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Enzymes as Biocatalysts: Review on Investigations on Synthesis, Mechanism, Kinetics, Applications and Potential

Sunil Kulkarni [1,*]

[1] Gharda Institute of Technology, Lavel, Maharashtra, India
* Correspondence: suniljayantkulkarni@gmail.com;

Scopus Author ID 57209247314

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Abstract: Sustainable development is becoming the goal of many investigations carried out in chemistry and chemical engineering. Because of the waste generated by chemical reactions, there is a shift from traditional thinking about the catalyst's yield, selectivity, efficiency, and effectiveness. Mild, low temperature, highly selective alternative was found in biological reactions. Biocatalyst application fulfills the two important requirements. It does not deplete natural resources and does not have any significant environmental footprints. Modeling of biological reactions is a very important area of investigation on enzyme-catalyzed reactions. Monod and Moser growth kinetics can be applied to cell growth and substrate utilization. The discovery of new enzymes and optimization of the synthesis and application methods for biocatalysts are being investigated widely for better and industrially applicable technologies.

Keywords: yield; selectivity; kinetics; catalysis; sustainable development; resources.

1. Introduction

Cells are the basic building blocks of our bodies. Cells can utilize enzymes. The enzymes have amazing catalytic power and high specificity [1]. Side reactions and by-products are rarely produced in biological or enzyme-catalyzed reactions [2]. The quantity of enzymes required is very small compared to the substrates, and they remain completely unchanged in the reaction [3]. Michalis Menten Kinetic equations form the basis for many investigations on enzyme kinetics [4]. Sustainable development is becoming the goal of many investigations carried out in chemistry and chemical engineering [5]. Because of the waste generated by chemical reactions, there was a shift from traditional thinking about the catalyst's yield, selectivity, efficiency, and effectiveness [6,7]. Mild, low temperature, highly selective alternative was found in biological reactions. The biocatalyst application fulfills the two important requirements. It does not deplete natural resources and does not have significant environmental footprints [8, 9]. Many biological methods can synthesize many products, such as single-cell proteins, ethanol, vinegar, glucose, amino, and lactic acids [10-20]. Modeling of biological reactions is a very important area of investigation on enzyme-catalyzed]reactions[21]. Monod and Moser growth kinetics can be applied to cell growth and substrate utilization [22, 23]. Many times, it becomes necessary to form a new model based on the mechanism of adsorption [24]. Bacterial growth kinetics can also provide insight into

biochemical reactions [25]. Better results can be obtained by investigating various sources of carbon [26].

2. Biocatalysts: Advantages and Uses

Biocatalysts can be used for many fermentation, reduction, decomposition, and other reactions [26-31]. The production of chiral 2-hydroxyalkylphosphonate esters can be carried out by reducing cyanobacteria as biocatalysts [26]. Optically pure phosphonates can be synthesized by biochemical enzymatic reactions [27]. Biocatalyst processes are accepted widely in pharmaceutical and fine chemical synthesis. High specificity is an advantage in these applications. Proper design and control strategy is a very important aspect of biocatalyst synthesis and applications as these biocatalysts are very sensitive [28]. Biocatalysts are very effective in stereoselective applications, also [29]. Aspects such as limited commercial availability, thermal instability, limited range of substrates, and poor stereoselectivity put limitations on the application of biocatalysts for such applications [30]. The discovery of new enzymes and optimization of biocatalysts' synthesis and application methods is investigated widely for better and industrially applied technology [31]. Different techniques of enzyme immobilization have also been studied by various investigators for studying effectivity [32-36].

3. Investigations on Enzyme Synthesis by Efficient Pathways

Research work on green synthesis and enzyme kinetics is summarized in Tables 1 and 2, respectively. Proteins carry out a variety of functions like transport, storage, support, and antibodies. Proteins also act as an enzyme in many reactions. For enzyme or biocatalyst, selectivity and volume efficiency are very important properties [37]. For the synthesis of glycosides, enzymatic pathways offer a better option by overcoming the limitations of the chemical synthesis method. Immobilization by a suitable method such as adsorption can be very effective for efficiently using enzymes in biochemical reactions. Adamczak and Krishna investigated the improvement of enzymes for efficient biocatalysts [38]. Bio-catalysis has a wide scope in the pharmaceutical and agrochemical industries. Excellent results are obtained by the application of gene encoding for enzymes. Improvement in the activation methods and microbial screening has resulted in novel enzymes resulting in new biocatalysts pathways for different properties. Barbosa *et al.* investigated lipase immobilization [39]. They used Mesoporous silica as support for the biocatalyst. They observed that when modified by the protic ionic liquid, the yield and operational stability increased. According to this investigation, lipase immobilized into silica aerogel by encapsulation methods showed the best immobilization technique.

