**International Journal of Research Publication and Reviews**

Journal homepage: www.ijrpr.com ISSN 2582-7421

# Characteristics, Categories, Processes and Applications of Lipase Enzyme: A Review

***[1]Harshita Bhayani, [2]Trupti Pandya***

[1]M.Sc. Microbiology Student, Bhagwan Mahavir College of Basic and Applied Sciences, Bhagwan Mahavir University, Surat, Gujarat, India.
[2]Teaching Assistant, Bhagwan Mahavir College of Basic and Applied Sciences, Bhagwan Mahavir University, Surat, Gujarat, India.

**ABSTRACT**

The lipidic enzyme lipase was the focus of the current investigation. The hydrolases include lipase, also referred to as triacylglycerol acyl hydrolase, glycerol ester hydrolase, and fat splitting. In an oil-water interface, lipase catalyzes the hydrolysis of triglycerides, turning them into glycerol and fatty acids. These are widely utilized in the food, dairy, taste, pharmaceutical, biofuel, leather, cosmetic, detergent, and chemical sectors as well as in the manufacturing of leather. Lipases can be derived from plants, animals, or microorganisms; nevertheless, microbial lipases are the most often employed family of enzymes in biotechnological and organic chemical applications. Their use in daily life is gradually expanding. It is categorized by its source specificity. These can be derived by various processes like batch process, repeated-batch process and fad process. Different Thus, today's biotechnologists, organic chemists, process engineers, pharmacists, microbiologists, biophysicists, and biochemists prefer lipases as their enzyme of choice.

Keywords: Lipase, Characteristics of lipase, Batch fermentation, Categories of lipase, Lipolytic activity, Extracellular enzyme, Applications

## 1. Introduction

The hydrolysis of triglycerides into glycerol and free fatty acids is catalyzed by a group of hydrolytic enzymes known as lipases [1, 2]. For example, it may hydrolyze long-chain, water-insoluble triglycerides to diglycerides, which it can then again convert into monoglycerides, which are again composed of glycerol and fatty acids [3, 4, 5]. With a chain of 10 or more carbon atoms, lipases catalyze the hydrolysis of diacylglycerol [7]. All lipolytic enzymes operate as biocatalysts for a variety of processes, including acidolysis, alkalosis, hydrolysis, transesterification, esterification, and peptide synthesis.

Triacylglycerol + H2O $\xleftrightarrow{\text{Lipase}}$ Glycerol + 3 Fatty acids

Animals' stomachs and pancreas naturally manufacture lipases to aid in the digestion of fatty acids and lipids [8, 9].Other organisms that manufacture these enzymes include plants, mammals, and bacteria, yeast, fungus, and actinomycetes [10, 11, 12, 13,14]. They can also be discovered in hot springs, oil-contaminated soil, dairies, industrial waste, and enterprises that process vegetables [7]. Bacterial enzymes have high yields, and enzyme activity and larger yields can be achieved through genetic and environmental modifications in their brief generation [19, 15]. This enzyme is in great demand, consumes less energy than the standard approach, is more cost-effective, stable, and simple to produce on a large scale, and is genetically and environmentally optimized.

Extracellular lipase is isolated from many different bacterial species, particularly Bacillus [2] and Pseudomonas [2, 16] and is used in the organic production in the catalysis of aqueous solutions by some organisms [2, 12, 20]. It generated a variety of enzymes, including lipases [2, 21].

Lipases producers can be identified on agar plates using techniques such as tributyrin agar [17] and Rhodamine B agar [18], which form distinct zones around colonies that indicate lipase production [2, 17, 18]. We must offer the specially chosen ideal conditions, such as temperature, pH, and some sources of carbon, nitrogen, and substrate lipid for the activity of the enzyme, to produce the enzyme [1, 22].

Many different sectors, including detergent, agrochemicals, paper, chemical processing, dairy, pharmaceuticals, cosmetics, polymer synthesis, and surfactants, depend heavily on lipase. The lipase has been described, and attempts have been undertaken to increase its stability in organic solvents for a variety of applications [23, 24]. Numerous lipases are still active in organic solvents and can catalyze a wide range of reactions, including transesterification, esterification, regioselective acylation of menthols and glycols, and the creation of peptides and compounds.

**Table: 1.** Sources of lipases used in industry, together with their commercial availability [10]

| Type | Source | Application |
|---|---|---|
| Fungal lipases | *Candida rugosa* | Organic synthesis |
| | *C. antartica*A/B | Organic synthesis |
| | *Thermomyces lanuginosus* | Detergent additive |
| | *Rhizomucor miehei* | Food processing |

| | | |
|---|---|---|
| Bacterial lipases | *Burkholderia cepacia* | Organic synthesis |
| | *Pseudomonas alcaligenes* | Detergent additive |
| | *P. mendocina* | Detergent additive |
| | *Chromobacterium viscosum* | Organic synthesis |
| | *P. aeruginosa* | Organic synthesis |
| | *B. glumae* | Organic synthesis |
| | *P. fluorescens* | Organic synthesis |

## 2. General characteristics of Lipase

Initially, the lipolytic enzyme was identified In 1856, clude Bernard, and after that, it was derived from plants, microorganisms, and animals (fungi, bacteria and yeast). Lipase insoluble substrates are hydrolyzed and added to water to increase lipolytic products. Lipase's general characteristic is a ubiquitous enzyme that is necessary for both physiological and industrial importance uses. Glycerol and free fatty acids are lipases. Lipases are serine hydrolases that are the catalytic component of the enzyme. G is for glycine, S is for serine, X1 is for histidine, and X2 is either glutamine or aspartic acid. The structure of the serine proteases is also distinctive. Three-dimensional structure plays a crucial role in creating and structuring lipases for specific purposes [25]. A change in the conformation of the enzyme takes place in a non-water environment of a reverse reaction following contact with an insoluble substrate in water when lipases are used to catalyze the unique process of fat hydrolysis to glycerols and fatty acids, which can be water-lipid border take place. Biochemists, crystallographers, chemists, biochemical engineers, and molecular biologists all conduct extensive research on the interfacial activity of phenomena [26].

## 3. A Various categories of Lipase enzyme

Two distinct categories of lipases exist - based on the sources' specificity. The all necessary comparison enzymes had been similar or at least connected materials [27]. Lipase is an enzyme that has been discovered for many species, including animals, plants, insects, and microbes [28]. Due to their increased functionality, endurance under harsh conditions, stability in naturally soluble, chemo- and enantioselectivity, microbial lipases have drawn a lot of attention. In the creation of oil-processing detergents, lipases are frequently utilized [29].

depending on which lipases can be divided into three main categories:

1. Substrate-specific
2. Regioselective
3. Enantioselective

***3.1. Substrate-Specific Lipase:*** Lipases are utilized in substrate-specific reactions. They selectively operate on a blend of unprocessed raw materials in a particular substrate, as shown by the use of lipases in the manufacture of biodiesel. Alcohol and fatty acids are two common substrates that substrate-specific lipase can operate on [30].

