Food Science in Developing Countries:

A Selection of Unsolved Problems

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL
Washington, D.C. 1974

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A Selection of Unsolved Problems

Compiled by the
Advisory Committee on Technology Innovation
of the
Board on Science and Technology for International Development
Commission on International Relations

NATIONAL ACADEMY OF SCIENCES
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This publication has been prepared by the Advisory Committee on Technology Innovation of the Board on Science and Technology for International Development, Commission on International Relations, National Academy of Sciences–National Research Council, for the Office of Science and Technology, Bureau for Technical Assistance, Agency for International Development, Washington, D.C., under Contract No. CSD-2584.

NOTICE: The project from which this publication has resulted was approved by the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Board's judgment that the project is of international importance and appropriate with respect to both the purposes and resources of the National Research Council.

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Library of Congress Catalog Card Number 74-1602

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PREFACE

The Advisory Committee on Technology Innovation (ACTI) has as its mandate the identification of ways in which science and technology can be applied appropriately to specific problems of economic and social development. The committee, aware of the warm reception the scientific community in the United States gave the two volumes, *100 Problems in Environmental Health*[1] and *101 Problems in Food Science and Technology*,[2] felt that a similar approach directed to problems of immediate concern to developing countries would be useful.

The committee selected the fields of food science and nutrition for a pilot study and sent solicitations to more than 300 people, primarily in developing countries. The list of experts, drawn from a variety of sources, was used as a starting point for the preparation of this initial volume and does not include everyone who should have been consulted. Thus, the problems in this collection were selected primarily by scientists and other workers in the less developed countries as topics worthy of immediate examination, and inclusion in this publication reflects the contributors' priorities, not necessarily those of the National Academy of Sciences–National Research Council.

The object of publishing this compendium is to stimulate the interest of research workers and technologists in solving these and similar problems.

[1] Jack E. McKee, et al., eds. Work supported by grant from Public Health Service, U.S. Department of Health, Education and Welfare. Washington, D.C.: Jones Composition Co. & Kirby Lithograph Co., 1961. 185 p.

[2] C. O. Chichester, et al., eds. Work supported by grant from Public Health Service, U.S. Department of Health Service, U.S. Department of Health, Education and Welfare. n.p.: n.p., 1969. 192 p.

Furthermore, this publication is meant to convey to readers who are familiar with similar problems that there is a commonality of concern among scientists in other countries. This intention is especially directed to readers without ready access to international journals or opportunity to travel to international meetings.

After initial screening, the contributions were reviewed by the Technical Editing Committee for validity and completeness of information. Some were deleted because they already had been superseded by later developments; others were combined because of their similarity; and in several cases only one of two or more similar contributions was selected for review. For these reasons, contributors are identified in a separate list, and no individual authorship is assigned to the problems. Because of delays encountered in both domestic and overseas mail, as well as publication deadlines, some problems have been held over for the next edition.

By incorporating in subsequent volumes some reported solutions to these and similar problems, ACTI feels that it can contribute to improving scientific and technical communication within the developing world and facilitate the wider application of useful results, while discouraging needless duplication of effort. There is no intention to usurp the role of scientific or technical professional journals; the goal is to act as a useful supplement.

The committee wishes to thank all those who responded to the request for problems, to solicit contributions from those who were not contacted, and to request those who read this volume to participate in the project by suggesting problems and solutions that should be included in subsequent editions. (Contributions should be in the format described in "Note on Organization," p. x.) Scientists, technologists, and others in less developed countries who work in fields related to food science are earnestly requested to communicate to the committee chairman, or the staff officer for this project, their comments on the value of this work and their suggestions for modification or improvement. The committee's decision to proceed with subsequent editions of this volume and with similar volumes in other fields will be based on the readers' reactions to this initial effort.

George Bugliarello
Chairman
Advisory Committee on Technology Innovation

ACKNOWLEDGMENTS

The Advisory Committee on Technology Innovation wishes to express its appreciation to the members of the Technical Editing Committee for their time and effort devoted to this task. Their broad knowledge and expertise have helped to supply additional technical information and bibliographic references on many food-science problems. Particular acknowledgment must also be given Dr. Noel D. Vietmeyer of the ACTI staff for his role in the conception, initiation, and early development of this project. Finally, we wish to thank Professor Nevin S. Scrimshaw, who made an overall review of the collection and provided many valuable comments on several problems, and the staff of the Food and Nutrition Board of the Assembly of Life Sciences, National Research Council, particularly Dr. Paul E. Johnson, Executive Secretary, who provided much valuable advice.

NOTE ON ORGANIZATION

Each problem in this collection is organized under the following headings:

Problem Description
Background Information
Possible Approaches to a Solution
Special Requirements
Bibliography
Key Contact(s)

The section on special requirements is intended only as a guide in situations where the approach suggested involves specialized activity that may be new to the reader. The bibliography lists publications that the contributor and the Technical Editing Committee feel are useful sources of information on the background and status of research on the particular subject and on the useful and necessary techniques involved in the investigation suggested. Key contacts are experts who have agreed to cooperate in this project by acting as personal contacts to whom the interested reader may turn for advice and information while getting started on the research suggested in this volume or during the course of the investigation. If the investigator does not have access to a reference listed in the bibliography and cannot obtain the necessary specific information from the key contact, ACTI will try to supply the information. Requests should be addressed to:

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PART I NEW FOODS

1 AQUATIC WEEDS AS A FOOD RESOURCE

PROBLEM DESCRIPTION Aquatic weed growth is overabundant and costly in many developing countries. Clogged waterways and the attendant drainage, navigation, pollution, insect, and disease problems hinder national development. Attempts have been made to control weeds by chemical, biological, and mechanical means. Some biological and mechanical control methods present the corollary opportunity to utilize aquatic vegetation profitably as a food resource.

BACKGROUND INFORMATION The most direct way to use aquatic weeds is as a forage crop for aquatic herbivores that could serve as food for humans. Examples of such herbivores are the manatee (*Trichechus*) and *Dugong* belonging to the order Sirenia. Indeed, these mammals are so palatable to humans that they have been hunted almost to extinction. Understanding of sirenian breeding habits and feeding patterns, however, is incomplete, and breeding useful stocks in waterways with much motorboat traffic or other human activities is not likely to succeed even with strict conservation efforts.

If sirenians are a possible source of aquatic "beef," the white amur, a strictly herbivorous fish with a voracious appetite for aquatic vegetation, is potential aquatic "poultry." Its drawbacks are failure to spawn in tropical waters, the presence of intramuscular bones in the flesh, and a digestive system that only partially assimilates the vegetation it eats.

Mechanical removal of aquatic weeds from infested waterways leads to the collection of a large mass of vegetation consisting of up to 97 percent water and a correspondingly low proportion of useful nutrients. Subsequent dewatering, transportation, and dehydration operations are expensive. Nevertheless, aquatic weeds, particularly waterhyacinth and *Hydrilla*, may

have some value as components in cattle rations and in the development of ingenious systems for processing terrestrial leaves in which dehydrated plant matter is air-classified into a low-fiber fraction suitable for poultry and nonruminants and a fibrous residue suitable as a feed for ruminants.

Direct use of aquatic plants for human consumption in the form of a leaf-protein concentrate is now technically feasible but uneconomic because of low nitrogen concentration, poor protein extractability, and excessive off-color and off-flavor substances in the leaves. Some newer techniques being developed to recover protein from food-industry wastes (whey, slaughter, and fish wastes), such as reverse osmosis and ultrafiltration or production of single-cell protein from wastes as substrates, may in time be economically practical for recovering aquatic plant protein.

POSSIBLE APPROACHES TO A SOLUTION Approaches to a solution are likely to involve three large areas of research:

1. Extensive evaluation of all aspects of the life cycles of sirenians and the white amur is needed, as well as quantitative studies of their appetite for aquatic weeds. Sirenians must be protected by strict, enforceable conservation measures.
2. Continual screening may reveal other appropriate herbivorous, aquatic species, including some for which genetic upgrading is feasible.
3. Where removal of aquatic weeds is necessary, efficient harvesting, dewatering, transportation, and dehydration systems are badly needed, and the systems could be labor intensive. Increased research emphasis on reduction and recovery of useful ingredients from processing wastes will become increasingly relevant and applicable to aquatic-weed utilization.

SPECIAL REQUIREMENTS Although biological control schemes utilizing sirenians or the white amur have been evaluated for several years and much useful information has been accumulated, the investigations seem scattered and not extensively reported in the principal scientific literature. Many advances in waste handling and processing involve pollution problems that have much in common with those of aquatic weeds; investigators in different parts of the world may be unaware of this commonality and the needs and opportunities for common research. Thus, interdisciplinary research and improved communications are urgently needed to turn this aquatic weed curse into a useful crop.

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(See also Problem 3.)

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2 USE OF CAKE FROM TRADITIONAL OIL-EXTRACTION PROCESSES

PROBLEM DESCRIPTION Water extraction is a traditional method of vegetable-oil production in some countries, such as Ghana. By this process, unfortunately, only about 30 percent of the oil present in the oilseed can be extracted. The high oil content of the remaining presscake and the conditions under which the cake is manufactured make this residue unsuitable for use as animal feed and difficult to process further for human food. The problem is finding out how to remedy this waste.

BACKGROUND INFORMATION In many parts of the world oilseed proteins play a major role in improving nutrition. Because small, traditional

processors are widely scattered, any attempt to gather presscake for further processing takes so long that both oil and protein residues deteriorate, which discourages further processing. Since the small-scale, traditional method of vegetable-oil production cannot yet be discontinued, any method that improves the efficiency of the water-extraction process will strengthen the vegetable-oil industry of countries like Ghana. If the traditional process could be modified to stabilize the residues, protein-short countries could use valuable oilseed proteins in foods.

POSSIBLE APPROACH TO A SOLUTION A possible approach is to experiment with various techniques to enhance the release of oil from the water/oil emulsion typically produced. To stabilize the protein residues, one might investigate ways to remove the water and/or to add salt or other materials to inhibit deterioration.

SPECIAL REQUIREMENTS A laboratory equipped to conduct quality-control activities in oilseed-processing plants would be required.

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3 AGRONOMY OF LEAF-PROTEIN PRODUCTION

PROBLEM DESCRIPTION Today, leaf protein is recognized as a valuable source of both foods and feedstuffs; much work, however, remains to be done on sources and uses of leaf protein. Questions to be answered before

plants are grown for leaf protein are how yields from one variety compare with yields from others, and how different systems of husbandry affect yield. The more obvious variables are seed rate, fertilizer treatment, age at harvest, and amenability to repeated harvesting. Leaf protein is likely to be of particular nutritional importance in the wet tropics where soil erosion is a constant threat. Systems using perennial crops or maintaining continuous ground cover by intercropping will therefore be more valuable than systems in which ground cover is intermittent.

BACKGROUND INFORMATION It has been established that the yield of edible protein from leaf-protein production is greater than that of any other agricultural system. The annual yield in the United Kindgom is 2 tons of dry extracted protein per hectare, and in India, 3 tons; U.K. production is expected to be increased to 3 tons and the Indian to 5. A substantial extra yield of protein comes from feeding the fibrous leaf residue to cattle, and from cultivating microorganisms on the by-product "whey." Research heretofore has concentrated on perfecting the process of extraction and on establishing the nutritional value of the protein. Much more work is needed on these subjects and on methods for incorporating leaf protein into acceptable foods. But that research will be more fruitful when more is known about the species of leaf that will probably be used in practice. Almost all research so far has been on crops for which a system of husbandry has been developed because of their use for some other purpose.

POSSIBLE APPROACHES TO A SOLUTION A possible approach would involve planting large enough plots of each experimental plant to produce about 9 harvests of 4 kilograms each (wet weight), with enough room to leave adequate strips of uncut material between the harvested strips to prevent edge-effect errors. This method is based on a plan for three replicates each at three different ages at harvest, but experience may indicate different experimental designs.

The freshly harvested material is pulped, pressed, and extracted. A sample of the extract is treated with trichloroacetic acid, and the nitrogen in the precipitate measured. Similarly, nitrogen analyses of the residues should be made to determine total nitrogen production.

SPECIAL REQUIREMENTS Aside from the botanical and agricultural skills needed to initiate the proposed investigation and interpret the results, a chemistry laboratory with analytical capabilities is required.

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(See also Problem 1.)

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4 POTATOES IN THE LOWLAND TROPICS

PROBLEM DESCRIPTION Many groups of people in the tropics have monotonous and nutritionally unsatisfactory diets. Any development that would widen dietary choice without sacrificing nutritional quality would be useful. Potatoes (*Solanum tuberosum*) are already widely, and increasingly, grown in the upland tropics; they are often so popular they are also imported from temperate zones. Experience shows that existing varieties are generally unsatisfactory in the lowland tropics, though they sometimes do well. Thus, the potato seems to be on the threshold of adaptation. The problem is essentially genetic: how to breed varieties adapted to the lowland tropics.

