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An Updated Review on the Recent Advancements of Plasticizers in Transdermal Delivery of the Therapeutic Molecule

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ABSTRACT: A plasticizer is a significant chemical component that makes another material, especially a polymeric composite softer and more flexible by conjugating with it. Plasticizers when added to a polymer, generate a glass-transition temperature, resulting in enhanced stretchability, and workability. The selection of an appropriate plasticizer necessitates a broad knowledge base. This is because they are used in medication delivery systems that contain a variety of therapeutic ingredients that may react differently to the presence of plasticizers. In addition to the plasticizing effect, they also play an important role in modulating drug release profiles. The selection of a plasticizer is critical for the stabilityof dosage form, processing as well as in vivo performance.

KEYWORDS: Plasticizer, Transdermal patch, Skin, Penetration enhancer, Polymeric composite.

I. INTRODUCTION

A plasticizer is generally categorized as a nonvolatile compound with la ow molecular weight that has been used as additives in the polymer industry. A plasticizer is a substance with low vapor pressure organic materials that are added to a material to increase flexibility to work.Aplasticizerreducestheviscosity,theglasstransition temperature, and the elastic modulus. Plasticizers undergo several procedures of swelling and dissolution to form a homogenous physical unit via the interaction with the ester units.[1] Theintroductionofplasticizersintopolymer compounds in the alteration of the rheologicalpropertiesofthebonds which in turn enhances in useful life of the materials based on them, and reduces energy consumption andmaterialcosts.Theplasticizersreducethebrittlenessandincrease the hardness and increase the resistance to extreme temperature changes. However, they reduce thermal resistance and reducedielectricproperties there are two main types of plasticizers: internal plasticizers and external plasticizers. Internal plasticizers attach to the polymer chains through a chemical bond and, by polymer modification, and hence the polymer's elasticity increases. External plasticizers are low vapor compounds that do not have any chemical reaction with the polymer and show their plasticizing properties only through physical interactions with the polymer.[2]The main role of such materials is to improve the flexibilityandprocessingofpolymersbyreducingtheglasstransitiontemperature (T_g). These materials reduce the deformation, hardness, density,viscosity,andan electrostaticloadofthepolymerwhileincreasing the flexibility of polymer chains, fracture resistance, and dielectric properties.[3]Plasticizeraffectsotherpropertiessuchasdegreeofcrystallinity, optical clarity, electrical conductivity, fire resistance, and biologicaldegradation.[4] Migrationisoneofthemostsignificant drawbacksoftheplasticizers inthepolymericmatrix.Inthisphenomenon,theplasticizermolecules stay mobile in the polymer matrix and exude into the surface of the polymeric matrix, which is unpredictable even in mild storage conditions.[5]This problem significantly affects the efficacy of the polymer matrix,whichresultsinachangeinthemechanicalpropertiesandcontamination of other materials. Different strategies have been used to reduce plasticizer migration.[6]Among them, it is possible to increase the molecular weight of the plasticizer to reduce itsmobility and evaporation of themor the addition of the mineral nanoparticles forlinkingwiththeplasticizermolecules.Anothersolutionisthe compatibility of the polymer and the plasticizers. Factors that affect compatibility include polarity, size (molecular weight), and plasticizer shape. These factors lead to the formation of plasticizers and the polymeric matrix.[7]

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II. TOPICAL DRUG DELIVERY SYSTEM-

Researchers in the field of pharmaceutical science have significant problems when it comes to therapeutic compounds that pass through the skin. In recent times topical administration is the favored approach for administering therapeutic compounds locally due to its ease and cost. Formulations like ointment, gel, cream,andtransdermal patch are used as a topformulations. [8]

When shear stress is applied to ointments, they often act like viscoelastic materials. They usually contain medications and are designed to be administered to the body or mucous membrane externally. Ointments are homogeneous, semi-solid formulations that are applied to the skin or mucous membrane externally. They're applied as emollients or to apply active chemicals to the skin for protective, medicinal, or preventive purposes, and when a degree of occlusion is needed. [9] All ointments have a base that serves primarily as a carrier for the medicaments. The nature of the base influences its performance as well. As a result, the choice of ointment base is a critical part of their formulation. It is necessary to have a scientific grasp of the percutaneous absorption of ointment bases. It's critical to understand the skin's structure in regards to drug absorption [10]. Plasticizers play an impotent role in the preparation of ointment. Ointments are classified into three parts amphiphilic ointment b. hydrophobic ointment c. water-emulsifying ointment. Hydrophilic ointment bases are water miscible glycols, both liquid and solid,are commonly used as bases. [11]

Creams are dosage forms that are "viscous liquid or semi-solid emulsions of either the oil-in-water or water-in-oil type." This varies in texture based on the oil and water used.it is a topical preparation generally used for application to the skin. [12] Such external preparations are also used to transfer medicaments to the underlying layer of the skin or even the mucous membrane for a specific effect. Those formulations are prepared in such a way that it is used topically to improve therapeutic distribution to particular sites in the skin for skin diseases.[13]Because friction occurs between its chains, connecting them into a network, a "dry" polymer, a resin withouta plasticizer, is hard. The binding is weakened when the polymer is heated to be plasticized, allowing the smaller plasticizer molecules to slide in between the chains. The plasticizer molecules function as a lubricant between the chains when the polymer cools, allowing them to slide.[14]

Scientific data suggests that transdermal drug delivery system therapy is a safe and effective treatment option for skin disorders and that it can be utilized for local action to lessen the negative effects of other conventional dosage forms. In a liquid media, a gel is a cross-linked polymer network that has swelled.The combination of the solid-statepolymer with the liquid component has a significant influence on its properties. There is no steady-state flow in gels. [15]

- Gels are mostly classified using two methods:

1. **Nature of colloid phase:**

a) Inorganic gels (Two-phase system).
b) Organic gels (single-phase system).

2. Organic gels (single-phase system):

a) Hydrogel (Aqueous gels).
b) Xerogel
c) Organic gel (Nonaqueous gels) [16]

Plasticizers have little effect on gel formation. Polymers are separated and the area among polymer structures is increased, it lessens considering gel structure's rigidity. Furthermore, unconnected plasticizer monomers tend to clump together, enablingthemolecular chain to flow more easily, it's how plasticizer improves gel elasticity. [17]

In recent years transdermal drug delivery and transdermal patch have earned great interest. Transdermal drug delivery systems (TDDS), also called "patches," are delivery systems that administer a therapeutically effective quantity of medications to a patient through their skin.[18]The transdermal route is the most convenient for delivering drugs with a short biological half-life or that are poorly soluble. This approach has several advantages over other routes, including avoiding first-pass hepatic metabolism, fewer side effects, gastrointestinal effects, and higher bioavailability[19].The rapidity where the liquid medicament in the patch's reservoir may pass through the skin and into the circulation. is controlled by a specific membrane in a transdermal patch (Skin patch).[20] To be utilized in a skin patch, some medications must be mixed with chemicals that boost their capacity to permeate the skin, such as alcohol.[21] Plasticizers are utilized in transdermal systems to increase the fragility of the polymer while also maintaining flexibility [22]. These are non-volatile organic liquids or solids with low melting points that alter the physical and mechanical characteristics of polymers when applied [23]. Even as the tightness of intermolecular forces loosens with the addition

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ofplasticizers, the flexibility of polymer macromolecular segments increases. In pharmaceutical formulations, several polymers are employedand are rigid, necessitating a plasticizer to be added to the mix [24]. When comparing lower and higher molecular weight plasticizers, lower molecular weight plasticizers contain more molecules per unit weight [25]. These molecules can more readily infiltrate through film-forming agent's polymer chains and react with the polymer's particular functional groups[26]. It's believed that elongation at break, toughness, and flexibility will all improve. When plasticizer is added to a polymeric material; nevertheless, tensile stress, hardness, electrostatic charge ability, and glass transition temperature (Tg) are all projected to drop in the future. [27].

