MFR PAPER 1037

*Scientists study menhaden fish solubles and fish oils as nutrient supplements in mushroom culture.*

# Mushroom Culture: A New Potential for Fishery Products

JOHN H. GREEN

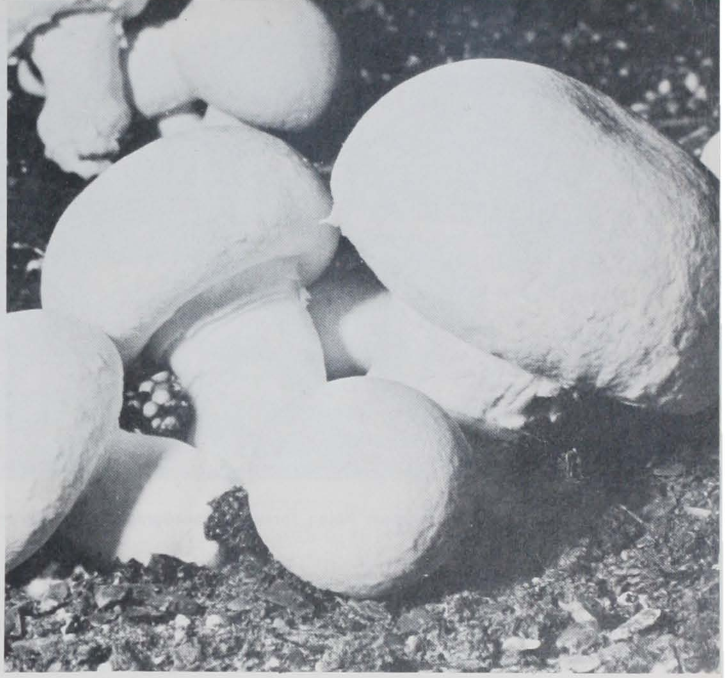

Figure 1.—Mushrooms growing on compost. (Photograph, courtesy of Pennsylvania State University.)


## ABSTRACT

*This paper describes research sponsored by the National Marine Fisheries Service, NOAA, and being done at the Mushroom Research Center, Pennsylvania State University, to explore menhaden* (Brevoortia tyrannus) *fish solubles and fish oils as nutrient supplements in mushroom culture. Fish solubles were successfully substituted for other organic nitrogen supplements commonly used in mushroom composting and subsequent mushroom culture. These experiments, performed in 1971-1972, indicated that in certain situations larger mushrooms were produced when combinations of fish solubles and other organic nitrogen supplements were used. Currently under investigation in 1973-1974 is the use of fish oils, substituted for polyunsaturated vegetable oils, to stimulate increased yields of mushrooms. A brief description of mushroom cultivation is given with emphasis on nitrogen supplementation of composts and polyunsaturated oil stimulation for increased mushroom yields.*

*These investigations of menhaden fish solubles and fish oil could open up new markets for these products. At the same time, they could offer the mushroom grower new and inexpensive sources of nitrogen supplements or nutrient stimulants. Both industries could benefit from these applications of fishery products or by-products. An economic prospectus is given of this potential market with estimations of the maximum volumes.*


## INTRODUCTION

Mushrooms (basidiomycetes) are fungi which man has used for food over countless centuries. Through interests in single cell protein production, we became aware of the possibility that fishery products and by-products might be utilized in mushroom culture. The centers of mushroom culture in the United States are located primarily in the northern Mid-Atlantic States, mainly in southeastern Pennsylvania. There is a smaller but expanding industry concentrated in the West Coast States and the Great Lakes Region, mainly in Michigan and Ohio. Several other states, including the coastal states of Massachusetts, Virginia, Georgia, and Florida, produce mushrooms on a scale smaller than the above-mentioned areas. The mushroom industry in the United States is growing.

The College Park Fishery Products Technology Laboratory became interested in exploring the feasibility of using fishery products and by-products in mushroom culture. Helpful information and guidance on the requirements of mushroom culture were initially received from Drs. James P. San Antonio and Claude Fordyce, Jr., of the U.S. Department of Agriculture Mushroom Research Group, Beltsville, Md. (Dr. Fordyce is now with the L. F. Lambert Spawn Company, Coatesville, Pa.). A contract was made later with Dr. Lee C. Schisler of the Mushroom Research Center at the Pennsylvania State University, and his expertise was put to work to explore the feasibility of using fish solubles as an organic nitrogen supplement in making compost for mushroom culture and fish oil as a stimulant for increased mushroom yield. The initial results of these experiments look promising and although further experimentation will have to be done, there are promises of new potential

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Figure 2.—Large pile of compost being formed. (Photograph, courtesy of Butler County Mushroom Farms, Inc.)

uses for fish oils, fish solubles, and perhaps other fishery byproducts or condensed waste effluents as nutrient supplements in mushroom culture (Green et al., 1973; Schisler and Patton, 1973).

