Leaflet No. 3/2009

Ministry of Forestry

Forest Department

Forest Research Institute

Study on the Production of Wood Adhesive from Cashew Nut Shell Oil

Thida Cho, Research Assistant-2
Khin May Lwin, Research Officer
Su Myint Than, Research Assistant-2
Forest Research Institute

December, 2009

သီဟိုစေ့ခွံဆီမှ သစ်သားကပ်ကော်ထုတ်လုပ်မှုလေ့လာခြင်း

သီတာချို၊ သုတေသနလက်ထောက်-၂
ခင်မေလွင် ၊ သုတေသနအရာရှိ
စုမြင့်သန်း၊ သုတေသနလက်ထောက်-၂
သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်း

သီဟိုထုတ်လုပ်မှုအဆင့်ဆင့်မှ အရေးပါသောတန်ဖိုးမြင့် ဘေးထွက်ပစ္စည်းတစ်မျိုး ဖြစ်ထွန်းလာပါသည်။ ဈေးနှန်းသက်သာ၍ ခေတ်ပေါ်အသုံးဝင်သည့် သီဟိုစေ့ခွံဆီကို စက်မှုလုပ်ငန်းနှင့်ဆိုင်သော အသုံးပြုမှု ၂၀၀ ကျော် ရှိပါသည်။ ကမ္ဘာနေရာအနှံ့အပြားတွင် သီဟိုစေ့ခွံဆီကို အသုံးပြုမှုအမျိုးမျိုးပြုသော်လည်း မြန်မာနိုင်ငံတွင် ၎င်းကို မျက်နှာပြင်ပြောင်လက်ချောမွေ့စေသည့် ကြာရှည်ခံပထမတန်းစား ထုတ်ကုန်များအဖြစ်နှင့်သာ ထုတ်လုပ် နိုင်ခဲ့ပါသည်။ မြန်မာနိုင်ငံတွင်သီဟိုစေ့ခွံဆီမှ ရေစိုခံသစ်သားကပ်ကော် အဖြစ်သုံးစွဲနိုင်မှု မရှိသေးပဲ အထပ်သားပြုလုပ်ရန်အတွက်ကော်ကို နိုင်ငံခြားမှယနေ့တိုင် မှာယူသုံးစွဲနေရပါသည်။

လက်ရှိလုပ်ဆောင်မှုတွင် သီဟိုစေ့မှ သီဟိုစေ့ခွံဆီကို အခြားဝတ္ထုပစ္စည်းများကို အရည်ပျော်စေနိုင်သော ဓာတ်စမ်း ပစ္စည်းကိုသုံး၍ သီဟိုစေ့ခွံဆီကို ထုတ်ယူခဲ့ပါသည်။ သီဟိုစေ့ခွံဆီ CNSL ၊ Formaldehyde ပမာဏ(၃)မျိုး၊ CausticSoda (NaoH) ဓာတ်ကူပစ္စည်းနှင့် 80% Lead Naphthenate Drier အခြောက်မြန်ပစ္စည်းများကို အသုံးပြု၍ ကော်အချိုး(၃)မျိုး ဖော်စပ်ပါသည်။ ကော်ပမာဏ(၄)မျိုး ဥပမာ ၀.၄၈ရမ်၊ ၀.၅၈ရမ်၊ ၀.၆၈ရမ် နှင့်၀.၇၈ရမ် များကို ချိန်တွယ်၍ ကျွန်းနမူနာတုံး နှစ်ခု၏ Radial သို့မဟုတ် Tangential မျက်နှာပြင်နှစ်ခုလုံးကို သုတ်လိမ်းပါသည်။ ၎င်းနောက်ကော်သုတ်ပြီး ကျွန်းနမူနာတုံးနှစ်ခုကို ဘေးချင်းယှဉ်၍ကပ်ပြီး အလေးချိန်(၇၀) ကီလိုဂရမ် ရှိသော အရာဝတ္ထုဖြင့်ဖိအားပေးကာ အခန်းအပူချိန်တွင် (၂)ရက် အခြောက်ခံပါသည်။ အခြောက်ခံပြီးနောက် ကော်သုတ်၍ကပ်ထားသော ကျွန်းနမူနာတုံး များကို ရေတွင်စိမ်ကာ ၎င်းနမူနာတုံးများရေထဲတွင် ကွာမည့်အချိန်ကို မှတ်သားပါသည်။ ဤလေ့လာချက်မှ ကော်သုတ်၍ကပ်ထားသော စမ်းသပ်ကျွန်းနမူနာတုံးအားလုံးသည် သုံးပတ်တိုင်ရေထဲတွင် စိမ်သော်လည်း ပြောင်းလဲ မှုမရှိကြောင်း တွေ့ရှိရပါသည်။ သို့ဖြစ်ပါ၍ CNSL နှင့် Formaldehyde အချိုးအမျိုးမျိုးနှင့် ပြုလုပ်ထားသော မည်သည့်ကော်ကိုမဆို ရေစိုခံသစ်သားကပ်ကော်အဖြစ် သုံးစွဲရန်သင့်လျော်ပါသည်။ သို့သော် ကော်အသီးသီး၏ ကုန်ကျစရိတ်များကို နှိုင်းယှဉ်သော်အခါ Formaldehyde ပါဝင်မှုအနည်းဆုံးဖြစ်သော ကော်အချိုးသည် ရေစိုခံ သစ်သားကပ်ကော်အဖြစ် အမြောက်အမြားထုတ်လုပ်ရန်အတွက် အသင့်လျော်ဆုံးဖြစ်ပါသည်။

Study on the production of wood adhesive from Cashew nut shell oil

Thida Cho, Research Assistant-2

Khin May Lwin, Research Officer

Su Myint Than, Research Assistant -2

Forest Research Institute

Abstract

Cashew nut processing allows for the development of an important by-product, which can increase its added value. There are more than 200 registered patents on cost effective modern materials, CNSL for its industrial application. . Although the cashew nut shell liquid (CNSL) has innumerable application in other parts of the world, it can only be produced as the first-class finished products in Myanmar., As water-proof adhesive from the cashew nut shell liquid (CNSL) has not yet utilized in Myanmar and also adhesive for making plywood is imported from the abroad until now.

