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BIOTECHNOLOGY IN FOOD PROCESSING - PROSPECTS IN NIGERIA.

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INTRODUCTION

Biotechnology in its, classical emergence has been defined as the application of microorganisms, plant and animal cells or simply the application of biological systems to manufacturing industry (Smith, 1981; Houwink, 1984). Therefore it is pertinent to describe biotechnology as a multidisciplinary effort of scientific disciplines to application areas such as chemical, pharmaceutical, fermentation, food and feed, environmental and medical diagnostics. The potentials of biotechnology are very obvious which has led to its promotion world-wide. In reality only the term is new because biotechnology is based on ancient microbiological processes (brewing, breadmaking, alchoholic beverage production, and fermented milk preparation). It was after the recognision of the role of microorganisms (Pasteur, 1965) that it was turned into an engineering oriented industry to produce not only food but organic chemicals such as alcohol, butanol, acetone, glycerol, organic acids etc. This period ended in 1940. The next 20 years is termed the antibiotic era which was based on the development of microbiology, biochemistry, genetics, process engineering, production of antibiotics, virus vaccines and microbial steroids.

The following next 15 years were termed as the post-antibiotic era when the fermentation industry was utilized to produce amino acids, single cell protein (SCP), enzymes,

polysaccharides, biogas, gasohol and later gave rise to enzyme technology. From approximately 1975 up till now the era of new biotechnologies namely genetic engineering, hibridoma technology, and bioprocess technology are dominating biotechnology which has resulted in the production of monoclonal antibodies, new vaccines and human insulin - just to mention a few examples. It is predicted that the above three new innovations will determine the development of biotechnology in the next decade and lead to even broader utilization not only of product but application wise (Houwink, 1984).

At present the leading powers in biotechnology are the USA, Japan and Europe. The biotechnological importance of each country is determined by her contribution to low-and high technology bio-processes and its ability or rather competitiveness to export. The priorities were choosen by each country in accordance to her resources or established tradition in fermentation industry. In Europe, s approach eventually determined the role and priorities of biotechnology namely in industrial and environmental applications excluding some breeding aspects and medical technology.

BIOTECHNOLOGY IN WEST AFRICA

It is relatively easy to summarize the position of biotechnology in developed countries but rather difficult to talk about it in Africa, especially in Nigeria, where the position of this discipline is not clearly defined in its terms and priorities.

Biotechnology in its earliest occurence - food fermentation - in West Africa is analog in some aspects to the early European practice. From among the fermentations, the alcoholic beverages, fermented milk, cassava and maize represented priorities followed by many other applications involving different seeds. The fermented foods were made by local processors who produced the raw materials and sought to preserve and market the remains. The fermentations were empirical and remained so for a much longer time than in Europe. We call the period as the pre-Pasteur era. The industrialization of fermentations after the recongnision of the versatile role of microorganisms in Europe had little influence in West Africa, possibly due to the lack or unavailability of industrial equipment and trained personnel to handle it (up till 1950). Efforts were made during the colonial period to promote mechanisation of fermentations of a few crops such as cocoa and coffee to improve both quantity and quality of the products. This development did not, however, have any significant effect on indigenous fermentations.

The first industrial scale fermentation technology occurred with the establishment of breweries (1950 - 60) to produce larger beer - the liquid bread-which was advertised for its nutritive and energy providing capacity. The popularity of beer grew on a fantastic rate and within West Africa, Nigeria took the lead in a very

short period (Beazley, 1977). One cannot under-estimate the value of this progress from the point of view of other fermentations and the interest among scientists to study the micro-organisms involved in local fermented foods of Africa (Ekundayo, 1980).

The period of 1960 - 1976 was a period of very promising economic prospects in Nigeria and some other African countries. This led to the establishment, apart from breweries, of large industries to process milk, and milk products, while breadmaking was developed into a wide-spread practice. Processing techniques were worked out for the pilot plant or semi-industrial production of fermented cassava, maize, palmwine, ethanol and vinegar (Banigo and Muller, 1972, Akinrele et al, 1969, Okafor, 1978, Ikeokwu, 1973). Efforts were also made or proposed for single cell protein production from industrial wastes (Trevelyan, 1974, Tate & Lyle, 1975). The agricultural achievements of biotechnology between 1960 - 1976 are mainly concerned with breeding for better quality raw materials, desease resistance and pest control. The interest was focused on cyanide free cassava, better yielding, storable maize and legume varieties are summarized recently (IITA, 1983, Reddy, 1983).

