

# Extraction of Aleuritic Acid from Seedlac and Purification by Reactive Adsorption on Functionalized Polymers

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Reactive extraction of aleuritic acid from seedlac was carried out at different NaOH concentrations and temperatures. A mathematical model was proposed for the hydrolysis of seedlac considering the breaking of ester linkages at any position along the length of the polymeric chain. Recovery and purification of aleuritic acid from the product mixture was further achieved by reactive adsorption using weakly basic polymeric resin containing tertiary amino group as the functional group. Aleuritic acid was recovered by continuous column studies with 92% yield and 94% purity.

## Introduction

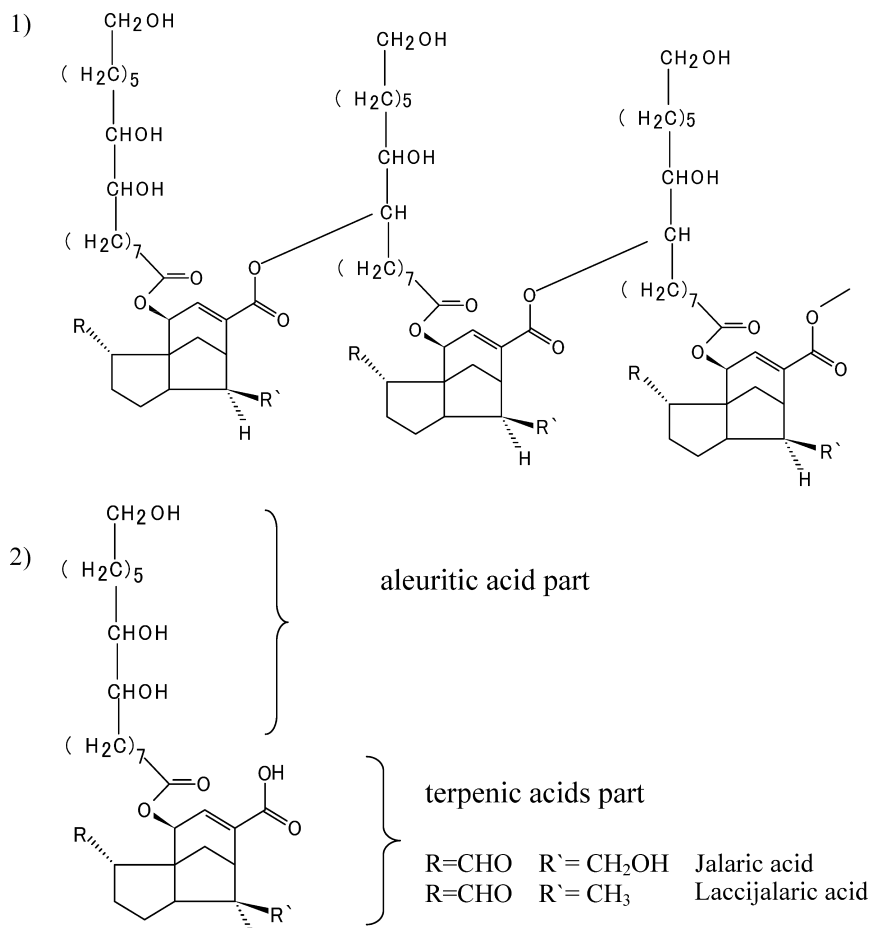
Lac, an organic resin, is secreted by the insect *Kerria lacca*, by feeding on the sap from selected berry trees. Sticklac, collected from the resin-rich branches of the host tree, is crushed and sieved to remove impurities to yield seedlac. The natural coloration of the lac residue is influenced by the sap consumed by the insect and the season of the harvest. Because of the flexibility of the properties, lac finds its importance in a variety of applications such as surface coatings, textiles, cosmetics, pharmaceuticals, adhesives, and electrical industry. It consists of 68% resin, 6% wax, and 1–2% dyes such as laccaic acid and erythrolaccin.<sup>1,2</sup> Lac resin is a mixture of cross-linked polyesters of closely related straight chain or cyclic aliphatic polyhydroxy acids and sesquiterpenic acids. The lac hydrolysate shows the presence of aleuritic acid (30–35%), aldehydic acids (20–25%), shellolic acids, other water-soluble acids (20–25%), and butolic acids (2%), as shown in Figure 1.<sup>3</sup> The major contribution to the polyester framework of the resin comes from aleuritic acid, that is, 9,10,16-trihydroxy-hexadecanoic acid. The presence of terminal hydroxyl and carboxyl functional groups on aleuritic acid makes it an excellent starting material for the synthesis of perfumery chemicals like macrocyclic lactones such as civetone, ambrettolide, isoambrettolide, and various bioactive compounds like prostaglandins, cyclic ureides, and pheromones. It is also used in the synthesis of compounds like diketones, dilactones, triesters, and substituted coumarin derivatives.<sup>4</sup>

