SCOPE FOR DEVELOPMENT OF FERMENTATION INDUSTRIES IN PAKISTAN

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A general survey of the field is given with emphasis on the applications of microbiological fermentation processes to the production of industrial chemicals, pharmaceuticals, foods, etc., in Pakistan.

An efficient utilization of surplus and waste agricultural materials is always an important consideration, particularly for an agricultural country like Pakistan. The majority of substrates used in the fermentation processes originate as products of agriculture. Carbohydrate materials such as molasses; wood wastes, like saw dust, wood chips and wheat, rice, oat and barley straws; linseed, mustard, sunflower and cottonseed cakes; corn cobs, vegetable and fruit wastes; textile and paper trade wastes, etc., can be utilized directly or indirectly as raw materials abundantly available for many fermentation processes. The fermentation processes include the production of organic solvents, ketones, organic acids, antibiotics, vitamins, enzyme preparations, proteins, fats and plant and animal growth factors as well as sewage disposal, curing of hides, retting of flax, silage making and those food products which depend on micro-organisms and enzyme systems for their character and flavour, e.g., cheese, cocoa and beverages.

Cane molasses, a by-product of the sugar industry is an important raw material for fermentation, but it is not being adequately used in the country at present. The present annual production is estimated at about 64,000 tons, and molasses is being sold at about Rs. 25/- per ton on the basis of the raw sugar present in it. With the establishment of more sugar factories a still bigger surplus of this versatile raw material will be available. On the other hand, in the West where molasses has been a boon to the fermentation industry, the present cost of molasses in the United States is 13 cents a gallon (approximately Rs. 100/- per ton) and is becoming far too high for economic use in many of the industrial fermentation processes. Since the Second World War, there has been a tremendous and apparently a permanent increase in the demand for molasses for animal feed.

More recently, finding no adequate industrial use for this material in the country, it was being planned to export cane-molasses to foreign counties to earn foreign exchange, but the limiting factor was high transportation costs from the factory sites to Karachi by rail. By initiating fermentation industries in the country, it would be possible to produce chemicals and other products of great economic value which are at present being imported.

During the latter half of the nineteenth century more fermentation industries were developed. The use of black mould in the tanning industry was shown to depend on the production of gallic acid from tannin by *Aspergillus niger*. Lactic acid was produced commercially in the United States as early as 1881 by modifying the existing processes for producing alcoholic beverages which were followed by acetone-butanol process. During the First World War, glycerol was produced in Germany and U.S.A. and soon after mycological production of citric acid on a commercial scale by the use of *Aspergillus niger* became possible.

Apart from the production of alcoholic beverages, industrial alcohol and glycerol, yeast is an excellent source for enzyme preparations such as invertase and the yellow enzymes, growth factors, bios I, bios II and vitamins especially those of the B-complex, including vitamin B_{12}. Ergosterol, the precursor of vitamin D, is also produced industrially from yeast. A more direct utilization of yeast for this purpose is the production of yeast itself for food. As nitrogen can be supplied in an inorganic form, this amounts to a most economical method of synthesizing protein.

Purified vitamin B_{12} is also being produced from *Streptomyces olivaceus*:, and it is also being recovered as a by-product in various fermentations as well as from activated sludge from sewage treatment farms.

The discovery of pencillin in 1929 and its utilization during the Second World War opened a vast field of new fermentation processes and techniques in the field of antibiotics. In a period of less than 10 years, starting with the first deep fermentation plant of pencillin in 1944, microbiological processes became firmly established in industry.

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A few classical examples of the utilization of bacteria are worth mentioning: coversion of ethanol to vinegar by the acetic acid bacteria, oxidative potentialities of *Acetobacter xylinum* in the oxidation of sorbitol to sorbose in the synthesis of ascorbic acid. Apart from these, several other bacterial fermentations have achieved commercial usages, one of these being the use of *Bacillus aceto-ethylicus*, the main end products being ethanol, acetone, formic acid, acetic acid, lactic acid and hydrogen. The products using *Clostridium acetobutylicum* are *n*-butanol, acetone, ethanol, carbon dioxide and hydrogen. By choosing different strains, it is possible to modify the ratios of solvents or to produce isopropanol instead or together with acetone. Blackstrap molasses, starchy mashes or vegetable wastes can be used as carbon sources in these fermentations. The solvents are removed by distillation, carbon dioxide is collected for conversion to 'dry ice' and hydrogen is used in the production of ammonia or methanol. The residue left after removal of the solvents is spray-dried and the resultant butyl stillage is a rich source of riboflavin and other vitamins.