BACKGROUND INFORMATION The estimated yield potential of potatoes in the tropics is at least comparable to that of established tropical root crops. Potatoes (steamed in their skins) contain more protein than do many vegetables, and the quality of the protein is relatively good for vegetable protein, surpassing that of weat protein, for example. Because their protein/calorie ratio is near optimum (about 11 percent), potatoes are a valuable dietary component. Large stores of potato plants with genetic variability, at both tetraploid and diploid level, exist at various research institutes; foundation breeding stocks are thus readily available. Varieties with resistance to the troublesome late blight and bacterial wilt are also available. Maintaining healthy planting stocks would present practical problems, but the necessary technology exists. Unforeseen problems arising from other diseases, however, could become major obstacles to success. No serious attempt to breed potatoes for the lowland tropics has yet been made, though several valuable upland programs are operating in, for example, Mexico, Colombia, and Kenya.

POSSIBLE APPROACHES TO A SOLUTION The first aim should be genetic screening of widely based seedling populations (both diploid and tetraploid) for general adaptation and viability in the lowland tropics. Mass selection and a quick turnover of generations should be the rule. Only when a body of reasonably well-adapted clones has been accumulated should recourse be had to pedigree breeding. The emphasis in selection should be viability (including field resistance to diseases) and yield, with solanin alkaloids at an acceptable level; any temptation to select by arbitrary aesthetic standards of foliage type, tuber shape, color, etc., should be resisted. For operational reasons, it would be worthwhile to consider the possibility of linking any such program to a neighboring upland breeding project.

SPECIAL REQUIREMENTS The main needs will be competently run seedling and field-raising facilities and, probably, a cool store. Some guidance in plant pathology in the early stages (and perhaps rather more than guidance later) will be required. If and when the project is successful, a seed-production system should be set up, probably based on imported basic stocks locally multiplied under good control.

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5 SOY-PROTEIN-BASED MILK WITH COW OR BUFFALO MILK FLAVOR

PROBLEM DESCRIPTION Soy milks have been developed with flavors quite acceptable to people of Chinese background, and some formulas have been sweetened and adapted for use as soft drinks by non-Chinese populations. Generally, these milks are characterized by a beany flavor, however, and are unacceptable to people used to cow or buffalo milk. The problem of duplicating cow or buffalo milk flavors in soy-protein-based milk is unsolved. If such milks could be made to taste as much like cow or buffalo milk as margarine now tastes like butter, they would probably find widespread acceptance. They could thus improve nutrition in countries where enough reasonably priced cow or buffalo milk to serve as a significant source of protein in children's diets may not be available in the foreseeable future.

BACKGROUND INFORMATION Considerable progress has been made in improving the flavor of traditionally processed soybean milks by grinding soybeans with boiling water, thus inactivating the lipoxidase before it can cause the development of beany and other off-flavors in the resulting milk. Other, more sophisticated processes are used for the complete deflavoring and defatting of the soy protein base, resulting in soy milks with a low flavor profile. But these processes require the addition of an acceptable refined oil to replace the crude oil extracted from the soybean, as well as the introduction of cow or buffalo milk flavoring agents.

POSSIBLE APPROACHES TO A SOLUTION This problem should be attacked in the countries interested in developing acceptable vegetable-protein-based substitutes for cow or buffalo milk. Vegetable oils and flavoring agents used must be acceptable to the population in the specific country; also, the amounts used must be adapted to local tastes and economic

conditions. Collaborative studies with groups that have been working on these problems, such as the one at Cornell University (see Key Contacts), could help to speed the development and use of these important protein supplements.

SPECIAL REQUIREMENTS A food laboratory equipped to work on dairy product process control is required, including an array of appropriate flavor components and facilities for conducting taste tests.

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6 MILK PRESERVES FOR HOT, HUMID AREAS

PROBLEM DESCRIPTION Milk and milk products are difficult to preserve in tropical climates, so they are usually imported in the form of packaged dry skim milk, canned dry whole milk, or canned condensed or evaporated milk. These products are usually expensive and, of course, require foreign currency for their purchase. The question is, Can the problem of milk preservation be solved by producing yogurt locally?

BACKGROUND INFORMATION Foods prepared from high-extraction wheat flour or parboiled wheat (*burghul, bulghur,* or *bulgur*) and yogurt are extremely popular in the Middle East, where they are called by a variety of names—*tarhana* in Turkey; *kishk* in Syria, Jordan, and Egypt; and *kishuk* in Iraq. Their manufacture differs from place to place, but yogurt is almost always one component. The yogurt is often put in a closed filter bag for a few days to drain off liquids and then mixed with salt and incubated in a jar with soaked wheat flour or parboiled wheat for a few more days. The mixture is then dried in hot shade or sun. Instead of wheat flour or parboiled wheat, a sour dough can be used, and instead of yogurt, buttermilk. In Turkey tomato, tomato paste, red peppers, chopped onion, etc., may be added before incubation and drying. Because the final product is not hygroscopic, it can be stored in open jars for 2–3 years without deterioration. Moreover, a fairly low pH after reconstitution with water makes it an unsuitable medium for the development of pathogenic organisms.

In general, two, three, or more parts of the milk component are used for one part of cereal; the protein content varies from 15 to 30 percent; the moisture content from 10 to 14 percent.

These wheat-and-fermented-milk combinations have been shown to have a high nutritive value. Mixtures with a protein level of 8–8.5 percent had much higher PERs than have the cereals alone and lower PERs than standard casein.

The higher the yogurt content, the higher the total protein content and the percentage of milk protein in the dry product and, therefore, the greater the nutritive value (unless the product is seriously damaged during drying). But increasing the amount of yogurt also increases the cost of the final product, an important practical consideration.

Special attention has been given to a wheat flour *kishk* in which tomato juice was incorporated to make a product with a much improved flavor and a higher riboflavin and provitamin-A content, but still with a negligible ascorbic acid content. Other foods and juices should also be tried as additives to improve the acceptability and nutritive value of *kishk*. So far, only a few combinations with yogurt and wheat flour have been studied, but many more are possible.

POSSIBLE APPROACHES TO A SOLUTION Yogurt and cereal flours (wheat, corn, millet) should be combined in different portions and the nutritive value of the resulting products investigated.

Separating the surplus liquid after a few days might be advantageous; the liquid should contain most of the lactose, and removing it before evaporation might help to avoid the consequences of lactose intolerance (see problem 29). Adding other sources of vitamins and protein to make a more complete food should be tried. Shelf life, economic aspects, and acceptability should be investigated.

SPECIAL REQUIREMENTS Standard nutritional/biochemical laboratory facilities, including an animal room, would be needed. Amino-acid analysis equipment would be advantageous but not essential.

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7 INTRODUCING QUALITIES OF EWE'S MILK CHEESE INTO PASTEURIZED COW'S MILK CHEESE

PROBLEM DESCRIPTION The number of dairy cows is increasing in Southeast Asia while that of sheep and goats is stationary or declining. White brined or ripened cheese and yogurt, made by nomads from raw sheep's milk and raw goat's milk, are important food staples in this area.

Increased demands for these foods and the potential public health danger of tuberculosis, undulant fever, and typhoid fever brought about by the consumption of raw milk products present serious challenges. One possible solution is the diversion, as cow herds increase, of pasteurized cow's milk from municipal dairies to cheese manufacture, but the absence of the typical flavor of sheep's or goat's milk cheese has prevented consumer

acceptance. A more acceptable product might be developed by isolating, preparing, and introducing lipolytic enzymes from animal or microbial sources into cow's milk to increase the level of flavor-producing short-chain fatty acids to simulate those in sheep's or goat's milk cheese. If the process is successful, pasteurized cow's milk cheese would be widely accepted, and new enzyme concentrates might become export products.

BACKGROUND INFORMATION In recent years, new enzymes for food applications have been developed—for instance, microbial enzymes to coagulate milk for cheesemaking and enzymes from the throat glands of goats to develop a piquant flavor in ripened Italian-type cheeses. Both are acceptable, conforming to the guidelines of the fifteenth meeting of the Food and Agriculture Organization (FAO)–World Health Organization (WHO) Expert Panel on Food Additives, which state that enzymes derived from natural foods or food-producing microorganisms are by themselves foods and not additives.

POSSIBLE APPROACHES TO A SOLUTION As a first line of attack, food or dairy research institutes in developing countries could screen microorganisms for lipase activity and obtain from local slaughterhouses lipase-rich tissues of slaughtered lambs or ewes. Next, procedures might be developed for recovering and freeze-drying sufficient quantities of enzymes for cheesemaking trials. Trials could then be organized, to add, with use of adequate controls, various levels of enzyme preparations to pasteurized cow's milk.

SPECIAL REQUIREMENTS A food- or dairy-technology laboratory equipped to recover and freeze-dry enzymes from clean animal tissues is required, as well as basic, simple cheesemaking equipment and a pasteurizer. Facilities for determining lipolytic activity, and a microbiological laboratory or other suitable facility for growing organisms and making crude cell preparations are also needed.

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8 RAISED BREADS WITHOUT WHEAT

PROBLEM DESCRIPTION To make raised bread, entrapped gasses must be retained by the bread during preparation, and wheat is the only flour that naturally imparts this property to bread dough. The obvious question: Can a suitable means of achieving gas retention be developed to make raised bread from other flours?

BACKGROUND INFORMATION The growing popularity of bread in developing countries increases the demand for imported wheat. Both economic and nutritional benefits might be realized if other, nonwheat staples grown in these countries could be substituted for wheat flour in bread-making. Work done under the sponsorship of FAO has resulted in the development of several composite flours in which part of the wheat flour is replaced by some other staple. Attempts to eliminate wheat flour altogether have been made by replacing wheat with additive binders such as gums and proteins that have the ability to retain gasses. These materials, however, are fairly expensive.

POSSIBLE APPROACHES TO A SOLUTION A considerable amount of information is now available on the manufacture of bread in which wheat has been totally or partly replaced by other ingredients. This information should be used as the basis for the investigation and evaluation of locally available foodstuffs as potential binders for gas retention.

SPECIAL REQUIREMENTS The binder should be inexpensive. If possible it should be produced, or capable of being produced, in the country using it. The flavor of the binder should be bland and compatible with nonwheat flours. A food technology laboratory with baking facilities is needed.

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9 FLAT BREADS WITHOUT WHEAT

PROBLEM DESCRIPTION In the Middle East, from Turkey to the borders of India and Pakistan, wheat is a staple food. Much of the wheat is baked into bread quite different from that consumed in Europe and the United States. Thin Middle Eastern bread is baked for a short time in direct contact with a hot surface. Broken into small pieces and used as a spoon to take up food, this flat bread is eaten in large amounts with each meal. Analytical data and further details of the breadmaking techniques used can be found in the first three entries in the bibliography. Other published studies describe work on vitamin and amino-acid fortification of Arabic bread. The question is, Can the consumption and nutritive value of such bread be increased by using nonwheat flours? To answer this question, researchers must investigate problems of biochemical and organoleptic changes associated with traditional methods of baking.

BACKGROUND INFORMATION Typical, widely consumed Middle Eastern breads include *marhouk* and Arabic bread. *Marhouk* is a large, round (60-cm diameter), thin (1.5-2 mm) bread, baked on only one side for 1-1.5 minutes on a shallow metal dome and usually made of high-extraction

wheat flour and some degree of yeast leavening. Arabic bread (*khubz arabi-abyad*) is round, but smaller (25-cm diameter) and thicker (5-8 mm). It is usually baked in commercial bakeries for 1-2 minutes, separating into two layers during baking, and is used for local sandwiches. This type of bread, often smaller in size, is baked and sold in the United States as Syrian or Middle Eastern bread. Although ordinary Arabic bread is widely consumed in Egypt, one variety of Egyptian bread (*khubz masri-baladi*) is darker and does not separate into layers.

In Iran, similar types of bread are consumed. They may be leavened for a short time (*bazari* and *sangak*) or unleavened (*tanok* or *lavosh*), but all are flat, thin, and baked for a short time on metal sheets or pebbles, or in commercial bakeries.

POSSIBLE APPROACHES TO A SOLUTION Investigations should be similar to those for leavened breads (problem 8): tests should be made with other flours alone and in combination with wheat and with and without various additives. The resulting breads should be tested for baking quality, taste acceptability, tearability (important when bread is used as a spoon), and nutritional value, especially as supplements to other components of the local diet.