In the present work, the cashew nut shell liquid (CNSL) was extracted from the cashew nut by solvent extracted and three ratios of adhesives with three different amount of formaldehyde to CNSL were prepared by using caustic soda (sodium hydroxide) as a catalyst and 80% lead naphthenate drier especially acts as an accelerator of polymerization in baking finishes. Four kinds of adhesive amounts were weighed and coated either radial or tangential surfaces of two teak specimens. Then, they were combined with side by side, pressed with 70kg load and dried at room temperature for two days. After the drying, the tested combined specimens were immersed into the water and the splitting times of each in the water were recorded. This study shows that all the tested combined specimens until immersing into the water for three weeks unaffected in water. Thus, any adhesive made from CNSL and formaldehyde with different ratios is suitable to use as water-proof adhesive. But, when compared the costs of each prepared adhesive the ratio of adhesive that contains the lowest formaldehyde amount is suitable to use as water-proof adhesive for commercial scale production.

Keywords; Cashew nut, wood adhesive**,** CNSL, Formaldehyde, Splitting times

Contents

1. Introduction

The cashew nut(*Anacardium accidentale)* shell contains a dark reddish brown viscous liquid, it is called the cashew nut shell liquid (CNSL), which is the pericarp fluid of the cashew nut, it is traditionally obtained during the process of removing the cashew kernel from the nut. The nut has a shell of about 1/8 inch thickness inside which is a soft honeycomb matrix. Cashew nut processing allows for the development of an important by product, which can increase its added value. The government of Myanmar has laid down an ambitious expansion plan for rubber, oil palm and cashew. Of these, cashew has a targeted annual increment of 3,000ha. In the situation of global recession, some company of Myanmar loaded 16MT of by-product CNSL to China.

The cashew nut shell liquid (CNSL) is one of the sources of naturally occurring phenols. It classified into two types; natural (i.e. cold, solvent-extracted) and technical (i.e heat extract) based of the mode of extraction from cashew nut shell. The chief constituents of the oil in the shells are cardol, methyl-cardol and mainly cardanol (decarboxylated amacardic acid), a meta-substituted n-long chain (C_{15}) unsaturated alkyl phenol. Although not a glyceride, it is a drying oil, easily soluble in most of the organic solvents. With suitable driers, it gives a smooth, shining film of dark reddish brown color.

The cashew nut shell liquid (CNSL) and cordanol are used in the manufacture of special phenol resins for coating, adhesive, varnishes, paints and as friction materials. These polymers are synthesized from CNSL or cardanol either by polycondensation with electrophylic compounds such as formaldehyde, furfuraldehyde or by chain polymerization through unsaturation presented in the side chain using an acid or base catalyst. Thus, CNSL is an important, versatile industrial, medicinal and engineering raw material.

There are more than 200 registered patents of different uses of shell oil. Although CNSL has a great variety of uses in other parts of the world, it can only be used in the manufacture of coating, paints and resin in Myanmar. As adhesive from the CNSL for plywood has not yet utilized in Myanmar. Also adhesive for making plywood is imported from the abroad until now. Thus, plywood which is made from the bamboo and timber has not yet produced much cheaper. If the adhesive is produced within the country, there may be wide range of economic, social and environmental benefits.

The major component of water-proof adhesive is “phenol” compound. That phenol (cardanol) compound can be collected from the CNSL. Also cardanol is a phenolic compound with C_{15} aliphatic chain in the meta- position, obtained from the cashew nut shell liquid. Moreover, CNSL is renewable, highly reactive and cheaper than phenol which is the most important raw material for water-proof particle board and plywood adhesive. The advantage of the cashew adhesive compared with synthetic phenolic adhesive is that they are more economical and produce a softer material, which gives a quieter braking action (CTCS, 1993).

The cashew nut shell liquid (CNSL) can also give many industrial significant, such us-low cost phenol, versatility in polymerization and chemical modification, possibilities for development of high performance polymers and property advantage over phenolic in certain applications such as impact resistance, flexibility, faster heat dissipation etc.

Otherwise, most phenolic adhesives are prepared by reacting formaldehyde with phenols, which are considered to be toxic and harmful for the environment. Most of the phenol-formaldehyde coatings contain harmful materials like phenols and Volatile Organic Chemicals (VOCs). The use of CNSL or mostly cardanol as an eco-friendly substitute can reduce VOCs from the coatings. Thus, it has been observed that by-product CNSL provide renewable and environmentally friendly resources for the environmental protection.

Hence, the way comes out that as the cashew nut shell liquid (CNSL) is phenol based, it is useful like phenol. Therefore, aiming with the future prospect of bamboo and timber products, this research is curried out.

