

Properties

Functionality and nutrition

Surimi is, essentially, a purified protein. It provides nutritional value to the human system and functional value to the food processing system. Surimi is attractive as an ingredient because of both values, but its most important characteristics have more to do with functionality than with nutrition.

The nutritional value of surimi is important for several reasons: Current trends in the U.S. toward healthy eating will make surimi-based foods attractive to some consumers, and the fact that surimi is lower in cholesterol and higher in some amino acids than shellfish—and lower in price—may boost the U.S. market for surimi products.

The nutritional values of surimi are also important to secondary processors in labeling their products. The U.S. Food and Drug Administration (FDA) requires that any product which imitates another, but is nutritionally inferior to the product it imitates, must be labeled with the word “imitation.” In addition, there is some concern in the industry that the sugar and sorbitol added to surimi as preservatives may counteract any positive nutritional values that surimi might have. It is clear that the nutritional values of surimi have a significant effect on its marketability.

But surimi will find that its future depends more on what it can do than how healthful it is. The functional properties of surimi—its potential as a cold binder in meat systems, its ability to gel and bind and foam, its water-holding capacity—are the factors that will determine the potential of surimi as a food ingredient.

In this chapter, both the nutritive and the functional properties of surimi, as well as how surimi behaves in processed pork, beef and poultry systems, will be discussed. It will also chart AFDF's progress toward gaining USDA approval for the use of surimi in processed meats.

Nutritional properties

In the surimi manufacturing process, undesirable components are removed from the fish, leaving only water and pure myofibrillar protein, which is the component of muscle which possesses all the desirable functional properties of meat. In its final stage, with cryoprotectants added, the composition of surimi is approximately:

- Water - 76%
- Protein - 16%
- Sucrose - 4%
- Sorbitol - 3.5%
- Polyphosphate - 0.3%
- Fat - 0.2%
- Calcium - .0038%

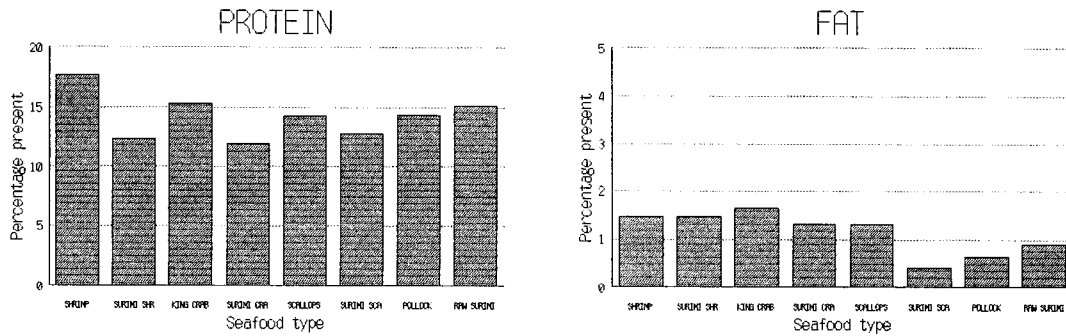


Fig. 1. Average percentage of protein in shrimp, crab, and scallops compared to corresponding surimi-based analogues. Also provided are protein levels for Alaska pollock (raw) and for frozen pollock surimi. Figs. 1-16 were compiled from information published by the National Food Processors Association (NFPA).

Fig. 2. Comparison of fat levels (percentage).

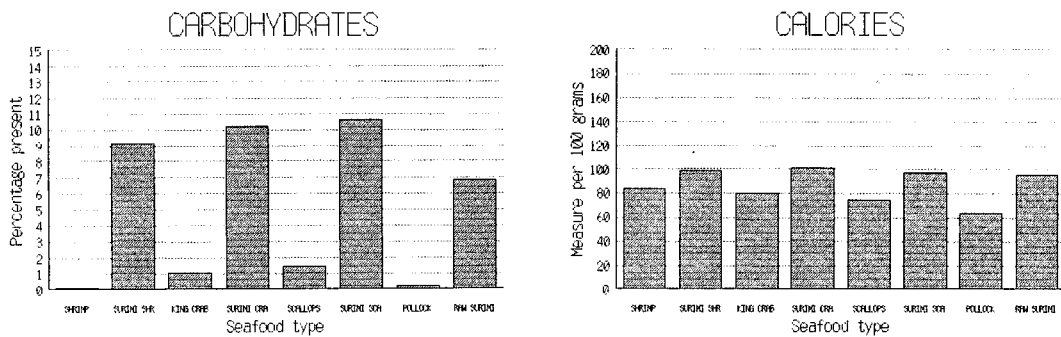


Fig. 3. Comparison of carbohydrate levels (percentage). Carbohydrate levels in surimi and surimi-based products are significantly higher than in raw shellfish because of sorbitol added to raw surimi during processing. It is possible to produce surimi without sorbitol if the product is to be used immediately and thus needs no cryoprotective agents.

Fig. 4. Comparison of caloric levels of shellfish, surimi-based shellfish analogues, pollock, and raw surimi. As in carbohydrate levels (Fig. 3), surimi and analogues are higher in calories because of the sorbitol added.

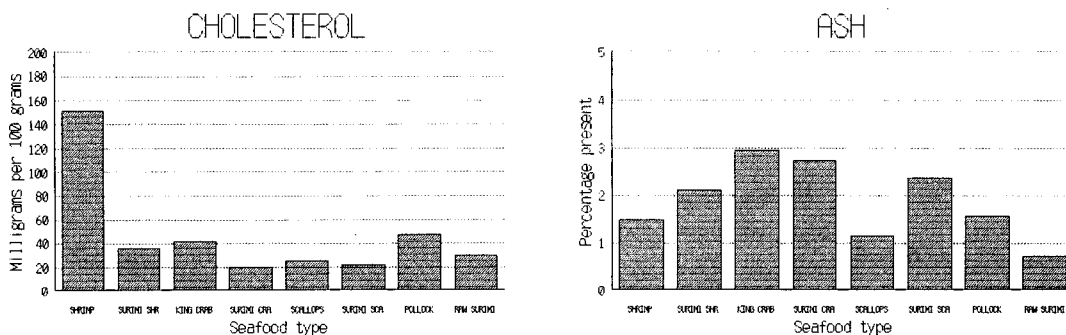


Fig. 5. Comparison of cholesterol levels. Surimi-based analogues are usually lower in cholesterol than their corresponding shellfish due to the quality of protein provided by surimi. Note that surimi is lower in cholesterol than the raw pollock it was made from; this is because fats and oils present in raw flesh are washed out during the surimi process.

Fig. 6. Comparison of ash levels (percentage).

Bar legend (l-r): Shrimp, surimi shrimp, king crab, surimi crab, scallops, surimi scallops, pollock, raw surimi.

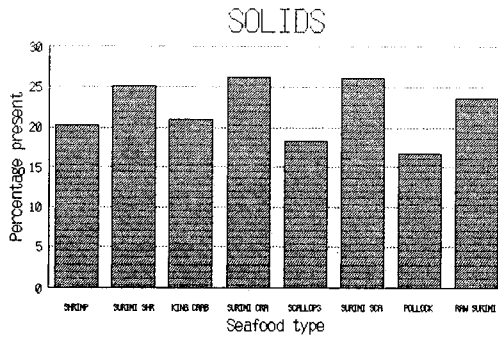


Fig. 7. Comparison of solids (percentage).

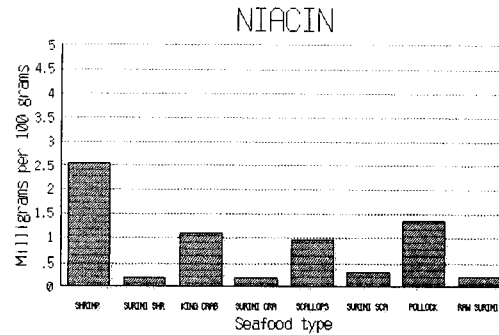


Fig. 8. Comparison of niacin levels.

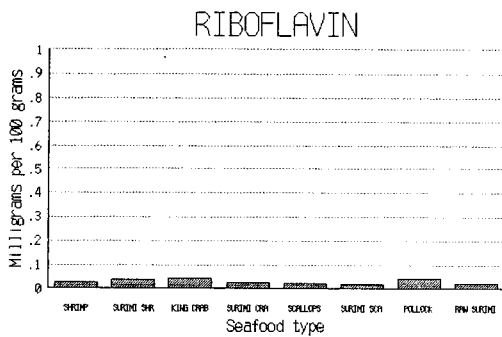


Fig. 9. Comparison of riboflavin levels. Neither shellfish nor surimi-based analogues provide significant amounts of riboflavin.

