United States Department of the Interior
Fish and Wildlife Service

Fishery Leaflet 118

Chicago 54, Ill. * April 1945

AGAR, AGAROIDS, AND THE AMERICAN AGAR INDUSTRY

By Horace H. Selby, American Agar & Chemical Company, San Diego, Calif.

Agar is a colloid obtainable from marine algae which possesses such an unique combination of physical properties that many important uses have developed for it. Bacteriological agar uses are so vital that, in February 1942, the War Production Board issued an order limiting the use of agar to bacteriology alone and freezing all agar stocks. The order remained in force until August 1944.

The term agar should be used in the generic, rather than in a specific, sense, for agars appear to differ markedly in chemical composition. They apparently have but one constitutional factor in common--they all have as a foundation a linkage of carbohydrate fractions. The commonly, but not exclusively, encountered carbohydrate is probably B-galacto-pyranose. Most agars appear to contain combined calcium. In many of them, sulfur is present as sulfate or thio-sulfonate, variable amounts being organically bound. However, analysis of several gums of algal origin which show all the agaroid physical properties yields negative or insignificant amounts of calcium and sulfur. In a few cases, the pyranose configuration cannot be demonstrated.

Since agar uses are based upon the behavior of the material, it seems logical to define agar in terms of its physical properties. Such a definition might well read as follows:

"Agar is a gum derived from marine Rhodophyceae. When boiled with sixty-five times its weight of water for ten minutes with constant stirring and adjusted to one and one-half percent by weight with water, it forms a clear, colorless liquid which congeals at 32° to 39° C. to form a firm, resilient gel, the melting point of which is higher than 85° C."

The properties which make agar superior to other colloids are:

High gelling power.
High gel hardness.
High sol clarity.
Low gelation temperature.
High hysteresis.
High moisture absorption.
Low sol viscosity.
Low syneresis.
Low insoluble matter.

Probably ninety-five percent of the agar manufactured in the United States is extracted from algae of the genus Gelidia. Other genera, as Pterocladia, Gracilaria, Endocladia, Gigartina, and Ahnfeldtia contain agar or agaroid gums but commercial use of them is not general. Most California production is from Gelidium cartilagineum. The Gracilariae yield a large percentage of the Atlantic coast output, much of which is not agar, as defined above.

Gelidium agar differs from Gracilaria gum in some respects. The properties of the colloids obtained from commercially plentiful species of either genus are sufficiently similar to justify a comparison based on averaged data. However, significant differences in physical properties on both sides of the average values given below are to be found in isolated instances. These are the result of climatic, geographic, seasonal, specific, and processing factors.

Physical and Chemical Properties

	American Agar & Chemical Co. Gelidium No. 1 Flake Agar	Commercial Gracilaria (Gum) (3 sources)
Gelling power (threshold value)	0.14 percent	0.28 percent.
Gel hardness 1.5 percent	High	Medium to low.
Clarity, 1.5 percent	300 mm.	70 mm.
Gelation temperature 0.5 percent, pH 7.3	32.5° C.	40° C.
Gelation temperature 1.5 percent, pH 7.3	36° C	45° C.
Gelation temperature 5.0 percent, pH 7.3	42.5° C.	55° C.
Insoluble matter	0.08 percent	2.75 percent.
Moisture absorption 37° C., pH 7.3	20 X	9 X.
Hysteresis differential 1.5 percent	58° C.	44° C.
Syneresis, 1.5 percent 37° C.	None	3 percent.
Viscosity 1.5-5 percent	Low	High.

The above comparison indicates that Gelidium agar is superior to Gracilaria gum for use in microbiology, dentistry, pharmacy, medicine, photography, food manufacture, and industry with the exception of those uses which favor a high gelation temperature. Such uses might be found in continuous-flow processes and in meat and fish canning if prompt transportation after heating were essential. However, when Gelidium agar was not available for industrial uses, Gracilaria extract was pressed into service in the manufacture of storage battery separators and cosmetics and as an emulsifier in colloidal graphite, die-lubricants.

Although agariferous algae were probably used as food in China prior to the Christian era, commercial manufacture is historically recent. It is said to have begun in the vicinity of Tientsin, China, circa 1700 A.D. The Japanese seem to have initiated their operations near Osaka some sixty years later.

The first California production occurred at Glendale in 1920 under Japanese management. The business was later conducted by Americans, but competition from the industry in Japan soon made the venture unprofitable and it was abandoned.

In 1924, the American Agar Company was formed in San Diego. It operated irregularly, producing as much as 9,000 pounds per month until 1934, at which time Japanese agar was available at prices as low as forty cents per pound. This competition was too severe and manufacture ceased. One member of the organization, S. H. Corfield, was undeterred by circumstances, however, and immediately established his United States Agar Company in National City, where agar production was continuous until 1942. The excellence of his product

enabled him to sell his output of 3,700 pounds per month with ease. Meanwhile (1933-1936), the Golden State Agar Company and the California Agar Company had entered and left the field, having contributed at their peak a total of 3,700 pounds monthly.

In 1942, the current war with Japan having stopped agar importation, the need for more agar was so urgent that the National City equipment was transferred to the original American Agar Company site and augmented. Here, as the American Agar and Chemical Company production has been increased to 15,000 pounds per month. The present national stock-pile of agar accumulated by Defense Supplies Corporation for the war needs of the Allies has absorbed a large percentage of this output.

