ISSN (Online): 2455-7838
SJIF Impact Factor (2016): 4.144

EPRA International Journal of

Research & Development

(IJRD)

Monthly Peer Reviewed & Indexed International Online Journal

Volume:1, Issue:10,December 2016

Published By :
EPRA Journals

SJIF Impact Factor: 4.144 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)
Volume: 1 | Issue : 10 | December | 2016

BIOCONVERSION OF WASTE FEEDSTOCK INTO USEFUL PRODUCTS: AN INSIGHT INTO RECENT STUDIES AND INVESTIGATIONS

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ABSTRACT

Biochemical engineering and biotechnology has wide scope in the synthesis of various fine chemicals, drugs, intermediates, compounds. The production of compounds by using chemical synthesis methods has disadvantages such as energy requirement and environmental footprints. Biotechnology is helping tool for synthesizing many of these chemicals by environmental friendly and energy effective way. The use of raw and waste feedstock in the synthesis of products like ethanol, citric acid, lactic acid, amino acids, oxalic acid etc. has encouraged the researchers to investigate the synthesis of many such products. This approach finds wide acceptance as it helps in solving the solid waste issues along with synthesis of useful products. Many investigators have carried out research on synthesis of various compounds from raw feed stocks. These were mainly aimed at studying kinetics of the reactions involved and effect of various parameters on the synthesis process. The current review summarizes some significant investigations carried out in the recent past on biological and biochemical production of compounds.

KEY WORDS: *Yield, enzyme, fermentation, biodegradation, feedstock.*

1. INTRODUCTION

The chemical and biochemical engineering deals with synthesis of various chemicals and compounds in economical and environmental friendly manner. The processes used for production of compounds may involve physical, chemicals or biological changes in the raw materials. Many synthesis methods used in chemical pathways are energy intensive and cause environmental problems such as high temperature discharge and polluted effluent discharge. Many compounds such as amino acid, ethanol, lactic acid, oxalic acid, citric acid, vinegar etc. can be manufactured by using waste feed stocks [1-7]. Use of enzyme catalyzed reaction is also being explored for more and more products [8-14].

Immobilization of enzyme can help to reduce the efforts as it increases yield of the products [15-20]. Biocatalysts and enzyme catalyzed reactions are important areas of investigation. Many investigators have carried out research on synthesis of various compounds from raw feed stocks. These were mainly aimed at studying kinetics of the reactions involved and effect of various parameters on the synthesis process. The current review summarizes some significant investigations carried out in the recent past on biological and biochemical production of compounds.

2. BIOCONVERSION OF WASTE FEEDSTOCK INTO USEFUL PRODUCTS

Azam et.al. used Aspergillus niger and Saccharomyces cerevisiae for production of single cell protein from orange peels[21].They used orange peels as carbon source for the two strains. They carried out solid state fermentation for Aspergillus niger and submerged fermentation for Saccharomyces cerevisiae. They obtained the product with high protein content. Mondal et.al. utilized fruit waste for synthesis of single cell protein[22]. According to them, the bioconversion of fruit waste to single cell protein has the potential to solve the worldwide food protein deficiency. They evaluated the use of cucumber and orange peels or the production of single cell protein using Saccharomyces cerevisiae by submerged fermentation. They observed that these wastes were susceptible to hydrolysis. They found that cucumber peel generated higher amount of protein with 53.4 percent crude protein while orange peels produced 35.04 percent crude protein. By growing the strain on supplemented fruit hydrolysate medium yielded only 17.47 percent single cell protein. It was also observed that glucose addition to the supplemented fruit hydrolysate medium enhanced the protein content (60.31%) within the yeast cell.

Themelis and Kim investigated the aerobic bioconversion of organic wastes [23]. In their research, they estimated the preferred values of operating parameters and of the biochemical rate constants of oxidation to CO_2 and H_2O. According to these studies, compared to the heat released by oxidation, conduction/ convection and radiation losses to the surroundings amounted to a relatively small fraction. They employed an upward water-saturated airflow for removal of excess heat. Their study indicated the key difference in anaerobic and aerobic bioconversion of organic matter. They concluded that in anaerobic bioconversion most of the chemical energy in the converted organic matter is stored chemically in the generated methane gas. In case of anaerobic bioconversions, energy is released in the cell. It is necessary to carry out aerobic bioconversion in a relatively large air/water vapor flow through the cell.