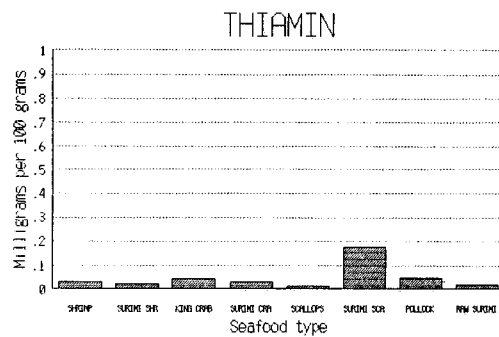


Fig. 10. Comparison of thiamin levels. There are insignificant amounts of thiamin in all products, except for surimi-based scallop analogues, where thiamin most likely appears in one of the ingredients.

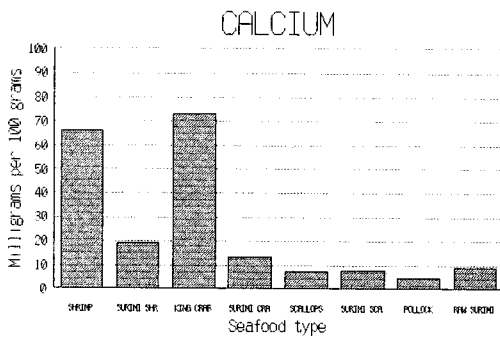


Fig. 11. Comparison of calcium levels. Crab and shrimp are significantly higher in calcium than their surimi-based counterparts, scallops and pollock.

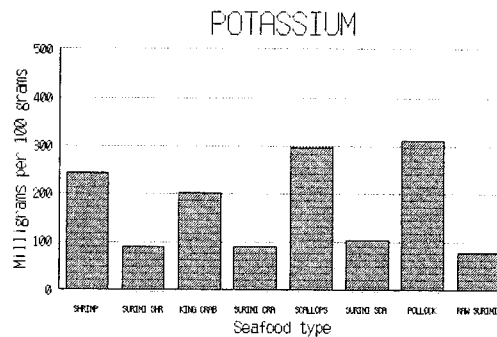


Fig. 12. Comparison of potassium levels. Surimi-based products provide less than half the potassium found in shellfish or pollock. This graph and Fig. 11 may indicate possible areas of attention if analogue producers decide to enrich products to achieve nutritional equivalency with shellfish.

Bar legend (l-r): Shrimp, surimi shrimp, king crab, surimi crab, scallops, surimi scallops, pollock, raw surimi.

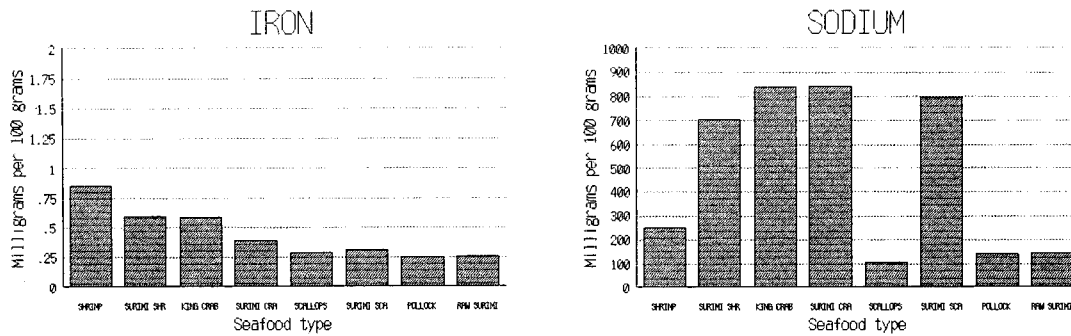


Fig. 13. Comparison of iron levels. Note that crab and shrimp exceed their surimi-based counterparts in iron content; however, surimi-based shrimp is about equal to king crab in iron.

Fig. 14. Comparison of sodium levels. Though crab and surimi-based crab are about equal in sodium content, surimi-based shrimp and scallops significantly exceed their "natural" counterparts in sodium. During the analogue-making process, salt is added to the formulation to increase the gel quality of the product.

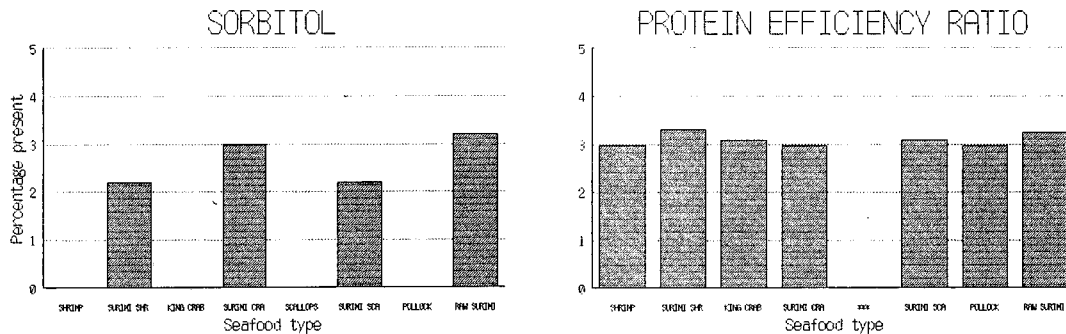


Fig. 15. Sorbitol is not naturally present in crab, shrimp, scallops or pollock. It is added to the surimi during manufacturing as a cryoprotective agent at levels of about 0.4%. The percentages of sorbitol present in the analogues differ according to the amount of surimi used in each formulation.

Fig. 16. Protein efficiency ratio (PER) of all products in the study. PER for scallops was negative due to presence of thiaminase activity, not to poor protein quality.

Bar legend (l-r): Shrimp, surimi shrimp, king crab, surimi crab, scallops, surimi scallops, pollock, raw surimi.

Surimi compared to beef, pork, chicken, turkey

The chemical composition of surimi exceeds the standard values for beef and turkey. It equals chicken, but falls slightly under that of pork. Surimi may be more easily digestible and more readily assimilated into the human metabolism than avian or mammalian muscle fiber because the muscle fiber of surimi is shorter.

It is expected that surimi could enhance the nutritional value of meat systems now on the market if used in conjunction with other processed meats.

The following four charts analyze the amino acid composition and the chemical score of surimi and those of raw beef, pork, chicken and turkey.

— % of Total Protein —

Amino Acid	Raw Surimi*	Raw Beef**	Raw Pork	Raw Chicken	Raw Turkey
A Essential					
Histidine	2.50	2.90	5.10	3.10	3.10
Isoleucine	6.20	5.10	4.80	5.30	5.20
Leucine	10.60	8.40	8.10	7.50	8.00
Lysine	11.70	8.40	9.90	8.50	9.40
Methionine	3.10	2.30	2.50	2.80	2.90
Phenylalanine	3.80	4.00	4.00	4.00	4.00
Threonine	4.60	4.00	4.70	4.20	4.40
Tryptophan	1.30	1.10	1.30	1.20	1.10
Valine	4.90	5.70	5.40	5.00	5.30
B Non-Essential					
Alanine	6.50	6.40	5.90	5.40	6.20
Arginine	7.00	6.60	6.90	6.00	7.00
Aspartate	11.60	8.80	9.30	8.90	9.70
Cystine	1.00	1.40	1.30	1.30	1.00
Glutamate	18.90	14.40	15.50	15.00	16.30
Glycine	3.60	7.10	4.60	4.90	5.00
Proline	4.50	5.40	3.80	4.10	4.20
Serine	5.20	3.80	4.10	3.40	4.40
Tyrosine	3.60	3.20	3.60	3.40	4.00

*Suzuki, T. 1981. Fish & Krill Protein: Processing Technology. Applied Science Publishers LTD. London, England, p. 162.

**Price, J.F. & B.S. Schweigert. 1971. The Science of Meat & Meat Products, 2nd ed. W.H. Freeman and Co. San Francisco, CA. p. 304.

Fig. 17. Amino acid composition of surimi compared to that of raw beef, pork, chicken and turkey.

— % of Total Protein —

Essential Amino Acids	Amino acid pattern for high quality protein*	Surimi	Beef	Pork	Chicken	Turkey
Histidine	1.70	2.50	2.90	5.10	3.10	3.10
Isoleucine	4.20	6.20	5.10	4.80	5.30	5.20
Leucine	7.00	10.60	8.40	8.10	7.50	8.00
Lysine	5.10	11.70	8.40	9.90	8.50	9.40
Total Sulfur Containing Amino Acids (Methionine & Cystine)	2.60	4.10	3.70	3.80	4.10	3.90
Total Aromatic Amino Acids (Phenylalanine & Tyrosine)	7.30	7.40	7.20	7.60	7.40	8.00
Threonine	3.50	4.60	4.00	4.20	4.20	4.40
Tryptophan	1.10	1.30	1.10	1.20	1.20	1.10
Valine	4.80	4.90	5.70	5.00	5.00	5.30

*Calculated from Recommended Dietary Allowances, 9th ed. 1980. National Academy of Sciences. Washington, D.C. p. 43

Fig. 18. Amino acid comparisons for high quality protein, surimi, beef, pork, chicken and turkey.