One cannot extrapolate findings on European breads to Middle Eastern breads. Because of short fermentation and high temperature—short-time cooking—the effects of changes in composition would be unlike those in European breads. The ratio of crust to crumb is also different. Additional investigations are needed on the possibility of surface protein damage due to the high-temperature baking and on the role of high phytate intake (and the consequent effects on mineral absorption) that may occur with high consumption of unleavened bread made from high-extraction flours (see last two bibliographic entries).

SPECIAL REQUIREMENTS Dough-mixing equipment, farinographs or other instruments for testing dough quality, and baking ovens are necessary for evaluating the capacity of other flours to replace wheat in breadmaking. Taste-panel facilities and expertise should also be available to evaluate the product's acceptability. An animal house and an analytical-services laboratory are needed for nutritional and toxicological testing. Nutritional evaluation of the products is essential, both alone and in combination with other dietary components approximating the local diet.

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10 UPGRADING UNUSED OILSEED CAKES

PROBLEM DESCRIPTION Oilseeds such as rapeseed, linseed, sunflower, and palm kernel are widely cultivated for their oil, rather than protein, content. Yet, the U.S. President's Science Advisory Committee reported in 1967 that the potential protein production for humans from current oilseed production equaled the amount of protein supplied by animal sources.[3] All oilseeds contain protein of varying quality; in most, it is fair to good. But oilseed cakes have not been used for human consumption because they also contain undesirable, and sometimes toxic, factors. Those with toxic factors have not been used much even in animal nutrition. These valuable protein sources could be used for animal, or even human, consumption if toxic or other undesirable constituents could be removed.

[3]*The World Food Problem.* A Report of the President's Science Advisory Committee. Vol. 2, *Report of the Panel on the World Food Supply.* Washington, D.C.: U.S. Govt. Printing Office, 1967. p. 336.

BACKGROUND INFORMATION Of the many attempts to remove the undesirable factors from these potential food or feed materials, particular success has been achieved with cottonseed. In rapeseed, isothiocyanate and oxazolidinethione removal has been tried by steaming to vaporize and destroy these chemicals, after an initial treatment to activate enzymes that produce them from glucosinolates. Water extraction, continuous or batch, and at various temperatures, has also been tried. These methods have met with some success, and meals of low toxicity have been produced on an experimental scale. At present, however, there seems to be no industrial capacity for either process. For sunflower seeds, methodology on a laboratory scale has been evolved to decrease the fiber content of the food protein and to remove some undesirable flavoring constituents. Again, no industrial capacity exists for this process.

Only minor attempts have been made to develop protein concentrates from other oilseeds.

POSSIBLE APPROACHES TO A SOLUTION Because rapeseed toxins are water soluble, the possibility of removing them by water washing has been investigated. This involves the use of a large amount of water, however, even with countercurrent operations. The evaporation or removal of the subsequent wash waters is expensive on the scale and with the approach suggested. The method could be improved by heat recycling and possibly by using selective solvents after removing the initial toxic compounds. In linseed, the responsible factors are similar; investigating water extraction or heat degradation of the toxic factors is also in order. Similar approaches are applicable to the other oilseeds.

The major difficulty occurs in the translation of laboratory-scale techniques to industrial scale. Analyses of alternate methods of detoxification are urgently needed. Techniques using recycled solvents and clean-up techniques of recycling systems must be investigated, as well as the technology of grinding, classification, solid/liquid separation, and desolventizing.

The approach should be systematic; the techniques now available in the laboratory should be analyzed for their applicability to the specific product being investigated and to other, similar products. The intercomparison of these technological approaches should give information for least-cost analysis. New technologies may have to be developed, such as extruder cooking of wet detoxified cake, to allow the simultaneous removal of water and the production of homogeneous or texturized products.

SPECIAL REQUIREMENTS A multidisciplinary approach will be needed: toxicologists, engineers, food technologists, and nutritionists should be included in the investigating team.

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11 LOCAL LOW-COST WEANING FOODS

PROBLEM DESCRIPTION For most people in many developing countries, animal milk is unavailable or too costly to supplement the diet of breast-fed infants. Urbanization increases the need for a processed, protein-rich food to fulfill the nutritional role of milk at a cost needy populations can afford. Such a food must be not only nutritious and cheap, but also safe and acceptable to local tastes. Several such products already exist—for example, Incaparina in Guatemala and Colombia, Pro-Nutro in South Africa, Superamine in Algeria, and Faffa in Ethiopia—but their distribution is limited, and most areas in need do not have a satisfactory product.

After more than 20 years of hard work and a large cost in energy and money, results are disappointing. One reason is that processing and distribution costs make most protein-rich foods too expensive for the population in need. Often manufactured from imported ingredients unknown in the country of intended use and formulated more on the basis of nutritive value than on acceptability, they are often unacceptable to young children and their mothers. The problem is to find out if this situation can be changed.

BACKGROUND INFORMATION In the last 20 years active research programs have led to the development of many vegetable-protein mixtures for infant feeding throughout the world. Other extensive work has concentrated on supplementation and/or enrichment of foods with protein or individual amino acids. Quantity and quality of needed proteins have been elucidated, as well as the need for enough calories in the diet. The quality of baby food depends largely on its components, but the sanitary conditions under which the food is produced are of paramount importance.

The combination of one-third of any properly processed oilseed meal with two-thirds of any cereal grain yields a product with a satisfactory protein value. Vitamins can be added as yeast or in synthetic form and the protein value usually improved by fortification with lysine. Guidelines for such foods have been prepared by the Protein Advisory Group of the United Nations System (FAO/WHO/UNICEF). Researchers encounter problems such as loss of nutritive value in processing, the presence of toxic substances (e.g., aflatoxin, gossypol), poor flavor acceptability, and development of rancidity. Most of these products require prolonged cooking, but precooked products should also be explored.

POSSIBLE APPROACHES TO A SOLUTION More information is needed on the composition and type of foods that are used locally for infant and child feeding, as are investigations to learn how acceptable food products can be modified and improved inexpensively to increase their nutritive value and shelf life. Liquid products such as soups could be dehydrated by conventional methods or by mixing with a suitable absorbing ingredient, which itself is a locally used food. An example is *kishk*, a mixture of yogurt and wheat flour used in the Middle East, which can be kept for years and whose nutritive value is much greater than either of its constituents (see problem 6). Many such mixtures can be developed in the laboratory. The availability and suitability of packaging materials such as glass jars and plastic films must be studied.

SPECIAL REQUIREMENTS The requirements of this work include pilot-scale equipment for formulating and processing different types of baby foods. The chemical, nutritional, and organoleptic studies can be accomplished in laboratories equipped for chemical and biological work in food science.

Intimate knowledge of the country and population for whom the product is designed is also mandatory. Consideration must be given not only to the product itself, but also to its packaging, distribution, and promotion, including acceptable price and necessary government approval and support.

Essential for success are acceptability trials with young children and infants and, most important, their mothers.

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PART II FOOD PROCESSING

12 HIGH COST OF PACKAGING THERMALLY PROCESSED FOOD

PROBLEM DESCRIPTION Thermal processing (canning) is an extremely practical way to extend the availability, convenience, and safety of indigenous food supplies, but lack of available containers and high cost are serious economic barriers to the production of processed foods in developing countries. Food technologists can, rather easily, scale down and adapt thermal processing to indigenous or underutilized food resources in developing countries. But manufacturing containers, if importing them is impractical, remains a problem: manufacturing cannot be scaled down economically to meet the much smaller volume typical of developing countries. Glass- or can-manufacturing lines capable of turning out hundreds of containers per minute cost too much in capital and foreign exchange, and usually far exceed the capacity of processing facilities or the demand for processed products. At best, container costs often exceed the raw material and processing cost of the contents. Wherever the aim of thermal processing is to improve the local food supply, high container cost cannot be tolerated; it is a barrier to national self-sufficiency in processed foods.

BACKGROUND INFORMATION In April 1970 the League for International Food Education (L.I.F.E.) held a workshop on Meeting Food-Packaging Needs of Developing Countries. Many technological and economic problems in packaging thermally processed foods were identified, as were individuals and organizations with specific expertise in packaging.

Packaging technology is highly innovative, geared toward higher production rates and increased automation—in short, capital-intensive. Container manufacturers are affronted by serious inquiries about a unit

with a capacity of less than 50 containers per minute for less than $20,000—in preference to their $X00,000, Y00-containers-per-minute line. Similarly, they deem a reduction in operating manpower highly desirable; this trade-off of labor for capital is not, in their opinion, what developed countries need. The obvious economic advantage of advanced technology and the reliable market demand for greater production efficiency make the low throughput and labor-intensive operations required in developing countries unattractive to developed industry.

POSSIBLE APPROACHES TO A SOLUTION Reducing high container costs is likely to require work in three main areas:

1. *Emphasis on reuse.* Recycling is appropriate to glass containers and was traditionally the basis for home canning. Although glass containers are expensive and limited in some applications, their reuse feature is a big advantage. Metal cans can also be reused if the seam portion is cut off and the top reflanged. However, equipment to perform these operations is no longer generally manufactured in the United States.

2. *New packaging materials.* The use of new materials is the long-term approach. Aluminum-foil laminates have already been used successfully in thermal processing, but the pouch stock is expensive, the throughput is slow, and the approach has yet to gain wide acceptance in the United States. For developing countries, however, a severe limit in filling and sealing speed would cause no great problem and would be compatible with labor-intensive, low-production-rate industries, if pouch costs can be reduced and processing reliability increased.

Other plastic and composite materials are competing with glass, tin plate, and aluminum in many food applications that do not require high retort temperatures and pressures. Breakthroughs are likely, but initial costs will still be high, and the attendant technology and logistics may not be appropriate to developing countries.

One particularly innovative yet simple packaging system mentioned in a German patent application uses ceramic clays to form glazed earthenware containers. Where ceramic materials are available, such an approach should be looked into.

3. *Intermediate technology.* No matter what packaging systems evolve for thermal processing, a compromise is badly needed between the latest advances in container fabrication and inexpensive, low-throughput, labor-intensive manufacturing techniques. Reviving the equipment of the 1920s or earlier may be impractical, but some approaches used then are relevant today in some areas of the world. Given tin plate, proper sand, aluminum

ore, plastic resin, or other raw or semirefined material, is it possible to fabricate containers locally with reasonably simple, inexpensive equipment? Could 5 workers produce about 10,000 containers per day? Where is the break-even point between importation of inappropriately large-scale machinery and this almost village-scale container-manufacture operation? Answering these questions may be as great a challenge as designing the latest highly automated high-speed production line, and a lot more relevant to the needs of the food industry in developing countries.

SPECIAL REQUIREMENTS A food technology laboratory with facilities for microbiological quality control is needed. Research must emphasize systems tailored to specific situations, not a grand scheme to solve the problem with one single prototype for all developing regions.

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13 INDIGENOUS SOURCES OF ENZYMES FOR MORE RAPID FERMENTATION OF FISH

PROBLEM DESCRIPTION In all of Southeast Asia fermentation is a traditional method of fish processing. In the Philippines, for example, where it is still the most common practice for processing fish, this method

has not been improved significantly for several decades. There and elsewhere in the region, fish is a major source of protein and a traditionally popular food. Because these countries are trying to increase their fish harvests but lack the necessary distribution and refrigeration facilities to allow increased harvests to be eaten fresh, improving such traditional methods of preservation as fermentation is a nutritional and economic imperative.

The two fermented fish products most commonly consumed in the Philippines are fish paste (*bagoong*) and fish sauce (*patis*). Traditional production, utilizing the endogenous enzymes of the fish, requires 8–10 months. The problem is to find a way to shorten this process.

BACKGROUND INFORMATION Although details of the mechanisms involved in the process of making fermented fish products are not well understood at present (see problem 16), we know that all fermentation involves enzymatic proteolysis. A large body of information exists on the action (specific activity, optimum conditions of pH and temperature, optimum concentrations, and breakdown products) and, in some cases, recovery for reuse of many proteolytic enzymes. Applying this experience and information to fermentation of fish could accelerate the process and reduce the capital required to maintain a production inventory.

POSSIBLE APPROACHES TO A SOLUTION Papaya and pineapple are found in all countries where fermented fish products are traditional foods. These fruits are the sources of two active proteolytic enzymes, papain and bromelain. Papain is extracted from the latex of green, ripening papaya; bromelain comes from the juice, cores, and peels of pineapple. For both enzymes, extraction methods and optimum conditions of use are well known. Studies have shown that bromelain is just as effective as papain in tenderizing meat; its action is concentrated on the muscles and connective tissues. In addition, the rice mold *Aspergillus oryzae*, the banana, and the lima bean are good sources of proteolytic enzymes.

