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Natural Materials and Products from Insects: Chemistry and Applications

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Contents

Chemistry and Applications of Lac and Its By-Product

K. K. Sharma, A. Roy Chowdhury, and S. Srivastava

Abstract Lac is a natural resin secreted by Indian lac insect, *Kerria lacca* (Kerr), which thrives on the tender twigs of specific host trees. Lac is collected as the minor forest produce and cultivated since time immemorial in India, and lac cultivation is an important source of income for livelihood of the forest and sub-forest dwellers of central and eastern India. Lac still enjoys the monopoly of non-toxic, biodegradable, natural and safe resin and used for applications in pharmaceuticals, cosmetics and surface coatings for variety of uses in industries. India is the largest producer, processor and exporter of the lac, having average production of 20, 000 tons for the last 5 years. Organized research on lac was started in India after realization of its commercial potential worldwide. Research as well as documentation on all aspects of production, processing, product development and use diversification of lac has led to generation of authentic information. During processing of lac, various economically important by-products are obtained. The major component of lac is resin (65%) followed by two important by-products, *viz*. lac dye (1%) and lac wax (5–6%). The lac resin is processed into various value-added forms as per the need of the different industrial applications. Similarly, the dye and wax find its application in various sectors such as pharmaceutical, textile, etc. This chapter covers processing, chemistry of lac and its by-products and industrial and other applications, and also on outlining the future scope of the work.

Keywords Lac resin · By-product · Lac dye · Lac wax · Chemical constituents · Application

1 Introduction

Lac is derived from the Sanskrit word '*laksha*' which means 100,000 and refers to the vast swarms of insect larvae that cover twigs of host trees during brood season. Lac is a general term used in the trade for all forms of natural resin, which is secreted

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by the tiny lac insects on certain host trees, principally found in India, Thailand, China and Indonesia. Lac history can be traced back to Vedic period (c.1500–500 BC). Atharva Veda devotes a chapter containing vivid description of '*laksha*' (lac insect) and its use in invigorating potion and wound healing. In the great epic, Mahabharata, Purochak constructed 'Lakshagriha' (house of lac) at the instance of Kauravas for killing Pandavas. The works of a number of foreign travellers reveal the trade of lac from India to a number of countries during post-Vedic and medieval periods.

Lac is a natural resin secreted mainly by Indian lac insect, *K. lacca* (Kerr), which thrives on the tender twigs of specific host trees, *viz. palash* (*Butea monosperma*), *ber* (*Ziziphus mauritiana*), *kusum* (*Schleichera oleosa*), *Flemingia semialata*, *Ficus* spp., etc. *Rangeeni* and *kusmi* are the two strains of lac insect which are classified based on (i) preference of the insect for specific host plants, (ii) time taken to complete one life cycle and (iii) quality of the resin produced. Each strain gives two crops in a year. Raw lac is the source of three valuable products, i.e. resin, dye and wax. The major crop obtained from *rangeeni* host principally from *palash* and *ber* in summer is called the *baisakhi* crop. The subsequent crop from these hosts maturing and collected in October–November is called *katki* crop. Similarly, the crops obtained from *kusum* trees in June–July and January–February are called *jethwi* and *aghani respectively.*

On the basis of survey in the markets of different lac-producing districts, the estimated national production of sticklac during 2015–2016 was approximately 18,746 tons comprising *rangeeni* (7597 tons) and *kusmi* (11,149 tons) sticklac. Among the lac-growing states, Jharkhand ranks first followed by Chhattisgarh, Madhya Pradesh, Maharashtra and Odisha. These five states contribute around 93% of the national lac production. Contribution of Jharkhand in national lac production is about 53% followed by Chhattisgarh (17%), Madhya Pradesh (12%), Maharashtra (8%) and Odisha (3%). Among the different cropping seasons, *jethw*i crop was ranked first with the contribution of 32% followed by *aghani* (27%), *baisakhi* (24%) and *katki* (17%) in total lac production (Yogi et al. 2018).

Lac encrustations on twigs of host trees are removed either by scrapping manually or by machines. Lac resin, thus, obtained is known as sticklac. It contains resin, wax, dye, insect body, bark of host trees as well as other impurities. This is, therefore, refined to obtain purified material of commerce (called shellac). The lac resin is a polyester complex of long-chain hydroxy fatty acids and sesquiterpenic acids. Indian lac dye is a mixture of at least five anthraquinone derivatives called laccaic acids. Lac wax is a complex mixture of long-chain acids, alcohols, esters and hydrocarbons.

In the present chapter, we are mainly dealing with the chemistry and various applications of lac and its by-products.