— & of Total Protein —

Essential Amino Acids	Essential Amino Acid Composition of Surimi	Essential Amino Acid Pattern for High Quality Protein		Chemical Scores for Each Essential Amino Acid
Histidine	2.50	1.70		147.00
Isoleucine	6.20	4.20		151.00
Leucine	10.60	7.00		148.00
Lysine	11.70	5.10		229.00
Total Sulfur Containing Amino Acids (Methionine & Cystine)	4.10	2.60	X100=	158.00
Total Aromatic Amino Acids (Phenylalanine & Tyrosine)*	7.40	7.30		**101
Threonine	4.60	3.50		131.00
Tryptophan	1.30	1.10		118.00
Valine	4.90	4.80		102.00

*Cystine can replace part of the requirement for Methionine & Tyrosine can replace part of that for Phenylalanine.

**The overall chemical score for a protein is that of the lowest score for a single amino acid (the limiting amino acid). With respect to surimi, the aromatic amino acids are limiting.

Fig. 19. Computing the chemical score for surimi. The overall chemical score for a protein is that of the lowest score for a single amino acid (the limiting amino acid). For surimi, the aromatic amino acids are limiting.

Essential Amino Acid	Surimi	Beef	Pork	Chicken	Turkey
Histidine	147	171	300	182	182
Isoleucine	148	121	114	126	124
Leucine	151	120	116	107	114
Lysine	229	165	195	167	184
Methionine & Cystine	158	142	146	158	150
Phenylalanine & Tyrosine	101	99	104	101	110
Threonine	131	114	120	120	126
Tryptophan	118	100	109	109	100
Valine	102	119	104	104	110

Overall Chemical Score*

Beef	99
Turkey	100
Chicken	101
Surimi	101
Pork	104

*Standard Value for a high quality protein.

Fig. 20. Chemical scores for essential amino acids in surimi, beef, pork, chicken and turkey, followed by overall chemical scores for each. Overall chemical scores are the standard value for a high-quality protein for each meat shown.

Functional properties

One of the primary goals of the AFDF surimi project has been to increase the U.S. market opportunities for surimi beyond seafood analogues. The unique properties of surimi indicate that its uses in the food industry might be many, and that its biggest potential might be in the processed meats industry. But before the potential of surimi could be assessed, it was first necessary to study the functional properties of the surimi protein itself: to discover how surimi behaves, what makes it behave, and what happens to surimi protein under different conditions.

Webb Foodlabs, Inc. of Raleigh, N.C., agreed to conduct a study of the functional properties of surimi for AFDF. Webb identified the functional properties of Alaska pollock surimi which are applicable to the food industry, especially the meat industry. The study was designed to provide a sound basis for expanding the domestic marketing opportunities for surimi.

Summary

While gel strength is most commonly used to evaluate surimi quality as a raw material for analogues, the processed meat industry relies more on protein content, protein extractability, aroma, flavor, texture attributes and color as measures of ingredient quality. Meat products are also heavily regulated and, in many cases, compositionally defined. With today's production volumes in the meat industry, minimal raw material handling is also desirable.

The introduction of surimi into emulsified meat products, such as franks and bologna, may require a different perspective and different set of handling procedures quite unlike those used in seafood analogue processing. Ideally, the meat industry prefers raw materials which can be used directly in present systems without having to change formulations, especially when limited quantities of a material are used or allowed. Therefore, for this project the surimi was used raw, as received, without prior preparation.

The results of this investigation of functional properties as related to processed meat applications indicated that frozen pollock surimi has considerable potential for incorporation into emulsified meat products. The fat emulsifying capacity is comparable to many ingredients now being used, and, in conjunction with cooked emulsion fat-binding results, indicates usefulness as a functional protein ingredient.

The results of water-holding capacity evaluations (both of surimi alone and in emulsion matrices) may be useful in defining process and formulation parameters, as well as in interpreting cooked emulsion liquid release data (yields). The results indicated that surimi did not bind water to the extent anticipated. It is postulated that further research on process parameters for emulsion systems would result in improvement in the ability of surimi to bind water.

Foaming capacity and stability, while not directly related to present day meat processing systems, has application to innovative foods manufacturing. Fine, white foams not unlike egg-white foams were produced, and these could be used as binders or matrices for protein-based "lite" foods as this functional property is further investigated and developed.

Results of this investigation indicated that low gel strength surimi was as adequate in most functional properties as high gel strength surimi for application in processed meat products. This would allow the use of high gel strength surimi in seafood applications while providing sufficient quantities of surimi for the meat industry. Thus, continued applications research may reveal that the efficient use of surimi in emulsified meat products at the anticipated use levels of up to 15% may not require the use of high-gel surimi.

In brief, Webb perceived a significant opportunity for the use of frozen pollock surimi in processed meat products. However, since some of Webb's analyses—particularly those of the water-binding capacity of surimi—differ from other analyses, the following information is to be interpreted as one step in the process of assessing the functionality of surimi. What follows here is not the final word.

Functionality in meat products

The potential for surimi in processed meat products partially depends on the meat industry's acceptance of a product which can provide functional advantages as well as be easily used. The meat industry uses a variety of raw materials that provide both economical benefits and a wide array of functional characteristics. The selection of ingredients is based upon a combination of functionality, cost savings, consumer acceptance, regulatory constraints, and availability.

To quantify the functional properties most appropriate for processed meat product applica-

tions, the following specific factors were evaluated for surimi:

1) The fat-emulsifying capacity of surimi using procedures typically used to evaluate meat ingredients;

2) The cooked stability of meat-type emulsions prepared with surimi under various meat process conditions;

3) The water-holding capacity of surimi under various process conditions; and

4) The foaming capacity and stability of surimi at different concentrations, salt levels and whipping times.

The functional properties of surimi were also compared to other protein ingredients, and to freeze-dried and spray-dried surimi.

The approach taken in this project was to evaluate frozen block surimi on the basis of its potential application in existing emulsified-type processed meat systems such as for the manufacture of frankfurters and bologna. These products are produced in substantial quantities (about two billion pounds annually in the U.S. alone), and provide (at a 15% use level) a potential market of up to 300 million pounds of surimi. Poultry-derived raw materials are now commonly used at this level in meat-type sausage products.

Application of frozen block surimi in meat products would be most readily accepted if the surimi were applied in a manner similar to presently available ingredients and processes. Therefore, in evaluating functional properties for this project, we considered the handling conditions (storage, tempering, size reduction) as well as usage conditions (incorporation time and sequence, heat processing, level of usage, etc.). Processed meat applications and methods were given priority over seafood analogue applications.

Experimental methods used

The experimental evaluation of the functional properties of surimi included the following methods:

1. *Cooked emulsion stability:* A modified, cooked emulsion stability test was performed using a model meat emulsion system to evaluate the ability of surimi to bind fat and moisture under simulated emulsion preparation conditions and subsequent heat processing. The treatment variables for this test included:

- a) High and low gel strength frozen surimi,
- b) Early and late addition to the model emulsion preparation,
- c) High (15%) and low (5%) usage levels,
- d) Standard and stressed emulsion systems,
- e) Standard and accelerated heat processing.

2. *Fat-emulsifying capacity:* The modified, fat-emulsifying capacity test of Saffle and Galbreath (1964) was conducted to determine the ability of surimi proteins to emulsify fats.

3. *Water-holding capacity:* A standard water-holding test was used to determine the ability of high- and low-gel surimi to hold water at varying saline concentration, solids to liquid ratios, and under heated and unheated conditions.

4. *Foaming capacity and stability:* A foam capacity and stability evaluation test was conducted with both high- and low-gel surimi to determine foaming properties at different surimi concentrations, whipping times and saline strengths.

Results

Fat-emulsifying capacity: Fig. 21 presents the results of the fat-emulsifying studies of surimi and other ingredients.

The frozen Alaskan high gel strength surimi showed an average fat emulsifying capacity (EC) of 138 mls/100 mg salt-soluble protein, as compared to 85.5 mls for the low gel strength surimi. The high gel strength Alaska surimi EC values compared favorably with Japanese surimi, which showed a range from 148-160 mls of oil emulsified, whereas the lean beef emulsifying capacity was substantially higher (260 mls/100 mg SSP). EC values for spray-dried and freeze-dried surimi were comparable to other surimi forms, with sodium caseinate and isolated soy protein being substantially lower than high gel strength surimi.

Ingredient	Emulsifying Capacity mls oil/100 mg salt soluble protein
Surimi:	
Alaskan, Frozen, 466 Gel-Value	138.0
Alaskan, Frozen, 250 Gel-Value	85.5
Japanese Factory Ship	160.0
Japanese Shore Plant	148.0
Spray-Dried, P.F.P.	151.0
Freeze-Dried, Probine	111.0
Other Ingredients:	
Lean Beef	260.0
Sodium Caseinate	105.0
Isolated Soy Protein, Purina 620	85.9

Fig. 21. Fat-emulsifying capacity of surimi and other selected processed meat ingredients. Source: Webb Foodlabs.

