HOW TO USE NEARLY ALL THE OCEAN'S FOOD

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The stark realities of the world population explosion and of world hunger cannot be ignored. Most nutritionists estimate that the present state of world food production does not provide an adequate daily diet for two-thirds the population. Even in the U.S., the underprivileged generally lack a good diet. This point was acknowledged by a recent meeting of concerned citizens in Washington, D.C., under the aegis of President Nixon. It was also recognized by President Kennedy in a March 1961 message to Congress.

Hunger can mean different things to different people. By and large, the nutrient most lacking in deficient diets is good-quality protein; seafoods, in general, are known as excellent sources. They are also good sources of polyunsaturated lipid. In abundant diets, which typically do not have a protein deficiency, the ability to replace other lipid sources with typical seafood polyunsaturates is an important consideration.

Resources Must Be Developed

Although some claim that a specific approach will solve overt or hidden hunger, most experts believe several conventional and unconventional resources will have to be expanded or developed to meet our present and future desires or choices for good-quality foods (Mateles and Tannenbaum 1968). Seafood is an example of a conventional resource, yet the ocean's capacity to produce food has not been achieved. For example, under present conditions and fishing techniques, there is a significant waste of potentially edible animal protein. Most vessels look for particular species; other species that come up with the catch are thrown overboard. This wastes time, effort, and potentially nutritious food. Even with species saved, more than half the body may be discarded at sea or ashore. It has not been economically feasible to harvest other species or to process them for food.

Total Oceanic Production

These considerations lead to the concept of total oceanic production of seafood (TOPS). It envisages using all potentially edible parts from all species landed. Traditional or conventional species and market forms of seafood are included. Also, "unconventional" applications are needed to utilize the remainder of the harvest. Obviously, these applications should tailor a product for consumer acceptance--rather than try to educate a consumer to a particular species that might become less available. Successful applications also would increase efficiency of harvesting effort and thereby maintain ocean's food resources in a more economically healthy condition.

Processing & Storage Techniques

To increase efficiency of utilizing our marine resources for food, we need to develop appropriate processing and storage techniques afloat and ashore. Such a development has occurred in Japan during last 20 years (Tanikawa 1963). To meet increasing domestic demands for good-quality protein foods, a family of machines and appropriate technology were developed. The machines remove edible flesh from bones and skin and convert the minced flesh into a "universal" material that can be preserved by freezing. It is called "surimi." It can be considered basic ingredient in manufacturing food items, such as fish cake or paste ("kamaboko"), several kinds of sausages ("chikuwa," "tokuyo," and ham sausage). Potentially, surimi can be used in other products, such as soups, fish puffs (different fish flavors), meat-flavored chunks, frankfurters, dehydrated cubes or

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flakes, controlled size portions, and snack-type items.

At present, such applications in U.S. seafood industry are limited to Japanese types of products made from surimi. However, another U.S. food industry dealing with proteinaceous flesh as food, the poultry industry, has learned recently how to use meat/bone separators to recover edible meat from processing "wastes" such as poultry necks and backs. This comminuted (pulverized) poultry meat (or "poultry surimi") is being added to soups, various types of meat sausages, or used as a binder for canned or frozen poultry meat.

Surimi-Type Ingredient

These considerations are similar to those developed by Miyauchi and Steinberg (1970). Although they used different species and machines, a more fundamental difference between their report and this one is present emphasis on a surimi-type ingredient rather than end-use food items. Obviously, various foods are helpful to evaluate or discuss the applicability of a food ingredient. Equally helpful, and perhaps more important in commercial applications, is developing technological and economic information on this surimi food ingredient.

The successful use of Japanese machines for seafood production, and the use of similar machines in the U.S., led us to explore potential applications of such machines in domestic seafood industry. This work involved three considerations: 1) sources of raw material, 2) technological and economic considerations in processing this material into surimi food ingredient, and 3) potential applications of this surimi.

Sources of Raw Material for Machine Separator

The ocean's fauna include many species. For this work, the sources of raw materials may be grouped into two broad categories: fish frames (waste material obtained from filleting lines), and underutilized fish (species caught incidentally to other species, or not presently caught). Characteristically, the anatomy or size of these underused species is not amenable to present filleting methods. Thus, this source could be used as headed and gutted (H&G) fish rather than fish frames.