The present stage of biotechnology, begining from approximately 1980, fell within the period when economically progressed African countries were restricted in the importation of raw materials, industrial equipment

etc. because of their exhaustion of credits. Within a short period a variety of problems arose and availability of existing products were drastically reduced. Possibly, one can ask what will be the role of biotechnology in conjuction with other disciplines in solving this problem and in what way will the application of biotechnology be promoted in the future? Perhaps, in answering this questions it is pertinent to review available information on fermented foods in Nigeria, as the largest country by population, production and in previous years of available financial resources.

FERMENTED FOODS

Gari. One of the major staple foods in Nigeria is gari, a dried product, manufactured from cassava (Manihot esculenta). The procedure of manufacture involves washing, peeling, cutting, grating, fermentation, frying and cooling (Fig. 1). Traditionally, the mash is fermented spontaneously by resident microorganisms which are present in the roots after washing. The fermentation process is a two-stage lactic type of fermentation of the grated cassava tuber by Corynebacterium manihot and Geotrichum candidum (Collard and Levi, 1959; Akinrele, 1964). Other microorganisms which have been isolated include Lactobacillus spp., Streptococcus spp and L. plantarum being associated with gari flavour under model conditions (Ngaba and Lee, 1979; Dougan et al., 1983). The fermentation process is

