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Present research on the composition and application of lac

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Abstract Lac is a natural polymer with atoxigenic, renewable, and naturally degradable characteristics. Nowadays, more and more attentions are paid to environment protection and resource conservation, so it has great significance to study the composition and application of lac. The paper summarizes the research of lac composition and emphasizes on the present research of lac resin. The applications of lac are also introduced. In addition, some suggestions are proposed, which is expected to provide some scientific references for further studies of lac.

Key words lac, composition, application

1 Introduction

Lac is a natural polymer derived from resinous secretion of lac insects. It is characterized by the high adhesive strength, great electrical insulation property, waterproofness, moisture and corrosion resistance, ultraviolet screening, oil and acid resistance, high plasticity, and good dye-fixing. It has been applied in industries, such as electric appliance, printing ink, leather, plastic, metallurgy, machinery, woodworking, food and medicine (Shi, 1986). Since the 1960s, it was partly replaced by synthetic resins, however, most of the synthetic resins are not environment-friendly, and may cause pollution. Nowadays, more and more attentions are paid to environmental protection and resources conservation, and lac is atoxigenic, renewable, and naturally decomposable, and products produced of it can meet the requirements of environment protection. So its application has great practical significance for the sustainable development. Accordingly, many studies have been done on its composition and application. The current situation of the research on the composition and application of lac is summarized and some suggestions are proposed in this paper.

2 The composition of lac

The clarification of the composition of lac is necessary to improve the lac performance and application. Some studies have been carried out as early as the 19th century, but few achievements were obtained. After the 1930s, some progresses were made by India Lac Research Institute (ILRI), London Shellac Research Bureau (LSRB) and United States Shellac Import Association (USSIA) (Yunnan Forestry Administration, 1976). A common sense recognized nowadays is that lac is composed of lac resin, lac pigment and lac wax (Cheng, 1996). Lac also contains some albumen of insect body, inorganic salt, sugar, odor substance and some extraneous adulterants.

2.1 Lac resin

Lac resin is the major component in lac. The qualitative and quantitative analysis of the lac resin carried out in the past 200 years showed that lac resin is a mixture of polyester, which consists of polyhydric fatty acid and sesquiterpenoid acid. Its average molecular weight is about 1,000 and each molecule contains four or five hydroxyls containing one free carboxyl, one aldehyde group, two or three ester radicals, and one unsaturated bond (Sharma et al., 1983).

Lac resin is an acidic resin with a quite complicated chemical composition. Various acids can be obtained through basic hydrolysis of lac resin. Three chain aliphatic acids (aleuritic acid, kerrolic acid, and butolic acid) and eight cyclical terpenic acids (shellolic acid, jalaric acid, epishellolic acid, laksholic acid, epilaksholic acid, laccishellolic acid, epilaccishellolic acid and laccijalaric acid) had been separated (Prasad and Agarwal, 1990; Ha and Wang, 1992).

It was reported from India that the aleuritic acid (about 26%–32% of the lac resin) covered most of the chain compounds, because the composition and structure of cyclical compounds were influenced by the secondary reaction in the hydrolysis reaction of lac resin, the yield of shellolic acid was only 1.5% of the lac resin, and the yields of other cyclical and chain molecules were below 0.1%. The result indicated that there are fewer chain compounds with concentrative amounts and

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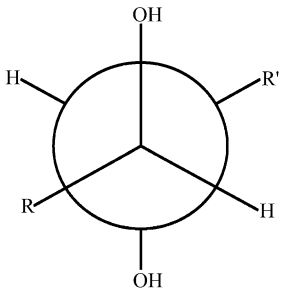
more cyclical compounds with dispersal amounts. It was also empirically decided that the lac resin was composed of chain aliphatic acids and cyclical terpenic acids with molar ratio of 1:1.

The predominant conformation of domestic lac resin was measured with NMR spectroscopy in 1994. It was found that two hydroxyl groups on $C_{9,10}$ of aleuritic acid were in the cross position (Fig. 1) (Zou, 1994).

Ha et al. (1999) studied the composition of domestic lac resin. It was firstly confirmed that lac resin was composed of chain aliphatic acids and cyclical terpenic acids with molar ratio of 1:1 (Ha and Wang, 1993). Based on the difference of produced salts between the long chain aliphatic and terpenic acids, aleuritic acid and shellolic acid were isolated. The experimental result showed that the molecular composition and structure of domestic lac resin were similar to those of Indian lac resin (Ha et al., 1999). The molecular structure of shellolic acid was confirmed with modern spectrograph (Fig. 2).