Enzyme deactivation or a dramatic drop-in catalytic activity may occur because of the use of organic solvents and harsh operating conditions [40]. Detailed molecular understanding and study can help to address such limitations. It is possible to finetune the catalyst by modifying the solvent, the support, or the enzyme's active site. DNA recombination can be used to enhance the catalytic properties of the enzyme. The biocatalyst system should be reusable for an effective process. So, in addition to stability and active nature, reusability is an important aspect of biocatalyst [40]. Preparation of magnetic biocatalyst is also reported [41]. Magnetically assisted bioprocesses can improve the production of biodiesel. Neumann *et al.* investigated surface properties and energetic properties of *Pseudomonas putida* in a two-phase

fermentation process [42]. They used the organic solvent 1-decanol(10 %) as the medium. Their investigation measured the cell surface hydrophobicity and charged in the presence and absence of 1-decanol. Growth rate and growth yield were affected due to n the presence of 1-decanol.

In the synthesis of various products by biochemical and enzymatic pathways, modernization and sophistication of the processes are important aspects [43]. For the production of many products such as biofuel, waste materials and by-products can be utilized as starting materials. Bio-catalysis is an environmentally friendly process. Such processes are a strategic choice in the modern economy than the only green alternative. These processes are environmentally friendly and safer. Crude liquid residues such as molasses, glycerine, and cassava residues can be used in submerged fermentation. Solid residues can be used as a cheaper culture media for solid-state fermentation [43]. Biocatalysts are very useful in effluent treatment also. Selective removal of compounds in effluent treatment can be facilitated by using a suitable biocatalyst. According to Chapman *et al.*, a multidisciplinary approach is required to develop immobilized biocatalysts [44]. They emphasized that enzyme immobilization can improve industrial processes. Catalysis can be improved in terms of activity and stability across a broader range of operating conditions by applying the immobilization technique. Immobilization techniques like carrier-bound attachment, encapsulation or entrapment, and the formation of cross-linked enzyme aggregates can increase the yield and selectivity. Smith *et al.* discussed the cell surface display method for novel and improved biocatalysts [45]. Many limitations in enzyme purification and substrate transport can be overcome by the surface display method.

Table 1. Research for enzymes for green synthesis.

Sr.No.	Authors	Details
[4]	Johnson, K. A.; Goody, R. S.	The authors translated the original Michaelis and Menten paper. In doing so, they observed that Michaelis and Menten analyzed initial velocity measurements and fit their full-time course data to the integrated form of the rate equations.
[5]	Sheldon, R.A.; Woodley, J.M.	The authors revealed that it is possible to develop enzyme transformations that can fit the predefined parameters, making it truly useful for sustainable design.
[6]	Sheldon, R. A.	The author discussed the fundamentals of green and sustainable chemistry principles in the context of organic synthesis.
[7]	Sheldon, R. A.	The author discussed the role of green chemistry in organic synthesis.
[8]	Graedel, T. E.	The author emphasized the importance of sustainable methods for the synthesis of organic compounds.
[9]	Oxford University Press	A report was prepared by the World Commission on Environment and Development about environmental decay, poverty, and hardship; also about the depletion of resources and increasing pollution.
[10]	Kulkarni, S.J.	The author discussed the increasingly important role of biotechnology in synthesizing various fine chemicals, drugs, intermediates, and compounds.
[11]	Kulkarni, S.J.	The author discussed the role of enzyme production of citric acid. According to him, Citric acid can be manufactured using various raw materials such as fruit peel, molasses, and other waste feedstock. He discussed literature on the use of various feedstocks such as molasses, fruit peel waste, corncob, and other waste material with appropriate enzymes.
[12]	Ramachandran, V.; Nisha Pujari, N.; Tanmay Matey, T.; Kulkarni, S.	The authors explored different sources of amylase enzymes like rice, maize, sorghum, and wheat and analyzed optimum germination and subsequent hydrolysis conditions.

