Enzymes: Sustainable Product Development by Solid State Fermentation - A Review.

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ABSTRACT:

The environmental management facet is the most important part to be considered by the engineers and technocrats along with the management professionals to build a technology which will guarantee a better world to reside as it requires technical competence and scientific excellence. The modern manufacturing production and processes thus must be extremely flexible, environmentally respectable, sustain anyof the frequent market fluctuations with “sustainability” both environmentally andeconomically. Solid State Fermentationhas been used for the production of enzymes, organic acids, food animal feed,and both pharmaceutical and agricultural product.

The paper reviews Solid State Fermentationas a tool using agro industry residues and wastes to produce value added products like enzymes responsible for development of sustainable society.

Key words: Sustainability, Solid State Fermentation, Enzymes.

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INTRODUCTION:

Sustainability is the capacity to endure.Sustainability is equated with clean industrial products and processes Sustainability requires the reconciliation ofenvironmental, social equity and economic demands - also referred to asthe "three pillars" of sustainability or the 3 E’s.“Sustainable development is development that meets the needs of thepresent without compromising the ability of future generations tomeet their own needs” [1].

Environmental issues often considered to be synonymous with sustainability – the other two pillars overlooked. Environmental concerns often concentrate predominantly on the biosphere and aesthetics (visual and landscape impacts)[2].

The environmental management facet hence is the most important part to be considered by the engineers and technocrats along with the management professionals to build a technology which will guarantee a better world to reside as it requires technical competence and scientific excellence.

The modern manufacturing production and processes thus must be extremely flexible, environmentally respectable, sustain anyof the frequent market fluctuations with "sustainability" both environmentally andeconomically.

In order to be economically and environmentallymore sustainable than an existing process, a new process must be designed notonly to reduce the consumption of resources (e.g., raw materials, energy, air, water),waste production, and environmental impact, but also to increase the recycling ofwaste per kilogram of product [3].

Sustainable industrial development means continuous innovation, improvement, and use of''clean'' technologies to make a fundamental change in pollution levels and resource consumption.Recycling of materials, minimization of energy utilization, retrofitting ofexisting industrial processes to alleviate pollution, and applications of innovative science have providedroutes to clean or cleaner technology, which promotes biotechnologicalmethodologies for clean industrial products and processes, represents a logical approach to sustainabledevelopment.Biotechnology is competitive with and in many cases complements chemical methods forachieving clean technologies [4].

Biochemical engineering is concerned with conducting biologicalprocesses on an industrial scale. This area links biological scienceswith chemical engineering.The biochemical processing is a helpful technological development in conversion of agro-industrial residues into value added products.Theagro-industrial residues include renewable lignocellulosic materials such as the stalks, stems, straws, hullsand cobs which all vary slightly in composition and can be processed to yield a number of valuableadded products, such as food, fuel, feed and a variety of chemicals [5].

MICROORGANISMS:

Microorganisms decompose organic matter by producingenzymes. Enzymes are the biocatalysts of all biochemical reactions. By the action of enzymes on organic matter,the substrate composition and pH ofthe medium changes and in the course of this metabolic activity heat is released.Enzymes function within certainranges of temperature and pH.

The prokaryotes and the eukaryotes are the decomposers and play vital role in maintaining ecosystems. The eukaryote fungiavailable in nature produces hydrolytic enzymes for the breakdown of organic waste materials, plant residues, vegetables and all sorts of waste into inorganic mineral compounds.

During biodegradation, different microbial population dominates various stages and playsdifferent roles in breaking down organic matter [6]. In general, there are three main groups ofmicrobial population involved in the composting process; bacteria, actinomycetes, and fungi [7].

Bacteria, yeasts and fungi can grow on solid substrates,and find application in Solid State Fermentationprocesses. Filamentous fungiare the best adapted for solid state fermentation and dominate in researchworks.Filamentous fungi are the most important group ofmicroorganisms used in solid state fermentation process owing to their physiological, enzymological and biochemical properties[8].

SOLID STATE FERMENTATION:

Fermentation has been widely used for the production of a wide variety of substances that are highly beneficial to individualsand industry. Over the years, fermentation techniques have gained immense importance due to their economic andenvironmental advantages. Ancient techniques have been further modified and refined to maximize productivity. This has alsoinvolved the development of new machinery and processes. Two broad fermentation techniques have emerged as a result ofthis rapid development: submerged fermentation (SmF) and solid state fermentation (SSF)[9].