One possible approach to accelerating fish fermentation is to investigate the effect of adding proteolytic enzymes. The necessary modifications of the fermentation conditions to optimize the rate of proteolysis should be investigated, as well as the effects of the modified process on the organoleptic properties of the product.

A supplementary industry could be developed from the pineapple-canning industry since bromelain is present in the pulp, peels, and cores of the fruit. The fibrous materials left after pressing could be dried and sold for cattle feed.

SPECIAL REQUIREMENTS The equipment and analytical facilities of a standard food technology laboratory would be adequate for the kind of investigation suggested.

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14 COOKING QUALITY OF STORED BEANS

PROBLEM DESCRIPTION For the developing world, beans are the second most important source of protein, in terms of intake and quality. Yet, the availability of beans tends to be low, perhaps because of low production rates. Consumption of beans is further reduced because bean quality for cooking decreases rapidly during storage. The problem is to discover the reasons for this loss in quality, to establish optimum storage conditions, and thereby to encourage increased production.

BACKGROUND INFORMATION "Hardshell" describes mature, dried bean seeds that fail to absorb water after soaking for a reasonable time. A problem for the housewife because working time and cost of cooking hardshell seeds are increased, the seeds are also unpopular with the breeder or seedsman because of their low germination rate.

In some attempts to establish relationships between seed characteristics, cooking quality, and germination rate, it was found that small seeds are usually more apt to be hardshell than larger seeds, which can also become hardshell if not properly stored.

POSSIBLE APPROACHES TO A SOLUTION Two possible lines of attack offer themselves at present: (1) studies designed to correlate storage conditions (temperature, relative humidity, and time) and cooking quality of good-quality seed; (2) an attempt to detect biochemical changes in the seed after harvest, particularly in the protein fraction and the development of the hardshell characteristic. The first would identify optimum storage conditions for different seed varieties; the second would point the way to physical or chemical treatments to inhibit the undesirable changes or even enhance the desirable ones.

SPECIAL REQUIREMENTS Besides the usual food-chemistry laboratory equipment, storage chambers with monitoring instruments to measure changes in storage conditions are required.

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15 STORAGE FOR FOOD PRODUCTS OF PLANT ORIGIN

PROBLEM DESCRIPTION In the absence of adequate storage, the annual supply of food–particularly grains, fruits, and vegetables–may alternate feast and famine unless crops mature throughout the year. As supplies diminish, food prices rise steeply. A serious need exists for a food storage or processing unit capable of assuring a family of near-uniform supply of food year-round. Whenever possible, local construction materials should be used.

BACKGROUND INFORMATION Since the earliest recorded times, grains have been stored in clay containers, straw or wood huts and baskets, and in the ground. Most modern research has emphasized the development and use of large storage facilities for commercial operations rather than family-sized units. Construction materials vary throughout the world. The grain crops involved are primarily wheat, corn, rye, and rice; their moisture content at time of storage varies greatly, depending on location. Fruits and vegetables, with higher moisture contents, often have to be at least partly dried before storage. The environmental requirements for maintaining the nutritional value of the products to be stored vary as widely as the composition of the individual foods.

POSSIBLE APPROACHES TO A SOLUTION The approach should include the following steps:

1. Identify the products of importance to a particular area.
2. Describe the storage requirement of the product.
3. Identify indigenous materials that can be used to provide the handling and/or storage structures.
4. Specify, design, and construct a storage unit and its components, taking into account air flow, application of chemicals, limitations of oxygen availability. Develop operational procedures for the system.
5. Consider use of natural ventilation for maintaining quality of the product, depending on the atmospheric environment and the product needs.
6. Evaluate two or more approaches for solving the problem.

SPECIAL REQUIREMENTS This problem needs an interdisciplinary approach: experts on environmental conditions, potential construction materials, and on the availability, storage requirements, and general properties of local foods of plant origin must cooperate closely. The facilities of

a food laboratory may also be required in the course of the project, to determine quantitative effects of storage conditions on specific product properties.

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16 PROCESSING FERMENTED FISH PRODUCTS

PROBLEM DESCRIPTION Fish pastes and sauces produced by fermentation are widely used as traditional condiments in Asia, providing a valuable source of protein nitrogen in rice diets otherwise deficient in protein. Traditional processing methods, however, are time consuming, and uniform quality is rare. A scientific study of the process of making fish pastes and sauces is needed, that would investigate ways to (1) shorten the process time, (2) establish scientific quality-assurance measures, and (3) provide information for further research on fish sauces and pastes and on fish-protein utilization.

BACKGROUND INFORMATION Little is known about the details of the mechanisms involved in making fermented-fish products. Processes for making the traditional sauces and pastes fall roughly into two categories: some rely mainly on action of enzymes in the fish's viscera, and others employ the additional action of microbial enzymes. Both processes use salt to prevent bacterial decomposition. Although differing in detail and length of time, most processes require several months. Some products taste fishy; others have a characteristic taste of protein hydrolysate with no, or only a faint, fish odor. Because of the time required for processing, industrial

operations tie up large amounts of capital in the inventory of material being processed.

POSSIBLE APPROACHES TO A SOLUTION Actual, on-the-spot studies of the various processes in different countries should be made, with microbiological and chemical analyses correlated with observed changes and development of flavor. Identification of microbial flora and enzymes involved and the extent of hydrolysis–polypeptide chain length, free amino acids–should be a part of the study, as should the effects of salt concentration, temperature, and pH. Establishment of quality-control measures and quality standards must await a biochemical and microbiological elucidation of the process, but these measures are necessary to control dangerous practices designed to increase processing yields, such as leaching the fish residue (as in the preparation of *Nuoc-mam*, the liquid fish sauce of Vietnam) and adulterating fish pastes with extenders and coloring matter.

SPECIAL REQUIREMENTS A laboratory equipped for chemical and biochemical analysis, in addition to facilities for microbiological work, is necessary. Capabilities for amino-acid analysis by biological or chemical methods is also required.

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17 SEPARATING COCONUT OIL AND PROTEIN BY FERMENTATION

PROBLEM DESCRIPTION Production of high-quality coconut oil and recovery from the meat of high-quality protein suitable for human foods are still problems. The traditional dry-copra process produces oil or protein; either is often unwholesome and dangerous as a food because the raw material is infected with molds and infested by insects.

BACKGROUND INFORMATION The only really wholesome production of coconut products is found in the desiccated-coconut industry. Aside from this minor source, most of the coconut produced is dried by primitive, traditional processes to yield the copra that is shipped in commerce and from which oil is extracted; the resulting oilseed cake is fit only for animal feed. If the oil is efficiently extracted, the defatted coconut cake can contain as much as 20 percent protein of good quality, but it also has a high fiber content. Obviously, the protein is not useful for human food unless the fiber is removed. The prospect is doubtful that traditional methods of drying copra can be refined enough to yield ingredients for human foods.

Wet processing is possible; fresh coconut meat is removed from the shells and immediately processed to oil and protein under wholesome conditions. It is the basis of the desiccated-coconut industry which merely shreds, processes, and dries the coconut. Desiccated coconut is a good food, but it is expensive and used mainly as a condiment. Most coconut in the world goes into production of coconut oil; any economically viable process must yield, first, high-quality oil, and, second, high-quality, undenatured protein that can be used in formulating human foods. Unique among plant proteins because it coagulates like egg white when heated, undenatured coconut protein could be used as a base for such foods as instant desserts.

Grinding fresh coconut meat with water and filtering it produces coconut milk, an emulsion containing coconut oil and protein. Past experiments have demonstrated that certain bacteria can grow in coconut milk, break the emulsion, and thereby separate the milk into an excellent-quality

coconut oil and a high-quality, relatively undenatured coconut protein. Further research with additional microorganisms might result in more efficient ways to separate coconut oil and protein from the milk, making possible commercial wet-processing of coconut oil and protein.

POSSIBLE APPROACHES TO A SOLUTION The study should be divided into several steps:

1. Developing the most efficient methods of grinding the coconut meat with water to extract the maximum oil and protein;
2. Developing the most efficient ways to remove insoluble fiber from coconut milk;
3. Searching for the most effective microorganisms capable of breaking the coconut-milk emulsion to separate the oil and protein. The microorganisms used should be restricted to the acid-producing bacteria that (a) lower the pH, inhibiting potential food-spoilage organisms, and (b) break the emulsion in a minimum time and result in precipitation of the coconut protein so that it can be easily separated from the coconut oil, water, and other components.

SPECIAL REQUIREMENTS A food technology laboratory is needed for experimentation on methods of comminuting the coconut. In addition, facilities for chemical and biochemical analyses and microbiological work are necessary.

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18 KEEPING QUALITIES OF BUFFALO MILK AND ITS PROCESSED PRODUCTS

PROBLEM DESCRIPTION Buffalo milk is the major source of milk in India. Compared with cow's milk, however, it has poor keeping qualities. Indigenous Indian milk products prepared from buffalo milk, such as *khoa, rabri, paneer,* and butter, have an unusually brief shelf life.

Although several Indian research workers have tried to improve the keeping quality of buffalo milk, they have not published much on this subject in the scientific literature. The problem is to determine if more progress can be achieved.

BACKGROUND INFORMATION In 1966, the latest year for which published figures are available from FAO, buffalo milk in India was about 53 percent of total milk production. Consequently, it is a very important source of nutrients in the Indian diet. Consumption has not increased more rapidly because the stability of the milk and its products leaves much to be desired. Direct evidence of the poor keeping quality, aside from obvious organoleptic changes, is borne out by two tests. The methylene blue test, a quick index of bacterial load, shows that buffalo milk has a significantly shorter reduction time than cow's milk, indicating the presence, on the average, of a greater burden of dye-reducing microorganisms in buffalo milk; measurements of "poising capacity," an index of oxidation potential, show that buffalo milk on the average is less resistant than cow's milk to microbial spoilage and, perhaps, to oxidative rancidity of its fats. The basic problem seems to be a combination of bacterial contamination and rancidification of a high-fat product.

POSSIBLE APPROACHES TO A SOLUTION This problem calls for a basic approach to provide the background for a long-range solution. Probable elements of an integrated study are

1. The composition and nature of the major constituents of buffalo milk;
2. The role of these constituents in the growth of microorganisms present;
3. The changes in these constituents that accompany deteriorative changes in the milk associated with conventional processing; and
4. Establishment of modern manufacturing, processing, and packaging procedures to minimize these undesirable changes.

A useful initial approach would be to investigate the sanitary conditions that seem to differentiate between the handling of buffalo and cow's milk and to improve both—especially buffalo milk—by adding a vegetable fat more resistant to oxidative deterioration. Reducing total fat content by toning might also be considered. Another approach would investigate the effect of animal feeds on the quality of the milk, particularly the effect of the presence of natural antioxidants such as alpha-tocopherol. Experiments might be conducted on the effects of feed supplements with high alpha-tocopherol contents, such as rice bran and palm oil residues, on the stability of fats in buffalo milk.

SPECIAL REQUIREMENTS The work suggested can be performed if the facilities of a food technology laboratory are available.

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19 SALT FOR PRESERVATION PURPOSES

PROBLEM DESCRIPTION Salt (especially sea salt) is used all over the world, particularly in developing countries, as an inexpensive and useful preservative primarily for fish and meat. Fish treated with crude sea salt, however, cannot be preserved as well as they can with a more refined sodium chloride: they do not keep well after drying, do not have the right taste, become rancid easily, and soon spoil. Clearly, the impurities in crude sea salt must interfere with the effectiveness of sodium chloride as a preservative agent, and we need to find ways to remove them.

BACKGROUND INFORMATION Often, sea water is evaporated in shallow, open ponds, and the crude salt obtained is used directly. Often, too, the crude salt is made into small hills or heaps and left to be leached

out by rain. Most of the undesirable mineral admixtures disappear in this way, but so does much of the salt; the remaining, less hygroscopic product, after sun or artificial drying, becomes more expensive.

POSSIBLE APPROACHES TO A SOLUTION Instead of leaving sea-salt purification to the vagaries of nature, developing countries could possibly control it better without much increase in cost. Sea salt, in small or large batches, might be refined by being placed in suitable containers to which limited amounts of water are added, varying with the kind of salt. Perhaps most magnesium salts can be extracted with only a little water, but this approach, apparently, has received little attention in developing countries.

SPECIAL REQUIREMENTS Researchers should investigate the amounts of water needed for different kinds of sea salt and construct a simple apparatus for its extraction, for family or community use, or even for larger fishing areas. On a larger scale, determining whether the magnesium, calcium, and other salts in the washings could be used for other purposes might be economically desirable.