The potential volume and value of these two sources are important considerations. The greater potential volume will come from underutilized species (headed and gutted fish). However, accurate figures on the sustainable harvest of this resource are hard to find (Bardach 1968). Although potential volume of filleting wastes is smaller, it depends on landings of fish used for filleting. So, it can be estimated with reasonable certainty. In New England alone, for example, the potential volume of machine-separated meat from filleting wastes has been estimated at 56.9 million pounds annually (Carver and King 1970).

Raw-Material Cost Important

Obviously, the cost of raw material is as important as its availability in considering its potential use. In developing cost estimates for these two categories, we have attempted to recognize all cost increments up to point where the material enters a meat/bone separator. For fish frames, an estimated value of 6 cents per pound appears reasonable (Table 1). For underutilized species (H&G), about 9 cents (Table 2), even though there is much speculation about estimate because of variety of species involved. For example, some underused species may require special harvesting methods, heading and gutting machinery, or they may have an unattractively low yield of machine-separable ground meat.

Marine Invertebrates Included

Theoretically, such marine invertebrates as crustaceans, molluscs, and other groups are considered as sources. Although some of these species now are fully utilized, edible meat can be recovered from processing wastes. Typically, these wastes come from such cooked animals as crabs, lobsters, or shrimp. Ground meat has been recovered from such wastes by machine separators (Carver and King 1970; Miyauchi and Steinberg 1970). It contains shell fragments and has lost some important functional properties of raw meat. However, it can be processed into such food products as spreads, pastes, or bisques. Recovery of raw meat from animals containing a brittle exoskeleton has been done with an ordinary chopper followed by filtering. However, a meat/bone separator was unsuccessful in removing raw meat from intact rock crab legs or cores. For such reasons, it is advisable to consider marine invertebrates separately from finfish sources.

Table 1 - Estimated cost of raw material source for machine-separated ground meat when obtained from fish frames

Description of processing or handling step	Estimated cost in cents per pound	
	Cost added by step indicated	Total cost at step indicated
1. Price of filleting wastes--contain heads but no viscera and no skins from filleting operation	1	1
2. Handling, temporary storage by icing, and transport to using facility	1	2
3. Beheading (to remove eyes for aesthetic reasons)		
a. Labor 4 men @ $2.50 per hour each @ 250 lbs. per hour each.	1	3
b. Yield of 48% usable material remaining[1/]	$\frac{3}{.48}$	6.25[2/]

1/Experimentally determined value using cod frames.
2/If heads can be sold for gurry at one cent per pound, this figure will be reduced by 1 ¢ (52%) or 0.52 cents.

Table 2 - Estimated cost of raw material source for machine separated ground meat when obtained from underutilized fish

Description of processing or handling step	Estimated cost in cents per pound	
	Cost added by step indicated	Total cost at step indicated
1. Ex-vessel price for harvest[1/]	3	3
2. Heading and gutting, Theoretical machine with capacity of 1000 lbs. per hour and two men at $2.50 per hour each to operate it. Cost of machine and its operation.	2	5
3. Yield of suitable raw material for separation of flesh after step 2 is 55 percent.[2/]	$\frac{5}{.55}$	9.1[3/]

1/This figure is based on special trips for this material. Ex-vessel prices for material caught incidental to efforts for species with other end uses may be lower, but this source of supply may be smaller and more erratic.
2/Assumed average value for all species. The yield of headed and gutted ocean perch was determined on 107 individuals in one lot with an average yield of 55.4% ± 2.1%. The yield of headed and gutted red hake was determined on 10 representative individuals in a 75 pound lot with an average yield of 62.1% ±7.6%. Yield data for nine other species are presented in Miyauchi and Steinberg (1970).
3/If heads and viscera can be sold for by-products at one cent per pound, this figure can be reduced by 1 cent (45%) or 0.45 cents.

Machines For Experimental Work

Most experimental work reported here was based on using the Bibun[1/] family of machines. The basic unit in this family is a meat/bone separator (Figure 1). This machine removes flesh from suitable materials by squeezing and tearing actions. It contains a wide flexible belt that moves against the outside of a rotating, perforated metal drum. The belt and drum move at different speeds in same direction. In operation, flesh is separated from skin and bones by a shearing action due to difference in speeds between drum and belt. Since flesh is softer and is less cohesive than skins or bones, the pressure developed between drum and belt drives it through perforations of drum. Skin and bones remain behind on belt.