Sr.No.	Authors	Details
[13]	Ramachandran, V.; Pujari, N.; Matey, T.; Kulkarni, S.	The authors studied enzymatic hydrolysis of cassava using wheat seedlings. They investigated the effects of various parameters on the quality of glucose syrup.
[14]	Kulkarni, S.J.	The author highlighted the role of enzyme technology in the synthesis of various products from various waste feedstocks.
[15]	Kulkarni, S.J.; Shinde, N.L.; Goswami A.K.	Ethanol production from agricultural waste raw materials like potato waste, molasses, banana waste, waste food grain, etc., was discussed. The review highlighted that enzymatic hydrolysis is the most potent alternative process for saccharification of complex polymer.
[16]	Bekmuradov, V.	The author investigated standard and modified cellulose organic-solvent-based lignocellulosic fractionation for source-separated organic waste. The modified method was 20 percent more effective.
[19]	Wadhwa, M.; Bakshi, M.P.S.	The authors pointed out that the key to the development of sustainable feedstock lies in the use of readily available feedstock and the development of sustainable processes with minimum waste generation.
[20]	Vishwakarma, H.S.; Kumar, A.; Singh, J.; Dwivedi, S.; Kumar, M.	Ethanol was synthesized from fruit wastes by using Saccharomyces Cerevisiae. Optimum temperature and pH were observed to be 32°C and 5.5, respectively.
[21]	Kulkarni, S.J.	The author discussed the modeling of biological reactions. He discussed investigations on enzyme kinetics. Kinetics of substrate utilization and cell growth can be modeled by Moser and Monod like kinetic equations.
[31]	Robertson, D.E.; Steer, B.A	According to the authors, enantiomerically pure fine chemicals and the movement away from chemically burdened technologies are driving factors for the rapid acceptance of enzyme-catalyzed processes.
[40]	Osbon, Y.; Kumar, M.	The authors discussed enzyme improvement technologies and highlighted their limitations and advantages in real-world technological applications.
[41]	Rodrigues, P.M.; David, G.F.; Ferreira, P.R.; Delatorre, A.B.; Teixeira, V.F.T.; Cubides, D.C.; Pereira, N.C.;Perez, V.H	The authors discussed the synthesis and application of biocatalysts with magnetic properties.
[42]	Neumann, G.; Cornelissen, S.; van Breukelen, F.; Hunger, S.; Lippold, H.; Loffhagen, N.; Wick, L.Y.; Heipieper, H.J.	The investigation established that *putida* DOT-T1E as the biocatalyst and 1-decanol as the solvent is a stable system for two-phase biotransformations
[124]	Jeandet, P.; Sobarzo-Sánchez, E.; Silva, A.S.S.; Clément; Nabavi, A.F; Battino, M., C.; Nabavi, A.F; Battino, M.; Rasekhian, M.; Belwal, T.; Habtemariam, S.; Koffas, M.; Nabavi, S.M.	The authors examined various approaches for the synthesis of potential pharmacological resveratrol derivatives

Table 2. Research on enzyme kinetics.

Sr.No.	Authors	Details
[23]	Liu , Z.; Li, X.	The authors established a new model for the kinetics of ethanol fermentation.
[24]	Van Den Wijngaard, A.; Richele, W.; Dick, J.	In this investigation, the kinetics of bacterial growth on chlorinated aliphatic compounds was studied. It was found that chlorinated compound removal efficiency was influenced by the first catabolic enzyme's kinetic properties and cellular content.
[25]	Muthuvelayudham, R.; Viruthagiri, T.	Fermentative production and kinetics of cellulase protein on *Trichoderma reesei* were studied for various carbon resources. Maximum enzyme activity was observed on cellulose with lactose and bagasse with xylose.
[26]	Monika Gorak, M.; Żymańczyk-Duda, E.	Investigators used autotrophic microorganisms as a biocatalyst for the reduction of oxoalkylphosphonates.
[27]	Rodak, M.B.	A wide range of enzymatic activities was observed towards a number of non-physiological substrates.
[28]	Kaushik, N.; Biswas, S.; Singh, J.	The authors discussed aspects like scope and types of biocatalysts, their application, reuse, screening technics.
[29]	Kulkarni S J	The author has summarized research on the analysis and properties of oxalic acid. Also, its synthesis from low-

Sr.No.	Authors	Details
		cost feedstocks, removal from water, and its different applications were discussed.
[30]	Kinfe, H.H.; Chhiba, V.P.; Frederick, J.; Mathiba, K.; Brady, D.	Applications of stereoselective biocatalysts for the enantiomeric resolution of beta-hydroxy nitriles were investigated.
[43]	Ferreira-Leitão, V.S.F.; Cammarota, M.C.; Aguieiras, E.C.G.; Vasconcelos de Sá, L.R.; Fernandez-Lafuente, R.; Freire, D.M.G.	The utilization of renewable resources for enzymatic processes was discussed. The role of enzymatic processes to support sustainability was also highlighted.
[47]	Contois, D.E.	The relationship between population density and the specific growth rate of continuous cultures was discussed for the bacterial growth kinetics.
[48]	Olaoye O.S.; Kolawole O.S.	A non-structured model was applied to the kinetics of ethanol formation from glucose biomass in batch culture.
[49]	Rao, G.V.R.S.; Murty, K.S.; Nagendra B. D.	A fluidized bed bioreactor was used for COD and BOD removal from domestic sewage. The kinetics of removal was studied.
[50]	Prakash, N.B.; Sockan, V.	Tannery effluent was treated biologically to study decomposition and evaluate kinetic parameters.