2. Literature Review

Common name	: Cashew nut tree
Botanical name	: *Anacardium occidentale*
Family	: *Anacardiaceae*
Origin	: Originally native to tropical Americas but is now grown in most tropical climates.

A.occidentale is a hardy and drought resistant plant, but is very sensitive to frost. It thrives under a variety of soil and climatic conditions but sandy places are best suited to it. The tree starts to flower in December and the flowering continues for about three months. Generally, it takes 2-3 months before the fruits are ripe enough to be gathered, and only the mature one are collected before they fully ripen and fall to the ground. The season for collection extends from the end of February to the end of May or early June. A fully developed tree is capable of yielding 100 lb of nuts par annum (The wealth of India, part VI.M-p_1).

Traditionally, extraction of the kernel from the shell of the cashew nut has been a manual operation. The first processing operation is to remove foreign matter and dirt from the nuts. Then, the nuts are soaked in water to avoid scorching them during the roasting operation. The application of the heat to the nut releases the CNSL and makes the shell brittle which facilitates the extraction of the kernel when breaking the shell open. At this step, the CNSL is released as the by product.

Three methods of roasting exist: open pan, drum roasting and the hot oil method. In Myanmar, Local processing is carried out by two methods. The First method consists of traditional roasting and the second method of processing is similar to that followed in Thailand (Maung Maung Lay).

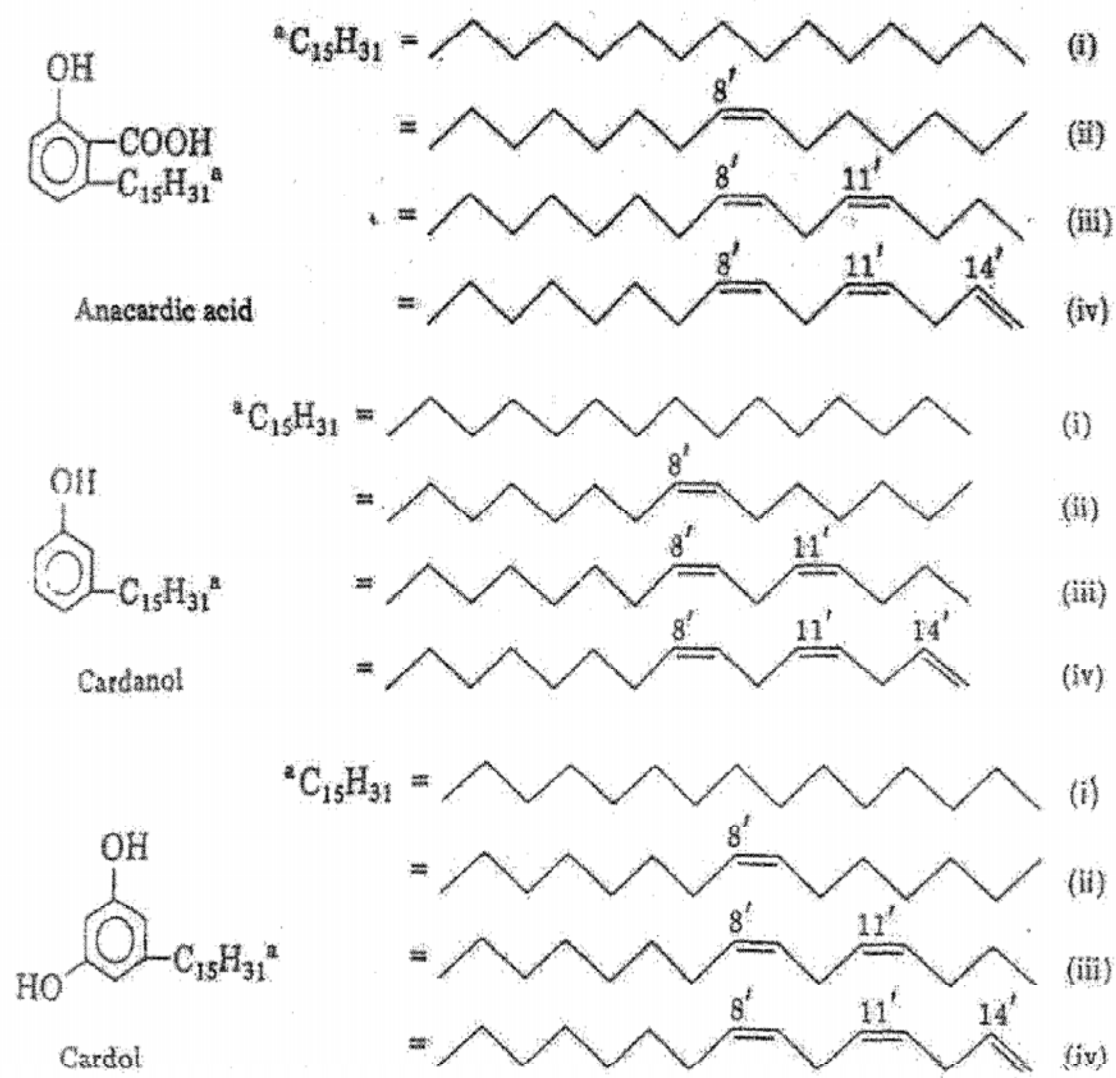
Three main cashew products are traded on the international market: raw nuts, cashew kernels and cashew nut shell liquid (CNSL). A fourth product is the cashew apple; which is processed and consumed locally (the international journal of small-scale food processing).

