

SYNTHESIS AND CHARACTERIZATION OF ALKYD RESIN IMMERSED IN SILVER-NANOPARTICLE DERIVED FROM COTTON SEED OIL

Abstract

Alkyd resin prepared from *Gossypiumhirsutum*(cotton seed) seed oil and immersed in silver nanoparticle has been characterized and evaluated using standard analytical methods. Gas Chromatography-Mass Spectrometry(GCMS) was used to determine the fatty acid profile of the seed oil extract which was physicochemically characterized using AOAC standard method. The results obtained are as follows: Iodine value; 102.36 gI₂/100g, Acid value; 3.19 mgKOH/g, Saponification value; 202.32 mg/KOH/g, Refractive index; 1.46, Specific gravity; 0.91 and Moisture content; 1.20. The alkyd resin was prepared using alcoholysis-polyesterification reaction. The prepared resin was then immersed in silver benzoate to give *Gossypiumhirsutum* immersed silver nanoparticle alkyd resin (GHSOR-AgNps) and the formulated resin analyzed using Ultraviolet-Visible spectroscopy (UV), Fourier Transform Infrared Spectroscopy (FTIR), and Scanning Electron Microscopy (SEM). UV- visible spectroscopy was used to analyze the silver benzoate salt. The performance of the formulated resin was assessed and revealed thus: soluble in both polar and non-polar organic solvents used in the study, dried through after 24 hours, showed chemical resistance to 0.1M NaOH with total removal, and its acid value was below 10 mgKOH/g. Therefore, *Gossypiumhirsutum* seed oil (GHSO) has shown to be a cost-effective, renewable and sustainable feedstock for alkyd resin production in the coating industry.

Keywords: Alkyd resin, cotton-seed oil, *Gossypiumhirsutum*, physicochemical properties, Silver-Nanoparticle.

Introduction

The increased interest in nanotechnology and nanoparticles in particular for more than two decades in various fields of study has necessitated scientists to explore more into the nanoworld. Nanoparticles are tiny or small materials ranging between 1 nm to 100 nm in diameter and can be classified into: one, two or three dimensions (1). Nanoparticles are said to have high surface area to volume ratio, which gives each nanoparticle its unique surface (2). The disadvantage of conventional methods in synthesizing nanoparticles include: high cost, production process time, as well as the use of toxic materials. Recent studies have employed the use of green, eco- friendly and one-pot synthetic processes, especially in polymer synthesis (3).

The cotton plant is a major crop grown in the world (4). In Nigeria, it is majorly grown in the Northern states and some areas in the South Western states. It is grown mostly for the cotton, which is used in the textile industry and for the manufacture of some household materials and

industrial products. Cotton seed (*Gossypium hirsutum*) is the second major product from the cotton plant after the cotton fiber which serves as raw material for oil extraction or animal feed production (5,6). Over the years, researchers have used cotton seed as a renewable raw material in the coating industry; either as a reinforced biomass, used directly as a starting material, or its fibers which are used as a mix for animal feed (7,8,9,10).

Silver nanoparticle (Ag-Nps) have found use in diverse applications due to its eco-friendly nature (12,13,14). Alkyd resins have been synthesized by various researchers using different methods and catalysts such as: Lithium hydroxide, lead (II) oxide, calcium carbonate, sodium hydroxide and calcium oxide (15,16,17,18,19,20).

This study reports the synthesis of alkyd resin from cotton seed oil, which is eco-friendly, and immersion of same in silver nanoparticle. The formulated alkyd resin embedded in silver nanoparticles was characterized using modern analytical techniques such as Gas Chromatography Mass Spectrometry (GCMS) for the fatty acid profile of the seed oil extract, Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM). Ultra-Violet Visible Spectroscopy (UV) was used to characterize the Ag-Nps salt. The formulated resin was analyzed using standard analytical methods for its drying time, chemical resistance, solubility and acid value to evaluate its applicability in the coating industry.

Materials and Methods

Sample preparation

Cotton seed (*Gossypium hirsutum*) was sourced from Dawanau international grain market located at latitude $12^{\circ}51'12.23''$ N and $8^{\circ}26'27.99''$ E longitude at Dawakin Tofa local government area of Kano state Nigeria. Grits were removed, these seeds were dehulled, sun dried, milled into fine powder and stored in an airtight container for further use.

All reagents and solvents used were of analytical grade and were used as received without further purification.