***3.2. Regioselective Lipase:*** The creation of isomeric molecules that perform at their best requires the use of regioselective lipases, which are crucial to the chemical and pharmaceutical industries. The acylation of ferulic acid with quercetin utilizing Rhizopus was discovered to be one of the region-selective lipases [31].

## 4. Synthesis of Lipase enzyme

Various samples were used, including kitchen trash [15] cooking grease [8], oil-spilled soil [2] and gasoline-spilled soil [1]. In a sealed plastic bag, all samples are gathered [1]. To segregate the bacterial strains from the materials, a serial dilution approach was applied [1] Sub-culturing into nutritional broth media [2], LB medium [32], and tributyrin agar plate [33, 2] using aseptic circumstances, and plating on the nutrient agar plate[34, 2]. After incubation, the plate is counted for bacteria at a level of 30-300 CFU/ml and is ready to be examined for other features, such as morphological and biochemical analysis, as well as lipase activity [34, 2].

The bacteria were checked for contaminants after being isolated on the nutrient agar plate medium. By altering the substrate's appearance, lipolytic action is clearly visible on the plate. In the Luria-Bertani medium, it was also screened on agar with tributyrin (1 percent w/v) and agar (2 percent w/u) [32, 34]. The developed bacterial colonies displayed distinct haloes surrounding them, indicating the generation of lipase on the tributyrin agar plate [7, 15, 35].

According to Mobarak-Qamsari [36] and Ali [37], the production medium was composed of yeast extract, sucrose, CaSO4, K2HPO4, MgSO47H2O, olive oil, and distilled water and was immersed during the 24- to the 48-hour incubation period [36, 37]. Centrifuge the culture for 20 minutes after incubation at 10,000 rpm. Using a colorimetric technique, the enzyme activity was assessed using cell-free supernatants as the substrate. With the use of the cupric acetate/pyridine reagent, we can use hydrolyzed olive oil)[2], triacylglycerol [10] bile salt, and glycerol as substrates. According to Lowry et al., the complex formed by the copper and fatty acids from the cupric salt absorbs light with a blue tint in the visible range of 715 nm [38].

**Table: 2. Physico-chemical parameters for lipase production through various microorganisms**

| Organism | Growth | | Activity | | Growth Medium | | Max Activity | |
|---|---|---|---|---|---|---|---|---|
| | **Temp** | **pH** | **Temp** | **pH** | **Carbon source** | **Nitrogen Source** | **(U/ml) & (Substrate)** | **Reference** |
| *B. thermoleovorans ID-1* | 65 | 6.0 | 70 | 7.5 | Triolein | - | 520 (p-nitro phenyl butyrate) | 39 |
| *B. thermoleovorans IHI-91* | 65 | 6.0 | 65 | 6.0 | Various | | 0.3 (para-nitrophenol) | 40 |
| *Bacillus THL027* | 65 | 7.0 | 70 | 7.0 | Nutrient broth + 3% NaCl + 1% rice bran oil | | 8.3 (olive oil) | 41 |
| *Corynebacterium sp.* | 33 | 8.0 | 60 | 8.0 | Starch | Peptone & ammonium chloride | 28 (olive oil) | 42 |
| *Flavobacterium odoratum* | 30 | 7.0 | 60 | 10 | Glucose | - | - | 43 |
| *Fusarium solani* | 28 | 5.5 | 35 | 8.0 | Sesame oil | | 0.889 (p-nitro phenyl palmitate) | 7 |
| *Pseudomonas fluorescens* | 30 | 7.2 | 55 | 9.0 | Ground nut oil | Ammonium Dihydrogen Phosphate | 69.7 (olive oil) | 44 |
| *Pseudomonas sp. G6* | 34 | 6.8 | 30 | 7.0 | nhexadecane | Sodium nitrate | 25 (tributyrin) | 45 |
| *Streptomyces rimosus* | 30 | 7.5 | 25 | 8.0 | Dextrin | - | 12.8 (p-nitro phenyl palmitate) | 46 |

## 5. Batch Production

Most publications that describe the synthesis of lipase employ shaken flasks in batch mode. However, there is a lot of research that concentrates on the utilization of stirring, airlift, and bubble bioreactors. As the use of flasks in batch mode for lipase production has previously been presented in other sections of this work, the main characteristics and application of these bioreactors will be reviewed in this section [47]. Lipolytica in a 20-L batch bioreactor in various scale-down devices that have been created to simulate each factor's environmental behavior in a lab setting. For the three factors on microbial growth, extracellular lipase production, and the activation of the gene LIP2 encoding for the major lipase of Y. lipolytica, these systems enable the replication of the hydrodynamic phenomena seen in large-scale equipment.

The dissolved oxygen fluctuations produced in a controlled scale-down reactor have the most notable physiological impact among the group of environmental conditions examined, lowering the level of LIP2 gene expression. In a partitioned scale-down reactor, the other environmental parameters, such as methyl oleate dispersion and pH changes, led to less severe stress that was simply interpreted by a fall in microbial yield and the development of a process for the extracellular lipase secreted by Y. lipolytica [48].

Lower stirring rates appeared to limit oxygen levels, whereas higher stirring rates led to mechanical and/or oxidative stress. Faster lipid uptake and anticipation of enzyme release were caused by an increase in oxygen availability at higher air flow rates in the culture medium. The majority of studies indicate lipase production in tray bioreactors (conical flasks), utilizing a few grams of the substrate [50, 51, 52, 53, 54, 55]. This tendency has been confirmed for lipase production in submerged fermentation. SSF is primarily limited to a packed-bed format, unlike SMF, which has a variety of bioreactor configurations. No reports concentrating on the utilization of a revolving drum, an intermittently agitated bioreactor, or a fluidized bioreactor have been discovered [56].

## 6. Repeated Batch Production

The advantages of fed-batch and batch processes are combined with repeated-batch processes, which primarily allow for the conduct of the process over extended periods of time and increase productivity in comparison to batch operations. According to Yang study's examined the generation of lipase by immobilized R. arrhizus mycelium in submerged fermentation utilizing repeated-batch fermentations. For repeated application, immobilized cells demonstrated good stability. It was discovered that maintaining a consistent cell concentration was necessary to increase the number of consecutive cycles and that a high lipase yield required a sufficient cell growth rate. The authors of the previously quoted investigation confirmed that the pH adjustment had a significant impact on the synthesis of lipase [57].