2 Processing of Lac

The process of purification of lac, in general, consists of two steps. The first step involves grinding and washing of sticklac or raw lac to remove sand and wood chips, followed by drying of resin. This semi-refined form is called seedlac. The pure resin, shellac, is then obtained by hot filtration, either by the country (*bhatta*) process or in mechanized factories. The purified lac in the form of button obtained from the country process is called the button lac. Shellac obtained/processed in mechanized factories is called machine-made shellac. The lac can be used in other forms like dewaxed decolorized lac (DDL) and bleached lac. Dewaxing of lac is usually done by dissolving it in cold alcohol (optimum 10%), in which wax is insoluble, filtering to separate wax and reclaiming lac after distilling of solvent and for preparation of decolourized lac; refluxing the lac with suitable solvent and pure and dry grade of activated carbon was found quite effective. Bleached lac is one of the most important lac-based products for which there is a constant demand in the western markets. The number of methods of bleaching of lac is available in the literature, but the most commercially adopted methods involve bleaching with sodium hypochlorite (NaOCl) with some recent modification (Srivastava et al. 2015). During the processing of sticklac into seedlac and then seedlac to shellac, certain valuable by-products are obtained and presented in Fig. 1. They contain a good amount of lac resin. Several methods have been developed for the utilization of these by-products. The main by-products are *molamma*, *kiri*, *passewa*, etc. These are also exported at a comparatively lower price than seedlac and shellac. The by-products obtained during washing of sticklac are lac dye and lac wax. Both of these are valuable by-products of lac industries having different applications (Goswami and Sarkar 2010a, b).

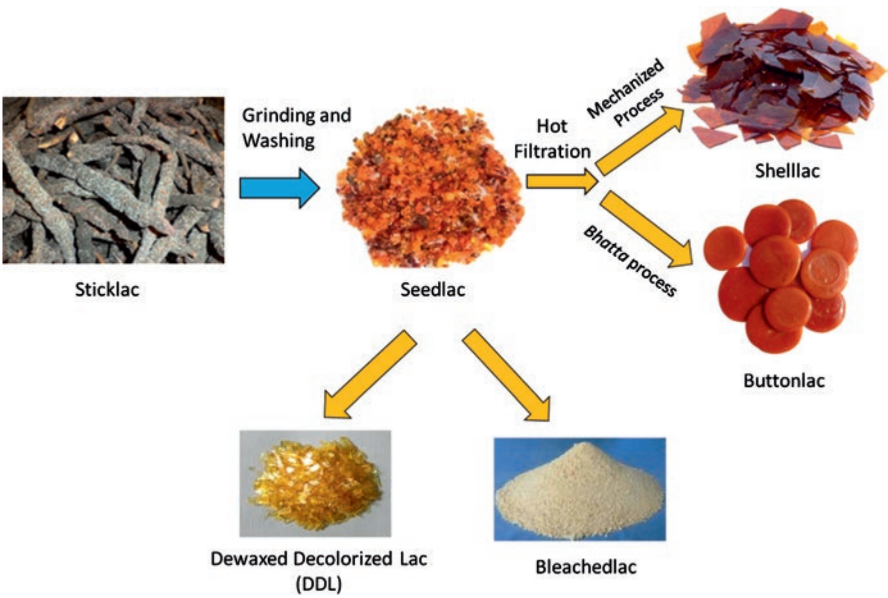


Fig. 1 Schematic diagram of processing of lac and its related products

Table 1 Constituents present in different forms of lac

Constituents	% in sticklac	% in seedlac	% in shellac
Resin	68	88.5	90.9
Dye	10	2.5	0.5
Wax	6.0	4.5	4.0
Gluten	5.5	2.0	2.8
Foreign bodies	6.5	–	–
Impurities	4.0	2.5	1.8

Source: Hatchett as cited by Bose et al. (1963)

3 Chemical Constituents of Lac

Raw lac (sticklac) contains resin, wax, dye, insect body, bark of host trees as well as other impurities. This is, therefore, refined to obtain purified material of commerce (called shellac). The chemical composition and constituents of shellac have been discussed elsewhere. The lac resin is a polyester complex of long-chain hydroxy fatty acids and sesquiterpenic acids. Indian lac dye is a mixture of at least five anthraquinone derivatives called laccaic acids. Lac wax is a complex mixture of long-chain acids, alcohols, esters and hydrocarbons. On the basis of the earlier literature, the constituents present in sticklac, seedlac and shellac have wide variations and are presented as follows (Table 1).