The most common method of recovering aleuritic acid is alkaline hydrolysis of the lac resin for extended periods, sometimes as long as 7 days in concentrated aq NaOH (~20%, wt/wt%) solutions whereby sodium salts of the acids are precipitated.<sup>5</sup> Efforts have been made in the past to improve the process for production of aleuritic acid.<sup>6</sup> Zhou et al.<sup>7</sup> claimed recovery of acids by saponifying the lac over 20 min at 70–110 °C and then salting out the acid salts using saturated brine solution, although no details of the process are available. The filtration of these salts, however, is very slow due to the sticky characteristics and foaming tendencies of the solution. The complete salting out of the carboxylates requires a large amount of common salt, that is, NaCl, without which the process leads to the loss of sodium aleuritate in the filtrate. The crude acid is then liberated by the addition of a mineral acid to the salt. The presence of waxes and coloring pigments in the crude product, so obtained, makes repeated crystallization imperative to recover

the acid in a purer form for its further applications, particularly in perfumery products. The use of a cation exchange resin to liberate the acids from the salt solution followed by chromatographic separation of the methyl esters of the acids has been reported.<sup>8</sup> This process, however, loads the ion-exchange resin column considerably and because of lower solubility of aleuritic and other lac acids in water at low pH conditions can cause precipitation of the acid(s) inside the resin matrix, lower recovery of the acid, and create operational problems. The hydrolysis of the polymeric wax esters to acids and further purification steps seem to follow an empirical approach in practice, and a better understanding of the hydrolytic reaction is warranted. Similarly, multistage crystallization and chromatographic purification add significantly to the cost of the product.<sup>1,2</sup> An alternative is, therefore, warranted for purification of aleuritic acid.

The hydrolysis of polyester is an interesting phenomenon to investigate. Either the hydrolysis can take place only at the terminal ester groups or it can be random at any location along the length of a linear polyester chain. The concentration dependence of the rates of the hydrolysis would be different in these two cases as the former case would show a constant rate of hydrolysis while the latter case should show an apparently autocatalytic effect. To understand the mechanism of the hydrolysis reaction, different researchers over the years have developed models for hydrolysis and biodegradations of similar natural polymers.<sup>9–12</sup> Some of the earlier workers regarded the hydrolysis of the polyesters as a pseudo first-order reaction with respect to the polyester, and the hydrolysis results were fitted in a model that considered the dependence of rates of individual bond cleavages on the size of the polyester.<sup>13</sup> Giudicci and Hamielec<sup>14</sup> proposed a model considering random scission of branched chains of the polymer. A simple regular morphology was postulated for all of the chains in the polymer to compute its effect on the fragmentation along with the understanding of structural changes of each chain during the scission process. Pathria and Nanda<sup>15</sup> considered equal probability for breakup of all bonds, while Amemiya<sup>16</sup> introduced indiscretion on account of different probability of breakup of the bonds. Ziff and McGrady<sup>17</sup> systematically considered various cases in the fragmentation patterns of polymeric chains and derived mathematically a number of kinetic expressions for each case. However, none of them were validated against any experimental data.

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**Figure 1.** Structure of the resin: (1) polyester, (2) single ester.

The kinetics of the hydrolysis of the wax polyester is reported in this Article to understand the reaction mechanism. A mathematical model for the hydrolytic reaction has been developed to analyze the kinetic data. We have further investigated the recovery and purification of aleuritic acid from the extract using reactive sorption of the acid on an amine-functionalized polymer in nonaqueous conditions. The major advantage of the reactive sorption is recovery of aleuritic acid in a much purer form in shorter time of operation. Reactive sorption under nonaqueous conditions on functionalized polymers has been recently reported by our group for a variety of compounds, ranging from removal of acidic impurities from esters and separation of isomeric and nonisomeric phenolic compounds.<sup>18–23</sup> The major advantage of polymeric adsorbents lies in the flexibility of choosing required functional groups as ligands on the polymer matrix and modification of selectivity by appropriately selecting the functional groups for the specified separation. Macroporous polymeric adsorbents also have not been widely used for nonaqueous conditions, although their applications in aqueous conditions are widespread. There are very few references in the literature on the use of polymeric adsorbents for separations in organic solvents.<sup>24,25</sup> The polymeric adsorbents with sulfonic and carboxylic acid groups have been used for catalyzing a variety of chemical reactions and characterizing sorption of organic compounds on the polymeric matrix.<sup>26–28</sup>