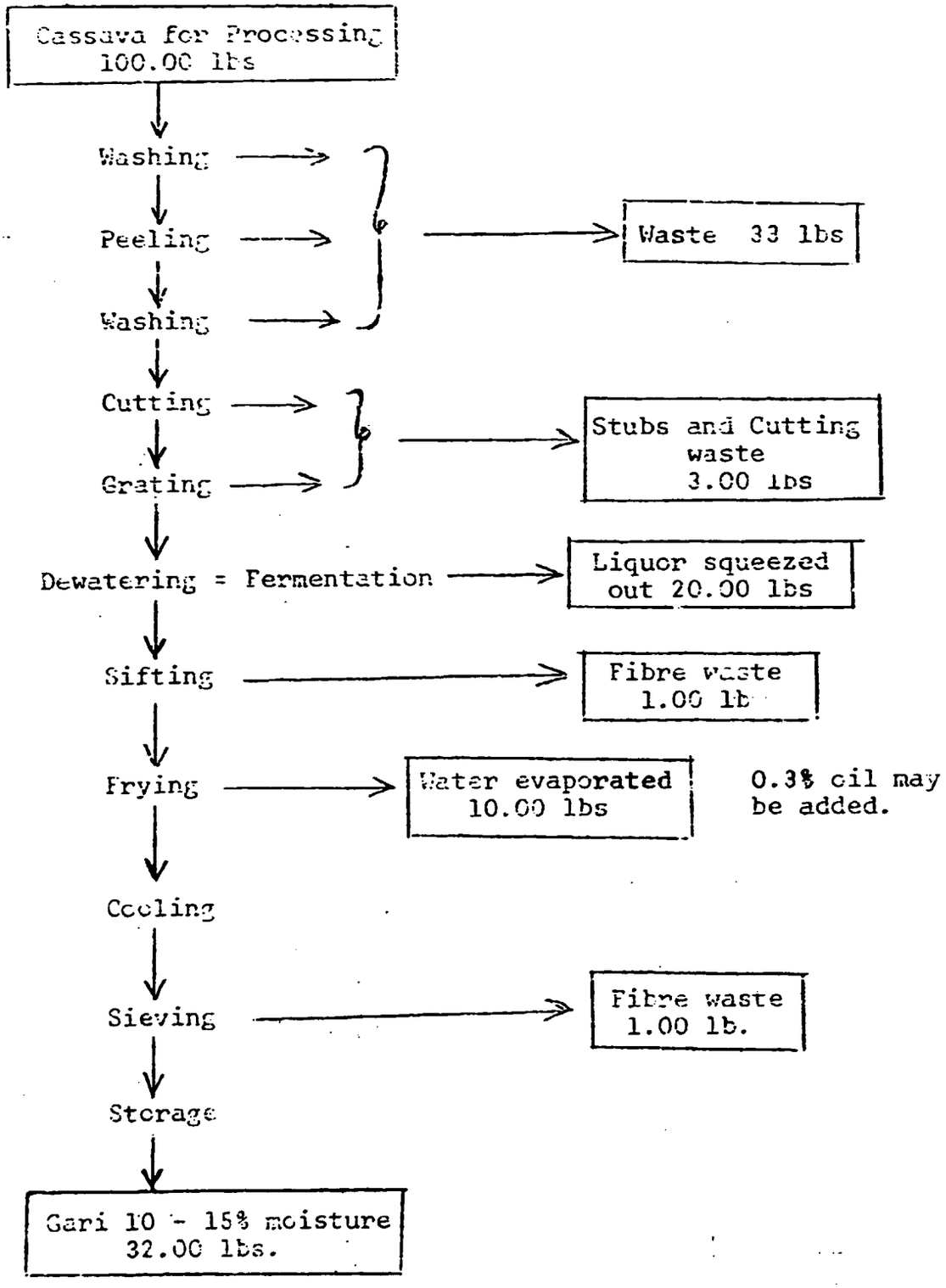

Fig. 1: Flow sheet depicting the traditional technique for gari processing (Cook et al., 1975).

complete within a maximum of 5 days which can be reduced by recycling parts of the fruit water to the cassava mash (Heuser and Smolnik, 1980).

The technology of traditional processing of cassava to gari has been documented (Cook et al., 1975). The fermentation process aims at flavour production (Dougan et al., 1983) and the removal of cyanogenic glucosides. However, it was later shown that the fermentation is less important than the frying process in the removal of residual cyanide (Boszormenyi, 1972, Olarewaju and Boszormenyi, 1975).

The first sustained effort at modernizing the technology for gari processing in Nigeria was initiated at the Federal Institute of Industrial Research (F.I.I.R), Lagos in the early fifties (Cook et al., 1975). Their attempt followed the traditional main lines in the preparation of raw materials. The fermentation is hastened by the reinoculation of already fermented cassava press juice into unfermented lots. In the further steps of drying and sieving the main advantage is the use of industrial equipment to obtain better quality product. Joint efforts between F.I.I.R. and Newell Dunford of England led to the manufacture of a fully mechanized plant. The first of these plants was installed in the Gambia in 1973 (Ekundayo, 1980). However the full description of the plant together with its functioning was provided by Akinrele in 1964. Despite the establishment of small scale gari industries

which operate on the industrial principles as specified by F.I.I.R., the local manufacturers, who still depend on the age-long tradition still dominate the markets.

Protein content of gari could be as low as 1%, therefore it seemed important that gari should be fortified with additional protein sources both of plant and of microbial origin (Trevelyan, 1974, Ready and Gregory, 1975, Balogh, 1976). To this end, reports are available in literature on gari fortification with defatted groundnut meal, full fat soya flour, sesame seed flour and dried brewers yeast (Akinrele, 1967, Morse and Uriah, 1975, Ojofeitimi, 1978).

Ogi. In Nigeria, ogi is a major food item prepared from maize, sorghum or millet (Adeyemi, 1983). The process of manufacture involves fermentation (steeping) of grain in water for two to three days, followed by wet-milling, wet-sieving and souring for about 12 - 48 hours. The final product is a white mash which when cooked produces a thin gruel (porridge) which is used as a weaning food for infants and major breakfast cereal for adults (Banigo and Muller, 1972, Banigo and Adeyemi, 1975, Muller, 1980, Ekpeyong, 1980). Ogi is also cooked and turned into a stiff gel called eko or agidi, to make a meal (Akinrele, 1970, Umoh and Fields, 1981). Similar product, kenkey is widely consumed in Ghana (Muller, 1980, Withby, 1968).

