TECHNOLOGY AND THE WORLD FOOD PROBLEM: CHALLENGES WITH INDIGENOUS FERMENTED FOODS

E. H. MARTH

Department of Food Science and The Food Research Institute
University of Wisconsin
Madison, Wisconsin 53706

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ABSTRACT

Microorganisms can contribute to the world’s food supply if used to modify presently unacceptable raw materials so they become palatable; to convert wastes or other inedible materials to edible proteins, fats, and carbohydrates; and to preserve foods for later consumption. Challenges in the use of microorganisms for these purposes include: use of available native raw materials, selection of microorganisms, further processing of fermented foods or of microbial proteins, potential public health hazards, acceptance of new foods by undernourished persons, and cost of production and distribution as related to the ability of potential consumers to purchase the needed nutrients.

Through the ages, man has utilized microorganisms to manufacture many foods such as cheeses, cultured milks, bread, alcoholic beverages, vinegar, cocoa, and other products (1). Although the role of microorganisms in food fermentations was not recognized until late in the nineteenth century, processes for production of these foods were developed empirically. Discovery of microorganisms and of methods to cultivate them has led man to a greater, although still incomplete, understanding of fermentation processes which yield certain desired food products.

Use of microorganisms to assist in meeting present and future demands on the world’s food supply has been suggested by numerous research workers and others who have been concerned with problems of malnutrition (9). It is generally conceded that microorganisms can contribute to the world’s food “bank” in several different ways. First, they can be used to modify flavor, texture, and appearance of presently unacceptable materials so that such products can be included in the food supply. Second, microorganisms might find application in converting waste materials and other inedible substrates into edible proteins, fats, and carbohydrates. Finally, certain microbial processes could help to preserve for later consumption some highly perishable foods which are produced seasonally.

Successful and widespread application of fermentation processes to aid in meeting present and impending world-wide food shortages offers a number of challenges, some of which will be explored in the following discussion. Specifically, the challenges which will be considered are: (a) availability of native materials, (b) selection of microorganisms, (c) further processing of fermented foods or microbial proteins, (d) potential public health problems, (e) acceptance of fermented foods or products derived from fermentations by persons most in need of dietary supplements, and (f) cost of production and ability of potential consumers to purchase foods derived from fermentations.

AVAILABILITY OF NATIVE MATERIALS

Many of us who are concerned with food fermentations are too parochial in our approach to the problem. We have spent too much time dealing with fermentations which use rather conventional substrates such as milk or grains and hence we attempt to use these processes in areas where they may be unsuitable because entirely different raw materials are available.

Before the fermentologist can make significant contributions to feeding the world’s undernourished populations, he must become familiar with the materials available which can serve as substrates for fermentations in a given region suffering from a depressed food supply. He must be familiar with native crops which are high in carbohydrate content and hence might be candidates for nutritive upgrading through fermentation. He also must give consideration to waste materials which contain nutrients that presently are unavailable to the area’s population. Can some of these wastes be upgraded into edible products through fermentation? If not, can some of the wastes serve as substrates for the production of microorganisms which can be harvested and converted into edible products? Can crops able to furnish substrates for fermentations but presently not indigenous to a food-deficient area be introduced and successfully cultivated? What about indigenous plants presently considered as weeds? Can they be cultivated and can fermentable substrates be recovered from their leaves, stems, roots, or seeds?

It is apparent from the preceding questions that...
to maximize his impact the expert in food fermentation must deal with a variety of problems outside of his field. Cooperation between agronomists, horticulturists, soil scientists, and experts in fermentation is necessary if maximum use is to be made of materials indigenous to a particular area where the population suffers from a lack of adequate and proper nutrients.

Selection of Microorganisms

The choice of a microorganism for use in a food fermentation is governed by ability of the microorganism to: (a) utilize the available substrate and (b) efficiently produce the desired change in or yield from a given substrate. Depending on conditions, the microorganism might be selected from among the molds, yeasts, or bacteria, since all types are employed either singly or in combination in certain food fermentations.

Unfortunately, selection of a microorganism to do a particular fermentation job is not as simple as might be suggested by the previous comments. Consideration must be given to the following before a decision is made.

(a) Frequently a desired change can be accomplished by more than one species in a given genus or by species in several genera. Comparisons must then be made to determine which particular species will do the desired job best under the set of environmental conditions which exist.

(b) A variety of strains of a given species may exist; some may be more suitable than others for use in a given fermentation. Again, comparative studies must be conducted to determine the most desirable strain for use under a given set of conditions.