## COMPOSTING AND NITROGEN SUPPLEMENTS

Mushrooms are grown commercially on the traditional horse manure compost. In more recent decades a "synthetic" mushroom compost has been developed consisting of corn cobs and hay. Horse manure compost is still being used by the majority of the mushroom growers and "synthetic" compost is used by about 40 percent of this industry. There is now a growing interest by many concerns to grow mushrooms on composted waste such as city garbage, agricultural waste, and residue from various industrial processes. Disposal of waste by composting followed by mushroom culture could help solve some of the solid waste disposal problems. Although the technique is largely experimental now, the future may see more of this in actual production. No matter which type of compost is used, the ingredients of gypsum for texture and one or more types of organic nitrogen sources are mixed in at the initiation of composting.

Figure 3.—Experimental pile of compost, containing fishery byproducts, at Pennsylvania State University.

In order to assure the good composting which is necessary for good mushroom production, the grower must raise the initial nitrogen content of the compost from approximately 0.8-1.2 percent to 1.5-1.7 percent on a dry weight basis. To do this, he adds one or more organic nitrogen sources, such as dried chicken manure (2-6 percent N), dried brewers grains (4 percent N), cottonseed meal (7.0 percent N), cocoa bean hulls (3 percent N), and other materials containing organic nitrogen. Chicken manure varies in its nitrogen content and presents problems to the mushroom grower in terms of consistency, proper mixing, and occasional excess ammonia formation during composting. Excess ammonia inhibits mushroom growth. Inorganic nitrogen or small organic molecules, such as urea, are usually less expensive but they often leach out of the compost pile during watering operations. In addition, inorganic nitrogen does not give results as good as those of organic nitrogen, hence the desire for organic nitrogen substances by the mushroom grower. Their supplies of desired nitrogen supplements are becoming more expensive as the demand for these materials increases for this and other uses. There are companies that supply mushroom growers with a mixture of dried, fortified organic nitrogen substances of guaranteed nitrogen consistency. We became interested in the possibility that fish solubles, which is quite consistent in nitrogen, 5 percent, might be used for this purpose. A contract was made with Dr. Schisler to explore the use of menhaden fish solubles as a nitrogen supplement in mushroom composting.

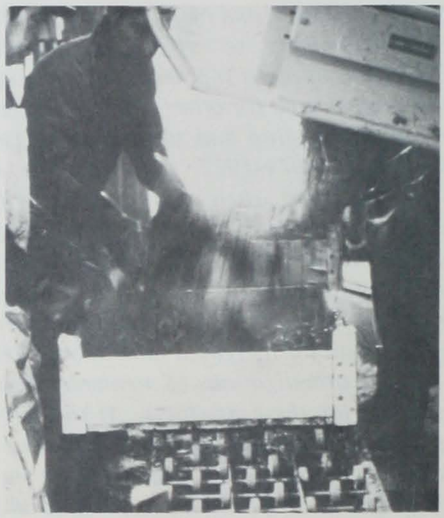


Figure 4.—Filling trays with experimental compost containing polyunsaturated oils at Pennsylvania State University.

The nitrogen supplement does not directly supply nutrients to the mushroom. Nitrogen and other supplements are important in supporting the microbial growth of the compost process which must go on prior to planting with mushroom spawn. The composting is carried on by a variety of microorganisms, including thermophilic bacteria, actinomycetes, and fungi. To further encourage this compost

Figure 5.—Typical mushroom growing houses on a Pennsylvania farm. (Photograph, courtesy of U.S. Department of Agriculture.)

Figure 6.—Professional supervision and maintenance of mushroom spawn cultures which are used to inoculate new beds or trays of compost. (Photograph, courtesy of Butler County Mushroom Farms, Inc.)

microbial growth, the huge piles of compost ingredients are periodically watered and aerated by turning to achieve good aerobic growth. Temperatures of the compost reach as high as 165-175°F. When the peaks of rapid microbial growth and temperature are reached, which ends Phase I of composting, the hot, raw compost is placed in beds or trays inside mushroom houses which are then steamed to continue Phase II of composting at a lower temperature (120-135°F) to finally condition compost. The heat generated during Phase II and supplemental steam are utilized to pasteurize the mushroom house by killing off insects, nematodes, and competing fungi.