4. Biocatalysts: Enzyme Kinetics and Substrate Utilization

Many investigations on enzymes are focused on kinetics, as listed in Table 2. The oxygen uptake rate method was studied by Toretta *et al.* [46]. They studied biological kinetics in a conventional municipal wastewater treatment plant [46]. In their investigation, they observed that the kinetic parameters were in agreement with the literature ranges. The kinetics of bacterial growth was investigated by Contois [47]. He studied the effect of population density upon specific growth rates of bacterial populations. Olaoye and Kolawole [48] investigated ethanol formation from glucose biomass in batch culture. Their investigation indicated that the Logistics model and Gompertz model described experimental data. They neglected the inhibitory effects of the substrate. Rao *et al.* used a fluidized bed bioreactor to remove biological oxygen demand, BOD, and chemical oxygen demand, COD [49]. According to this investigation, the bio-kinetic reactions taking place in the reactor confirm the first-order rate of equations. Prakash and Sochan treated tannery wastewater [50]. They investigated biotransformation reactions during anaerobic decomposition. They observed that the BOD reduction could be increased by proper maintenance of the required alkalinity.

5. Some Advanced Investigations on Enzymes

In the synthesis of antibacterial agents, heterogeneous biocatalysts were investigated by Afridi *et al.* [51]. They synthesized a superparamagnetic folic acid-coated nanocomposite as a catalyst. Many investigations have reported on magnetite-supported catalysis [52,53]. Synthesis of nanoparticles and nanomaterials has also been reported by using biocatalysis [54]. As biological methods are environmentally friendly and sustainable, attempts are being made to synthesize nanomaterials by biological methods [55, 56]. Enzyme inhibitors affect enzyme activity. Investigations on enzyme inhibitors are a very important part of biocatalyst studies [57-59]. Tables 3 and 4 provide a summary of studies and investigations on immobilization and inhibition, respectively.

Many investigations are carried out on the preparation, analysts, and effect of enzymes on biological reactions and exploring the possibility of replacing chemical pathways with enzymatic ones [60, 61]. However, according to Dua, the validity of Michaelis–Menten (MM) expression is limited to macroscopic amounts of enzymes and substrates [62].

Table 3. Investigations on Enzyme Immobilization.

Sr.No.	Authors	Details
[17]	Petre, M.; Zarnea, G.; Adrian, P.; Gheorghiu, E.	Biodegradation of cellulose wastes was carried out using bacterial and fungal cells immobilized in radiopolymerized hydrogels. The study emphasized the importance of the physical structure and chemical properties of such polymeric matrices used to preserve their metabolic activity.
[32]	Kulkarni, S.J.	Various methods of enzyme immobilization were discussed, and investigations on enzyme immobilization were summarized by the author.
[33]	Kulkarni, S.J.	Synthesis of vinegar from various feedstocks was discussed. The role of enzymatic processes was underlined in the production of vinegar-like products.
[34]	Nawani, N.; Singh, R.; Kaur, J.	An investigation was carried out on immobilization and stability studies of a lipase from thermophilic *Bacillus* sp. Various methods to increase thermostability were applied and compared.
[35]	Ding, L.; Yao, Z.; Li, T.; Yue, Q.; Chai, J.	The authors investigated papain immobilization on a macroporous polymer carrier.it was observed that the immobilized papain by this method had higher activity recovery, remarkable stability, better reusability, and environmental adaptability
[36]	Abdelmajeed, N.A.; Khelil O.A.; Danial, E.N.	Investigators discussed various methods for immobilization for enhancing the bio-products industry. It was reiterated that immobilization technologies are very useful in bi-product synthesis.
[37]	Nair V.K.; More M.K.; Sawant J.J.; Thikekar V.P.;, Philip P.A.;Ojha M.D.; Gomase V.S.	The use of proteins as biocatalysts and biomaterials was discussed. The authors also discussed the discovery and development of extremophilic enzymes and industrial enzymes.
[38]	Adamczak, M.; Krishna, S.H.	The gene encoding a particular enzyme was found to yield excellent results.
[39]	Barbosaa, A.S.; Lisboaa, J.A.; Silvaa, M.A.O.; Carvalhoa, N.B.; Pereirab, M.M.; Fricksa, A.T.; Mattedid, S.; Limaa, A.S.; Franceschic, E.; Soaresa, C.M.F.	Silica aerogel modified with protic ionic liquid was investigated for lipase immobilization and found to be suitable.
[86]	Bashir, N.; Sood, M.; Bandral, J.	The authors discussed enzyme immobilization for its applications in food processing. The authors emphasized the need to overcome the current limitations related to immobilization techniques.
[87]	Labus, K.; Wolanin, K.; Radosinski, L.	Invertase immobilization was investigated using alginate and gelatin.
[88]	Chou, C.; Syu, S.; Chang, J.H.; Aimar, P.; Chang, Y.	Bioinspired pseudo-zwitterionic hydrogels with bioactive enzyme immobilization via ph-responsive regulation were studied. It was observed that pH-responsive adsorption holds the potential for designing a biocompatible tissue engineering matrix.
[89]	Bao, Z.; Xian, C.; Yuan, Q.; Liu, G.; Wu, J.	The authors summarized work on the progress of natural polymer-based hydrogels with enhanced mechanical properties.
[90]	Basso, A.; Serban, S	Industrial applications of immobilized enzymes were discussed by the authors.
[91]	Bilal, M.; Zhao, Y.; Noreen, S.; Shah, S.Z.H.; Bharagava, R.N.; Iqbal, H.M.N.	According to the authors, physical or covalent coupling and cross-linked enzyme crystals are the most promising methods for immobilization.
[92]	Liu, Q.; Xun, G.; Feng, Y.	The state-of-the-art strategies of protein engineering for enzyme stabilization were discussed. The authors highlighted practical cases to show the importance of enzyme stabilization.