(c) Microorganisms are biological entities which are subject to variation (2). Since this tendency does not appear to be uniform, it may be possible to select "stable" strains and thus be reasonably assured of dependable performance by the microorganism. Consideration also must be given to the possibility of genetic manipulation to develop strains of microorganisms which produce a desired end product, are efficient, or can utilize a particular substrate.

(d) Certain bacteria are subject to infections by bacteriophages. When this happens, a given culture invariably loses its ability to function and the fermentation is not completed (12). Selection of bacteriophage-resistant species or strains, if possible, or creation of environmental conditions which minimize this hazard must be considered if this problem becomes apparent (12, 16).

(e) Modification of the substrate may permit use of different microorganisms. It is possible that adjusting the pH, changing the degree of aeration, adding nutrients, or varying the heat treatment given may make the medium suitable for growth of a variety of microorganisms (11). Consequently, treatment of the substrate will, in part, govern the choice of the microorganism to carry out a given fermentation.

Although other factors may be of concern in certain fermentations, those which have been cited suffice to demonstrate the challenges associated with selection of the proper organism to do a given job.

Further Processing of Fermented Foods or Microbial Proteins

When food fermentations are discussed, we are generally concerned with two approaches. In the first, a microorganism is introduced into a substrate principally to bring about a desired change. Acid production in cultured dairy products is an example of this approach. The second procedure is that of introducing a microorganism into a substrate, allowing it to grow, harvesting the organism, and using it as a source of nutrients. Products obtained from the use of either procedure may benefit from further processing. It is conceivable that a more palatable product with desired characteristics may be obtained if the fermented material is subjected to heating, drying, freezing, concentration, a second fermentation, or another process. Both the initial substrate and changes brought about by the microorganisms will govern whether or not further processing is possible and the kind of technology which may prove useful.

Further processing is of greater significance when one is concerned with finding food applications for proteins produced by algae, molds, yeasts, or bacteria. For purposes of this discussion, we will consider that suitable methods exist for harvesting microorganisms from their substrate, usually a liquid, and this is not to be thought of as further processing.

We are told that dried preparations of algae such as Chlorella vulgaris and Scenedesmus obliquus contain approximately 40% crude protein (1). In contrast to this, yeasts such as Candida utilis and Saccharomyces cerevisiae, when dried, contain approximately 50 to 60% protein (1, 4, 8). The protein content of bacteria, on the basis of dry weight, will often be higher, ranging from 63% for Bacillus subtilis to 87% for Lactobacillus fermentans (1). Dried preparations of molds generally contain less protein, ranging from 18% for Aspergillus flavus to 38% for Penicillium notatum (1). In addition to information on the total protein content of these microbial preparations, we have some information on amino acid composition, particularly for dried yeasts, and on biological value, again mainly for proteins derived from yeast. Our
knowledge about the technology of handling these proteins is woefully inadequate. At this point suggested uses for these materials are generally limited to supplementing other foods at relatively low concentrations.

In contrast to this, a substantial body of knowledge has and is continuing to accumulate on milk, meat, and certain plant proteins. This information makes possible the processing of these proteins into foods which differ from the raw material in odor, flavor, texture, and appearance. Similarly, an understanding of the nature of microbial proteins is needed before they can be satisfactorily processed into foods which are palatable as well as nutritious—a condition which must precede the widespread use of these nutrients in the diet.

PUBLIC HEALTH PROBLEMS

Food products of microbial origin or made with the aid of microorganisms must not only be nutritious but also must be safe for consumption. The possibility of public health problems appears to be associated with (a) composition of the substrate used for the fermentation, (b) composition of the organisms being harvested, and (c) contamination with known toxigenic microorganisms which can proliferate and elaborate toxins during the fermentation process.

As was pointed out earlier in this discussion, if fermentation processes are to contribute markedly to the supply of available nutrients, then use of substrates indigenous to a deficient area but not now being employed as foods must be considered. Use of such media needs to be evaluated in the light of whether or not they contain substances which may be toxic to the consumer.

The presence of poisonous substances in certain plants is well recognized. Examples include: (a) the goitrogens such as the thiocyanates, derivatives of 2-thiooxazolidone, 3-indolylacetonitrile, and polysulfides of the Brassicae (cabbage and related plants) (14), (b) the estrogens genistein, genistin, and daidzein of soybeans (13), (c) alkaloids in a large variety of plants (10), (d) the carcinogenic substances associated with cucucds (palm-like trees and their nuts) (10), (e) lathyrins derived from certain peas and other plants in the genus Lathyrus (4), and (f) many others too numerous to cite in this discussion.