Natural fermentation in ogi manufacture is a wild process and effective microorganisms are not controlled (Banigo and Muller, 1972). Microorganisms associated with steeping were investigated by Akinrele (1970) and found to include Cephalosporium, Fusarium, Aspergillus and Penicillium. Others include Corynebacterium sp. Aerobacter cloacae and Lactobacillus plantarum (Akinrele, 1970). Okeafor (1979) isolated the following microorganisms in ogi: Pediococcus gunthen and Pediocuccus pentosaceus and Candida sp. In a related study, Fields et al., (1981) identified Lactobacillus fermentum Lactobacillus cellobiosus and Pediocuccus acidilactici in fermented cornmeal mixed with water at 37°C. The overall effect of steeping and souring is to develop the flavour characteristics of ogi which have been attributed to carboxylic acids, the most important being lactic, acetic and butyric acids (Banigo and Muller, 1972).

Two industrial processes of ogi manufacture have been developed. The first is the manufacture of soy-ogi, a mixture of 70 parts of corn to 30 parts of soybeans (Akinrele et al., 1970). The first step involves separate steeping and wet-milling of maize and dehulled steamed cooked soybeans. In the fermentation process corn and soya slurries are mixed and allowed to ferment naturally in the presence of microflora developed

during steeping phase. The product is fortified with vitamins and minerals, pasteurized, spray-dried and packaged (Fig. 2).

The second industrial approach involves dry-milling of whole maize and dehulled maize to produce maize flour. The flour is then mixed with requisite amounts of water, cooked, innoculated and fermented with a mixed culture of Lactobacillus planterum, Streptococcus lactis and Saccharomyces rouxii (Banigo et al., 1974). Three types of ogi could be obtained from this process: fermented ogi (uncooked) fermented ogi (partially cooked) and dried instant ogi.

A simplified approach has also been suggested for ogi manufacture. This involves cleaning of grain, conditioning, dehulling/degerming, dry-milling, sieving and packaging of the flour (Adeyemi, 1983). Such flour would then be used for ogi manufacture by steeping for 2 - 3 days. One aspect of hastening the fermentation process is addition of freeze-dried or powdered starter cultures to bring about the desired flavour and textural changes.

Bread. Consumption of bread in Nigeria has increased dramatically in the last few years as reflected by the present flour consumption of 1.5 million tons (F.A.O., 1983). The technology of bread manufacture and changes taking place during fermentation are well documented