4 Chemistry of Lac Resin

The chemistry of lac resin is very complex and at the same time extremely fascinating (Bose et al. 1963). Commendable results could only be achieved in the 1960s with the techniques such as column, paper, thin layer and gas-liquid chromatography and spectroscopic as well as conventional methods.

It is believed that the resin on an average has five free hydroxyls, one free carboxyl, one aldehyde partly free and partly combined and a point of unsaturation, and linkages present are esters, acylal, acetal and ether. The oxidation of the resin with periodic acid (Sengupta 1964) has shown that one-third of the vicinal hydroxyl groups, in terms of aleuritic acid (a major constituent acid), is free and the rest are in combined form. The oxidation affords in the case of aleuritic acid, ω-hydroxyheptan-1-al and azelaic semi-aldehyde. But after oxidation (Sengupta 1964; Madhav et al. 1967) of the resin no appreciable amount of either of the degradation products could be isolated. This suggested that most probably in this part of aleuritic acid, the carboxyl and the primarily hydroxyl groups are not free. The rest of the aleuritic acid appears linked up at least through one of the vicinal hydroxyl groups.

The resin is not a chemical entity and that it is composed of at least seven components (Sengupta 1970) was made clear by its successful resolution into its components by thin layer chromatography over silica gel. It can be broadly resolved into two fractions by diethyl ether, an insoluble solid mass (~75%) called hard resin and a soluble soft mass (~25%) called soft resin. Sukh Dev and coworkers (Upadhye et al. 1970; Singh et al. 1974) succeeded for the first time in isolating a few pure fractions by fractional precipitation from hard and soft resins. Sankaranarayanan and Kunhunny (1962) isolated a neutral fraction from soft resin, which was believed to be a lactone with one free hydroxyl group having empirical formula $C_{21}H_{37}O_3$. Later, Banerjee and Sengupta (1965) established that the neutral fraction, m.p.49 °C, is not a chemical entity but a mixture of at least seven components. Prasad and Sengupta (1972, 1975) have fractionated hard resin into six fractions through the formation of urea complexes. A few of these appeared to be essentially pure.

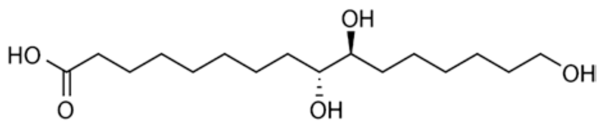
The constituent acids of the resin and its fractions fall under two categories: (i) hydroxy fatty acids and (ii) hydroxy terpenic acids having the rare cedrene skeleton. The former was least soluble and the latter was highly soluble in water. The most successful method of isolation of these constituent acids is by alkaline hydrolysis. A certain portion of them was found present in uncombined state (Bose et al. 1963). The investigators have taken either shellac, hard resin or its various fractions such as soft resin, pure and neutral fractions for study and the results obtained are described regarding isolation and characterization of various constituent acids.

4.1 Aleuritic Acid

This is readily obtained as sodium salt from alkaline hydrolysate. The acid (m.p. 100–101 °C) was first isolated by Tschirch and Farner (as cited in Bose et al. 1963) and was characterized as threo-9,10,16-trihydroxypalmitic acid (Fig. 2) by researchers. The structure was re-examined by Sengupta (1970) by chromatographic techniques after subjecting the acid to oxidation with periodic acid. The resulting acidic semi-aldehyde and the neutral semi-aldehyde after further oxidation and methylation were identified by GLC as dimethyl azelate and pimelate, respectively, thus confirming the envisaged structure (I). The first conversion of the natural threo acid to erythro isomer (m.p. 126 °C) was through the tribromo derivative (as cited in Bose et al. 1963).

The lac resin is composed of aleuritic acid and the hydroxy terpenic acids. There are terpenic acids in the form of butolic acid, shellolic and related acids, jalaric and laccijalaric acids and other minor acids presented in variable quantities. The brief details of the terpenic acids are given as follows.

Fig. 2 Aleuritic acid



4.2 Butolic Acid

Butolic acid (m.p. 58-590C), first isolated by Sengupta and Bose (as cited in Bose et al. 1963), was believed to be 6-hydroxypentadecanoic acid. Later, Christie et al. (1963) and Wadia et al. (1969) independently proved it to be 6-hydroxytetradecanoic acid.

4.3 Minor Acids

Christie et al. (1964) isolated and identified a number of acids, which are present in minor quantities in lac hydrolysate. These are tetra-, hexa- and octa-decenoic acids, 16-hydroxyhexadec-cis-9-enoic acid, threo-9,10-dihydroxytetradecanoic acid and threo-9,10-dihydroxyhexadecanoic acid.

