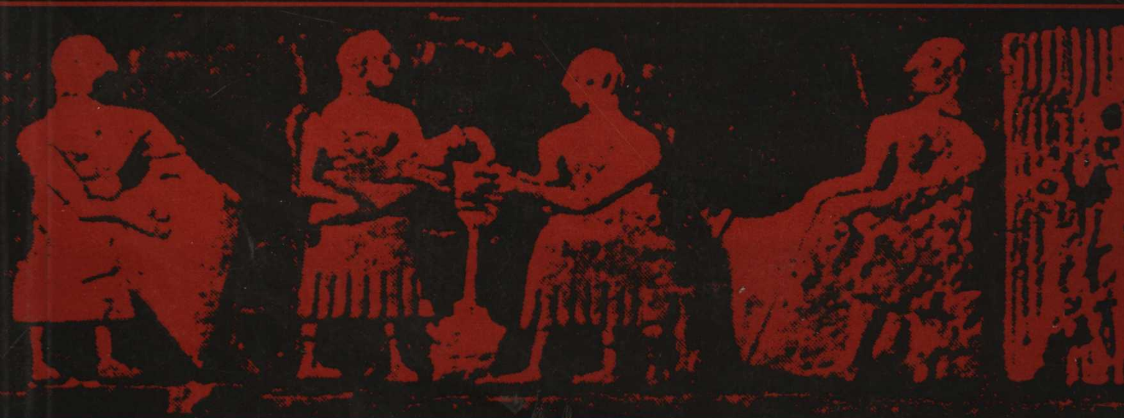

Applications of BIOTECHNOLOGY to TRADITIONAL FERMENTED FOODS

APPLICATIONS OF BIOTECHNOLOGY TO TRADITIONAL FERMENTED FOODS

Report of an Ad Hoc Panel of the
Board on Science and Technology
for International Development

Office of International Affairs
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1992

This report has been prepared by an ad hoc advisory panel of the Advisory Committee on Technology Innovation, Board on Science and Technology for International Development, Office of International Affairs, National Research Council. Staff support was funded by the Office of the Science Advisor, Agency for International Development, under Grant No. DAN-5538-G-00-1023-00, Amendments 27 and 29.

Library of Congress Catalog Card Number: 91-68331
ISBN 0-309-04685-8
S526
Printed in the United States of America

COVER DESIGN by DAVID BENNETT

Panel on the Applications of Biotechnology to Traditional Fermented Foods

ELMER L. GADEN, JR. (*Chairman*), Department of Chemical Engineering, University of Virginia, Charlottesville, Virginia

MPOKO BOKANGA, International Institute of Tropical Agriculture, Ibadan, Nigeria.

SUSAN HARLANDER, Department of Food Science and Nutrition, University of Minnesota, St. Paul, Minnesota

CLIFFORD W. HESSELTINE, Northern Regional Research Center, U.S. Department of Agriculture, Peoria, Illinois

KEITH H. STEINKRAUS, Institute of Food Science, Cornell University, Ithaca, New York

Advisory Group

K. E. AIDOO, University of Strathclyde, Glasgow, United Kingdom

SAMUEL ANGEL, Agricultural Research Organization, Bet Dagan, Israel

MOGESSIE ASHENAFI, Awassa College of Agriculture, Awassa, Ethiopia

E. V. CARPIO, Institute of Food Science and Technology, University of the Philippines at Los Baños, Philippines

HAMID A. DIRAR, Faculty of Agriculture, University of Khartoum, Sudan

SARA FERESU, University of Zimbabwe, Harare, Zimbabwe

ABED HAMAMA, Institut Agronomique et Veterinaire, Hassan II, Rabat-Instituts, Morocco

DAVID B. HARPER, Queen's University of Belfast, Belfast, Northern Ireland, United Kingdom

HIROSHI MOTAI, Research Division, Kikkoman Corporation, Chiba, Japan

FELIXTINA E. JONSYN, Njala University College, Freetown, Sierra Leone

J. MAUD KORDYLAS, Arkloyd's Food Laboratory, Douala, Cameroon

M. KROGER, The Pennsylvania State University, University Park, Pennsylvania

J. A. KURMAN, Agricultural Institute, Grangeneuve, Switzerland

L. B. MABESA, Institute of Food Science and Technology, University of the Philippines at Los Baños, Philippines

REYNALDO MABESA, Institute of Food Science and Technology, University of the Philippines at Los Baños, Philippines

NGUYEN HOAI HUONG, Institute for Experimental Biology, Ho Chi Minh City, Vietnam

NGUYEN NGOC THAO, Institute for Experimental Biology, Ho Chi Minh City, Vietnam

M. J. R. NOUT, Food Science Department, Agricultural University, Wageningen, The Netherlands

NDUKA OKAFOR, University of Nigeria, Nsukka, Nigeria

MINERVA SD. OLYMPIA, Institute of Fish Processing Technology, College of Fisheries, University of the Philippines in Visayas, Iloilo, Philippines