Organisms which are grown to supply nutrients also must be free of hazardous substances. It is necessary to demonstrate that potentially harmful compounds present in the medium at low levels are not concentrated by the microorganisms. This is of particular importance when sewage or other waste materials serve as the substrate.

It also is necessary that the microorganisms grown on a satisfactory substrate do not contain cellular components which are hazardous to health. Some investigators believe that the consumer of yeasts might experience harmful effects attributable to the high content of cellular purines (1). It has been suggested that the intake of an excessive amount of purines may cause a corresponding increase in the concentration of uric acid in the blood. By calculation it can be determined that 15 to 20 g of dried yeast would provide sufficient purines to give the maximum safe concentration of uric acid in blood. Some experts are not willing to accept this value since an increase in purine consumption does not necessarily result in a corresponding increase in blood uric acid (1). The answers to questions about the hazards of excessive purine compounds in the diet must be supplied before these suspicions will be laid to rest.

It also has been reported that yeasts grown on certain substrates produced liver necrosis when fed to rats, but the same yeasts grown on other media were entirely satisfactory for use in the diet (1). Other reports in the literature have suggested toxicity with food supplements derived from algae and from fungi such as Penicillium and Aspergillus species (1).

Finally, it is necessary that the substrate undergoing fermentation be protected from contamination by pathogenic microorganisms which can grow concurrently with the bacteria, yeasts, or molds responsible for the desired food product. It is well recognized that in certain dairy fermentations, contamination of milk with staphylococci can be hazardous since these bacteria produce an enterotoxin which, if present, can cause illness in consumers (15). This toxin is rather heat stable and once present in food can survive conditions which are detrimental to the organism responsible for its production. Staphylococci are widespread in nature, especially in and on animals and human beings. Consequently, contamination of food can easily occur unless proper precautions are exercised.

Another group of organisms, the salmonellae, are ubiquitous and their presence on many substrates is not unusual. The more than 1300 species in the genus Salmonella are all believed to be pathogenic to man and most cause gastrointestinal disturbances (7). Recent studies have shown that these bacteria can proliferate during the manufacture of certain fermented foods and that they can survive for many months in the fermented product (3).

Mycotoxins, which have not been studied intensely until the last eight or nine years, also can occur in fermented foods which are contaminated with cer-
tain molds. Molds in the genera *Aspergillus*, *Penicillium*, *Stachybotrys*, *Cladosporium*, *Fusarium*, and others have been found able to produce toxic compounds which more often than not are hepatocarcinogens (6). Molds are often used to produce certain fermented foods. It is obvious that they must be carefully selected so that toxigenic strains are not employed in the fermentation.

From the foregoing discussion, it is evident that great care must be exercised before new fermented foods are consumed. It must be established that the substrates and microorganisms employed are harmless and that toxigenic or other pathogenic microorganisms do not enter and grow in the substrate during the fermentation process.

**Acceptance of New Food Products**

It is obvious that producing and stockpiling fermented foods or microbial nutrients is useless unless they are consumed by persons who are suffering from malnutrition. Introduction and acceptance of a new food may meet great resistance when persons have a low degree of literacy and a high degree of attachment to native ancestral and cultural ways. Education and advertising programs necessary to attain acceptance may be expensive added costs of production. It may be necessary initially to develop foods which closely resemble native dishes, hence a study of dietary habits in a given area would be in order. Acceptance of the new foods by governmental and other influential leaders in a community may aid in their utilization by the rest of the population. Although this is not an exhaustive treatment of this subject, it is one which cannot be ignored when development of new fermented foods is being considered.

**Cost of Production and Ability to Purchase**

The per capita income of many persons in food-deficient areas of the world is less than $200 per year and of many others it is below $1000 per year. This fact must be realized before plans are made to supply nutrients via the route of fermentation. The question that must be asked is: "Can foods be produced economically enough to permit their purchase by these persons and at the same time provide a profitable operation?"

It is here where some of the real challenges can be found. The process must be made to operate as efficiently and economically as possible. The substrate must be cheap, the process simple, the microorganism efficient, the equipment inexpensive, and the finished product must be safe, nutritious, palatable, and inexpensive. Thought also must be given to waste disposal problems if large quantities of spent media result from fermentations used to produce microorganisms. Obviously, participation of governments in these programs may markedly alter the economic outlook.

**References**