Cellulase was produced in submerged fermentation by Legodi *et al.* [63], for these fungi, was isolated from the natural compost. Cellulase is becoming an increasingly important enzyme in the biofuel industry [64]. Yeast can be used for deriving thermostable cellulase [65]. Research work on applications of cellulase, amylases are tabulated in Table 5. Cellulase enzymes can be produced from bacteria and yeast. Cellulase obtained from yeast is active in a wide range of pH, hence, gaining importance. These are capable of producing cellulase at high temperatures (60-70^{o}C) [66,67]. Enzymes in human beings, animals, and parasitic organisms have been well established [68]. Pectinase is one of the important enzymes used for the degradation of pectic substances. They are used in the food industry, especially fruit juice

clarification [69-71]. Investigations on reductase, pectinase are listed in table 6. Many investigators have studied the characteristics of pectine and various production methods. Pectinase has contributed significantly to the pharmaceutical sector, also [72-74].

Amylases are used for the hydrolysis of starch. Alpha-amylase helps in the prevention and medical treatment of metabolic syndromes [75]. Many molecules have α-amylase inhibitory activity [76-78]. In green plants, alpha-amylase genes are being investigated and evolved [79]. Bhattacharjee *et al.* have discussed the different types of bacterial and fungal amylases and their various applications in industries [80]. They discussed alpha and beta amylases and their applications. They discussed applications of amylases in food, bakery, brewing, detergent, textile, and paper industries.

According to Timson, four major challenges for better biocatalysts are protein folding understanding, a qualitative understanding of the hydrophobic effect, understanding and quantification of the effects of organic solvents on biomolecules, and understanding of enzymatic catalysis [81]. Nevertheless, many attempts are being made to improve biocatalysts. For example, in ester formations, lipases are now used with success [82,83].

Biocatalysts are becoming increasingly important in the pharmaceutical industry [84]. The use of various enzyme routes to obtain products such as aldehydes has been reported [85]. The immobilization of the enzyme helps in retaining catalyst activity [86]. Higher turnover over a considerable period can be achieved due to immobilization. Hydrogel matrices can be used for enzyme immobilization [87-89]. Many investigations on hydrogel enzymes are focused on studying mechanical properties and enhancing those, synthesis, a study of structures and properties [89-91]. The selection of enzymes in immobilized form can be made by evaluating costs versus benefits obtained in the process [89-91]. According to Liu *et al.*, combining computational enzyme design with molecular evolution will hold considerable promise in this field [92].

Enzymes are used in food processing since ancient times [93]. Modern microbial enzymes are more stable than food or plant enzymes [94]. Enzymes such as amylases, glucoamylases, proteases, lactases, lipases, phospholipases, lipoxygenases, cellulases, xylanases, etc., are used widely in the food industry [95-97]. Various approaches, including molecular and biochemical methods, can be used for the modification of microbial enzymes. Many investigations on microbial enzymes are reported in Table 7. Attributes like environmentally friendly nature, efficient process control, high yield, low refining costs, and process safety makes them the attractive choice for the synthesis of various products.