The Strainer

The strainer (Figure 2) is used to "finish" comminuted (pulverized) flesh obtained from a separator. Material fed into this machine is moved by an auger against a stationary perforated metal cylinder (Figure 3). These perforations are only about one millimeter in diameter, so any small bones or pieces of

1/The use of trade names facilitates description of experimental procedures; no endorsement is implied. At least two other Japanese firms, Yanigiya Machinery Works, Ltd., and Ikeuchi Iron Works, Ltd., one Swedish firm, A. B. Iwema, and at least two U.S. firms, Beehive Machinery, Inc. and Stephen Paoli Manufacturing Co., manufacture meat/bone separators. The Bibun Machine Construction Co., Ltd. is the only firm we know that manufactures a strainer as well as a separator.

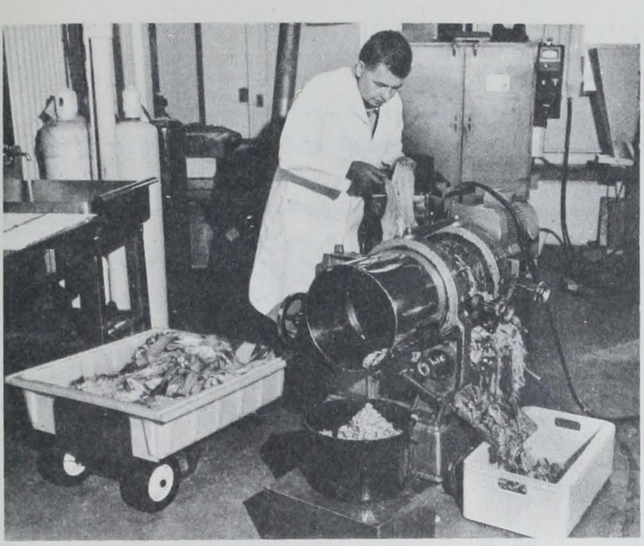

Fig. 1 - Processing filleting leftovers in Bibun meat/bone separator.

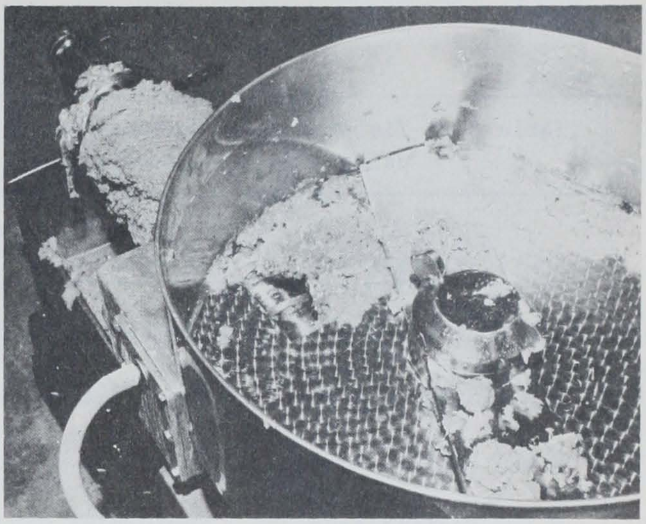

Fig. 3 - Close-up view of a Bibun strainer.