Oil Extraction

The *Gossypium hirsutum* (Cotton seed) oil was extracted via Soxhlet extraction. One hundred grams (100g) of the ground cotton seed was weighed and the oil extracted using n-hexane (1:2) for 6

hours; the extracted oil was further concentrated using rotary evaporator (RE.300). Weights of the obtained oil extract was noted, and the formula below was used to calculate the % yield.

$$\text{Percentage Yield} = \frac{W_2 - W_1}{W_2} \times 100$$

W_1 = weight of *Gossypium hirsutum* before extraction

W_2 = weight of *Gossypium hirsutum* extracted oil

Synthesis of the *Gossypium hirsutum* Seed Oil Extract Alkyd Resin

The resin was prepared using alcoholysis-polyesterification reaction according to the method described by (21,22) with slight modifications. Eighty-five grams (85.0g) equivalent of the cotton seed extract was transferred into a 4 neck round bottom flask which was heated to a temperature of 130⁰C to debar moisture. Twenty grams (20.0g) volume equivalent of glycerol and a catalytic amount of (0.40g) NaOH was added to the mixture and heated to 220⁰C under reflux for 1 hour. The reaction was complete when the solubility of formulated resin in anhydrous methanol gives a clear solution, which gives an indication of the production of monoglyceride.

The reaction temperature was raised to 180⁰C and phthalic anhydride and 10% v/v xylene was added to the produced resin to distill off the water of esterification. The esterification reaction proceeded at a temperature of 250⁰C for 4 hours. An aliquot of the reaction mixture was sampled at a time interval of 30 minutes to ascertain a drop in the acid value of the resin. The reaction was stopped when the acid value of the resin dropped to a value below 10 mg/KOH.

Silver Nanoparticle Immersed Alkyd Resin

The procedure for the immersion of the alkyd resin in silver benzoate was the method described by (23) with slight modification. 0.136g of Silver benzoate salt was dissolved in 150ml of toluene. 9.60g equivalent of the alkyd resin was dissolved into the mixture and allowed to stand in the dark for a period 12 hours.

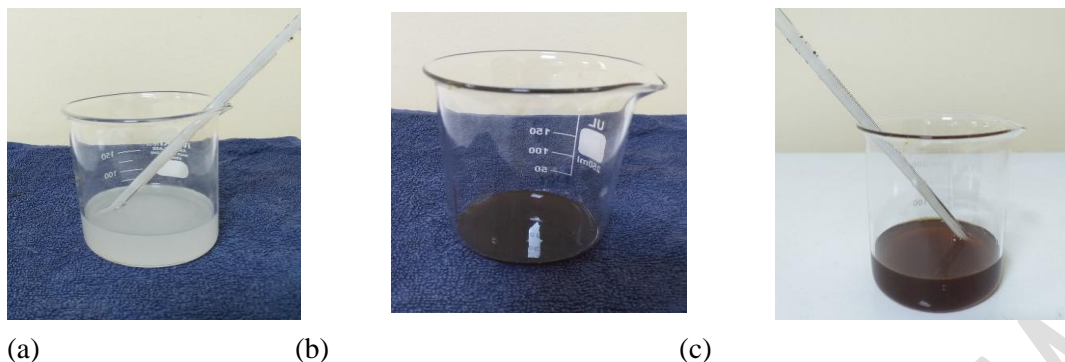


Figure1: showing the solution mixture of (a) silver benzoate salt, (b) freshly prepared alkyd, (c) alkyd resin immersed nanoparticle respectively.

Characterization

Physicochemical properties of the seed oil extract such as; Acid value, saponification value, iodine value, free fatty acid, refractive index and specific gravity analysis was assessed using Association of Official Analytical Chemists (24) standard analytical method and procedure.

Gas Chromatography Mass Spectra(GC-MS)

The Fatty acid profile of *Gossypiumhirsutum* seed oil (GHSO) extract was carried out. The samples (100 μ l) were extracted from the reaction mixture at specified time intervals (7,8 and 10 minutes) and analyzed using a Gas Chromatograph, coupled mass spectra (Agilent, 6890A). The GC machine contained a HP-5 capillary column supplied by Agilent with the dimensions 30 m \times 0.32 mm \times 0.25 μ m. The samples were centrifuged for 4 minutes at 50⁰C then the top layer of the sample was isolated for GC analysis; with helium as the carrier gas. The column temperature was held at 50⁰C for 4 minutes and gradually increased to 300⁰C at a heating rate of, 10⁰C for 8 minutes. The injector temperature was set at 250⁰C while the temperature of the detector was maintained at 300⁰C.