## Materials and Methods

Seedlac and aleuritic acid were obtained from Shellac Industries, Gondia, Maharashtra. The purple colored and

unprocessed raw material was powdered before the hydrolysis reaction. *n*-Butanol and methanol were obtained from Merck (I) Ltd., Mumbai. A polymeric adsorbent (INDION 850) from Ion Exchange Ltd., Mumbai, was used for reactive sorption of the acids. It is a weak base polymeric macroporous adsorbent with *N,N*-dimethyl amino groups on a styrene-divinyl benzene copolymer matrix with an exchange capacity of 3.9 mol/kg on dry weight basis and 7–8% cross-linking.<sup>29</sup> The adsorbent has a pore size and pore volume of 39 nm and 0.52 cm<sup>3</sup>/g, respectively, with specific surface area of 35 m<sup>2</sup>/g.

The total aleuritic acid content in the raw material was determined by a method reported in the literature.<sup>5</sup> Seedlac powder of average size 400  $\mu\text{m}$  was added to 20% (w/v) aq NaOH solution, and the mixture was kept for 10 days at a room temperature of 300 K. The precipitated sodium aleuritate was filtered from the solution and dissolved in hot water followed by the addition of 10% H<sub>2</sub>SO<sub>4</sub> (v/v) aqueous solution to precipitate crude aleuritic acid. The acid was further crystallized from ethyl acetate. The total aleuritic acid content was estimated to be 28% (w/w) in the raw material.

The hydrolysis of seedlac was conducted in a fully baffled cylindrical glass reaction vessel (150 cm<sup>3</sup>) equipped with a six-bladed turbine impeller (2 cm i.d.) at 1000 rpm. Beyond this speed of agitation, there was no effect of agitation on the rate of extraction, indicating insignificant mass transfer resistance to the process. The finely ground seedlac was introduced in the alkaline solution, which readily dissolved the material. The rate of reaction was followed in terms of the total acid content of the solution. Samples were withdrawn from the solution after definite time intervals. Each sample was acidified separately

using 10% H<sub>2</sub>SO<sub>4</sub>, and the precipitated gummy residue was dissolved in *n*-butanol. One part of the sample in *n*-butanol was analyzed by HPLC for determining aleuritic acid content and other acids. The other part of the sample was evaporated completely and titrated against alcoholic KOH solution to determine the acid value of the sample, as the amount of KOH (in milligrams) required to neutralize free acids contained in 1 g of the sample.

The gummy residue, obtained by acidification of the alkaline extract of seedlac by 10% H<sub>2</sub>SO<sub>4</sub> solution, dissolves readily in *n*-butanol. The solubility of aleuritic acid in *n*-butanol was separately determined to be 0.30 mol/dm<sup>3</sup> (w/v) at room temperature of 303 K. The separation of the acids from the hydrolysate was carried out by adsorption on INDION 850 adsorbent as described later in this Article.

**Batch Adsorption of Aleuritic Acid on Indion 850 Polymeric Adsorbent.** Separate batch adsorption studies were carried out with standard aleuritic acid obtained from Shellac Industries to estimate the maximum capacity of the adsorbent. The polymeric adsorbent was pretreated with 5% (w/v) aq NaOH solution followed by washing with a large volume of deionized water to make it completely alkali free. The adsorbent was then thoroughly washed with methanol and dried in an oven at 333 K. A known amount of the adsorbent (0.5 g) and the solution of aleuritic acid in *n*-butanol (10 cm<sup>3</sup>) were added to a stoppered conical flask and then kept in a constant temperature shaker for a period of 8 h to attain equilibrium. Samples were collected after every 1 h in separate studies to determine the time required for the equilibrium, and the residual concentration of aleuritic acid was determined by HPLC.

**Separation of Aleuritic Acid.** For the column studies, a glass column of diameter 1.2 cm was packed with the pretreated adsorbent up to the height of 18 cm. The column was packed with small glass beads in the top and bottom zones to avoid mass transfer effects and reduce the dead volume. A layer of nonadsorbing cotton was placed between the glass beads and the resins for compact packing. The gummy hydrolysate, which was dissolved in butanol, was directly taken for the adsorption on the resin column. The solution was pumped from a feed tank through the column in the upward mode of flow at a constant flow rate of 0.5 cm<sup>3</sup>/min. Samples were collected after regular time intervals at the exit of the column for analysis. Once the entire solution was passed through the column, hexane was passed in the upward direction to remove all waxes and resinous materials from the column. Because of the insolubility of aleuritic acid in hexane, there was no trace of the acid in the samples collected during the hexane wash. Methanol was then passed again with upward flow as the desorbing solvent at the constant flow rate of 0.5 cm<sup>3</sup>/min. Methanol fractions were collected and analyzed until no aleuritic acid was detected in the desorbate. This ensured substantial (>90%) recovery of the acid from the adsorption column. Methanol from the solution was evaporated in a rotary evaporator to recover the acid. A diethyl ether wash was given to the solid to remove residual stickiness of the solid. The recovered acid was then analyzed using high performance liquid chromatography (HPLC).

