*[5] studied on the solubilization of FPC using an alkaline process. Iseki *et al.*[6] reported that in the deodorization of liquefied FPC by steam distillation with or without organic solvents, azeotrope former such as toluene, xylene or cyclohexane was effective. Many researchers have studied on the enzymatic solubilization of FPC[7~9]. Recently, Bhumiratana *et al.*[10] could solubilize the insoluble FPC by using the proteolytic enzyme, trypsin. The succinylation of fish myofibrillar protein with subsequent extraction with isoproply-alcohol, neutralization and drying resulted a white powder which showed a improved dispersibility, superior emulsifying capacity and was heat-stable[11,12].

A new type FPC from Alaska pollack developed by Suzuki *et al.*[13] can be used as a new food material for the substitute of livestock meat as much as 70 % on wet basis.

To utilize effectively the fish as protein resources in coastal countries, we carried out an investigation on the processing conditions and quality of meaty textured FPC from filefish and sardine.

Materials and Methods

Materials

Filefish and sardine were used as raw materials. Fresh filefish, *Navodon modestus Günther*, was purchased on Jagalchi fiish market in Busan, Korea and stored at 0°C until used. Frozen sardine, *Sardinops melanosticta Tomita*, offered from Daerim Fisheries Factory in Busan was stored at −30°C. The body weight and body length of the samples were 115 to 130 g, 22 to 28 cm for the former, and 80 to 135 g, 22 to 26 cm for the latter, respectively.

Processing method of meaty textured FPC

Filefish and thawed sardine were skinned and filleted, and then minced with chopper. The minced fish meat was adjusted to pH in the range of 6.0 to 8.5 with sodium bicarbonate or citric acid and then kneaded with 0.5 to 3.5 % of sodium chloride based on the weight of sample for a few minutes. The fish meat paste was extruded through a plate having hole of 2.5 mm diameter into chilled 95 % ethanol. After soaking for 10 min in chilled ethanol the noodle shaped coagulated materials were cut in the length of 3 to 5 mm, and then soaked again in chilled ethanol for 30 min under continuous agitation. The remaining ethanol in the product was removed by forced air drying at room temperature 13°C for 3 hr.

General composition and volatile basic nitrogen (VBN)

The contents of moisture, crude protein, ash and lipid were determined by conventional methods. Volatile basic nitrogen was determined by Conway microdiffusion method.

Determination of rehydration capacity

The moisture content in the products was determined by the conventional method. Three grams of product were soaked in distilled water corresponding to 10 times the product for 1 hr at 10°C and then drained on a stainless steel wire screen (0.5×0.5 mm) for 5 min. The rehydration capacity was determined with the following relation :

$$\text{Rehydration capacity} : \frac{\text{Kg } H_2O \text{ rehydrated}}{\text{Kg dry product}}$$

Drying conditions

Three drying methods were applied and compared each other to determine the optimal drying condition in relation to the rehydration capacity of the end product. The drying period was 1 hr and the conditions checked were as follows:

1. A forced-air drying with an air velocity of 2.8 m/sec at 13 and 50°C.
2. A vacuum drying in a rotary vacuum evaporator with 150 r.p.m. at 50°C.
3. A natural drying at 13°C in a shaddy place.

Amino acid of meaty textured FPC

a. Preparation of sample

An accurately weighed 50 mg sample in ampoule was hydrolyzed with 2 *ml* of 6 *N* HCl at 110°C for 22 hr in sand bath. The hydrolyzate was filtered through a glass filter, and then evaporated to dryness under reduced pressure in a rotary evaporator. The residue was measured up to 25 *ml* with citrate buffer solution. The solution was ampouled and stored in refrigerator until analyzed.

b. Analysis of amino acid

The ampoules were brought to room temperature and 0.8 *ml* of the solution was applied to the chromatographic column of Amberlite CG-120 for the analysis of amino acids using amino acid autoanalyzer (JLC-6AH, No. 310).