$R = -(CH_2)_7COOCH_3$, $R' = -(CH_2)_5CH_2OH$

Fig. 1 The predominant conformation aleuritic acid

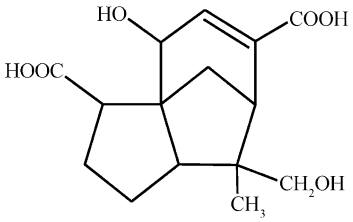


Fig. 2 Molecular structure of Shellolic acid

2.2 Lac pigment and lac wax

The lac pigment can be separated into two parts: one is lac haematochrome, a kind of anthraquinone derivative conposed of five laccaic acids (A, B, C, D and E); and the other is lac flavochrome, which contains erythrolaccin, deoxyerythrolaccin, and isoerythrolaccin (Liu and Lu, 2005).

The lac wax can also be separated into two parts: one is the mixture consisting of beeswax alcohol, beeswax ester, beeswax acid, cerinic acid, oleic acid, and cetylic acid, which can be dissolved in hot ethanol; and the other is laccerol and lacceroic acid, which can be dissolved in benzene but not in hot ethanol (Wu, 1990).

3 The application of lac

Lac is a multipurpose resin which has been applied in industries of military, electric appliance, printing ink, leather, plastic, metallurgy, machinery, woodworking, food, and medicine, etc. However, its shortcomings, such as brittleness, low softening point and bad water resistance, etc, limited its application. In order to expand its application field, various formulations were developed, some additives were employed in the modification of lac properties, and many lac products with special functions were produced.

3.1 Application in military industry

Lac is an indispensable and an important raw material in military industry. It can be used as coating agent, insulated material, and adhesive. Moreover, aleuritic acid, the dominant composition in the lac resin, can be applied as bulletproof glasses and military equipment with the function of ultraviolet intercepting and radiation shielding.

3.2 Application in wood ware industry

The shellac varnish can be easily obtained and is convenient to use. The varnish film has good gloss property with good adhesive strength and good elasticity. The shellac varnish can occlude the wood to prevent the wood secretion and extraneous oil substance from destroying the surface coat. It has been a long time, since it was widely applied in wood ware industry.

Ren and Li (1984) used modified lac as the primer, which showed that, after coating, the flooding property and the paint gloss of the primer were improved. The properties of adhesive strength, heat resistance, waterproofness and solvent resistance were also meliorated.

A kind of polyurethane dope was manufactured through the curing of the mixture of pre-polymerized isocyanate and the lac modified with linseed oil and glycerin by Wu et al. (1995). The dope obtained had good gloss, strong adhesive strength, and good waterproof properties, and it could tolerate the corrosion of 20% H_2SO_4 and 5% NaOH.

It was reported that the graft-polymer could be prepared for lac and MMA with potassium permanganate as initiator, and the modified lac had better waterproofness and toughness (Dong et al., 2004).

3.3 Application in metallurgy and machinery industry

In metallurgy and machine industry, lac was mainly used as the surface coating and adhesive agent to protect and decorate the metal products.

It was reported that the heat resistance and adhesive strength of lac were improved when modified with tannic acid and abietic calcium; the corrosion resistance could be improved if modified with urea-formaldehyde resin; and the color of the lac resin could be meliorated with oxalic acid. The result of "salt-fog" experiment showed that the corrosion resistance of lac paint was increased by 1.38 times (Li et al., 1989).

Bhadani et al. (1993) prepared the shellac film coating on metal sheets with electrochemical polymerization. It was found that the addition of methylacrylamide to the shellac solution would result in more adherent and smoother coatings onto metal sheets.

3.4 Application in electric industry

The lac resin had very good electrical insulation property, adhesive property, charing resistance, and thermoplasticity, etc. It was widely used as insulating varnish, laminated insulator and moulded insulator.

The tracking property of shellac varnish modified with epoxy resin was reported by Goswami (1992). It was found that varnishes prepared with 70:30 and 50:50 (parts) shellac-epoxy resin showed a great resistance to arc tracking. The air-dried varnish film prepared with 70:30 shellac-epoxy resin could resist heat of 180°C after baking at 175°C for 30 min.