The fermentation products can be produced by cultivating fungi in the absence of free flowing water on a solid substrate calledsolid state fermentation (SSF) and when cultivated in liquid nutrient broth, called submerged fermentation (SmF).The water content of atypical submerged fermentation (SmF) is more than95 %. The water content of a solid mash insolid-state fermentation often varies between 40 % and 80 % [10].

Solid substrate cultivation (SSC) or solid state fermentation(SSF) is envisioned as a prominent bio conversion technique to transform natural raw materials into a wide variety of chemical as well as bio-chemical products[11].

Solid state fermentation (SSF)has been used for the production of enzymes, organic acids, food animal feed,and both pharmaceutical and agricultural product. Substrates that have been traditionally fermented by solid state include a variety of agricultural products such as rice, wheat, millet barley, grains beans, corns and soya bean. However nontraditional substrates which may also be of interest in industrial process development include an abundant supply of agricultural, forest and food processing waste [12].

Solid state fermentation (SSF)has been gaining attention in industry due to the low waste water production andoperating expenses, simpler fermentation media requirement, superior productivity, andeasier prevention of bacterial contamination [13,14,15] compared to the submerged fermentation (SmF), in which the nutrients andmicroorganisms are present in a large amount of water. The use of solid-state fermentation (SSF) is particularly advantageous for enzyme production by filamentous fungi, since it simulates thenatural habitat of the microorganisms [16].Socio-economic applications of solid state fermentationoffer the potential of significant raising standards with only a low technology input requirement.

Another attractive advantage of solid state fermentation is the utilization of lignocellulosic residues as substrates to relieve the wastes disposalproblem, as well as to enhance their values for other applications.The outcome of fermentation highly varies for eachsubstrate; hence, it is extremely important to choose theright substrate. Fermentation techniques have to beoptimized for each substrate. This is primarily due to thereason that an organism reacts differently to eachsubstrate. The rates of utilization of various nutrientsdiffer in each substrate, and so does productivity. Some ofthe common substrates used in solid state fermentation arewheat bran, rice and rice straw, hay, fruit and vegetablewaste, paper pulp, bagasse, coconut coir, and synthetic media [17].

The efficient industrial bioreactors for Solid state fermentation is important, as sizeableproblems such as transfer resistance, steep gaseousconcentration and heat gradients that develop withinthe medium bed cause effect on performance of fermentor. The bioreactors commonly used, canbe distinguished by the type of aeration or the mixed system employed compriseTray,Packed-bed, Horizontal drum,Fluidized bed fermentors.

Problems with solid-statefermentation include incomplete utilization of thenutrients because of poor oxygen and heat transferin the substrate [18].

Optimization of solid state fermentationconditions is critical in supporting the growth ofmicroorganisms and maximizing the production yield. Key parameters for optimization ofsolid state fermentationinclude the carbon and nitrogen sources, compatibility of strains and substrates, initialpH of the growth medium, incubation temperature and period, aeration, mixing, moisturecontent, and water activity in the substrate [19.20].

The major advantages ofsolid-state fermentation [21, 22] over submerged fermentationsystems are:

- Small volume of fermentation mash or reactor volume, resulting in lower capital operating costs
- Lower chance of contamination due to low moisture levels
- Easy product separation
- Energy efficiency
- Simple technology
- Product yields are usually higher
- Oxygen is typically freely available at the surface of the particles.

Several other features of solid state fermentation [16, 23, 24, 25, 26] that have an edge over submerged fermentation can be mentioned as:

- No waste production in the case of enzyme fermentation
- Resembles the natural environment for several microorganisms
- Longer production phase in amyloglucosidase production
- Absence of co-produced carbohydrates
- Use of waste or spent low value raw materials to produce high value products
- No foam generation
- Elimination of the need for rigorous control of many parameters during fermentation.

Agro-industrial residues are generally considered best substrates for the solid state fermentationprocesses and enzyme production by solid state fermentation is not an exception to that [27].Research on the selection of suitable substrates for solid state fermentation has mainly been centered around agro-industrial residues due to their potential advantages for filamentous fungi, which are capable of penetrating into the hardest of these solid substrates, aided by the presence of turgor pressure at the tip of the mycelium [28].

Solid state fermentation uses agro-industrial waste as support and/or carbon source for production of various value added products, such as single cell protein, industrial enzymes, secondary metabolites, and fine chemicals [29], production of largeamounts of cells rich in proteins that commonly contain allthe essential amino acids, in addition to favorably highvitamin and mineral levels [30].