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20 MILLING QUINUA SEEDS

PROBLEM DESCRIPTION Developing countries have serious problems of undernutrition, especially in young children. Milk is an excellent food and is among the first supplements usually suggested for diets of undernourished children, but for large sections of the population it is unavailable or too costly; milk productivity is low in areas where it is most needed, and its price on the world market is constantly increasing. Furthermore, in some population groups lactase insufficiency interferes with the proper

utilization of milk. In the search for other protein foods, the sources considered are usually the well-known grains, legumes, and oilseeds.

Quinua *Chenopodium quinoa* is a little-known plant belonging to the family Chenopodiaceae; it produces a grain that has been shown to have a high protein content. Unfortunately, use of this seed—even in Peru, its country of origin—is hampered by problems related to its acceptability.

BACKGROUND INFORMATION An annual herb, the quinua plant grows to a mature height of 1-2 meters in 5-6 months. It produces seeds about 2 mm in diameter that contain about 12 percent protein. Although the quinua seed has a long history of use in human foods—in soups, bread, and fermented beverages—the undesirable flavor characteristic of some of its constituents, chiefly the saponins, limits its wider use. In traditional household use, the seeds are washed in cold water to remove the bitter components before cooking. Because this procedure is not completely effective, it does not assure a product of uniform high quality for widespread industrial production. The objectionable components apparently are present in the outer layer of the seed, but conventional milling techniques cannot extract the saponins because the embryo protrudes and forms a belt around the middle of the grain. Previous trials with this approach have given variable results, with about a 55 percent yield of a flour with nonuniform acceptability.

POSSIBLE APPROACHES TO A SOLUTION One approach is to develop new milling equipment or techniques to eliminate the outer layers of the quinua seed.

A second, perhaps more fruitful long-term solution is to experiment with altering the flavor components of the seeds by varying cultivation techniques. This approach could be combined with genetic selection to increase the grain size, modify its shape to improve the milling characteristics, and/or decrease the saponin content. Several varieties currently exist in Peru and Bolivia that could provide material for experimentation.

A third approach is to concentrate on saponin removal by improved extraction techniques with water or other solvents. Examining the composition of the extracts might prove interesting in terms of finding uses for saponins in the pharmaceutical industry.

SPECIAL REQUIREMENTS The requirements of this work are easily met by an agronomic experimental station or food technology laboratory with facilities for the analysis of saponins and for taste-panel testing.

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21 AGING OF STARCHY PRODUCTS

PROBLEM DESCRIPTION Cheap calories, proteins, and other nutrients are derived from foods prepared from cereals, roots, and tubers in tropical developing countries. Many of these foods have not been developed as commercial products, mainly because of their short shelf life. Some are acceptable when taken fresh and hot from the oven but become quite tough a few hours later. For example, baked products made from cornmeals, in contrast to wheat breads, undergo rapid staling. This doubtless explains, at least in part, why wheat bread predominates in the markets of corn-producing countries that have become wheat-importers. A phenomenon

known as starch retrogradation is thought to play a central role in this problem.

Unfortunately, the influence of retrogradation on the staling process in nonwheat products is still largely unexplained; consequently, little technology is available to prevent it. Research on, and development of, new technologies are needed to help maintain and increase the supply of starchy foods, important sources of calories in the diets of low-income groups in developing countries.

BACKGROUND INFORMATION "Retrogradation" is the slow, progressive tendency of starch molecules to come together or associate in cooked foods. Although all the changes that occur during staling of baked products such as bread cannot be completely explained by retrogradation of the starch, it is known to be the most important single factor.

The staling of wheat products, particularly bread, has received much more attention than the staling of products prepared from other cereals and starchy materials. An approach to evaluation of starch retrogradation has been developed, but the process of staling is still not completely understood, and much more work on applied and theoretical problems needs to be done.

POSSIBLE APPROACHES TO A SOLUTION Two main lines of approach should apply the knowledge acquired so far in the study and prevention of aging of wheat products to the study of similar changes that occur with greater intensity in products prepared from other cereals and starchy materials.

1. An integrated research program should be developed to elucidate the basic factors that promote starch retrogradation, alone and in the presence of other substances, in raw materials and in finished foods. Model systems of different types of starches, alone and with other ingredients, could be subjected to retrogradation under controlled conditions. Researchers will probably have to develop and standardize better methods than those now available for measuring this phenomenon.

2. Simultaneously, a technological approach could apply some techniques that have proved useful in retarding staling in wheat products: adding surface-active agents, freezing, changing temperatures, or substituting starch derivatives for some of the starch in question. The effects of adding protein supplements such as soy flour or fish-protein concentrate could also be studied. The sensory texture profiling technique, combined with instrumental measurements, could help evaluate the staling process. Perhaps

an attempt should be made to organize, among the individuals and groups around the world—academic, governmental, and industrial—concerned with this problem, a coordinated research effort, using to best advantage the existing expertise, instrumentation, sources of foods, and experience in cooking methods.

SPECIAL REQUIREMENTS The facilities of a well-equipped food-science laboratory are needed, including apparatus for texture measurement, such as an Instrom Press adapted for food use, or a penetrometer.

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22 INCREASED USE OF RED PALM OIL

PROBLEM DESCRIPTION A serious problem in world nutrition is vitamin-A deficiency. Palm oil, a significant source of provitamin A in many African diets, could serve in other areas where the palm is cultivated for its oil content. Concentrations of carotenoids amount to 500 mg per kilo or more in the crude unbleached oil, with some oils having concentrations up to 3,000 ppm. Alpha- and beta-carotene are the major carotenoids present, with beta predominating. Refining the oil by deodorizing at 150° C tends to reduce the provitamin-A content significantly, and bleaching by hydrogenation or filtration depletes the provitamin-A activity even more. As tastes become more sophisticated, use of crudely refined red palm oil decreases. The essential problem is to find a low-cost way to remove flavors without removing provitamin-A activity.

BACKGROUND INFORMATION Use of vitamin A itself is an obvious solution to the widespread deficiency. It has been used directly to fortify such diverse products as sugar, dried milk, and even tea, but these special fortifications may not in all cases be the most economical way of delivering vitamin A to the people who need it most. Fats and oils are used universally; in some dietaries they are a significant part of total caloric intake. Enriching food materials with fats and oils—particularly food materials of a protein nature and, more particularly, weaning foods—has been suggested. Because palm oil is an excellent, if not outstanding, source of vitamin-A precursors, its use could be encouraged.

Unfortunately, almost all methods used for refining red palm oil include bleaching and deodorizing to make the stable commercial oil, which tends to reduce its vitamin-A content. Bleaching is specifically designed to remove carotenoids (as objectionable coloring matter). Deodorizing has similar results; even in the absence of air it tends to destroy much of the color. To summarize, upgrading red palm oil to increase its acceptability and usefulness destroys some of its obvious nutritive advantages.

POSSIBLE APPROACHES TO A SOLUTION Deodorization could be attempted in the absence of air or under inert gasses under reducing conditions to help retain the carotenoids. Other techniques for deodorization

such as vacuum processes, probably in the presence of antioxidants to reduce loss of the vitamin-A precursors, could be explored.

Another possible approach is to concentrate the colored fraction, deodorize (and possibly hydrogenate) the rest of the oil portions, and then add back the colored fraction to return the carotenoid content to higher levels. In compounded food materials deodorization and stabilization might be effected by processing in the presence of high protein levels and/or substrates containing antioxidants such as the ascorbic palmitates. Also, it may be possible to take advantage of the fact that the residual fiber in some species of oil palm is higher in carotene content than the normally expressed oil. The fiber might be another source of carotenoid to add back to the refined oil.

SPECIAL REQUIREMENTS No special requirements are anticipated that are not available in a standard food technology laboratory with analytical facilities.

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PART III FOOD COMPOSITION

23 FACTORS GOVERNING TEXTURE AND SOFTNESS OF FERMENTED FOODS IN INDIA

PROBLEM DESCRIPTION Some popular fermented foods in India (*idli, vada, dosa,* etc.) are made from mixtures of rice and legume flours. Among the legumes are black gram (*Phaseolus mungo*), mung beans (*Phaseolus aureus*), and chickpeas (*Cicer arietinum*). Usually, these foods are made by preparing a batter from a mixture of flours and then allowing it to leaven overnight. *Idlis* are made by steaming the leavened batter, *dosas* by pouring it in a uniformly thin layer and frying in a small amount of oil, and *vadas* by deep-frying the leavened dough. The consumer values these products for their softness and texture, which are largely governed by both the quality of the legumes and the proportions of the different flours. The nature of the components in the flour and the leavening agents responsible for the texture of the products are not known. Research aimed at isolating and characterizing such factors may help to control the quality of these preparations in culinary practice.

BACKGROUND INFORMATION Some studies have been reported on the microbial species responsible in leavening of *idli* batter. It has been suggested that a mucilaginous principle in black gram serves the same function as gluten in leavened wheat products and helps to give the required adhesiveness for making a dough and imparting a spongy porous texture to *idli* or *dosa*. One recent report claims that this principle is a glycoprotein, but no other studies confirming or denying the claim have been reported.

POSSIBLE APPROACHES TO A SOLUTION Legume flours used in making fermented foods may be fractionated by procedures generally used for separation of polysaccharides and proteins. The fractions may then be

incorporated in cereal flours (such as rice in *idli* and *dosa*) and their effect on leavening the batter and texture of the final product ascertained. These fractions can be further resolved until an active principle is isolated, the chemical nature of which can then be determined. For such an investigation, published studies on wheat-flour constituents responsible for imparting desirable baking quality of dough in preparation of bread will serve as useful guidelines.

SPECIAL REQUIREMENTS This work can be carried out in any biochemical or food-science laboratory.

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24 EVALUATING USEFUL PROPERTIES OF PROTEINS, POLYSACCHARIDES, AND LIPIDS OF CEREALS AND LEGUMES

PROBLEM DESCRIPTION Organoleptic properties of many foods prepared in Indian homes from cereals and legumes (such as *chapati*, an unleavened bread made from wheat flour; *vada*, a patty prepared from chickpeas; and *halwa*, a sweet made from highly refined wheat and maize) are largely governed by the types of proteins, starches, and lipids present. Characterizing different types of proteins, starches, and lipids in cereals and legumes, as well as studying their physicochemical properties, would help define the factors responsible for desirable sensory attributes in food preparations.

BACKGROUND INFORMATION Extensive work has been done in the developed countries on relationships between quality of food products and chemical composition of grains, such as the effects of gluten and starch in

wheat flour on determining the desired organoleptic characteristics of bakery products. No such systematic work has been carried out with any of the popular Indian food preparations.

POSSIBLE APPROACHES TO A SOLUTION Studies should be carried out on several food preparations made from different varieties of grains. Proximate chemical composition of these varieties can then be ascertained in terms of proteins, polysaccharides, and lipids. These components can be isolated and, if necessary, subfractionated from the variety that gives a superior food product, and the effect of the isolated components on improving the quality of the product made from inferior grains can be determined. Physicochemical properties of these quality-imparting components can then be studied.

In some instances, the inferior quality of food products made from certain varieties of grain may be due to the presence of certain constituents. The effect of removing these constituents on enhancing the quality of the food product can also be studied.

SPECIAL REQUIREMENTS This work can be carried out in any biochemical or food-science laboratory. A good book of local recipes should be consulted and the quality of preparations carefully evaluated by expert taste-test panels.

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25 FAT COMPOSITION OF FRIED FOODS IN INDIA

PROBLEM DESCRIPTION A wide variety of fried foods, based mainly on cereals and legumes, are used daily in the average Indian diet. (Examples are *bhajias*, made from a paste of gram flour mixed with spices and other ingredients such as potato slices, onion slices, and small pieces of vegetable and then deep-fried; and *puries*, made from wheat flour and also deep-fried.) Little is known of their biochemical composition and nutritional characteristics. Assessing the wholesomeness of many of these popular fried preparations would be facilitated if detailed information were available on the amount of fat in them, composition of fatty acids, extent of rancidity, and polymerization of fatty acids. Such surveys might also lead to improving frying practices, perhaps by selecting particular oils for cooking particular products.

BACKGROUND INFORMATION Frequent reuse of cooking oil used to fry these foods is common, and the temperature of the heated oil is usually not carefully controlled. A great deal of work has been done on the nutritive and chemical changes that occur in heated fats; for example, there have been many studies of production of toxic compounds in edible oils during deep-fat frying. Some polymeric fractions isolated from heated oils have been found to be very toxic when fed to rats at 12 percent of the diet.