Jelly strength

a. Preparation of model meat balls

The meaty textured FPC of filefish and sardine was soaked in 5 volumes of distilled water. After 1 hr, the water was decanted from the vessel. In preparation of meat balls, minced beef was partially substituted with the meaty textured FPC as shown in Table 5.

The mixed materials were ground in mortar for 30 min, sealed in stainless steel molder (3.0×3.2 cm) and then steamed for 30 min at 98 to 99°C. After cooling, the meat balls were served as sample for the determination of jelly strength and the sensory evaluation.

b. Measurement of jelly strength

Jelly strength was determined by using an apparatus of Okada type jelly strength tester, which records the internal mechanical stress of the meat balls under continuously increasing pressure.

Sensory evaluation of hamburger

a. Preparation of model hamburger

To prepare a model hamburger, the minced beef was partially substituted with meaty textured FPC as shown in Table 6 and ground in a mortar. The mixture was fried in edible oil.

b. Sensory evaluation

The sensory evaluations of meat ball and hamburger were carried out by technical panels of 8 trained members, who evaluated the sensory characteristics of model products; odor, taste and texture. The sensory characteristics were scored by using an intensity scale of 1 (extremely poor) to 6 (excellent).

Results and Discussion

Chemical composition, volatile basic nitrogen and pH of raw fish

As shown in Table 1, lipid contents of filefish and sardine were 0.4 and 6.8 %, respectively. On the other hand, protein content of filefish was a little higher than that of sardine.

Optimum conditions for processing of meaty textured FPC

a. Effect of pH on the rehydration capacity of meaty textured FPC

Minced meat of filefish and sardine was adjusted to pH 6.4, 6.5, 7.0, 7.5, 8.0 and 8.5, respectively, kneaded with 1 % sodium chloride, extruded into chilled ethanol and then soaked for 40 min. The effect of pH on the rehydration capacity of meaty

Table 1. Chemical composition, volatile basic nitrogen and pH of raw fish (g/100 g)

	Filefish	Sardine
Moisture	70.8	72.5
Protein	26.2	18.8
Lipid	0.4	6.8
Ash	1.9	1.4
V.B.N*	7.5~16.4 mg%	15.3~20.7 mg%
pH	6.3~6.4	6.0~6.1

* Volatile basic nitrogen

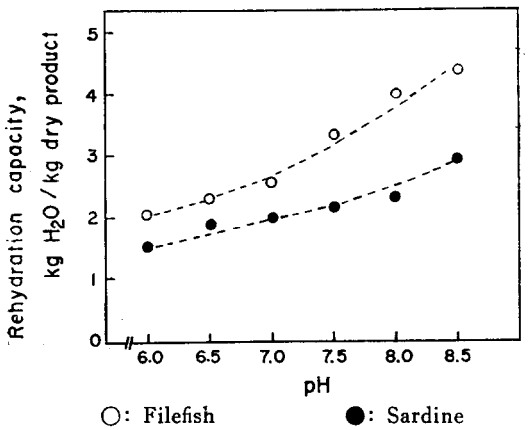

Fig. 1. Effect of pH on rehydration capacity of meaty textured FPC

meaty textured FPC is shown in Fig. 1.

Rehydration capacity of the product of filefish and sardine increased with increasing pH. However, organoleptic test showed that the taste of products at pH above 8.0 was not so good. Therefore, it was considered that the optimum pH for the processing of the meaty textured FPC was 7.5.

In case of Suzuki *et al.*[13], the pH of raw fish flesh was fixed at pH in the range of 7.4 to 7.8 with regard to the processing of meaty textured FPC from Alaska pollack.

b. Effect of sodium chloride concentration on the rehydration capacity of meaty textured FPC

Minced meat was adjusted at pH 7.5 and then kneaded with 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and 3.5 % of sodium chloride, respectively. The next procedure for the model product was the same as that mentioned above.