The commercial shell oil obtained by the roasting of cashew nut is dark brown viscous oil, which is one of the major cheapest sources of non-isoprenoid phenolic liquids, which have a variety of industrial and biological properties (A.A.C. Melo Cacvalcante 2008).

The cashew nut shell liquid (CNSL) is contained between the inner and outer shell (pericarp) in a honeycomb structure. The process used is mainly hot-oil and roasting in which the CNSL exudes out from the shell and about 30-35% CNSL is present in the shell. From the open pan and drum roasting only 20-25% CNSL can be yield (Cardolite Corporation, Inc 2002).

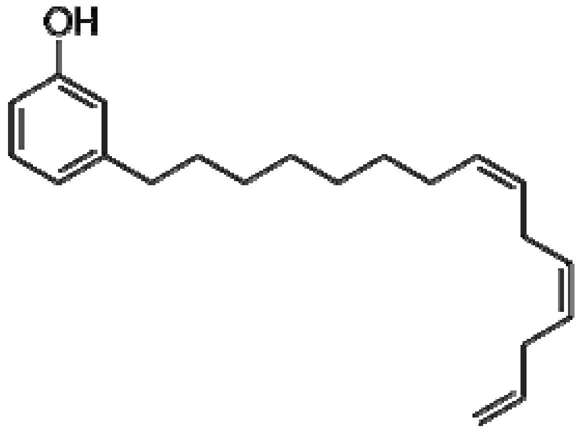
From the two types of classifications, a typical solvent-extracted material contains anacardic acid (60-65%), cardol (15-20%), cardanol (10%), and trace of 2-methy cardol. Depending on the conditions of the roasting process, the composition of the technical CNSL can change and have higher cardanol content (83-84%), less cardol (8-11%) and maintain polymeric material at 10% and 2-methy cardol content at 2% (A.A.C. Melo Cacvalcante 2008).

According to the following structures anacardic acid, cardol and cardanol consists of mixture of components having various degrees of unsaturation in the alkyl side-chain (Cardolite Corporation, Inc 2002).



The cashew nut shell liquid (CNSL) is a unique natural source of meta-alkyl phenol with a variable degree of unsaturation attached to the benzene ring. Harvey and Capian (loc.cil.) have found that from the thermal decomposition of any of the naturally occurring anacardic acid, decarboxylated derivatives cardanol is obtained. This includes more than one compound because the composition of the side chain varies in its degree of unsaturation. Tri-unsaturated cardanol, the major component is (41%). The remaining cardanol are 34% mono-unsaturated, 22% bi-unsaturated, and 2% saturated.

The general formula of cardanol is R = $C_{15}H_{31-n}$; n = 0,2,4,6. The structural formula of tri-unsaturated cardanol is following.



The cashew nut shell liquid (CNSL) undergoes all the conventional reactions of phenol. Cardanol differ from phenol only in the C_{15} side chain. It can be polymerized through the unsaturation in the side chain. One of the significant advantages of the cardanol is its amenability to chemical modification to effect desirable structural changes so as to get specific properties. Structural changes could be effected at the hydroxyl group, on the aromatic ring and on the side chain (Prabhakaran,K.;Asha Narayanan,C.Pavithran 2001).

The industrial applications of the CNSL are based upon its polymerization to a rubber like material under the influence of acids, and on the formation of a wide range of condensation products with aldehydes. The latter are generally hard, infusible and extremely resistant to the action of chemicals such as acids and alkalis (Messrs.Harvey and Caplan).

The driers are also incorporated in CNSL compositions to serve as oxidation and polymerization catalysts and speed up solidification and drying. The driers in common use are salts of lead, cobalt, manganese, zinc, calcium, and iron with polythenoid fatty acid, rosin acids, naphthenic acid, and octoic acid (Amon, 1965).

The usual driers are salts of metal with a valence of two or greater and unsaturated organic acids. The approximate order of effectiveness of the more common metals are cobalt, manganese, lead, chromium, iron, nickel, uranium and zinc. They are usually prepared as the linoleates, naphthenates and resinates of the metals. Paste driers are commonly the metal salts as acetate, borates or oxalate dispersed in a dry oil (Gessner G.Hawely, 1981).Driers of naphthenates and octates are more stable than linoleates, and resinate. Surface active agents are used for promoting emulsifying, leveling, and spreading properties of coating composition.

Adhesion, adhesives and adherent are coating elements of a general adhesion technology which is of great important to many fields of engineering, including the glutting of wood. Glue joints play important role in economical woodworking since they allow the improvement of block boards and of low grade plywood cores by veneering, the manufacture of rather complicated constructions, the production of plywood and laminated board, beams and arches, the utilization of smaller wood sections and the binding in particleboards. Three major adhesives used in the board industry, they are urea-formaldehyde (UF), phenol-formaldehyde (PF), and melamine-formaldehyde (MF) (Ni Ni THIN 2009).

CNSL undergoes the well known formaldehyde condensation reaction of phenols that gives rise to phenolic polymers (Bull.imp.Inst., Lond.,loc.cit.). CNSL- aldehyde condensation products and CNSL- based resins are used in applications such as surface coatings, adhesives, varnishes and paints. CNSL resins have been used extensively in the manufacture of friction-resistant components in application such as brake and clutch linings. CNSL and its derivatives have been used in the manufacture of the cashew lacquer, insulating varnish, electrical conductors' windings, epoxy resins, cashew cements, laminating resins, rubber compounding resins, foundry chemicals and plasticizers, etc (Cardolite Corporation, Inc 2002). In tropical medicine, CNSL has been used in treating leprosy, elephantiasis, psoriasis, ring worm, warts and corns. Moreover, it has antioxidant property (George Watt,M.B.,C.M.,C.I.E.).

