MUSSELS: A POTENTIAL SOURCE OF HIGH-QUALITY PROTEIN

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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 ırld supply of protein has been widely pub- lized. Among the proposals for reducing is deficit, the one for converting unutilized arine organisms into a dry, protein-rich, wdered concentrate has attracted much tention. The Bureau of Commercial Fish- ies has undertaken extensive technological search into the development of a system for e conversion of fish into FPC (fish protein ncentrate) of good quality with a promising arket potential.

A viable protein-concentrate industry will quire the use of a number of different spe- es as sources of raw material. FPC of high ality has been produced from hake, as well from oily species such as menhaden, her- ng, and anchovy. The need for high-quality arine protein for both human and animal e dictates a continuing search for suitable w materials.

In any assessment of other marine sources protein, mussels appear very promising. eir wide distribution, fecundity, rate of owth and growth density already have been apted to highly successful culture systems many parts of the world. The bulk of the rld's commercial mussel harvest is sold sh, in the shell. Development of markets r significant additional production will re- ire close attention to development of suit- le preservation and storage techniques-- well as to the stimulation of new markets r preserved and processed mussel prod- s. 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

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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.

Table 1 - Nutritional Evaluation and Chemical Composition of Mussel Protein Concentrate

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.

Table 2 - Annual Mussel Production

	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.

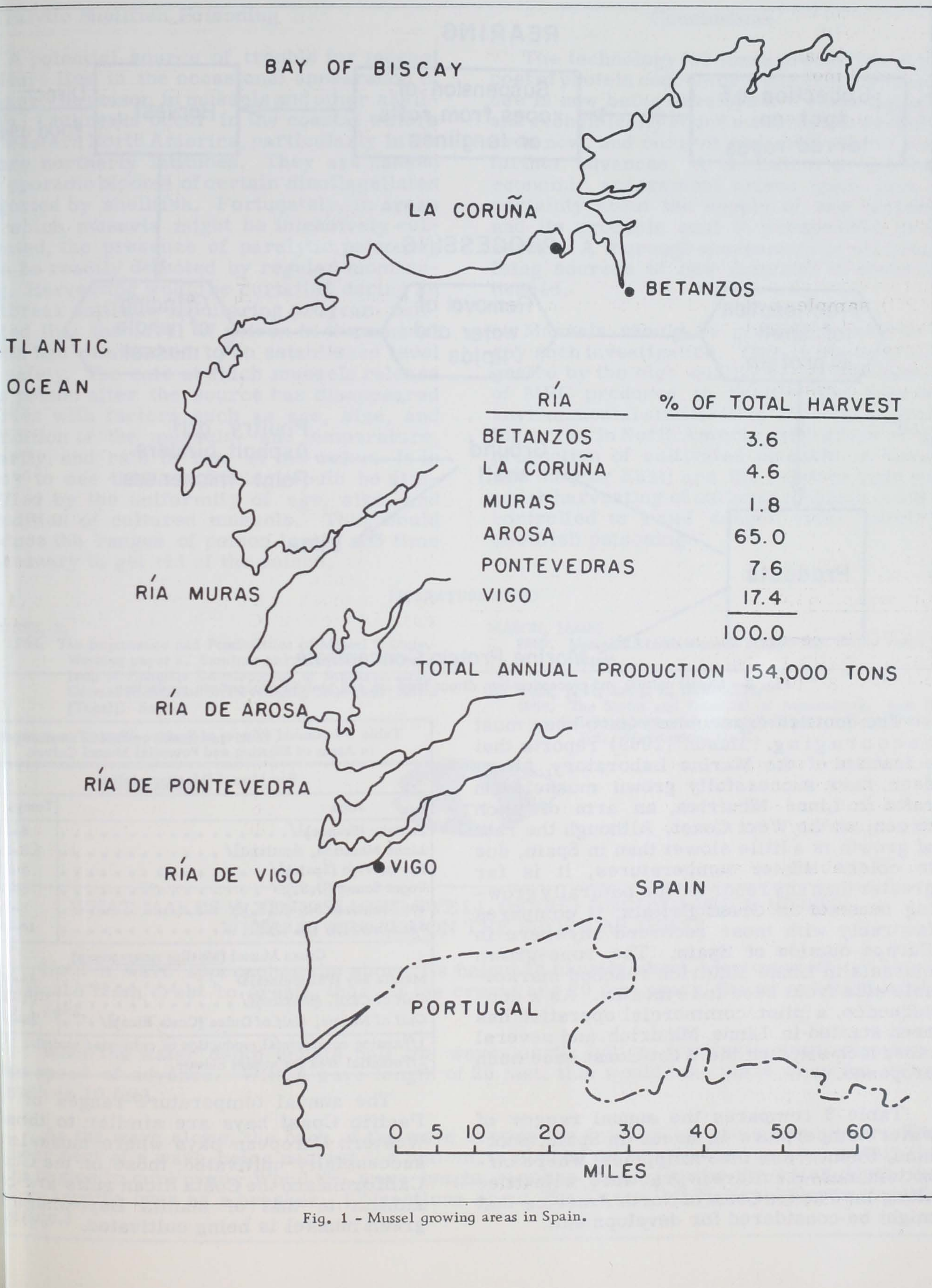
2/ e FAO yearbook of Fishery Statistics (1967). 1961-67 statistics
f Ryther and Bardach (1968)
g Andreu, B. (1968)

