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Cashew Nut Shell Liquid

Project Summary

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Note: For now on I will refer to the Cashew Nut Shell Liquid as ***CNSL***

Abstract

What is CNSL?

Cashew nut Shell Liquid (CNSL) is a reddish brown viscous liquid, having the honeycomb structure of the shell of cashew nut obtained from cashew tree.

Botanical name of Cashew: Anacardium occidentale L

CAS number: 8007-24-7

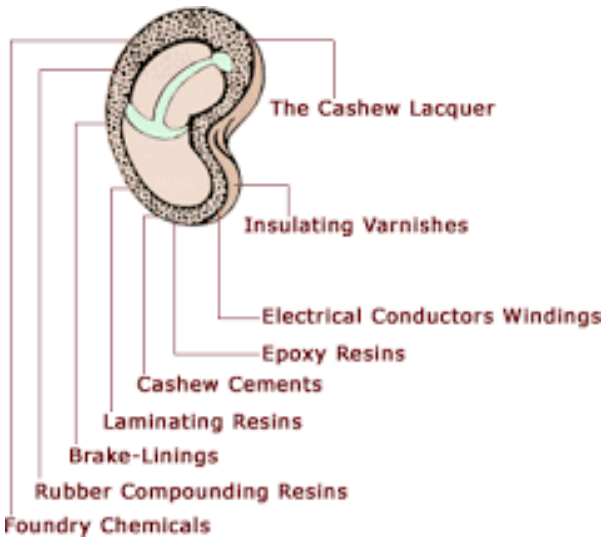
Area of growth of Cashew tree Coastal areas of Asia and Africa. Mozambique, India, Vietnam and Brazil

Specification of Cashew nut shell

The shell is about 0.3 cm thick, having a soft feathery outer skin and a thin hard inners kin. Between these skins is the honeycomb structure containing the phenolic material known as CNSL. Inside the shell is the kernel wrapped in a thin skin known as the testa.

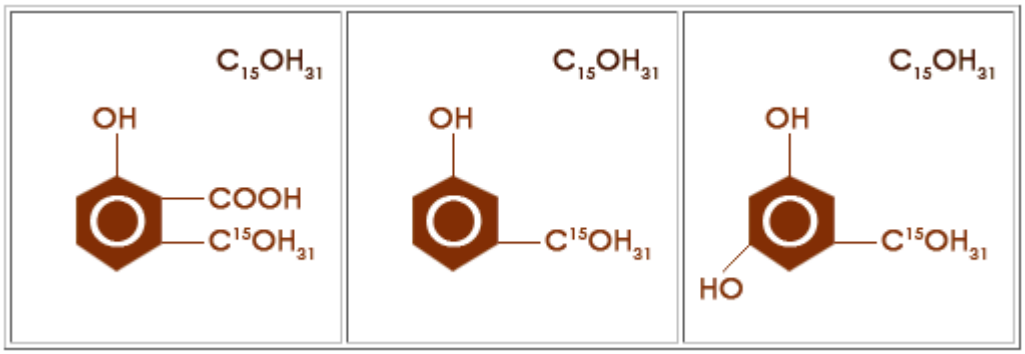
Composition of cashew nut

The nut consists of the following:
Kernel 20 to 25%
Kernel liquid 20 to 25%
Testa 2%
Others Rest being the shell.



CNSL structure

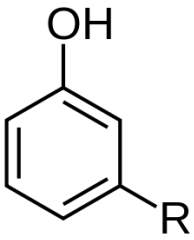
As you can see, the CNSL can be shown in 3 different structures as follow:



What is Cardanol?

Cardanol is a phenolic lipid obtained from anacardic acid, the main component of cashew nutshell liquid (CNSL), a byproduct of cashew nut processing.

The name cardanol is used for the decarboxylases derivatives obtained by thermal decomposition of any of the naturally occurring anacardic acids. 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 (41%) is shown below. The remaining cardanol is 34% mono-unsaturated, 22% bi-unsaturated, and 2% saturated.



CAS registry number: 37330-39-5

Cardanol is a naturally occurring Phenol manufactured from CNSL. It is a monohydroxyl Phenol having a long hydrocarbon Chain (C15H27) in the Meta position.