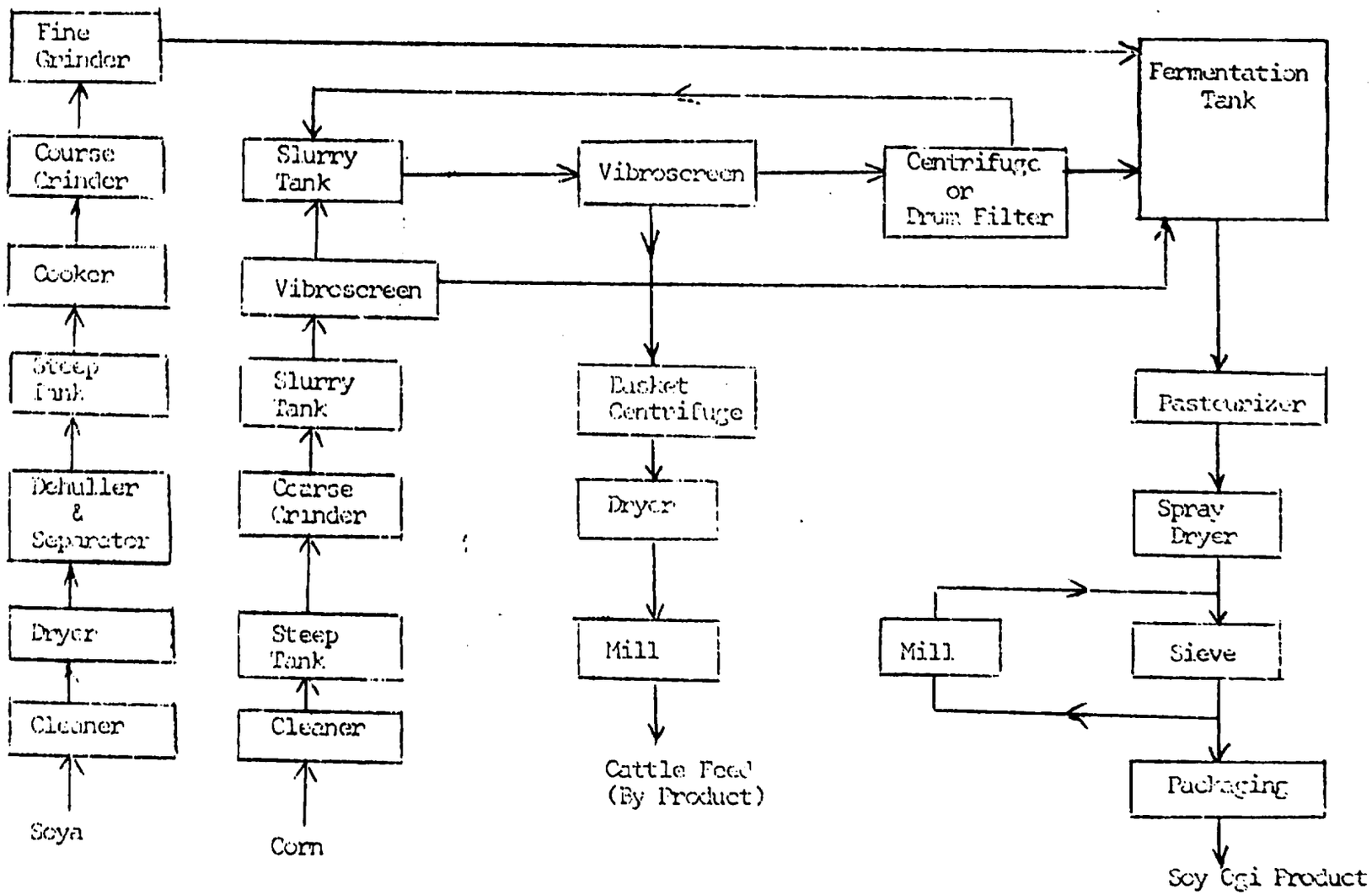

Fig. 2: Soy Ogi Process (Amon, 1977)

(Pederson, 1979). Most bakers in Nigeria use the straight dough system with bulk fermentation for making their baked goods.

CONDIMENTS

Ogiri. It is a popular fermented condiment of the Southern part of Nigeria. It is prepared from fermentation of melon seed (Citrullus vulgaris, Schrad) and used in soup preparation (Akindele, 1978). The organisms present during the fermentation process include Bacillus sp., Lactobacillus plantarum, Leuconostoc mesenteroides, Streptococcus faecalis, Pediococcus cerevisiae and Staphylococcus aureus (Akindele, 1978).

Iru. Obtained from fermented African locust bean (Parkia filicoides) is another popular nutriticus flavouring condiment in Nigeria. In its fermentation mainly Bacillus subtilis and Staplylococcus species are claimed to play a role (Odunfa, 1981).

Vinegar. The vinegar is a recently accepted condiment, but obtained first by palmwine souring, and later by fermentation and consequent distillation (F.I.R.O., 1972). Initiatives for industrial promotion were elaborated by Kuboye (1977) using a three stage fermentation procedure, where the acidifying microorganisms were harbored on corn-cobs (analogue to oak wood-havings). Efforts were

made to utilize by consequent enzymic conversions of breadfruit carbohydrates into alcohol and its conversion into vinegar (Mbajunwa, 1983).

FERMENTED ALCOHOLIC BEVERAGES AND WINE

Pito and Burukutu. The production and consumption of fermented beverages from cereals is ancient in most parts of Africa. Such beverages include pito, and burukutu (Nigeria), kaffir beer (South Africa), merissa (Sudan) and busaa (Kenya) (Ekundayo, 1980, Faparusi, et al., 1973, Ogundiwin, 1977, Nout, 1980).