Water-holding capacity: The results of the water-holding capacity tests for surimi are shown in Fig. 22 at various saline concentrations. Several surimi quality levels as well as surimi:saline ratios were evaluated.

The results indicated that aqueous blends of high gel strength surimi, as well as some 3% saline blends, showed the most liquid retention in uncooked blends at all surimi:saline ratios. In the cooked blends, the aqueous solution showed the greatest liquid retention.

In low gel strength, uncooked surimi blends, water-holding capacity increased at 3% saline, especially at a 1:2 surimi:saline ratio. The aqueous blends released less added liquid than either 1% or 2% saline, while cooked blends of low gel surimi returned very little liquid.

Surimi Type	Saline Conc.,%	Surimi:Saline Ratio			
		1:2		1:5	
		Uncooked	Cooked	Uncooked	Cooked
Alaskan, Frozen 466 Gel Value	0	39.5	31.3	34.7	24.9
	3	68.6	18.4	31.1	11.1
Alaskan, Frozen 250 Gel Value	0	22.5	36.5	45.6	21.5
	3	100.0	36.8	37.0	7.0

Fig. 22. Percent of added liquid retained in surimi blends with varying saline concentrations.

Foaming capacity/foam stability: Fig. 23 shows the results of the foaming capacity and stability for 10% surimi in 5% saline solution when whipped for either 5 or 10 minutes.

Highest foam volumes were produced at higher (5% and 6%) saline concentrations from both low and high gel strength 10% surimi solution. The low gel strength surimi produced greater volumes per unit of whipping time. Increased foam stability, as measured by a decrease in liquid released over time after whipping, was also produced at higher saline concentrations, longer whip time, and with the low gel strength surimi.

Surimi Type	Whip Time (min)	Initial Foam Volume	Foam stability at selected time intervals (mls drip @ specified times)		
			1 min	5 min	10 min
Alaskan, Frozen 466 Gel Value	5	465	69	95	101
	10	1200	0	0	0
Alaskan, Frozen 250 Gel Value	5	570	15	32	50
	10	1250	0	0	0

Fig. 23. Foaming capacity and stability of 10% surimi solutions in 5% saline at 5- and 10-minute whip times.

Emulsion-cooked stability: Fig. 24 represents selected results of the emulsion cooked stability evaluations for various surimi treatments. Generally, the use of surimi resulted in improved fat binding and reduced liquid cookout over control emulsions. Higher process temperatures also showed slight improvement in fat-binding and water-holding capacity at the 15% surimi usage levels. At the 5% surimi usage level, low gel surimi had lower fat cookout values than either the high gel surimi or the control.

Emulsion Treatment	Cook Temp (°C)	Total Cook Loss (%)	Fat Cookout mls/100 g Emulsion	Liquid Cookout mls/100 g Emulsion
15% High Gel, Alaskan Late Addition	70	15.5	1.0	14.0
	90	14.7	0.8	12.8
15% Low Gel, Alaskan Late Addition	70	8.2	0.4	6.8
	90	7.0	0.3	5.8
Control, No Surimi	70	22.4	3.7	17.4
	90	23.5	4.7	17.2

Fig. 24. Total fat and liquid cookout values for emulsions prepared with surimi under varying process conditions

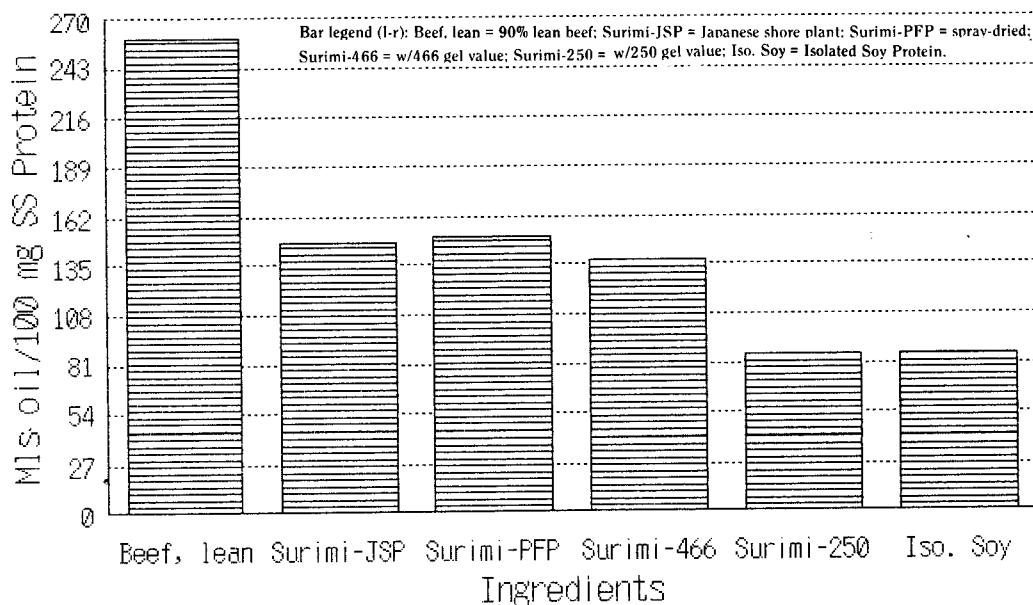


Fig. 25. Emulsifying capacity of various protein-based ingredients.

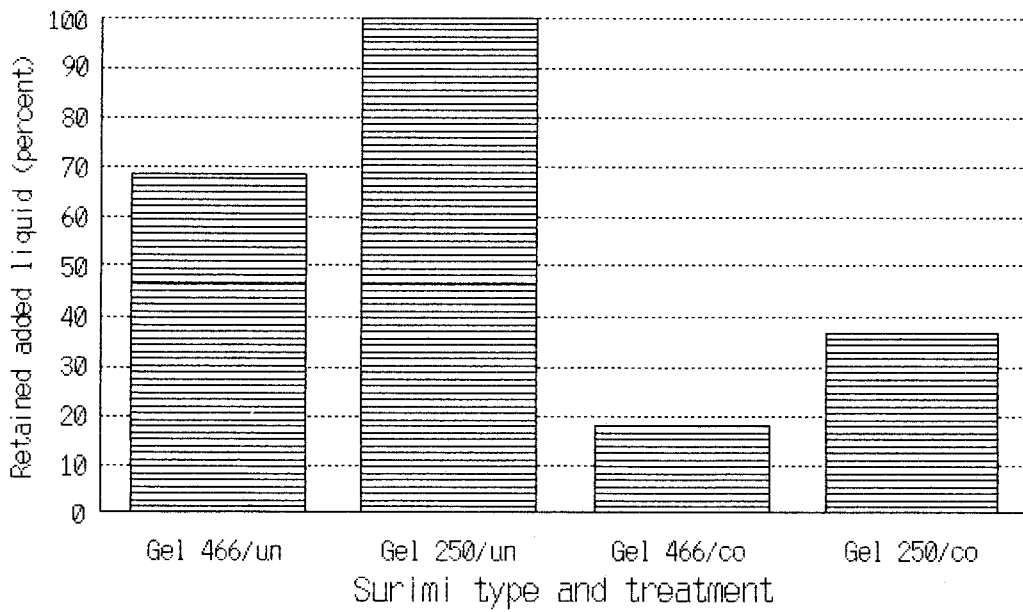


Fig. 26. Percentage of added liquid retained by cooked and uncooked blends containing surimi and 3% saline (1:2).

Bar legend (l-r): 1 = 466 gel value/uncooked; 2 = 250 gel value/uncooked; 3 = 466 gel value/cooked; 4 = 250 gel value/cooked.

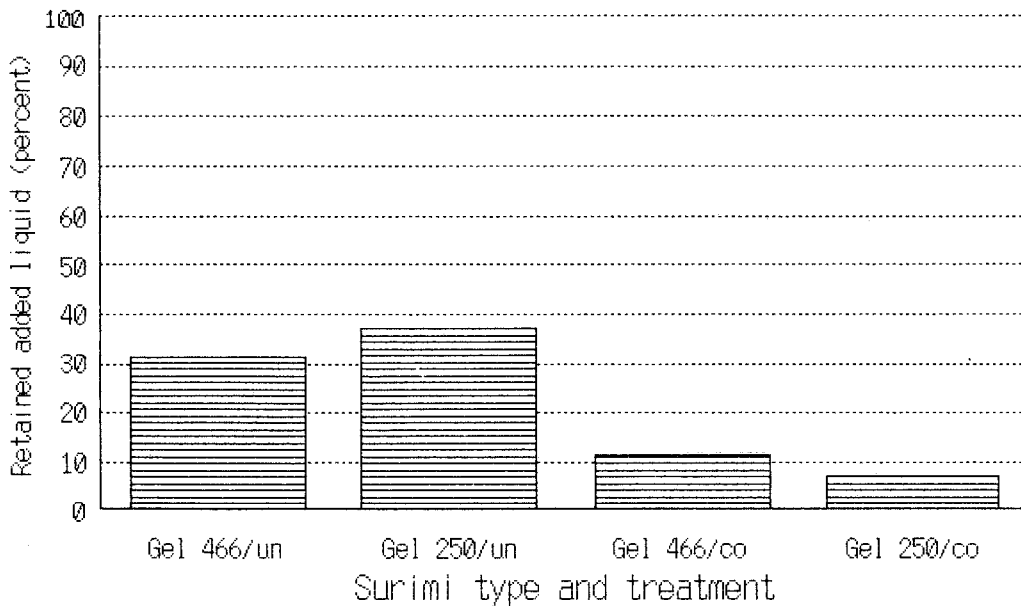


Fig. 27. Percentage of added liquid retained by cooked and uncooked blends containing surimi and 3% saline (1:5).