Cardanol is obtained in the distillation process of technical CNSL under reduced pressure. The composition of Cardanol contains approximately 78% of cardanol, 8% cardol, 2% polymeric material, less than < 1% 2-methyl cardanol, 2.3% heptadecyl homologue triene, 3.8% heptadecyl homologue diene and the remainder other homologous phenols

Cardanol is a phenol which has a C15 unsaturated alkyl chain with 1-3 double bonds at meta position. Cardanol is a mixture of cardanol 90% and cardol 10%.

The component of commercial Cardanol differs in the degree of unsaturation of the side chain but for the practical purposes it can be represented by the following formula.

$$C_6H_4\ (OH)\text{-}(CH_2)_7\text{-}CH{=}CH\text{-}CH_2\text{-}CH{=}CH\ (CH_2)_2\ \text{-}CH_3$$

The average unsaturation of about two double bonds in the side chain of the Cardanol molecules make cross linking easy and provides a satisfactory gradual drying and baking properties to paints prepared from it. Because of its peculiar structure Cardanol Varnishes have high electric Insulation, greater resistance to water, chemicals and good flexibility.

The long hydrocarbon side chain has an effect on Cardanol aldehyde condensate greater solubility in drying Oils such as linseed DCO, or Tung Oil and aliphatic hydrocarbons.

Properties: 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 for making tailor-made polymers of high value. Thus, structural changes could be effected at the hydroxyl group, on the aromatic ring and on the side chain. The unique Molecular structure of Cardanol, especially unsaturation of long Hydrocarbon side chain, makes the cross linking easy on polymerization Besides the side chain impacts hydrophobic nature to the polymer, its coating is water and weather resistant.

What is Residol?

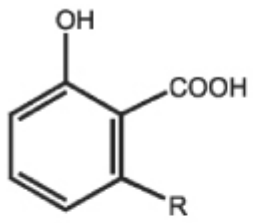
Residol, a highly viscous dark substance is a partially polymerized cashew nut shell liquid (CNSL) obtained as a byproduct during the Cashew Nut Shell Liquid process.

Residol or **Residue** or **Residuel** obtained as a byproduct during the CNSL process after separating the monohydroxyl phenol.
Thick product is highly reactive, homogeneous and natural phenolic material which is playing interesting role in industry

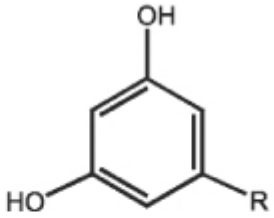
What is Cashew nut shell cake?

Cashew Shell Cake or Cashew Nut Shell Waste or De-Oiled Cashew Nut Shell Cake is used for Boiling, Heating (Burning) Purpose or used as Fuel by manufacturing Units.
Cashew Nut Shell Cake Manufactured from Cashew Nut Shells, after removing Cashew Shell Oil from Expeller.

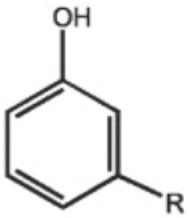
Chemical structures



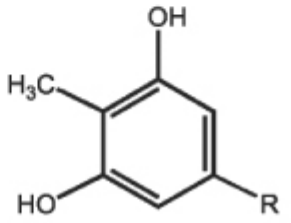
Anacardic Acid



Cardol

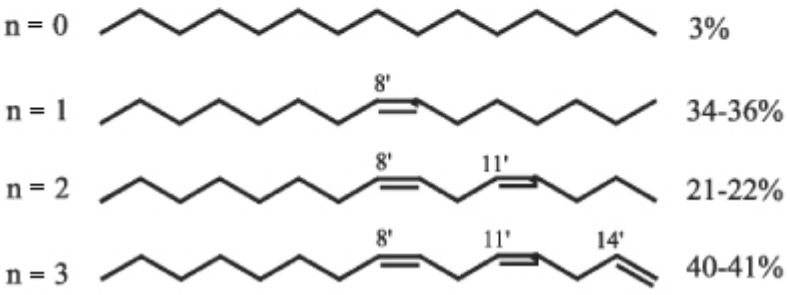


Cardanol



2-Methyl cardol

$R = C_{15}H_{31-2n}$



Applications

Cashew Nut Shell Cake

Cashew Nut Shell Cake will give a very good temperature when heating directly or mixing with other Fuels or Fuel substitutes. CNSL Cake is the ideal fuel for high calorie requirements where high heat requires to be generated and it gives very long shelf life.