On the other hand, constant feeding of dissolved oxygen might be adjusted to promote a sufficient growth rate for the creation of lipase. In a 2.5-L bioreactor, the lipase production reached 42,000 U h1. When the enzyme activity was at its highest (17.9 U mL1). The fermentation was done batch after

batch. A method utilizing an Arabic gum-containing feed media and caprylic acid while maintaining the feed's flow rate allows each cycle to run for 0.4 mL min-1 12 h [58].

## 7. Fed-Batch production

The fed-batch operations are characterized by the continuous supply of one or more nutrients to the bioreactor, which keeps the products contained inside until fermentation is complete. The fed-batch procedures are extensively used to reduce the impacts of cell metabolism control and, primarily, avoid substrate- or metabolic product-induced inhibition. Both in the lab and on the pilot size, the fermentation conditions were perfected. The pH control in conjunction with exponential feeding was successful in small-scale research, but a two-stage fermentation technique that changed after 48 hours by fine. The culture's pH and temperature were adjusted and deemed efficient in fermenting at a pilot scale. An activity of lipase of about 14,000 U mL-1 and at the 800-L scale, a cell wet weight of 500 g L1 was obtained in scale [59].

Using a fed-batch with non-limited methanol has a number of disadvantages. Early cell dry weight was when oxygen constraint first became apparent, and high cell death was noted. To address both issues, a temperature-limited fed-batch has been suggested. Better productivity was obtained with a batch that was given methanol without restriction. Finally, cell death issues were solved by using a medium with reduced salt concentration. Following that, a temperature-limited fed-batch was used to address oxygen transfer limitations. When compared to a methanol non-limited fed-batch, this combined method had lower productivities [6]. However, a 1.3-fold purer final product was produced as a result of a longer cultivation period and a decrease in cell death [66]. To increase cell concentration and lipase activity, fed-batch cultures (intermittent and stepwise feeding) were carried out in a 7.5-L bioreactor. After 138.5 hours of fermentation, the final cell concentration for the intermittent feeding was 52 g L-1, and the lipase activity was 6.3 U mL-1 0 [60].

Stepwise feeding was used to mimic exponential feeding and explore how a certain growth rate affected cell development and lipase synthesis. When the specific growth rate was set at 0.02 h-1 and the greatest lipase activity was 23.7 U m-1 at 179.5 h, the highest final cell concentration was 90 g L-1. Due to the accumulation of excessive oleic acid, high specific growth rates in fed-batch cultures reduced the generation of extracellular lipase in the latter stages [61]. According to fed-batch 's fermentation method was created to allow for the mass manufacture of recombinant human lysosomal acid lipase in Schizosaccharomyces. The ideal feed rate of a carbon source solution made of 50% glucose was determined using a feedback fed-batch system (5 L bioreactor) [62]. The batch-phase culture's automatic nutrition delivery was started at the exact moment that the first glucose was consumed by watching the respiratory rate change. The feed forward control fermentation was used with the resulting feed rate profile [6].

A fed-batch growth phase and a production phase, in which lipase was triggered by the addition of 5 percent stearic acid, were both used in the two-step lipase manufacturing method 81. The authors discovered that lipase activity was decreased when nitrogen was scarce. To determine the optimal process techniques for C. rugosa's lipase production, the obtained results were compared to earlier data from batch and fed-batch cultures. Oleic acid-based fed-batch fermentation produced the highest lipase output [63].

A model involving the synthesis of growth-associated lipase and the hydrolysis of olive oil can be used to predict the oleic acid buildup seen during batch fermentation. Simulations proved that this buildup was what caused the abrupt growth halt in batch fermentations with greater initial amounts of olive oil. Additionally, the latter model anticipated an oscillating behaviour that was seen in some chemostat tests.

A straightforward mathematical model with a hierarchical framework was provided by Montesinos et al. and used to produce batch and continuous lipase from C. rugosa. With the help of Advanced Continuous Simulation Language, process modelling was completed. After the model's parameters were chosen, the entire model was validated, and the outcomes were satisfactory. Various simulations of the optimum technique to increase lipase productivity are used to estimate [64].

## 8. Applications of lipase enzyme

Natural biocatalysts including enzymes. The crucial classes of biocatalysts are the lipase enzymes, which have biotechnological potential [58, 65]. These enzymes are used in a variety of industries, including dairy, food, detergents, textile, pharmaceutical, medical, rubber, and others [66, 7]. Lipase enzymes are used in detergents like industrial laundry and home dishwashers to remove fatty acid residues and clean [89]. Vulfson and associates, 1994 Proteases, carbohydrases, and lipases are just a few of the enzymes that are ranked as the third largest group in terms of total scale volume[69]. Lipase enzymes are utilized commercially and have a wide range of uses and are worth billions of dollars [96]. The most specialized and useful industrial enzymes, such as lipase and cellulose, will produce more due to recombinant DNA technology. Application of Lipases as biological catalysts for the creation of other products (like components) (in making fine chemicals) [76].

**Table 3** : Various industrial applications of microbial lipases

| Industry | Action | Application | Reference |
|---|---|---|---|
| Detergents | Hydrolysis of fats | Removal of oil stains from fabrics | 96 |
| Bakery foods | Flavor improvement | Shelf-life prolongation | 67 |
| Beverages | Improved aroma | Beverages | 67 |
| Fats and oils | Transesterification, Hydrolysis | Cocoa butter, fatty acids, Glycerol | 68 |
| Dairy foods | Hydrolysis of milk fat, cheese Ripening | Development of flavoring agents in milk, cheese, butter | 68 |
| Leather | Hydrolysis | Leather products | 69 |
| Pharmaceuticals | Transesterification, hydrolysis | Speciality lipids, digestive aids | 69 |

### *8.1 In Dairy Industries*

In the dairy industry, lipase enzymes are frequently utilised for the hydrolysis of milk fat and cheese additives [70, 71]. Animal tissues like pancreatic glands and the pre-gastric tissues of young ruminants like lamb and calf are the typical sources of lipase for cheese flavouring additions. When cheese is heated to its highest temperature while being incubated with enzymes to produce a concentrated flavour, the cheese is enzyme modified, and this cheese has a 10 times greater enzyme concentration of fat [81, 71, 72]. By producing enzymatic cations like lipolysis, the intracellular enzymes are liberated after cell lysis and add flavour. *Pseudomonas roqueforti* and *Pseudomonas camemberti*, which are found in blue vein and camembert cheese, respectively, are responsible for the lipolytic action of milk lipase in cheese manufactured from unpasteurized milk. Additionally, these enzymes are typically used in Italian cheese, including Parmesan, Provolone, and Romano, for the robust flavour [73]. Triglycerides are used by lipases to release fatty acids, which results in the creation of the cheese flavour [74].

