REALITIES, POTENTIAL AND LIMITATIONS OF SSF INDUSTRIAL APPLICATIONS

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Introduction. Solid State Fermentation (SSF) can be defined as a microbial process where the organisms grow as a thin layer on, or within, a solid support structure having a specific area in the range of 100/cm, exposed to an aerial inter-phase, supplied with a nutrient source and with high enough water activity to foster microbial growth. This departs from the conventional definition of a microbial culture grown on a substrate support without free water in order to encompass SSF processes on thin layers of water dispersed within polymer matrices, such as, polyurethane foam. Here, a brief review is presented on the potential or present industrial applications of SSF processes in the fields of bio-pesticides, bio-pharmaceuticals, food enzymes and bio-refineries.

Methods. A bibliographic review was done, including scientific papers, patents and commercial internet sites with emphasis in the most cited and applied knowledge of SSF industrial applications. Patent literature was reviewed using network analysis with Matheo licensed program. Network analysis of scientific literature was done using ISI-Web software. Current proposals of SSF industrial application were sieved using a rough cost-benefit analysis.

Results. It was found that the major present fields of SSF industrial application are the production of, bio-pesticides, crude enzyme preparations for food and feed formulation and bio-pharmaceuticals, mainly in the field of statins, as well as large scale composting technology. But most cited SSF publications are in the field microbial digestion of lingo-cellulosic fibers for the production of feed-stocks for future bio-refineries. A new potential SSF application is the production of recombinant proteins using the unique proteomic patterns of SSF fungal cultures. In example, using special induction signals and promoters of excreted enzymes that are unique to SSF cultures of *Aspergillus* species. Preliminary cost-benefit analysis of potential applications indicates the need to use the integrated approach between fermentation, product recovery and final use in order to have sustainable industrial processes.
Most popular approach to the production of fungal spores as bio-pesticides agents involves the use of the artisanal plastic bag technique, precluding on-line process control of critical variables such as gas composition, humidity and temperature. This seems to explain the low quality and commercial failure of bio-pesticide production in the Third World.
Most research papers on enzyme production by SSF technique do not take into account the need of speciallized mutant strains with very high enzyme titers (> 10^6 U/Kg). Hence, the lack of proper strain development is a major hindrance for enzyme SSF technology transfer.
Present applications of enzyme production by SSF involve the use of crude extracts, either wet (koji type) or oven dry, to prevent enzyme dilution and reduce or eliminate purification costs. Therefore, enzyme SSF seems most useful when crude preparations are better than pure enzymes. For example, when enzyme synergy is a bonus for substrate breakdown. This could be an interesting area of R&D for bio-refineries where ligno-cellulosic fibers ought to be partially hydrolized. In this case, engineering of the integrated process should be considered instead of only considering the fermentation step. Also, advanced composting technology involves the use of “natural” microbial consortia with material recycling and aireation and temperature control through periodic mixing. Combination between anaerobic digestion and composting is becoming a competitive approach for large scale breakdown of organic wastes.
Development of recombinant protein production by SSF requires the use of present design considerations, plus the appropiate genetic engineering of competitive strains with submerged fermentations. For example, production of chymosin using special mold strains geared to produce high titers, using solid substrates compatible with cheese making.
Patent analysis shows that the key seminal patents of SSF reactors, such as Plafractor, as well as the genomes of *A. niger* and *A. oryzae*, are now in the public domain. Thus, this is the beginning of a race to assimilate and adapt existing industrial SSF industrial technology to the needs of many developing countries.

Conclusions. Present survey indicates the importance of mass, energy, economic and patent analysis of integrated SSF processes in order to identify the best way to transfer present R&D results to industrial applications. Special attention should be paid to the physical and biological constraints of SSF for static (tray) cultures or stirred reactors. It seems crucial to consider the proper design of product recovery and final commercial application in order to avoid unnecessary waste treatment or purification costs.

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