From 1941 to 1943, at least four other and smaller California producers of agar entered the field: the Pacific Agar Company at Whittier, the Agar Products Company at South Pasadena, the Pacific Chemical & Agar Products Company in Los Angeles, and another at Orange. No figures on production are available and three of these plants have allegedly suspended operations.

On the Atlantic seaboard, since 1942, there has been much experimental and semi-commercial agar and agaroid production. The American Chlorophyll Company of Alexandria, Va., and the Krim-Ko Company at Scituate, Mass., have been mentioned as commercial producers.

Production of agar is insufficient to meet current demand despite adequate potential capacity. Inability to obtain raw material is to blame. Paradoxically, there is and has always been an ample quantity of Gelidium off the Pacific coast of North America and the localities in which the genus abounds have been well-known to fishermen and divers for years. This is at variance with press releases mentioning "lost, secret agar beds." Such stories were probably pure press-agentry. The Gelidium shortage is due to harvesting difficulties--lack of hulls, engines, diving gear, and manpower.

The future of agar manufacture in the United States will be influenced by many unpredictable factors. The superior quality of the American material will continue to hold a portion of the market regardless of any reasonable price differential. The cost of manufacture is high at present, largely due to inefficient utilization of manpower energy and raw material. By taking full advantage of advances in technique developed by industrial and governmental research, large cost reductions can be achieved. Industrial research has made considerable headway and governmental research by V. J. Senn of the Fish and Wildlife Service shows prospect of greatly decreasing the cost of extraction operations. Post-war manufacture may possibly occur at much less than the present figure, but only through good management and the use of modern technology in every phase of the business from diving for the raw material to the merchandising of by-products.

REFERENCES

ROBERTSON, G. ROSS. (University of California, Los Angeles.)

The agar industry in California. Industrial and Engineering Chemistry, vol. 22, No. 10, p. 1074, Oct. 1930. (A limited number of reprints designated as FI. 322 may be obtained from the Fish and Wildlife Service, Department of the Interior, Chicago 54, Ill.)

SCHEFFER, VICTOR B.

The commercial importance of seaweed gums in the United States. Fishery Market News, vol. 5, No. 6, p. 1. June 1944. (Reprints are obtainable as Sep. 23 from the Fish and Wildlife Service, Department of the Interior, Washington 25, D. C.)

SMITH, GILBERT M. (Professor, Stanford University.)

The marine algae of California. Science, vol. 101, No. 2617, p. 188, Feb. 23, 1945.

STOLOFF, LEONARD S.

The agar situation, Fishery Market News, vol. 5, No. 11, p. 1, Nov. 1943. (Reprints are obtainable as Sep. No. 44 from Fish and Wildlife Service, Department of the Interior, Washington 25, D.C.

TSENG, C. K.

Utilization of seaweeds. The Scientific Monthly, vol. LIX, No. 1, p. 37, July 1944.

TSENG, C. K. (Scripp Institution of Oceanography, La Jolla, Calif.)

America's agar industry; a series of articles in Food Industries, vol. 17, No. 1, p. 80, Jan. 1945, and in succeeding monthly issues.

United States Department of the Interior, J. A. Krug, Secretary
Fish and Wildlife Service, Albert M. Day, Director

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Washington 25, D. C. Reissued June 1948

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REFERENCES

ADAMS, CLAUDE M.

1946. The Japanese agar-agar industry. Report No. 42, Fisheries Division, Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, Tokyo. (Reprints are obtainable as F.L. 263 from the Fish and Wildlife Service, Department of the Interior, Washington 25, D. C.

ROBERTSON, G. ROSS. (University of California, Los Angeles.)

1930. The agar industry in California. INDUSTRIAL AND ENGINEERING CHEMISTRY vol. 22, no. 10, p. 1074.

SCHEFFER, VICTOR B.

1944. The commercial importance of seaweed gums in the United States. FISHERY MARKET NEWS, vol. 5, no. 6, p. 1. (Reprints are obtainable as F.L. 156 from the Fish and Wildlife Service, Department of the Interior, Washington 25, D. C.)

SENN, VINCENT J.

1946. Agar-weed, a fishery resource. COMMERCIAL FISHERIES REVIEW, vol. 8, no. 8, pp. 1-4, August 1946. (Reprints are obtainable as Sep. 144 from the Fish and Wildlife Service, Department of the Interior, Washington 25, D. C.)

SMITH, GILBERT M. (Professor, Stanford University)

1945. The marine algae of California. SCIENCE, vol. 101, no. 2617, p. 188, Feb. 23, 1945.

STOLOFF, LEONARD S.

1943. The agar situation, FISHERY MARKET NEWS, vol. 5, no. 11, p. 1. (Reprints are obtainable as F.L. 173 from the Fish and Wildlife Service, Department of the Interior, Washington 25, D. C.)

1947. A partial bibliography relating to agar. F.L. 261, Fish and Wildlife Service, Department of the Interior, Washington 25, D. C.

TSENG, C. K.

1944. Utilization of seaweeds. THE SCIENTIFIC MONTHLY, vol. LIX, no. 1, p. 37, July 1944.

1945. America's agar industry. A series of articles in FOOD INDUSTRIES, vol. 17, no. 1, p. 80, Jan. 1945, and in succeeding monthly issues.

Issued: April 1945

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