Bar legend (l-r): 1 = 466 gel value/uncooked; 2 = 250 gel value/uncooked; 3 = 466 gel value/cooked; 4 = 250 gel value/cooked.

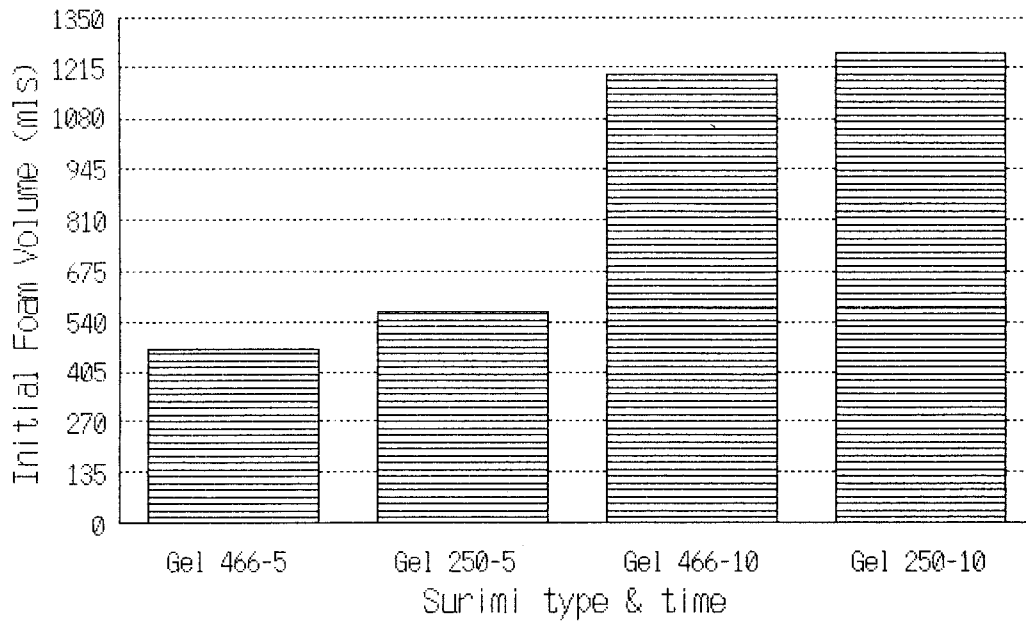


Fig. 28. Foaming capacity (mls) of 10% Alaska surimi in 5% saline at 5- and 10-minute whipping times.

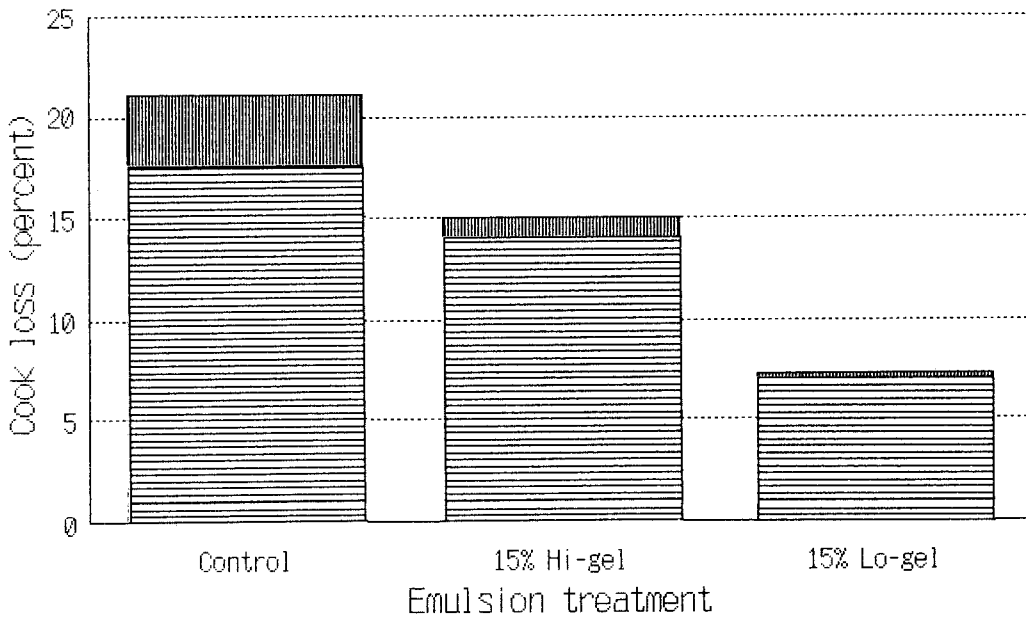


Fig. 29. Fat and aqueous cooking losses for meat-type emulsions containing high and low gel surimi at 158°

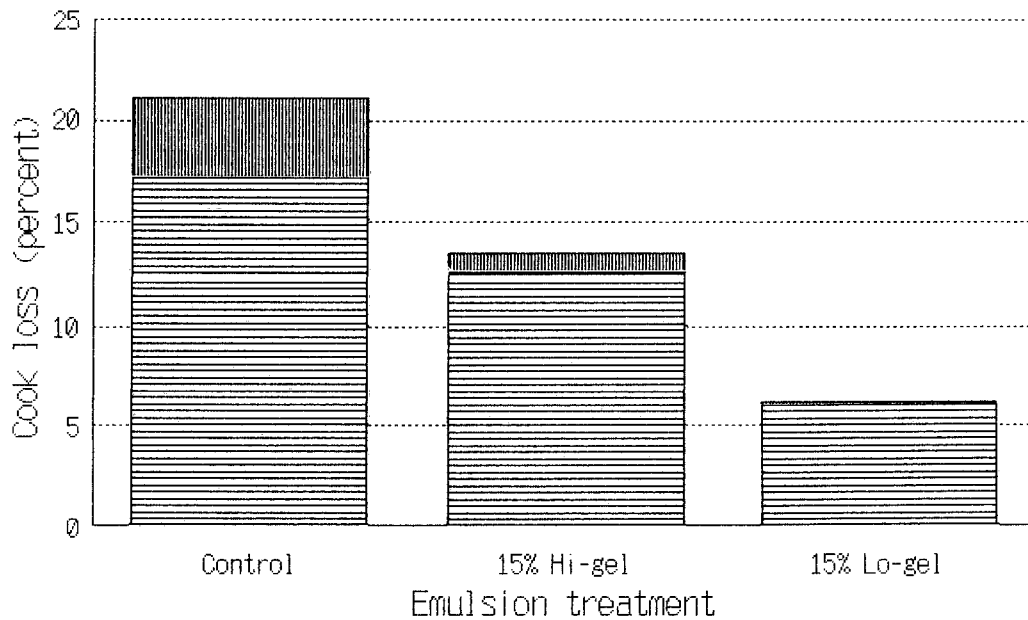


Fig. 30. Fat and aqueous cooking losses for meat-type emulsions containing high and low gel strength surimi at 194°F (90°C).

Surimi in meat products

Surimi is the functional “essence” of fish muscle. The myofibrillar protein of the pollock meat is insoluble in fresh water, so it is isolated during the wash cycles in surimi production. This is what gives surimi the gel-forming capacity for which it is noted.

The unique gelling ability of surimi is partially related to its ability to gel at lower temperatures than other proteins; it is less heat-stable than mammalian or avian muscle proteins. Therefore, surimi is capable of setting into strong network structures at the relatively low processing temperatures desired in many formulations.

By studying the effects of Alaska pollock surimi on red meat and poultry gelation in ground meat products, we can better understand how raw meats used in processed products interact to affect the texture, mouthfeel and overall sensory attributes of a product. Research on the interaction between red meat and surimi proteins indicates that the addition of surimi to a red meat system could improve the binding potential of the red meat by as much as 318%.

Most of the following research on the interaction between surimi and red meats was done by Patricia Manning at the University of Arizona. The following information was excerpted from her research reports to AFDF.