Fourier Transform Infrared Spectrometry (FTIR)

Fourier Transform Infrared Spectrometry (FTIR) spectra analysis of the resin produced from *Gossypiumhirsutum* seed oil (GHSO) extract and *Gossypiumhirsutum* seed oil resin-immersed nanoparticle (GHSOR- AgNp) samples were scanned in the 4000 – 650 cm^{-1} range using CAREY630 machine at 1nm interval.

Scanning Electron Microscopy (SEM)

The morphology of the *Gossypiumhirsutum* seed oil extract resin (GHSOR) was examined at different sample sizes of 20um and 50um at a working distance of 3mm and 10.8mm with a

magnification of 9000X and 10000X respectively at a pressure of 70pa at 15KV, and an horizontal field width of 125 μ m.

UltraViolet-Visible Spectrophotometry

The absorption peak profile for Silver benzoate salt and GHSOR-AgNp were determined using a UV-visible spectrophotometer at wavelength range of 200-700 nm.

Evaluation of Formulated Alkyd Resin

The formulated resin from GHSO was evaluated for parameters such as: drying time, chemical resistance, solubility and acid value.

- a) Solubility: the resin (0.25g) was weighed and dissolved with 5ml each of acetone, toluene, benzene and methanol(25).
- b) Acid value: The acid value of the resin was monitored with the reaction time, which was taken every 30 minutes interval.
- c) Drying time: The drying time was evaluated at room temperature, for set to touch, surface dry, dry and dry through.
- d) Chemical resistance: This was determined in solutions such as: distilled water, 0.1M HCl, 0.1M NaOH and 5% NaCl respectively.

Results and Discussion

Extraction yield

The yield of *Gossypium hirsutum* seed oil (GHSO) extract was achieved as 26.67%. This yield varies from one cotton seed plant to another as a result of temperature, planting season, storage and extraction process among other factors (26).

Physicochemical Properties

The physicochemical properties of *Gossypium hirsutum* seed oil extract are shown in Table 1. The acid value and free fatty acid of the seed oil extract of *Gossypium hirsutum* was 3.19 mgKOH/g and 1.60 mgKOH/g respectively. The acid value is used to determine the deterioration and curing of the oil, and the value gotten was similar to that reported by (27).

As shown in Table 1, Iodine value is one of the most important parameters to look out when considering oil for resin preparation. Iodine value is used to determine the drying property of an oil (28).

Iodine value classifies oils as non-drying; when the value is less than 90 gI₂/100g, semi drying when it value falls between 90-130gI₂/100g, and drying when it is higher than 130gI₂/100g. The iodine value for *Gossypiumhirsutum* was found to be 102.36 gI₂/100g which indicates that it is a semi-drying oil, this is similar to that reported by(29)

The specific gravity of *Gossypiumhirsutum* seed oil was found to be 0.91 g/cm³. This value is similar to 0.93 g/cm³ reported for rubber seed oil and cotton seed oil by(30,29) respectively; and also within the range reported by(31); value for sunflower seed oil.

The refractive index (RI) can be used to test for oil purity. The RI value for GHSO was found to be 1.46; this value falls in the (RI) range reported by(30, 21) for most seed oils.

The hydrocarbon carbon (HC) chain can be determined by saponification value (SV), The higher the hydrocarbon chain the lower the saponification value. The saponification value for GHSO is 202.32 mg/KOH/g which is in the same range as that reported by(29,32) The colour of GHSO was physically observed as golden yellow, the odour is agreeable and the moisture content was found to be 1.20% which aligns with observations reported by(9)

Table 1: Physicochemical Parameters of *Gossypiumhirsutum* Seed Oil Extract

S/N	PARAMETERS	GHSO
1	Acid value (mgKOH/g)	3.19
2	Free fatty acid	1.60
3	Iodine value (gI ₂ /100g)	102.36
4	Specific gravity g/cm ³ (30°C)	0.91
5	Refractive index	1.46
6	Saponification value (mg/KOH/g)	202.32
7	Moisture content (%)	1.20
8	Viscosity(30°C) (m ² /S)	42.00
9	Percentage yield (%)	26.67
10	Odour	Agreeable
11	Colour	Golden yellow