3.5 Application in printing ink industry

Because lac showed a series of good characteristics with good adhesive strength, quick drying, moist resistance, abrasive resistance and good glossiness, it was widely applied in the production of printing ink.

Yang et al. (1995) studied the preparation method of modified lac resin for printing ink from bleached lac and found that the product was suitable for printing process. The utilization of lac resin was expanded and new products were developed.

3.6 Application in medicine and food industry

In medicine industry, lac was mainly used as the moisture-proof coating of pill, tablet and capsule. After coated with shellac on the surface, the medicine achieved gloss, moist resistance and long shelf life, moreover, the coating could effectively mask the unpleasant taste of medicine. As a kind of enteric coating material, the shellac could protect medicine from dissolving in gastro but not in intestine.

The pharmaceutical application of shellac was reported by Pearnchob et al. (2003). The shellac-coated tablets showed better humidity resistance than the hydroxypropyl methylcellulose (HPMC)-coated ones, and the shellac coating could effectively mask the unpleasant taste of acetaminophen. In addition, the shellac was found to be suitable for extended-release tablets.

Pearnchob et al. (2004) found the method to improve the solvability of shellac-coated soft gelatin capsule in simulated intestinal fluids through the addition of pore-formers, such as organic acid and hydrophilic polymer, and retaining gastric resistance. The result showed that the best disintegration was achieved with sorbic acid as pore-former.

The shellac paint was also used in food industry (Mcguire and Hagenmaier, 1996; Bai et al., 2002; Bai et al., 2003). For example, after being coated with shellac paint, the candies and cakes, showed properties of glossiness, moist resistance, caking resistance and long shelf-life. When fruits were coated with the shellac paint, they could hold water and prevent rotting, and also could keep fresh and good appearance (Ma, 2004).

The impact of shellac coating on post-harvest physiology in Hami melon was reported by Bian et al. (2000). Shellac coating could reduce water loss and be in favor of antistaling. When the melon was treated with shellac coating, its respiratory rate and ethylene evolution decreased. Meanwhile, accumulation of carbon dioxide in the cavity increased greatly.

The edible film made of lac alcohol solution and starch was reported by Tang et al. (2003). It showed that the film had characteristics of better waterproofness, moist resistance and higher strength, was harmless to human body, and was decomposable in natural conditions. If bread was coated with this film, it could be protected from molding and extend its shelf life.

3.7 Application in plastic industry

Because the lac resin is a kind of typical thermoplastic substance and has heat resistance to some extent, it can also be used in plastic industry. When the accelerator and filling was added into the lac resin, it could be made into molding powder or molding block, and be used as the material of bakelite product.

Effects of shellac on structure and property of phenolic foams were studied by Vongdara et al. (1991). After the Phenol Foam Plastics (PFP) was filled with shellac residue, its mechanical strength was obviously improved, meanwhile, its moisture absorption was reduced.

The modified lac phenolic moulding material was reported by Xia et al. (1993). Modified lac resin (RL_2) was used to prepare modified lac phenolic moulding

material. These products had achieved all the quality indices stipulated in GB1404-89 with production cost decreased by 10% compared with those non-modified lac resin products. This was the first time to use lac resin to prepare modified lac phenolic moulding materials in China.

3.8 Application in other industries

Lac could also be used as the polishing and dressing agent of leather, the polishing and protective coating of paper sheet, and the ion exchange resin, etc. Lac haematochrome could be applied in textile dyeing, staining of drink and candy, etc. Lac wax could be used as shoeshine, floor wax and carbon paper. The fruit wax could be made from lac wax and it could be used as antistaling agent of eggs, fruits, and vegetables.

4 Suggestions

4.1 The research on the composition of lac

With the knowledge of its composition, the technology of comprehensive utilization of lac resin resources will be able to be determined, and some properties of lac products will be improved. Although many research works have been done by scientists all over the world, the chemical composition of lac resin remains a secret, and only some of dominant acids were separated. The separation and study of physical-chemical property of other acids are still under way. The further research on the composition of lac is necessary to extend its application.

4.2 The research on the application of Lac

As a natural resin, lac has a lot of excellent characteristics, but some properties are not so good comparing with synthetic resin, and should be improved to compete with synthetic resin in application. Organic acids constituted the lac resin, should be separated and be utilized separately.

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