III. PLASTICIZER

A plasticizer is a chemical that increases the flexibility of a polymer. The plasticizer goes between the chains of polymer and maintains their separation enhancing the material's flexibility by increasing the forces of attraction between them. Because of this plasticizer, the polymer's strength and stiffness will likely be diminished however, if flexibility is necessary, the material will be more effective. [28]. Although numerous plasticizers are utilized in the chemical sector, only a handful has been recognized for use in pharmaceuticals. Natural-based plasticizers with minimal toxicity and migration are currently required in a variety of applications, not just pharmaceutical and medical ones [29]. In this regard, the majority of conventional plasticizers are ineffective. External plasticizers added to pharmaceutically utilized polymers interact with their chains these days, but because they aren't chemically bonded to them by main bonds, they can be lost by evaporation, diffusion, or extraction. [30]. The use of exogenous plasticizers has several advantages. That you may choose the optimum type and concentration of plasticizer based on the therapeutic system that is intended features, especially when it comes to drug administration. Plasticizers can be liquid medications or liquids having a possible pharmacological impact [31].

In addition, the hydrophilic polymer's structural water seems to act as a polymeric drug's internal plasticizer. Methods of delivery the hydrophilic plasticizer can be removed if it comes into touch with bodily fluids after application. As a result of the polymer's release, and hence the circumstances for the release of a medicine that has been integrated have been altered. The water-repellent plasticizer stays in the system and guarantees that the quality is maintained. During the medication release process, several parameters must be met [32]. But on the other hand, the insertion of a hydrophilic plasticizer for the polymeric, when the drug carrier is present in high concentrations, might cause an increase in the amount of the drug. Diffusivity is the rate at which water diffuses into a polymer. The system's settings are altered. As a result, the elimination of a substance alters the kinetics of drug release. The time it takes for a medication to be released. Plasticizers hurt the environment. Viscosity, which might help or hinder the application Some preparations, for example, must have a suitable low viscosity at room temperature. For convenient handling, a temperature of less than 50° C is required. Manipulation as well as the simple and safe use of implants placed in the body via a trocar device or an injectable needle [33].

IV. PLASTICIZER EFFECT ON TOPICAL DRUG DELIVERY SYSTEM

Plasticized polymers are now being employed as a new technology in the pharmaceutical industry to regulate adjusts release drug properties in the systemic system. Recently, a wide range of polymerized plasticized materialshave become available. Microparticles matrices, and systems have all been examined [34]. It aids in the improvement of film flexibility and the reduction of brittleness in formulations. By lowering the polymer's glass transition temperature, plasticizer enhances strip characteristics dramatically [35]. The plasticizer's compatibility with the excipients, medication, and kind of solvent used in the development of pharmaceutical formulations are all significant factors to consider. [36]. For non-aqueous solvent systems, plasticizers can reduce the melting temperature of polymers by 40–600°C, and an aqueous solvent systems by below 750°C. The sort of plasticizer used in the production of the film should impart permanent flexibility, It is influenced by the plasticizer's unstable nature as well as the type of interlink aging with the polymer. It must be compatible with the medicine as well as the other excipients used in the film's manufacture [37]. Plasticizers play an important part in pharmaceutical formulations such as gastro-retentive films, ocular films, transdermal films, buccal films, and Oro-dispersible films due to their critical relevance in these formulations.

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Plasticizers, which finally imparted required characteristics an extreme usage of this excipient in the formulation, could Flexibility, endurance, resistibility, and stability is all desirable qualities in a formulation. [38].

Ideal characteristics of Plasticizer used in Topical drug delivery system-[39-42]

1. Plasticizer is an important component of fast-dissolving films. By lowering the polymer's glass transition temperature, it improves film-forming characteristics dramatically.
2. Plasticizer improves the strip's flexibility while also reducing the deformation of the films.
3. The molecular structure and concentration of plasticizers are critical variables in decreasing polymer glass-transition temperatures.
4. The plasticizer used is based on the polymer's compatibility and also the type of solvent used in the film's casting.
5. Plasticizer improves the flow of polymeric solutions and raises the strength of a polymer. Glycerol, propylene glycol, low-molecular-weight polyethylene glycols, citrate derivatives like tributyl, triethyl, acetyl citrate, triacetin, and castor oil, and also phthalate derivatives like dimethyl, diethyl, and dibutyl phthalate, are all examples of plasticizer excipients.
6. Plasticizers are usually used at a concentration of 0–20 percent by the weight of the dry polymer. Incorrect use of plasticizer, on the other hand, might cause the strip's film to fracture, break, and peel.
7. It has also been shown that the usage of some plasticizers might affect the rate of medication absorption.

V. THEORY OF PLASTICIZERS

There are several ideas that describe the actions of plasticizers and their variations, allowing the concept of polymer plasticization to be explained.

Gel theory

Polymers are held together by weak secondary bonding strength (van der Waals' forces, hydrogen bonding), which form a three-dimensional internal network of polymer structures along their chains. External strain given to the material may quickly reduce these bounding forces, bending, stretching, or compressing the plasticized polymer [43]. Plasticizer molecules are bound to polymeric chains, reducing polymer-polymer interactions and disrupting the bonds that keep polymer chains together. It reduces the stiffness of the gel structure by separating the polymer chains and increasing the space between polymer molecules. Furthermore, particles of plasticizers that aren't connected to polymer molecules tend to agglomerate, giving additional freedom of movement to polymer molecules, which is how plasticizer improves gel flexibility [44].

Lubricity theory

According to the article, a plasticizer serves as a lubricator, decreasing Polymer molecules coming into contact with each other, causing enter particle friction, which is responsible for the polymer's stiffness. Plasticizer particles Interact with polymer chains when they heat up, reducing the strength of polymer-polymer interactions and sheltering polymer chains from one another. This prevents a rigid network from reconstructing and produces a polymer matrix that is more flexible, softer, and distensible.[45]

Free volume theory

The incorporation of plasticizers lowers the polymer's glass transition (Tg). The term "free volume" refers to the amount of a polymer matrix's interior space. An internal polymer movements, three major sources of free volume in polymers are the motion of polymer end groups, the motion of polymer side groups, and the motion of polymer end groups. Volume increases when more room (or free volume) becomes available for polymer chain movement. [46]. A glassy polymer is an interior structure with densely packed molecules and a small amount of empty space. The material becomes stiff and as a result, the material stiffens and hardens. Thermal energy and molecular vibrations give more free space when a polymer is heated over its transformation temperature, allowing for higher internal chain rotation and segment mobility. As a result, the system becomes more flexible and rubberier. The polymer chain's free volume segments increases or decrease the glass transition temperature when tiny chemicals such as plasticizers are introduced [47].

Plasticizer molecules are not bonded to the polymer continuously, according to the mechanistic hypothesis of plasticization, but rather create a dynamic exchange process in which continual affiliations and Polymer-polymer, polymer plasticizer, and plasticizer-plasticizer molecular disassociations occur. Some plasticizers bind to polymers more strongly than others [48] At low plasticizer levels, the plasticizer polymer interactions are the dominant interactions. which explains "ant plasticization." Plasticizer-plasticizer relationships prevail at high plasticizer loadings [49].

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VI. PLASTICIZERS DERIVED FROM NATURAL SOURCES-

Epoxidized soybean oil (ESO)

Epoxidized plasticizers are used in the plastics, rubber, coatings, and innovative polymer materials sectors because they are environmentally benign. [50]. In comparison In the epoxidized plasticizer structure, the polymer group might absorb and neutralized hydrogen chloride generated by PVC after light or heat breakdown, inclusion in their plasticizers, which limits or slow down their continuous fragmenting of PVC, ensures optimum light and temperature stability to PVC products and extends their duration of service [51]. Furthermore, because of the exceptionally nonharmful of epoxidized plasticizers, it's been permitted In many countries and locations, packaging materials and medical device materials are approved, causing their production and price to rise in recent years [52]. The most prevalent biomass-based epoxidized plasticizers include vegetable oils, fatty acid esters, and epoxy groups including cardanol derivatives. Presently natural oils and fatty acid esters are available. [53]. ESO stands for epoxidized soybean oil and refers to a range of chemical compounds derived from soybean oil epoxidation, which has long been used as a PVC plasticizer and heat stabilizer Figure depicts the chemical composition of ESO.

Ferrer et al. discovered that PVC formulations with varying levels of ESO are an acronym for "Environmental 30 to 50 percent enhanced thermal characteristics and compatibility [54].