Petre et.al. investigated submerged fermentation[24]. They carried out microbial composting of fruit tree wastes. The aim of their experimentation was to establish the ecological valorising of organic compounds. They carried out experimental investigation to estimate the optimal needs of bacterial and fungal pure cultures to grow inside different marc made of apple, cherry and plum wastes. They investigated affecting factors such as chemical composition, temperature, pH, oxygen/carbon dioxide concentration. They found that the optimal temperatures were registered between 23-25°C. The corresponding initial pH levels were observed to be 4.5 to 6 and agitation speed was 30-90 rpm.

Arumugam and Manikandan investigated fermentation of pretreated hydrolyzates of banana and mango fruit[25]. They carried out this hydrolysis for production of ethanol. They carried out the analysis to determine the chemical composition of these two materials. This analysis provided the potential of these two fruits to synthesize ethanol. They found that the methodology with dilute acid pretreatment followed by enzymatic saccharification of mixed fruit pulps (banana and mango) and the banana fruit peels was best for higher ethanol production. M. Petre and V. Petre studied environmental biotechnology for bioconversion of agricultural and forestry wastes into nutritive biomass [26]. They used Ganoderma lucidum (Curt. Fr.) P. Karst, Lentinula edodes (Berkeley) Pegler and Pleurotus ostreatus (Jacquin ex Fries) Kummer as pure strains in their investigation. They carried out experiments with three repetitions. They found that submerged fermentation of barley bran exhibited high percentage of dry matter content of fungal biomass produced.

Inacio et.al. carried out biotransformation of orange waste by oyster mushroom [27]. They also synthesized some enzymes in their investigation. According to these studies wood decay fungi was able to bioconvert a wide variety of lignocellulosic residues. This, according to them was due to the secretion of extracellular enzymes. Amaeze et.al. carried out an investigation on cellulase production by aspergillus niger and saccharomyces cerevisiae[28].They used fruit waste as substrate. The fruit waste they used contained pineapple and orange peels (fruit wastes).They also studied the effects of pH, temperature and substrate concentrations in the enzymes activity. They also compared Cellulase activity and amount of glucose produced by the test organisms. They observed optimal cellulase secretion achieved on day 5 with A. niger.

Petre et.al. carried out an investigation on producing of natural fertilizers[29]. They carried out microbial composting of fruit wastes. They estimated optimal needs of bacterial and fungal pure cultures to grow inside different marc made of apple, cherry and plum wastes. They studied the parameters like chemical composition, temperature, pH, oxygen/carbon dioxide concentration. They used pure bacterial cultures of Bacillus genus and the fungal ones. They found that an increasing of reducing sugars was correlated with an increasing of protein content. They observed that optimal conditions for both bacteria and mycelia cultures to produce microbial biomass through controlled submerged fermentation as mono- and co-cultures were, temperature between 23–25 °C, corresponding to initial pH levels of 4.5–6.0 and the agitation speed was tested in the range of 30-90 rpm.

C. Berde and V. Berde investigated the potential of vegetable waste as a culture media [30]. They tested composition of the media and the efficiency of the media to support microbial growth. Their research indicated that the medium supported growth of bacteria, fungi and yeast. They found that growth was comparable to that obtained on routine commercial media. Bekmuradov carried out an investigation on bioconversion process of source-separated organic(SSO) waste for ethanol production[31]. They investigated the factors such as enzyme savings, sugar formation and ethanol yields. Also they developed experimental kinetic model capable of predicting behavior of batch source-separated cellulose fractionation, SSCF on SSO waste with different SSO substrate concentrations. They observed that SSO was an excellent feedstock material for ethanol conversion. They also observed that, compared to standard method using ethanol washing of pretreated SSO samples, the efficiency of modified COSLIF pretreatment was better by 20%. Also their model prediction at higher substrate concentration indicated that ethanol inhibition was a major factor in bioethanol conversion.