Aleuritic, butolic and all other non-hydroxy, hydroxy- and oxo-fatty acids except 9,10-dihydroxyhexadecanoic acid were isolated from soft resin by Agarwal et al. (1976). Another dihydroxy acid was also isolated which was confirmed to be 10,16-dihydroxyhexadecanoic acid. All the above non-, mono-, di- and tri-hydroxy acids along with the oxo-acid were found present in free state in shellac/seedlac (Sengupta 1964) to the extent of nearly 6%.

4.4 Shellolic and Related Acids

Shellolic acid was first isolated by Harries and Nagel (as cited in Bose et al. 1963) and is an unsaturated dihydroxy dibasic hydroaromatic acid having molecular formula $C_{15}H_{20}O_6$. Yates and Field (1960) correctly proposed that it is a sesquiterpene with rare cedrene skeleton.

An isomer of shellolic acid was also isolated (as cited in Bose et al. 1963) and may be similar to the one mentioned by Kirk et al. (as cited in Bose et al. 1963). It was later identified as the epimer of shellolic acid and named epishellolic acid (as cited in Bose et al. 1963).

4.5 Jalaric Acid

An aldehydic acid was isolated by Sengupta (1954) from shellac as well as from soft resin which he believed to be lactonic in nature. Almost simultaneously Kamath and Potnis (1955) also separated a similar acid from jalari (*Shorea talura*) seedlac which they named as jalaric acid. It is believed to be present to the extent of nearly 1% in the free state (Sengupta 1954). Pure jalaric acid (m.p. 178–180 °C) was later obtained by Wadia et al. (1969) and has the molecular formula $C_{15}H_{20}O_5$. It contains one carbonyl, one carboxyl and two hydroxyl groups and an α,β-unsaturated carboxyl group.

4.6 Laksholic and Epilaksholic Acids

During the preparation of shellolic acid in large scale by the method of Cookson et al. (1962a, b), Wadia et al. (1969) noticed the presence of two more new acids which after isolation were termed laksholic (m.p.181–183 °C) and epilaksholic (m.p. 201–203 °C) acids. Both the acids were analysed for $C_{15}H_{22}O_5$ and titrated for monobasic acids. In addition to OH groups, the α,β-unsaturated carboxyl function was also present in the structure.

4.7 Laccijalaric, Laccishellolic, Laccilaksholic, Epilaccishollolic and Epilaccilaksholic Acids

Singh et al. (1969) isolated two more acids (m.p.s. 196–198 °C and 235–236 °C) whose dimethyl esters were analysed for $C_{17}H_{24}O_5$ (m.p.s. 85–87 °C and 94–95 °C). Based on spectral data it was deduced the structures of these two acids, the first acid being the epimer of the second and termed them laccishellolic and epilaccishollolic acid, respectively.

The cedrene skeleton for shellolic acid (and related acids) was well established by confirmatory degradative and X-ray studies. The cedrene skeleton for laccijalaric acid and related acids has also been well established by Sukh Dev (1974).

5 Structure of Lac Resin

Though at present almost all of the constituent acids of lac resin are known, it is not yet fully known how these are linked up to form this versatile resin. Earlier investigators have put forward some arbitrary structures but none satisfy chemical and physical properties of the resin. An attempt was made by Sukh Dev (1974) to put forward structures of some pure components of the resin. They had isolated a pure fraction (m.w. 2095 ± 110) in a yield of ~12% from hard resin. By means of alkaline silver oxide hydrolysis/oxidation, esterification, formylation and GLC analyses of this, they found that for every one mole of laccijalaric acid approximately three moles of jalaric acid and four moles of aleuritic acid are generated (Sharma et al. 2014). Thus they concluded that in pure lac resin there are aleuritic acid and terpenic acids (jalaric/laccijalaric acid and derived dicarboxylic acids) in a ratio of 1:1.