POSSIBLE APPROACHES TO A SOLUTION Published procedures can be used to estimate amounts of fats and their products in fried-food preparations and in edible oils heated as in commercial frying operations. Studies can be conducted to assess extent of polymerization and rancidization of edible oils with successive cycles of frying operations and the levels of undesirable products of heated oils found in the fried preparations during these cycles.

Attempts can also be made to evolve cooking procedures to greatly minimize formation of toxic fractions.

SPECIAL REQUIREMENTS The equipment required should be available in a laboratory engaged in work on oils and fats.

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26 TRACE ELEMENTS IN ANIMAL FEEDS

PROBLEM DESCRIPTION During the past 24 years researchers have frequently investigated the dietary role and suitable sources of calcium, phosphorus, sodium, and chlorine in animal feeds, especially in India. Recent emphasis on the role of elements occurring in micro amounts, such as zinc, copper, cobalt, and selenium, has increased interest in the results of deficiencies (or excesses) of these microelements in diets of farm animals. Identifying the particular elements that give rise to specific deficiency syndromes becomes an increasingly important problem in a country trying to build up its livestock population.

BACKGROUND INFORMATION The effects of mineral deficiencies on the health of farm animals have been reasonably well established. Such deficiencies are known to affect growth, reproduction, milk production, wool growth in sheep, and egg production in poultry. Many disabling physical effects have also been directly associated with deficiencies or excesses of certain elements normally found in low concentrations in feeds and fodders.

POSSIBLE APPROACHES TO A SOLUTION The trace-element status of samples of local feeds and fodders should be systematically determined to identify soil-mineral deficiencies, or specific deficiencies or excesses in particular feeds. Based on the analyses and feed rates, the animal's intake should be determined to ascertain how well it meets the dietary requirements. In addition, long-term effects of both traditional and improved cultivation practices on trace-element composition of feeds should be investigated and correlated with analyses of the blood and other tissues of farm animals fed these materials.

The study could take place in parts at various institutions in a particular country. Depending on the analytical facilities available for trace-element analysis, each institute could concentrate on the elements within its analytical capabilities. The investigation should include not only elements and substances toxic in themselves, but also those that interfere with absorption of others, such as molybdenum with copper and nitrates with iodine.

SPECIAL REQUIREMENTS A laboratory with analytical capabilities for trace quantities of the essential trace elements Fe, I, Cu, Zn, Mn, Co, Mb, Se, Cr, and Sn is required. In addition, analyses for Ni, F, Br, V, Cd, Ba, and Sr will be needed, plus ability to determine As, Pb, Hg, and nitrates.

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27 BIOCHEMICAL FACTORS LIMITING THE USE OF LEGUME GRAINS

PROBLEM DESCRIPTION Many developing areas are food poor, particularly protein poor. One potentially large source of supplementary protein is legume grains. Compared with cereal grains, however, consumption of legume grains is usually low, although it could well be increased several-fold. Increasing consumption of legume grains depends on solving the problem of whether low utilization of legumes is due to their low availability or to the presence of biochemical factors affecting their palatability or nutritional value.

BACKGROUND INFORMATION Legume grains are food staples relatively high in protein content. They are natural protein supplements for cereal- or cassava-based diets (although the protein quality of legume-cassava combinations suffers from a deficiency of sulfur-amino acids), but they contain trypsin inhibitors and hemagglutinins which, if not removed, inactivated, or destroyed, will have undesirable effects on the nutritive value of the food and may even result in toxic reactions. A perhaps more important undesirable effect on the nutritive value of legume proteins is the unavailability of many of their essential amino acids; even when legumes are cooked to the point at which all the known toxic factors have been destroyed, evidence indicates that many of the essential amino acids are not available for growth. This suggests the presence of other antinutritional factors.

POSSIBLE APPROACHES TO A SOLUTION Additional information should be obtained to demonstrate the presence of the antinutritional factors that interfere with proteolysis, to identify them, and to devise ways to inactivate or destroy them, or to combat their adverse effects on legume proteins. A line of attack would be to fractionate legume grains into identifiable chemical components, which could then be tested biologically for possible biochemical activity, with particular emphasis on their effects on the action of proteolytic enzymes and on the availability of specific essential amino acids.

SPECIAL REQUIREMENTS The project requires animal as well as chemical laboratory facilities for its development.

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PART IV NUTRITION AND HEALTH

28 FAVISM

PROBLEM DESCRIPTION Broad beans (fava beans *Vicia faba*) are widely consumed in the Mediterranean area and in some countries of the Middle East, such as Iran. Unfortunately, ingesting the bean or inhaling the pollen of *Vicia faba* can sometimes result in favism. This acute hemolytic disease usually starts soon after exposure with chills, weakness, and pallor—symptoms caused by a massive intravascular hemolysis followed by hemoglobinuria and jaundice. The disease is markedly more frequent in children under 4 years of age. Most cases recover, but death has been observed, especially in young children. It is important to eliminate this danger, which precludes the systematic use of a low-cost, nutritious foodstuff, rich in high-quality protein, in the feeding of young children.

BACKGROUND INFORMATION A similarity between favism and drug sensitivity, notably to primaquine, has been observed, and the same genetic abnormality has been incriminated in both cases. In both cases, lower-than-normal reduced glutathione (GSH) levels and low concentrations of glucose-6-phosphate dehydrogenase (G6PD) in the erythrocytes are observed. So far, scientists have not been able to reproduce favism experimentally in laboratory animals, which hinders progress in identifying the factors in the beans responsible for the disease. The physiologically active substances that have received the most attention are the glycosides vicine and convicine and their aglycones divicine and isouramil, and dihydroxyphenylalanine (DOPA).

POSSIBLE APPROACHES TO A SOLUTION Although the just-mentioned substances have been incriminated as the causative agents of favism, their definitive involvement as responsible factors remains to be established.

Identification of the active substances would open the way to

–methodology for their inactivation, either chemically or physically; and

–development of new genetic varieties of *Vicia faba* containing low or zero levels of the toxic substances.

Factors accounting for the variability of incidence of favism should also be identified. Differences in the level of toxic substances between varieties of broad beans may account for this variability, but other factors may be incriminated, such as the genetic characteristics of the host, differences in the intestinal flora, and the culinary habits of preparing and consuming broad beans.

SPECIAL REQUIREMENTS The facilities of a biochemistry laboratory are required for the detection and identification of the active substances involved in this problem.

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29 LACTOSE INTOLERANCE

PROBLEM DESCRIPTION During the last few years, the world medical literature has reported on the occurrence in different parts of the world of low intestinal lactase (β-galactosidase) activity in large groups of apparently healthy, nonwhite populations. Some studies have also indicated that milk and milk products, rich sources of lactose, consumed in large quantities all at once, induce clinical symptoms of intolerance in some individuals with

low intestinal lactase activity. These reports raise doubts about the desirability of expanding the production and consumption of milk or of promoting the use of milk as a supplementary food for children in areas where low intestinal lactase activity is frequently observed.

BACKGROUND INFORMATION A low lactase activity can be demonstrated in a human being either directly by examination of biopsy material or indirectly by performing a lactose tolerance test. A low lactase activity, however, is not synonymous with either lactose intolerance or milk intolerance. In individuals with clinical manifestations of milk intolerance, it can be assumed that the absorption of protein, lactose, and other milk nutrients is affected to a variable extent. A few studies suggest that protein absorption from milk in individuals with low lactase activity is not disturbed, but this needs to be confirmed.

POSSIBLE APPROACHES TO A SOLUTION Approaches to a solution are likely to include these steps:

1. More information, based on standardized procedures, is needed on the prevalence of low lactase activity in non-Caucasian population groups of various ages. Information on milk-consumption patterns should be collected at the same time.
2. The relationship between lactose intolerance and milk intolerance should be clarified.
3. Adaptation studies should be made to establish if it is possible to increase, by prolonged administration of milk, the lactase activity in subjects presenting a low lactase activity or, similarly, to reduce milk intolerance in subjects intolerant to milk.
4. The effect of low lactase activity, lactose intolerance, and milk intolerance on the utilization of milk nutrients should be determined.
5. Development of milklike products and low-lactose milk should be initiated and/or encouraged.

SPECIAL REQUIREMENTS These approaches will require the facilities of a biochemistry and a food technology laboratory.

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30 MALNUTRITION: A SOCIOLOGICAL MALADJUSTMENT SYNDROME?

PROBLEM DESCRIPTION Man praises himself for being able to adjust to extreme circumstances, citing his own inventions, from the primitive digging stick of the sweet-potato eaters in New Guinea to the spacesuit of moon visitors. He also accuses himself of being unable to adjust when, for example, he needs to modify emotional or cultural values. It is one thing to have the technical skills to catch fish but quite another to give fish to a child when local belief has it that fish cause diarrhea, worms, or even leprosy. Even when a child suffers from protein-calorie malnutrition or other severe deficiency syndromes, repeated advice from nurses and doctors may not induce the mother to give her child "good" or "strong" foods, if doing so violates the rules laid down by society. Too often, customs survive and children die. Moreover, many parents cannot believe that their child's illness is due to lack of certain nutrients; the blame (correct in part) is put on gastroenteritis, respiratory infections, or other diseases.

It has been said that common sense and moral choice and ethics, like other aspects of thought, are culturally conditioned, and their forms are determined by the culture in which they must function. When and where common sense cannot prevent disease, and even promotes it, as in malnutrition, man is perhaps maladjusted to the realities of everyday life. In this sense, malnutrition can be considered a sociological maladjustment syndrome (assuming that necessary foods can be purchased, caught, or grown without major efforts).

Specific investigations are needed to throw more light on the behavior of the individual and the family in their cultural setting. Only when we

know much more about the behavior of specific population groups can we hope that health and nutrition education will produce results in a reasonably short time. The question no longer is "How much protein is contained in a cassava diet?" but "Why do people continue eating it in spite of repeated advice to the contrary and availability of other foods?"

BACKGROUND INFORMATION The literature abounds in valuable information about the nutrient intake of population groups, the availability of foodstuffs, seasonal influences, etc. Nowadays, the tendency seems to be to change to more expensive surveys, including sophisticated biochemical determinations and studies of mental development. A few publications have dealt with the psychological-sociological aspects of food, feeding patterns, and related subjects–including studies of the more affluent forms of malnutrition, such as overweight, obesity, diabetes, and other syndromes caused wholly or partly by bad food habits.

POSSIBLE APPROACHES TO A SOLUTION Recent great advances, especially in methodology, psychology, and sociology should be applied to nutrition research and education. A single behavioral trait never exists on its own; decisions are built on one another. Whether a food will be eaten, when, how much, how prepared and by whom involves the consumer in making decisions comprising alternatives, values, beliefs, pay-offs, and the social position of the persons involved. It must be realized that the values and beliefs of a group will at least partly determine which diseases–including malnutrition–that group will suffer from. Acquired knowledge should be used to strengthen or modify food and nutrition policies.

SPECIAL REQUIREMENTS Fieldworkers are required who have a keen interest in the psychological and sociological factors related to food and nutrition. A close collaboration with sociologists and other behavioral experts is often essential.

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31 VITAMIN-A FORTIFICATION OF TEA

PROBLEM DESCRIPTION Although estimates of the scope of the problem vary widely, many doctors think that vitamin-A deficiency is the most serious micronutrient deficiency in the diets of low-income countries, such as India. Synthetic vitamin A is inexpensive—an extra 1,000 IUs daily would cost only a few cents a year. The problem is to find low-cost and reliable ways to deliver vitamin A to large numbers of potential beneficiaries.

BACKGROUND INFORMATION One approach with substantial promise for reducing vitamin-A deficienceis in young children and in clinical cases is the use of massive oral dosages. But the effectiveness of this method in reaching individual recipients is limited by the professional and managerial resources available to carry it out. To reduce the pressing need for massive dosages, medical workers have been looking for a carrier for vitamin A

among foods commonly consumed and centrally processed in India. Tea was selected because about half the population, including young children, drink tea regularly. Only a dozen blending plants process at least half the tea consumed in India. Later, coffee may be tried, too.

POSSIBLE APPROACHES TO A SOLUTION Studies are being made to determine the efficacy of various ways to incorporate stabilized vitamin-A palmitate in tea, at either the tea-processing factory or the blending plant. Laboratory tests have shown great stability for the vitamin A under extreme storage and brewing conditions. Professional tea tasters have not been able to detect any differences between fortified and unfortified tea. The approach might be adapted to other foods and beverages more suited to other countries or regions.

SPECIAL REQUIREMENTS The facilities of a standard food technology laboratory are adequate for this kind of study.