Surimi as a binder in pork

The first representative red meat analyzed was a Class 1 striated skeletal muscle, lean boneless pork picnics obtained from a local industrial supplier. Three lots of surimi from Alaska Pacific Seafoods (APS) were selected as representative of low, medium and high gel strength surimi based on quality specifications obtained from compression and torsion testing.

The first study analyzed the binding potential of surimi as related to gelation of lean pork picnics. Some significant trends were identified early in the research process:

1. A significant relationship was indicated between interacting meat and surimi systems.
2. Binding potential was increased by the addition of low, medium or high gel strength surimi at addition levels of either 5% or 15%.
3. The level of surimi added does not appear to play as significant a role in bind enhancement as does the fact that surimi is added.
4. The greatest increase in bind potential as related to gelation, for the first experiment, was observed with medium gel strength surimi added at a level of 15%.

These trends, as they become validated, indicate significant benefits to meat processors, namely:

1. Increased binding potential of meat blend formulas can easily be obtained with the addition of relatively low levels of lower-cost surimi.
2. Since the level of surimi addition does not appear to contribute as significantly to the possible binding potential as does the actual inclusion of surimi into the formula, processors can use surimi at levels ranging from 5% to 15%, depending on their specific needs, with consistency in the final product. In other words, processors are not restricted or limited to usage levels.
3. Possible production problems may be avoided with the addition of lower-cost surimi at low levels.
4. The use of surimi in a meat formulation may offer more flexibility to the processor in two ways: Marginal binding formulas can be enhanced with low levels of surimi, and using lower-cost surimi could help cut costs in expensive formulas. In addition, possible production failures may be avoided with the addition of surimi at relatively low levels.

One Factor ANOVA X_1 : Gel Strength Y_1 : B-Bind

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
None vs. low	-.783	.549*	3.116	3.058
None vs. medium	-.868	.586*	3.366*	3.178
None vs. high	-.665	.641*	1.648	2.224
Low vs. medium	-.085	.609	.03	2.98
Low vs. high	.118	.662	.049	.382

* Significant at 95%

Fig. 31. Effect of the addition of surimi to a pork picnic product, analyzed by gel strength of the surimi

A one-factor statistical analysis of variance (ANOVA) clearly shows significant differences (at 95%) in bind potential as related to gelation of the admixed meat blend based on the gel strength of the surimi over that of the meat alone.

Significant increases in bind as related to gelation were seen with the addition surimi of all three gel strengths over the lean pork alone. Greater significance was seen with the addition of medium gel strength surimi over that of the low or high gel strength.

No significant difference in bind as related to gelation was observed between the additions of low vs. medium or low vs. high gel strength surimi.

One Factor ANOVA X_1 : Level		Y_1 : B-Bind		
Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
None vs. at 5%	- .56	.448*	3.555	2.667
None vs. at 15%	-1.003	.448*	11.413*	4.778
at 5% vs. at 15%	- .443	.448	2.228	2.111

Significant at 95%

Fig. 32. Effect of the addition of surimi to a pork picnic product, analyzed by level of surimi added.

A one-factor statistical ANOVA performed on the level of addition (0%, 5%, 15%) of surimi to lean pork shows significant increases in bind as related to gelation at 5% and 15%.

No significant difference was observed between additions of 5% and 15% surimi. Greater significance was seen with 15% surimi addition.

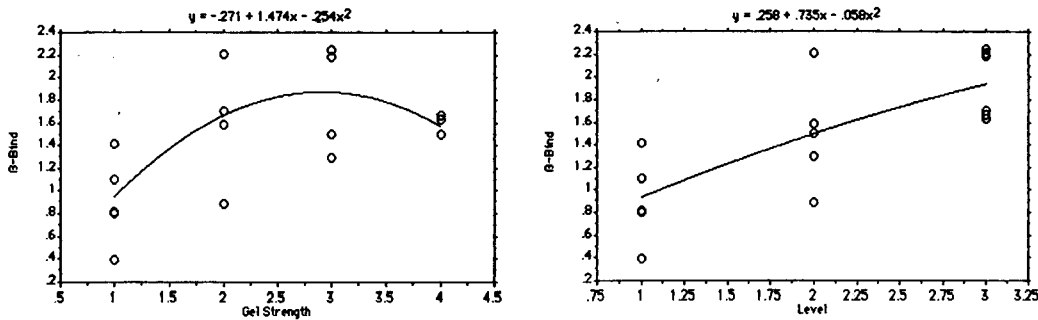


Fig. 33: Effects of surimi of varying gel strength on the bind potential of a pork picnic product.

Fig. 34 The effect of surimi at different levels on the bind of a pork picnic product. Second-order polynomial regression analysis shows a straight line increase in binding potential as related to gelation based on the level of addition of surimi.

Second-order polynomial regression analysis shows a trend developing toward a decrease in bind potential as related to gelation with the high gel strength surimi. However, the binding potential of the high gel strength surimi-lean picnic system still remains greater than that of the lean picnic alone.

This particular finding may indicate a trend toward an adverse effect of the higher gel strength surimi on a lean, good-binding meat. But meat processors probably would not opt to use high gel strength surimi for the following reasons:

1. High gel strength surimi could possibly be viewed as a competing protein source for lean, good-binding meats which might position it as a negative protein.
2. High gel strength surimi is the most expensive. It is highly unlikely that meat processors would purchase it when cheaper grades of surimi are available.
3. There would be no cost advantage to meat processors who use high gel strength to substitute for high-binding lean meats, even if they so desired.

Another reason meat processors probably will not use high gel strength surimi is that the type of texture it imparts may not be suitable for maintaining the typical "meat" texture associated with meat products. Most meat products do not have a rubbery or extremely firm gel set, and to make it such would be undesirable.

For these reasons, a trend indicating a possible decrease in binding potential is not necessarily a negative fact. Rather, further thought leads one to view it as extremely interesting information on how the different protein sources interact. This knowledge may benefit those studying the uses of surimi in other applications.

Surimi in high-quality pork and beef

Further functionality studies were done on lean pork trimmings, 50/50 pork trimmings, lean beef trimmings, and 50/50 beef trimmings purchased from a commercial supplier. Results show that the interaction of surimi with red meats continues on a one-to-one basis.

Adding surimi of any gel strength to the high quality red meats increased binding potential as related to gelation, though low and medium gel strength again caused the most significant increases.

Results indicated a synergism between interacting meat and surimi proteins to improve binding potential of red meats even at temperatures known to produce the classic "modori" effect in surimi resulting in weakened gels.

In certain applications, surimi in admixed meat systems increased the binding potential of the proteins by as much as a 318% functional improvement.

Notes on the results

The trends indicated in the first series of experiments continued in subsequent experiments with only minor differences attributable to individual meat variation.

Increases in binding potential of the various meats evaluated ranged from 12% to a 318%

functional improvement, depending on the condition of the meat proteins. With some meats, particularly the high binders, the addition of surimi may actually result in an adverse effect on bind potential if the meat proteins are of the highest quality with respect to functionality. However, it is not likely that meat processing plants would obtain meat with their respective binding proteins in their most functional state.

An interesting observation was made during experimentations: The temperature at which the meat-surimi systems were heated is 158°F (69°C), well within the range which produces the “modori” effect in surimi gels, a phenomenon which significantly decreases the gel strength of surimi when cooked at a certain temperature. Low, medium and high strength gels improve the binding functionality of red meats at temperatures considered detrimental to surimi proteins. This further substantiates the indication that there is a significant relationship, a synergism perhaps, between interacting meat and surimi protein systems.

The only application in which high gel strength surimi enhanced binding potential as much as medium and low gel strength surimi was when added to abused or mishandled meats. When high quality, good binder red meats are subjected to temperature abuse either by prolonged holding at elevated temperatures greater than 50°F (10°C), or from multiple freeze-thaws, the proteins responsible for the bind are rendered less functional or completely non-functional. In this case the addition of high gel strength surimi could redeem bind potential, though it probably couldn't redeem the quality of the meat.

Often it is extremely difficult to assess the exact state of the incoming meats into production plants. Unless the meats have been subjected to extreme handling abuse, in which case a visual examination would suffice, the status of the functioning proteins cannot be determined. Proximate analysis for meat composition will not show whether any of the proteins have been rendered less useful, nor will any of the commonly used standard quality control tests. Thus, it is not surprising to find many production failures resulting from poor quality raw materials.

Results indicate that adding 15% surimi to abused binder meats that are rendered less or non-functional will supply the necessary functionality to the system and permit successful processing. The 15% addition level appears to work best with meat proteins abused to total non-functionality. In some instances, the addition of 15% high gel strength surimi will not only bring the binding potential up to the original “fresh” level, but will increase it significantly *beyond* the original functionality.

It appears that the way each meat responds to the addition of surimi depends largely on the status of the functional proteins, and to what degree denaturation has occurred. Low and medium gel strength surimi appears to enhance the binding potential of good quality meats, while high gel strength surimi appears to function as a binding compensator in abused meats.