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 rías (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 Riá de Arosa, is a bay 20 miles in length and 8 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



RÍA	% OF TOTAL HARVEST
BETANZOS	3.6
LA CORUÑA	4.6
MURAS	1.8
AROSA	65.0
PONTEVEDRAS	7.6
VIGO	17.4
	100.0

TOTAL ANNUAL PRODUCTION 154,000 TONS

Fig. 1 - Mussel growing areas in Spain.

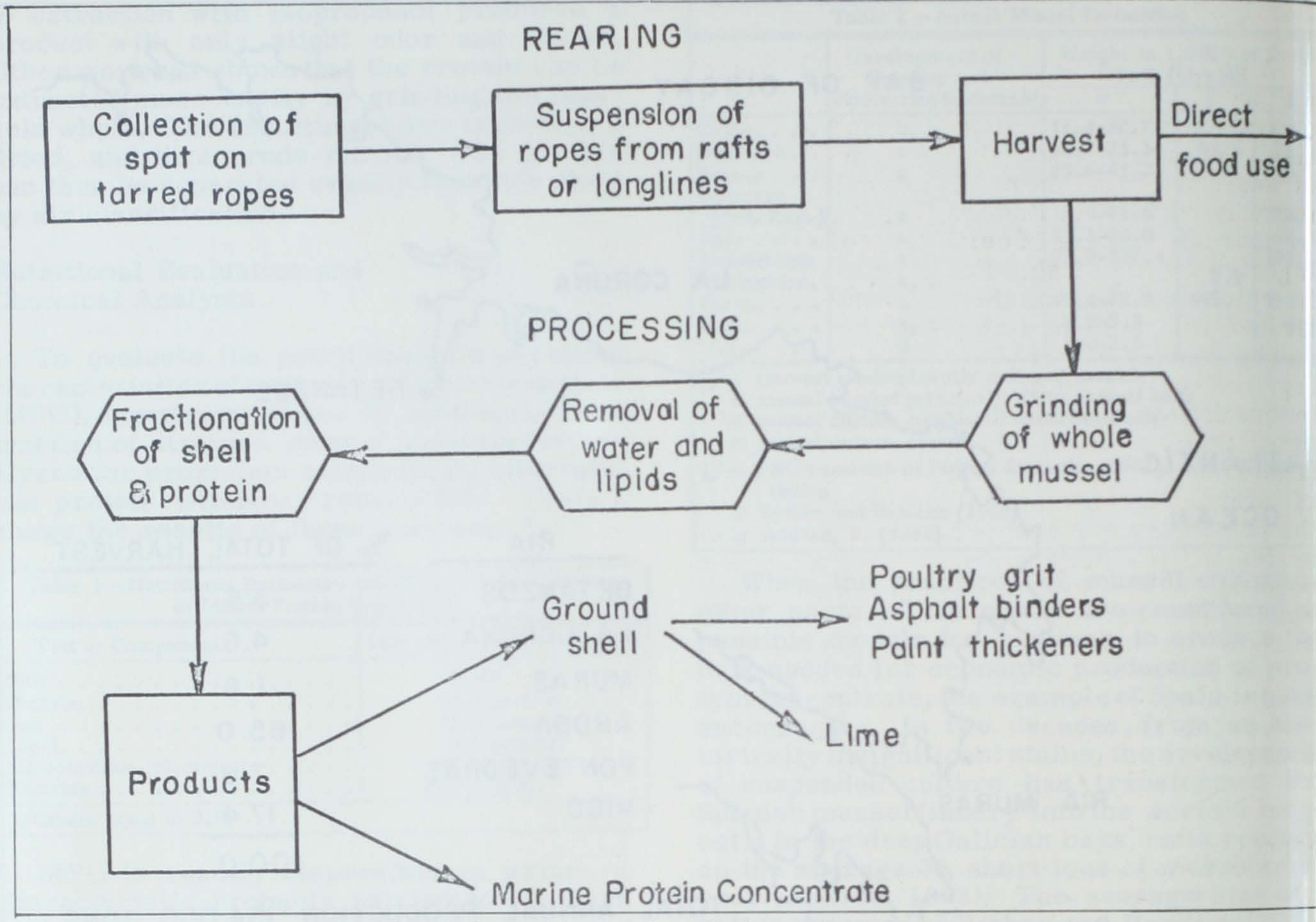


Fig. 2 - Mussel culture and processing into direct food use and protein concentrate production.

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

Area	Temp. °C
Bay Mussel (*Mytilus edulis*)	
Brittany (France)1/	5-20
Linne Mhuirich, Scotland1/	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 (*Mytilus smaragdinus*)	
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. Pacific Coast bays are similar to those Western European bays where mussels a[re] successfully cultivated; those of the Gulf [of] California and the Costa Rican gulfs are qu[ite] similar to that of Manila Bay, where t[he] green mussel is being cultivated.

aralytic Shellfish Poisoning

A potential source of trouble for mussel lture lies in the occasional appearance of aralytic poison in mussels and other shell-sh. Outbreaks occur in the coastal waters western North America, particularly in the ore northerly latitudes. They are caused sporadic blooms of certain dinoflagellates gested by shellfish. Fortunately, in areas which mussels might be intensively cul-ated, the presence of paralytic poisoning n be readily detected by regular monitor-g. Harvesting would be curtailed during an tbreak until the monitoring program indi-ted that the level of poison in the mussel esh had diminished to an established level safety. The rate at which mussels release e poison after the source has disappeared ries with factors such as age, size, and ndition of the mussels--and temperature, arity, and rate of flow of the water. It is sy to see that monitoring would be sim-ified by the uniformity of age, size, and ndition of cultured mussels. This would duce the ranges of poison levels and time cessary 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.

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WHAT MAKES A VERY SLIGHT SWELL (WAVE) BECOME MUCH HIGHER WHEN IT BREAKS ON THE SHORE AS SURF?

Until a wave approaches the shore, its height is usually about one-twentieth its length distance from crest to crest); thus, if the crests are 20 feet apart, the wave height would e 1 foot.

When the water depth equals half the wave length, bottom friction begins to slow down ne speed of advance. With a wave length of 20 feet, this would take place when the water epth is 10 feet.

As the wave slows, the back of the wave crowds the front, piling the water higher. The ower part of a wave, being nearest the bottom, is slowed more than the top; as a result, the op begins to curl over. When the wave height reaches three-fourths the water depth, the ave topples over as a breaker. ("Questions About The Ocean," U.S. Naval Oceanographic Office.)