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32 IRON FORTIFICATION OF SALT

PROBLEM DESCRIPTION In many developing nations iron insufficiency in the dietaries is a serious public health and nutritional problem. In India, for example, many consider vitamin-A and iron deficiencies to be the most serious nutritional problems. To change eating habits to increase the use of iron-rich foods is not practical, nor is the distribution of iron supplements in either rural or urban areas. Salt, as the only commodity consumed in fairly constant amounts by all people in every society, represents a logical first choice as a carrier for supplemental iron. A further advantage is that it is usually produced in only a few locations in any country or region. Implementing such a project involves two basic problems: (1) identifying an iron compound that is biologically available and inexpensive, and does not

react chemically with the salt or adversely affect its color, taste, or acceptability; and (2) developing a simple, reliable and easy mixing method.

BACKGROUND INFORMATION Human requirements for iron are fairly well established; they vary significantly with age and sex. The group with the largest requirement is women of childbearing age, and most cases of iron-deficiency anemia are found in this group. Fortification of universally eaten foods at levels that would supply the full recommended daily allowance of iron (18 mg) in the diets of this vulnerable group does not entail a significant risk of adverse physiologic consequences to other members of the population, notably active males, whose daily intake might then exceed 30 mg. Thus, salt could be fortified without risk, at lower levels, merely to supplement an iron-deficient diet.

POSSIBLE APPROACHES TO A SOLUTION The simple approach of incorporating finely divided iron particles in the salt as it crystallized from the brine was tried in India. The tests revealed that uniform distribution of iron by this process was not possible. Efforts then turned to the use of ferrous sulfate, the source of iron of the highest biological availability, and to the development of a dry-mixing process adapted to conditions in Indian salt factories and using equipment manufactured in India. Initial experiments with combinations of ferrous sulfate, at a level of about 2500 ppm, with other salts have shown that adverse color formation can be prevented for at least 6 months; tests to evaluate acceptability and nutrition are scheduled for the near future.

The approach under test in India might serve as a starting point for similar experiments in other countries with similar problems. Ferrous sulfate added to salt at a level of about 2,500 ppm will provide approximately 8-12 mg of iron daily to an adult consuming 10-15 gm of salt per day. Formulations combining the iron source with other substances that will maintain the appearance, taste, and texture of the salt should be investigated. Adapting currently available equipment for dry-mixing the ingredients would keep down processing costs. Moreover, the principle of fortification might be extended to the use of other nutrients in other foods—suited to a given region—as vehicles.

SPECIAL REQUIREMENTS The facilities of a normal food technology laboratory are adequate for the required formulation and organoleptic testing. For availability studies, clinical facilities and/or a biochemistry laboratory are needed.

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33 SYSTEMS APPROACH TO FOOD AND NUTRITION POLICIES

PROBLEM DESCRIPTION There is a need to establish a common frame of reference for planning food and nutrition policies at both national and regional levels. This should include specification and systematic analysis of alternative solutions to nutritional problems within the context of various causes of the problems. Therefore, to establish adequate food and nutrition policies, the interrelationships among these different causal factors (food production, marketing, trade, prices, food habits, demography, etc.) must be taken into account within an interdisciplinary context.

BACKGROUND INFORMATION "Systems analysis" is used here in the sense of "systems approach": the study of specific problems within a complete context and with the interrelationships among the different parts of the system. When applied to the food and nutrition process the "systems approach" can assist in providing the necessary information for policy formation.

Systems analysis is increasingly considered an excellent aid for policy and decision makers because it is a systematic study dealing with solution alternatives that take into account the interrelationships among different correlated factors. It is a process for identifying areas of research needs of special importance and relevance by considering cause-and-effect relationships and feed-back loops, thus permitting more objective—rather than subjective—decisions on policies to solve food and nutrition problems. Too often, such decisions have been made on rather subjective bases, that is, without adequate consideration of the other mutually interdependent problems of a society. In any event, the criteria of nutrition specialists are still needed to interpret results and to adapt them to present conditions.

POSSIBLE APPRROACHES TO A SOLUTION The application of systematic analysis to social problems has not been widespread because of the difficulty associated with having the data required available to the analysts. This is especially so in matters of food and nutrition. We do not know, therefore, to what extent it is possible to use the existing data, or to introduce personal judgment for other data not available. The danger lies in falling into the analysis of the different parts, which can disturb the overall study required for the establishment of food and nutrition policies and strategies for solving existing problems.

Many groups are now working on this subject, but there is a great need for a general discussion among them in order to establish the most useful model for the first steps of a study of the food and nutrition process.

The best way to apply the systematic approach to the integration of nutrition in planning for national development would be to start with studies of specific cases in selected countries. The available data should be assembled first to determine if the information is sufficient to be used as a basis for decision making. If not, special attention should be paid to the concentrated study of the collection of specific data needed for using this type of analysis, with the objective of identifying the points of intervention where specific research tasks are of critical importance.

SPECIAL REQUIREMENTS No special equipment or laboratories are needed to initiate and conduct this approach to nutrition planning.

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34 FACTUAL KNOWLEDGE OF FOOD-CONSUMPTION PATTERNS

PROBLEM DESCRIPTION Many countries have studied food-consumption patterns to identify existing food and nutritional problems by locale, to assign programming priorities, and to plan specific programs on food and nutrition for special population groups. This same information is equally important for the evaluation of (1) specific food and nutrition programs conducted to solve existing problems; (2) the effects on food consumption of social, economic, and cultural changes during the development of national or regional plans for improving living conditions; and (3) planning, marketing, and food-processing activities.

BACKGROUND INFORMATION Assessment of food-consumption patterns may be indirect, through the analysis of food balance sheets, or direct, through the survey of household food-consumption expenditures.

Although they have some limitations, food balance sheets are useful, particularly in the absence of other sources of information; by indicating general patterns of consumption they help nutritionists influence agricultural planning.

Household food-consumption expenditure surveys should provide not only information on food consumption and expenditures but also sound information on consumption patterns of specific members of the family.

FAO has prepared a world manual of food-consumption surveys that has long been useful. Also, nutritionists in some Latin American countries have developed a series of studies that allow for adjustments in the existing methodology that enable it to be more easily and economically applied, In addition, this new methodology is less bothersome to the family being studied.

POSSIBLE APPROACHES TO A SOLUTION A great need exists for a sound study aimed at developing a modern methodology for household food-consumption/food-expenditure surveys that can be applied to the various socioeconomic groups in a given ecology. By also contributing to a classification of food-consumption patterns, this kind of study would permit some comparative studies, for instance among Latin American countries and within them by subregion. The results of such a study would greatly improve the planning and evaluation of food and nutrition programs in Latin America.

SOME SPECIAL REQUIREMENTS Ways must be devised to interest some sociologists or cultural anthropologists in working with nutritionists in the study of new methodologies for determining household food-consumption patterns among various population groups.

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35 MICROBIOLOGICAL MONITORING KIT FOR SMALL FOOD PLANTS

PROBLEM DESCRIPTION Valuable foods in developing countries are wasted because of microbial spoilage or contamination by pathogens. A thorough microbiological evaluation of food-processing steps is necessary to pinpoint the critical points of control, but such an undertaking requires complete laboratory support, which places microbiological testing beyond the means of small food-processing plants.

A simplified, portable, and preferably disposable microbiological monitoring kit that can be used by non-microbiologists following simple directions would greatly aid in improving food-plant sanitation and helping to assure food safety.

BACKGROUND INFORMATION Extensive research has been carried out to simplify and sometimes to automate microbiological testing procedures; for example: fluorescence techniques for antibody detection, gel electrophoresis, gas chromatography, membrane filtration techniques, multiple biochemical reaction testing, and electronic colony counters. Unfortunately, the demand for sophistication and special skill makes these procedures unsuitable for routine use.

Clinical laboratories are increasingly dependent on prepoured media, reagent-impregnated test strips, single inoculation for multiple biochemical tests, and multiple antibiotic-sensitivity determinations. Their experience should be considered in developing the microbiological monitoring kit for food plants.

POSSIBLE APPROACHES TO A SOLUTION A portable replica-plating apparatus using the contact-plate principle appears most attractive.

A contact plate from a food or food-processing area is made with a nonselective medium, incubated at room temperature; then a total colony count is made. An imprint of the colonies can then be made on a sterile felt pad, mounted on a block with a handle, and it can be stamped on a

set of differential or selective agar plates contained in the kit. The plates are either examined by the operator for the appearance of a typical colony or sent to a central laboratory for confirmation.

Selection or development of test media must be made, depending on the special need of the food commodity being processed. Limiting the degree of selectivity should be considered, to avoid false negatives. Many existing media may be included in such a kit, with slight modification.

SPECIAL REQUIREMENTS The development of the kit requires expert guidance, cooperation of an interested equipment (plastics) manufacturer, and cooperative testing by independent laboratories.

To realize maximum benefit, a central laboratory to handle the confirmation tests is necessary.

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36 SPOILAGE OF TROPICAL FISH

PROBLEM DESCRIPTION The chemical and bacteriological spoilage of fish from temperate or cold waters has been the subject of much research. With the associated technological developments, this research has resulted in significant improvements in fish preservation and distribution. In the case of tropical fish, however, no such progress has been achieved. Most attempts to introduce modern fish-preservation techniques in the tropics have been based on work carried out in temperate- or cold-water species. In

recent years, several reports have suggested that fish from tropical waters, whether freshwater or marine, have different spoilage characteristics from those of cold-water species. Suggestions have also been made that autolytic spoilage is a major factor in the spoilage of tropical fish; whereas bacteria are considered the main cause of spoilage in cold-water fish. It is possible that the small numbers of bacteria present on tropical fish may have a disproportionate effect. Further information is required, because improved fish preservation could play a useful part in alleviating protein deficiency in many tropical countries.

BACKGROUND INFORMATION The relationship between autolytic and bacterial spoilage in fresh, iced, and frozen cold-water fish is fairly well documented. Limited information is available on the enzymes involved in autolytic spoilage, but virtually no attempts have been made to control this spoilage because of the emphasis on controlling bacterial spoilage. For tropical fish, information on bacterial spoilage is sparse; on autolytic spoilage and its control, it is almost nonexistent.

POSSIBLE APPROACHES TO A SOLUTION The first step might be to establish the spoilage pattern in intact fish kept at ambient tropical temperatures and stored in ice. No completely satisfactory chemical tests have so far been developed, but there is some evidence that the Total Volatile Base (TVB) and Hypoxanthine (Hy) contents of the fish may prove to be useful indicators of spoilage in tropical fish. Also, records should be kept of the changes in the physical appearance of the fish during storage, and total viable bacteria counts made on the skin and in the flesh, using a range of incubation temperatures (e.g., 30°C, 15°C, 5°C). Cooked samples should be presented to a trained taste panel. Tropical fish stored at an ambient temperature of 25°–30°C usually reach the limits of edibility in 24 hours or less. Fish stored at ambient temperatures should therefore be sampled at intervals of about 4–6 hours. If kept in melting ice from the time of death, tropical fish can be expected to reach the limits of edibility after 25–30 days. Iced fish should therefore be sampled at intervals of 3–5 days.

The second stage would be to attempt to establish the parts played in protein breakdown by autolytic and bacterial enzymes. The most convenient approach would be to eliminate bacterial effects and to work with sterile muscle tissue. Different procedures have been suggested: for example, the preparation of minces by both aseptic methods and use of bacterial inhibitors; the use of muscle blocks, with bacteria suppression by

either anitbiotics or radiation. A preferred approach would be to obtain sterile muscle blocks from freshly killed tropical fish by removing the muscle aseptically. The rate of protein breakdown as shown by a chemical indicator (e.g., measurement of total true protein or of peptides and amino acids) should then be compared in sterile and nonsterile samples of muscle and an indication obtained of the relative importance of bacterial and autolytic enzymes in the spoilage processes. If endogenous proteolytic (i.e., autolytic) enzymes play a dominant role in the spoilage processes, then this role could be eliminated by an inactivation procedure such as a simple heat treatment, which would thus lengthen the storage life at ambient temperatures.

In an empirical approach, the role of autolytic enzymes could be tested by subjecting the fish to a range of heat treatment in which time and temperature are varied. An alternative approach would be to isolate and identify the enzymes responsible for proteolysis to establish what conditions inhibit activity of these enzymes and apply these conditions in a practical way to obtain an increase in storage life under commercial conditions.

If it is shown that bacterial enzymes play a dominant role in the spoilage of tropical fish, empirical attempts could be made to control the bacteria responsible. Since an empirical approach is unlikely to produce replicable results, it would probably be necessary to isolate individual strains of bacteria from spoiling fish, inoculate sterile muscle blocks with them to identify the active spoiling agents, and then to attempt practical methods for controlling them.

SPECIAL REQUIREMENTS A laboratory for fish-inspection service, equipped for microbiological testing, will be required.