The epoxide group reacts faster than the double bond; it provides a more powerfully efficient reaction site, producing the oil as an effective scavenger and plasticizer of hydrochloric acid. To change the -C=C- connection to an epoxide group by adding an atom of oxygen, a peroxide or peracid is usually utilized [55].The epoxidation technique is used to create ESBO from soybean oil. Because they have a large number of double bonds between carbon atoms accessible for epoxidation, unsaturated vegetable oils are commonly employed as precursors to epoxidized oil products [56].

Wei He et al the merging of epoxidation catalyzed by α -Al2O3H2O and ring-opening process catalyzed by H2SO4 resulted in four new plasticizers based on epoxidized soybean oil (ESO). In the epoxidation process, different D50 values of -Al2O3H2O were used to study the influence of particle size on catalytic performance [57].

Xiaoyan Ge, Long Yu et al To increase the moisture sensitivity and gas permeability of starch-based films, an acrylate epoxidized soybean oil (AESO)-based coating was developed [58]. Jingjing Si et al In this study epoxidized soybean oil, it is possible to increase the compatibility of asphalt and epoxy resin (ER) (ESO). With rising ESO concentrations, the viscosity and glass transition temperature (Tg) fall, and the asphalt disperses more equally in the ER.[59].

S. Ammar et alpolyisocyanate (NCO) as the curing agent, varied loading ratios of epoxy resin (E) and epoxidized soybean oil (ESO) were being as a plasticizer into an acrylic–silicone polymeric mix in this work. The findings revealed that combining E and ESO at a specific concentration, 9:1, can improve the overall performance of the polymeric matrix by achieving an optimal curing level, improved drench, excellent physical-mechanical qualities, and enhanced corrosion resistance, and better thermal stability [60].

Linseed oil

Linseed oil, popularly known as flaxseed oil or flax oil, is a colorless or yellowish oil derived from dried, mature seeds of the flax plant (Linum usitatissimum).Crushing is a technique that is used to get the oil, which is occasionallyafter that, solvent extraction. it is a curing oil that comes from linseed seeds, which means It has the ability to copolymerize and solidifyand becomes a solid-state.Linseed oil is used to bind fabrics, Due to its polymer-forming qualities, it is used as a color binder in oil paints, as a plasticizer and hardener in putty, and in the manufacture of linoleum as a drying oil finish or varnish. [61]. Linseed oil, like other fats, is a triglyceride. Linseed oil is notable for having an extremelylinolenic acid, which interacts with oxygen from the air in a particular way. A typical linseed oil's fatty acids are split into the following categories: Unsaturated -linolenic acid, saturated acids palmitic acid, and stearic acidmake up the triply unsaturated -linolenic acid. Oleic acid is an unsaturated fatty acid that ranges from 18.5 to 22.6 percent. Linoleic acid is double unsaturated (14.2–17%) [62].

J.F. Balart et al investigated Different quantities of epoxidized linseed oil (ELO) that were added to poly(lactic acid)-PLA composites with hazelnut shell flour to generate a plasticizing effect and improve the weak inherent ductile qualities of PLA/HSF composites (HSF). These results show that ELO has a plasticizing effect [63].

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M.P. Arrieta et al Plasticized Epoxidized linseed oil (ELO) combined with poly-vinyl chloride and also (TEGR) tri-ethylene glycol ester of gum rosin, a natural viscosity enhancer is used. Despite the fact that the addition of both chemicals resulted in minor color differences, all formulations were bright & clear, with TEGR causing a red-toned and ELO causing an amber-toned. [64].

Milovan R et al The invention of a liquid-liquid bi-phasic model withepoxidation of vegetable oils with formic acids showing an ion-exchange resin like a catalyst that accounts for the fatty acid content of the oil in this kinetics process.The epoxidation of linseed- oil using acetic acid produced from acetic acid in situ and a 30% solution of hydrogen peroxide is carried out Amber lite IR120-H ion exchange resin was used as a catalyst, resulting in a relative epoxy yield of more than 85%.[65].

Yupei Su et al Linseed oil & acrylic acid, and boron tri-fluoride diethyl ether were used as the raw materials. ingredients and boron tri-fluoride diethyl ether as a catalyst, a unique one-step process for developing 2.5-functional acrylate pre-polymers based on linseed oil (ALO) was developed [66].

Sheela S. Fernandez et al Linseed oil plasticizer was used to make vulcanizes Expandable graphite (EG) & natural rubber (NR). To assess its potential as a plasticizer, researchers looked at the effects of linseed oil on the cure and mechanical characteristics of NR/EG vulcanizates, such as cure duration, tensile strength, rip strength, and modulus, elongation at break, and swelling behavior [67].

Castor oil

Castor oil is commonly used more as a subordinate plasticizer in PVC, It is blended in quantities ranging from 10% to 20% with major plasticizers such as dioctyl phosphate (DOP) or tricresyl phosphate [68]. Epoxidized acetylated castor oil gives vinyl flexibility and increases thermal stability, and it might be employed as the only plasticizer in mixtures with a plasticizer concentration of less than 45 percent [69]. Castor oil was a vegetable oil derived from the castor bean's seeds; which is made up of a combination of triglycerides & ricinoleates accounting for around 90% of the fatty acids [70]. The other important components are oleate & linoleates [71]. Ricinoleic acid is an 18-carbon unsaturated fatty acid, that is abundant in castor oil. Ricinoleic acid is unique among fatty acids in that it possesses a hydroxyl functional group at the 12th carbon atom. Ricin-oleic acids & castor oil are more polar than other fats because of this functional group. Chemical derivatization is also feasible due to the alcohol group's chemical reactivity, which is not achievable with most other seed oils [72].

Puyou Jai et al produced a new propargyl ether EAMR-DOPO, a phosphorus-containing castor oil-based derivative that was covalently coupled bonded to internally as a plasticizer, PVC-N3 is used in this work. Materials made of PVC developed were added thermally It was stable between 350 and 500 degrees Celsius and had a lower Tg over PVCThe migration stability testing revealed no migration [73].

Goudong et al Phosphate plasticizer made from castor oil with phosphaphenanthrene groups were produced & described. PGPP's initial Td was 356.8 C, which was greater than DOP's (255.1 C) [74].

Qinghe Fu et al developed a Castor oil was utilized to make a variety of novel environmentally friendly plasticizers that wereused to make nitrile rubber plastic (NBR). NBR vulcanizates plasticized with castor oil-based plasticizers had higher tensile strength, elongation at break, and rip strength be satisfactory in the tests. Dioctyl phthalate's performance is superior (DOP) [75].**James Anthony Dicks et al** they shown that employing Renewable alternatives to petroleum-derived polymeric foams could be made using modified castor oil and iso-bornyl methacrylate as feedstock made [76].

Weidi He et al In this study, self-crosslinking epoxidized castor oil (ECO) structures are created & PLA/ECO mix samples were madeby means of dynamic solidifies. Effects of toughening with this ECO and regular castor oil on PLA are next examined. Both FTIR and NMR measurements show that castor oil has been successfully epoxidized [77].

VII. PLASTICIZERS DERIVED FROM SYNTHETIC SOURCES-

Citrate esters derivatives

Triethyl citrate is a citric acid ester. It's a colorless, odorless liquid that's used as a food additive to stabilize foams, particularly for egg white whipping. It's also utilized in plastics and medicinal coatings. Plasticizers such as polyvinyl chloride (PVC) and related polymers employ triethyl citrate as a plasticizer.[78] Tri-ethyl citrate was a trimester of ethyl alcohol & citric acid that was used as a water-soluble plasticizer in aqueous environment. At 25°C, it also has a viscosity of

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35.2 cP [79] At 107° C; the vapor pressure is 1 mm Hg [80]. The plasticizers tri-ethyl citrate, tri-butyl citrate, acryl tri-ethyl citrate, and acetyl tri-butyl citrate are employed. Laura Aliotta et al studied the acetyl tri-butyl citrate plasticizer's (ATBC) attraction for PLA & PBAT polymers. The effects of varied amounts of ATBC (from 5 to 20 wt percent) PLA and PBAT mixtures that have been fully plasticized were studied. DMTA experiments were used figure out how the glass transition temperatures (Tg) of the both polymers changed as the quantity of ATBC increased. The main change in Tg was detected for PLA rather than PBAT, leading to the conclusion that the ATBC has a stronger affinity for PLA rather than PBAT [81].

