

MUSSELS: A POTENTIAL SOURCE OF HIGH-QUALITY PROTEIN

T. Joyner and John Spinelli

The success of mussel culture in several parts of the world suggests that further mechanization of cultivation practices--and their extension to appropriate growing areas not now utilized--could make a substantial contribution to increasing the supply of inexpensive, high-quality protein.

Mussels can be readily processed into dried concentrates, rich in protein, with desirable flavor, odor, and nutritional characteristics.

The exponentially growing deficit in the world supply of protein has been widely publicized. Among the proposals for reducing this deficit, the one for converting unutilized marine organisms into a dry, protein-rich, powdered concentrate has attracted much attention. The Bureau of Commercial Fisheries has undertaken extensive technological research into the development of a system for the conversion of fish into FPC (fish protein concentrate) of good quality with a promising market potential.

A viable protein-concentrate industry will require the use of a number of different species as sources of raw material. FPC of high quality has been produced from hake, as well as from oily species such as menhaden, herring, and anchovy. The need for high-quality marine protein for both human and animal use dictates a continuing search for suitable raw materials.

In any assessment of other marine sources of protein, mussels appear very promising. Their wide distribution, fecundity, rate of growth and growth density already have been adapted to highly successful culture systems in many parts of the world. The bulk of the world's commercial mussel harvest is sold fresh, in the shell. Development of markets for significant additional production will require close attention to development of suitable preservation and storage techniques--as well as to the stimulation of new markets for preserved and processed mussel products. If a dried concentrate, rich in protein,

could be produced from mussels at low cost, it might generate market interest as a nutritional ingredient.

To explore the feasibility of using mussels as a source of dry, protein concentrate, we prepared samples from Puget Sound bay mussels (*Mytilus edulis*).

Preparation of Protein Concentrate From Mussels

Meats were removed from the shell, ground in a food chopper, and steamed for 5 minutes at a pressure of 5 lbs. After being steamed, the meats were extracted twice with hot isopropanol (80° C.) at a ratio of 2 parts solvent to 1 part meat. The extracted meats were then dried in a vacuum at 80° C. for 6 hours. The dried product was milled and screened to separate the protein from the byssal threads (holdfasts) that had remained with the meats.

A 13.5-percent yield (based on the weight of wet meats; 6.75% based on total weight of the mussels) of light-tan-colored concentrate was obtained by this process. Various opinions were expressed by a panel of tasters. Clam-like flavor, lobster-like flavor, hydrolyzed protein flavor and odor, and seaweed color were some of the descriptive terms used by the panelists. Subsequent work has shown that these qualities can be controlled by varying the extraction process. For example, washing the protein with acid in the presence of sodium hexametaphosphate prior

Mr. Joyner is Oceanographer, BCF Biological Laboratory
 Mr. Spinelli is Research Chemist, BCF Technological Laboratory

Seattle, Wash.

U.S. DEPARTMENT OF THE INTERIOR
 Fish and Wildlife Service
 Sep. No. 847

to extraction with isopropanol produced a product with only slight odor and flavor. Other work has shown that the protein can be extracted more easily by grinding the mussels whole. The resulting slurry is steamed, dried, and then crude milled. The protein can then be separated readily from the shell by air classification.

Nutritional Evaluation and Chemical Analysis

To evaluate the nutritional and chemical characteristics of mussel protein concentrate (MPC), samples produced by isopropanol extraction of steamed mussel meats were analyzed for proximate composition, minerals, and protein efficiency ratio (PER). Table 1 shows the results of these analyses.

Test or Component	Test Value or Concentration
PER	3.6 ^{1/}
Protein	70.0 percent
Ash	12.0 percent
Lipid	0.2 percent
Carbohydrate (glycogen)	15.0 percent
Fluoride	< 5 p.p.m.

^{1/}Casein equal to 3.0.

MPC is readily dispersible in water--a characteristic probably related to its high content of glycogen.

Requirements for Production of MPC

From the standpoint of a potential processor of protein concentrate, the primary considerations--other than costs--underlying the desirability of a raw material are:

1. reliability of supply
2. ease of processing
3. quality (as reflected in the final product).

The first of these is strongly suggested for mussels by their successful commercial culture in Spain, Holland, France, Denmark, Italy, and Germany; and by recent successful experiments with off-bottom culture in Scotland, the Philippines, Venezuela, and Chile (Table 2). In a preliminary way, the last two characteristics have been demonstrated for the MPC sample prepared by BCF's Seattle Technological Laboratory.

