CASHEW NUT SHELL LIQUID: AN AGRICULTURAL BY-PRODUCT WITH GREAT POTENTIAL FOR COMMERCIAL EXPLOITATION IN KENYA

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Abstract

Cashew nut shell liquid (CNSL) is the main by-product from cashew nuts processing and is obtained during roasting of the nuts by the oil-bath method. It may also be obtained through expression of residual shells or solvent extraction of the pulverized shells.

Kenya has the potential to produce 200,000 Tonnes of cashew nuts and 45,000 Tonnes of CNSL if all the nuts were to be processed locally and with recovery of the liquid. Currently, the country realizes only about 5-10% of its nuts production potential. Processing of the nuts has been left to small scale processors who in many cases, burn residue shells as fuel or as waste. This practice pollutes the environment profoundly through emission of thick dark smoke with particulate matter. No CNSL is recovered in Kenya currently. The aim of this review paper is to highlight a number of products which can be manufactured in Kenya based on research initially done at Kenya Industrial Research and Development Institute and more recently at Jomo Kenyatta University of Agriculture and Technology Recovery of CNSL and its exploitation in Kenya will not only enhance the economic returns to the cashew industry but also contribute significantly to conservation of the environment. It is recommended that further work be done to scale-up production of CNSL based products and demonstrate feasibility of the same. Production and local processing of the cashew nuts accompanied by recovery of CNSL should be enhanced.

Key words: Cashew nuts, CNSL utilization, cashew nut production, Kenya

1.0 Introduction

1.1 The Cashew Tree

The cashew tree (*Anacardium occidentale*) is native to the Amazonian Basin (which is today part of North Eastern Brazil). It has since been established as an important cash crop in many tropical and sub-tropical countries of the world. The Portuguese helped to spread the tree first to Eastern African Coast and India in the 15th and 16th Centuries from where it was spread further on (Muturi and Arunga, 1988). The cashew tree is one of the wonders found in nature. Almost all the parts of the cashew tree find applications for human use. The leaves, bark and roots have medicinal value while the trunk may be used for building dug-out canoes. The fruit and the kernel find applications as food. On the other hand, cashew nut shells and the liquid extracted from them (CNSL) are useful industrial raw materials for production of numerous products such as friction dust for brake linings and clutch facing, coatings, adhesives, pharmaceuticals, dyestuffs, surfactants, pesticides and many more (Tyman, 1979), (Chittenden and Paddon ,1973).

Figure 1: Cashew Trees

Figure 2: Cashew Fruit and Nut

The cashew tree, (Figure 1) is exploited mainly for the nut which is edible, and the cashew apple. The cashew apple is a fleshy false fruit which may be eaten as fresh fruit or made into jam, juice or alcoholic drink. The nut, which is 2-3 cm in length and kidney shaped is externally attached to the base of the cashew apple (Figure 2). It is worth noting that in some parts of the world, commercial exploitation of cashew apple supersedes that of the nut. This is the case in some parts of Southern America.

The main aim of the paper is to highlight the importance of the cashew industry in Kenya and more specifically the need to exploit the main by-product of cashew processing; the cashew nut shell liquid (CNSL), locally. This will not only create economic benefits for the country but also contribute to conservation of the environment.

1.2 Global Production of Cashew Nuts

Today some of the chief producers of the nut include; Vietnam, Nigeria, India, Brazil, and Indonesia. The largest producer of the nut in Africa is Cote D' Ivoire followed by Tanzania. Kenya is a minor producer accounting for less than one percent of the global output. Table 1 illustrates global production of the nut as of June, 2008, (FAO Report 2008)

Table 1: Main producer countries of cashew nuts

Country	Production (Tonnes)
Vietnam	961,000
Nigeria	660,000
India	620,000
Brazil	176,000
Indonesia	146,000
Cote d' Ivoire	130,000
Phillipines	118,000
Tanzania	92,000
Guinea-Bissau	81,000
Mozambique	58,000
Others	56,000
TOTAL	**3,186,000**

1.3 Cashew Industry in Kenya

The cashew tree with a history spanning more than 500 years at the coast of Kenya is clearly the oldest cash crop to be established in the country. Cashew nuts are grown mainly in Kwale, Kilifi, Malindi and Lamu counties. Commercial processing of the nut was initiated in a small scale in the 1930's. As the processing of the nut did not match its production, a significant fraction of the raw nut continued to be exported.