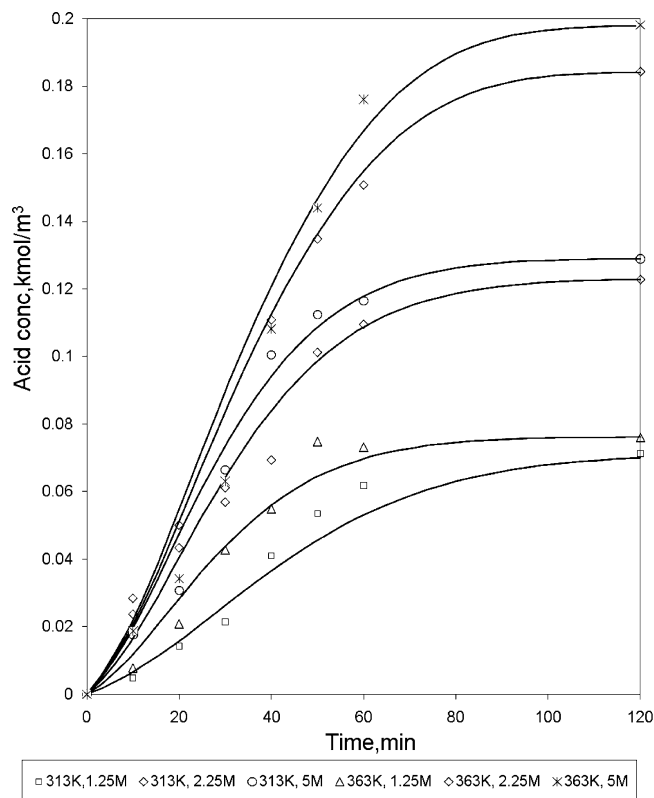
**Analytical Methods.** The concentration of aleuritic acid in the solution was determined by HPLC with Hi-QSil-C-18 column. The HPLC column was initially washed with methanol for 30 min and then equilibrated with acetonitrile–water (75:25) mobile phase. The column was mounted on a Knauer HPLC chromatograph equipped with a 20  $\mu$ L loop injector and ELSD 2000ES All-Tech detector and a Perkin-Elmer LC-25 RI detector.

The molecular weight of the lac ester was determined with a Knauer vapor pressure osmometer (model K-7000) using Benzil as a standard for calibration. The osmometer consists of two thermistors, which are placed in an airtight cell. Alkaline solutions of seedlac at different concentrations of alkali solution and methanol solutions of benzil were prepared. The experiments for the molecular weight determination were conducted by placing a drop of alkali solution of seedlac on one thermistor and a drop of benzil solution on the other, which was taken for developing calibration data. A change in resistance of the two thermistors is observed due to the two drops attaining different temperatures. This difference in the vapor pressures of the sample and benzil solution was measured in terms of difference in the resistances of the two thermistors. By the calibration plot and sample measurements, the molecular mass of the seedlac ester was determined to be 6422 g/mol. The average number of ester linkages was determined to be 21 from the molecular weight.

## Results and Discussion

**Mathematical Model of the Hydrolysis Reaction.** In the present study, the hydrolysis of the ester groups in the polyester chain is catalyzed by alkaline conditions. The rate of the reaction depends on the molar concentration of the polyester and that of the alkali. At each step of the hydrolytic reaction of an ester linkage in the chain, there is formation of an acidic group, which is neutralized by the alkali. The increasing acid value of the product is, therefore, an indication of the extent of the depolymerization of the polyester. There have been references to the rate of hydrolysis of cellulose studied by Freudenberg et al.,<sup>30</sup> where they have postulated that the rate of hydrolysis of the terminal linkages of the cellulosic chain is faster than the internal linkages. Yet to understand the mechanism, we considered two different situations in which a polyester chain can undergo the chain scission. Either the hydrolysis of the polyester can take place preferentially only at the terminal ester groups or it can be random at any location along the length of the polyester chain with each ester linkage having equal probability of undergoing the scission. The concentration dependence of the rates of hydrolysis is different in the two cases. If the hydrolysis takes place preferentially at the terminal ester groups, then stepwise scission of an *n*-mer chain leads to the generation of an (*n* – 1)-mer at every step. The molar concentration of the reacting polymeric molecule remains the same until, finally, the dimer hydrolyzes to monomers. If the alkali concentration is in a large excess, the hydrolytic rate should remain constant throughout. The liberated acid group concentration in the reaction mixture will increase linearly with time of the reaction.