Advantages of CNSL based Polymers

- Improved Flexibility and reduced brittleness.
- Solubility in Organic Solvents.
- Improved Process ability.
- Low Fade Characteristics for Friction.
- Resistance to 'Cold Wear'.
- Good Electrical Resistance.
- Better Water Repellence.
- Improved alkali and acid resistance.
- Compatibility with other polymers.
- Antimicrobial Property.
- Termite and Insect Resistance.
- Structural Features for Transformation into High Performance Polymers (www.saichemicals.co.in/CNSL-oil.html).

Polymerisation Characteristics of CNSL

CNSL can be polymerised by a variety of methods:

- Addition Polymerisation through the side chain double bonds using cationic initiators such as sulphuric acid, diethylsulphate etc.
- Condensation Polymerisation through the phenolic ring with aldehydic compounds.
- Polymerisation after Chemical Modification to introduce speciality properties.
- Oxidative Polymerisation.
- Various Combinations of the above (www.saichemicals.co.in/CNSL-oil.html).

CNSL and its products have a significant role to play. Being renewable, it offers much advantage over synthetics. The constituents of CNSL possess special structural features for transformation into specialty chemicals and high value polymers. Thus, CNSL offers vast scope and opportunities for the production of speciality chemicals, high value products and polymers (Menon, A.R.R.; Pillai,C.K.S.; Sudha,J.D.; Mathew,A.G.C 1985).

3. Materials and Methods

3.1 Materials

Cashew nuts samples were collected from Department of Agriculture Research Campus and Forest Research Institute Campus, Yezin.

The following materials were used for testing.

1. Soxhlet apparatus
2. Plantation teak specimens 2cm X 2cm X 6cm
3. Oven
4. Cashew nut
5. Lead acetate
6. Naphthenic acid
7. Sodium hydroxide (Caustic soda)
8. Formaldehyde
9. Glacial acetic acid

3.2 Methods

3.2.1 Sample Preparation

Cashew nuts were collected and cleaned to remove dust and dirt. Then, the nuts were soaked in water for 24 hours. After the soaking in water, the nuts were dried in an oven at 105·c for two days. The oven dry nuts were cooled at room temperature. To separate the shells and the kernels from the nuts, shelling was carried out by using a hammer. Then, the shells were ground by motor and pestle to get small pieces.

3.2.2 Cashew Nut Shell Liquid (CNSL) Extraction

The ground shells were put into the porous thimble and placed in the soxhlet apparatus. The extraction was carried out on with 500ml petroleum ether until the mixture was clear. After the extraction, the extract was distilled and dried in an oven at 75·c for three days and the dark reddish brown viscous Cashew Nut Shell Liquid (CNSL) was obtained.

3.2.3 Determination of some chemical, physical characteristics and oil content of CNSL

Some chemical and physical characteristics such as Specific gravity, Iodine Value, Saponification Value, Free fatty acid (%), Moisture (%) and oil content of CNSL samples extracted by petroleum ether (solvent-extracted) were tested. After the testing, some chemical and physical characteristics and oil content of each were compared with the Indian standard (ISI) properties of CNSL.

3.2.4 Adhesive Preparation

Before making adhesive, 80% lead naphthenate drier was prepared firstly. To compare adhesive properties, CNSL and formaldehyde were mixed with caustic soda and lead naphthenate drier by the following ratios (table). For each ratios of adhesive, the same weight of caustic soda used as catalyst and lead naphthenate drier were added to act as an accelerator of polymerization in baking finishes. Driers enhance the drying of applied films by absorption of oxygen to from peroxide linkages across the double bonds. When the peroxide begins to decompose, active cross linking sites are formed as cross linking proceeds during the polymerization.

50ml of CNSL, 20g of lead naphthenate drier and 2.08g of caustic soda were weighed and put then into a beaker, and shake well. Then, 25ml (for1:0.5 ratio), 50ml (for1:1 ratio), 75ml (for1:1.5 ratio) of formaldehyde was introduced. The beaker was placed into the boiling water bath and set up the condenser, and boil it up to 100·c and stirred continuously. The temperature was maintained to avoid strong boiling. After 30 minutes boiling, the solution became viscous. The contents of the beaker were cooled at room temperature for 15minutes. After cooling, red color viscous CNSL (phenol) – formaldehyde adhesive was obtained.

Table1. Different ratios and mixtures of CNSL

Sr.N0	Ratios	Mixtures
1.	1:0.5	CNSL(50ml) + Formaldehyde(25ml) + NaoH(2.08g) +80%Drier(40g)
2.	1:1	CNSL(50ml) + Formaldehyde(50ml) + NaoH(2.08g) +80%Drier(40g)
3.	1:1.5	CNSL(50ml) + Formaldehyde(75ml) + NaoH(2.08g) +80%Drier(40g)

3.2.5 Adhesive Tests

Firstly, four kinds of adhesive amounts such as 0.4g, 0.5g, 0.6g and 0.7g respectively were weighed from each ratio of adhesives. Then, the adhesive was coated both the radial or tangential surfaces of two teak specimens. The moisture content of teak specimens were nearly (10). After the coating, the tested specimens were combined with side by side and they were pressed by 70kg load at room temperature for 24 hours so as to polymerise and harden the adhesive. Then, the tested combined specimens were dried for two days. When all specimens were dried, they were soaked in water. The split time of each tested combined specimens in the water were recorded. For all the adhesive ratios (treatments) each tested was conducted using 20 combined specimens by the following table.