The entire composting operation takes from 2 to 3 weeks. Good aerobic growth of these composting microorganisms yields a biologically stable compost of mushrooms, which are really slow growing fungi. Poor composting produces poor or no yields of mushrooms. Therefore, the compost ingredients and procedures are very important in order to get good yields of mushrooms.

When composting is completed, the trays or beds of compost are planted with a pure culture of mushroom spawn. The newly spawned compost is allowed to develop mycelium growth and then it is covered with a thin layer, usually topsoil or peat called casing. This casing layer is necessary in order for the mycelium growth to produce fruiting bodies (mushrooms). Sometimes nutrients are added to the mushroom cultures at the time of casing. This is referred to in the trade as SACing (Supplementation At Casing). In the future, some of the fishery products and byproducts might find uses in SACing. Experimentation would be needed to show this application.

In the United States the only mushroom species grown of commercial importance is *Agaricus bisporus;* however, there are many different strains which are grown for various purposes. In the Eastern and Midwestern States, fresh mushrooms sold in markets are usually white strains. The faster and more abundant growing cream or brown strains are grown for canning because either white, cream, or brown essentially are the same color in the final canned product. In the West Coast States, only the cream

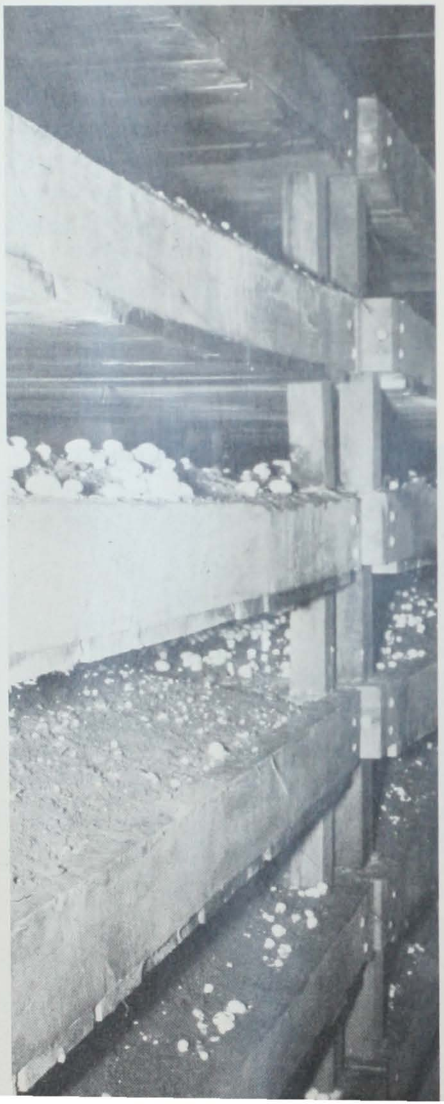
Figure 7.—Mushroom spawn (mycelium grown on sterilized, sprouted cereal grains) being spread on compost. (Photograph, courtesy of U.S. Department of Agriculture.)

or brown strains are grown and used for either the fresh market trade or canned products.

Some general references to mushroom culture are the following: Lambert (1967), Butler County Mushroom Farms Inc. (1969), Snetsinger (1970), and Kinrus (1971). Fish solubles have been described by Soares et al. (1970, 1973).

Figure 8.—Thin layer of casing (top soil or peat) being placed over tray of spawned compost to enhance the production of fruiting bodies (mushrooms). (Photograph, courtesy of Butler County Mushroom Farms, Inc.)

Figure 9.—Stacked trays of growing mushrooms inside mushroom house. (Photograph, courtesy of U.S. Department of Agriculture.)



## THE EXPERIMENT

Dr. Schisler and his assistant Mr. Thomas Patton conducted an experiment using Atlantic menhaden fish solubles as a nitrogen supplement in compost. The fish solubles were substituted for either one or the other or both of the two organic nitrogen supplements routinely used on a 50:50 nitrogen basis at the University's experimental mushroom research facility. These two nitrogen supplements were: brewers grains which is known to be among the best of nitrogen supplements, but is becoming expensive for the grower; and a commercially available fortified nitrogen supplement called Acto 88[1] (Mushroom Supply Company, Toughkenamon, Pennsylvania) which has a guaranteed nitrogen content of 8.8 percent and is used by many growers in the Eastern States. Four experimental composts, including one control, were placed into 2-ft × 2-ft trays and spawned with two strains of mushrooms—a white and a cream strain. Throughout the harvest period, the experimental trays were picked daily and the weight and number of mushrooms for each tray were recorded. At the end of harvest the total yields and the average weights as determined by yields divided by number of mushrooms were made for each experimental condition and subjected to statistical comparison.