Anshu Anjali Singh et al investigated the effects of adding Tri-ethyl citrate & glycerol tri-acetate are two bio-based plasticizers as well as Hallo site nanotubes & chitosan powder are two fillers, in many combinations, on polylactic acid (PLA) sheets' mechanical, thermal, barrier, and antibacterial characteristics. Tensile studies demonstrated that now the TEC plasticizes the PLA effectively, as the elongation at break increased considerably (80 times), while the tensile modulus and tensile strength decreased dramatically[82]. **S. A. N. Ahmad Zuber et al** main purpose of this study was to examine the two natural-based plasticizers tri-acetic and tri-ethyl citrate could be utilized in both polyvinyl alcohols (PVA) along with identical molecular weight but differing degrees of hydrolysis (88 percent & 99 percent). PVA and plasticizers were used to blended together using a solvent blending process, then the PVA solution are cast to make PVA that is plasticized. TRI reduced glass transition temperature (Tg) and melt temperature (Tm) in both PVAs at a set amount of plasticizer (10%), with the biggest reduction in 88 percent hydrolyzed PVA, whereas TEC exhibited no significant changes in Tg and a modest drop in melt temperature implying that TRI has a higher plasticization effectiveness in 88 percent hydrolyzed PVA (PVA88) [83].

Miji Lee,et al The purpose of the whole study was to investigate the water vapour adsorption behavior & mechanical properties of PLA/zeolite composites 5, 10, or 15 phr, Made by a melting procedure using tri-ethyl citrate (TEC; 20 phr). TEC was employed to increase the PLA's flexibility and the zeolite's dispersibility in ultrasonicated TECzeolite suspensions. The presence of zeolite in the PLA matrix was discovered, as was the fact that TEC increased the interfacial bonding in between PLA matrix and the zeolite. [84].

Xin-Gui L et al A revolutionary two-tons-scaled process has been developed in order to fabricate without the need of a catalyst of VOC-unrestricted WPU diffusion & films with hard-segment ratios of 50-60%. ATBC may be utilised to successfully replace NMP and DMF in the preparation of WPU dispersions and films without sacrificing quality. The ATBC found WPUs had demonstrated similar tensile characteristics and glass- transition temperatures as standard WPUs based on NMP that have similar molecular structures, However, it possessed a higher molecular weight, better thermal stability, and better water resistance.. Furthermore, ATBC plays an essential role in hydrophilic chain extension and stays a non-toxic and stable plasticizer for WPU films [85].

Fatty acid ester derivatives

All vinyl plasticizers give normally brittle and non-elastic polyvinyl resins somewhat permanent flexibility, toughness, and flow characteristics. In terms of affinity they are different, durability, productivity also a variety to other factors. Flexibility at room temperature, flame resistance so on as well as electrical qualities there isn't a single plasticizer structure that is perfect. The diverse set of qualities needed for each of the polyvinyl resins have a wide range of applications . Epoxy fatty acid ester plasticizers are made by epoxidating undivided fatty acid esters of monohydric and polyhydric alcohols with asperic acid. Epoxidation also its companion process, hydroxylation, are two reactions that occur simultaneously. A fatty acid and its derivative could be easily transformed with in the equivalent epoxy & di-hydroxyl compound using an aromatic per acid-e.g., per acetic or hydrogen peroxide-in combination with an open chain acid, depending on experimental circumstances.[86]

Xiaojiang Liangs et al Through two phases of trans esterification and epoxidation reactions, a biodegradable and environmentally friendly plasticizer Ep-FABEs is produced utilizing as the feedstock. The trans esterification Iso-butanol was used to create FAMEs carried out in a reactor with a gas-liquid tower that the researchers designed themselves. After a 5-hour response, the maximum FAMEs conversion rate might reach about 100%. The trans esterification process was studied kinetically, and the predicted activation energy was 48.93 kJmol1. Then utilized the primary materials of FABEs to make Ep-FABEs as a plasticizer that might replace dop [87].

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Jiaxi Lis et al Three distinct pure MGs and seven different glycerol monostearate (MS) combinations were tested: The influence of mono-glyceride (MGs) acyl chain length and compounding of MGs on the oleo gel characteristics and stability was investigated using glycerol mono-behenate (MB) ratios with high oleic sunflower oil (HOSO) as the liquid oil. The findings revealed that the lengths of the MG chains and the MS vs. MB ratios regulated an oleo gel characteristics & stability in a non-linear manner. Distinct melting temperatures and solubility were caused by MG chain lengths and MS:MB ratios have changed, which altered the crystallization & pattern of crystal development, resulting in various microstructures [88]. Swati Kanwars et al Wheat straw was used to extract arabinoxylan (AX) and cellulose, whereas potato peel was used to extract starch. Then, using following that, cellulose , starch fatty acid esters & starch fatty acid esters with DS 2.1 to 2.8 were produced using lauric, myristic, palmitic, and stearic acids. were prepared. Crystalline phase reduction for cellulose & starch as a result of fatty acid esterification was observed in an XRD research. The insertion of palmitate & stearate esters of cellulose and starch were added to AX produced microstructures of laminar films that restricted water vapour but films formed by combining AX with starch and cellulose laurate and myristate esters have a lower permeability produced non-layer microstructures that didn't work as well as a water vapour barrier [89].

Chia Chun Lois et al Because of its low solubility in water although glycerol mono-oleate (GMO) increases creaming strength in protein-stabilized emulsions, it is not suited for non-stop aqueous applications. Encapsulation can transform a waxy solid GMO into such a water-soluble powder. They studied the effects of emulsion preparation (GMO content (33.6 percent, 47.0 percent); dextrose equivalent (DE) values of maltodextrin (DE 10, 18)) on emulsion and powder qualities, as well as spray-drying to make instantised GMO powders. Because of their great emulsion solidity, monomodal Distributions of droplet sizes 150 to180nm & low viscosity 20 to 65 mPas , Spray drying was shown to be possible with all homogenised emulsions. [90]. **Sharareh Salar-Behzad s at el** This paper offers a revolutionary direct compaction method for developing prolonged release matrix tablets with reliable performance. For the creation of extended-release tablets, selected compounds from the poly glycerol esters of fatty acids category of lipid-based excipients (LBE) with increased solid-state stability were employed. Metformin HCl was utilised as a model material since it is an easily water soluble API. As the matrix forming agents, Three PGFA compounds with HLB values ranging from 1.8 to 4.5 has been chosen. The flow characteristics and deformation behaviour of tableting mixes with and without PGFAs were investigated [91].

Sebacate Derivatives

Since it has a higher plasticizing effectiveness than other plasticizers, it is the primary option and common for non-aqueous & aqueous systems. When exposed an aqueous fluids, DBS was essentially insoluble in water, which considerably minimizes the evaporation from the film. This serves to prevent drug release while still maintaining film integrity, resulting in efficient and repeatable regulation of drug release from the dose form. It's much less volatile, with a boiling point of 344 to349°C and a vapour pressure of 0.4 kPa at 180°C than other liquid plasticizers, resulting in less loss from the film during the curing stage. However, due to its low solubility, the polymer takes longer to plasticize in an aqueous polymer environment takes longer (7 hours) [92]. Due of its great compatibility, DBS is generally utilized in ethyl cellulose and Eudragits-based compositions as a plasticizer. Furthermore, because of its very hydrophobic nature, it aids in reducing vapour incorporation into the formula during store during maintaining for the formulation's mechanical and therapeutic release qualities [93].

Antonios Keirouzs et al The scalable nozzle-free electrospinning technology was used to create a Poly(vinylpyrrolidone) & Poly(glycerol sebacate) blends have been used to create a novel structure for skin tissue engineering . Morphological, thermochemical and the mechanical property of the PVP:PGS blends generated was studied. The mix ratio was associated with the produced fibres' shape [94].