The experimentally observed acid concentration, however, shows a sigmoidal variation of the acid group concentration with time (Figure 2), ruling out sequential hydrolysis of the terminal ester linkage. Initially, the rate of increase in the acid value (AV) is slow, but the AV rapidly rises almost exponentially for some time after the initial lag phase, before reaching a plateau at longer times of reaction where most of the ester is reduced to monomeric form. This behavior indicates that hydrolysis does not take place preferentially at the terminal ester linkages but most probably takes place randomly along the chain of the polyester. To mathematically explain the observations, a model is developed by considering the hydrolysis of the polyester at any position along the length of the chain. Each such scission, at a time, results in two fragments, both of which are equally capable of undergoing further hydrolysis, except when the hydrolysis takes place at the terminal ester group when



**Figure 2.** Effect of NaOH concentration on hydrolysis of seedlac at 313 and 363 K.

only one fragment remains reactive in subsequent hydrolytic reaction while the monomer cannot react further.

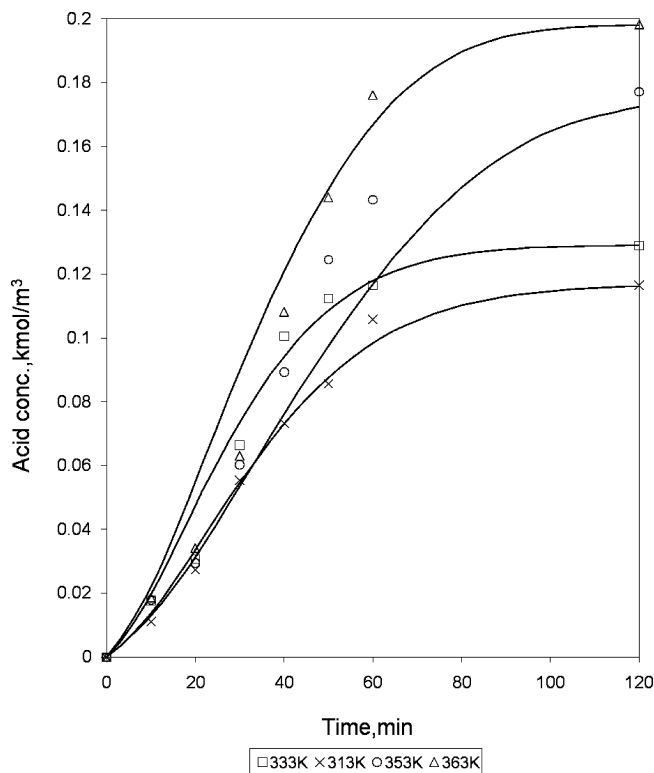
The rate of the hydrolysis of an  $n$ -mer is considered to be first order with respect to both the  $n$ -mer and the alkali concentrations. Initially, the  $n$ -mer's molar concentration is low, and thus the observed rates are also low. However, as the reaction proceeds forming more fragments, molar concentration of the reacting species, which includes all oligomers formed as a result of the hydrolysis of longer polymers, also increases with time. This, in turn, increases the rate of increase of the acid value of the product mixture. At any time, there are oligomers in solutions that are consumed by the hydrolytic reaction, but they are also formed by hydrolysis of longer chain polyesters. In effect, the observed rate of hydrolysis should show an autocatalytic effect, until the rate of disappearance takes over the rate of formation of the fragments and the oligomers are reduced to monomers in the reaction mixture, which slows the rate of acid value increase. Finally, when all or most of the ester linkages are hydrolyzed into monomers, the rate falls to zero with a constant acid value of the product.

The rate equation of the degradation of an  $N$ -mer, the largest polymeric chain, can be written as follows:

$$\frac{dP_N}{dt} = -k[P_N][\text{NaOH}] \quad (1)$$

where  $[P_N]$  is the concentration of the initial  $N$ -mer polymer ( $\text{mol dm}^{-3}$ ), and  $k$  is the second-order hydrolysis rate constant ( $\text{min}^{-1} \text{mol}^{-1} \text{dm}^3$ ).