Hachemi et.al. carried out an investigation on bioconversion of orange wastes for pectinase production[32]. They used aspergillus niger under solid state fermentation. They used complete factorial design approach to investigate the factors namely content of ammonium sulfate, glucose and water in the culture medium and particle size of dry orange waste.They employed ion exchange chromatography to isolate a polygalacturonase (PG).They found that apple juice treatment with purified enzyme extract yielded a clear juice. This juice was at par with juice yielded by pure Sigma Aldrich Aspergillus niger enzyme.

Petre et.al. used bacterial and fungal cells immobilized in radiopolymerized hydrogels for biodegradation and bioconversion of cellulose wastes using bacterial and fungal cells[33].They studied continuous enzymatic activities of immobilized bacterial and fungal cells as improved biotechnological tools. These tools were employed for the biodegradation of redundant cellulose wastes from agriculture and food processing. The cellulose wastes were biocomposted to produce natural organic fertilizers and single-cell protein(SCP). By using multi-flatted bed design of the culture vessel, they were able to achieve a significant increase in the contact surface between the immobilized fungal cells and the cellulose substratum.

Boula et.al. used date palm fruit waste fermentation with solar energy for production of bioethanol[34]. They obtained 33% efficiency in their studies. According to them, it is possible to valorise the common date-palm waste (CDPW) by bioconversion. Raikar used grape waste for enhanced production of ethanol [35]. They used Saccharomyces cerevisiae (baker's yeast) and Benzyl penicillin. In their investigation, they studied effect of various parameters such as pH, Benzyl penicillin, temperature, initial sugar concentration and specific gravity on the quantity of ethanol produced. They observed that, with the progress of fermentation, the ethanol production increased. This was indicated by decrease in specific gravity. Acidity and aldehyde contents of distillate were low enough to consider ethanol produced for various purposes. Ezejiofor et.al. reviewed waste utilization for recovery and conversion into valuable products [36]. It is always envisaged to manage the waste from the unpleasant consequences of their accumulation. According to their review most of the agro-waste or agro food industry waste can be reused as raw material in some or other form. Their review discussed resources recoverable from agro-food wastes using the tool of biotechnology.

Wadhwa and Bakshi studied the use of fruit and vegetable wastes as livestock feed[37]. They used these materials for substrate generation for synthesis of value-added products. According to their studies many of the fruit wastes are rich in nutrient content. These fruits wastes can be used very effectively for fed after drying or ensiling with cereal straws, without effecting the palatability, nutrient utilization, health or performance of livestock. Value products such as essential oils, polyphenols, anti-carcinogenic compounds, edible oil, pigments, enzymes, bio-ethanol,bio-methane, bio-degradable plastic, single cell proteins etc. can be synthesized from these wastes. According to them effective utilization of fruit waste can minimize the animal food cost. Also production of value added products adds to the economy of the plant or process.

Kandari and Gupta carried out an investigation on synthesis of viable products from vegetable and fruit peel wastes[38].Their study suggested that it was feasible to use the fermentative production of alcohol and biomass (SCP). Papaya peels were found to be best for alcohol production followed by banana and apple peel extract. They observed that almost 96 percent of sugar out of the total convertible sugar was converted to yield biomass in batch submerged fermentation. They also found that the carbohydrate content was much lower than recorded value of market yeast. Fruit of beles (opuntia ficus-indica l.) peels were used for production of single cell protein by Haddish[39]. They studied feasibility of using Beles fruit peels (the remained wastes of cactus pear fruit which is common in northern Ethiopia, Tigray region) for Saccharomyces cerevisiae production. They also evaluated the protein quality of produced single cell protein (SCP) biomass. They used submerged fermentation for production of single cell protein. In their investigation, they found that for 100 gm of substrate, Beles fruit peels generated 51.1% and 27% crude carbohydrate and crude protein, respectively. Supplemented Beles fruit peels hydrolysate medium, when combined with added glucose, exhibited enhanced the protein content(63.5%).

Petre et.al. carried out an investigation on bioconversion of fruit tree wastes into nutritive biomass[40]. They used mushroom cultures of Ganoderma lucidum, Grifolafrondosa and Lentinula edodes, and the culture substrates.The juices and pulps of the industrial processing of apples, cherries and plums were used to obtain these cultures. They carried out the submerged fermentation inside the culture vessel of an automatic laboratory-scale bioreactor. The high contents of mushroom biomass in carbohydrates and proteins were obtained in the investigations.