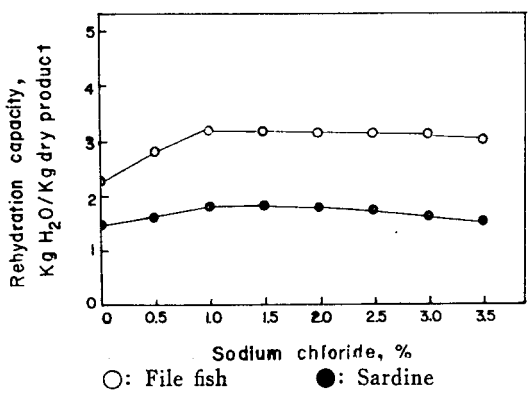

Fig. 2. Effect of the concentration of sodium chloride on the rehydration capacity of meaty textured FPC

As shown in Fig. 2, the rehydration capacity of the product without sodium chloride was very low. The rehydration capacity of the product increased showed maximum value at 1 % sodium chloride. Little change was observed at higher sodium chloride concentrations above 1 % and could be neglected.

Subjective evaluation for brittleness indicated that the product was fragile when no sodium chloride was added. Therefore, 1 % sodium chloride was suitable to produce the product with good rehydration capacity.

Suzuki *et al.*[13] reported that in case of the use of 1 to 2 % sodium chloride in processing of meaty textured FPC of Alaska pollack, the hardness of the product was similar to that of livestock meat. The rehydration capacity of filefish meaty textured FPC was higher than that of sardine.

c. Effect of soaking time on the rehydration capacity and lipid content

Minced meat was adjusted to pH 7.5, kneaded with 1 % sodium chloride, extruded and soaked in chilled ethanol for 10, 20, 30, 40, 50, 60 and 90 min, respectively.

In case of hot ethanol lipid extraction, Lee *et al.*[14] recognized that 5 min was reasonable for the preparation of FPC from minced meat at 80°C.

According to the investigation of Suzuki *et al.*[13] it needed 15 min for the extraction of lipid from the Alaska pollack meat paste by extruding into chilled ethanol for processing meaty textured FPC.

In the present experiment, it was assumed that 30 min was reasonable for the chilled ethanol soaking time in relation to the rehydration capacity of the end product as shown in Fig. 3.

Under the same soaking conditions, the rehydration capacity of the meaty textured FPC from filefish was greater than that from sardine.

d. Effect of the amount of ethanol for soaking on the rehydration capacity and lipid content of the meaty textured FPC

Minced meat was adjusted to pH 7.5, kneaded

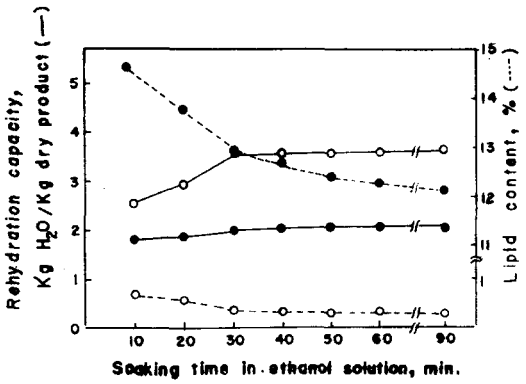

Fig. 3. Effect of soaking time in chilled 95 % ethanol solution on the rehydration capacity and lipid content of meaty textured FPC

with 1 % sodium chloride, extruded into chilled ethanol and soaked for 30 min. The amount of ethanol was varied from 1 to 7 times the weight of the fish meat extruded.

Rehydration capacity of filefish and sardine increased with increasing the amount of ethanol. However, when the amount of ethanol increased more than 3 times, the changes of the rehydration capacity were not significant as shown in Fig. 4. The lipid contents also showed practically constant values regardless the volume of ethanol at more than 3 times. Suzuki[15] reported that the amount of ethanol in the range of 3 to 10 times was effective for the processing of meaty textured FPC with regard to removal of lipids.

