Soy Bean Oil-derived Elastomers and Foams Produced Using Silicones

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PURPOSE OF THE ABSTRACT
Soybean constitutes a major world crop, estimated to be in excess of 300 million metric tons annually. As a result, soy protein and soy oil are an abundant natural resource that is used in a variety of food-based applications for humans and animals. The oil is a complex mixture of saturated and unsaturated triglycerides; on average 99% of the soy oil constituents contain at least one double bond that can be used as a linker to other ingredients.

The potential benefit of soybean oil as a constituent of industrial materials has previously been recognized; notable examples include soy protein-based adhesives [1] and flexible as well as rigid polyurethane foams [2, 3] or elastomers prepared from polyols derived from soybean oil. Alternative approaches with soybean oil epoxides[4] have also been reported. We were attracted to the use of silicone polymers as crosslinkers for soybean oil as, in other applications, the resulting elastomers and foams were shown to be much less prone to problematic decomposition in the presence of flames [5].

Two strategies were adopted to incorporate the appropriate functionality in soybean oil: ene and thiol-ene reactions [6]. Starting from commercial oil it was possible to incorporate one or more alkoxysilane groups/oil molecule by heating the oil with a vinylsilane in the presence of a peroxide catalyst [7]. Alternatively, the thiol group in the coupling agent 1 could be added under thermal or photoinduced radical conditions. In either case, the resulting oil contained grafted trialkoxysilyl groups.

Elastomers could be prepared from these materials by the use of traditional silicone cure chemistry, based on moisture induced condensation with hydroxy-terminated silicones. Room temperature vulcanization (RTV) in the presence of a tin catalyst allowed materials of different hardness and resilience to be prepared by adjusting the crosslink density. Formulations ranging from 20-80 weight% soybean oil could be prepared. Since silicones and hydrocarbon oils are mutually insoluble, the materials were mostly opaque; we are currently attempting to control domain sizes of the two constituents. An analogous approach directly crosslinked soy oil with thiopropyl-modified silicones to give elastomers.

The alternative approach to crosslink the materials utilized the Piers-Rubinsztajn reaction, catalyzed by B(C6F5)3. In this case, the soy oil was crosslinked with H-terminated or H-pendant silicones. The by-product, ethane or methane, served as a blowing agent. Thus, it was possible to create foams of different hardnesses and densities. However, care must be taken to quench any residual SiH groups otherwise the foams will continue to crosslink leading to changes in their physical properties.

The properties of the foams and elastomers, as noted above, could be manipulated by adjusting the crosslink density, the molecular weight of the silicone hydride crosslinker as well as the use of various additives. The feel depended also on the relative fraction of silicone in the material; higher silicone concentrations led a less sticky, less greasy feel. However, the main benefit to these materials is the ability to incorporate large quantities of renewable (and less expensive) materials into useful industrial products. The preparation process and the relationship between properties and constitution will be presented in more detail.
FIGURE 1

Soy Bean Oil Modified with Silicons

Strategies to give silicone/soy oil composites. A: ene or B: thiol-ene reaction to give alkoxy-silane-modified hydrocarbon. C: thiol-ene crosslinking of unmodified oil. D: Piers-Rubinsztajn crosslinking to give a foam, or E: RTV to give an elastomer.

KEYWORDS

soy oil | silicone | foams and elastomers | ene and thiol-ene

BIBLIOGRAPHY