Enzymes are playing a key role in modern agricultural developments. Soil enzymes work as bioindicators for soil quality and its health [98-100]. Biological equilibrium, soil quality changes, and properties can be monitored by using the soil enzymes as indicators. The use of different fertilizers to improve productivity may alter enzyme activities over a period of time [101]. Many applications of enzymes and their role in agriculture are being explored by many investigators, as indicated in Table 8. Soil extracellular enzymes are agents for the creation and decomposition of organic material. Technological advancement may sometimes have an adverse effect on biodiversity, including soil enzyme activities [102]. Factors such as favorable soil pH, a higher content of organic C, and a total N and C/N ratio can positively affect the activity of enzymes in the organic system [103]. Biofilms formed by pathogenic bacteria can be dealt with by various nonconventional methods based on bacteriocins, bacteriophages, disruptive enzymes, essential oils, nanoemulsions, and nanoparticles, and the use of alternative technologies [104]. Disruptive methods can be used for the efficient release

of enzymes [105]. Investigations are reported on various methods for increasing the enzyme activities and effective enzyme release [106-110]. Enzymes play a vital role in the technological developments in other agriculture-based small-scale industries such as dairy, fishery, poultry farms, and food industries [111-118]. From ancient times enzymes are used for beverage manufacturing. Investigations for improving the enzymatic processes' economy are being carried out, and novel technics are being explored [119-124]. Investigations on inhibitory effects, substrate utilization, enzyme kinetics, synthesis of thermostable enzymes indicate that there is still a lot of potential in biotechnology and enzyme technology for intensifying many processes and finding economical methods for the synthesis of various products.

Table 4. Investigations on inhibition.

Sr.No.	Authors	Details
[57]	Kacar, D.; Baltaci, A.K.; Ayar, A.; Mogulkoc, R.	The authors investigated the effects of different phosphodiesterase type 5 enzyme inhibitors on the isolated rat myometrium contraction. It was found that tadalafil inhibits the frequency, amplitude, and area under the contraction curve.
[58]	Ayar A.,	This investigation predicted that parecoxib could be of therapeutic use in the management of preterm labor and dysmenorrhoea.
[59]	Nagiub, M., Filippone, S., Durrant, D., Das, A., Kukreja, R.C.	The authors proposed that tadalafil can be used for improving cardiac function in survivors of childhood cancer.
[60]	Lauro, F.V.; Francisco, D.C.; Marcela, R.N.; Virginia, M.A.; Patricia, H.V.; Laura, B.C.; Pool Gómez, E.; Lenin, H.H.; Maria, L.R.; Regina, C.C., *et al.*	Three steroid derivatives were synthesized, and their activities were evaluated.

Table 5. Applications of cellulase, amylases.

Sr.No.	Authors	Details
[63]	Legodi, L.M.; La Grange, D.; Rensburg E.L.J.; Ncube, I.	In this investigation, the authors isolated fungi from natural compost and produce cellulases in submerged fermentation.
[64]	Zhuang, J.; Marchant, M.A.; Nokes, S.E.; Strobel, H.J.	The authors concluded that solid-state cultivation might increase the potential of bioethanol to become a viable supplemental fuel source.
[65]	Touijer, H.; Benchemsi, N.; Ettayebi, M.; Idrissi, A.J.; Chaouni, B.; Bekkari, H.	Yeast-derived cellulases could hydrolyze soluble and insoluble substrates at elevated temperatures and at a wide pH range.
[66]	Xu, Z; Cen, Y; Zou, S; Xue, Y; Zheng, Y.	The authors discussed recent advances in the improvement of enzyme thermostability by structure modification. Protein structure modification can improve thermostability.
[67]	Megha, S.V.; Maragathavalli, S.; Brindha, S.; Karthikeyan, V.; Annadurai, B. ; Gangwar, S.K.	The authors discussed the isolation and purification of cellulase. According to these studies, enzyme activities were at their best at pH 4-7 and the temperatures between 40°C to 50°C.
[68]	Prast-Nielsen, S.; Huang, H.H.; Williams, D.L.	The role of Thioredoxin glutathione reductase in redox and its potential as a target for drugs was investigated. Thioredoxin glutathione reductase plays a vital role in the redox biology of parasitic flatworms.
[95]	Aiyer, P.V.	The author discussed applications of amylases in various fields.
[122]	Ogasawara, M.; Yoshii, K.; Wada, J.; Yamamoto, Y.; Inouye, K	The authors identified guanine, guanosine, and inosine for α-amylase inhibitors in the extracts of the earthworm *Eisenia fetida*. Also, they characterized their inhibitory activities against porcine pancreatic α-amylase.