Yingmei Zhangs et al A PGS/SF scaffold was successfully created in this study, with PGS having great elastic properties and SF having higher solidity and biocompatibility. After electro spinning into small-diameter artificial blood arteries, the spinning solution consisted of a mixture of PGS pre-polymer and SF, which had to be solidified. As per findings, the solidification procedures utilised to create artificial blood vessels had no discernible impact on the secondary structure or amino acid content of silk fibroin.[95]

Janeni Natarajans et al Despite tremendous advancements in recent years, the search for the ideal biomaterial continues. In this context, combining natural and artificial polymers have

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grown in popularity. This is the simplest approach toward compensate for flaws & produce a superior stuff. The purpose of this study was to develop a new polyester called poly(galactitol sebacate) and combine this beside three natural polymers: alginate, chitosan, and ethyl cellulose. Both polymers were detected in the mixes using FT-IR. 1H NMR was used to confirm the chemical composition of the produced poly (galactitol sebacate). DSC thermal characterization revealed that the polymer was naturally nebulous, and that as the polymer ratio grew, the glass transition temperatures climbed [96].

Ahmad Saudi s el al Electro spinning of natural and manmade polymers produces fibres, which opens up a new point of view to tissue engineering. For nerve tissue engineering, Various amounts of pectin 0, 1, 3, and 5% wt were added to aligned electro spun poly(glycerol sebacate) & poly(vinyl alcohol fibers were created. SEM (scanning electron microscopy) was used to examine the samples which influence of varied amounts of phenol on the structure & diameter of the fibers. The testing included FTIR, tensile strain, contact angle, water absorption, and deterioration were used to investigate the physicochemical characteristics of fibres. PC12 cell proliferation and adhesion were assessed using the MTT assay and SEM, respectively. Immunocytochemistry and gene expression analysis the effects of lignin on cell differentiation were investigated using immunocytochemistry and gene expression. The results demonstrated that the manufactured fibres were smooth with a consistent diameter, and that the increasing quantity of polysaccharides lowered the fiber diameters ranging from 530 to 370 nanometers. By increasing this lignin %, Elastic modulus increased from 0.1 to 0.4 MPa. In the PC12 cell culture, tannins increased cell proliferation. Gfap, Tub III, and Map2 mRNA expression levels, as well as immunocytochemistry (Map2), demonstrated that lignin had a beneficial influence on brain cell development. Finally, the data suggest that PVA-PGS/5 percent lignin could be used to construct nerve tissue. [97].

Yan Zhangs et al to create the ultra-thin polyurethane films, an ecologically friendly approach of decreasing waste formation and manufacturing time was presented (LPUfs). Through the application of hexamethylene diisocyanate, lignin was employed poly-caprolactone glycol as hard sections and poly(-caprolactone) glycol as soft segments (HDI). New manufacturing procedure might save more than six times the amount of solvent used and cut the production time in half. Severalepoxidized soybean oil (ESO), dioctyl sebacate (DOS), acetyl tributyl citrate (ATBC), cardanol, and an ant sticking agent was utilised as additives to increase the performance of the films, and the ATBC have benefits as a plasticizer for the LPUf.. At a thickness of 20 m, the without breaking, the biofilm became flexible and bendable, with optimal elongation at break and tensile strength [98].

Phthalate derivatives

phthalates are rapidly metabolised and eliminated, due to the phthalate ester metabolites indicates that the parent diester has been exposed. The alkyl-aryl-esters or di-alkyl also also referred as 1,2-benzenedicarboxylic acid; non to be baffled along with terephthalic that is structurally isomeric or iso-phthalic acids. The word "phthalate" is come from the word "phthalic acid." This is originating from the word “naphthalene”. The phthalates are transparent, syrupy liquids with Low volatility, limited water solubility, and high oil solubility. The polar carboxyl group has little effect on the physical features of phthalates excluding when R and R' are very small. Phthalates are colourless, odorless fluids created by mixing phthalic anhydride with such an appropriate alcohol (usually 6- to 13-carbon)[99].diethyl phthalate, dibutyl phthalate, dioctyl phosphate.

Shi Yao s et al we investigated the absorption of di-butyl phthalate (DBP) molecule to a range of polyethylene micro-plastics, including irregularly shaped of unmixed polyethylene micro- plastics. The particle size of PE micro-plastics has no bearing on their DBP sorption, but the shape and crystallinity of PE micro-plastics are crucial in defining their sorption capacities [100].

Gan B. Bajracharya s et al Phthalates are anhydride esters is kind of phthalic an-hydride. The reaction of phthalic anhydride with alcohols produces phthalate monoesters and diesters, the latter of which is widely used as a plasticizer around the world. During the presence of a catalyst containing 10% FeCl3, this two-step process takes place in a single pot. The first stage is the creation of phthalate monoesters 3 through a simple addition displacement route and the following step is basically Catalysis by Lewis acids resulting in extremely high yields of phthalate diesters 4. The current reaction is illustrated by synthesizing a macrolide 5 utilising Dialyl phthalate ring-closing metathesis using Grubb's 2nd generation catalyst [101].

Michiel Bastiaensen s et al this study looked at the amounts of seven PEs (DEP, DnBP, DiBP, BBzP,

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DEHP, DINP, and DIDP) as well as three alternative plasticizers (DINCH, DEHTP, and DEHA) in the urine of a representative sample of Flemish youths. We compared current PE exposure levels to past cycles in the FLEHS IV (Flemish Environment and Health Study) design and looked at AP exposure for the first time. As a result, the current study's goals were to establish reference values of numerous PE and AP urine metabolites in teenagers from Flanders, examine the temporal trend of PE exposure from FLEHS II to FLEHS IV, and identify possible exposure predictors based on. As a result, the current study's goals were to establish reference levels of multiple PE and AP urinary metabolites Examine PE exposure in adolescents from compatible families through time from FLEHS II to FLEHS IV, identify possible exposure predictors based on questionnaire data, and compare observed levels to published health-based advice values for a preliminary risk assessment. [102].

Simoní Da Ross et al For the first time, the partitioning behaviour of DEP on glass and aluminium surfaces has been studied at temperatures ranging from 20 to 80 degrees Celsius. We also evaluated the influence of temperature on the partitioning behaviour of DEP between these surfaces and the air around them, and presented a model to represent this connection. Nonlinear regression is used to estimate model parameters using experimental data taken on 109 samples that were equilibrated between 20 and 80 degrees Celsius in sealed settings [103].

Kun Gao s et al The goal of this study was to look at the demographic and physiological impacts of DMP and DEP exposure on P. tricornutum. The specific goals were to characterize DMP and DEP biodegradation compare the inhibitory effects of DMP and DEP on the above- mentioned diatom by determining the values of their effect concentrations leading to a 50% growth inhibition of this alga (EC50); compare the inhibitory activity of DMP and DEP on the aforementioned diatom by calculating the values of their effect remains at top to a 50% inhibitory activity of this alga study the two PAEs' underlying toxic processes by identifying their toxic mechanisms [104].

Glycol derivatives

Glycol's derivatives have varying molecular weights are used in a variety of medicinal applications. Solubilizers, stabilizers, binder, carrier, and plasticizer are only a few of its uses. PEG's physical state, like that of other polymers, is determined by the mass of the molecule for example, PEG 400 is a plasticizer that exists in a liquid form, PEG 6000, on the other hand, is a solid-state plasticizer with a melting temperature of 55-69 degrees Fahrenheit, which influences the plasticization effect [105]. Yuan et al s found that PEG with a lower molecular weight is more effective it's at lowering the plasticized polymer's glass- transition-temperature. They also discovered that as the PEG molecular weight increased, the slope of the rise in % plasticized elongation decreased. With cellulose acetate polymer, PEG 400 has been shown superior film mechanical characteristics than PEG 1000 and 3350 [106]. polyethylene glycol, propylene glycol,

D.R. Tapia-Blácido s et al A multi-response analysis was used to find the best formulation for making amaranth Glycerol and sorbitol were used to plasticize flour films. The project's objective is to optimization was to produce films with stronger break resistance, moderate elongation, and decreased water solubility. Response surface approach was used to investigate the effects On the mechanical properties and solubility of amaranth flour films, the effects of plasticizer percentage (Cg, glycerol, or Cs, sorbitol) and process temperature (Tp) (RSM). These formulations were characterized and found to be satisfactory, indicating that the optimization process used in this study was successful. The most appropriate plasticizer was sorbitol [107].