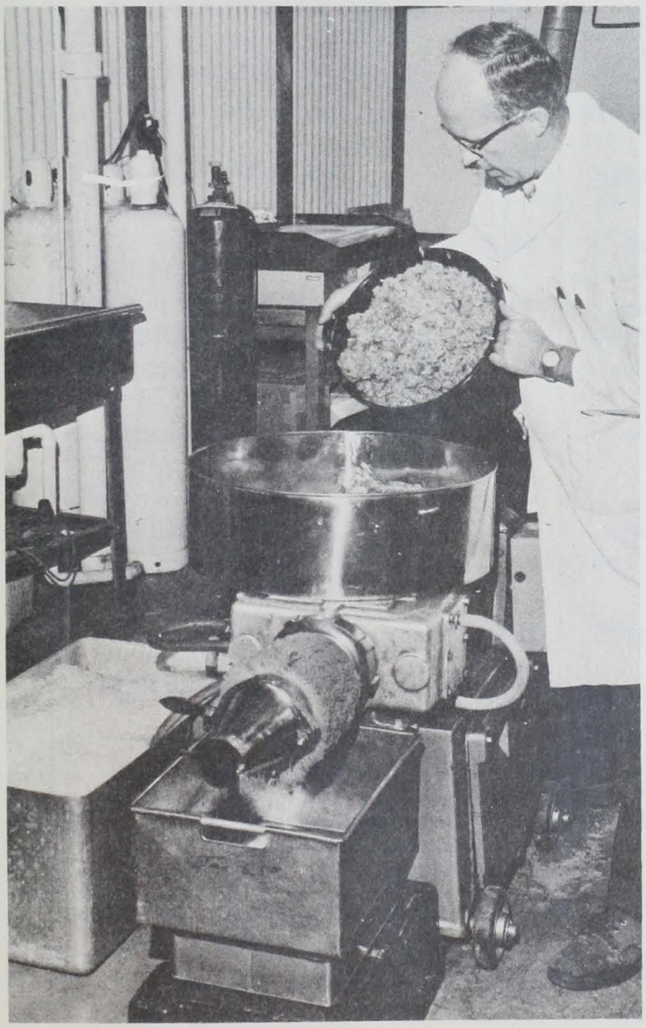

Fig. 2 - Processing machine-separated flesh through a Bibun strainer.

skin present are separated from flesh, which is homogenized by passing through these holes. The auger is kept cold to prevent heat damage to fish flesh by circulating cold water inside it.

Although this strainer was designed for use with material containing raw flesh and bones, we have tried using it to remove shell fragments from cooked blue crab, lobster, and shrimp material. The shell fragments and the lower moisture content of the flesh in these materials created some difficulties in processing them through this machine. However, by redesigning auger and by adjusting throughput rate, it appears these difficulties can be overcome. After passing through small holes of strainer, these shellfish pastes or bisques did not have organoleptically detectable (involving sense organs) shell fragments.

Considerations In Using Machines

An estimate of the cost of using this family of machines is given here. The figures used are intended merely to visualize the process. A commercial processor should check our assumptions against his particular situation. In this concept, one separator and two strainers are assumed at an initial total cost of $20,000 and depreciated over 5 years. (Leasing instead of buying machines might reduce cost.) To this cost, add costs for running machines, such as energy utilization, replacement parts, and maintenance.

To develop this concept, we also assumed these machines should handle up to 4,000

Table 3 -- Yield of flesh obtained from several species of headed and gutted fish using a meat-bone separator. 1/

Source of material	Scientific name of species	Yield of flesh obtained	Reference source
H & G Northern anchovy,	Engraulis mordax	92.6	Calculated from table 1 of Miyauchi and Steinberg (1970)
H & G Spiny dogfish	Squalus acanthias	77.0	
H & G English sole	Parophrys vetulus	84.1	"
H & G Pacific hake (Puget Sound)	Merluccius productus	88.4	"
H & G Pacific herring	Clupea harengus pallasi	69.5	"
H & G Lingcod	Ophiodon elongatus	77.0	"
H & G Silvergray rock-fish	Sebastodes brevispinis	80.6	"
H & G Starry flounder	Platichlhys stellatus	79.4	"
H & G Pacific cod	Gadus macrocephalus	69.4	"
H & G Croaker	Micropogon undulatus	70	Miyauchi and Steinberg(1970)
H & G Croaker	"	75	"
H & G Porgy	Calamus sp.	65	"
H & G Ocean perch	Sebastes marinus	69.4	
H & G Ocean perch	"	62.4	
H & G Whiting	Merluccius bilinearis	86	
H & G Mackerel	Scomber scombrus	65.0	
H & G Red hake	Urophycis chuss	69.8	
H & G red hake	"	83	
H & G Israeli carp	Cyprinus sp.	72.4	

1/ Yield data based on material entering and leaving the separator. It is not based on the whole animal since it does not include the heads and viscera.

Table 4. --Yield of flesh obtained from fish frames (filleting wastes) using a meat-bone separator 1/

Source of material	Scientific name of species	Yield of flesh obtained
Cod frames	Gadus morhua	59.0
Cod frames	"	66
Pollock frames (large)	Pollachius virens	60
Pollock frames (small)	"	72.2
Haddock frames	Melanogrammus aeglefinus	56
Wolffish frames	Anarhichas lupus	66
Cusk frames	Brosme brosme	70
Whiting frames (from only large fish)	Merluccius bilinearis	55
Ocean perch frames	Sebastes marinus	38.6
Ocean perch frames	"	31.2
Yellowtail flounder frames	Limanda ferruginea	47
Rockfish frames	Sebastodes sp.	51.0 2/
Trout frames	Salmo gairdneri	68 2/

1/ Yield data based on material entering and leaving the separator. It is not based on the whole animal since it does not include heads, viscera, or fillets.