[1] Reference to trade name does not imply endorsement by the National Marine Fisheries Service, NOAA.

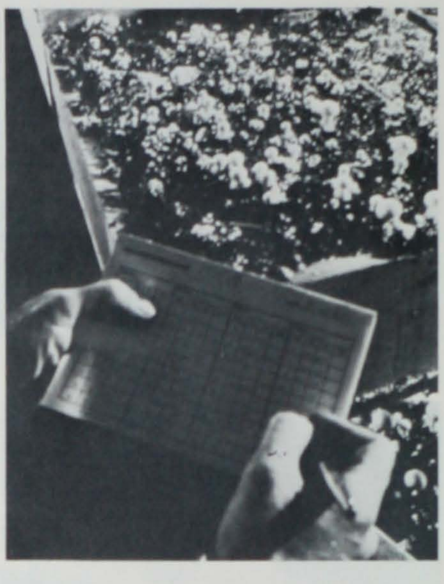


Figure 10.—Experimental trays of mushrooms being checked for yields. (Photograph, courtesy of Butler County Mushroom Farms, Inc.)

The results of Dr. Schisler's experiment with fish solubles are shown in Tables 1 and 2. It is observed in Table 1 that in most situations when fish solubles replace brewers grains (Composts Nos. 2 and 4), the yields are significantly less. However, fish solubles can replace Acto 88 (Compost No. 3) and give equal results. An interesting observation is made in Table 2 that when fish solubles are in combination with brewers grains (Compost No. 3), the mushrooms were significantly

Figure 11.—Picking mushrooms, trimming butts (waste), and sorting into baskets. (Photograph, courtesy of Butler County Mushroom Farms, Inc.)

**Figure 12.—Mushrooms cultured on compost (upper right), freshly picked and trimmed (center) and trim waste (lower left). (Photograph, courtesy of Pennsylvania State University.)**

larger; also in the white strain (Compost No. 2) even though the total yield was less in the latter. Dr. Schisler and Mr. Patton are preparing a report of these results.

Larger sized mushrooms would be of economic importance to the mushroom grower. The larger sized mushroom would bring a better price in the market and they would also represent less picking time for the same harvest yield. Hand picking is one of the remaining costly operations for mushroom growers. Many other operations involved in mushroom growing have been mechanized, but the present system found on many mushroom farms of fixed mushroom beds stacked inside houses can only be picked by hand. Hence, there is interest in nutrients which will stimulate larger sized mushrooms.

**Table 1.—Relative yields of mushrooms grown on horse manure-straw-gypsum mixture compost containing fish solubles as nitrogen supplement and compared to control.**

| Nitrogen supplement[1] | White strain[2] | Cream strain[3] |
|---|---|---|
| 1. Brewers grain Acto 88 | Control | Control |
| 2. Fish solubles Acto 88 | Less[4] | Less[4] |
| 3. Brewers grain Fish solubles | Equal | Equal |
| 4. Fish solubles | Equal | Less[4] |

[1] Nitrogen supplements were added so that each supplement contributed 50 percent of the N. The total N in all composts is the same.
[2] White strains are used for fresh market mushrooms in the Eastern states.
[3] Cream strains usually grow faster, yields are greater, and they are used for commercial canning.
[4] Very significant differences ($P<0.01$).

**Table 2.—Relative size of mushrooms grown on horse manure-straw-gypsum mixture compost containing fish solubles as nitrogen supplement and compared to control.**

| Nitrogen supplement[1] | White strain[2] | Cream strain[3] |
|---|---|---|
| 1. Brewers grain Acto 88 | Control | Control |
| 2. Fish solubles Acto 88 | Larger[4] | Equal |
| 3. Brewers grain Fish solubles | Larger[4] | Larger[4] |
| 4. Fish solubles | Equal | Equal |

[1] Nitrogen supplements were added so that each supplement contributed 50 percent of the N. The total N in all composts is the same.
[2] White strains are used for fresh market mushrooms in the Eastern states.
[3] Cream strains usually grow faster, yields are greater, and they are used for commercial canning.
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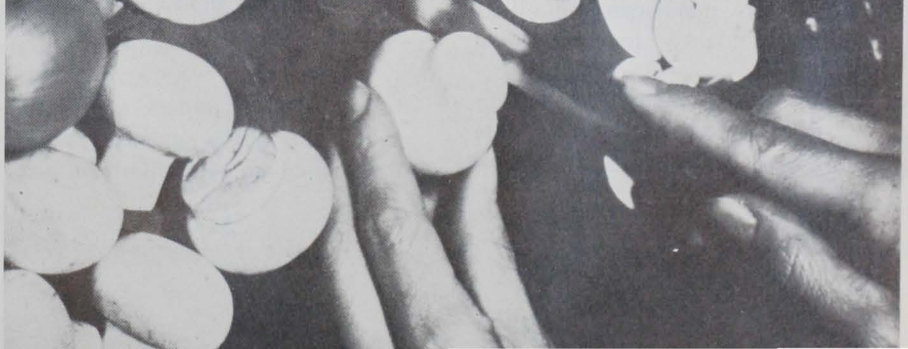
## IN TERMS OF FISH SOLUBLES, OTHER BYPRODUCTS