Mayte M. Quispe s et al The primary purpose of this study were to determine the efficacy of glycerol-based compounds as PHB additives, such as glycerol, poly-glycerol's & glycerol tri-esters. Different characterization techniques were used to assess the influence of these additions on the thermal, mechanical, and barrier properties of PHB films, as well as their shape and crystalline structure [108].

Sheyla Moreira Gonçalves et al The aim of the research was to see how varied glycerol concentrations in cellulose acetate films influenced the visual, physical, thermal (DSC), and mechanical qualities of the films, as well as to evaluate chemical interactions utilized Fourier Transformation Infrared Spectroscopy (FTIR), X-ray diffractometer (XRD), and scanning electron microscopy (SEM) [109].

Lucio Ballesteros-Mártinez s et al The usage of combinations of different Plasticizing compounds such as glycerol & sorbitol are used in polymers has led to improvement the properties for biomaterials made from natural biopolymers such as starch. The effect of plasticizer type (glycerol and sorbitol) and concentration (10, 20, 30, 40, and

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50percentage starch based) on water solubility, colour deviation, water vapour permeability and mechanical properties of sweet potato starch films was investigated in this study. The Puncture Strength technique was used to assess mechanical characteristics, whereas gravimetric methods were used to calculate WVP and WS, and a colorimeter was used to determine ΔE. The finding revealed an inverse link between the two variables plasticizer concentration and puncture resistance and E of the films. Sweet potato starch films' extension, WS, and WVP percent increased as the plasticizer concentration increased [110].

Badri Parshads et al The use of enzymatically/chemo-enzymatically produced glycerol, azidoglycerol, and Copolymers premised on azido-triglycerol as a longitudinal scaffold in the development of nanocarriers for clinical and bio-Nano technological purposes has been highlighted in this study [111].

Plasticizer	Material	Objective	Reference
Soybean oil	epoxidized soybean oil (ESBO), α-cellulose, N-Methylmorpholine N-oxide monohydrate	The goal of this study is to create a new biocompatible network out of cellulose and epoxidized soybean oil that may be used in tissue engineering scaffolds.	[112]
Soybean oil	polylactide (PLA) and natural rubber (NR)	This article focuses on the use of epoxidized soybean oil (ESO) as a simultaneous conformable and plasticizer for the PLA-unmodified NR-based chemistry. Epoxidized soybean oil is beneficial to elastomers and plastics.	[113]
Soybean oil	epoxidized palm oil; epoxidized soybean oil; compatibilizer; starch; empty fruit bunch; epoxidized palm oil; epoxidized soybean oil	This work employed emulsion casting and compression moulding to strengthen starch/EFB-based bioplastic composites with EO. The interactions between components and interfacial adhesion inside the composites were investigated using FTIR and SEM..	[114]
Soybean oil	Fast-growing radiata pine, furfuryl alcohol, and epoxidized soybean oil,	Plasticizers such as polyvinyl chloride (PVC) and ethyl cellulose (EC) films typically employ ESO as a plasticizer in items that come into contact with food. The findings demonstrated that both ESO and ELO improved the epoxy matrix's toughness and elongation at break, with ESO increasing toughness more than ELO due to ESO's reduced functionality.	[115]
Soybean oil	Shale inhibitor Inhibition method Hydrophobically modified polyampholyte Epoxidized soybean oil Drilling fluid based on water	An Study of internal hydrophobic monomer (ESO-MA) was produced as a prospective shale inhibitor, and a polyampholyte hydrophobically modified by ESO-MA (AADE) was synthesised and compared to the unmodified one in this work (AAD).	[116]

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Soybean oil	Nanocomposites Tissue engineering of the bones Manufacturing with additives Scaffold with direct ink printing	We expected that scaffolds made with these AESO/nHA nanocomposite inks and printed with DIW would have mechanical qualities suited for BTE while allowing MSCs to differentiate into osteogenic cells efficiently.	[117]
Soybean oil	TS-1, Cadmium-modified soybean oil, Epoxidized soybean oil, Epoxidation	A series of TS-1 supported Cd (xCd/TS-1) catalysts were synthesised and studied using different techniques, including XRD, N2-physisorption, FT-IR, UV-vis, NH3-TPD, SEM, TEM, and XPS, in order to create an acid-free and efficient epoxidation process for the manufacture of ESO from SO.	[118]
Soybean oil	Plasticizer made of poly(vinyl chloride) Epoxidation reaction of used frying oil	Using waste cooking oil as source materials, a new epoxidized chemical (EGE-WCO) with an epoxy value of 6.57 percent was created. This approach has the benefit of making full use of the C] C link and glycidyl ester in waste cooking oil through addition and epoxidation processes.	[119]
Soybean oil	UV crosslinking; moisture resistance; starch; coating; acrylated epoxidized soybean oil; UV crosslinking	An acrylated epoxidized soybean oil (AESO)-based coating was created in this study to increase the gas permeability of starch-based films and minimise moisture sensitivity..	[120]
Soybean oil	Epoxy asphalt that has been cold-mixed Compatibility of epoxidized soybean oil Mechanical efficiency	The impact of ESO on the compatibility of asphalt and ER in the CEA system was explored in this study, which was based on rotational viscosity, pot life, micromorphology, and melting point.	[121]
Linseed oil	Corn starch, Polyvinyl alcohol, silver nitrate, tween 80, glutaraldehyde [GA], d-glucose, sodium chloride, urea, potassium iodide [KI], ethanol, Linseed oil-based polyol [LP]	Polyvinyl alcohol , Corn Starch , Linseed oil polyol, and silver nanoparticles [NP] were used to make a nano composite hydrogel film. Linseed oil [LO] was epoxidized and hydrated to produce LP. The insertion of hydroxyl groups in LP by an epoxide ring opening process at epoxidized LO was validated by IR and NMR.	[122]

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Linseed oil	non-isocyanate polyurethane; carbonation process; selectivity optimization; carbonated epoxidized linseed oil	By reacting linseed oil (LO) with carbon dioxide (CO2) and tetrabutylammonium bromide (TBAB) as catalysts, carbonation of epoxidized linseed oil (CELO) containing five-membered cyclic carbonate (CC5) groups has been improved to 95%.	[123]
Linseed oil	flax; basalt; dynamic–mechanical; green composites; mass loss; resin transfer moulding; epoxidized linseed oil (ELO); epoxidized linseed oil (ELO); epoxidized linseed oil (ELO); epoxidized linseed oil (RTM)	This paper focuses on the development of flax and flax/basalt hybrid reinforced composites based on epoxidized linseed oil (ELO) resin, utilising the feasibility of different glutaric anhydride (GA) to maleinized linseed oil (MLO) ratios	[124]
Linseed oil	impact strength; rigid packaging; mechanical characteristics; polylactide; thermoplastic elastomer	The potential of maleinized linseed oil (MLO) as a biobased compatibilizer in polylactide (PLA) and a thermoplastic elastomer, specifically, polystyrene-b-(ethyleneran-butylene)-b-styrene (SEBS) blends (PLA/SEBS), with increased impact strength for the packaging sector is reported in this study work.	[125]
Linseed oil	fibroplast cell; graft copolymers; linseed oil peroxide; radical polymerization; cell adhesion and proliferation	This research focuses on the polymerization of linseed oil via peroxide linkages during drying in the air or under oxygen flow, as well as the use of this polymeric peroxide in the polymerization of vinyl monomers to produce graft copolymers with oily segments that are biodegradable and biocompatible.	[126]
Linseed oil	Rubber from the ground Linseed oil is a kind of vegetable oil that comes from Mechanical \sproperties	NR vulcanizates were made utilising LO as a plasticizer and 10 phr of EG as an addition in the current investigation. By assessing the cure parameters, thermal degradation, glass transition temperature, and mechanical properties of the composites, the influence of plasticizer loading on the NR vulcanizate	[127]