	Development of Growing and Harvesting Systems ^{1/}	Weight in 1,000's of Short Tons (Live) ^{2/}		
		e	f	g
Chile	b, c	17.4-32.7		
Denmark . .	a	12.4-21.1	51.5	21.1
France . . .	a	28.6-41.2		33.0
Germany (Fed. Rep.)	a	5.3-12.6		12.6
Italy	a	13.3-23.0		13.3
Netherlands	a	93.9-127.4		101.6
Philippines	a, c		2.2	
Spain	a	40.4-72.9	165	154
U.K.	a, c	3.2-5.3		4.1
U.S.	d	1.0-2.8		

^{1/} a Harvest predominantly cultured mussels
b mussel harvest principally from natural beds
c mussel culture conducted experimentally
d mussel culture absent.

^{2/} e FAO yearbook of Fishery Statistics (1967). 1961-67 statistics
f Ryther and Bardach (1968)
g Andreu, B. (1968)

When the practices of mussel culture in other parts of the world are considered as possible models for systems to produce the bulk needed for economic production of protein concentrate, the example of Spain is most encouraging. In two decades, from an historically insignificant status, the development of suspended culture has transformed the Spanish mussel fishery into the world's largest. In the deep Galician bays, rafts produce on the average 55 short tons of mussels per year (Andreu, 1968). The average size of a raft is reported by Ryther and Bardach (1968) to be 20 x 20 meters (4,300 square feet approximately 0.1 acre).

The total production in 1968 of six Galician rias (Fig. 1) was estimated at 154,000 short tons (Andreu, 1968). These drowned valleys occur within a 100-mile stretch of coastline facing the Atlantic. One of them, the Ria de Arosa, is a bay 20 miles in length and 89 square miles in area. There are 1,800 rafts covering but a small fraction of the total area. Estimated production for 1968 was 90,000 tons of mussels. Based on 6.5% yield of protein concentrate from whole mussel, this would be more than sufficient for a plant with an annual output of 5,000 tons of protein concentrate--enough to provide 12 grams per person, daily, for 1 million people.

Potential for Mussel Growing in U.S.

Whether culture systems in United States waters can be developed to approach the level of mussel production in Spain's Galician bays is not yet known. Fishery agencies in Scotland, Chile, and Venezuela have undertaken to adapt Spanish techniques to their waters.