It should be pointed out that the addition of surimi of any gel strength or level will not improve the functionality of spoiled, rotten, or grossly abused meats, and should not even be considered for such uses.

Water-holding capacity of freeze-dried surimi

Samples of freeze-dried surimi were evaluated for water-holding capacity, gel properties with and without salt, and for heating effects on gel properties. Key findings were as follows:

Salt increased the protein solubility and stabilized the protein matrix formed as evidenced by spontaneous gelation, and resistance to separation of a water phase during high speed centrifugation.

Freeze-dried surimi has the highest water-holding capacity of any meat-origin dried protein product, and is approximately four times (400%) greater than soy isolates commonly used as binders in the processed meats industry.

Centrifugation of surimi pastes appeared to decrease sensitivity of the gels to the “modori” effect upon heating.

Rheological and visual properties of freeze-dried surimi were manipulated with centrifugation, salt, and heating to simulate a variety of properties characteristic of modified food starches.

Spontaneous gelation occurred with salted samples upon centrifugation, with or without the application of heat.

On a sample basis, freeze-dried surimi in a 2% salt solution, at pH 6.6, will hold 10 times (or 1,000%) its own weight in water.

On a protein basis, freeze-dried surimi proteins in a 2% salt solution, at pH 6.6, held 15.1 grams of water/gram protein (15.1x or 1,510%).

On a sample basis, freeze-dried surimi without salt, at pH 7.0, held 9.6 times (960%) its own weight in water, compared to soy isolates which will hold 3.32 times (or 332%) its weight.

On a protein basis, freeze-dried surimi proteins, without salt, at pH 7.0, held 14.6 grams water/gram protein (14.6x or 1,460%), compared to soy isolates, which hold 3.7 times (or 370%). Freeze-dried surimi has almost four times (or 400%) greater water-holding capacity than soy isolates.

Unsalted freeze-dried surimi samples released approximately 5.2% soluble protein in the water phase of the centrifuged sample, indicating low protein solubility.

Heating non-centrifuged unsalted samples imparted a sheen or gloss to the resulting gel, solid, paste or fluid.

Freeze-dried surimi in a 2% salt solution imparted a sheen or gloss to the resulting paste or gel without heating.

The resulting gel formed from the centrifuged 2% salt solution samples showed the classic "modori" effect with heat treatments; however, the effect was not very dramatic.

The gels formed from unsalted samples were totally unresponsive to heating temperatures.

The resulting gels formed from non-centrifuged 2% salt solution samples were extremely sensitive to heat treatments, showing very pronounced "modori" effects.

The gels formed from non-centrifuged unsalted samples were sensitive to the heat treatments, showing moderate "modori" effects.

Notes on the results

The results of this work closely compare to those reported by Battelle in Chapter VI, "Applications for Surimi."

Freeze-dried surimi has low protein solubility; this was expected since the water-soluble proteins are removed during surimi processing. Only 5.2% of the total proteins were found in the water-phase of the centrifuged unsalted samples, indicating very low water-solubility. A possible advantage of this property could be that surimi proteins would not be lost as part of water losses occurring during the manufacturing of processed meat products.

Despite low solubility, the proteins in freeze-dried surimi possess superior water-holding properties under a variety of conditions. This would suggest that the proteins, applied in admixed meat systems, would enhance the entrapment of water by the protein matrix during commercial processing.

The water-holding capacities determined by this study were higher than those reported by Battelle, though they were on a very comparable level: 3.8 grams water/gram sample was reported by Battelle; 9.6 grams water/gram sample was the result of this study done by Manning under similar conditions.

One explanation of the difference in results would be that the surimi samples evaluated were of different origin. How frozen surimi is processed, where it is manufactured, the gel strength, and other factors have definite effects on the properties exhibited by freeze-dried samples produced from the original frozen surimi. It is not unexpected that the results would not be identical. What is significant is that this new set of results indicates that freeze-dried surimi has a greater potential than previously thought.

Rheological and visual properties of freeze-dried surimi indicated some manipulative processing potential. Centrifugation, salt, and/or heating surimi resulted in gels with a variety of properties characteristic to modified food starches used in dressings and sauces such as grainy and gummy textures, color opacity and whiteness, and high gloss or sheen.

The thick pastes and gels also displayed the same properties as those reported by Battelle. The pastes and gels were less adhesive than some modified starch pastes or other proteins such as egg whites; however, they were extremely cohesive and held together in a cohesive mass despite the softness of the gel or paste.

Further research would have to be conducted to fully assess the manipulative processing potential of freeze-dried surimi.

Experimental methods used

Samples of freeze-dried surimi were mixed with distilled water using a ratio of 1:10 (1 part surimi to 10 parts distilled water) on a weight basis. One sample set had 2% salt added to the total weight.

After mixing, the sample sets (2% salt and no salt) were then separated into two treatment

groups. Group 1 was centrifuged for 40 minutes at 13,000 X G; Group 2 was not centrifuged.

After centrifugation was completed, samples from both groups were stuffed into glass tubes and stoppered. Tubes containing samples from each set and treatment group were heated for 20 minutes at one of three temperatures: 86°F (30°C), 140°F (60°C), or 194°F (90°C).

After heating, the samples were immediately placed on ice water and held at 36°F (2°C) until completely cooled. The cooled samples then were pushed out of the tubes and evaluated.

Depending on the type of treatment and salt addition, the resulting forms of the cooled freeze-dried surimi gels were as follows:

1. Firm gel
2. Brittle gel
3. Dry, gummy gel
4. Shiny, opaque, soft gel
5. White, shiny soft gel
6. Paste
7. Fluid

Fish protein in processed meats: The potential of surimi

AFDF has devoted much of its 1986 and 1987 program effort toward pursuing markets for surimi in the processed meats industry. But food scientist and “apostle of surimi” Dr. Tyre Lanier has studied surimi and meats far longer. Lanier’s studies have shed much light on the potential uses of surimi in processed meats and other products. In the following section, Lanier discusses some of his studies, and the opportunities presented when surimi is thought of as a gel rather than an emulsion, and why surimi proteins function as they do in concert with meat proteins.

Comparisons of the heat-gelation properties of surimi with those of beef, pork and turkey have indicated that certain gels prepared from surimi were up to four times stronger and twice as cohesive as gels from red meat and poultry samples. Such a marked gelling potential by surimi was attributed to two factors:

First, surimi is a concentrate of the functional salt-soluble proteins of animal muscle—the only such material commercially available. Second, surimi gels possessing the greatest strength and cohesiveness had been pre-incubated at 104°F (40°C), a treatment which had no effect on the gels from other meats.

Fish proteins, especially those of cold-water species, are much less thermally stable than those of warm-blooded animals. This explains the absolute requirement for cryoprotectant addition prior to freezing, and also the ability of fish proteins to “set” into elastic gels at very low temperatures. Upon further processing, these “pre-set” gels will possess greater strength.

Previous researchers, using a thermal scanning rigidity monitor (TSRM), demonstrated that gel initiation during slow heating occurs at a temperature approximately 50°F (10°C) lower than that of poultry or red meats, and that this initiation corresponds to a conformational change in the proteins, which can be detected by differential scanning calorimetry. Subsequent work has indicated that this initial conformational change may involve the exposure of hydrophobic amino acid residues which leads to intermolecular hydrophobic associations and the formation of a gel matrix.

Surimi’s “ordered matrix”

Slow heating allows for the formation of a more “ordered” gel matrix, one which will presumably possess stronger and more elastic textural properties and which is better able to entrap fat and water in a food system. Such an “ordered” structure is formed by some fish proteins at temperatures as low as 32°F (0°C). However, longer incubation times (generally 8-12 hours) are required, and doubtless a different molecular mechanism is involved than for the “setting” phenomenon observed at higher temperatures (near 104°F, or 40°C).

The food science lab at North Carolina State University (NCSU) prepared samples of lean beef, pork and turkey which were very fresh (24-48 hours postmortem) and which were ground

and mixed with 8% of a 1:1 sucrose-sorbitol mixture prior to freezing. The amount of polyphosphate which normally is added to frozen surimi (0.3% sodium tripolyphosphate) was added to the meats along with salt as part of the preparation of heat-induced gels. Surprisingly, the textural properties of these gels approached the levels reported earlier: nearly four times stronger and twice as cohesive as red meat gels. Subsequent experiments indicated that the addition of phosphate only partially accounted for the large increase in textural measurements.

Thus, this preliminary experiment, repeated in triplicate, indicates that mammalian and avian muscle proteins may also benefit from the stabilizing treatments which have been developed for surimi, such that the bind properties of frozen meats may be much improved. Sampling for this experiment has thus far extended only over one month frozen storage; sampling at longer intervals is needed to determine the full extent to which the meat and poultry proteins were stabilized.