Burukutu is normally brewed from guinea corn (Sorghum vulgare, S. bicolor, Moench). The traditional methods of preparation and biochemical changes taking place during fermentation have been extensively reviewed by Ekundayo (1980). Faparusi et al., (1973) isolated over ten microorganisms from sorghum malt used in the preparation of burukutu beer. These included Saccharomyces cerevisiae, Candida tropicalis, Mucor rouxii, Aspergillus flavus, A. oryzae, Penicillium citrinum. The microflora of fermenting mixture of sorghum mash and gari included Saccharomyces cerevisiae, S. chevalieri, Leuconostoc mesentroides, Lactobaccillus sp. and Streptococcus lactis. The microflora of the burukutu beer during maturation consisted of Candida mycoderma, C. tropicalis, Hansenula anomala, Kloeckera apiculata and Saccharomyces pastorianus.

Pito is a similar product to burukutu in its processing but it differs in its main ingredient for brewing since maize, sorghum or their combination is involved. The microorganisms responsible for the fermentation are Aspergillus flavus, Penicillium funiculosum, Geotrichum candidum, Candida spp. Lactobacillus spp. and Mucor rouxii (Ekundayo, 1980). We consider that Pito is more similar to Kaffir beer both in its processing and complex microbial requirements which may lead to a similar industrial production.

Palm wine. This is an alcoholic beverage produced from the sap of various palms and contains a heavy suspension of live yeasts and bacteria (Okafor, 1974). Several microorganisms are known to be present in palm-wine. About 17 yeasts were isolated by Okafor (1978), 12 of which belonged to the genus Saccharomyces, 4 were Candida sp., and 1 was an Endomycopsis sp. The bacteria isolated from palmwine included Micrococcus, Streptococcus, Lactobacillus, Bacillus, Brevibacterium. Presently efforts are being directed at the controlled processing and preservation of palmwine and on the preparation of formulated palmwine (Mmegwa, 1984). Ogogoro, a distilled alcohol is obtained from palmwine by distillation (Oduyemi, 1977).

The production of these fermented alcoholic beverages has not been fully industrialized inspite of available information on the traditional processes. Of recent,

there is a move at promoting large scale production of barley in the Northern states where it is traditional agricultural crop (Yakubu, 1983). Meanwhile interest has been developed in the use of sorghum in brewing as adjunct or possibly replacing barley malt in a novel type of larger beer. This is an attempt to reduce importation of barley which has been estimated to be over ₦300 million ($450 million) annually in the last few years (Okafor, 1980).

OTHER FERMENTATIONS

Cocoa. Cocoa is prepared from the seeds of the cocoa tree (Theobroma cocoa). The curing of cocoa beans by fermentation is a long-established practice and serves not only to remove the pulp but also to produce desirable changes in aroma, flavour and colour. Species of not only yeasts Saccharomyces ellipsoideus and S. apiculata, but also lactic acid, butyric acid and acetic acid bacteria and several species of molds may be present during the fermentation process. The acetic acid bacteria were identified as strains of Acetobacter rancens, A. aceti, A. oxydans and A. melanogenus (Pederson, 1979).

Although processing of fermented cocoa beans into cocoa powder involves high technology but the present practice of fermentation not always provide the right quality of beans. This is due to the fact that the

fermentation processes are not controlled by any means and the cocoa beans during their growth are highly susceptible to diseases.

BIOTECHNOLOGY EDUCATION AND RESEARCH IN NIGERIA

Up till the recent development of petroleum mining, the Nigerian economy was almost completely based on agriculture, the latter employing about 70% of the labour force (Arnold, 1977). It is this underlying factor that has encouraged the establishment of research institutes that are agro-based. Such institutes include Federal Institute of Industrial Research (F.I.I.R.), Cocoa Research Institute of Nigeria (CRIN) Institute of Agricultural Research (I.A.R.), National Cereals Research Institute (N.C.R.I.), National Root Crops Research Institute (NRCRI) and International Institute of Tropical Agriculture (I.I.T.A.). The latter (I.I.T.A.) is jointly subsidized by the Rockefeller and Ford Foundations and the Federal Government. Research activities in most of these institutes center on breeding, cultivation and utilization of food and cash crops.