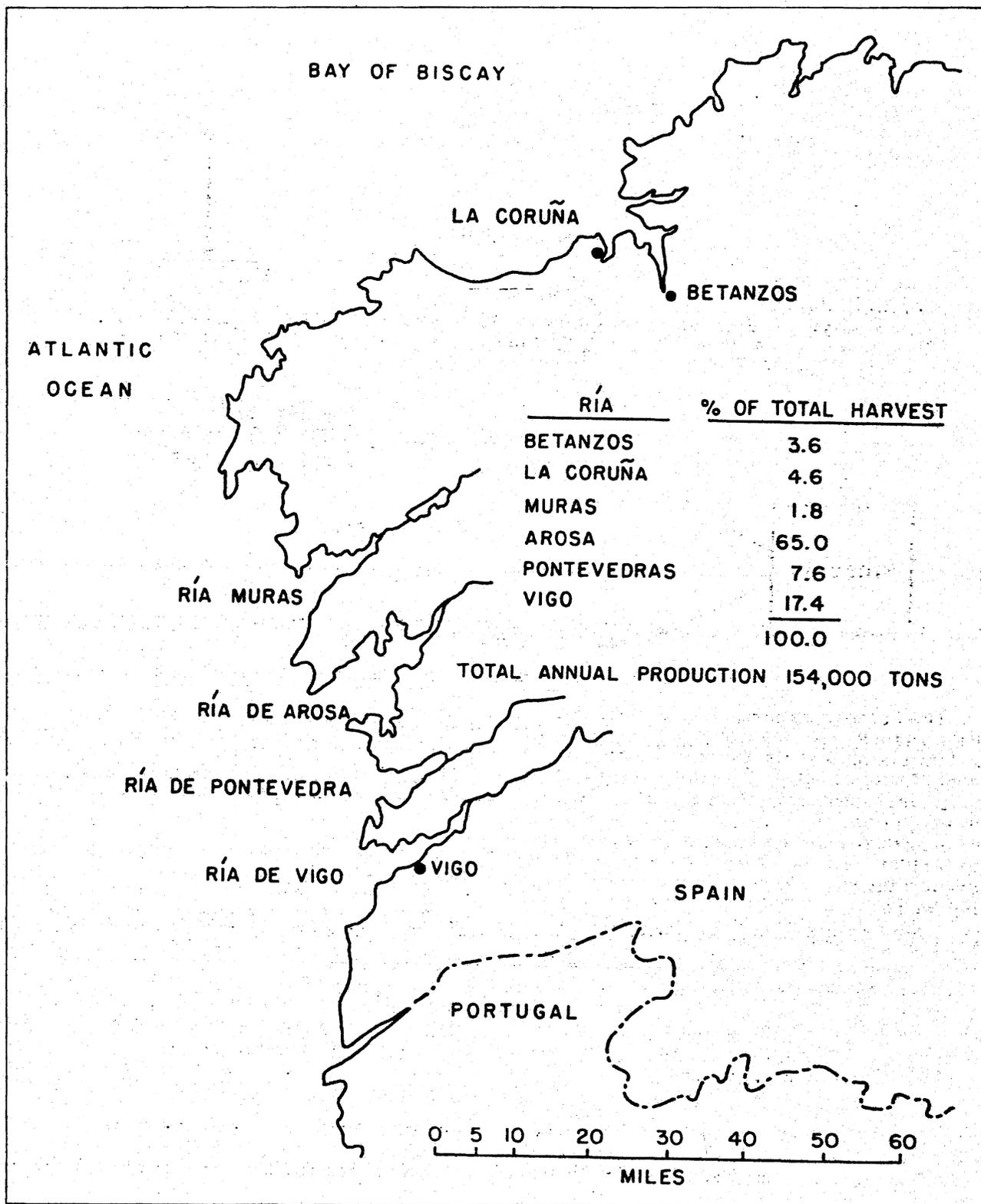


Fig. 1 - Mussel growing areas in Spain.

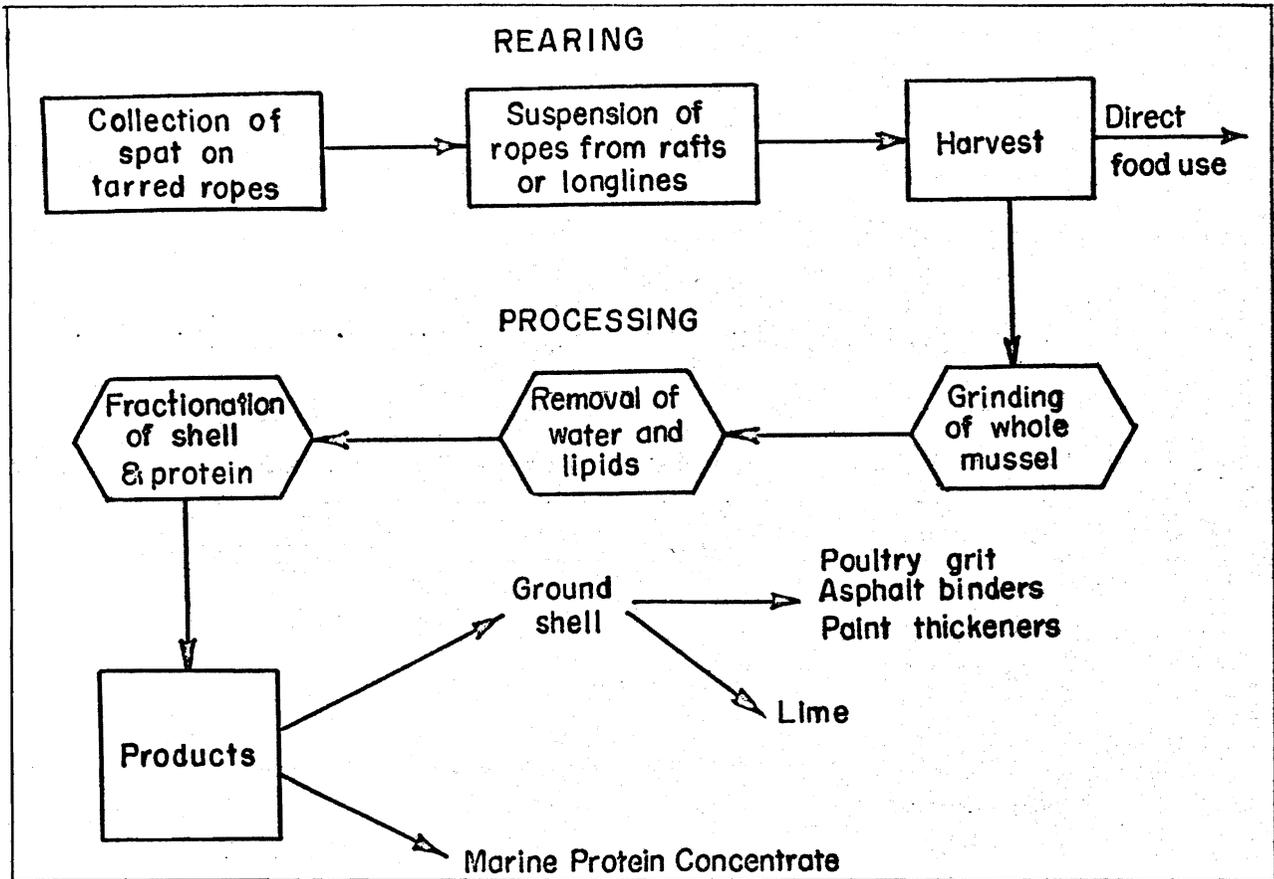


Fig. 2 - Mussel culture and processing into direct food use and protein concentrate production.