The year 1975, however saw a turning point in the cashew industry in the country with the installation and commissioning of a modern plant under Kenya Cashew Limited, at Kilifi which could process 15,000 tonnes of nuts per year. It became operational in 1976. This new development could not be celebrated for long as several problems continued to dog the industry. Production of the nuts remained erratic during the period 1970s and 1980s. This was attributed to a number of problems and constraints which, may be summarized as:

i. Price disincentives
ii. Reduction in productivity of cashew trees due to expiry of their productive life.
iii. Poor crop husbandry
iv. Weather related problems for example heavy rains during flowering stages.
v. Limited research and other market constraints.

These and other constraints resulted to neglect of the trees whose yield declined to below optimum. A local daily (Kihara, 2011) reported that the prices for the nut at the farm gate went as low as 34 to 46 Ksh per kg in March 2011, and most of the sale was through middlemen who would often fleece the farmers.

Consequently, the area under the crop has declined from 36,000 hectares in the late 1980's to 27,000 hectares in 2006 (Kithi, 2006).

Further, the enumerated constraints among others precipitated into the closure of the Kilifi plant in 1998 leaving processing of the nuts to a few fairly small scale processors. Most of the nut continued to find its way into the export market until 2009 when the Government slapped a total ban on exports, a move which was meant to encourage local processing of the nut and value addition of the commodity.

Although Kenya has the potential to produce 200,000 tonnes of nuts per year and about 45,000 tonnes of CNSL (assuming that all the nuts are processed locally), yet currently it produces a paltry 8,000 to 10,000 tons per year This is notwithstanding the fact that in the 1970’s and 1980’s production could go as high as 20,000 Tonnes in some years.

1.4 Merits of Processing of Cashew Nuts in Kenya

This paper advocates for the stakeholders in the industry and especially the Government to look for solutions to the problems facing the industry and continue to give preference to local processing of all the nuts produced in the country.The reasons may be advanced as follows:

i. The industry if well managed can be a good foreign exchange earner for the country.

ii. Local processing will ensure better returns to the processors and by extension to the whole industry as opposed to direct exports of the nuts.

iii. The industry will create employment, considering that cashew processing is labour intensive.

iv. The by- products of cashew nut processing, the cashew nut shell liquid (CNSL) and the spent shells after the oil extraction have potential as industrial feed stocks on their own right as shown by research initially done at KIRDI and subsequently at JKUAT. This would improve further the returns to the industry.

v. While the spent (milled) shells could be utilized as fuel, it could also find application as a soil conditioner or mulching for horticultural crops.

Figure 3: Women grading cashew kernels for the market

1.5 The Cashew Nut Shell Liquid (CNSL)

The cashew nut consists of an ivory colored kernel covered by a thin brown membrane (testa) enclosed by an outer brown porous shell, the mesocarp which is about 3 mm thick and has a honey comb structure which contains the cashew nut shell liquid (CNSL), a reddish brown phenolic oil.

(a)

(b)

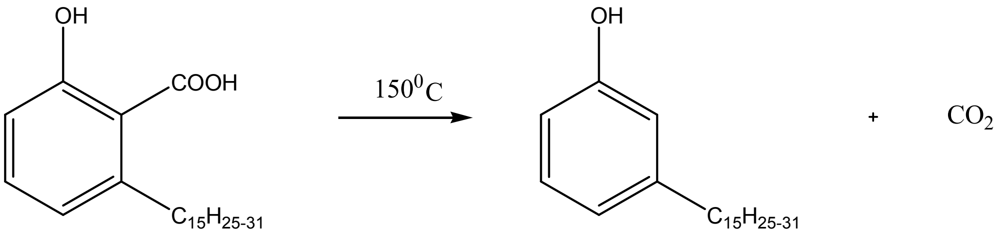
(c)

Figure 4: (a) Raw cashew nuts, (b) Opened nuts exposing the kernels and (c) CNSL.

The CNSL content is in the range of 18 to 27% of the total nut weight. The kernel approximately 20-25% and the balance is the shell, with the testa accounting for 2% of the total nut weight. All this depends on the variety of the nut and where it is grown, (Tyman, 1979).

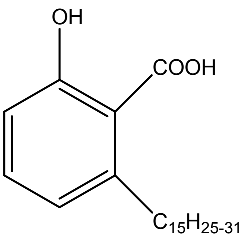
Commercially, the most important by-product of the cashew industry is cashew nut shell liquid (CNSL). Naturally occurring CNSL consists of two major components, anacardic acid and cardol. Anacardic acid accounts for about 90% while the balance of 10% consists essentially of cardol with traces of 2-methylcardol and cardanol. On heating, anacardic acid decarboxylates to give cardanol and carbon dioxide.

Natural CNSL Scheme 2, consists of four main components. (Muturi and Arunga, 1988).