Name	Calorific Value	
1	Gross Calorific Value	5000 Kcal / Kg
2	Proximate analysis (% weight)	8.5
	Moisture	8.5
	Volatile matter	65
	Ash	2
	Fixed Carbon	20
3	Bulk density	4.430kg/1000cc

Activity	Application
As furnace fuel	In power generation , boilers , thermic fluid heaters , tile factories
As raw material	For briquette manufacturing , gasifier etc

Residol

Residol or **Residue** or **Residuel** obtained as a byproduct during the CNSL process after separating the monohydroxyl phenol. Thick product is highly reactive, homogeneous and natural phynolic material which is playing interesting role in industry. Residol is used with great advantage for the manufacture of high quality yet economical surface coating. Oil soluble resins, varnishes, lacquers and points clutch facings breaking compositions for preparation of foundry core oil and binder lamination and other allied products.

Residol is used in brake pads as friction dust and to make Foundry core oils.
Residol is a comparatively cheap material and can partially or completely replace linseed oil and other drying oils and resins in coating formulations where light color is not a consideration. It retains its phenolic character and can be condensed with formaldehyde, hexamine etc., and can react with styrene monomer, drying oil and synthetic resins easily.

The film of varnishes, enamels and paints formulated from Residol, dries hard either under ambient conditions or on baking. The films of such varnishes have high gloss, good hardness, flexibility, resistance to water, dilute alkalizes, acids and common organic solvents. They have exceptional anti-corrosive properties.

Specifications of Residol

Appearance	Dark black thick liquid
Specific gravity at 30 degree Celsius	1.01
Viscosity cps	71500
Flash point degree Celsius	Beyond 100
Solubility in hydro carbon	Sparingly soluble
Polymerization time in mins	2 mins max

Residol Applications

Foundry Core Oil	Formaldehyde Condensate of Residol used in core oil binders
Surface Coatings	used in cycle paints, black paint medium
Brake Lining & Carburetor	Acidification & Formaldehyde condensation brush manufacturing product form friction particle used in brake lining
Rubber Industries	Residol is used as plasticizer and as re-enforcing agent in rubber compounding
Friction Dust	Residol resin is pulverized and graded for different mesh size

Friction Dust

Friction Dust is a products used as additive in Manufacturing of Friction Material (Automotive & Industrial) like Brake Linings, Disc Brake Pads, Railway Brake Blocks and Clutch Facings etc. to stabilize the friction level.

Friction Dust is crossed linked product obtained from the reaction of Cashew Nut Shell Liquid with different aldehyde donors like Formaldehyde/ hexamine /Para Formaldehyde to achieve the desired Friction dust properties. Basically it is a phenol formaldehyde resin, which is polymerized and reacted with any one of the aldehyde donors and made to powder form of various standard mesh sizes.

Based on the expected function, the break materials and additives are grouped into four categories: Abrasives, Friction Modifiers, Fillers and Reinforcements and Binder Materials

Friction Dust is used as a Friction Modifier which consists of cashew resin and additives and modifiers used to meet the specific requirement of the brake lining formulations. Friction dust is a granular, brown or black color, free flowing polymerized resin. Brake manufacturers can choose the most appropriate friction dust material from a broad range of mesh sizes and granulation to be used in metallic, semi-metallic and non-asbestos brake products.

Properties:
Friction Dust has a resilient nature which cushions the engaging property of a piece of lining. In addition, they decompose on the surface of a lining at various elevated temperatures which controls the wear and offers a protective device by prohibiting excessive temperature from being developed. The inclusion of friction dust in the composition of the brake lining friction material also helps control brake noise.