The fatty acid composition of *Gossypiumhirsutum* seed oil extract is as shown in Figure 2. The most abundant unsaturated fatty acid is oleic acid (7.45 ppm) (octadec-9-enoic acid) and the least is linoleic acid (octadec-9, 12-dienoic acid) (0.02 ppm) this is reported by(29). The most abundant saturated fatty acid is heptadecanoic acid (4.24 ppm) (Margaric acid) and the least is Arachidonic

acid (cis-9-cis-12-cis-15-cis-19-Eicosanoic acid)(0.09ppm). The total saturated and unsaturated fatty acid of *Gossypiumhirsutum* is 26.62% and 75.72% respectively which compares favorably with most literatures on cotton seed oils(33,29).The iodine value obtain for GHSO 102.36 gI₂/100g is confirmed by the saturated and unsaturated fatty acid profile of the seed oil. which confirms it use as a viable feedstock for resin production.

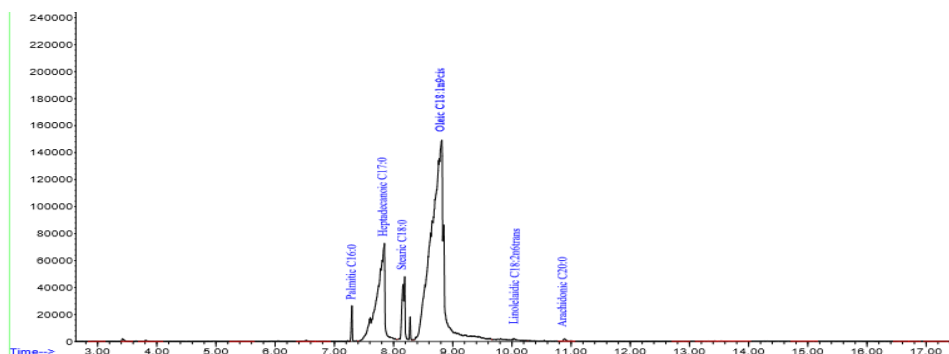


Figure 2: GCMS fatty acid profile of *Gossypiumhirsutum*seed oil (GHSO) extract

The FTIR spectra of the alkyd resin seed oil formulated from GHSOR and GHSOR-AgNps is shown in Figures 3 and 4 respectively. Similar functional groups which correspond to C-H aliphatic stretch absorption bands were observed at 2925 cm⁻¹ and 2825 cm⁻¹ for both GHSOR and GHSOR-AgNps. Olefinic C-H stretching vibration peaks were observed at 3011 cm⁻¹ and 3089 cm⁻¹ respectively for both resins. Absorption peaks at 1748 cm⁻¹ and 1741 cm⁻¹ arise from conjugated carboxylic C=O ester bonds. The observed peaks at 1465 cm⁻¹ and 1499 cm⁻¹ correspond to C=C stretches arising from symmetric and asymmetric bending of the methyl groups. The absorption band observed at 1607 cm⁻¹ is due to C=C aromatic stretching vibration which confirms that the polyesterification reaction was successful. The new absorption peak at 698 cm⁻¹ is due to Ag-O bond indicative of the formation of GHSOR-AgNps as this peak is non-existent in the GHSOR (figure 3), same was observed by (34,20,22).

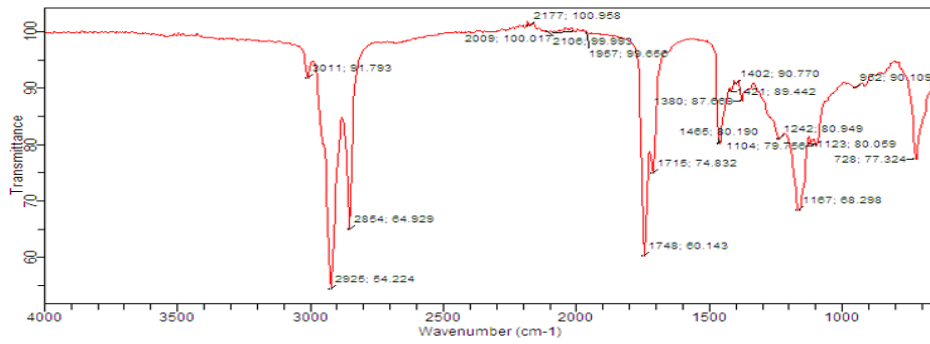


Figure 3: FTIR of Alkyd resin from *Gossypiumhirsutum*seed oil extract (GHSOR)