Sr.No	Treatments	Weights				Tested Combined Specimens (20x4)
1.	1:0.5	0.4	0.5	0.6	0.7	80
2.	1:1	0.4	0.5	0.6	0.7	80
3.	1:1.5	0.4	0.5	0.6	0.7	80

3.2.6 Determination of Solid Content of Adhesives

2g of adhesive was weighed and it was placed in a previously oven dried, cooled and weighed Petridis. It was kept inside the oven for over night. Then, took back the Petridis containing adhesive and placed it in a desiccators for cooling. When the adhesive was cooled, it was weight again. Finally, calculate the solid content. The same procedure was repeated for each ratio of adhesives.

$$\text{Solid content of adhesives\%} = \frac{(C - A)}{(B - A)} \times 100$$

Where,

A = weight of empty Petridis

B = weight of empty petridis + liquid adhesive

C = OD weight of petridis + solid adhesive

3.2.7 Determination of Ash Content of Adhesives

For the ash content of adhesive, 2g of adhesive was weighed and it was placed in a previously oven dried, cooled and weighed crucible. It was ignited in a Muffle furnace at 900·c for six hours. After ignition, crucible was cooled in the desiccators and weighed. Heating, cooling and weighing were repeated until constant weight of the crucible with ash was obtained. Ash content of adhesive was calculated when the constant weight of the crucible with ash was obtained. The same procedure was repeated for each ratio of adhesives.

$$\text{Ash content of adhesives\%} = \frac{(C - A)}{(B - A)} \times 100$$

Where,

A = weight of empty crucible

B = weight of Weights + solid adhesive (OD basis)

C = OD weight of Weights+ solid adhesive

3.2.8 Determination of Specific gravity or Density of Adhesives

The adhesive was filled into the small bottle until overflowing, holding the bottle on its side in such a manner as to prevent the entrapment of air bubbles. Then, the stopper was inserted and carefully wiped off. The bottle and its content were weighed and specific gravity or density of adhesives was calculated. The same procedure was repeated for each ratio of adhesives.

$$\text{Specific gravity or density of adhesives} = \frac{(C - A)}{(B - A)} \times 100$$

Where,

A = weight of bottle

B = weight of bottle + distilled water

C = OD weight of bottle + adhesive

4. Results and Discussion

The chemical, physical characteristics and oil content of CNSL are shown in table3.

Table 3. Comparing chemical, physical characteristics and oil content of tested CNSL with Indian Standard properties.

Sr. No	CNSL	Specific gravity	Iodine Value	Saponification Value	Free fatty acid(%)	Moisture (%)	oil content (%)
1.	Indian Standard CNSL	0.966 - 0.1310	270 -296	106 -190	94 -107	0.5	30 -35
2.	Tested CNSL	0.9273	86	79	99	0.4	32

According to the tested properties, it was found that Moisture (%), Oil content (%), Specific gravity and free fatty acid (%) of the tested CNSL are nearly the similar to that of Indian Standard Institution. Iodine Value and Saponification Value are much lower than standard values. This is due to the tested CNSL is not composed of a single phenolic component. The tested CNSL may contains the mixture of anacardic acid, cardol, cardanol, traces of 2-methyl cardol, some metallic impurities as well as trace of sulphur compounds. Indian Standard CNSL is mostly composed of a single phenolic component (70%), with an unsaturated side chain in the meta-position. This substance has been termed “Cardanol”, as it is presumably the decarboxylation product of anacardic acid. Cardanol gives condensation products with formaldehydes, is volatile with steam, and may be employed for the preparation of adhesive.

The result of splitting time of each tested combined specimens for all the treatments are summarized in table 4.

Table 4. Splitting time of tested combined specimens in different treatments (ratios) and different weight

Sr.No	Treatments	Weight of adhesive(g) From different ratio				Tested combined specimens (20x4)	Soaking time in water		
							One week	Two weeks	Three weeks
1.	1:0.5	0.4	0.5	0.6	0.7	80	*	*	*
2.	1:1	0.4	0.5	0.6	0.7	80	*	*	*
3.	1:1.5	0.4	0.5	0.6	0.7	80	*	*	*