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	Graphite that expands	was investigated.	
Linseed oil	Linseed oil is a kind of vegetable oil that comes from Synthesis in a single step Acrylate prepolymers are a kind of acrylate prepolymer. Coatings that are UV-curable Films that have been cured Biodegradable materials	An innovative one-step approach was employed to make linseed oil-based 2.5-functional acrylated prepolymers using linseed oil, acrylic acid, and boron trifluoride diethyl ether as raw materials and boron trifluoride diethyl ether as a catalyst (ALO). FT-IR and 1H NMR characterizations were used to confirm the successful synthesis of ALO, and the viscosity of ALO was evaluated with a rheometer.	[128]
Linseed oil	Epoxidation of vegetable oil System of liquid-liquid-solid reaction Modeling of kinetics estimate of parameters	The epoxidation of linseed oil using formic acid produced in situ from acetic acid and a 30% hydrogen peroxide solution was conducted in the presence of the Amberlite IR120-H ion exchange resin as the catalyst, yielding a relative epoxy yield of more than 85%.	[129]
Linseed oil	Linseed oil Polyurethane rigid polyurethane foam	The creation of a new form of rigid polyurethane foam (RPUF) that contains linseed oil (LO) as a natural modifier. The use of natural bio-oils in polyurethane composites expands the spectrum of functional qualities while lowering manufacturing costs.	[130]
Linseed oil	PVC Epoxidized linseed oil Gum rosin derivatives	Plasticized polyvinyl chloride (PVC) was mixed with linseed oil (ELO) and a natural viscosity enhancing agent, triethylene glycol ester of gum rosin (TEGR). The use of both chemicals did, however, result in some colour alterations.	[131]
Plasticizer	Material	Objective	Reference
Castor oil	Self-healing; Recyclability; Shape memory; Castor oil; Hindered urea bonding	A two-step reaction between castor oil, N,N'-di-tert-butylethylenediamine (DBDA), isophorone diisocyanate (IPDI), and tetraethylene glycol (TEG) was used to design and prepare a series of robust, self-healing, shape memory, and reprocessable polymers based on hindered urea bonds (HUBs) and hydrogen bonds.	[132]
Castor oil	Epoxidized castor oil; Dynamic vulcanization;	The PLA/ECO blend is made from ECO (epoxidized castor oil) with self-crosslinking structures.	[133]

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	Poly (lactic acid) toughening	Dynamic vulcanization is used to create the samples in this study. After that, there are the toughening effects to consider. PLA is being modified with this ECO and regular castor oil. FTIR and NMR findings Both NMR and spectroscopy show that castor oil has been successfully epoxidized.	
Castor oil	Iso bornyl methacrylate; renewable; biodegradable; vegetable oil; polymeric foam; castor oil; reactive diluent; isobornyl methacrylate; renewable; biodegradable	This study showed that utilizing modified castor oil and isobornyl methacrylate as feedstocks, renewable alternatives to petroleum-derived polymeric foams may be made.	[134]
Castor oil	nitrile rubber; mechanical qualities; age resistance; thermal stability; castor oil-based plasticizers	Five ecologically acceptable castor oil-based plasticizers were produced in this work and utilized to plasticize NBR using simple esterification and epoxidation processes. The characteristics were researched and compared to those of the commercial plasticizer DOP in order to see if petrochemical-based phthalate plasticizers might be replaced in NBR.	[135]
Castor oil	PVC Plasticizer Castor oil Flame retardancy TGA-FTIR-MS	A castor-oil-based phosphate plasticizer (PGPP) containing phosphaphenanthrene groups was produced and described. Flame retardant PVC blends with various amounts of PGPP were created.	[136]
Castor oil	Biopolymers Hydrophobic liquid Mechanical properties Thermal stability	Glycerol plasticized soy protein plastics with castor oil are made in this study. Scanning electron microscopy (SEM), dynamic mechanical analysis (DMA), and thermogravimetric analysis were used to evaluate the effects of castor oil on the structure and characteristics of the resultant polymers (TGA),	[137]

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Castor oil	Castor oil, PVC, Migration	We produced a new phosphorus-containing castor oil-based derivative, propargyl ether EAMR-DOPO, which was covalently bonded to PVC-N3 as an internal plasticizer in this work.	[138]
Castor oil	acetone, hydrogen peroxide, acetic anhydride, benzoyl chloride, acetic acid, calcium oxide, toluene, sodium hydroxide, sodium carbonate, hydrochloric acid, sodium hydroxide, sodium carbonate, sodium hydroxide, sodium carbonate	Five types of environmentally friendly material plasticizers based on castor oil were produced in this study. The qualities of these PVC blends were tested and compared to the commercial plasticizers DOTP and ESO, which were added to PVC as the major plasticizer.	[139]
Castor oil	PVC; tensile strength	ECO (high oxirane value) was used as a co-plasticizer with ESBO in this study. The approach allows for the preparation of bio-plasticizer from vegetable oils in a variety of ways, and it is projected to partially replace petroleum-based plasticizers in the production of PVC products.	[140]
Castor oil	Natural rubber,Mercaptobenzothiazoledisulphide (MBTS) and tetramethyl thiuram disulfide (TMTD	We employed castor oil as a plasticizer in a typical natural rubber compound comprising 45 phr of carbon black in this investigation. These compounds were compared to a control compound containing naphthenic oil in terms of mechanical and thermal properties.	[141]
Plasticizer	Material	Objective	Reference
Triethyl citrate	Films made of cellulose acetate Plasticizers Physical characteristics Polymers	the aim of this analysis was to validate or disprove the notion that molar concentrations of triethyl citrate (TEC) (1.8; 3.6; 5.4; and 7.2 mol) impact the primary features of CA films, including physical and chemical aspects.	[142]

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Triethyl citrate	Ionic liquid of imidazolium a derivative of citrate Derivative of graphene Poly(3-hydroxybutyrate-co-3-hydroxy valerate) Polygonal (ethylene-co-vinyl acetate)	Melt extrusion was utilized to generate hybrid samples by adding rGO-ZnO, as a possible nucleating agent, and EVA18, because of its extremely flexible nature, in this study, keeping in mind the ways previously indicated to increase PHBV functioning.	[143]
Triethyl citrate	Water vapor sorption; Polylactic acid; Zeolite; Dispersibility	The goal of this research was to look at the water vapor adsorption behavior and mechanical characteristics of PLA/zeolite (5, 10, or 15 phr) composites made using triethyl citrate (TEC; 20 phr) via a melting method.	[144]
Acetyl tributyl citrate	DSC; Dynamic TG; Poly(3-hydroxybutyrate); Thermal degradation; Acetyl tributyl citrate	Differential scanning calorimetry (DSC) and thermogravimetric (TG) techniques were used to investigate the effects of acetyl tributyl citrate (ATBC) as a biodegradable plasticizer on the thermal stability of poly(3 hydroxybutyrates) (PHB) under dynamic settings.	[145]
Triethyl citrate	PHB \Plasticization Aging Thermal characteristics Mechanical characteristics Modeling	By assessing changes in the mechanical, dynamic mechanical, and thermal characteristics of PHB and triethyl citrate (TEC) formulations at room temperature, we investigate the effects of plasticizer quantity and time on the extent of aging. Melt extrusion was used to create formulations with a changeable mass percent of TEC, which were then injection molded into specimens.	[146]
Acetyl tributyl citrate (ATBC)	LC-MS/MS, migration, food contact material	The goal of this research is to create a liquid chromatography-tandem mass spectrometry (LCMS/MS) approach for ATBC migration testing on plastic food-contact items.	[147]