The Scottish experiments have been most encouraging. Mason (1969) reports that scientists of the Marine Laboratory, Aberdeen, have successfully grown mussels on rafts in Linne Mhuirich, an arm of Loch Sween, on the West Coast. Although the rate of growth is a little slower than in Spain, due to colder winter temperatures, it is far greater than any recorded for naturally growing mussels in Great Britain; it compares favorably with those recorded anywhere in Europe outside of Spain. The rope-grown mussels in Linne Mhuirich reached marketable size from seed in 14 months. As a consequence, a pilot commercial operation has been started in Linne Mhuirich, and several other loch sites on the West Coast have been proposed.

Table 3 compares the annual ranges of water temperature in areas in Spain, Scotland, France, and the Philippines, where off-bottom mussel culture is practiced, with those along the Pacific Coast of North America that might be considered for development.

Table 3 - Annual Ranges of Surface-Water Temperatures in Areas of Existing and Potential Mussel Culture	
Bay Mussel (<i>Mytilus edulis</i>)	
Area	Temp. °C.
Brittany (France) ^{1/}	5-20
Linne Mhuirich, Scotland ^{1/}	2.5-20
Bay of Vigo (Spain) ^{1/}	9-21
Puget Sound (U.S.) ^{2/}	5-20
San Francisco Bay (U.S.) ^{2/}	7-20
San Diego Bay (U.S.) ^{2/}	14-20
Green Mussel (<i>Mytilus smaragdinus</i>)	
Manila Bay (Philippines) ^{1/}	25-30
Gulf of Calif. (Mexico) ^{2/}	21-30
Gulf of Nicoya, Gulf of Dulce (Costa Rica) ^{2/}	28-29
^{1/} Existing commercial production of cultivated mussels.	
^{2/} Potential area for mussel culture.	

The annual temperature ranges of U.S. Pacific Coast bays are similar to those of Western European bays where mussels are successfully cultivated; those of the Gulf of California and the Costa Rican gulfs are quite similar to that of Manila Bay, where the green mussel is being cultivated.

Paralytic Shellfish Poisoning

A potential source of trouble for mussel culture lies in the occasional appearance of a paralytic poison in mussels and other shellfish. Outbreaks occur in the coastal waters of western North America, particularly in the more northerly latitudes. They are caused by sporadic blooms of certain dinoflagellates ingested by shellfish. Fortunately, in areas in which mussels might be intensively cultivated, the presence of paralytic poisoning can be readily detected by regular monitoring. Harvesting would be curtailed during an outbreak until the monitoring program indicated that the level of poison in the mussel flesh had diminished to an established level of safety. The rate at which mussels release the poison after the source has disappeared varies with factors such as age, size, and condition of the mussels--and temperature, clarity, and rate of flow of the water. It is easy to see that monitoring would be simplified by the uniformity of age, size, and condition of cultured mussels. This would reduce the ranges of poison levels and time necessary to get rid of the poison.

Conclusions

The technology for mass production at low cost of protein concentrate suitable for human use is now being developed. Technologically and economically sound methods are available even now, and current research should yield further advances. A limitation to accurate economic assessment arises from lack of certainty about the supply of raw material and its probable cost to prospective processors. A thorough assessment of all promising sources of raw material is obviously needed.

Mussels should be given high priority in any such investigation. This is strongly suggested by the high quality of the test sample of MPC produced in Seattle; the apparent environmental similarities of potential growing areas in North America with areas of high production of cultivated mussels in Europe and the Far East; and the relative ease with which harvesting of cultured mussels could be controlled to avoid danger from paralytic shellfish poisoning.

LITERATURE CITED

ANDREU, B.

1968. The Importance and Possibilities of Mussel Culture. Working paper S. Seminar on Possibilities and Problems of Fisheries Development in Southeast Asia. German Foundation for Developing Countries. Berlin (Tegel). Sept.

FAO yearbook of Fishery Statistics. 1967.

MASON, JAMES

1969. Mussel raft trails succeed in Scot' land. World Fishing, April.

RYTHER, J. H. and J. E. BARDACH.

1968. The Status and Potential of Aquaculture. Part II. Invertebrate and Algae Culture. Am. Inst. Biol. Sci., Washington, D. C.



