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Addition polymers from natural oils—A review

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Abstract

Emerging technological knowledge is leading research into new ventures. One such is the conversion of natural oils to polymers to augment the use of petroleum products as the source of polymeric raw materials. Natural oils, such as vegetable oils, now mainly used in the food industry, offer alternatives, and recent research has studied new routes of synthesis of polymers from natural oils. This review paper discusses the synthesis and characterization of new polymers from different natural oils such as soybean, corn, tung, linseed, castor, and fish oil. The effects of different levels of unsaturation in the natural oils and various types of catalysts and comonomers on the properties of copolymers are considered.

Keywords: Natural oils; Dynamic mechanical analysis; Cross-linking; Polymerization; Drying oil; Glass transition temperature

Contents

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1. Introduction

In recent years natural oils have attracted renewed attention as raw materials for the preparation of resins and polymeric materials, to replace or augment the traditional petro-chemical based polymers and resins. Natural oils such as linseed and tung oil have long found various uses in the paint and varnishes industries. These oils have traditionally been used in organic coatings either as resins or as a raw material for the preparation of resins. Soybean oil, safflower oil, sunflower oil and canola oil have also been used in polymerizations.

Natural oils are tri-glyceride esters of fatty acids, the general structure of which is shown in Fig. 1. Triglycerides comprise three fatty acids joined by a glycerol center [1]. Most of the common oil contains fatty acids that vary from 14 to 22 carbons in length, with 1–3 double bonds. The fatty acid distribution of several common oils is shown in Table 1 [1]. In addition, there are some oils comprise fatty acids with other types of functionalities (e.g., epoxies, hydroxyls, cyclic groups and furanoid groups) [2]. It is apparent that on a molecular level, these oils are composed of many different types of triglyceride, with numerous levels of unsaturation. In addition to their application in the food industry, triglyceride oils have been used for the production of coatings, inks, plasticizers, lubricants and agrochemicals [3–9]. In general, drying oils (these can polymerize in air to form a tough elastic film) are the most widely used oils in these industries, although the semi-drying oils (these partially harden when exposed to air) also find use in some applications. The polymers obtained from natural oils are biopolymers in the sense that they are generated from renewable natural sources; they are often biodegradable as well as non-toxic.

Some biopolymers obtained from natural oils are flexible and rubbery. Generally, they are prepared as cross-linked copolymers. Bacterial polyesters are obtained from a large number of bacteria when subjected to metabolic stress. The cross-linking process for unsaturated bacterial polyester is shown

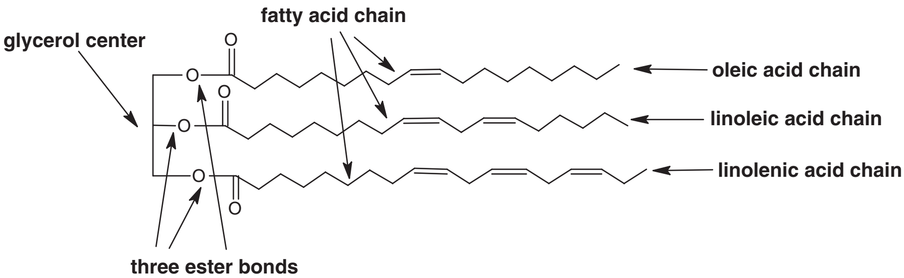

Fig. 1. The triglyceride chain containing three fatty acid chains joined by a glycerol center. Reprinted with permission from Polymer 2001; 42: 1569 © Elsevier Science Ltd., [10].

Table 1
Main fatty acid contents in different oils

Fatty acid	[#C: #DB*]	Canola oil	Corn oil	Cottonseed oil	Linseed oil	Olive oil	Soybean oil	Tung oil	Fish oil†
Palmitic	16:0	4.1	10.9	21.6	5.5	13.7	11.0	—	—
Stearic	18:0	1.8	2.0	2.6	3.5	2.5	4.0	4	—
Oleic	18:1	60.9	25.4	18.6	19.1	71.1	23.4	8	18.20
Linoleic	18:2	21.0	59.6	54.4	15.3	10.0	53.3	4	1.10
Linolenic	18:3	8.8	1.2	0.7	56.6	0.6	7.8	—	0.99
α-elaeostearic acid	—	—	—	—	—	—	—	84	—
Average #DB/triglyceride.	—	3.9	4.5	3.9	6.6	2.8	4.6	7.5	3.6

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*#C stands for number of carbon atoms in chain and #DB stands for the number of double bonds in that chain.

†Fish oils tend to contain a high double bond content; for example, the composition of a Norway fish oil examined in one study contained a fatty acid (ethyl ester) composition with 8.90% having no double bonds, 6.03% having four double bonds, 37.25% having EPA or DPA and 24.72% (DHA) having six double bonds [29].