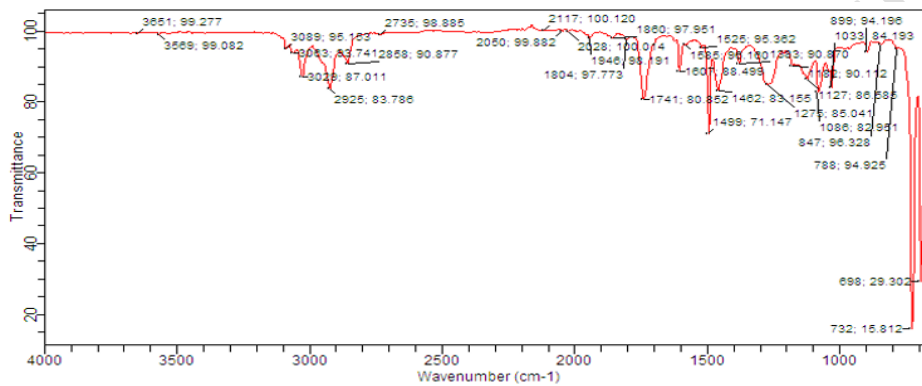
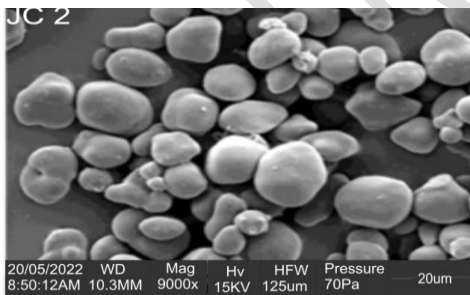
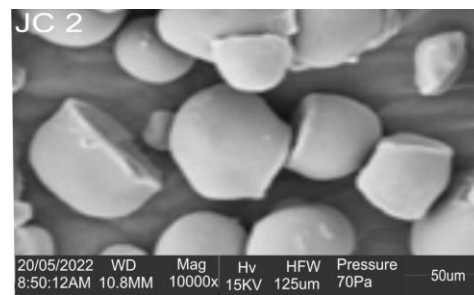


Figure 4: FTIR of silver nanoparticle immersed on *Gossypiumhirsutum*seed oil alkyd resin (GHSOR-AgNp)

On examination of the SEM micrograph shown in Figure 5, the morphology of the resin at 9000x and 10000x resolutions shows they were spherical in shape with good and uniform roughness and dispersion.



(a)



(b)

Figure 5: SEM Micrograph of GHSOR showing (a) 20µm (b) 50µm

The UV-Visible analysis of silver benzoate salt and GHSOR-AgNps is shown in Figure 6. The maximum absorption wavelength was seen at 283nm for Ag^+ ion and 459nm for Ag-Nps due

tosurface plasmon resonance (SPR),which is confirmation of the resonance effect due to the interaction of conduction electrons of metal nanoparticle(22).

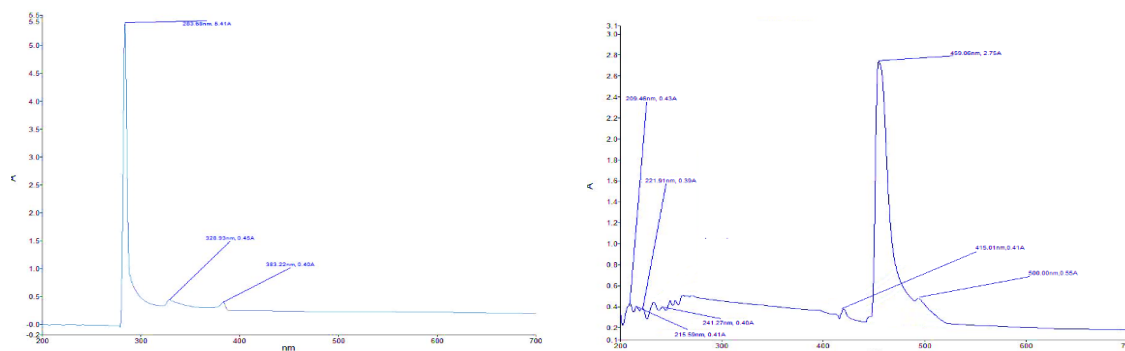


Figure 6: UV-visible spectra of (a) silver benzoate salt, and (b) alkyd resin immersed nanoparticle

Performance Evaluation of the Prepared Resin

The formulated resin (GHSOR) was evaluated for its solubility, drying time and chemical resistance as shown in tables 2, 3, and 4 respectively.