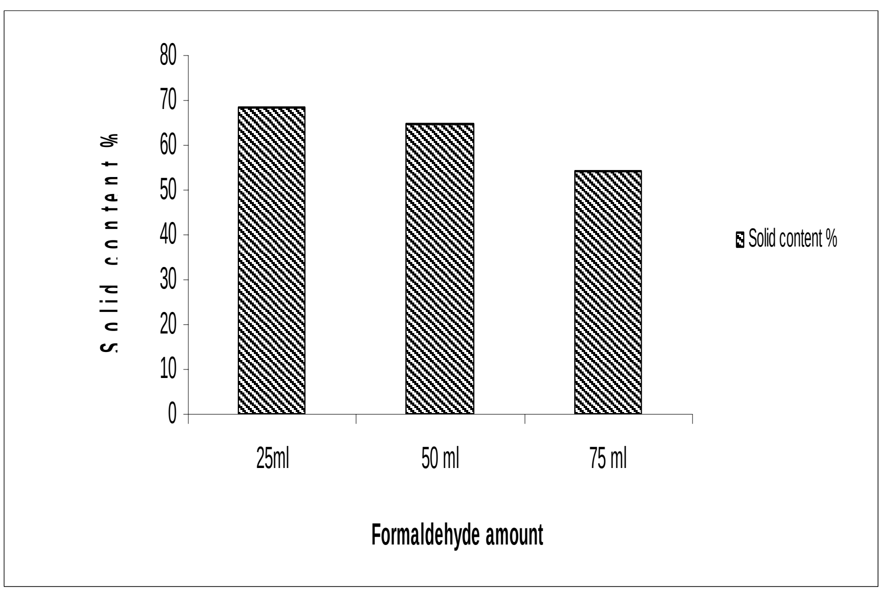
* = not split

It was found that the tested combined specimens, which are coated four kinds of adhesive weights from the three different ratios, do not split each other until immersing into the water for three weeks. Adhesives made from CNSL and formaldehyde with different ratios such as 1:0.5, 1:1, 1:1.5 can be used as water proof adhesives. Being all the tested combined specimens were unaffected in water, all prepared adhesives showed 100% adhesive, reasonably good flexibility, lower hardness, excellent gloss and good impact resistance due to the presence of the OH groups and C_{15} long side chain in the adhesive. Moreover, all prepared adhesives indicated good resistance properties because of a higher degree of cross linking and non-polar nature of the adhesive structure having the C_{15} long chain.

The results of solid content of adhesives from each ratio of adhesives are shown in table5.

Table 5. The solid content of adhesives in different ratios

Sr. No	Mixtures	Ratios	Solid %
1.	CNSL(50ml) + Formaldehyde(25ml) + NaoH(2.08g) + Lead drier(40g)	1:0.5	68.4
2.	CNSL(50ml) + Formaldehyde(50ml) + NaoH(2.08g) + Lead drier(40g)	1:1	64.7
3.	CNSL(50ml) + Formaldehyde(75ml) + NaoH(2.08g) + Lead drier(40g)	1:1.5	54.5

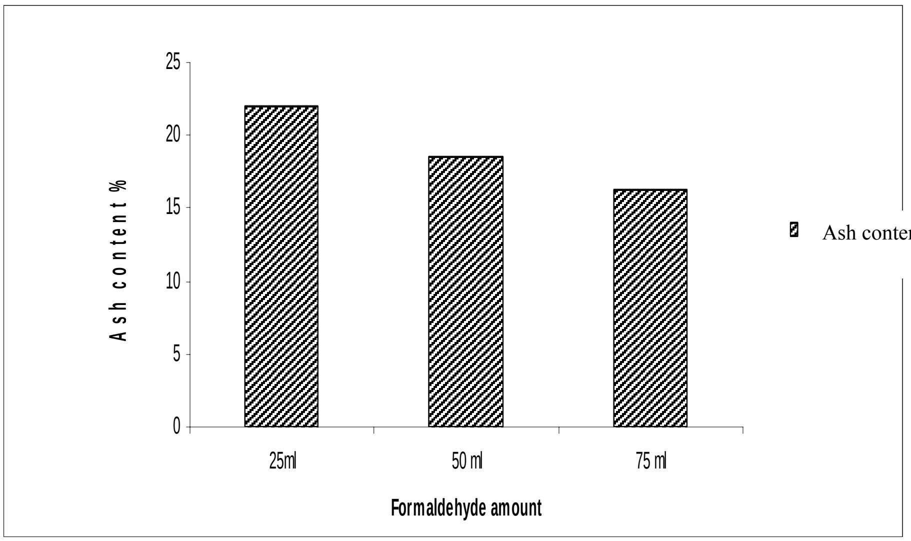


According to the tested results, the solid content of adhesives decrease with increased d in the formaldehyde content in the mixture. This is because of the formaldehyde content is responsible for the methylolation of the CNSL or cardanol.

The results of ash content of adhesives from each ratio are shown in table6.

Table 6. The ash content of adhesives in different ratios

Sr. No	Mixtures	Ratios	Ash %
1.	CNSL(50ml) + Formaldehyde(25ml) + NaoH(2.08g) + Lead drier(40g)	1:0.5	22.1
2.	CNSL(50ml) + Formaldehyde(50ml) + NaoH(2.08g) + Lead drier(40g)	1:1	18.5
3.	CNSL(50ml) + Formaldehyde(75ml) + NaoH(2.08g) + Lead drier(40g)	1:1.5	16.3