O. B. OYEWOLE, University of Agriculture, Abeokuta, Nigeria

OCTAVIO PAREDES-LOPEZ, CIEA-Instituto Politecnico Nacional, Irapuato, Gto., Mexico

J. L. RASIC, Food Research Institute, Novi Sad, Yugoslavia

S. SALMINEN, Dairies Cooperative Association, Helsinki, Finland

TAKASHI HAMADA, Research Division, Kikkoman Corporation, Chiba, Japan

PAIROTE WIRIYACHAREE, Chiang Mai University, Chiang Mai, Thailand

MARGY J. WOODBURN, Oregon State University, Corvallis, Oregon

YAICHI FUKUSHIMA, Research Division, Kikkoman Corporation, Chiba, Japan

LESLIE FOOK-MIN YONG, Aroma Biotech Pte. Ltd., Singapore

National Research Council Staff

GRIFFIN SHAY, *Senior Program Officer and Staff Study Director*

F. R. RUSKIN, *Editor*

CONSTANCE REGES, *Administrative Secretary*

MICHAEL MCD. DOW, *Acting Director, Board on Science and Technology for International Development*

Preface

The purpose of this report is to create greater awareness of the opportunities to reduce hunger and improve nutrition in developing countries through the application of biotechnology to widely practiced methods of food preparation and preservation. The report discusses opportunities for the application of biotechnology to traditional fermented foods. Scientists from developed and developing countries describe their research in this field and provide their recommendations on priorities for future research.

Preparation of this report was coordinated by the Board on Science and Technology for International Development in response to a request from the U.S. Agency for International Development.

Contents

I. RESEARCH PRIORITIES

Research Priorities in Traditional Fermented Foods

The Advisory Panel

Biotechnology has been described as the application of scientific and engineering principles to the processing of materials for the provision of goods and services through the use of biological systems and agents. In a very real sense, biotechnology originated with traditional food fermentations in developing countries. Over the generations, this pioneering practice has been expanded and improved so that microorganisms and other biological agents have found use in many other areas. Recent developments in genetics, enzymology, recombinant technology, and fermentation technology have led to advances in biotechnology far beyond the original traditional scope.

In many developing countries, village-art methods and age-old techniques are still used for food processing. Developing countries appear to be neglecting the advances in biotechnology. But they cannot continue to depend on historic methods for food processing. Increasing populations, drought and other natural disasters, and inadequate food production dictate that better options for food processing be adopted. Biotechnology offers this opportunity.

Current food biotechnological research in developing countries seems largely limited to the identification of microorganisms for starter culture development. There is little research involving gene manipulation and there are few centers of operational biotechnological research. The reasons for this are obvious. Biotechnological research is capital intensive, usually in scarce foreign exchange. Also, biotechnology requires the use of sophisticated equipment and reagents backed with a consistent energy and water supply, which are often not available in developing countries. A crucial part or essential chemical—which should be no more than a telephone call away, and can be obtained, at most, overnight in industrialized countries—cannot be obtained in months or even years. Or, just when all the necessary personnel and materials are available, the electricity is cut off.

To meet the current and future challenges in developing countries, it is important that these countries develop the capabilities to benefit from biotechnological developments. Developing countries will need to acquire expertise in biotechnology through education and training. The infrastructure and equipment required for biotechnological research will need to be established. Scientists of the developing world will need to collaborate with laboratories in advanced countries in order to benefit from their knowledge and to obtain infrastructural support and funding. It is through these strategies that the earliest application of biotechnology can be enhanced through help from its heirs.

PRIORITIES

The recommended research priorities encompass four broad categories: (1) improving understanding of the fermentation processes; (2) refining of the processes; (3) increasing the utilization of the processes; and (4) developing local capabilities. In this research, special emphasis should be given to fermented products that serve as major sources of nourishment for large populations (cassava, for example), processes that reduce food loss, foods that may alleviate starvation in famine or drought, and foods for weaning and young children.

IMPROVING THE KNOWLEDGE BASE

For fermented products like cheese, bread, beer, and wine, scientific and technological knowledge of the processes is well developed. However, for traditional fermented products, this knowledge is poor. Many indigenous fermented foods are produced by spontaneous or natural fermentation, but specific microorganisms predominate. Isolation and characterization of predominant organisms is essential.

Information should be collected on all traditional fermented foods and it must be thorough. No food should be excluded because it is not important or well known. A thorough microbiological, nutritional, and technical investigation should be carried out on each of the processes. The various microorganisms involved in each fermentation should be isolated, characterized, studied, and preserved. The biotechnological worth of each organism should be determined. Isolation should not be confined to the dominant organisms because other microbes found in lower numbers might have an important function in the process. The role of each organism should be identified.

Much basic research is needed to determine the scientific and technological factors in the preparation of these traditional products. Since the qualities of fermented foods are largely controlled by the participating microorganisms, understanding their role is vital.