In the present experiment, it appeared that the amount of added ethanol as much as 3 times the weight of the fish meat extruded was adequate for the removal of lipid from extruded meat paste of filefish or sardine.

e. Effect of temperature of ethanol on the rehydration capacity and lipid content

Minced flesh was adjusted to pH 7.5 with sodium bicarbonate. After this process the minced flesh was kneaded with 1 % sodium chloride and extruded into 95 % ethanol at various temperatures. The amount of ethanol was fixed at 3 times the weight of the fish meat extruded.

As shown in Fig. 5, the rehydration capacity of filefish and sardine meat after soaking and drying decreased with increasing temperature of ethanol while lipid content showed no remarkable changes.

Suzuki *et al.*[13] reported that the temperature of ethanol for producing meaty textured FPC from Alaska pollack was adequate at 5 to 10°C. But in the present experiment, the rehydration capacity of filefish and sardine was almost stationary in the temperature range of 5 to 20°C. Above 20°C, the rehydration capacity showed a slightly decreasing tendency.

The temperature of ethanol was, therefore, adequate in the range of 5 to 20°C for processing meaty textured FPC with good rehydration capacity.

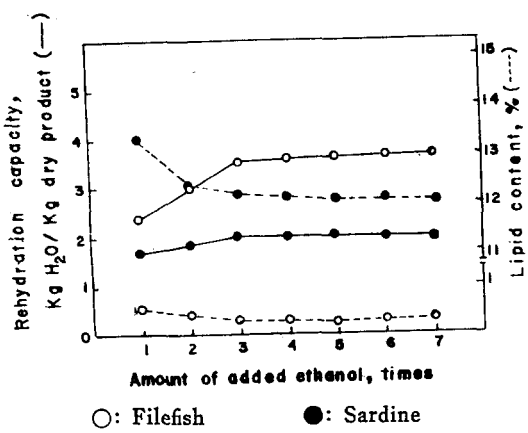

Fig. 4. Effect of the amount of added 95 % ethanol solution on the rehydration capacity and lipid content of meaty textured FPC

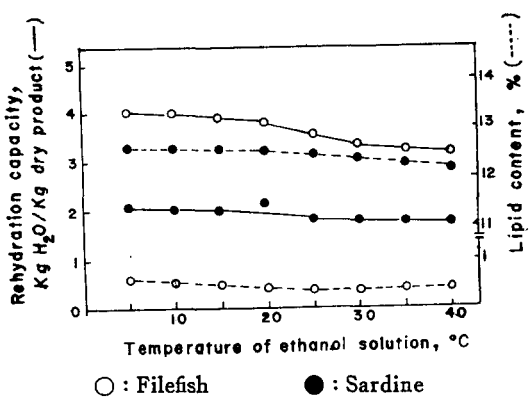

Fig. 5. Effect of the temperature of 95 % ethanol solution for soaking on the rehydration capacity and lipid content of meaty textured FPC

f. Effect of soaking times on the rehydration capacity and lipid content

Minced meat was adjusted to pH 7.5, kneaded with 1 % sodium chloride, and then extruded into chilled ethanol. The amount of ethanol was 3 times the weight of the fish meat paste extruded and the temperature was maintained at below 20°C. Under such conditions, the soaking of fish meat paste extruded into ethanol was repeated 1 to 6 times (Fig. 6). The optimum soaking times for processing of meaty textured FPC were, therefore, 2 and 4 times for filefish and sardine meat, respectively.

g. Effect of water content of product on the rehydration capacity of meaty textured FPC

Minced meat with pH 7.5 was kneaded with 1 % sodium chloride, extruded and soaked 3 times in ethanol each for 30 min. The meaty textured products were then dried under various conditions as described in drying conditions.

The results of the effect of water content of meaty textured FPC after drying were shown in Fig. 7. Forced-air drying at 50°C showed lower rehydration capacity of meaty textured FPC than the other drying methods. Sensory evaluation showed that texture of these products was easily crumbled.