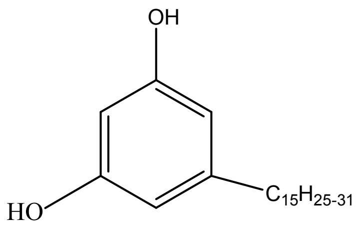


Anacardic acid Cardanol Carbon dioxide

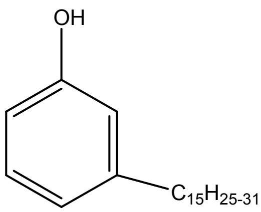
Scheme 1: Decarboxylation of Anacardic Acid



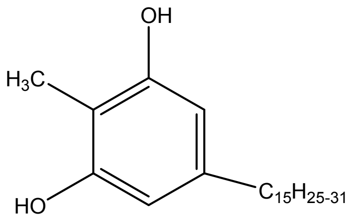
Anacardic acid (84%)



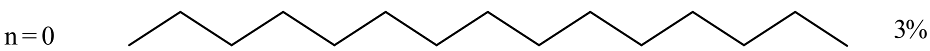
Cardol (11.8%)

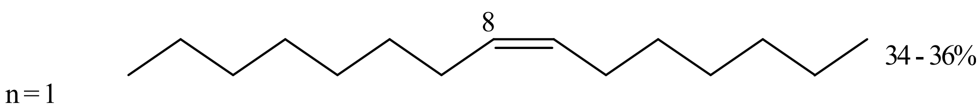


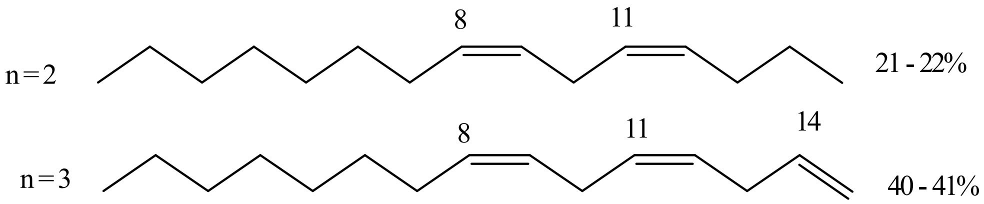
Cardanol (1.6%)



2-methylcardol (2.6%)







Scheme 2: Chemical composition of naturally occurring CNSL

Constituents of commercial CNSL (The 15-C chains represent the alkyl groups attached to the meta position of each of the fractions of CNSL, while n represents the number of double bonds occurring on the alkyl chain. The percentages accompanying the alkyl chains represent the respective percentage content of the chain each of the fractions has. Considering that each of the four fractions has in turn the possibility of having any of the four alkyl chains, sixteen different compounds therefore exist in the commercial CNSL.

It is interesting to note that the double bonds on the alkyl chains occur, as a rule in the carbons numbers, 8, 11 and 14.

2.0 Extraction and processing of CNSL

It is estimated that the potential global production of CNSL in the 1970s stood at 125,000 Tonnes (Tyman,1979). Most CNSL is now extracted by the hot CNSL bath process in which previously moistened nuts are heated at 180 – 190^{o}C while held on a traveling conveyor belt submerged below the liquid level for about 1.5 minutes and discharged at the end of the conveyor. An overflow pipe ensures that the CNSL level remains constant while additional liquid is continually or intermittently drained off into a holding tank. CNSL may also be obtained by mechanical expression of residual shells obtained after the kernel has been removed. This may be attained by the use of a suitable screw press. Natural CNSL may be obtained by cold solvent extraction of pulverized shells from unprocessed (unheated cashew nuts). As a rule all CNSL for the market has to be decarboxylated whereby it is heated at around 150^{o}C until frothing ceases (FAO,1969).

2.1 Applications of CNSL in industry

CNSL is a versatile raw material and has many industrial applications. There are currently more than 200 patents for its industrial application. By far the most important use of CNSL is in the manufacture of friction modifying material for brake lining, clutch facing and industrial belting. Other major industrial applications of the liquid include the following (CBRI, Undated):

2.1.1 Coatings

Various types of coatings based on CNSL and its isolates have been developed and commercialized. These include, industrial and marine coatings, varnishes, lacquers, and enamels among others. Electrical insulating varnishes are obtained by treating CNSL with formaldehyde and compounding the resulting material with pure phenolic resin varnish or alkyd resin in suitable proportions. Films of those materials are water and chemical resistant and can be used as insulating varnishes with high electrical resistance and as bobbin enamels and laboratory bench tops. It has been claimed that the films formed from CNSL based coatings (CBRI, undated) have high toughness and elasticity, excellent gloss and super fine adhesive qualities and that the dried films are superior to those of ordinary oil paints in respect of resistance to oils, grease moisture and chemicals.