Application:
Cashew Friction Dust is as common ingredient of friction linings formulations. Friction Dust represents up to 20% by weight of friction elements used in manufacturing of brake lining, brake pads, brakes shoes, railway block and clutch facings where high absorption and frictional properties are needed. Friction dust of various mesh sizes is supplied according to

requirements of various manufacturers for making Brake linings and clutch facings which are used in the friction formulations to be used in metallic, semi-metallic and non-asbestos brake products.

Cardanol

Cashew phenol popularly known as Cardanol or Card-Phenol manufactured from cashew nut shell liquid (CNSL). It is a monohydroxyl phenol having a long hydrocarbon chain (C15H27) in a meta-position. The products obtained from CARDANOL have many advantages over these manufactured from other substituted phenols. It is therefore widely used in the manufacture of surface coating, insulating varnishes, Epoxy and oil soluble resins, laminates, rubber and wax compounding, pesticides, Foundry, dyes etc.

Cardanol has an excellent properties ideal for the coating industry. It is widely used to manufacture Epoxy Curing Agents and other resins for paints, varnishes, laminates. It's widely used in rubber, pesticides, adhesives, mineral oils, brake linings, electrical isolation putty, ink printing.

Cardanol contributes to improved flexibility, good drying after baking, high electric insulation properties and thermal stability.
These properties make Cardanol an effective substitute for the petroleum-based Phenol.

The products obtained from Cardanol have many advantages over these manufactured from other substituted Phenols. It is therefore widely used in the manufacture of surface coatings, Insulating Varnishes, Oil and Alcohol soluble resins, Laminating resins, Rubber compounds, Azo dyes, etc.

Specifications of Cardanol

Appearance	**Water White**	**Pale Straw Yellow**
Color on Gardner Scale	Max 6	Min 8
Specific Gravity @ 30 Degree Celsius	0.92+-0.01	0.93+-0.01
Viscosity CPS	Max 45	Max 65
Viscosity @ 30 Degree Celsius Sec bt f4 CUP	21+-1	25+2
Ash Content %	NIL	NIL
Volatiles at 163 Degree Celsius	Max 1.0	Max 1.0
Acid Value mg KOH/g	Max 3.0	Max 5.0
Iodine Value (wiz's method)	200+-20	200+-20
Polymerization time in Mins	Max 12	Max 10
Boiling point Degree celcius @ VAC.3 to 5 TORR	215-218	225-230

Cardanol Applications

Applications	Characteristics
Foundry Core Oil	• Formaldehyde Condensate of Residol used in core oil binders
Surface Coatings	• Used in cycle paints(dark paints) • Residol-Drying oil varnishes • Aluminum paints • Black enamels • Zinc Chrome-Iron Primers
Brake Lining	• Acid-catalyzed condensations of formaldehyde and Residol are used in break lining as Friction Dust
Rubber Industries	• Residol is used as plasticizer and as re-enforcing agent in rubber compounding
Friction Dust	• Pulverized to different grades Residol resin is used as stabilizing agent in brake products

Cashew Nut Shell Liquid (CNSL)

CNSL can be defined into 3 grades which are based on the "extraction method".

Raw CNSL is a cold press or solvent extracted liquid from Cashew Nut Shell. It contains approximately 70% of anacardic acid, 18% of cardol, 5% of cardanol and 2% of 2-methyl cardanol with the remainder being made up of other phenols and less polar substances. Anacardic acid and Cardanol are monohydroxy phenols. Cardol and methyl cardanol are dihydroxy phenols.

RCT-446 can be decarboxylases to obtain a Technical CNSL (TCNSL) or it can be decarboxylases and distilled to yield high purity Cardanol, highly desirable alkyl phenolic compounds in the coatings and adhesive industries.

Technical CNSL (heated), the heating process of the Raw CNSL leads to decarboxylation of the anacardic acid to Cardanol and the typical composition of technical CNSL is approximately 52% cardanol, 10% cardol, 30% polymeric material, with the remainder being made up of other substances.