This study also revealed that gel strengths of the meat and poultry proteins were enhanced by a 140°F (60°C) process for 30 minutes as compared to a faster (15-minute) cook at 194°F (90°C). As was expected from previous reports, the 104°F (40°C) pre-incubation for 20 minutes had little effect upon the properties of the meat and poultry gels. It may thus be concluded that these proteins also display a type of low-temperature “setting” phenomenon, but at higher temperatures than surimi. This higher temperature for gel strength enhancement corresponds with the higher denaturation temperature of these proteins as compared with fish muscle proteins.

Other functions in processed meats

It may be apparent that the only “functional property” mentioned thus far in this section has been that of gel-forming ability, measured in terms of the strength and cohesiveness of pure protein gels. This is because it is believed that water-binding and fat-binding, the other primary functional properties of meat proteins in highly processed products, largely result from the ability of the myofibrillar proteins to polymerize into a network structure which is capable of entrapping these liquid (at processing temperatures) components of the product.

In restructured muscle foods, gelation of soluble myofibrillar proteins is responsible for a fourth function similar to the first—that of “gluing” chunks or flakes of muscle together into a coherent mass.

The surimi-based *kamaboko* products of Japan, of which the shellfish analogues are a group, represent the largest category of processed comminuted fish products being manufactured. A smaller group of products known as fish “sausage” is also produced in Japan and is similar in composition to domestic comminuted meat and poultry products such as frankfurters and bologna. The literature generally refers to *kamaboko* products, which are low in fat (generally less than 2%) but high in starch and water content, as “gel” type products; the latter high-fat (generally 20-30%) products are called “emulsions.”

This choice of terminology also has seemed to influence, or been influenced by, the approach taken by meat scientists studying these systems. The properties of the “gel” type products have been largely attributed to the ability of the muscle proteins to gel, and thus studies of the heat denaturation and gelation properties have predominated in the meat (often fish) science literature of Japan. The properties of “emulsion” type products have been attributed more to the fat-coating, or “emulsifying,” ability of the protein, and studies of this emulsifying ability have predominated in the Western meat science literature. However, it is likely that these two types of food systems are actually very similar.

Surimi in gel-type products

The gel-type food product is considered to consist essentially of a protein matrix in which other food components, both liquid and solid, are entrapped. A previous report showed that such products possess two fundamental textural or rheological properties, which may be called strength and cohesiveness. These may be measured by the force (stress) and the deformation (strain), respectively, required to produce mechanical failure in the gel. A torsion geometry is preferred for this test, but the measurements are fundamental properties of the material which, unlike the results of most “texture” tests, are independent of the test geometry.

The gel rigidity is computed from stress/strain values. We have found that the rigidity measurement is very responsive to changes in the protein or solids concentration of the gel, while the cohesiveness (strain at failure) is most responsive to the quality or “functionality” of the

protein. Thus, the addition of protein “fillers” to comminuted meat products at the expense of water or fat will generally result in a firmer or more rigid texture, whereas addition of these ingredients at the expense of functional muscle protein will primarily reduce cohesiveness of the product.

The effects of fat addition on textural properties of protein gels have not yet been fully documented. Such study should reveal much about how to replace the fat in “emulsion” products with other components to produce low-fat products of acceptable texture.”

Emulsion products can thus be viewed as gel products in which one of the major non-gelling components is fat. This view, then, emphasizes the role of protein gelation rather than protein coating of fat particles as being the critical event in the stabilization of the fat within the product. One researcher, in a recent paper on protein-fat interactions in processed meats, concluded that the single most important factor affecting fat-holding ability of sausage products may be gel strength of the batter matrix.

Surimi as a protein coating

Protein-coating of the fat particles comes into play mainly in the dispersing of the fat in the aqueous protein sol. It is desirable to disperse the fat in fine particles in some products simply because it makes the product organoleptically more homogeneous; such fine dispersion is not required for stability of the fat. Pre-emulsion technology uses non-meat proteins, such as soy or caseinate, to form a fat dispersion prior to its incorporation into the muscle protein sol. This obviates the need to comminute the muscle proteins at temperatures where protein denaturation might occur prematurely (and therefore reduce functionality) solely for the purpose of dispersing the fat.

Heating the mixture makes the fat melt and induces gelation of the proteins. According to emulsion theory, too-rapid heating causes fat particles to rupture due to expansion of melted fat within a coagulated and contracted protein membrane in an aqueous medium. However, this assumes that the system is comprised simply of fat globules surrounded by protein membranes. Actually, the fat globules are encased in a gel network. The physical arrangement of this network, as evidenced by its rheological properties, is closely tied to the time/temperature profile. Thus, it would seem that deficiencies in the nature of the gel network caused by rapid heating may be responsible for the poor binding properties under these conditions.

Gel theory would also yield different explanations for fat instability caused by such factors as overchopping and low quality meats. According to emulsion theory, overchopped batters are unstable because not enough protein is available to cover the huge surface area of the too-finely-chopped fat particles. However, it is unlikely that such a problem could exist at the high protein-to-fat ratios found in meat batters. At much higher fat concentrations of liquid oils, very little quantity of protein is needed to coat and thus stabilize the fat in an emulsion.

Emulsifying capacity of surimi

Published reports also show that the emulsifying capacity (EC) of proteins, when measured as grams of oil emulsified (stably dispersed) per 100 mg of protein, decreases to a minimum with increasing protein concentration, and that the total grams of oil dispersible does not increase proportionately with increases in protein concentration. It is more likely that overchopping weakens the structure of the gel because chopping at elevated temperatures causes premature denaturation of the proteins and greater disruption of the protein matrix is caused by the finer dispersion of the fat component throughout the protein sol.

The use of poor quality or “short” meats would be expected to lead to poor fat stability because there is an inadequate quantity of salt-soluble protein available to form the proper type of gel network, and that network may be disrupted by the high content of non-gelling proteins present.

While there is not yet proof that this “gel” theory is indeed the correct one, it does, in many cases, offer a more satisfying explanation for the phenomena observed in the processing of comminuted meat batters. At the very least, this discussion should encourage meat scientists to broaden their thinking on the subject, perhaps opening up new investigations which will more clearly elucidate both the biochemical and physical mechanisms of fat- and water-binding in comminuted meat systems. If it is true that the gel strength of the batter mix is the effective factor in the fat-holding ability of sausage products, then torsion testing of protein gels may prove a valuable laboratory test for evaluating the bind potential of various ingredients for processed meats.

Surimi as a tool for technologists

Fish proteins in the form of surimi give the meat scientist a new tool for the study of meat batter systems. Our research has shown that the type of gel structure as evidenced by rheological properties can be easily influenced by manipulating the heating of these proteins. This should facilitate studies of the relationships between gel structure development and fat- and water-binding functions. Additionally, because fish proteins are capable of gelling at such low temperatures, it is possible to induce gelation prior to the event of fat melting. It may be that the time sequence of fat melting and protein-protein associations will turn out to be quite critical to the ultimate fat- and water-binding properties of meat proteins.

While this section has emphasized the physical entrapment of water, fat and other food components by a protein matrix, the role of chemical interactions should not be overlooked, particularly with regard to water binding. The optimum pH for heat gelation of myosin is near 6.0, while the water-binding properties of proteins are known to increase with increasing pH. Thus it will be important to determine the relative role of physical entrapment versus chemical attractions in optimizing the water- and, possibly, fat-binding properties of muscle food system.

The low temperature "setting" properties of surimi proteins may be especially useful in restructured meat applications. Coating of the meat chunks or flakes with surimi of a cold water species (e.g., pollock) would enable that product to be bonded into a coherent mass without the necessity of heat processing. A freeze-dried preparation of surimi now is being commercially produced in Japan expressly for this application. There are also a few sources of dried surimi in the U.S.

Conclusions

The excellent gelation properties of surimi should recommend it to meat processors who need to increase the bind level of a formulation at a reasonable cost. Considering that its gelation properties will generally exceed those of bull meat, which is priced perhaps 50% higher, this could be a significant improvement in least-cost formulations. (Surimi prices fluctuate weekly; see Chapter XII, "Additional References.")

To produce surimi of this gelling quality, the fish must be handled and processed with the utmost care. Surimi generally is a primary product, rather than a by-product of a filleting operation, and to attain the high quality desired, extensive leaching is required. Thus, a highly functional surimi is likely also to be of superior bacteriological quality, more homogeneous in appearance (no specks of skin or bone), and possess a blander flavor and aroma as compared to minced fish. As such, it should receive more favorable attention by the U.S. Department of Agriculture as a potential ingredient for processed meat products. Additionally, the blandness and high quality of surimi should allay consumer objections to its use in these traditional meat products.

Information on the use of fish protein in processed meats is from "Fish Protein in Processed Meats: The Surimi Potential," by Dr. Tyre C. Lanier, Food Science Department, North Carolina State University, Raleigh, North Carolina.

Information on surimi's functional properties is from the executive summary of "Functional Properties of Alaska Pollock Surimi for Applications in the Food Industry," by Webb Foodlabs, Inc., 3309 Drake Circle, Raleigh, N.C. The full report was published by AFDF in 1985 and is available by arrangement.