2/ Calculated from Figure 2 of Miyauchi and Steinberg (1970)

Table 5. -- Comparison of fillet yield with yield of edible flesh obtained from filleting leftovers.

Source of material as landed 1/	Yield of fillets 2/	Yield of machine-separated flesh obtained from filleting waste 3/	Total estimated yield of edible flesh 4/
Cod, eviscerated	37	19	56
Cod, eviscerated	37	12	49
Wolffish, eviscerated	34	20	54
Cusk, eviscerated	36	22	58
Whiting, eviscerated (large fish only)	48	17	65
Pollock, eviscerated	40	18	58
Pollock, eviscerated	38 5/	20	58
Haddock, eviscerated	40	17	57
Yellowtail flounder, whole	34	16	50
Ocean perch, whole (min. amount of candling)	30	19	49
Ocean perch, whole (avg. amount of candling)	25	20	45

1/ Scientific names of species are given in Tables 3 and 4

2/ Estimated values based on current commercial filleting yields. Values expressed as lbs. of fillets per 100 lbs. of fish as presently landed (whole or eviscerated). These values are for "skin-off" fillets. For "skin-on" fillets, these values would be higher by about 3 lbs. per 100 lbs. of fillets.

3/ Values expressed as lbs. of edible flesh per 100 lbs. of fish as presently landed (whole or eviscerated). These yield figures are lower than those in Tables 3 and 4 because fillets, heads (eviscerated fish) or heads and viscera (whole fish) were not fed into a separator.

4/ Sum of values for fillet yield and machine-separated flesh yield given in preceeding columns. Expressed in lbs. of edible flesh per 100 lbs. of fish as presently landed (whole or eviscerated).

5/ Measured yield for this lot of fish which were smaller than those normally used in the trade.

Table 6 -- Recent prices for some present-day frozen fish products. All of these prices are F.O.B. Boston or Gloucester, Massachusetts. They do not include charges for storage over one to three months.

Description	Marketing Unit	Price per pound
Frozen blocks 1/		
Cod (regular)	16 1/2 lbs.	$0.30
Cod (minced)	13 1/2 or 16 1/2 lbs.	0.15
Haddock (regular)	16 1/2 lbs.	0.38
Pollock (regular)	16 1/2 lbs.	0.21
Flounder (regular)	16 1/2 lbs.	0.42
Greenland Turbot (regular)	16 1/2 lbs.	0.32
Ocean Perch (regular)	16 1/2 lbs.	0.21
Frozen fillets, 10 lb. package of cello wrapped fillets.	Five 10-pound packages per master carton.	
Cod	"	$0.33
Haddock	"	0.55
Pollock	"	0.28
Flounder	"	0.58
Greenland Turbot	"	0.40
Ocean Perch	"	0.37
Whiting	"	0.31
Ocean Catfish	"	0.38
Hake	"	0.26

1/ Block is a trade designation for fillets (regular block) or pieces from fillets (minced block) which are packaged into a box and then frozen en masse.
Scientific names for these species, except Greenland turbot (Reinhardtius hippoglossoides), are contained in Tables 3 or 4.

pounds of input material per hour during 7,000 hours of operation in this depreciation period. Based on these somewhat arbitrary assumptions, a machine cost of less than 0.1 cent per pound of input material was obtained. To this add relevant labor costs. (Overhead and other indirect costs will be totaled with projected costs of products obtained.) Since all the machines are assumed to have automatic feed and discharge systems, the assumed labor costs were based on two semiskilled operator-laborers at $2.50 per hour each. Adding this labor cost of 0.125 cent per pound of input material to machine cost of less than 0.1 cent per pound, you get a total cost of about 0.2 cent per pound.

The costs of using these machines must be absorbed by yield of final product, so several laboratory tests were made here and elsewhere to estimate yields from various sources. The yields presented here were based on using only the separator. In other experiments, the ground flesh output from separator was fed into strainer. It was found that the strainer could be operated in a variety of ways to influence properties of comminuted flesh. However, there was relatively little effect on yield of material when over 100 pounds of ground flesh were processed through strainer.