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Triethyl citrate	plasticized polyvinyl alcohol; triacetin	The major goal of this study was to see if two natural-based plasticizers (triacetin (TRI) and triethyl citrate (TEC)) could be used in two polyvinyl alcohol (PVA) with identical molecular weight but differing degrees of hydrolysis (88 percent and 99 percent).	[148]
Triethyl citrate	Poly(lactic acid); Nanocomposites	The goal was to make hybrid PLA composites using natural fibre (hemp) and inorganic filler (Nanosilica), with and without tributyl citrate (TBC) plasticizer. Thermomechanical characteristics and morphological structure were examined.	[149]
Triethyl citrate	Poly(vinyl chloride) , Migration	The researchers created PVC material that has been treated using a bio-based triethyl citrate plasticizer. To get azide-functionalized PVC, PVC was first reacted with sodium azide (PVC-N3).	[150]
acetyl tributyl citrate	Large-scale manufacturing, sustainable polymer, catalyst-free polymerization; greener waterborne polyurethane; VOC-free polyurethane;	In this experiment, ATBC was chosen to replace poisonous, volatile, and poor water-resistant additives such as traditional NMP and DMF in order to create VOC-free WPU dispersions with the same or superior qualities.	[151]
Diethyl phthalate	Persulfate; Carbon and hydrogen isotopic fractionation; Zero-valent iron; Compound-specific stable isotope analysis	The 13C and 2H isotope separation related with both the oxidation of diethyl phthalate (DEP) by persulfate (PS) reacted with zero-valent iron (ZVI) was investigated utilising three concentration levels (0.2, 0.5, and 1.0 g L-1) at varied pH values (3, 7, and 11).	[152]
phthalates	Epoxidation Citrullus lanatus is a kind of citrus fruit. Polyvinyl chloride (PVC) is a kind of plastic. Plasticizing ability of crystallinity	The objectives of this paper was to create epoxidized products from a sustainable resource, Citrullus lanatus seed oil, and polyvinylchloride (PVC) sheets using various concentrations of ECLO.	[153]

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Dibutyl phthalate	Mixed-control adsorption, dynamic surface tension	The plasticizer DBP's adsorption kinetics in water were examined. At eighteen DBP concentrations, the pendant bubble tensiometer was used to measure dynamic and equilibrium ST data of aqueous DBP solution.	[154]
Diethyl phthalate,	Acetylcholinesterases, Heat shock protein, Ecdysone, Antioxidant enzymes	The focus of this research is to see how antioxidant enzymes in C. circumdatus react to DEP-induced stress. Changes in the expression of heat shock protein70 (hsp70), a conserved stress-responsive gene found in most eukaryotes, would also be investigated to learn more about its involvement in stressful situations.	[155]
Dimethyl phthalate Diethyl phthalate	Phaeodactylum tricornutum is a species of Phaeodactylum. Stress due to oxidation Oxygen species that are reactive	To evaluate the toxicities of dimethyl phthalate (DMP) and diethyl phthalate (DEP), a marine diatom (Phaeodactylum tricornutum) was subjected to varying doses of DMP and DEP for 96 hours in a batch-culture method.	[156]
Diethyl phthalate	Partition coefficient Phthalates adsorption Building materials Parameter estimation	the partitioning behaviour of diethyl phthalate on borosilicate glass and aluminium surfaces was examined at temperatures ranging from 20 to 80 degrees Celsius.	[157]
Diethyl phthalate	PEs ,Human biomonitoring Estimated daily intake Exposure biomarkers Flanders	In this study, we present data on the urinary metabolite levels of seven PEs (DEP, DnBP, DiBP, BBzP, DEHP, DINP and DIDP) and three alternative plasticizers (DINCH, DEHTP and DEHA) in a representative sample of Flemish adolescents	[158]
Diethyl phthalate	Sequencing of the 16S rDNA gene Pseudomonas Biodegradation Kinetics of degradation	This is likely the first investigation of Pseudomonas juntendi strain CCNU-SK1, Pseudomonas putida strain CCNU-SK2, and Pseudomonas nitritireducens strain CCNU-SK3 biodegrading DEP. Morphological, biochemical, physiological, and 16S rDNA gene sequencing methods were used to isolate bacterial strains.	[159]
Dioctyl phthalate	Catalysis Esterification Organic synthesis	We designed a straightforward methodology for the synthesis of phthalates monoesters (3a-e) and diesters (4a-e), with the latter	[160]

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	of macrolides Metathesis that closes the ring	molecule being the emphasis.	
dibutyl phthalate	Microplastic\Phthalate \Polyethylene\Sorption \Crystallinity	The sorption of dibutyl phthalate (DBP) as a probe molecule to a variety of polyethylene microplastics, including irregularly shaped pure polyethylene microplastics (IPPM), black plastic film microplastics (BPFM), white plastic film microplastics (WPFM), and commercial microspheres, was investigated in this study (CM),	[161]
Plasticizer	Material	Objective	Reference
glycerol	Beads of gel Oil of peppermint Drying using a vacuum Glycerol \sβ-cyclodextrin	The texture of gel beads is prone to stiffening after drying, which limits their use. The focus of this research was to see how adding glycerol to vacuum-dried gel beads encapsulating peppermint oil/-cyclodextrin complex affected the shape, encapsulation properties, texture, water distribution, and moisture status.	[162]
glycerol	Films made of cellulose acetate Physical characteristics Polymers	This work was designed to validate or disprove the notion that glycerol (GLY) or triethyl citrate (TEC) molar concentrations (1.8; 3.6; 5.4; and 7.2 mol) impact the primary features of CA films, including physical and chemical aspects.	[163]
glycerol	Plasticizing impact in a synergistic manner Starch film properties with water and glycerol Blowing extrusions	The physicochemical and structural characteristics of starch-based films made by extrusion blowing were examined using a synergistic plasticizing action of water (W) and glycerol (G). In the presence of appropriate quantities of water, Fourier transform infrared spectroscopy (FT-IR) demonstrated that glycerol might operate as a conventional plasticizer (approximately 15 percent)	[164]
glycerol	Azido-glycerol \copolymer \Amphiphilic \Self-assembly \Nanocarrier	Enzymatically/chemo-enzymatically synthesized glycerol, acid glycerol, and azido-triglycerol-based copolymers have received special attention as a linear scaffold in nanocarrier development for biomedical and bio-nanotechnological applications.	[165]
glycerol and polyvinyl alcohol (PVOH)	Acetobacter xylinum is a kind of bacteria. tensile resistance Young's modulus percentage of elongation at	Highly flexible composite films with UV barrier qualities were created using bacterial cellulose, glycerol, and polyvinyl alcohol (PVOH). Bacterial cellulose's open Nano scale network enables it to be immersed with glycerol and polyvinyl alcohol. The bacterial cellulose structure was preserved as a result	[166]

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	break Films that are environmentally friendly	of this approach.	
Glycerol,	Alginate, Film, Drying, Temperature, Flow Rate	his work was to see how drying circumstances (temperature and air flow rate) affected the physical, mechanical, optical, structural, and morphological properties of sodium-alginate films, which is one of the most commonly studied biopolymeric films.	[167]
Glycerol	Thermo-mechanical mixing, Alginate	Thermo-mechanical mixing (using an internal batch mixer) of glycerol-plasticized alginate, and then to investigate the influence of glycerol addition on the morphology and physical properties of the associated multiphase materials. We chose sodium alginate for this work since it is currently the most industrially manufactured polysaccharide.	[168]
Glycerol	Adhesion,Biodegradable, Tack, Peel Adhesion	low glycerol concentration leads to a non-adhesive product, as demonstrated by other researches producing non-adhesive films by using low glycerol concentration, it is important and necessary to evaluate the appropriate proportion between the viscoelastic fraction (gluten) and the plasticizer content.	[169]
Glycerol	Chitosan, Poly(vinyl alcohol), Plasticization, Blend	The physical and mechanical properties of PVA/chitosan mixes plasticized using PEG and glycerol was examined.	[170]
Glycerol	Starch \Elongation Permeability of water vapor	The usage of combinations of different polymers with plasticizing agents such as glycerol and sorbitol has led to the improvement of the properties of biomaterials made from natural biopolymers such as starch.	[171]

VIII. CONCLUSION

Plasticization of polymers used in pharmaceutical technology can solve a variety of challenges during the formulation of dosage forms and improve the quality of the finished product. Polymeric drug delivery device in its final form. The procedure for processing,as a result, obstacles can be overcome, or even a new product can be created. It is possible to enable technology. It is, for this reason, that for their ability to merge with both traditional and non-traditional styles of plasticizers. These drug carriers' viscosity must be controlled. low enough for optimal workability or in order for their administration with a trocar applicator or injectable needle. The kind and concentration of plasticizers have an impact on the entire medication release profile They do improve adaptability as a result of the flexibility and plasticity of films, they can be modified and controlled. release of medication.

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