The resin was found to be soluble in acetone, toluene and benzene which are polar and non-polar solvents and partially soluble in methanol. Asimilar observation was reported by(35).The drying time of theresin was assessed at different time intervals of 30 minutes to 24 hours. At 30 minutes, the resin was set to touch, which is a touch on the surface with little smear on the hand; surface dry was observed at 1 hour timing and dry at 3 hours which is convenient to touch.The dry through was observed after 24 hoursthis shows a property comparable to other literature reported for oil modified alkyd resins (9,25).

Table 2: Solubility of the formulated resin

Acetone	Toluene	Benzene	Methanol
soluble	soluble	soluble	Partially soluble

Table 3: Drying time of the formulated resin

Appearance	Set to touch	Surface dry	Dry	Dry through
drying time schedules	30minutes	1 hour	3 hours	24 hours

The chemical resistance of the resin was assessed after 24 hours. No effect was observed on the alkyl resin immersed in distilled water at 0.1M NaCl and 0.1M HCl which was sufficient time to test for resistance. At 24 hours there was removal on 0.1M NaOH which shows that the resin formulated has a high chemical resistance to alkali solvents, this was also reported in literature(36,37).

Table 4: Chemical resistance of the formulated resin

Chemicals	Observation	Immersion time
Distilled water	No effect	24 hours
0.1M HCl	No effect	24 hours
0.1M NaOH	Removal	24 hours
5% NaCl	No effect	24 hours

The acid value of the formulated resin (GHSOR) was determined at different reaction time. A plot of these value at different reaction time intervals is illustrated in Figure 7. The plot showed a sudden drop in the acid value at the first 30 minutes then a gradual drop of the acid value to value below 10mgKOH/g which is due to the reaction of 1° and 2° -OH groups of glycerol with the -COOH groups of phthalic anhydride. This is similar to that reported in literature for most seed oils (36,27).

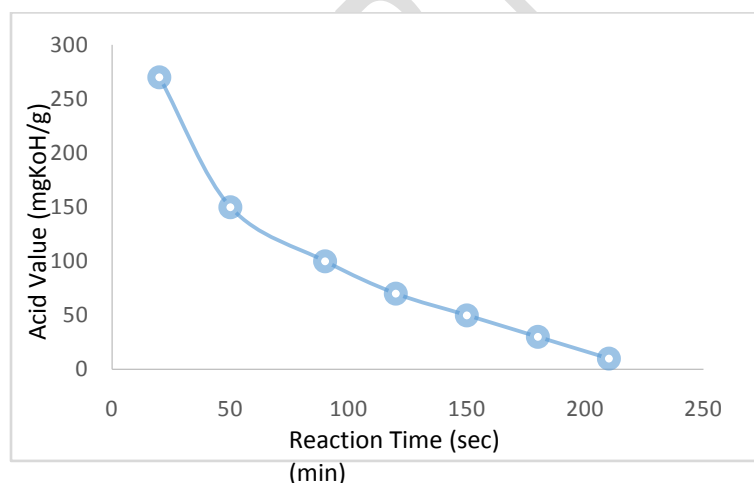


Figure 7: Acid value versus reaction time of GHSOR

Conclusion

From this study, it can be concluded that alkyd resin based on pure *Gossypium hirsutum* (GHSO) have been successfully synthesized and immersed in silver nanoparticle. The FTIR confirms the chemical structures of the resin and the functional group of the resin immersed in silver nanoparticle (GHSOR-AgNps); hence *Gossypium hirsutum* is a good starting material in the coating industry.