2.1.2 Rubber compounding

The use of CNSL in rubber compositions has been found to improve the performance of rubber products. It helps in processing and enhances the vulcanisate properties.

2.1.3 Adhesive

CNSL-based adhesives for the manufacture of ply-wood and particle boards, among other applications have been made.

2.1.4 Lamination

CSNL or Cardanol derivatives are extensively used in the laminating industry for reducing brittleness and improving the flexibility of the laminates.

2.1.5 Modified CNSL

The various components of cardanol can be suitably modified to obtain emulsifiers and surface active agents, dyestuffs, antioxidants, plasticizers, stabilizers, accelerators, curatives, reclaiming agents and ion-exchange resins.

2.1.6 Binder in the Foundry

CNSL is also used as a substitute for linseed oil in the manufacture of foundry core oil, which is used as a binder in the foundry.

2.1.7 Pesticidal action

Chlorinated and copperized CNSL have been found to have pesticidal effects on insects and fungi.

2.2 Research on CNSL

CNSL has been stated to be the only natural product which combines abilities to polymerize and to condense with an aldehyde donor (Date, 1965). When polymerized with aldehydes in acidic condition, it is said to yield a polymer having excellent water and chemical resistance. (Chittendem & Paddon, 1973). The characteristics and properties of CNSL from different sources have been studied (Ramalingam *et al.,* 1967) and (Muturi, 1984) and different standard specifications for the liquid have been elaborated (Wilson, 1975), (Cornelius, 1966) and (Anon, 1973).

The characteristics of CNSL which determine its usefulness in industrial applications includes; foreign matter content, total volatiles, viscosity, specific gravity, iodine value, ash content and

In recent years attention has shifted to research towards development of high value and specialty products based on CNSL. Several researchers have studied the various methods of isolation of the main compounds that constitute CNSL, namely, cardanol and cardol . This is basically to facilitate development of products of predictable and consistent quality from these materials. (Paramashivappa *et al.,* 2001) have come up with a method for isolation of anacardic acid, cardanol and cardol from CNSL using solvent methods.

(Risfaheria *et al.,* 2009), developed a method for isolation of cardanol from CNSL by vacuum distillation, whereby cardanol was obtained at 4-8 mm Hg, and the optimum temperature was achieved at 280°C with 74.22 % yield.

(Bhunia *et al.,* 1998) developed a novel thermoplastic polyurethane polymer from cardanol, a derivative of CNSL. Cardanol was recovered from cashew nut shell liquid (CNSL) by double vacuum distillation. The polyurethane was synthesized from a dihydroxy compound synthesized from cardanol and which was subsequently treated with 4,4′-diphenylmethane diisocyanate (MDI) in dimethylformamide (DMF) solvent at 80–90°C under nitrogen. Venmalar and Nagaveni (2005), developed a pesticide by copperising CNSL and Neem seed oil. This pesticide had high protection on wood against wood rotters (fungi) and termites.

(Pokhakar *et al.,* 2008) investigated the anti-bacterial activity of 2-hydroxy-6-pentadecylbenzamide synthesized from CNSL. (Mwalongo *et al.,* 1999) investigated on chemical products based on CNSL. Sulphited wattle tannins and copper (II) chloride treated with CNSL were demonstrated as environmentally safe termite repellents. Some other applications of CNSL that have been investigated in recent years include in drugs, fungicides and antioxidants. Lubi (2000), reported that, CNSL by itself is useful for insecticidal, fungicidal, anti-termite and medicinal applications and as an additive in many plastic formulations.The foregoing are just a few examples of the extensive research that is going on globally on the applications of CNSL and its derivatives.

3.0 Status of CNSL Research in Kenya

Currently no CNSL is produced locally because of two reasons. First, steaming process as opposed to the oil bath roasting method, is applied for nut processing in the country. Secondly the cashew shells are burned as fuel for processing more nuts and the excess may be burned as waste. Either way, burning of the shells produces heavy smoke with particulate matter which pollutes the environment. A better proposition would be to extract CNSL before burning the shells. Ongoing research at JKUAT is trying to establish the energy content of exhausted cashew nut shells visa avis shells that are still bearing the oil.