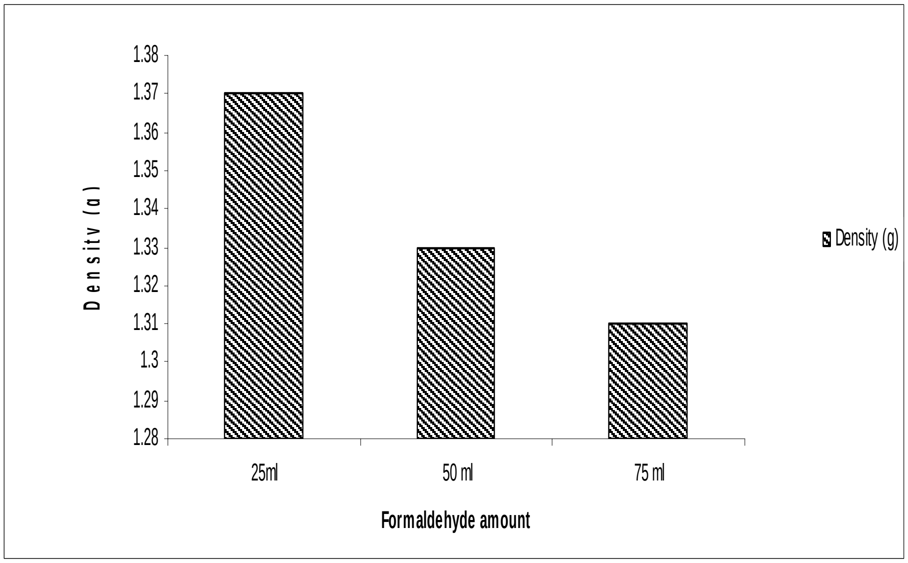


It was found that, ash content of adhesive decreased with increased in the formaldehyde content in the mixture. The formaldehyde content affected to get rid of metallic impurities as well as traces of sulphur compounds.

The density or specific gravity of adhesives from each ratio is shown in table7.

Table7. The density or specific gravity of adhesives in different ratios

Sr. No	Mixtures	Ratios	Sp.gr %
1.	CNSL(50ml) + Formaldehyde(25ml) + NaoH(2.08g) + Lead drier(40g)	1:0.5	1.37
2.	CNSL(50ml) + Formaldehyde(50ml) + NaoH(2.08g) + Lead drier(40g)	1:1	1.33
3.	CNSL(50ml) + Formaldehyde(75ml) + NaoH(2.08g) + Lead drier(40g)	1:1.5	1.31



It was found that, the specific gravity of adhesive decreased with increased in the formaldehyde content in the mixture. This is not only due to the influence of the meta-substituted long chain but also the methylolation of the CNSL.

5. Conclusion

Most of the phenol adhesives are prepared by reacting formaldehyde with phenol, which are consider being toxic and harmful for the environment due to the present of harmful materials like phenols and volatile organic chemicals (VOCs) in organic coating compositions. The use of cardanol, a constituent of CNSL, in place of ordinary phenol in the preparation of adhesive can reduce VOCs and protect the environment. The industrial applications of the CNSL are based upon its polymerization to the formation of a wide range of condensation products with aldehyde such as formaldehyde.

Although the tested CNSL which contains the mixture of anacardic acid, cardol, cardanol and traces of 2-methyl cardol, is not composed of a single phenolic component, it has efficient qualities for the production of water-proof adhesive. Since all the tested combined specimens showed good resistance to water, any of prepared adhesives made from different ratios and weights can be applied in the formulation of primers as protective coating for water. Hence, all the prepared adhesives indicated 100% adhesion, good flexibility, lower hardness and good impact resistance due to the presence of OH groups and C_{15} long side chain in the CNSL. Otherwise, because of fewer methylol hydroxyls and a higher degree of cross linking in the CNSL, all the prepared adhesives are showed good water-proof ability.

When the cost of each prepared adhesives are compared, the ratio of adhesive that use highest formaldehyde amount is necessary to use more chemicals and its cost is higher than others. From this study, the ratio of adhesive that contains lowest formaldehyde amount is suitable to use as water-proof adhesive for the commercial scale production.

6. Recommendation

Most phenol-formaldehyde adhesives are considered to be toxic and harmful for the environment. Now, with increasing concern for environmental protection and, due to stringent regulations to ensure the same, it has became a must for industry to find eco-friendly substitutes for all harmful materials present in organic coating compositions. Therefore, the technological developments are focused on reducing VOCs from the coatings to meet industrial requirements. To this end, the use of CNSL or mostly cardanol which is a natural substitute for ordinary phenol in the preparation of adhesive can achieve an important industrial goal.

References

1. Maung Maung Lay; Integrate Production Practices of Cashew in Myanmar. www.fao.org/docrep/ 005/ac451e/ac457e06.htm
2. Mathew, A.G 1994: Cashew Processing, FAO Consultancy Report.
3. Ni Ni Thin, 2009; Utilization Potential of Sawmill Residuces For Particleboard Manufacturing in Myanmar.
4. Khing Khing Htun and Khin May Lwin, 2001; Study on the betterment of Fast drying quality of Myanmar lecqure through the chemical modification.
5. Memon, A.R.R; Pallai, C.K.S; Sudha, I.D; Mathew, A.G. (1985; Cashew Nut Shell Liquid its polymeric.
6. Shobha, S.V; Revindranath, B.(1991); Supercritial Carbondioxide and solvent extraction of the phenolic.
7. Knop A. and Schieb W., springer verlay, NewYork (1979); Chemistry and application of phenolic resins.
8. Ranjana Yandav and Deepak Srivastava, vol.2, No.3, 2008; Studies on Cardanol-Based Epoxidized Novolac Resin and Its Blends.
9. George Watt, M.B., /C.M., C.I.E, Dictionary of the Economic Products of India Vol.I, Abct to Buxus.
10. Council of Scientific & Industrial Research New Delhi; The Wealth of India, Industrial Products, Part VI.M.Pi.
11. The International Journal of Small-Scale Food Processing www.oreworld.org/itdg
12. Cardolite Corporation, Inc; Revised Test plant Cashew Nut Shell Liquid, CAS No. 8007-24-7 www.cardolite.com
13. Processing of Purification of Cashew Nut Shell Liquid For Isolation of Cardonaol www.enpromer 2005.eg-ufrj-br/nukleo/pdfs
14. Cashew Nut Export, Posted 2008, December 07 www.commrce.gov.mm