### *8.2 Textile Sector*

Lipase enzymes are employed in the textile industry to remove size lubricants and to raise the amount of dying. Because it contains lipase enzymes, it is commercially used for desizing denim and other cotton fibers. Some of their benefits include great strength, suppleness, stretch and stain resistance, machine washability, and more. Enzymatically altered synthetic fibers are used to produce yarns, fabrics, textiles, and a variety of other products [75, 76]. Polyester offers a number of significant benefits to the textile industry, including high strength, a soft hand, stretch resistance, stain resistance, machine washability, wrinkle resistance, and abrasion resistance. Enzymatic modification has been used for synthetic fibers. for usage in the creation of rugs, yarns, and fabrics and further consumer goods. It has to do with changing the polyester fiber's properties so that such polyesters are less resistant to post-modification therapies. Making advantage of a lipase-related enzyme called polyesterase to enhance the of polyester fabric to absorb chemical substances, including cationic chemicals, fabric finishing formulations, dyes, antistatic, anti-staining, antibacterial, and antiperspirant compounds [77] .

### *8.3 The Detergent Sector*

The most prevalent and significant commercial application for hydrolytic lipases in detergents is in commercial and residential laundry. Based on comparable detergency mechanisms, all detergents have comparable components. They include enzymes like protease, amylase, cellulose, and lipase, among others [78, 76].

The enzyme can lessen the impact that detergent products have on the environment, save energy, make room for less desirable, biodegradable content, have no adverse effects on sewage treatment procedures, and pose no risk to aquatic life.

To remove oil from surfaces and fabric surfaces, lipase is immobilised on the surface. Fabric lipase complexes are created by lipases that have been sorbed onto fabric to eliminate oil stains. When a garment is dry or being laundered, the lipase enzyme is working to hydrolyze an oil stain. The enzyme can be deactivated by heat and surfactants to denaturate. When there is a surfactant present and the pH is basic, oil hydrolysis byproducts can remove stains from fabrics. It is employed as a detergency to remove fats from a variety of products, including frying fats, salad oils, buttery sauces, soups, some cosmetics, and more [76].

In terms of quantity and cost, the detergent industries are the main consumers of enzymes. the use of enzymes in the production of detergents enhances detergents' capacity to eliminate harsh removing stains and ensure the detergent is suitable for the environment. Currently, a combination of enzymes comprising amylases, cellulases, proteases, and lipases are present in a variety of laundry detergent formulations[102].

### *8.4 Industry of Pharmaceuticals*

Polyunsaturated fatty acids from plant and animal lipids are enhanced using microbial lipase enzymes. Their diacylglycerids and monoacylglycerids are utilised to make a variety of medicinal ingredients [80].

Because of their benefits for metabolism, poly unsaturated fatty acids are frequently employed in medicines, nutraceuticals, and food additives. The enzyme lipase is utilised to extract polyunsaturated fatty acids from plants, animals, menhaden oil, and tuna oil. Pharmaceutical industry use free fatty

acids and their derivatives [81, 76]. Because lipases can catalyse synthetic processes, they can be used as life-saving medications. Nikkomycin B, non-steroidal anti-inflammatory medicines, antiviral medication, antibiotics, vitamins, antitumor agents, and anti-allergic chemicals are a few examples [86].

A medicine called lovastatin is used to reduce serum cholesterol levels. The lipase from C. rugosa is used as a catalyst in the synthesis of this medication. Diltiazem hydrochloride, a widely used medication for coronary vasodilation, is produced via the asymmetric hydrolysis of 3- phenylglycidic acid ester by S. marcescens lipase [82, 83].

### *8.5 Lipases used in the oleochemical sector*

Depending on the water concentration of the reaction mixture, lipases can catalyse hydrolysis, esterification, and transesterification reactions [84]. The lipase-catalyzed reaction differs significantly from the chemical reaction. Compared to chemical processes, lipase-catalyzed reactions can proceed under less favourable conditions. Benefits include the ability to avoid undesirable side effects like substrate heat degradation [85, 76]. In the oleochemical sector, lipases are used to lessen the thermal deprivation that occurs during glycerolysis, hydrolysis, alcoholysis, and acidolysis [87]. Lipases can be used to clean up oil spills in processing plants, refineries, and beach sand [70].

Because of how they are structured, some fats are far more critical than others. Using a combination of chemical techniques, less valuable lipids can be transformed into more useful species, although these procedures provide a wide range of items. Transesterification is mediated by lipase. These less expensive oils can be used, for instance, to make cocoa butter from the middle of the palm [88]. Transesterification in organic solvents was facilitated by lipase. It is a new industrial use, such as the manufacture of "Betapol," a human milk fat replacement, is the equivalent of cocoa butter. Important polyunsaturated fatty acids for medicine (PUFA) "Designers fats or structured lipids," "rich/low-calorie lipids," and biodiesel generation from vegetable oils [89, 90].

### *8.6 Lipases in the creation of biodiesel*

Vegetable oils have been investigated as potential substitutes for fossil fuels for a variety of reasons, including the finite (and rapidly depleting) supply of fossil fuels, rising crude oil prices, and environmental concerns [91]. In comparison to the current petroleum-based biodiesel fuel, the fuel made from vegetable oil does not emit sulfur oxide and reduces soot particulate by a third. Biodiesel fuel can be anticipated to replace traditional diesel fuel due to its environmental benefits [92].

Immobilized lipases from *Thermomyces lanuginosa* and C. antarctica served as biocatalysts in the synthesis of straightforward alkyl ester derivatives of restaurant grease [93]. Two Nigerian lauric oils, palm kernel oil and coconut oil, were transesterified with various alcohols utilizing PS30 lipase as a catalyst to create fatty acids esters. The maximum conversion rate, of 72%, was achieved by ethanol in the conversion of palm kernel oil to alkyl esters (biodiesel). Some of the fuel's characteristics compared well to worldwide biodiesel standards [94].

Studies on the mechanisms of microbial lipase formation and the function of lipidic compounds utilized as inducers in lipase production are limited [95], despite their significance. Future research in this area will be very interesting because lipases are a very adaptable class of bacterial extracellular enzymes that can carry out a wide range of significant reactions [96]. Researchers can create novel lipases that are specifically suited for biotechnological uses by understanding the links between structure and function [97].

Enzymatic or chemical transesterification of oils or fats can be used to produce biodiesel. Due to lipases' high catalytic activity, stability, cost-effectiveness, and eco-friendliness, enzymatic processes are favored over chemical ones [1, 98].