Muturi and Arunga (1988) published a comprehensive review on production of CNSL and research in Kenya since the inception of commercial processing of cashew nuts in the country around 1939. Since 1942, KIRDI and its predecessors East African Industrial Research Board (EAIRB) & East African Industrial Research (EAIRO) have collected very useful information on CNSL and carried out a number of investigations on this important commodity. Subsequent to that (Muturi, 1984, 1987) seven different coatings based on CNSL were developed and characterized and it was established that they compared favorably well with coating materials from the market. The new products required only minor improvements which could be addressed through further research. Further, characterization of CNSL extracted locally showed that it was generally within the international specifications for commercial CNSL.

Research on industrial applications of CNSL has been ongoing for the last three years or so at JKUAT and some of the areas covered include :

i. Development of superior cross-linked coatings based on CNSL
ii. Application of CNSL as a reactive diluents in alkyd coatings
iii. Development of a wood adhesive based on CNSL
iv. Development of a surfactant based on CNSL and
v. Development of new polymer material based on CNSL.

Provisional results of these investigations have been quite successful and demonstrated CNSL as a material with great potential for its commercial exploitation in Kenya.

Some of the products provisionally developed are illustrated in Figures 5 to 9, in Appendix 1.

4.0 Conclusions

Investigations carried out both at KIRDI and JKUAT have demonstrated that there is great potential in exploitation of CNSL available in Kenya. Five (5) different types of products including coatings, adhesives, a surfactant and reactive diluents for alkyd coatings have been developed. Adopting processes and methods developed in Kenya and elsewhere, many different products of commercial value such as, coatings and resins, adhesives, surfactants, different pesticides, and other specialty chemical products may be manufactured in the country.

5.0 Recommendations

i) It is recommended that effort should be made by all stakeholders to promote production of cashew nuts in the country, and a bigger proportion of this should be processed locally for the purposes of value-addition.

ii) CNSL should always be extracted from the shells before they are burned as fuel. Adopting this recommendation will have double benefit, first a valuable raw material will be recovered and pollution through emission of thick smoke will be eliminated.

iii) It is recommended that further work be done to scale-up production of CNSL based products and demonstrate feasibility of the same.

iv) Further research in CNSL utilization should be supported by the Universities and stakeholders of the cashew nut Industry.

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APPENDIX 1
EXTRA FIGURES COVERING CNSL RESEARCH AND APPLICATIONS

Friction Materials

CNSL find numerous application in different industries.

One of the major uses is in manufacture of friction materials used in brake linings, clutch facings and industrial belting.

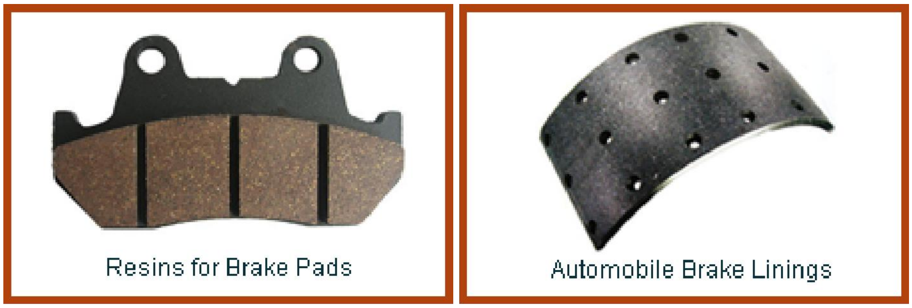


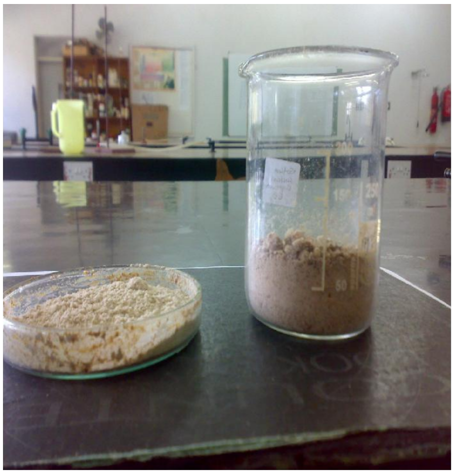
Figure 5. Products made from CNSL based Friction Materials

Coatings

Different coatings, ranging from lacquers and varnishes to waterborne, and oil based pigmented coatings. Air dried and stoved coatings are also made from CNSL.

Figure 6: Coatings based on CNSL developed at JKUAT

Figure 7: Surfactants and Detergents Developed from CNSL at JKUAT



Adhesives

CNSL is also utilized in the manufacture of adhesives for such applications as in plywood, particle and block boards.

Figure 8: Adhesive being developed from CNSL developed at JKUAT

Figure 9: New Polymer, (Thermoplast) based on CNSL developed at JKUAT