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37 EVALUATING SPOILAGE OF FOODS OF ANIMAL ORIGIN

PROBLEM DESCRIPTION In most developing countries, because of inadequate storage and transport facilities, foods of animal origin do not always reach the consumer in a fresh condition—a problem of utmost importance in deciding organoleptic qualities and hence the price. For successful commercial practice, it is imperative to test freshness and quality of animal foods. Several tests are available for assessing the extent of microbial spoilage of animal foods by, for example, measuring levels of total volatile basic nitrogen and trimethylamine or reaction with thiobarbituric acid. But these tests do not necessarily relate to loss of texture and the appearance of freshness, for which better indices might be biochemical changes occuring in situ. A systematic study of deterioration patterns and associated biochemical changes of locally consumed animal foods is needed to help establish better methods for evaluating freshness and quality.

BACKGROUND INFORMATION Among many changes in properties that are studied during the storage of animal foods are those in pH, proteins, lipids, glycogen content, activities of cathepsins and lipases, and microbial populations. However, with many animal foods, correlating these changes with loss of freshness has not been done systematically, although much work has been conducted in the area of spoilage diagnosis. These widely scattered investigations should be carefully studied and the results evaluated.

POSSIBLE APPROACHES TO A SOLUTION Locally consumed foods of animal origin can be stored at varying lengths of time under conditions simulating those of commercial practice. Changes in texture, freshness, appearance, odor, and flavor can be carefully evaluated by expert taste-test panels and the results then correlated with changes in proteins (as studied by gel electrophoresis), extractibility of proteins, proteases, composition of lipids, lipases, and other biochemical parameters that might reflect organoleptic deterioration, in addition to microbiological studies of changes in number and types of organisms. For experiments in which it is desirable to dissociate microbial spoilage from autolytic spoilage, microbial growth inhibitors such as antibiotics can be used during storage.

SPECIAL REQUIREMENTS The equipment required should be available in any food-science laboratory.

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38 INFLUENCE OF GERMINATION ON DIGESTIBILITY OF PROTEINS IN PULSES

PROBLEM DESCRIPTION Pulses (legumes) constitute a major source of protein in Indian vegetarian diets, but they are known to contain proteolytic enzyme inhibitors, hemagglutinins, lathyrins, flatulence factors, etc., that can greatly inhibit growth. In Asia, pulses are often consumed after germination (e.g., mung beans in India, soybeans in China); hence it would be desirable to perform systematic studies of the manner in which their digestibility and wholesomeness are improved, or otherwise affected, during germination.

BACKGROUND INFORMATION Several studies have been published on the occurrence of trypsin inhibitor, hemagglutinins, and flatulence factors in beans such as soy and navy beans and on the effect of heat treatment on the activities of these constituents (see problem 27). In only a few papers, however, is work, itself only preliminary, reported on the effect of germination on amounts of these inhibitors.

POSSIBLE APPROACHES TO A SOLUTION There are specific tests that can be conducted in vitro to investigate the presence of growth-inhibiting factors such as trypsin inhibitor and hemagglutinins. These tests could be used to determine the levels of these agents in pulses at various stages of germination. To determine the presence of undefined toxic factors, animal feeding experiments can be conducted with ungerminated and germinated pulses.

SPECIAL REQUIREMENTS Analyses for essential amino acids, vitamins, and minerals as well as feeding experiments should be conducted to determine the composition of these foods and their nutritive value. These experiments, if conducted with both germinated and ungerminated pulses, may help to determine undefined toxic factors that may be present (see problem 27). Associated with, or following, the experiments to determine the effect of germination on the nutritive value of pulses should be an investigation of organoleptic changes that take place and of acceptable methods of incorporating these products into locally consumed foods.

All the equipment required for these studies should be available in any food-science or biochemical laboratory. An animal house will be necessary for conducting feeding experiments.

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39 SURVEY OF CLOSTRIDIUM BOTULINUM IN TROPICAL FISHING GROUNDS

PROBLEM DESCRIPTION Extensive surveys of the incidence of various types of *Clostridium botulinum* have been conducted in some western countries and Japan, but not in tropical areas. Such studies should be extended because they are important from the public health point of view and would be likely to stimulate similar investigations of other potentially harmful food-borne microorganisms.

BACKGROUND INFORMATION The importance of certain types of *C. botulinum* as toxic microorganisms in food has been well established. Voluminous literature is available on ways to identify various *C. botulinum* types and on surveys carried out in the United States, Japan, and some other countries.

POSSIBLE APPROACHES TO A SOLUTION Samples of commercially important fish varieties and of freshwater or marine sediments should be examined for the presence of *C. botulinum* types. These samples can be obtained by the methods standard to such surveys and should come from

various fishing grounds and at different seasons during the year. To facilitate intensive work, only a few fishing grounds at a time should be surveyed.

SPECIAL REQUIREMENTS The work can take place in any food microbiology laboratory, but special precautions may be needed, such as immunizing the workers against *C. botulinum* toxins. Because identification of *C. botulinum* type is based on toxicity to mice of the culture supernatant administered both with and without the respective antitoxin, a small animal house may have to be maintained.

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40 NUTRITIONAL FACTORS IN ENDEMIC DENTAL AND SKELETAL FLUOROSIS

PROBLEM DESCRIPTION Fluorosis is endemic in several countries—Japan, Argentina, parts of Indonesia and Morocco, and particularly in India. The most prominent symptom, markings on the teeth, was first described near Naples, Italy, in 1901. Thorough epidemiological studies in the United States and the United Kingdom have established a relationship between the concentration of fluoride in drinking water and the degree of endemic dental fluorisis. In some areas (e.g., parts of Italy and India), however, more dental fluorosis is seen than would be expected from similar concentrations of fluoride in drinking water in the United States and the United Kingdom. In certain areas in India, for example, endemic crippling

skeletal fluorosis has been observed at concentrations of fluoride in drinking water that are not associated with any observed symptomatology of such fluorosis in the United States. Several workers have suggested that nutritional factors are involved, but no data have so far been published relating the intake of such nutritional elements as calcium, magnesium, and phosphorus to the appearance of dental fluorosis.

BACKGROUND INFORMATION Current studies being prepared for publication indicate that calcium intake in India is about one-third the recommended dietary allowance in the United States. (These data are being compiled for publication as part of a PL480 grant, Endemic Fluorosis in India, terminated in June 1973; see Nanda, et al. in bibliography.) It is important to note also that crippling fluorosis has been observed largely in working-class males in India. Some factors that may be important in elucidating the causes of dental and skeletal fluorosis have been suggested, but not yet investigated: ingestion of fluoride by means other than consumption of water, dietary factors that may enhance the effect of fluoride, and total daily intake of fluoride. Some studies have been reported from India, and some are in the process of preparation for publication. However, no concerted effort has been made to prepare a comprehensive and authoritative review of factors affecting the relation between fluoride and dental and skeletal fluorosis.

POSSIBLE APPROACHES TO A SOLUTION As mentioned before, approaches to partial solution and elucidation of the inordinate effect of fluoride on dental and skeletal structures in developing countries such as India lie in careful evaluation of dietary intakes of such elements as calcium, magnesium, and phosphorus, which may affect fluoride availability. In addition, total intakes should be evaluated and, if possible, balance studies should be performed.

SPECIAL REQUIREMENTS The investigation would require the services of a dentist familiar with evaluating fluorosis of the dental structures, as well as a nutritional biochemist familiar with the metabolism of fluorides. The team should also include an orthopedist to evaluate skeletal changes during the period of fluoride intake.

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41 FOOD-SCIENCE TRAINING

PROBLEM DESCRIPTION Ready availability of food for increasing populations of the developing world is a serious concern. In Ghana, for example, a 1948 population of 4.1 million doubled to 8.6 million by 1970. There and elsewhere, available food has not followed such an upward trend, and a great portion of what food is produced goes to waste on the farm, in the markets, and in the home. Proper food storage, processing, and packaging could make much more food available and encourage farmers to produce more. Yet, few workers in developing countries have been trained in these aspects of food science. Education and training in food science, as in other fields of science and engineering, suffer from the developed-country orientation of curricula designed and followed in institutions of higher education in both developed and developing countries. Most food scientists are trained for jobs that are unsuited to the developing country's needs and for which no funds are available. Scientists, nutritionists, and allied workers could contribute much more to their country's development now and in the future if their training were reoriented toward the problems that abound in their villages and towns.

In most food-science courses, the sociocultural aspects of food and nutrition receive scant attention. Food habits, customs of distributing available food within the family, traditional food combinations, methods of preparation, and taboos are seldom examined in terms of their immediate importance to the health of a population. Therefore, most food scientists in developing countries overlook the importance of their work in influencing the social environment, and their activities fail to have the desired

effect on most of the people living in rural areas and urban slums. This situation should be rectified by curriculum changes in colleges and universities in developing countries.

BACKGROUND INFORMATION Various governments and international organizations such as FAO and UNICEF have encouraged developing countries to set up training and research institutions in nutrition and food science. In many institutions curricula have been imported almost wholesale from developed countries where professional organizations have set up standards and course material for training in food science. Though these standards and materials are basic to the training of a food scientist, they are definitely oriented to problems in developed countries. The need is urgent to develop broad training programs for workers in food science, nutrition, and allied professions–programs that look at food problems as a whole and take into account local environments in the developing world. The Central Food Technological Research Institute in Mysore is an example of an institution working toward such a goal.

Most new university departments of nutrition or food science in developing countries are now training narrow specialists at the first degree level. Courses in detailed aspects of food engineering, plant management, irradiation and microwave processing, and industrial fermentations are given during undergraduate training. No broad view of food problems typical of the developing countries is given, and traditional processing of food receives only scant attention. Graduates in food science who find that there are no big food complexes in their countries are further handicapped because they do not fit into the traditional food-processing structure.

POSSIBLE APPROACHES TO A SOLUTION To help solve problems of preserving, storing, packaging, and distributing food for the ever growing populations of developing countries, a different approach to training the requisite personnel will have to be adopted. In developing countries, a program of curriculum development should be undertaken to provide undergraduate training in food science with broadly integrated courses in food availability and food preservation, including traditional and modern methods of processing and storage; nutritional value of food; and food and society. The graduate food scientist could receive more specialized training later. This philosophy of training food scientists in developing countries needs to be examined and courses devised to enable food scientists to help to improve village-level food preservation and processing.

SPECIAL REQUIREMENTS Professional bodies such as the Institute of Food Technologists in the United States should detail experienced food scientists to work with others from developing countries to investigate and recommend training courses for developing countries. Some food problems of developing countries will be solved only by a cadre of appropriately trained personnel working in these countries.

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42 MYCOTOXICOSIS IN HUMANS

PROBLEM DESCRIPTION The problem of mycotoxins in foods has been the subject of increasing concern in recent years, especially with respect to aflatoxin produced by the mold *Aspergillus flavus*. Although aflatoxin has not been conclusively linked to acute or chronic illnesses and fatalities in man, enough presumptive evidence is accumulating to make the relationship one of grave concern. Recent investigations of incidence of aflatoxin in the diet of children in Thailand found that the occurrence of molds in a wide variety of foods consumed in Thailand correlates with the incidence of toxicity on both seasonal and geographic bases. Similar reports have come from Africa and India. Production and storage of foodstuffs in tropical areas such as Thailand, where both temperature and humidity create ideal conditions for mold proliferation, pose a serious threat to the safety of food supplies. Studies are needed to indicate ways to remove such a threat.

BACKGROUND INFORMATION Although mycotoxicosis in animals has been known for many years, it has received widespread attention only since 1961 after an outbreak among turkey poults in England. Subsequent intensive study has shown a wide species susceptibility to aflatoxin and the production of similar toxins by several common molds under appropriate conditions. To susceptible species, aflatoxin is among the most potent carcinogens known. Careful handling of crops (peanut, corn, rice cottonseed, etc.), rigorous inspection and testing, and development of detoxification procedures have minimized effects on animals in the United States and protected consumers from harmful effects.

POSSIBLE APPROACHES TO A SOLUTION Attempts to eliminate damage and toxic effects from mold should include the following procedures:

1. Developing food crops resistant to mold damage;
2. Developing storage facilities to prevent mold damage; and
3. Developing adequate inspection procedures to detect and identify all moldy foods, so that foods of known or suspected toxicity can be destroyed, and other rejected foods can be converted into meat by being fed to livestock; and
4. Developing detoxification procedures.

SPECIAL REQUIREMENTS Where conditions favor mold proliferation, more than one mycotoxin will undoubtedly be encountered. Therefore, the laboratory must have the capacity to identify the various molds encountered and the specific toxic agents involved.

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