For an  $m$ -mer ( $m < N$ ), there is its formation from hydrolysis of a  $j$ -mer ( $N > j > m$ ) as well as its disappearance by its own hydrolysis. The rate of formation of the  $m$ -mer is the sum of formations from all such  $j$ -mers (for  $N > j > m$ ). Because a  $j$ -mer undergoes a split in  $j - 1$  ways,  $2/(j - 1)$  is the probability



**Figure 3.** Effect of temperature on hydrolysis of seedlac using 5.0 mol/dm<sup>3</sup> NaOH.

of the formation of the  $m$ -mer from hydrolysis of a  $j$ -mer. By the above consideration, the rate of formation of  $m$ -mer can be written as follows:

$$\frac{d[P_m]}{dt} = \sum_{j=m+1}^N \frac{2k}{j-1} [P_j][\text{NaOH}] - k[P_m][\text{NaOH}] \quad m = 2 \dots N \quad (2)$$

where  $P_N(0) = [P_N]$  and  $P_j(0) = 0$  at  $t = 0$  for  $j < N$ .

At  $t = 0$ , no other  $P_j$ 's are present in the reaction mixture. The first term in eq 2 is the generation term for the  $m$ -mer from all polymers having size greater than  $m$ . The second term indicates its hydrolysis. At time " $t$ ", all of the fragments contribute to the total acid value of the product. Therefore,  $A(t)$ , the total acid content at time " $t$ ", is

$$A(t) = \sum_{j=1}^N [P_j](t) \quad (3)$$

From the average molecular mass of seedlac as wax polyester and molecular mass of aleuritic acid (304 g/mol), the chain length of the wax ester is about 21 ester long. A set of 21 differential equations, one equation for each oligomer concentration, was written representing the hydrolysis from the depletion of the polymer, through oligomers, to formation of the monomer. This set of differential equations (eq 2) was solved by a program developed in MATLAB 6.5, to determine the rate constant of the reaction under given set of conditions, by fitting the total acid value to estimate the rate. Figure 3 shows a good agreement between the experimental acid values and the model equations. The model, which has been considering 21 probable linkages, can be successfully extrapolated to a larger system because the dependence on the size of the polymer molecule has been neglected. The model also demonstrated the expected sigmoidal behavior of the acid value as shown by the theoretical



curves in Figure 2 at two different temperatures of 313 and 363 K and at different NaOH concentrations. The hydrolysis leads to more number of reactive species, and consequently the acid value of product shows a sigmoidal behavior with respect to time.

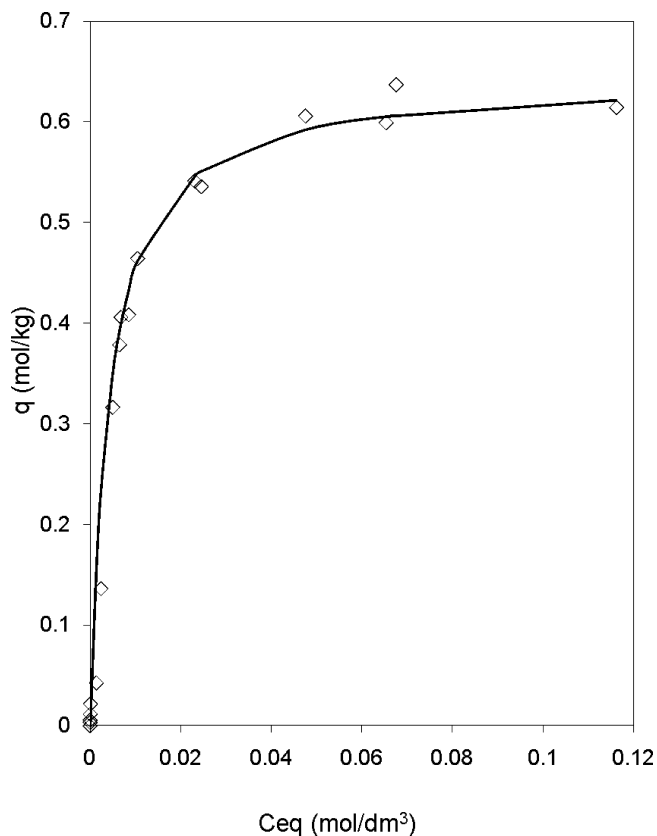
Maniar et al.<sup>9</sup> have claimed from their studies on hydrolysis of tartarate ester oligomers that the rate constant of the polymer of higher molecular weight should be higher than that for the lower molecular weight polymer because of the higher probability of the polymer of higher molecular weight to get degraded at the outset. Yet in the present case when the dependence of the rate constant was considered on the number of linkages, the experimental results did not fit the model predictions, nor could it predict the sigmoidal behavior of acid value of the product mixture with respect to time. Hence, we have retained the rate constant to be size invariant for the hydrolytic reaction, that is, the same for all ester linkages. We believe the incorporation of the probability of number of breakups and formation of fragments of different molecular weights has taken into account the system characteristics correctly. The dependence of the individual bonds accessible to the hydrolysis also can be neglected for the system, as we found the system to be homogeneous, ruling out any mass transfer effect.