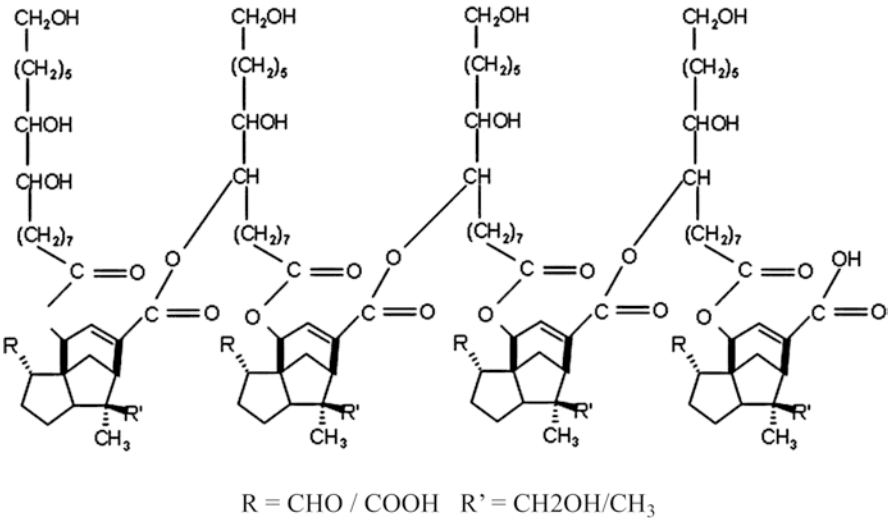


Fig. 3 Proposed structure of lac resin

Of the four terpenic acids, there are three jalaric/epishellolic acid and one laccijalaric/epilaccishollolic acid (Fig. 3). This molecule should have a molecular weight of 2194, which was in close agreement with the observed value.

6 Applications of Lac Resin

Lac possesses innumerable applications in various fields; the diversity is unmatched by any single resin natural or synthetic. This consists of traditional fields, which are being practiced by artisans through centuries, and researchers around the world have developed many more (Goswami and Sarkar 2010a, b).

More than 50% consumption of shellac is in the surface coatings. The age-old applications of shellac in surface coatings are believed to be due to the following qualities:

- Its ability to produce smooth, decorative and durable films from alcoholic solutions, which dry rapidly.
- Excellent adhesion and bonding material for a wide variety of surfaces, exhibiting high gloss, hardness.
- Ultraviolet resistance of films.
- Excellent compatibility with cellulosic materials and hence capable of yielding laminated products.
- Superb thermal plasticity, ready fusibility coupled with ability to absorb large amount of fillers.
- Ability of film formation of alkaline solution.

Table 2 Major applications of shellac

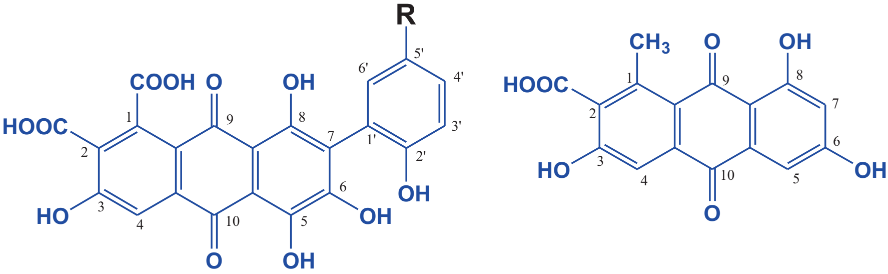
Field of application	Specific application area
Paint and varnishes	Wood finishing, metal foil, sealers, leather, rubber, car tyres
Printing ink	Felt pen inks, binder for flexographic inks for paper, cardboard, non-toxic printing ink for food packaging
Electronics	Lamps, fluorescent lamps, insulating agent for parts, insulating varnish Insulation, adhesion, laminate, lamp manufacture, glue for joining metal with glass, isolator coating, sockets of electrical lamps, PCB coating, etc.
Polishes	Fruits, furniture, floors, shoes, stain sealer, wallboard primer, knot and sap sealer on wood
Tapes	Masking, adhesive paper tape
Pharmaceuticals	Coating for tablets; enteric (digestive fluid proof) coating for tablets, pills, etc. Removing agent for medicinal odour. Enteric pills for sustained release medication
Food	Chestnuts, healthy foods, glazing agent for chocolates and sweets, protective coating for oranges, lemons, apples, etc. Binding agent for stamp inks for lemons, eggs and cheese. Barrier coating for feeds and seeds. Protective candy coating or glazes on candies. Coating of apples and other fruits. Coating of food materials
Cosmetics	Additive and binder for manicure, mascara, eye shadow and conditioning shampoo for personal care. Setting agent for hairspray, microencapsulation for perfumes for longer stay
Rubstones	Grinding wheel
Adhesive	Crystals, precious stones, lenses
Leather	Protection, polishes for leather finishing and stiffening of leather
Wood products	Finishes, primers, polishes and sealers for the harmful gases (formalin, etc.) that evaporate from building materials and protective coatings for wood
Others	Felt hats, pyrotechnics, gunpowder, strippable paints, cards, stiffening felt in hat manufacture and also in textile industries

- Unique dielectric properties.
- Non-toxic nature and renewable resources.

Major applications of shellac in different fields are depicted as follows (Table 2).