The recovery of sulphur from gypsum by the action of sulphate reducing bacteria is an example of the utility of micro-organisms in making available material that is otherwise recovered only with great difficulty. The bacterial degradation of sewage to give inflammable gas (mainly methane) employing *Clostridium methanigene* is another process. Over 50% of the products are gaseous, consisting of a mixture of methane and carbon dioxide. Apart from this, these micro-organisms are a good source of vitamins of the B group, and may be regarded as an indirect method of vitamin production.

The earliest substance to be recognized as of microbiological origin is lactic acid which is still being produced entirely by fermentation; molasses may be used as a raw material. It finds use in the textile and tanning industries as a solvent and its new use would be mainly in the plastics field. At present, there is not a clear and direct connection between moulds and plastics, but it is noteworthy that itaconic acid is produced far more easily by moulds (*Aspergillus terreus*) than by purely chemical process. Interest in itaconic acid as raw material for the plastic industry becomes clear if its formula is compared with that of methacrylic acid, whose methyl ester is the monomer from which 'Perspex' is obtained by polymerisation.

Some other mould acids are also potentially valuable because of the large yields obtained, e.g. kojic acid, fumaric acid, acids of carolic acid series and propionic acid.

Vitamin C is also produced by *Aspergillus niger* but in quantities which are too small to compete with the synthetic process at present. The position is completely different with regard to the latest members of the B-group vitamins, e.g., B_{12} which is now mainly produced as an important by-product in the streptomycin industry and is unique in being produced solely by micro-organisms alongwith vitamins B_{12a}, B_{12b}, B_{12c}, and B_{12d}.

The formation of cortisone, used in the treatment of arthritis by selective oxidation of the steroid molecule, is only possible by micro-organisms. Another example of a different type of process is based on the power of certain micro-organisms to synthesize from sucrose the higher molecular weight polymers of glucose known as dextrans for use as a plasma volume extender.

As regards antibiotics, except for chloroamphenicol, all other antibiotics are produced mainly by fermentation processes commercially.

Microbiological processes which could be locally developed are categorised as under:—

(*i*) *Industrial Chemicals*.—In the field of industrial chemicals, ethanol, butanol and acetone are the most important. These are however meeting keen competition from synthetic processes from petroleum and natural gas as raw materials in Western countries. This industry can however thrive in Pakistan, where low-cost molasses will continue to be available for a long time to come. Similarly, scope still exists for production of glycerol by fermentation, as demand for this material for various industries is very great indeed, and the existing soap factories in the country will not be able to cope with the increased demand; at the same time, plants for its production from petroleum are intricate and expensive.

(*ii*) *Pharmaceuticals*.—Antibiotics, vitamins, organic acids, dextrans, together with microbiological transformation of steroids are important applications of fermentation processes; especially the production of antibiotics, which has become a leading fermentation industry. Several of these could be commercially produced locally.

(*iii*) *Enzymes*.—Work is also needed on preparation of various enzymes: diastase in the liquefying and saccharifying starch, in the brewing and fermentation industries, desizing of textiles, sizing of paper etc. Similarly, commercial proteinases from fungal and bacterial sources find varied uses in industry. Pectinases prepared from fungi find use in clarification of fruit juices and

preparation of fruit concentrates.

(*iv*) *Foods, Feeds and Beverages*.—Microbiological investigations are also essential as we develop our food industries, e.g. canning industry where spoilage and food poisoning problems are of importance. Microbiology of dairy products, use of antibiotics for preservation of meat and fish, yeast as a source of human and animal food, improvements of the methods of manufacturing powdered milk, butter and cheese.

(*v*) *Preservation of Materials*.—Fibres from natural sources, ropes, building materials from wood etc. are all subject to microbiol deterioration especially in the sub-tropical climate in the country. Investigations are needed in this field as well.

As has been mentioned above, some of the products are being produced by synthetic means and from petroleum and natural gas in the West. In Pakistan, as agricultural by-products and wastes are available in plenty, application of microbiological processes should find greater and greater use for production of materials useful for chemical, pharmaceutical and other allied industries.