The amount of nitrogen supplement used per ton of compost would vary depending upon the initial concentrations of nitrogen in the horse manure, corn cobs, hay, etc. A range of about 6.7-13.2 pounds (dry weight) of nitrogen per ton is required to formulate the desired mushroom compost. This would be the equivalent of 135 to 270 pounds of fish solubles at 5 percent N. An estimated 1,200,000 tons of compost were produced in 1973, based on USDA Mushroom Report (1973) citing about 102 million square feet of mushroom production area for that year (each 1,000 sq ft of mushroom growing area would require about 11-12 tons of compost). This would have required the equivalent of about 80,00 to 160,000 tons of fish solubles for 1973. Assuming the maximum of 160,000 tons at a price of \$50/ton (general market price prior to 1973), this would represent a \$8 million market. Bearing in mind that certain nitrogen supplements, like brewers grains, are desired or

**Figure 13.—Fresh mushrooms ready for slicing and putting into tasty food dishes. (Courtesy, Butler County Mushroom Farms, Inc.)**



others, like chicken manure or cocoa husks, are readily available in certain areas, also that the amount of nitrogen used depends upon the initial nitrogen content of the horse manure, etc; this maximum potential for fish solubles could never be realized. However, even 25-50 percent of this estimate would represent a good new market for fish solubles.

More investigations should be done in the use of fish solubles in mushroom composting to achieve the following: to confirm the present results; to explore seasonal or regional variations; to try fish solubles as supplements to "synthetic" compost; and to explore different handling techniques. There is also need to explore other nitrogenous fishery byproducts or condensed waste effluents as nutrient supplements to mushroom culture. An important consideration for this potential fishery byproduct utilization is that byproducts with high fish oil residues would probably be advantageous for mushroom culture.

## POTENTIAL FOR FISH OILS

A few years ago, Dr. Schisler began experiments with vegetable oils as nutrients to mushroom growth. He discovered that polyunsaturated vegetable oils, such as cottonseed and soybean added before Phase II of composting stimulated increased yields of mushrooms by 15-20 percent (Schisler and Patton, 1970). After Dr. Schisler's investigations of about 3 years ago, mushroom growers began using vegetable oils. Now about 12 percent of the mushrooms grown are produced on composts supplemented with vegetable oils to increase their yields. It is expected that nearly all of the growers will eventually be using oils for this purpose. Since fish oils are more polyunsaturated than most vegetable oils, experiments were begun to explore menhaden fish oil as a possible stimulant to increase mushroom yields.

The estimation for the consumption of polyunsaturated oils as stimulants for increased mushroom production would be a maximum of 11,700 tons of oil (2.8 million gallons) per year based on 1973 mushroom production figures (USDA 1973). This is based on the recommendation of 110 gallons of oil per 4,000 sq ft of mushroom growing area, or approximately 45 tons of compost, which is the capacity of the common small growing unit ("single" mushroom house). At a market price of 12 cents per pound (an approximate 1972 price), a potential domestic market for fish oils of $2.8 million could be realized. Currently mushroom growers using oils in compost are purchasing crude cottonseed or soybean oil at about 30-32 cents per pound (summer, 1973). Mushroom production capacity has been increasing in the United States on the average of 6-8 percent in the past few years; therefore, it is a growing market. There is also a potential foreign market in Europe and Asia where large amounts of mushrooms are grown. Thus, the use of fish oils in mushroom culture could represent an economic advantage to the fisheries and to the mushroom grower as a supply of inexpensive polyunsaturated oil that would increase his mushroom yield.

## CONCLUSION

Both fish solubles and fish oils could represent economic advantages to both the fisheries as new markets and to the mushroom growers as inexpensive nutrient supplements that would increase their yields and that might increase mushroom size. Other fishery byproducts and solid/sludge wastes might also serve as nutrient supplements in mushroom culture. Such utilization would help in pollution abatement by finding outlets for fishery byproducts. It would also make new sources of nitrogen supplements available to the mushroom grower in his continual search for materials available and suitable for mushroom composting.

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