7 Lac Dye

Lac dye is secreted by the lac insects, *Kerria* spp. (family, Tachardiidae; order, Homoptera), feeding on the sap of specific host tree, allegedly to protect themselves from harmful UV radiations of the sun. It is obtained from sticklac. Laccaic acid is the principal colour imparting component of lac dye. It has been popularly used for dyeing silk and leather and in cosmetics in ancient Chinese and Indian civilizations.



Laccaic acid A, B, C & E

A: R= $CH_2CH_2NHCOCH_3$
B: R= CH_2CH_2OH
C: R= $CH_2CH(NH_2)COOH$
E: R= $CH_2CH_2NH_2$

Laccaic acid D

Fig. 4 Structure of laccaic acid

Lac dye is now legally registered as a natural food additive in a number of countries; the Chinese National Standard, CNS, No. is 08.104; the Korean Food and Drug Administration, KFDA, No. 13, and the Japanese no. 394. In India, Indian Institute of Natural Resins and Gums, Ranchi has transferred technology for manufacturing for technical grade lac and also developed a plant for production of food grade lac to expand the value-added product for more export (Srivastava and Baboo 2010).

Pure dye is sparingly soluble in water and is orange red in acidic pH and reddish violet in alkaline pH. In alkaline solutions, it decomposes rapidly (Srivastava et al. 2013). Its principal colour imparting component is laccaic acid, a hydroxyanthraquinone carboxylic acid (Fig. 4). Lac dye is a mixture of at least five closely related pure compounds all being anthraquinone derivatives designated as laccaic acid A, B, C, D and E (Chairat 2009; Pandhare et al. 1966, 1967, 1969; Rama Rao et al. 1968; Bhide et al. 1969; Mehandale et al. 1968; Venkataraman and Rama Rao 1972).

7.1 Extraction of Lac Dye

The scraped lac is processed (crushed and washed in desired uniform size) to get refined product known as seedlac. During this crushing and washing, the lac dye gets solubilized in water which in turn is processed to obtain the crystallized dye. The red colour of the resin comes from the insects. Lac dye is obtained during washing of sticklac for preparing seedlac. Pure dye is sparingly soluble in water, is orange red in acidic medium and reddish violet in alkaline medium. In alkaline solutions, it decomposes rapidly (Srivastava et al. 2010).

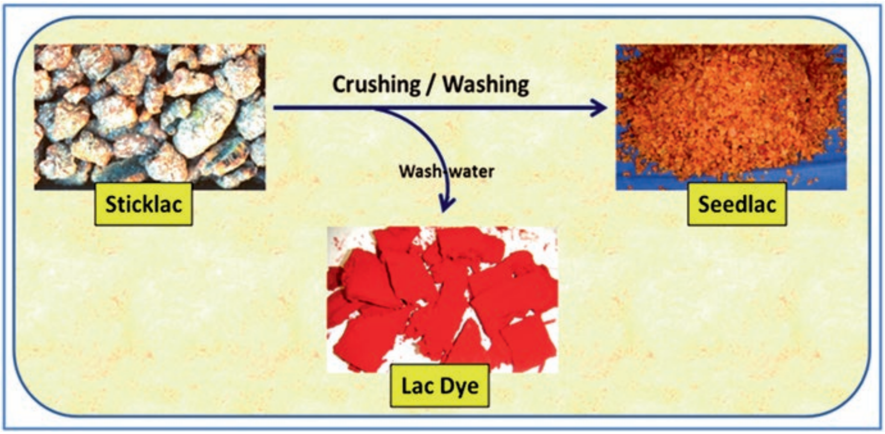


Fig. 5 Extraction of technical grade lac dye

7.1.1 Technical Grade Lac Dye

Sticklac wash water is acidified with sulphuric acid/hydrochloric acid (0.1% on the vol. of water) and the precipitate is allowed to settle in tanks. The supernatant clear liquor is collected by filtration. The acid precipitated sludge is separately extracted thrice with boiling water for removal of dye and washings are mixed with previous collections (Srivastava et al. 2010).

The mixed filtrate is then treated with calcium carbonate or quicklime till the liquor becomes almost colourless. The calcium salt of dye, which separates out, is collected by filtration and washed with water. The cold suspension of calcium salt of lac dye in water is acidified with 10% aqueous acid solution and kept for 7–10 days at room temperature when the dye crystallizes out (Ghosh et al. 1964; Ghosh and Sengupta 1977). It is filtered, washed and dried (yield approx. 0.5% on the weight of sticklac, dye content 80–90% depending on the quality and age of sticklac (Fig. 5).