Khan et.al. investigated the possibility of use of fruit waste for manufacture of production of single cell protein[41]. They carried out comparative studies on use of various fruit wastes such as banana skin, mango waste, sweet orange peel, rind of pomegranate and apple waste. They observed that banana skin generated highest amount of protein, followed by that of rind of pomegranate, apple waste, mango waste and sweet orange peel. The SCP production, in this case was cheaper as no supplements such as inorganic nitrogen sources, carbon and glucose sources were used to grow S. cerevisiae on fruit wastes. For rind of pomegranate, maximum protein content of 54.28 percent was obtained whereas minimum protein content of 26.26 percent was achieved for sweet orange peel.

Vikas and Umesh used acetobacter aceti for bioconversion of papaya peel waste in to vinegar [42]. They carried out the fermentative production of vinegar using the discarded papaya peel waste. They also carried out precise analysis of nutritive composition in the peels before fermentation. They found in the analysis that moisture content of papaya peel waste was 75.13 percent. They obtained 8.11 percent alcohol content in anaerobic fermentation. It was revealed from this research by Vikas and Umesh that dilute acid hydrolysis resulted in the conversion of complex sugars in the papaya hydrolysate in to simpler fermentable sugars. Manuel et.al. extracted ferulic acid from agro-industrial wastes[43]. Further, they also carried out bioconversion of ferulic acid to vanillin by streptomyces setonii. The agricultural materials evaluated for feuric acid manufacture were chestnut and pistachio shells, grass, leaf fruit, vine leaf, and, red and white grape stems. They also extracted other phenolic compounds such as gallic acid, p-coumaric acid, syringic acid etc. from this lignocellulosic biomass.

Dhanasekaran et.al. investigated the conversion of pineapple waste into single cell protein using yeast[44]. They cultivated two strains of yeast namely saccharomyces cerevisiae and candida tropicalis. In their investigation, they observed the biomass yield and the protein formation within the yeast cells at different concentrations of pineapple hydrolysate. They found that the conversion of pineapple to SCP from cheap, inexpensive agro waste material was promising method for waste minimization and utilization. Lim et.al. explored the potential bioconversion of empty fruit bunches into organic fertilizer[45]. They investigated the suitability of oil palm empty fruit bunches as feedstock of Eudrilus eugeniae. They investigated parameters such as pH and electrical conductivity. Empty fruit bunches were mixed with cow dung and converted into fertilizers. They concluded that, if the fruit bunches are mixed with cow dung in appropriate ratios, vermicomposting could be used as an efficient technology to convert empty fruit bunches into nutrient-rich organic fertilizers.

Vishwakarma et.al., in their experimentation studied production of ethanol from fruit wastes[46]. They found that the optimal conditions for ethanol production from fruit waste were pH 5.5, temperature 32°C, specific gravity 0.865, conc. of about 6.21%. Survase converted agro waste into edible protein rich mushroom by using pleurotus sajor caju (fr.) singer [47]. They cultivated Pleurotus sajor on the different agricultural wastes (substrates) singly. The agricultural raw materials, they use were wheat straw, paddy straw, soybean straw, pigeon pea straw and green gram straw or combine with Wheat + soybean, Wheat + pigeon pea, wheat+ green gram (1:1) and wheat alone. Wheat + pigeon pea were having maximum protein content of 29.45 percent. In the raw materials used the protein content was in the range 25 to 30 percent.

3. CONCLUSION

Many synthesis methods used in chemicals pathways are energy intensive and cause environmental problems such as high temperature discharge and polluted effluent. Biotechnology is helping tool for synthesizing many of these chemicals by environmental friendly and energy effective way. Many compounds such as amino acid, ethanol, lactic acid, oxalic acid, citric acid, vinegar etc. can be manufactured by using waste feed stocks. The bioconversion of fruit waste to single cell protein has the potential to solve the worldwide food protein deficiency. The conversion of pineapple to SCP from cheap, inexpensive agro waste material was promising method for waste minimization and utilization. Submerged fermentation of barley bran exhibited high percentage of dry matter content in the fungal biomass produced.

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