However, little difference in the rehydration capacity of the products was found between the forced-air drying at 13°C and vacuum drying at 50°C.

Therefore, it was concluded that the use of forced-air drying at 13°C was effective for drying meaty textured FPC of filefish or sardine. Rehydration capacity of the products dried at room temperature (13°C) in a shady place was low.

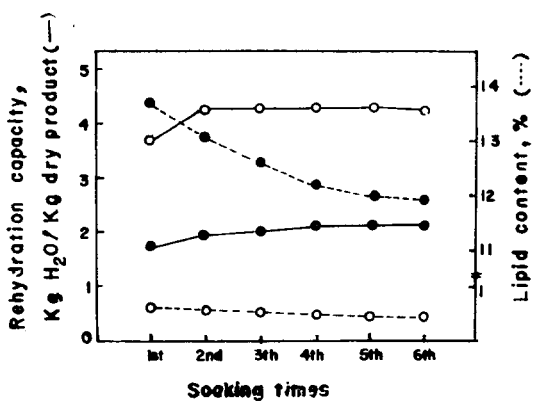

Fig. 6. Effect of the soaking times in 95 % ethanol solution on the rehydration capacity and lipid content of meaty textured FPC

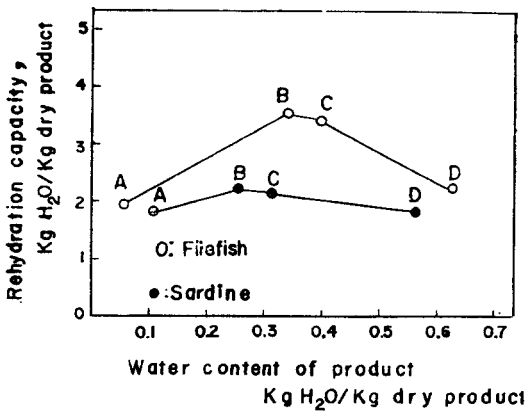

Fig. 7. Effect of water content of product after drying on the rehydration capacity of meaty textured FPC

A : Forced hot air drying
B : Vacuum drying
C : Forced air drying
D : Drying at room temp. in shady place.

In general, the rehydration capacity of products from sardine showed very little differences among drying methods.

Chemical composition and yield of product

Chemical composition and yield of meaty textured FPC of filefish and sardine are shown in Table 2. The protein contents of the product of filefish and sardine were 77.6 and 75.8 %, respectively. Lipid content of the product from filefish was lower than that from sardine, amounting to 0.2 and 3.6 %, respectively. However, the contents of moisture and ash of the product were 14.5, 6.8 % in filefish and 14.8, 5.5 % in sardine, respectively.

The yields of the product of filefish and sardine

Table 2. Chemical composition and yield of meaty textured FPC (g/100 g)

	Filefish	Sardine
Moisture	14.5	14.8
Protein	77.6	75.8
Lipid	0.2	3.6
Ash	6.8	5.5
Yield	21.1	24.3

Table 3. Amino acid composition of meaty textured FPC (wet basis)

Amino acid	Filefish			Sardine		
	mg/100 g	mg/1 gN	g/16N	mg/100 g	mg/1 gN	g/16N
Lysine	6512.7	524.4	8.39	7215.4	594.4	9.51
Histidine	1083.9	87.3	1.63	1518.0	125.0	2.00
Arginine	3940.9	317.3	5.94	4312.1	355.2	5.68
Aspartic acid	6983.3	562.3	10.52	7371.9	607.2	9.72
Threonine	2510.0	202.1	3.78	2794.1	230.2	3.68
Serine	2134.4	171.9	3.22	2367.2	195.0	3.12
Glutamic acid	9455.2	761.3	14.25	10498.1	864.8	13.84
Proline	1126.6	90.7	1.69	1304.6	107.5	1.72
Glycine	3080.4	248.0	4.64	3311.2	272.8	4.36
Alanine	4164.3	335.3	6.27	4013.3	330.6	5.29
Valine	4406.7	354.8	6.64	4876.7	401.7	6.43
Methionine	984.0	79.2	1.48	887.1	73.1	1.17
Isoleucine	3365.7	271.0	5.07	3202.1	263.8	4.22
Leucine	5514.4	444.0	8.31	5469.6	450.6	7.21
Tyrosine	2234.3	179.9	3.37	1660.3	136.8	2.19
Phenylalanine	2433.9	196.0	3.67	2879.5	237.2	3.80
Total	59930.7	4825.5	83.13	63681.2	5245.9	83.94