7.1.2 Pure (Food) Grade Lac Dye

Technical grade dye is further purified by dissolving it in mild alkali, filtering the insolubles, acidifying the filtrate and, finally, keeping it for 8 days for crystallization. The crystallized dye is filtered, washed and dried (yield approx. 0.25% on the weight of sticklac, purity 99% and above). The purified lac dye is bright red. It is sparingly soluble in cold water (0.13–0.14%) but completely soluble in dimethyl formamide. It can be used for colouring food materials as it gives deep orange-red colour in aqueous solution like colour of beverages and cold drinks available in the market (Pandhare et al. 1969).

7.2 Uses of Lac Dye

Lac dye is non-toxic, principal red dye, hence incorporated in the manufacture of skin creams, food and drug manufacturing and textile industries. The use of lac in India probably dates back many centuries. From ancient times, lac dye has been employed in India as a skin cosmetic and for the dyeing of wool and silk, while China has a tradition of usage for leather dyeing. The colour of the lac dye can be modified by the appropriate choice of mordant from violet to red and brown.

Lac dye is used in classical Persian carpets and to dye silk, yielding a range of colours from rose to purple. During the eighteenth century India exported large quantities of lac dye (Hunter 2000), exporting 901,649 kg in the year 1868–1969. It is also known as Natural Red 25 (CI Number 75450) in international trade (Tanaka 1997). In China, pure lac dye (obtained from technical grade) is extensively used in a number of food products as per the national food safety standards, Health Ministry of China (GB 2760–2011; Ling 2003; Lu et al. 2007; Zheng et al. 2003). These products include fruit beverages, vegetable juice (pulp), fruit-flavoured beverages, soda pop, compound seasonings, jam, cocoa products and fillings for bakery wares, imitation wine, chocolates and chocolate products. It is in the approved food additive list of China (CNS No. 08.104), Japan (Natural additive 394) and Korea (Natural Additive 13). To be used as food additive, lac dye must conform to the requirements of standard specification of respective countries, e.g. GB 2760–2011 in China; Japan external trade organization specifications and standards for foods, food additives, 2011; and KFDA in Korea (KFDA 2019). Recently methyl derivatives of lac dye have been reported as potent antifungal and antibacterial agents (Srivastava et al. 2017b).

As per the reports from Directorate of Economics and Statistics, MoA, Govt. of India, India produced about 17,000 tons of lac in the year 2014–2015 (Yogi et al. 2017). Processing of this raw lac may yield around 200 tons of lac dye, majority of which is lost during washing. Some processors use the partially pure form (technical grade) of dye for utilization as textile dye, while other processing industries dispose the sludge of washing as manure to villagers. Thus, an enormous potential exists for utilization of this by-product of lac factories. Even if half of the potential is exploited, then it will be possible to turn trade of lac dye into profitable business of specialty product with assured foreign market. Furthermore, because of the ban on potentially carcinogenic red dyes Sudan IV, Sudan I and few others, there is a great demand of red colour dyes in food industry. The manufacturers are working hard to meet new laws of safety approval by recognized agencies such as JECFA, EFSA and others, to avoid use of unsafe pigments. Being natural and biodegradable, lac dye has great potential to replace currently used synthetic dyes.

Fig. 6 Lac wax

8 Lac Wax

Lac wax is a constituent of natural resin lac. It is secreted by the lac insect along with the resin, in the form of thin white filaments. It is generally found to the extent of nearly 4–5% in seedlac, 3–5% in shellac and slightly higher percentage in sticklac (5–6%).

Lac wax is recovered directly during processing of sticklac and also during the preparation of solvent-based dewaxed shellac generally called shellac wax (Fig. 6).

8.1 Chemical Constituents of Lac Wax

Lac wax is complex mixture of long-chain acids, alcohols, esters and hydrocarbons. Alcoholic components are mixtures of n-primary alcohols, 26–34 carbon atoms (Srivastava et al. 2010).

Tschirch and Schaffer (1926) observed that about 85% of the wax is soluble in boiling alcohol and wax melts at 80–81 °C. An alcohol, m.p.79 °C, and acid, m.p.78 °C, were separated from the wax. Based on the investigations of Tschirch and Schaffer (1926), the following were the conclusions:

1. About 85% of lac wax fraction is soluble in boiling alcohol and consists of an alcohol $C_{25}H_{51}OH$ and an acid $C_{26}H_{52}O_2$.
2. A boiling alcohol-insoluble fraction, consisting about 15%, is an ester of alcohol $C_{32}H_{66}O$ and acid $C_{32}H_{64}O_2$.
3. About 2% of wax is reported to be a hydrocarbon $C_{25}H_{52}$.