Table 6. Applications of reductase, pectinase.

Sr.No.	Authors	Details
[69]	Agorio, A.; Chalar, C.; Cardozo, S.; Salinas, G.	The authors investigated alternative mRNAs arising from trans-splicing code for mitochondrial and cytosolic variants of *Echinococcus granulosus* thioredoxin glutathione reductase.
[70]	Rendón , J.L.; Miranda-Leyva, M.M.	Thioredoxin-Glutathione Reductase (TGR) enzyme follows a two-site ping-pong bi kinetic mechanism
[71]	Roy, K.; Dey, S.; Uddin, M.K.; Barua, R.; Hossain, M.T.	Bacterial isolates were isolated from the vegetable dump waste soil. It was observed that the pectinase of the isolate has potentiality on different types of fruit juice clarification.
[72]	Satapathy, S.; Rout, J.R.; George Kerry, G.; Thatoi, H.; Sahoo, S.L.	In this article, the authors described various production methods related to the optimization of the product. They also highlighted the significant contribution of pectinase to the pharmaceutical.
[73]	Nigam, P.S.	The author highlighted special characteristics like thermotolerance and pH tolerance. He observed that the enzyme activity was not affected by pH and temperature over a wide range of these parameters.
[74]	Wilkowska, A; Nowak, A; Antczak-Chrobot, A; Motyl, I; Czyzowska, A; Paliwoda, A.	Investigators carried out our research to identify the composition and biological activity of pectin-derived oligosaccharides (POS) generated from mild acid or enzymatic hydrolysis of apple pomace (AP).
[76]	Kato, C.C.; Gonçalves, G.D.A.; Peralta, R.A.; Seixas, F.A.V.; Sá-Nakanishi, A.B. ; 1,2 Lívia Bracht, L.; Comar, J.F.; Bracht, A.; Peralta, R.M.	Investigations were done on inhibition of α-Amylases by condensed and hydrolyzable tannins. Kinetics and hypoglycemic actions were studied in detail.
[77]	Kumari, N.; Sushil, Rani, B.; Malik K.; Avtar, R.	The authors discussed recent advancements in microbial amylases.
[78]	Martina, M.F.; Okpob, E.A.; Andyc, I.E.	The authors discussed alpha-amylase, beta-amylase, and glucoamylase and their unique way of action.
[79]	Liangliang, J.; Zhifen, P.; Haili Zhang H.; Qiao L.; Junjun, L.;, Guangbing, D.; Maoqun,Y.; Hai, L.	The authors discussed the origin and evolution of α-amylase genes in green plants in detail.
[80]	Bhattacharjee, I.; Mazumdar, D.; Saha, S.P.	The authors discussed microbial amylases and their potential application in industries, highlighting the role of these compounds in green synthesis.
[81]	Timson, D.J.	According to the author, four challenges for better biocatalysts are understanding protein folding, a qualitative understanding of the hydrophobic effect, studying the effects of organic solvents on biomolecules, and understanding enzymatic catalysis.
[82]	Yang, Y.; Zhang, J.; Wu, D.; Xing, Z.; Zhou, Y.; Shi, W.; Li, Q.	Lipases were employed as a catalyst for the chemoenzymatic synthesis of polymeric materials.
[83]	Kumar, A.; Dhar, K.; Kanwar, S.S.; Arora, P.K.	The advantages of lipase-catalyzed reactions in organic solvents were highlighted. Also, various effects of organic solvents on their activity were summarized.
[84]	Zhang, M.M.; Su,X.; Ang, E.L.; Zhao, H.	The authors discussed the strategic application of the tools like recombinant DNA technology, protein engineering, and bioinformatics.
[85]	Lee, J.; Kim, J.;Kim, H.; Kim, E J.; Jeong, H.; Choi, K.; Kim, B.	Investigators characterized Tryptophan 6-Halogenase from *Streptomyces albus.* Also, they studied its Regioselectivity Determinants.
[95]	Aiyer, P.V.	The author discussed applications of amylases in various fields.

Table 7. Microbial enzymes

Sr.No.	Authors	Details
[93]	Raveendran, S.; Parameswaran, B.; Ummalyma, S.B.; Abraham, A.; Mathew, A.K.; Madhavan, A.; Rebello, A.; Pandey, A.	Easy, cost-effective, and consistent production is advantages of the application of microbial enzymes in food preparations.
[94]	Rodríguez Couto S, Ángeles Sanromán M.	Solid-state fermentation is becoming an alternative to submerged fermentation in specific applications because of advancements in reactor design.