**Effect of Concentration of NaOH.** There was a significant effect of NaOH concentration at 0.25, 2.5, and 5 mol/dm<sup>3</sup> of NaOH at both temperatures, 313 and 363 K. As expected, the rates are lower at 313 K but not insignificant. When the polyester undergoes hydrolysis, it breaks down to give sodium salts of acids, polymeric residues, and waxes. The acids of the seedlac are liberated as salt, but the remaining fragments form a gummy residue upon acidification.

The increase in alkali concentration leads to more hydrolysis reactions of different ester linkages, and thus dependence of the rate on alkali concentration is expected. The sodium salts of the acids from the seedlac also have amphiphilic structures and solubilize some of the other species in the aqueous solutions, probably through micellar formation above a particular concentration.<sup>31–33</sup> The density and viscosity of the reaction mixture were observed to be increasing with respect to the reaction time, suggesting an increase in the number of particles in the reaction mixture. Although the number of particles is increasing during hydrolysis, the change in viscosity is not so significant. This observation could be attributed to the ability of sodium salts of aleuritic acid and other acids to encapsulate the polymeric residues and the products of hydrolysis.

**Effect of Temperature.** Figure 3 shows the effect of temperature on the rate of increase in the acid content of the seedlac hydrolysate. Because the hydrolysis of seedlac is conducted at different NaOH concentrations, the density of each of those solutions should also be considered so as to negate any effect of alkali concentration on rate constants. Rate constants for the hydrolysis reaction at 313, 333, 353, and 363 K at 5 mol/dm<sup>3</sup> concentration of NaOH are 0.1435, 0.1632, 0.1716, and 0.1746 min<sup>−1</sup> mol<sup>−1</sup> L<sup>2</sup> kg<sup>−1</sup>, respectively. There is no significant effect of temperature on the rate constant, but the values obtained cannot be discounted on the basis of obvious increase in the rate of reaction observed.

**Purification of Aleuritic Acid by Adsorption on Polymeric Adsorbent.** The reactive adsorptive technique was further employed to recover the acids from the lac hydrolysate. Equilibrium sorption batch studies of aleuritic acid were conducted separately on INDION 850 polymer to determine its maximum loading as the moles of the adsorbed acid per



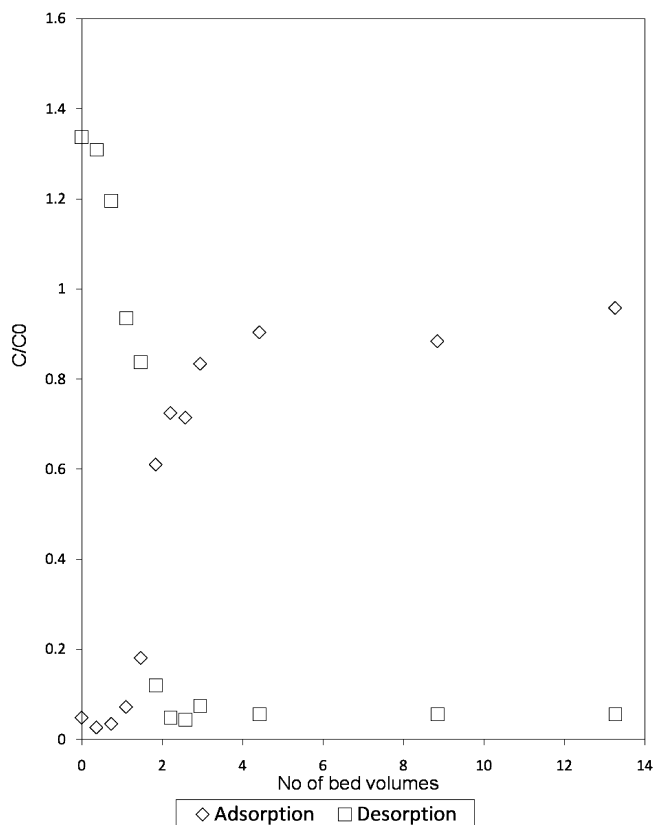
**Figure 4.** Adsorption of aleuritic acid on INDION 850 resin from butanol solutions.