### *8.7 Lipases used in cosmetics and fragrance*

Isopropyl myristate, isopropyl palmitate, and 2-Ethylhexyl palmitate are now being produced by Unichem International (Spain) for use as emollients in personal care goods such as skin and sun-tan lotions, bath oils, and other similar items. As a biocatalyst immobilized *Rhizomucor meihei* lipase was employed. According to the business, using enzymes in place of traditional acid catalysts results in substantially higher-quality goods that only require minimal downstream refining [88].

Similar uses in personal care products can be found for wax esters, which are similarly produced enzymatically. Wax esters are esters of fatty acids and fatty alcohols (Croda Universal Ltd.). The company claims that while the overall cost of manufacturing is marginally greater than that of the traditional approach, the cost is justified by the superior caliber of the finished good [88]. The commercial potential of retinoids (Vitamin-A and its derivatives) in medicines and cosmetics, such as skin care items. Immobilized Retinol is made with the help of lipase. derivatives that are water soluble[101].

### *8.8 In the Pulp & Paper Industry*

In the pulp and paper business, a sizable amount of lignocellulosic biomass is treated annually.
Enzymes have historically been utilized in the paper industry for specific purposes, such as the alteration of raw starch.
Since 1990, large-scale paper manufacturers have routinely used the enzymatic pitch control technology employing lipases. "Pitch" refers to the hydrophobic components of wood, primarily waxes and triglycerides, which pose serious challenges for the production of paper. Lipases are used to remove the pitch from the pulp created for making paper. Nippon Paper Industry in Japan devised a technique for pitch control that involved using *Candida rugosa*'s lipase to hydrolyze timber triglycerides to up to 90% of their original strength[99].

When used for wastepaper deinking, lipase can speed up pulping, improve pulp whiteness and intensity, use fewer chemicals, extend the life of equipment, lower wastewater pollution levels, save time and energy, and lower composite costs. A deinking composition for ethylene oxide-propylene oxide adduct stearate was made whiter and had fewer lingering ink spots by adding lipase from the pseudomonas species (KWI-56) [100].

## 9. Conclusion

The results of this study allow us to draw the conclusion that foam is a source of bacteria that is valuable for industry and has practical applications. The findings of this study suggest that the provided sources are beneficial for the synthesis of lipase enzymes. Microbial lipases are among the enzymes that are most often generated, according to a critical study recent research. This assessment revealed that numerous researchers throughout the world focus on the search for novel lipase-producing microbes and, as a result, on the improvement of the medium operational factors and composition. All The tremendous diversity of these efforts is justified by applications of lipase. Much has happened. Advancements in the bioprocesses used to produce lipase mostly employ submerged fermentation, such as the effective screening of high lipase producer's replacement of synthetic media with agro-industrial residues, process scalability, and alternative methods modalities of operation, approaches of operating bioreactors, and the application of mathematical models as a process improvement. Most enzyme production is achieved by optimizing enzyme production under various physiological situations. For a range of industrial applications in the food and dairy, detergent, textile, pharmaceutical, etc. industries, lipase-producing bacterial strains are a very helpful candidate.

## 10. Acknowledgement

I appreciate working with Bhagwan Mahavir college of basic and applied science. Thanks to all for the guidance in the right way.

**References**

1. Bharathi, D., Rajalakshmi, G., & Komathi, S. (2019). Optimization and production of lipase enzyme from bacterial strains isolated from petrol spilled soil. *Journal of King Saud University-Science*, *31*(4), 898-901.
2. Veerapagu, M., Narayanan, A. S., Ponmurugan, K., & Jeya, K. R. (2013). Screening selection identification production and optimization of bacterial lipase from oil spilled soil. *Asian J Pharm Clin Res*, *6*(3), 62-67.
3. Gupta, R., Gupta, N., & Rathi, P. (2004). Bacterial lipases: an overview of production, purification and biochemical properties. *Applied microbiology and biotechnology*, *64*(6), 763-781.
4. Gilham, D., & Lehner, R. (2005). Techniques to measure lipase and esterase activity in vitro. *Methods*, *36*(2), 139-147.
5. Angkawidjaja, C., & Kanaya, S. (2006). Family I. 3 lipase: bacterial lipases secreted by the type I secretion system. *Cellular and molecular life sciences CMLS*, *63*(23), 2804-2817.
6. Kim, B. S., & Hou, C. T. (2006). Production of lipase by high cell density fed-batch culture of Candida cylindracea. *Bioprocess and biosystems engineering*, *29*(1), 59-64.
7. Jaeger, K. E., Ransac, S., Dijkstra, B. W., Colson, C., van Heuvel, M., & Misset, O. (1994). Bacterial lipases. *FEMS microbiology reviews*, *15*(1), 29-63.
8. Jaiganesh, R., & Jaganathan, M. K. (2018). Isolation, purification, and characterization of lipase from Bacillus sp. From kitchen grease. *Asian J Pharm Clin Res*, *11*(6), 224-227.
9. Winkler, F. K., d'Arcy, A., & Hunziker, W. (1990). Structure of human pancreatic lipase. *Nature*, *343*(6260), 771-774.
10. Kordel, M., Hofmann, B., Schomburg, D., & Schmid, R. D. (1991). Extracellular lipase of Pseudomonas sp. strain ATCC 21808: purification, characterization, crystallization, and preliminary X-ray diffraction data. *Journal of bacteriology*, *173*(15), 4836-4841.
11. Haba, E., Bresco, O., Ferrer, C., Marques, A., Busquets, M., & Manresa, A. (2000). Isolation of lipase-secreting bacteria by deploying used frying oil as selective substrate. *Enzyme and microbial technology*, *26*(1), 40-44.
12. Abada, E. A. E. M. (2008). Production and characterization of a mesophilic lipase isolated from Bacillus stearothermophilus AB-1. *Pakistan Journal of Biological Sciences*, *11*(8), 1100-1106.
13. Hellyer, S. A., Chandler, I. C., & Bosley, J. A. (1999). Can the fatty acid selectivity of plant lipases be predicted from the composition of the seed triglyceride?. *Biochimica et Biophysica Acta (BBA)-Molecular and Cell Biology of Lipids*, *1440*(2-3), 215-224.
14. Gunasekaran, V., & Das, D. (2005). Lipase fermentation: progress and prospects.
15. Gopinath, S. C., Hilda, A., & Anbu, P. (2005). Extracellular enzymatic activity profiles in fungi isolated from oil-rich environments. *Mycoscience*, *46*(2), 119-126.
16. Wang, S. L., Lin, Y. T., Liang, T. W., Chio, S. H., Ming, L. J., & Wu, P. C. (2009). Purification and characterization of extracellular lipases from Pseudomonas monteilii TKU009 by the use of soybeans as the substrate. *Journal of Industrial Microbiology and Biotechnology*, *36*(1), 65-73.