Further processing of technical CNSL in the distillation process at reduced pressure leads to removal of the polymeric material called Residol. The composition of the distilled CNSL contains approximately 78% of cardanol, 8% cardol, 2% polymeric material, less than < 1% 2-methyl cardanol, 2.3% heptadecyl homologue triene, 3.8% heptadecyl homologue diene and the remainder other homologous phenols

Properties:
Technical CNSL undergoes all typical phenolic reactions. Its versatility in polymerization and chemicals modification and low cost find its application in the polymeric based industries . Technical CNSL properties have advantage over phenolic in certain applications such as impact resistance, flexibility, faster heat dissipation, anti-corrosive, anti- microbial, insecticidal and resistant to alkali and acid solutions as well as mineral and fatty oils and various organic solvents.

CNSL Resin is a transparent viscous resin with golden color film. It is highly suitable for the surface coating application, where outstanding film properties and very high resistance to water and chemicals are required.

Therefore, CNSL Resin is used commonly as a paint raw material due to its high water and chemical resistant property.

Properties:

CNSL resin is the best modified Phenolic type. It offers the necessary traits of a straight phenolic nature without the oil bleeding and hence functions as a good binding agent.
The flexibility, thermal stability and impact resistance it provides, causes the decrease in the co-efficient of friction. It also combines the features of thermosetting and binding, especially used for Brake Lining.

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The flexibility, thermal stability and impact resistance it provides, causes the decrease in the co-efficient of friction. It also combines the features of thermosetting and binding, especially used for Brake Lining.

Application:
CNSL has innumerable applications, such as friction linings, paints, laminating resins, rubber compounding resins, cashew cements, polyurethane based polymers, surfactants, epoxy resins, foundry chemicals, and intermediates for chemical industry. It offers much scope and varied opportunities for the development of other tailor-made polymers.

CNSL undergoes all the conventional reactions of phenols, CNSL aldehyde condensation products and CNSL based phenolic Resins are used in applications such as surface coatings, adhesives. Various polyamines synthesized from CNSL are used s curing agents for epoxy resins. CNSL and its derivatives have been used as antioxidants, plasticizers and processing

aids for rubber compounds, modifiers for plastic materials and used to provide oxidative resistance Sulphur-cured natural rubber products. It is also added to rubber gum stock or nit rile rubber to improve the process ability, mechanical properties and resistance to crack and cut properties of the vulcanizes.

A number of products based on CNSL are used as antioxidants, stabilizers and demulsifies for petroleum products. Soluble metal derivatives of CNSL are used to improve the resistance to oxidation and sludge formation of Lubricating oils. Oxidized CNSL and its derivatives are also used as demulsifying agents for water in oil type petroleum emulsions.

CNSL used for manufacturing of CNSL resin, Cardanol or Card Phenol or Cashew Phenol, Cashew Friction Dust, Anti corrosive hiring (lining) chemicals, Paints, Varnishes, Enamels, Insecticides and Fungicides, Cashew Lacquers, Bakelite, Electrical conductress, Cashew Cements, Core Oil, Red Oxide, Wood, Fuel, Specialty Chemicals, Foundry Chemicals and many other Industries."

Technical CNSL has innumerable applications in polymer based industries such as friction linings, paints and varnishes, laminating resins, rubber compounding resins, cashew cements, polyurethane based polymers, surfactants, epoxy resins, foundry chemicals and intermediates for chemical industry.

(Attachment: CNSL application Appx.pdf)

Current and future markets

Nowadays we work in the following markets:

- Phenolic resins, straight and modified.
- Cashew polymers liquids and solids.
- Cashew oil as raw material for chemical application.
- Cardanol (distilled CNSL) as raw material for different application.
- Phenalkamines (epoxy hardeners) based on Cardanol.

And we wish to expend our production and cooperation into the following markets:

1. CNSL and CNS-cake as renewable fuel (solid, mixed, bio-fuel, burning oil…)
2. Nitrile rubber NBR liquid and powder
3. ABS thermoplastic.
4. Bio-Plastic industry

CNSL as Biodiesel

CNSL is not our common veg-based feedstock for biodiesel production.
Also it is not the oil from the kernel like other oil-seeds (sunflower, rapeseed, soy…) but and extraction from the shell which usually is lack of the properties the kernel has.

Here I will summarize 3 researches that I included here as an appendix where you can see the potential that CNSL has as a bio-fuel and as a feedstock to produce biodiesel.

Let me start by saying the biggest advantage CNSL has is the fact that this is a cheap feedstock that costs almost **50% less** than other veg-based feedstocks.