Table 4. Comparison of essential amino acid contents of meaty textured FPC, textured soybean protein (TSP), beef and FAO pattern (g/16 gN)

Amino acid	Meaty textured FPC		TSP*	Beef*	FAO pattern*
	Filefish	Sardine			
Lysine	8.39(9.81)	9.51(11.16)	5.88	8.90	4.2
Isoleucine	4.33(5.07)	4.22 (4.95)	5.24	4.82	4.2
Leucine	7.10(8.31)	7.21 (8.46)	7.54	8.11	6.8
Phenylalanine	3.14(3.67)	3.80 (4.45)	4.74	4.11	2.8
Methionine	1.27(1.48)	1.17 (1.37)	1.11	2.70	2.2
Threonine	3.23(3.78)	3.68 (4.32)	3.78	4.59	2.8
Valine	5.68(6.64)	6.43 (7.54)	5.74	5.00	4.2
Tryptophan	—	—	1.36	1.17	1.4
Total	33.14(38.76)	36.02(42.25)	35.39	39.40	28.6

* Hamdy, M. M. : *J. Am. Oil Chemists Soc.*, 51(1), 85A (1974), ( ) : dry basis

Table 5. Basic formulation of meat balls used for jelly strength and sensory evaluations

Substitution rate of meaty textured FPC / Material (g)	Control(A)	30 %(B)	50 %(C)	70 %(D)
Minced beef	77.0	53.2	38.0	22.8
Rehyrdated meaty textured FPC	0.0	22.8	38.0	53.2
Starch	20.0	20.0	20.0	20.0
Sugar	2.3	2.3	2.3	2.3
Salt	1.5	1.5	1.5	1.5
Monosodium glutamate	0.2	0.2	0.2	0.2

Table 6. Recipes of hamburger used for sensory evaluation

Material (g) \ Substitution rate of meaty textured FPC	Control(A)	20 %(B)	30 %(C)	40 %(D)	50 %(E)	70 %(F)
Minced beef	200	160	140	120	100	60
Rehydrated meaty textured FPC	0	40	60	80	100	140
Onion	70	70	70	70	70	70
Starch	20	20	20	20	20	20
Egg	40	40	40	40	40	40
Monosodium glutamate	0.3	0.3	0.3	0.3	0.3	0.3
Salt	3	3	3	3	3	3

Table 7. Results of jelly strength of meat balls supplemented with meaty textured FPC (g)

Material \ Substitution rate of meaty textured FPC	Control	30 %	50 %	70 %
Meaty textured FPC of filefish	340	435	642	757
Meaty textured FPC of sardine	340	407	507	693

to the minced meat weight were 21.1 and 24.3 %, respectively. The color of products of filefish and sardine were whitish and brownish, respectively.

Amino acid composition of the products

Amino acids of the meaty textured FPC prepared under the optimum processing conditions are shown in Table 3. Comparison of the essential amino acids of the product with those of textured soybean protein, beef and FAO pattern are also shown in Table 4.