17. Cardenas, F., Alvarez, E., de Castro-Alvarez, M. S., Sanchez-Montero, J. M., Valmaseda, M., Elson, S. W., & Sinisterra, J. V. (2001). Screening and catalytic activity in organic synthesis of novel fungal and yeast lipases. *Journal of Molecular Catalysis B: Enzymatic*, *14*(4-6), 111-123.

18. Kouker, G., & Jaeger, K. E. (1987). Specific and sensitive plate assay for bacterial lipases. *Applied and environmental microbiology*, *53*(1), 211-213.

19. Sharma, S., & Kanwar, S. S. (2014). Organic solvent tolerant lipases and applications. *The Scientific World Journal*, *2014*.

20. Karadzic, I., Masui, A., Zivkovic, L. I., & Fujiwara, N. (2006). Purification and characterization of an alkaline lipase from Pseudomonas aeruginosa isolated from putrid mineral cutting oil as component of metalworking fluid. *Journal of Bioscience and Bioengineering*, *102*(2), 82-89.

21. Georgieva, S., Iliev, I., Marhova, M., & Trifonova, S. Lipolytic activity of genus Pseudomonas.

22. Sharma, R., Chisti, Y., & Banerjee, U. C. (2001). Production, purification, characterization, and applications of lipases. *Biotechnology advances*, *19*(8), 627-662.

23. Hun, C. J., Rahman, R. N. Z. A., Salleh, A. B., & Basri, M. (2003). A newly isolated organic solvent tolerant Bacillus sphaericus 205y producing organic solvent-stable lipase. *Biochemical Engineering Journal*, *15*(2), 147-151.

24. Secundo, F., & Carrea, G. (2002). Lipase activity and conformation in neat organic solvents. *Journal of Molecular Catalysis B: Enzymatic*, *19*, 93-102.

25. Joshi, R., & Kuila, A. (2018). Lipase and their different industrial applications: A review. *Brazilian Journal of Biological Sciences*, *5*(10), 237-247.

26. Lason, E., & Ogonowski, J. (2010). Lipase-characterization, applications and methods of immobilization. *Chemik*, *64*(2), 100-102.

27. Brady, L., Brzozowski, A. M., Derewenda, Z. S., Dodson, E., Dodson, G., Tolley, S., ... & Menge, U. (1990). A serine protease triad forms the catalytic centre of a triacylglycerol lipase. *Nature*, *343*(6260), 767-770.

28. Chen, Y., Liu, J., Geng, S., Liu, Y., Ma, H., Zheng, J., ... & Liang, G. (2019). Lipase-catalyzed synthesis mechanism of tri-acetylated phloridzin and its antiproliferative activity against HepG2 cancer cells. *Food chemistry*, *277*, 186-194.

29. Hasan, F., Shah, A. A., & Hameed, A. (2009). Methods for detection and characterization of lipases: a comprehensive review. *Biotechnology advances*, *27*(6), 782-798.

30. Sarmah, N., Revathi, D., Sheelu, G., Yamuna Rani, K., Sridhar, S., Mehtab, V., & Sumana, C. (2018). Recent advances on sources and industrial applications of lipases. *Biotechnology progress*, *34*(1), 5-28.

31. Mayordomo, I., Randez-Gil, F., & Prieto, J. A. (2000). Isolation, purification, and characterization of a cold-active lipase from Aspergillus nidulans. *Journal of Agricultural and Food Chemistry*, *48*(1), 105-109.

32. Fakhereddine, L., Kademi, A., Aït-Abdelkader, N., & Baratti, J. C. (1998). Microbial growth and lipolytic activities of moderate thermophilic bacterial strains. *Biotechnology Letters*, *20*(9), 879-883.

33. Cherif, S., Mnif, S., Hadrich, F., Abdelkafi, S., & Sayadi, S. (2011). A newly high alkaline lipase: an ideal choice for application in detergent formulations. *Lipids in health and disease*, *10*(1), 1-8.

34. Rodriguez, J. A., Mateos, J. C., Nungaray, J., González, V., Bhagnagar, T., Roussos, S., ... & Baratti, J. (2006). Improving lipase production by nutrient source modification using Rhizopus homothallic cultured in solid-state fermentation. *Process Biochemistry*, *41*(11), 2264-2269.

35. Gopinath, S. C. B., Hilda, A., & Annadurai, G. (2002). Purification of lipase from Cunninghamella verticillata and optimization of enzyme activity using response surface methodology. *World Journal of Microbiology and Biotechnology*, *18*(5), 449-458.

36. Mobarak-Qamsari, E., Kasra-Kermanshahi, R., & Moosavi-Nejad, Z. (2011). Isolation and identification of a novel, lipase-producing bacterium, Pseudomnas aeruginosa KM110. *Iranian journal of microbiology*, *3*(2), 92.

37. Ali, A. A., Hameed, K. W., & Nadder, M. I. (2022). Isolation Of Pseudomonas Aeruginosa from Soil and Production of Lipase Enzyme. In *IOP Conference Series: Earth and Environmental Science* (Vol. 961, No. 1, p. 012087). IOP Publishing.

38. Lowry, R. R., & Tinsley, I. J. (1976). Rapid colorimetric determination of free fatty acids. *Journal of the American Oil Chemists' Society*, *53*(7), 470-472.

39. Lee, D. W., Koh, Y. S., Kim, K. J., Kim, B. C., Choi, H. J., Kim, D. S., ... & Pyun, Y. R. (1999). Isolation and characterization of a thermophilic lipase from Bacillus thermoleovorans ID-1. *FEMS Microbiology Letters*, *179*(2), 393-400.

40. Markossian, S., Becker, P., Märkl, H., & Antranikian, G. (2000). Isolation and characterization of lipid-degrading Bacillus thermoleovorans IHI-91 from an icelandic hot spring. *Extremophiles*, *4*(6), 365-371.

41. Dharmsthiti, S., & Luchai, S. (1999). Production, purification and characterization of thermophilic lipase from Bacillus sp. THL027. *FEMS microbiology letters*, *179*(2), 241-246.

42. Ray, N., Ray, L., Srimani, B. N., & Chattopadhyay, P. (1999). Isolation and identification of alkaline thermostable lipase producing microorganism,

cultural conditions, nutritional requirements and some properties of crude enzyme.

43. Labuschagne, R. B., van Tonder, A., & Litthauer, D. (1997). Flavobacterium odoratum lipase: Isolation and characterization. *Enzyme and microbial technology*, *21*(1), 52-58.

44. Kulkarni, N., & Gadre, R. V. (2002). Production and properties of an alkaline, thermophilic lipase from Pseudomonas fluorescens NS2W. *Journal of Industrial Microbiology and Biotechnology*, *28*(6), 344-348.