In spite of the number of these research institutes the decisive part of research activities takes place in the Universities. Presently there are 23 Universities, offering courses in engineering and technology related disciplines. In the last few years there were attempts

at coordinating teaching and research into certain areas of biotechnology in some of the research institutes and Universities. For example, at the University of Ife, fermentation technology, food and industrial microbiology, and food fermentation are taught in the departments of Food Science and Technology, Microbiology and Chemical Engineering. In some of the research Institutes and Universities research studies have been initiated in sewage treatment, fementation of local foods, and brewing of alcoholic beverages.

In the light of the above development it must be noted however that effective teaching and research in biotechnology and bioengineering could be a difficult task in some African countries. These subjects require well equipped- expensive laboratories, constant availability of basic supplies and specialists in all the related fields such as biochemistry, genetics, immunology, microbiology and engineering (Balogh, 1982). One cannot overlook the need of industrial experience of the academic and research staff, furthermore the requrements for well-trained middle-level personnel. It would therefore be a matter of importance to identify the educational and research perspectives of biotechnology in African countries.

CONCLUSION

From the summary presented above it is evident that traditional biotechnology in West Africa gained importance mainly in its food production aspects. The bioprocesses used are mainly open systems with a relatively limited amount of control and only a few process applies controlled pure cultures in closed systems, therefore biotechnology can be termed as low technology bioprocess. The development of fermentation industries in other continents indicates a fast progress, therefore the question is in what direction biotechnology should be oriented in West Africa? It is evident that not all aspects of biotechnology can be promoted neither investment-wise nor on the basis of application possibilities.

The international organizations in developed countries have set up years ago numerous working parties. commetties to define biotechnology and to decide on the trend of biotechnology applications based on the involvement of its scientific societies and their specific interest. Similar intergration is taking place recently in developing Asian countries under the leadership of Thailand. In Latin America already several plans are under study to identify the continent's priorities. It is a wellcome foresight from the international organisations to initiate the Lagos Plan of Action to specify and integrate biotechnology in Africa.

In our view, based on the history of biotechnology and on its recent achivements in West Africa the objectives of biotechnology should be based on the earlier principles, namely on food and agriculture. Almost no justification is needed to support this view in the light of the well known problems of the whole continent identified and evaluated by many international organizations. We can not but consider other application fields as well, in spite of the fact that there is very little or no earlier experience on those fields, namely the environmental and medical aspects of biotechnology. Again little explanation is needed at this stage since we all know the threatening problems carried or developed during the past decades and it is well documented by local and international authorities.

Already several applications of biotechnology are taking place at different levels in West Africa, partially based on research and successful pilot plant productions at institutions and universities apart from some industrial productions. Under the soaring economic situation prevailing in most of the developing countries a greater demand and interest have been developed, leading to willingness by industries, in new production areas to provide new products or rather to produce necessary ingredients for already existing industries. An excellent example is the recent scarcity of yeast for baking and to some extent for brewing in Nigeria. While yeast

production in its technological requirements can not be compared to let say amino acid production - a more complicated bioprocess, the industrial yeast production is considered a venture investment while many other much more capital demanding investments were made earlier. This is certainly the least desired policy by its consequences. It may discourage and slow down development both in the use or further application of biotechnological methods or undermine the sucess of others. We have to emphasize that coordination is needed to promote:

(a) the use of already existing (even if it is imported) biotechnological processes.
(b) the fully researched and well established pilot plant but firmly feasible processes for industrial application on a moderate level but with possibilities for expansion
(c) the safety of bictechnology.

We may further extend the need of coordination between research establishments and industries and governmental bodies. With due respect to all views, enthusiasm or doubt we have to take a unified stand to apply and develop biotechnology not as an overall solution but as a tool to solve our problems within the choosen priority applications.

Finally we present in Table 1 the summary of application of biotechnology in Nigeria as it is in our view.

Table 1: Suggested areas of present and future applications of biotechnology in Nigeria.

Food application	Non-Food application
Yeast (bakers, brewers)	Ethanol
Starter cultures	Agricultural waste utilization (ethanol, SCP)
Fermented cassava (gari	
Fermented maize (ogi)	Anaerobic waste water treatment
Brewing (indigenous alcoholic) beverages	Vaccine
Grain and legume breeding	Pesticides
SCP (industrial waste utilization)	

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