Sr.No.	Authors	Details
[100]	Rozylol, K.; Bohacz, J.	The microbial activity of the subsoil can be improved by using biogas digestate and mineral mining waste.
[101]	Holík, L.; Hlisnikovsky, L.; Honzík, R.; Trogl, J.; Hana .B.; Popelka, J.	This investigation indicated that the use of combined fertilization might improve biological characteristics in deeper parts of the soil profile.
[105]	Costa-Silva, T.A; Flores-Santos, J.C.; Freire, R.K.B.; Michele Vitolo, M.; Pessoa-Jr, A.	Microbial cell disruption methods for efficient release of enzyme L-asparaginase were studies. The studies indicated that the mechanical methods were the most effective for the disintegration of all microbial cells.

Table 8. Enzymes in agriculture.

Sr.No.	Authors	Details
[98]	Yuvaraj, M.; Ramasamy, M.	The authors discussed the role of fungi in agriculture. The role of fungi in changing root morphology, absorption of nutrients, nutrient mobility were discussed.
[99]	Gunjal, A.; Waghmode, M.; Patil, N.; Nawani, N.	The authors emphasized the significance of soil enzymes in agriculture. Soil enzymes are indicators of soil quality and fertility.
[102]	Catherine T.; Tony S.	It was predicted that the animal agricultural system would be replaced by food as a software model. In this, foods will be engineered at a molecular level.
[103]	Cezary A. K.; Elzbieta H.; Feledyn-Szewczyk, B.; Antonkiewicz, J.	The activity of enzymes was correlated with favorable soil pH, a higher content of organic C, and total N, and C/N ratio
[104]	Grigore-Gurgu,L.; Bucur, F. I.; Borda, D.; Alexa, E.; Neagu C.; Nicolau, A.	The authors discussed the ability of some pathogenic and toxigenic bacteria to form biofilms. Also, their contribution to the persistence of these microorganisms in the food industry was highlighted.
[112]	Dekker, P.J.T.; Koenders, D.; Bruins, M.J.;	The authors discussed the market developments and production possibilities and issues of lactose-free dairy products.
[113]	Bezie, A.; Regasa, H.	The authors reviewed the application of starter culture and enzymes/ rennet for fermented dairy products.
[114]	Attia, Y.A.	The authors discussed the use of enzymes in poultry diets.
[115]	Selim, N.A.; Magied, H.A.A.; Habib, H.H.; Waly, A.H.; Fadl, A.A.; Shalash, S.M.	According to the authors, protease and xylanase Enzymes can be employed as single or combined supplementation to corn-soybean meal broiler diets.
[116]	Barisic, V.; Kopjar, M.; Jozinovic , A.; Flanjak, I.; Ackar, D.; Milicevic, B.; Subaric, D.; Jokic, S.; Babic, J.	The authors discussed the chemistry behind chocolate production. They highlighted important reactions involving proteins, carbohydrates, lipids, and polyphenols.
[117]	Urbanska, B.; Derewiaka, D.; Lenart, A.; Kowalska, J.	The authors studied the changes in the composition and content of polyphenols in chocolate. These changes result from the pre-treatment method of cocoa beans and the technological process. The data collected by authors can be helpful for the processes which require further studies and analyses.
[118]	de Brito, E.S.; García, N.H.P.; Amancio, A.C.	It was observed that a product formulated with protease-treated cocoa had an enhanced perception of chocolate flavor and bitter taste.
[120]	Sibel Uzuner, S.; Deniz Cekmecelioglu, D.	The authors discussed enzymes used in the beverage industry. Typically, pectinases, amylases, cellulases, and xylanases are used to extract and clarify fruit juices. Pectinase holds 25 percent of the share of food enzymes globally.

6. Conclusions

Biocatalysts can be used for many fermentation, reduction, decomposition, and other reactions. Biocatalyst processes are accepted widely in pharmaceutical and fine chemical synthesis. The enzymes have excellent catalytic properties and specificity. In most biological processes(enzyme-catalyzed reactions), side reactions and by-products are rarely produced. The quantity of enzymes required is very small compared to conventional catalysts. Michali Menten Kinetic equations form the basis for many investigations on enzyme kinetics. Sustainable development is becoming the goal of many investigations carried out in chemistry and chemical engineering. In many reactions, the use of biocatalyst is limited because of the organic solvent. Some of the properties of the enzyme were found to alter for better catalysis in non-aqueous solutions. Enzymes are playing a vital role in the technological developments in other agriculture-based small-scale sectors such as dairy, fishery, poultry farms, and food industries. From ancient times enzymes are used for beverage manufacturing. Investigations for improving the enzymatic processes' economy are being carried out, and novel technics are being explored.

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Conflicts of Interest

The authors declare no conflict of interest.

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