kilogram of the dry polymer. The amount of the adsorbed acid increases with the increasing concentrations of the acid in butanol solutions and approaches a limiting value as the equilibrium is attained between the concentrations of the solute in the solvent and in the polymer. The Langmuir isotherm was used in the form

$$\frac{q}{q_{\max}} = \frac{KC_{eq}}{1 + KC_{eq}} \quad (4)$$

to fit the adsorption data, where  $q$  is the amount of solute adsorbed per kg of the resin,  $q_{\max}$  is the maximum amount of the acid adsorbed,  $K$  is the adsorption equilibrium constant, and  $C_{eq}$  is the equilibrium acid concentration in the solution. The interaction responsible for adsorption of acid on the polymer can be explained as a Lewis acid–base interaction between the lone pair of electrons of the nitrogen of tertiary amine and the acidic hydrogen of acids in nonaqueous conditions. This leads to the formation of a hydrogen bond. The acid is preferentially adsorbed from the butanol phase at various concentrations. The fitting of the adsorption data gave the maximum capacity for aleuritic acid on INDION 850 polymer to be 0.64 mol/kg at 313 K and the equilibrium constant to be 243 mol/kg. The lines in Figure 4 show the fitted curves, and the points show the experimental values. These studies indicated the possibility of using the polymeric adsorbent for purification of the acids from the rest of the waxes and nonacidic compounds in the extract.

The alkaline extract was acidified with 10% H<sub>2</sub>SO<sub>4</sub> acid solution to precipitate the acids as a gummy residue. This residue was dissolved in *n*-butanol, and the solution was passed through a column packed with INDION 850 polymer. The acids were retained on the polymer due to the interactions of the acidic groups of the organic acids with the amino groups of the



**Figure 5.** Adsorption and desorption of aleuritic acid from the reaction mixture using INDION 850 resin packed column.

polymer. Adsorption of hydrolysate on the polymer showed higher adsorption of aleuritic acid, most likely due to its relatively high percentage in the mixture.

The breakthrough curve of the acid was obtained by plotting the ratio of concentration of the acid in the effluent to its initial concentration against the number of bed volumes of the solution passed through the column. Figure 5 shows the breakthrough curve for the adsorption of aleuritic acid from the reaction mixture dissolved in butanol solutions and also its desorption using methanol. In the case of adsorption, 2 bed volumes were treated as the breakpoint up to which 61% of aleuritic acid from the initial feed solution was adsorbed. By the time the solution reached the sixth bed volume, the bed got saturated and 90% of the aleuritic acid got adsorbed. Other acids in the hydrolysate also compete for the adsorptive sites, which reduces the complete adsorption of aleuritic acid from the hydrolysate. Desorption was carried out using methanol, as the solubility of aleuritic acid in methanol is 0.845 mol/dm<sup>3</sup> (w/v). From the breakthrough curve, it is clear that the rate of desorption was initially high but reduced with the course of the desorption process. After passing 10 bed volumes, 92% of the adsorbed acid was recovered from the resin with 94% purity. A significant amount of pigments, however, was found to be retained on the column after the desorption of aleuritic acid. The retention of pigments is almost irreversible, and that reduces the capacity of the polymer for subsequent use. However, the analysis of the solutions during the purification of the acid could not be comprehensively done due to the involvement of species for which qualitative and quantitative data could not be obtained as it was giving rise to some operational problems.

## Conclusions

Because seedlac is a polyester with intermolecular ester linkages, it posed an interesting objective to be delved into.

Mathematical modeling of the alkaline hydrolytic reaction along with the experimental kinetic data on total acids in the reaction mixture indicates random scission of the polyester chain as a mechanism of hydrolysis. The model successfully predicts the time variant behavior at different alkali concentrations as well as at different temperatures. Because aleuritic acid is present, albeit in substantially high concentration as compared to other components, purification of the acid from the product mixture became a necessity. The batch adsorption on Indion 850, a weak base polymer, showed a considerable affinity of aleuritic acid toward the polymer. Indion 850 selectively adsorbs aleuritic acid from butanol solutions of the reaction mixture. The column adsorption studies indicate efficacy of the polymer in aleuritic acid purification and recovery. The reuse of the column, however, is questionable because of irreversible adsorption of pigments and other impurities in the bed.

## Appendix

### Nomenclature

$A(t)$  = total acid content at time “ $t$ ”

$C_{eq}$  = equilibrium concentration

$k$  = second-order hydrolysis rate constant, min<sup>-1</sup> mol<sup>-1</sup> L<sup>2</sup> kg of solution<sup>-1</sup>

$K$  = adsorption equilibrium constant

$[P_N]$  = concentration of the initial polymer, mol dm<sup>-3</sup>

$[P_j]$  = concentration of the  $j$ -mer

$[P_m]$  = concentration of the  $m$ -mer

$q$  = moles of acid(s) adsorbed per kg of polymer

$q_{max}$  = maximum moles of the acid adsorbed per kg of polymer

$t$  = time, min

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