So either investing in R&D to make a cheaper biodiesel or to use it in a blended fuel which can reduce the production costs and rise one's profit margin...this is something to think about.

Article No. 1 is talking about:
Cashew Nut Shell Oil — A Renewable and Reliable Petrochemical Feedstock
(Attachment : cnsl RF 1.pdf)
In this article the author is reviewing the possibility and potential of the CNSL to act as a feedstock for "renewable petroleum".

For example, here are the parameters that were tested per extraction method.

Parameter	CNSL (pyrolysis)	CNSL (hexane extracted)	CNSL (decarboxylated)
Colour	Dark brown	Dark brown	Dark brown
Moisture content	4.1	6.4	3.2
Refractive index	1.693	1.688	1.698
Specific gravity	0.943	0.926	0.928
Viscosity (centipoise)	57	40	38
Ash (%)	1.22	1.53	1.50
Saponification value (mgKOH/g)	58.5	47.2	56.3
Iodine value (mg/100g)	212	236	227
Acid value (mgKOH/g)	12.4	15.6	12.9
Free fatty acid (mgKOH/g)	6.5	7.9	8.2
pH	4.8	4.5	5.2
Calorific value (kJ/g)	47.62		

And as a "renewable chemical" the parameters were as follow:

Components	CNSL (pyrolysis)	CNSL (hexane extracted)	CNSL (decarboxylated)
Cardol (%)	27	30	31
Cardanol (%)	54	20	65
Anacardic acid (%)	5	43	2
Others (%)	14	7	2

Here you can see a table that compares the 3 main oils

Properties	Diesel*	Ethanol*	CNSL
Density (kg/m^3)	0.84	0.789	0.9326
Kinematic viscosity (cost)	2-5	1.19	17.2
Calorific value (kJ/kg)	42000	30000	47600
Flash point (°C)	62	16	193
Auto-ignition temperature (°C)	210	362	206

*Source: [28]

Finding the advantages and disadvantages in the CNSL properties can establish the "game plan" as to how to use this oil in the petroleum business.

One can find the high viscosity level suitable for his use while another one will find the flash point level in his favor.

I urge you to read the article to have a more deep understanding of this matter.

Article No. 2 is talking about:
A Review on CNSL Biodiesel as an Alternative fuel for Diesel Engine.
(Attachment: cnsl RF 2.pdf)
In this article the author is reviewing the possibility and potential of the CNSL to act as a feedstock for biodiesel, kind of "CNSME".

In this article you can review the methods that are offered to break down some of the disadvantages of CNSL like this one:

1.4. Methods of producing Biodiesel from CNSL

Studies have revealed that the usage of non-edible oil in neat form is possible but not preferable. The high viscosity of non-edible oils and low volatility affects the atomization and spry patterns of fuel, leading to incomplete combustion and severe carbon deposits, injector choking and piston ring sticking. The methods used to reduce the viscosity are.

- *Emulsification.*
- *Pyrolysis.*
- *Dilution.*
- *Transesterification.*

In the end you can see the matching table:

Table 6: Properties of cashew nut oil, its biodiesel and blends to ASTM D6751-02 and EN 14214