IMPROVING THE TECHNOLOGY

In food fermentations, raw materials are converted to products through the use of biocatalysts. Each member of this equation is important. For widely used plant substrates, for example, breeding to reduce toxic or antinutritional components, or to increase protein or vitamin content, would be useful. Alternatively or additionally, it would be valuable to identify microorganisms that can synthesize important ingredients (e.g., essential amino acids, vitamins) for populations where malnutrition is a problem. Some additional desirable traits for these microorganisms are: an ability to produce flavor components that which favor consumption of these foods in traditional and new markets; the capability to break down antinutritional factors (i.e., phytic acid) present in some substrates; the production of enzymes to utilize recalcitrant wastes as substrates; the inability to synthesize toxins and other undesirable secondary products; and thermotolerance and osmotolerance, which are important characteristics in solid substrate fermentation processes.

For lactic acid bacteria used in food fermentations, physiological characteristics of acid stability, bile stability, adherence to human intestinal cells, colonization of the human intestinal tract, and antagonism to pathogenic bacteria and cariogenic bacteria (oral health) are all desirable.

The safety and shelf life of fermented products may also be improved through the development of organisms that produce alcohols, antibiotics, or other substances that can inhibit the growth of undesirable organisms.

The art of traditional processes needs to be transformed into a technology to incorporate objective methods of process control and optimization, and to standardize quality of the end products without losing their desirable attributes. Fermentations can only be optimized when conditions like time, temperature, pH, substrate pretreatment, inoculum-substrate ratio, and so forth, are controlled. Because of the surface:volume relationships, the scale-up of solid state fermentations is particularly difficult. These solid state reactions can be valuable in reducing raw material losses.

The equipment needed for the improvement of some traditional processes can be a challenge in itself. Fermentations carried out in vessels with unusual surface characteristics such as charred wood, semi-porous clay, gourds, or the like, are difficult to replicate.

Research is also needed on the implementation of continuous fermentations using bioreactors with immobilized enzymes and cells. Research on the development of bioreactors with improved performance is required.

IMPROVING UTILIZATION

The introduction of new processes or products should take into account the sensory requirements of target social groups. Thus, the elucidation of the microbial origin of flavors in fermented foods and the relationship between microflora and the organoleptic properties of the product are imperative. Flavor and color must be generated to meet local population preferences.

The use of alternative plant materials such as triticale, oca, amaranth, and achira, which have been successfully grown in some developing countries, should be examined as substrates for fermentations. *Puto* is a fermented rice cake in the Philippines. In a taste test, *puto* in which cassava was substituted for half of the rice was preferred over pure rice *puto*. Acha (*Digitaria exilis*), a West African cereal crop also known as "fonio," and ensete (*Ensete ventricosum*) are being tested as alternative substrates for food fermentations. A major drawback of ensat is its low protein content (1.5 percent) compared with other cereals; a plus is that it contains twice as much methionine as maize and wheat. Acha is being examined for the production of traditional porridge, beer, pasta, and even bread. Studies of these less-known fermented products could lead to processes with minimum production cost and maximum substrate utilization, resulting in products with improved nutritional value, extended shelf life, improved quality, and a better spectrum of essential nutrients. Inclusion of soy or other vegetable proteins could also enhance the nutritive value of many low protein foods.

The ability to use alternative substrates could also reduce problems of sporadic nonavailability of traditional starting materials. Acceptability of new products or improvement of traditional ones could be improved through the distribution of starter cultures. Some cultures are difficult to maintain in dehydrated form, and this is an important area for research. Acceptability of fermented products based on alternative raw materials may hinge on using familiar processing steps such as roasting or germination.

Research on fermentations that use wastes as raw materials has several possible benefits. The use of agroindustrial residues and other wastes to produce fermented foods and feeds can optimize indigenous resources, increase the availability of nutritious products, and reduce pollution problems.

Research is also needed on improving the economics of fermentation processes. Reducing the time necessary to pretreat raw materials or the processing time can be valuable. It would be helpful, for example, to reduce the boiling time (6 to 8 hours) of sesame seed before fermentation. Reducing fermentation time can optimize equipment use.

DEVELOPING LOCAL CAPABILITIES

Biotechnology is possible only within an infrastructure of supply companies that can provide specialized equipment and reagents. In addition, there must be a constant source of electricity for continuing experiments, and often for the air conditioning necessary for the growth of specific organisms. Developing local or regional production of commonly used enzymes would help.

Training in basic microbiology, biochemical engineering, and the new techniques of molecular biology for personnel of less developed countries is one of the key components in improving traditional fermentation processes. In addition, developing country scientists would also benefit from opportunities for regional and international collaboration. This kind of information sharing could be facilitated through periodic seminars and workshops, through joint research programs, and through the establishment of computer networks. Each of these interactions could include scientists from industrialized countries. Centers of excellence, specializing in regionally important areas, could be established for the mutual benefit of cooperating institutions.

For large-scale fermentations, developing countries should give higher priority to industrializing appropriate indigenous processes, rather than importing the technology of the industrialized world. This imported technology often relies on imported crops or crops not well suited to the climate or soils of the country.

In modernizing the production of traditional fermented foods at the village level, appropriate and affordable technology should be emphasized. Process changes should take into account the role of the poor who originated and preserved the processes and how they will benefit from the modifications.

II. OVERVIEW