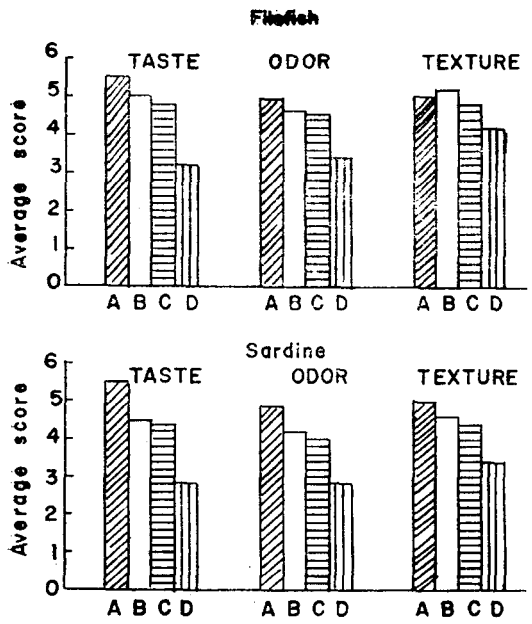

Fig. 8. Results of sensory evaluation of meat balls that is supplemented with meaty textured FPC

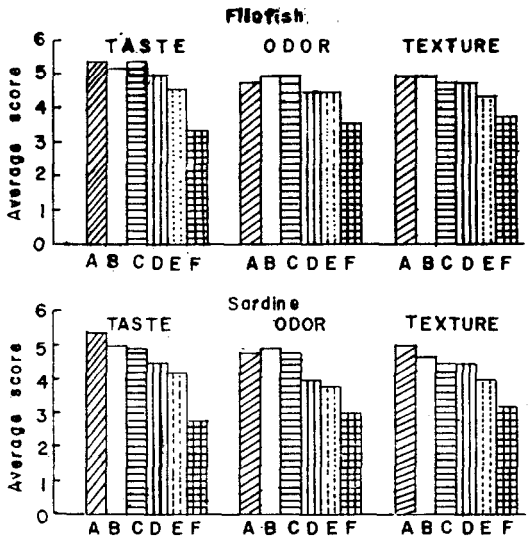

Fig. 9. Results of sensory evaluation of hamburger that is supplemented with meaty textured FPC

In general, the content of total hydrolyzed amino acids of the meaty textured sardine protein concentrate was slightly higher than that of filefish. The contents of essential amino acids of both the meaty textured FPC were also slightly higher than that of FAO pattern.

Texture of model meat balls

Model meat balls were prepared with a combination of minced beef and the rehydrated meaty textured FPC from filefish and sardine. The recipes were as shown in Table 5.

The jelly strength of meat balls increased with increasing partial substitution ratio of meaty textured FPC as shown in Table 7. Under the same substitution ratio, the meat balls prepared with minced beef and the meaty textured FPC from filefish showed higher jelly strength than that with minced beef and sardine product. However, Suzuki *et al.*[17] also reported that in case of model meat balls of minced Alaska pollack, the meat was lower than beef in hardness, but the texture profile on the rheometer of the rehydrated meaty textured FPC from Alaska pollack was almost same as that of ground beef.

Sensory evaluation of model meat balls and hamburger

Model meat balls and hamburger were prepared according to the formula shown in Table 5 and 6. Sensory evaluation of meat balls and hamburger for taste, odor and texture was shown in Fig. 8 and 9.

Beef meat could be subsituted with the meaty textured FPC up to 50 % in processing model meat balls and hamburger without any significant loss of taste, odor and texture.

According to the comparison of the sensory properties of the model products, the quality of product prepared with beef and meaty textured FPC from filefish was better than that prepared with beef and meaty textured FPC from sardine meat.

요 약

연안 수산 자원의 효율적인 이용 방법을 개발할 목적으로 축육과 유사한 가공 적성을 가지는 새로운 형태의 어육 조직 단백질 농축물을 가공하기 위하여 백색 육어인 말쥐치와 적색 육어인 정어리를 원료로 하여 최적 가공 조건 및 제품의 품질에 관하여 실험하였다.