Property	CNO	B100	B10	B20	Diesel	ASTM Limits	EN 14214
Density kg/m^3 902 at 15°C	874	854	856	850		860-900	
Relative density kg/m^3 at 15°C	0.914	0.875	0.855	0.857	0.852		
Cloud point °C	20	6	7	9	-12		
Pour point °C	13	1	5	5	-20		
Cold filter plug point °C	15	4	6	7	-15		
Flash point °C	167	136	82	89	68	93	120 min
Dynamic viscosity cts at 40°C	49.62	4.21	2.46	2.67	2.23		
Kinematic viscosity mm^2/s 40°C	54.92	4.81	2.88	3.12	2.62	1.9-6.0	3.5-5.0
Lower heating Value KJ/kg	37.30	37.20	42.80	42.20	43.40		
Higher heating value KJ/kg	40	40.40	45.30	44.85	45.90		
Calculated cetane number (ASTM D4737)	49.28	60.83	46.22	47.75		47 min	51 min
Free fatty acid % 2.29	0.188	0.188	0.225				
Acid value mgKOH/g	4.56	0.374	0.45	0.37		0.80 max	0.05 max
Iodine value gI2/100g	85.28	82.74	16.24	23.65	8.63		120 max
Peroxide value gI2/100g	21.70	27.00	17.30	16.30	15.00		
Oxidation stability (hours) 110°C	19	9	27	18		3 min	6 min
Saponification value mgKOH/g	117.11	187.94	162.69	165.50	159.89	120 max	159.89 max
Soap content %	0	4	0.5	1.0			
Cold soak filtration °C	310	230	77	95			
Water and sediments % (vol/vol)	10.00	0.02	0.002	0.004			500 max
Moisture content ppm	3420.	221.0	24	48			
Refractive index at 15°C	1.47	1.34	1.48	1.48	1.48		
Sulfated ash % (mol/mol)	0.60	0.03	0.01	0.01		0.020 max	0.02 max
Carbon residue 0.17 (mol/mol)	0.07	0.03	0.02		0.050 max	0.30 max %	
Copper strip corrosion test (3h, 50°C)	4	2	1	1		No.3 max	1
Distillation temperature 90% °C	355	350	320	322		360 max	

Part of the article's author conclusion was:

"In this paper we study the properties of CNSL oil, transesterification process, Properties and result of CNSL Biodiesel as an alternative fuel for CI engine. Based on this study on CNSL biodiesel, we can conclude that the CNSL oil can be used as an alternative fuel for diesel engine."

I urge you to read the article to have a more deep understanding of this matter.

Article No. 3 is talking about:
Influence of CNSL biodiesel with ethanol additive on diesel engine performance and exhaust emission. (Attachment: cnsl RF 3.pdf)
In this article the author is reviewing the potential of blended biodiesel that includes ethanol and CNSL.

In this article the author is showing the advantages and disadvantages in this blend and why CNSL benefits the blend as s opposed to "traditional" blend or ethanol blend.

At the beginning you can see the parameters in all 3 oils

Properties		No-2 Diesel	B20	B100
Kinematic Viscosity	cSt	2.82	4.53	29.77
Density	kg/m^3	840	858	884
Lower Heating Value	MJ/kg	42.3	42.25	39.4
Cetane Number	-	46	51	54
Flash Point	^oC	70	64	157

Along the article you can see the test results made to check the CO and NO parameters and as shown, the B20 blend is the most efficient of them all.

In conclusion the author wrote this:

The CNSL bio oil is cheaper than the other kinds of vegetable oils, which is an important advantage for biodiesel production. Some fuel properties of B20 such as cetane number, Calorific value, Sulphur content, and flash point are better than those of diesel fuel. In addition, ethanol as additive improves the density and the viscosity. Exhaust gas emission for 10% ethanol blend reduces CO2 emission by 27%, HC emission by 8% and NO emission by 57% at full load than that of B20. The smoke opacity slightly decreases while comparing with diesel and slightly increases compared with B20. In general, low NO and CO2 emissions were measured with the 10% ethanol as additive in B20 blend. Therefore Cashew nut shell liquid blends can be used in CI engines in rural area for meeting energy requirement in

various agricultural operations such as irrigation, harvesting, threshing, etc; Hence CNSL can be alternately used as fuel for diesel engine. Consequently 20% CNSL biodiesel and 10% ethanol as additive can effectively be used in diesel engines without any modification.

I urge you to read the article to have a more deep understanding of this matter.

My final words

I wrote this brief to open one's eyes to the opportunities lying in his doorstep.
Working with CNSL as a renewable chemical is known and has great potential now that the world is shifting to bio-building stones rather than polluting petro-chemical that always relay on the crude oil and politics.

Part of that shift is the potential in CNSL to be used as a renewable fuel / additive / feedstock, you name it.

It's cheap, it's has nothing to do with politics, it's not polluting the environment and has ZERO residues.

InLightMe – trading company works with a Spanish company that has refineries in Vietnam and India. We also have sources in Brazil for CNSL.

Please feel free to contact us on any question, remark, comment or anything else you have in mind.

Thank you