45. Kanwar L, Gogoi B K & Goswami P, Production of a pseudomonas lipase in n-alkane substrate and its isolation using an improved ammonium sulfate precipitation technique, *Bioresourse Technol*, 84 (2002) 207-211.

46. Abramić M, Ivana L, Tamara K, Ljubinka V, Wolfram S *et al*, Purification and properties of extracellular lipase from *Streptomyces rimosus*, *Enzyme Microb Technol*, 25 (1999) 522-529.

47. Kar, T., Delvigne, F., Masson, M., Destain, J., & Thonart, P. (2008). Investigation of the effect of different extracellular factors on the lipase production by Yarrowia lipolityca on the basis of a scale-down approach. *Journal of industrial microbiology and biotechnology*, *35*(9), 1053.

48. Gupta, N., Sahai, V., & Gupta, R. (2007). Alkaline lipase from a novel strain Burkholderia multivorans: Statistical medium optimization and production in a bioreactor. *Process Biochemistry*, *42*(4), 518-526.

49. Jaeger, K. E., Dijkstra, B. W., & Reetz, M. T. (1999). Bacterial Biocatalysts: Molecular. *Annu. Rev. Microbiol*, *53*, 315-51.

50. Kempka, A. P., Lipke, N. L., da Luz Fontoura Pinheiro, T., Menoncin, S., Treichel, H., Freire, D. M., ... & de Oliveira, D. (2008). Response surface method to optimize the production and characterization of lipase from Penicillium verrucosum in solid-state fermentation. *Bioprocess and Biosystems Engineering*, *31*(2), 119-125.

51. Vargas, G. D., Treichel, H., de Oliveira, D., Beneti, S. C., Freire, D. M., & Di Luccio, M. (2008). Optimization of lipase production by Penicillium simplicissimum in soybean meal. *Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology*, *83*(1), 47-54.

52. Dutra, J. C., Terzi, S. C. D., Bevilaqua, J. V., Damaso, M. C., Couri, S., Langone, M. A., & Senna, L. F. (2007). Lipase production in solid-state fermentation monitoring biomass growth of Aspergillus niger using digital image processing. In *Biotechnology for Fuels and Chemicals* (pp. 431-443). Humana Press.

53. Alkan, H., Baysal, Z., Uyar, F., & Dogru, M. (2007). Production of lipase by a newly isolated Bacillus coagulans under solid-state fermentation using melon wastes. *Applied biochemistry and biotechnology*, *136*(2), 183-192.

54. de Azeredo, L. A., Gomes, P. M., Sant'Anna, G. L., Castilho, L. R., & Freire, D. M. (2007). Production and regulation of lipase activity from Penicillium restrictum in submerged and solid-state fermentations. *Current Microbiology*, *54*(5), 361-365.

55. Falony, G., Armas, J. C., Mendoza, J. C. D., & Hernández, J. L. M. (2006). Production of Extracellular Lipase from Aspergillus niger by Solid-State Fermentation. *Food Technology & Biotechnology*, *44*(2).

56. Mala, J. G. S., Edwinoliver, N. G., Kamini, N. R., & Puvanakrishnan, R. (2007). Mixed substrate solid state fermentation for production and extraction of lipase from Aspergillus niger MTCC 2594. *The Journal of general and applied microbiology*, *53*(4), 247-253.

57. Yang, X., Wang, B., Cui, F., & Tan, T. (2005). Production of lipase by repeated batch fermentation with immobilized Rhizopus arrhizus. *Process Biochemistry*, *40*(6), 2095-2103.

58. Benjamin, S., & Pandey, A. (1997). Enhancement of lipase production during repeated batch culture using immobilised Candida rugosa. *Process Biochemistry*, *32*(5), 437-440.

59. Zhao, W., Wang, J., Deng, R., & Wang, X. (2008). Scale-up fermentation of recombinant Candida rugosa lipase expressed in Pichia pastoris using the GAP promoter. *Journal of Industrial Microbiology and Biotechnology*, *35*(3), 189-195.

60. Boareto, Á. J., De Souza Jr, M. B., Valero, F., & Valdman, B. (2007). A hybrid neural model (HNM) for the on-line monitoring of lipase production by Candida rugosa. *Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology*, *82*(3), 319-327.

61. T. Ito, H. Kikuta, E. Nagomori, H. Honda, H. Ogino, H. Ishikawa et al*., "*Lipase production in two-step fed-batch culture of organic solvent-tolerant *Pseudomonas aeruginosa* LST-03*",* Journal of Bioscience and Bioengineering, vol.91, no.3, pp.245–250, 2001.

62. Ikeda, S., Nikaido, K., Araki, K., Yoshitake, A., Kumagai, H., & Isoai, A. (2004). Production of recombinant human lysosomal acid lipase in Schizosaccharomyces pombe: development of a fed-batch fermentation and purification process. *Journal of bioscience and bioengineering*, *98*(5), 366-373.

63. B. Jensen, P. Nebelong, J. Olsen, M. Reeslev*, "*Enzyme production in continuous cultivation by the thermophilic fungus Thermomyces lanuginosus*",* Biotechnological Letters, vol.24, pp.41–45, 2002.

64. Montesinos, J. L., Dalmau, E., & Casas, C. (2003). Lipase production in continuous culture of Candida rugosa. *Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology*, *78*(7), 753-761.

65. Ray, A. (2012). Application of lipase in industry. *Asian Journal of Pharmacy and technology*, *2*(2), 33-37.

66. Saxena, R. K., Sheoran, A., Giri, B., & Davidson, W. S. (2003). Purification strategies for microbial lipases. *Journal of microbiological methods*, *52*(1), 1-18.

67. Chandra, P., Singh, R., & Arora, P. K. (2020). Microbial lipases and their industrial applications: a comprehensive review. *Microbial Cell Factories*, *19*(1), 1-42.

68. Joshi, R., & Kuila, A. (2018). Lipase and their different industrial applications: A review. *Brazilian Journal of Biological Sciences*, *5*(10), 237-247.

69. Vulfson, E. N. (1994). Industrial applications of lipases. *Lipases*.

70. Sharma, D., Sharma, B., & Shukla, A. K. (2011). Biotechnological approach of microbial lipase: a review. *Biotechnology*, *10*(1), 23-40.

71. Ghosh, P. K., Saxena, R. K., Gupta, R., Yadav, R. P., & Davidson, S. (1996). Microbial lipases: production and applications. *Science Progress (1933-)*, 119-157.

72. Makhzoum, A., Owusu-Apenten, R. K., & Knapp, J. S. (1996). Purification and properties of lipase from Pseudomonas fluorescens strain 2D. *International Dairy Journal*, *6*(5), 459-472.