References

1. Wiggington NS, Huas KL, Hochella MF. Aquatic environmental nanoparticles. *J Environ Monitor.* 2007; 9:1306-1316. <https://doi.org/10.1039/B712709J>.
2. Christian P, Von der kammer F, Baalousha M, Hofmann Th. Nanoparticle: structure, properties, preparation and behavior in environmental media. *Ecotoxicology.* 2008;17:326-343. DOI 10.1007/s10646-008-0213-1.
3. Faisal S, Khan MA, Jan H, Shah SA, Abdullah A, Shah S. *et al.* Edible Mushroom (*Flammulina velutipes*) as biosource for silver Nanoparticles: from synthesis of diverse biomedical and environmental applications *Nanotechnology.* 2021;32: (6) 5-101. DOI 10.1088/1361-6528/abc2eb.
4. Yu J, Yu S, Fan S, Song M, Zhai H, Li X. Mapping quantitative trait loci for cottonseed oil, protein and gossypol content in a *Gossypium hirsutum* × *Gossypium barbadense* backcross inbred line population. *Euphytica.* 2012; 187, 191-201. <http://dx.doi.org/10.1007/s10681-012-0630-3>
5. Hamilton KA, Pyla PD, Breeze M, Oslon T, Li M, Robinson E. Bollgard II cotton: compositional analysis and feeding studies of cottonseed from insect-protected cotton (*Gossypium hirsutum* L.) producing the Cry 1Ac and Cry 2Ab2 proteins. *J. Agric. Food Chem.* 2004;52,(23) 6969-69-76. doi: 10.1021/jf030727h.
6. Ashokkumar K, Ravikesevan R. Conventional and molecular Breeding Approaches for Oil and Seed Protein Content Improvement in Cotton. *International Research Journal of Plant Science.* 2011;2(2), 037-045.

7. Ibanga IO, Edet NW. Influence of Polybasic Acid Type on the Physicochemical and Viscosity Properties of Cottonseed Oil Alkyd Resins. *The International Journal of Engineering and Science*. 2013;5(2) :01-14.
8. Heba MA, Badran BM. Steel protective coatings of cottonseed oil alkyd modified urethane/mercapto methyl tetrazole adduct. *Research & Reviews in Polymer*. 2014;5(2):69-76.
9. Ezidinma TA, Onukwuli DO, Uzoh CF. Synthesis and Characterization of Water- Reducible Alkyd Resin from Cottonseed Oil. *International Journal of Engineering and Applied Sciences*. 2015;2 :(12) 2394-3661.
10. Prashant N, Aruna P. Study of the performance of polyurethane coatings derived from cottonseed oil polyol. *J.Coat. Technol. Res*. 2015;13:171-179. DOI:10. 1007/s11998-015-9741-9.
11. Yang AO, Cong Z, Beiyu Z, Zhiyun W, Luoyi Z, Yang M, et al. Effects of Dietary Cottonseed Oil and Cottonseed Meal Supplementation on Liver Lipid Content, Fatty Acid Profile and Hepatic Function in Laying Hens. *Animals*. 2021;11, 78. <https://doi.org/10.3390/ani11010078>.
12. Henlein A, Giersig M. Formation of colloidal silver nanoparticles: capping action of citrate. *J. phys.Chem. B*. 1999;103:9533-9539. <http://dx.doi.org/10.1021/jp9925334>.
13. Sajadi SM, Kolo K, Hamad SM, Mahmud SA, Barzinjy AA, Hussein SM. Green synthesis of the Ag/Bentonite Nanocomposite Using *Euphorbia larica* extract: A reusable catalyst for efficient reduction of nitro compounds and organic dyes. *Chemistry select*. 2018;3, 12274-12280.
14. Nasar MQ, Khalil AT, Ali M, Shah M, Ayaz M, Shinwari ZK. Phytochemical analysis, *Ephedra procera* CA Mey. Medicated green synthesis of silver nanoparticles, their cytotoxic and antimicrobial potentials. *Medicina*. 2019;55(7): 369. DOI:10.3390/medicina55070369.

15. Ogunniyi DS, Njikang GN. Preparation and evaluation of alkyd resins from castor oil. *Pakistan Journal of Science Industrial Research*. 2000;(42): 378-380.
16. Akanni MS, Adekunle AS, Oluyemi EA. Physicochemical properties of some non-conventional oilseeds. *Journal of Food Technology*. 2005;3(2):117-181
17. Asiagwu AK, Omuku PE, Okoye PAC, Olisa MA, Ajiwe VCE. Evaluation of the suitability of conophor oil for the production of alkyd resins and surface coatings. *Oriental Journal of Chemistry*. 2008;24(2): 405-408.
18. Nwosu-Obieogu, K, Kalu UC. In Situ Epoxidation of Sesame Seed Oil for Synthesis of a Bio-based Resin. *European Journal of Sustainable Development Research*. (2020);4(3),em0121. <https://doi.org/10.29333/ejosdr/7830>
19. Okolie PN, Uaboi-Egbenni PO, Ajekwene AE. Extraction and Quality Evaluation of Sandbox Tree Seed (*Huracrepitan*) Oil. *World Journal of Agricultural Sciences*. 2012;8 (4): 359-365.
20. Bora MM, Gogoi P, Deka DC, Kakati DK. Synthesis and characterization of yellow oleander (*Thevetia peruviana*) seed oil-based alkyd resin. *Industrial Crops and Products*. 2014;(52):721-728. <https://doi.org/10.1016/j.indcrop.2013.11.012>
21. Oladipo GO, Ighodalo C, Eromosele IC, Folarin OM. Formation and characterization of paint based on alkyd resin derivative of *Ximenia americana* (wild olive) seed oil. *Environment and Natural Resources Research*. 2013; 3(3): 113-116. DOI:10.5539/enrr.v3n3p52.
22. Haruna M, Abubakar AA. Synthesis, characterization and application of silver-nanoparticles-embedded alkyd resin derived from *Jatropha* seed oil. *Journal of Sciences*. 2019;3(1): 312-320.
23. Kumar A, Proven KV, Ajanyan PM, John G. Silver –nanoparticle embedded antimicrobial paints based on vegetable oil. *Nature materials*. 2008; 7:236-241.
24. Association of Official Analytical Chemists (AOAC) 1990. *Official Methods of Analysis*, 15th edition. Association of Official Analytical Chemists, Washington, pp 955–972.