It was found that yields of pure products were small in most cases, indicating that there was a large portion of the material left uninvestigated. Warth (1956) suggested following composition (Table 3).

Table 3 Composition of resin-free shellac wax

Esters of wax acids	80–82%
Ceryl lignocerate (m.p. 79 °C)	
Ceryl cerotate (m.p. 84 °C)	
Lacceryl lacceroate (10–12%)	
Ceryl aleuritate (1% or less)	
Free wax acids	10–14%
Lacceroic acid (m.p. 95–96 °C)	
Cerotic acid	
Free wax alcohols	Less than 1%
Neoceryl alcohol (tachardiacerol, m.p. 80.1 °C, Tschirch)	
Lacceryl alcohol	
Hydrocarbons	2–6%
Pentacosane (tachardiacerin) 2%	
Heptacosane	
Lac resins	2–4%

Further, composition of lac wax was recorded: acid component 3.1%, alcoholic component 26.4%, anhydrohydroxy acid 1.6%, esters 66.8% and hydrocarbons 2.1% of which acids are cerotic, myristic and palmitic acids. Alcoholic components are mixtures of n-primary alcohols, 26–34 carbon atoms (C_{26} alcohol, 0.5%; C_{28} alcohol, 4.9%; C_{30} alcohol, 14.9%; C_{32} alcohol, 4.1%; C_{34} alcohol, 2.0%).

The esters are derivatives of C_{26} to C_{32} alcohols and C_{14}, C_{16} and C_{26} to C_{34} acids. Acids appear to be a mixture of at least 15 different esters with a mean molecular weight of 718.5 and molecular formula of $C_{49}H_{98}O_2$. The hydrocarbon is likely to be a C_{27}, n-aliphatic hydrocarbon. The most important observation is the presence of myristic esters. Myristic acid itself has been fully identified and characterized as its anilide.

8.2 Uses of Lac Wax

Principal use of shellac wax has been reported in electrical industry, though it is of general use in formulations where use of a natural wax of a hard type is advantageous. True shellac wax commands high price, and the demand for refined product exceeds supply. High melting point of shellac wax and its high electrical insulation value favour its use as electrical potting compounds and appliances. In shoe creams, addition of a little shellac wax to an otherwise ordinary formula containing montan and paraffin waxes is a means of producing a high lustre. Shellac wax sold for polishes is said to be frequently admixture with Chinese insect wax, tallow, resin and montan wax. It also has application in floor and car polishes, food, confectionery and tablet finishing, lipsticks, crayons and tailor's chalk. Emulsifiable wax was formulated consisting of candelilla wax, shellac wax, lignite wax, stearic acid and zinc stearate. For making water in oil (W/O) polishes, wax stock is then emulsified with white mineral spirit containing little ammonia or an amine and a mild abrasive. An aqueous wax emulsion polish was a developed polish of the ‘dry bright’ type using alkali-soluble resin selected from the group consisting of rosin, shellac wax, casein, phenol formaldehyde resins, etc.; upon application of the polish, the wax is deposited and, on drying, leaves a hard surface having a bright lustre (Chapman and John 1958 - US patent no. US2964487A).

Shellac wax has also been utilized in manufacture of radio condensers because of its high melting point. Radio condensers require waxes of a more exacting specification than do stout electrical conductors or ordinary size wire. Condenser in the small radio set in service becomes readily heated, therefore necessitating the use of a wax that will withstand at least 160 °F (~71 °C) of heat without softening or partially melting. Miniature assemblies require even higher melting point waxes. Waxes such as shellac wax, esparto wax, candelilla wax, and fibre wax, when plasticized by an adequate amount of softer wax of high melting point, are suited for the purpose.

Shellac wax has been utilized in making of finishing waxes for boot soles, because of its hard and lustrous nature. Alkaline solution of shellac was used in preparing liquid finishes. Liquid finishes were also prepared from shellac dissolved in an organic volatile solvent, containing a small amount of carnauba and other waxes. Shellac wax has also been used in making shoe pastes.

Recently, it has been reported in the literature that the long-chain fatty alcohols like triacontanol, dotriacontanol, octacosanol and hexacosanol are well known for promoting plant growth regulatory activity whereas triacontanol is a natural plant growth regulator and used commercially also. It is naturally found in epicuticular waxes and responsible for plant growth promotion activities like growth, yield, photosynthesis, protein synthesis and uptake of water and nutrients. The lac wax policosanol which is a mixture of octacosanol (C28), triacontanol (C30), dotriacontanol (C32), hexacosanol and other lower fatty alcohols was expected to show the PGR activity (Srivastava et al. 2017a, Indian Patent Application no. 201631013579).

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