MAJOR PROCESSING STEPS OF SOLID STATE FERMENTATION:

At the most general level, the major processing steps of solid state fermentationprocess are no different fromthose of a submerged liquid fermentation (SLF) process. These processing steps include

- Inoculums preparation
- Substrate preparation
- Bioreactor preparation
- Inoculation and loading
- Bioreactor operation
- Unloading
- Downstream processing
- Waste disposal

ENZYMES IN DEVELOPMENT OF SUSTAINABLE SOCIETY:

Enzymes can be considered as green chemicals; they have very wide applicationsand can be referred to as household commodities owing to their role in today's human activities[31]. More or less all the known microbial enzymes can be produced bysolid state fermentation.

Enzymes are powerful tools to preservethe environment. They assist environmentalprotection by improving industrial processesby providing environmentally benigntechnologies, replacing harsh chemicals orprocessing conditions, helping convert wastematerials into useful products, detoxifyinghazardous wastes or aiding environmentalmonitoring by acting as either molecular detectorsor biosensors [32].

Because of improved understanding of production biochemistry, the fermentation processes, and recovery methods, an increasing number of enzymescan be produced affordably. Also, advances in methods of using enzymes have greatlyexpanded demand. Furthermore, because of the many different transformations that enzymescan catalyze, the number of enzymes used in commerce continues to multiply [33].

Enzymes are high molecular weight compounds made upprincipally of chains of amino acids linked together by peptide bonds.Enzymes are biological catalysts in the form of proteins that catalyzechemical reactions in the cells of living organisms.New and exciting enzyme applications are likely to bring benefitsin other areas: less harm to the environment; greater efficiency;lower costs; lower energy consumption; and the enhancementof a product's properties[34].

The enzymeswhich are originated from microorganisms arepreferable choice for industrial applications, becausethey are more stable even in organic solvents with lowcosts[35].As new enzymes and enzymatic processes continue to emerge, there is still scope for further development of the market.

Enzymes have unique shapes and reactive sites that allow them to bind with specific molecules(called substrate molecules).When bound to substrate the enzyme puts a slight strain onthe substrate providing the "push" needed to get the reaction started. This "push" is called the activation energy.Enzymes play a central role in thechemistry of living nature. It is expected that enzymes to play a key role in the developmentof a sustainable society as it predictedthatthere are around 25,000 enzymes,ofthese only 5,000 have beencharacterized, and there are a great manythat we do not yet know. Of these fewthousand, only 1-2% are used forcommercial applications and only ahandful are used on a large scale.Bysimulating the biochemical reactions, the enzymes can be produced in larger quantities and in the long term, can be used in industry [36].

In enzyme technology newprocesses have been and are being developed to manufacture both bulk and highadded-value products utilizing enzymes as biocatalysts, in order to meet needssuch as food (e.g., bread, cheese, beer, vinegar), fine chemicals (e.g., amino acids,vitamins), and pharmaceuticals. Enzymes are also used to provide services, as inwashing and environmental processes, or for analytical and diagnostic purposes[37].

Biomass-degrading enzymes are one of the most costly inputs affecting the economic viability of the biochemical route for biomassconversion into biofuels. It is extremely important that the new sustainableenergy sources developed reduce our relianceon fossil fuels for our major energy needs.Bioenergy, in the form ofbiofuels, can contribute to economic development andto the environment [38].

Life cycle assessment study [39], showed that, as compared to classical chemical sludge, enzymes can reduce by ten times the impact on global warming, reduce by a factor of two the impact on the ozone layer, reduce by a factor of three the impact on abiotic (non-living) components in the environment and decrease by a factor of three the impact on marine toxicity

Enzymes have application in a variety of areas including food biotechnology, environment, animal feed, pharmaceutical, textile, paper and others technical and chemical industries.Due to the large industrial application and significant cost, there is a necessity to develop processes able to minimize the production costs [40].

A brief positive influence by enzymes have a on the environment illustrating the sustainability of enzymes for societal development can be described as-

- Enzymes save energy.

- Enzymes play a vitalrole in developing alternative bio-based fuels.
- Detergent enzymes make it possible to achieve good wash results at lower temperatures.
- Many enzymes find applications in the food industry.
- Enzymes degrade protein and fat in tanning and leather industry.

CONCLUSION:

The potential of solid state fermentation in converging agro- industrial residues into value added products is immense. Enzymes are the solution to replace traditional means of meeting industry needs. The cost effective, environment friendly enzymes helps towards more sustainable industrial development.To meet energy and material needs in sustainable way enzymescan be a tool enabling conversion of variety of feedstock for worth industrial production.

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