Data show large variation among fish species. Much of this variation may be due to seasonal variability in feeding habits, as well as species differences in anatomical structure and size. This variability appears reduced when you recalculate available results from a basis of whole fish (as purchased) to a basis of headed and gutted fish as fed into a separator (Table 3). In absence of enough data on size or plumpness of fish used to yield of machine-separated flesh, these figures should be considered estimates.

With frames (filleting wastes), available yield data appear more consistent (Table 4). It appears that a yield value can be estimated with reasonable accuracy for a given anatomical structure. For a species, the principal batch-to-batch variations in yield of machine-separated flesh appear related to individual skill of hand-labor in cutting out fillets before we obtained the frames. If one combines yield of machine-separated flesh from these frames with estimate of filleting yield, the total amount of edible flesh can be estimated (Table 5).

Using Ground Edible Flesh From Machine Separation

In considering applications for ground edible flesh or "surimi" as an ingredient in food products, economic projections should be made to estimate whether addition of this food ingredient is justifiable. One such projection follows.

By using reasonable assumptions, arbitrary prices for machine-separated flesh can be derived. We have estimated a price of 6.25 cents per pound for fish frames delivered to the family of machine separators (Table 1), and a cost of 0.2 cent per pound using these machines (previous section). Assuming average yield of 60% for ground flesh (Table 4), value of meat at this stage is $\frac{6.45}{.60}$ or 10.8 cents per pound. (If skin and bones can be sold for meal production at one cent per pound, this figure can be reduced by 0.4 cent per pound.) Although this flesh can be used immediately, we assume it will be packaged and frozen-stored for later use in a food product. Packaging costs for labor and materials (10-pound waxed cartons in a 5-unit master case) are estimated at 2 cents per pound. Then, by adding freezing cost of one cent per pound, we obtain total value of 13.8 cents per pound for this meat. Storage costs are estimated at one cent per pound for first month, and 0.5 cent for each succeeding month. The duration of this storage period, transportation costs to final processor or user, profit, overhead, and insurance costs will vary considerably. If we assume these costs will average 20% of frozen meat's value, a final value of about 17 cents per pound is derived.

By using similar assumptions and calculations, a final value can be derived for frozen-stored meat obtained from underutilized (headed and gutted) fish. In this case, the raw material cost will be higher, say 9.1 cents per pound (Table 2), if harvesting costs have to be borne by this material. However, the yield of machine-separated meat should be higher, and an average yield of 78% is reasonable (Table 3). Using these figures, a final value of about 18 cents per pound is derived for frozen-stored meat delivered to final processor or user.

The estimated values of 17 or 18 cents per pound for this frozen-stored fish meat product ("surimi") are favorable when compared with recent prices for frozen-stored fish fillets (Table 6). The values are presumed at least comparable with poultry, beef, or pork meat.

On the basis of these value projections, it appears that several food applications are economically justifiable. Some potential applications already have been considered, although economic projections have not always been included.

Fish cakes and canned fish products have been proposed (J.M. Mendelsohn, unpublished work cited in Carver and King 1970). It has been used as a binder or matrix in fish loaf or jellied roll-type products (Carver and King 1970; Learson, et al., 1969). It has been proposed as basis for sandwich or hors d'oeuvres types of spreads (Miyauchi and Steinberg 1970). It can be used to make a beefless frankfurt or similar products (Carver and King 1970). In this application, more recent studies have demonstrated that by processing machine-separated flesh through the strainer, complete elimination of all bone particles in the product is assured and its textural quality improved.

Another potential application occurs in institutional or commercial mass feeding. These enterprises continually seek ways to maintain or upgrade nutritional quality of their menus, while holding line on ingredient costs. Several of their popular recipes, hamburgers, sloppy joes, meat loaf, American chop suey, stuffed pepper, chili con carne, or spaghetti with meat sauce, depend on ground beef for animal protein ingredient. Results of preliminary tests suggest it is possible to continue freshly prepared machine-separated fish flesh with ground beef ("hamburger") in such recipes. Currently, we are determining the frozen storage life of this minced fish flesh by combining it with ground beef in these recipes.

CONCLUSIONS

On the basis of preliminary evidence, it appears that meat/bone separators and ancillary machines could be employed profitably by U.S. seafood industry. Further exploratory work is suggested to determine storage characteristics of the ground flesh ingredient ("surimi") and to develop food applications for it.

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