73. Custry, F., Fernander, N., & Shahani, K. M. (1987). Role of lipases and other enzymes in flavour development. In *Proceedings of 24th annual Miles-Marschall Italian cheese seminar* (pp. 16-17).

74. Maia, M. D. M. D., Morais, M. M. C. D., Morais Jr, M. A. D., Melo, E. H. M., & Lima Filho, J. L. D. (1999). Production of extracellular lipase by the phytopathogenic fungus Fusarium solani FS1. *Revista de microbiologia*, *30*(4), 304-309.

75. Wavhal, S. D., & Balasubramanya, R. H. (2011). Role of biotechnology in the treatment of polyester fabric. *Indian Journal of Microbiology*, *51*(2), 117-123.

76. Hasan, F., Shah, A. A., & Hameed, A. (2006). Industrial applications of microbial lipases. *Enzyme and Microbial Technology*, *39*(2), 235-251.

77. Vertommen, M. A. M. E., Nierstrasz, V. A., Van Der Veer, M., & Warmoeskerken, M. M. C. G. (2005). Enzymatic surface modification of poly (ethylene terephthalate). *Journal of biotechnology*, *120*(4), 376-386.

78. Ito, S., Kobayashi, T., Ara, K., Ozaki, K., Kawai, S., & Hatada, Y. (1998). Alkaline detergent enzymes from alkaliphiles: enzymatic properties, genetics, and structures. *Extremophiles*, *2*(3), 185-190.

79. Jaeger, K. E., & Eggert, T. (2002). Lipases for biotechnology. *Current opinion in biotechnology*, *13*(4), 390-397.

80. Dong, H., Gao, S., Han, S. P., & Cao, S. G. (1999). Purification and characterization of a Pseudomonas sp. lipase and its properties in non-aqueous media. *Biotechnology and Applied Biochemistry*, *30*(3), 251-256.

81. Sharma, R., Chisti, Y., & Banerjee, U. C. (2001). Production, purification, characterization, and applications of lipases. *Biotechnology advances*, *19*(8), 627-662.

82. Verma, N., Thakur, S., & Bhatt, A. K. (2012). Microbial lipases: industrial applications and properties (a review). *International Research Journal of Biological Sciences*, *1*(8), 88-92.)."

83. Matsumae, H., Furui, M., & Shibatani, T. (1993). Lipase-catalyzed asymmetric hydrolysis of 3-phenylglycidic acid ester, the key intermediate in the synthesis of diltiazem hydrochloride. *Journal of fermentation and bioengineering*, *75*(2), 93-98.

84. Balcão, V. M., Paiva, A. L., & Malcata, F. X. (1996). Bioreactors with immobilized lipases: state of the art. *Enzyme and Microbial Technology*, *18*(6), 392-416.

85. Rai, B., Shrestha, A., Sharma, S., & Joshi, J. (2014). Screening, optimization and process scale up for pilot scale production of lipase by Aspergillus niger. *Biomed. Biotechnol*, *2*, 54-59.

86. Pandey, A., Benjamin, S., Soccol, C. R., Nigam, P., Krieger, N., & Soccol, V. T. (1999). The realm of microbial lipases in biotechnology. *Biotechnology and applied biochemistry*, *29*(2), 119-131.

87. Verma, N., Thakur, S., & Bhatt, A. K. (2012). Microbial lipases: industrial applications and properties (a review). *International Research Journal of Biological Sciences*, *1*(8), 88-92.

88. http://www.au-kbc.org/beta/bioproj2/uses.html.

89. Gupta, A., & Khare, S. K. (2009). Enzymes from solvent-tolerant microbes: useful biocatalysts for non-aqueous enzymology. *Critical reviews in biotechnology*, *29*(1), 44-54.

90. Jaeger, K. E., & Reetz, M. T. (1998). Microbial lipases form versatile tools for biotechnology. *Trends in biotechnology*, *16*(9), 396-403.

91. Shah, S., Sharma, S., & Gupta, M. N. (2004). Biodiesel preparation by lipase-catalyzed transesterification of Jatropha oil. *Energy & Fuels*, *18*(1), 154-159.

92. Iso, M., Chen, B., Eguchi, M., Kudo, T., & Shrestha, S. (2001). Production of biodiesel fuel from triglycerides and alcohol using immobilized lipase. *Journal of Molecular Catalysis B: Enzymatic*, *16*(1), 53-58.

93. Hsu, A. F., Jones, K., Foglia, T. A., & Marmer, W. N. (2002). Immobilized lipase-catalysed production of alkyl esters of restaurant grease as biodiesel. *Biotechnology and applied biochemistry*, *36*(3), 181-186.

94. Abigor, R. D., Uadia, P. O., Foglia, T. A., Haas, M. J., Jones, K. C., Okpefa, E., ... & Bafor, M. E. (2000). Lipase-catalysed production of biodiesel fuel from some Nigerian lauric oils.

95. Shimada, Y., Sugihara, A., Nagao, T., & Tominaga, Y. (1992). Induction of Geotrichum candidum lipase by long-chain fatty acids. *Journal of fermentation and bioengineering*, *74*(2), 77-80.

96. Jaeger, K. E., Dijkstra, B. W., & Reetz, M. T. (1999). Bacterial Biocatalysts: Molecular. *Annu. Rev. Microbiol*, *53*, 315-51.

97. Bharathi, D., & Rajalakshmi, G. (2019). Microbial lipases: An overview of screening, production, and purification. *Biocatalysis and Agricultural Biotechnology*, *22*, 101368.

98. El-Batal, A. I., Farrag, A. A., Elsayed, M. A., & El-Khawaga, A. M. (2016). Biodiesel production by Aspergillus niger lipase immobilized on barium ferrite magnetic nanoparticles. *Bioengineering*, *3*(2), 14.

99. Bajpai P. Application of enzymes in the pulp and paper industry. Biotechnol Progr 1999;15:147–57.

100. Fukuda, S., Hayashi, S., Ochiai, H., Iiizumi, T., & Nakamura, K. (1990). Improvers for deinking of wastepaper. *Japanese Patent*, *2*, 229-290.

101. Maugard, T., Rejasse, B., & Legoy, M. D. (2002). Synthesis of water-soluble retinol derivatives by enzymatic method. *Biotechnology progress*, *18*(3), 424-428.

102. Jeon, J. H., Kim, J. T., Kim, Y. J., Kim, H. K., Lee, H. S., Kang, S. G., ... & Lee, J. H. (2009). Cloning and characterization of a new cold-active lipase from a deep-sea sediment metagenome. *Applied microbiology and biotechnology*, *81*(5), 865-874.