25. Uzoh CF, Onukwuli OD, Odera RS, Okey-Onyesolu CF. Synthesis and characterization of palm oil based air alkyd resin for surface coating. *Research Journal in Engineering and Applied Science*. 2013;2(3): 187-191.
26. Uche IC, Chukwujike IC, Nwanonyi SC. Synthesis Characterization and Performance Evaluation of Breadfruit Seed Oil Modified Alkyd Resin. *European Journal of Advances in Engineering and Technology*. 2016;3(9): 5-11.
27. Hassen MS, Hamid S, Lahssen EB, Imed AN, Ubair AS, Moufida Romdhani-Younes, et al. Preparation and Characterization of Alkyd Resins Based on *Citrullus colocynthis* Seed Oil. *J. Renew. Mater.* 2018;6(6). DOI:10.7569/JRM.2018.634105.
28. Abayeh OJ, Ismail A, Abayeh OM. Quality characteristics of pumpkin (*Cucurbita Pepo L*) seed oil. *Journal of Chemical Society of Nigeria*. 2011;36(1): 220 – 223.
29. Isaac IO, Ekpa OD. Fatty Acid Composition of Cottonseed Oil and Its Application in Production and Evaluation of Biopolymers. *Am. J. Polym. Sci.* 2013;3 13–22.
30. Ikhuoria EU, Aigbodion AI, Okieimen FE. Enhancing the quality of alkyd resins using methyl esters of rubber seed oil. *Tropical Journal of Pharmaceutical Research*. 2004;3 (1): 311-317.
31. Aboki MA, Mohammed M, Musa SH, Zuru BS, Aliyu HM, Gero M, et al. Physicochemical and anti-microbial properties of sunflower (*Helianthus annuus L.*) seed oil. *International Journal of Science and Technology*. 2012;2(4):151 – 154.
32. Igbo UE, Igwe CC, Akubueze E, Ishola OR, Odusote AO, Oyewole AO. Utilization of beniseed oil for the production of alkyd resin. *Journal of Applied Chemistry*. 2014;7: 104-106.
33. Lukonge E, Labuschagne MT, Hugo A. The evaluation of oil and fatty acid composition in seed of cotton accessions from various countries. *J. Sci. Food Agric.* 2007; 87:340–347. <http://dx.doi.org/10.1002/jsfa.2731>
34. Guran C, Pica A, Fical D, Fical A, Comanescu C. Antimicrobial coatings-obtaining and characterization. *Bull Mater. Sci.* 2013;36(2):183-188. DOI:10.1007/s12034-013-0470-3.

- 35.EgbunaSO, Aninwede CS. Comparative Analysis of Alkyd Resins Produced from Castor and Soybean Seed Oils. International Journal of Novel Research in Engineering and Science.2018;5(1): 24-32.
- 36.Ikhuoria EU, Maliki M, Okieimen FE. Synthesis and characterization of chlorinated rubber seed oil alkyd resins. Progr in Org Coatings. 2007;59(1):134–137.<https://doi.org/10.1016/j.porgcoat.2007.02.001>
- 37.Umoren SA,Essien EE,Effiong EE. The utilization of *Lagenariabreviflorus*seed oil in the synthesis of alkyd resin. Journal of Material and Environmental Sciences.2016;7(6):1846-1855.

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