말쥐치 및 정어리로써 축육과 유사한 어육 조직 단백질 농축물을 가공하기 위한 최적 조건은 다음과 같다. 원료 어육의 pH는 7.5, 고기풀 제조시 소금의 첨가량은 어육 중량에 대하여 1.0 %, 압출기로 압출한 고기풀의 냉 에틸알코올중의 침지 시간은 30분, 침지시의 에틸알코올량은 어육량에 대해 3배, 그때의 에틸알코올 온도는 5내지 20℃가 적당하였다. 그리고 에틸알코올 중의 침지 회수는 말쥐치의 경우 2회 정어리는 4회가 적당 하였고, 에틸알코올을 제거 하는데는 냉풍 건조가 효과적이었다.

원료 어육에 대한 제품의 수율은 말쥐치는 21.1 및 정어리는 24.3 %이었다. 제품의 단백질 함량은 말쥐치가 77.6, 정어리는 75.8 %였으며, 지방은 각각 0.2 및 3.6 %였다.

말쥐치 및 정어리 조직 단백질 농축물의 필수 아미노산 함량은 쇠고기및 대두 조직 단백질과 비교하였을 때 손색이 없었으며, 두 가지 제품으로써 미트볼 및 햄버거를 만들었을 때 모두 쇠고기와 같은 량의 중량비로 혼합하여 맛, 색 및 촉감에 손색없이 식품 소재로 이용할 수 있다는 결론을 얻었다.

References

1. Spencer, H., Osis, D., Norris, C. and Coffey, J. : *Protein Nutritional Quality of Foods and Feeds*, Vol. 1, 23, Friedman, New York (1975)
2. Suzuki, T., Ohashi, H., Kanna, K. and Matsumiya, H. : *Bull. Tokai Reg. Res. Lab.*, 72(12), 43 (1972)
3. Kwee, W. H., Sidwell, V. D., Wiley, R. C. and Hammerle, D. A. : *Cereal Chem.*, 46(1), 78 (1969)
4. Sidwell, V. D. and Hammerle, D. A. : *Cereal Chem.*, 47(6), 739 (1970)
5. Tannenbaum, S. R., Athern, M. and Bates, R. P. : *Food Technol.*, 24, 604 (1970)
6. Iseki, S., Watanabe, T. and Kinumaki, T. : *Bull. Tokai Reg. Lab.*, 59(8), 81 (1969)
7. Cheftel, C., Ahren, M., Wang, D. I. C. and Tannenbaum, S. R. : *J. Agric. Food Chem.*, 19, 155 (1971)
8. Hevia, P., Whitaker, J. R. and Olcott, H. S. : *J. Agric. Food Chem.*, 24, 383 (1976)
9. Kinumaki, T. : *The Fish Utilization Technology and Marketing in the IPFC Region*, FAO, Manila (1978)
10. Bhumiratana, S., Hill, C. G. and Amundson, C. H. : *J. Food Sci.*, 42(4), 1016 (1977)
11. Groninger, Jr., H. S. and Miller, R. : *J. Food Sci.*, 40(1), 327 (1975)
12. Miller, R. and Groninger, H. S. : *J. Food Sci.*,

41, 268 (1976)

13. Suzuki, T., Kanna, K. and Yagi, T. : *Bull. Japan. Soc. Sci. Fish.*, 44(7), 781 (1978)
14. Lee, E. H., Park, Y. H.,, Pyeun, J. H., Kim, S. K., Yang, S. T. and Song, Y. O. : *Bull. Korean Fish. Soc.*, 11(1), 25 (1978)
15. Suzuki, T. : *U.S. Patent*, No. 4,060,642 (1977)
16. Hamdy, M. M. : *J. Am. Oil Chemists Soc.*, 51(1), 85A (1974)
17. Suzuki, T., Kanna, K., Okazaki, E. and Morita, N. : *Bull. Japan. Soc. Sci. Fish.*, 44(11), 1275 (1978)