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Valorization of *Gmelina arborea* Waste Leaves for the Synthesis of Bio-Disinfectants

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Abstract
This work is carried out to produce eco-friendly disinfectants from renewable sources to obey the clarion call for climate revival. Two bio-disinfectants, 2-3-dihydroxyl propanal (glyceraldehyde) and ortho-cresol (o-cresol) were synthesized from dry leaves of *Gmelina arborea* using barium chloride catalyst and distilled water at 60 ^{o}C. The products obtained were analyzed using GC-MS. The yield of 2-3-dihydroxyl propanal obtained at reaction temperatures of 10, 20, 30, 40, 50 and 60 ^{o}C were 2.94, 5.51, 5.47, 5.55, 11.61, and 1.14%, respectively. Similarly, the yields of ortho-cresol, at the corresponding reaction time, were 4.76, 8.14, 8.40, 7.63, 10.05, and 18.31%, respectively. The production of these two bio-disinfectants from biodegradable waste material has helped in the utilization and recycling of waste leaves into useful materials and also protects the environment and the entire ecosystem.

Keywords: bio-disinfectants, *Gmelina arborea* leaves, 2-3-dihydroxyl propanal, ortho-cresol, synthesis

Introduction
Disinfectants are substances when applied on non-living objects destroy microorganisms that are living on the objects [1]. They can penetrate deeply into all materials to kill all bacteria and other microbes [2]. They are antiseptic agents used during surgery to destroy bacteria, viruses, fungi, mould and other germs living on objects [3]. The most commonly used disinfectants are ethanol, chlorine and chlorine compounds, formaldehyde, glutaraldehyde, ortho-phthalaldehyde, hydrogen peroxide, iodophors, peracetic acid, phenolics, and quaternary ammonium compounds [4]. Ethanol is becoming very expensive due to its numerous applications, including its use as transport fuel [5]. The demand for ethanol has affected the prices of corn, indicating that ethanol production has an impact on food security [6]. Chlorine and chlorine compounds pose many health hazards [7], especially in wastewater effluents [8]. Also, chlorine disinfectant reacts with other matters to form by-products such as chloroform which causes miscarriage and cancer of the bladder [8]. This has led to the discontinuation of the application of chlorine disinfectant to drinking water.

The use of formaldehyde disinfectant causes irritation of the nose, mouth, and throat leading to throat and mouth burning [9]. Formaldehyde disinfectant causes respiratory distress, and swelling of the larynx and lungs may occur leading to bronchi and ulcers [10]. Glutaraldehyde disinfectant is corrosive to the skin, eyes, and respiratory tract [11], it also causes throat and lung irritation and rhinorrhea [12]. Hydrogen peroxide disinfectant causes severe irritation and inflammation of mucous membranes [13]: [14]. It also causes coughing and dyspnea [13]: [14]. It was reported by De Matteis et al. [15] and Johnson et al. [16] that exposure to Ortho-phthalaldehyde can cause induction of systemic anaphylaxis as well as pose a risk of respiratory sensitization. Peracetic acid contact can severely cause irritation and burn of skin and eyes leading to eye damage [17].

Biochemical disinfectants are known for being eco-friendly and nontoxic [18]: [19]. The compound, 2,3-dihydroxyl propanal also known as glyceraldehyde, and the ortho-cresol also known as o-cresol are used as a disinfectant and wood preservative [20]. They are less toxic disinfectants than chemical disinfectants [21]. Hauman and Love [22] described ortho-cresol as the least toxic antiseptic agent. Aside from its use as a disinfectant, ortho-cresol is found useful in the preparation of polyester and adhesive [23] and as a modifier for gelatin nanoparticles [24]. It is also used in the manufacturing of rubber and plastics [25]. It is used in the tanning of leather [26, 27]. Similarly, Singh and Patel [28] reported that the combination of 2,3-dihydroxyl propanal and dihydroxyl acetone are good ingredients for cosmetics. It is regarded as a metabolite as it has powerful antimicrobial activity [29]. Parodi et al. [29] also reported that 2,3-dihydroxyl propanal is a useful material for the preparation of adhesives and polyesters, and also as a cellulose modifier, and in the tanning of leather. Ortho-cresol is an essential oil, known for its long last fragrance, used in food and cosmetics [30]. Ortho-cresol is used to prevent hypersensitivity in skin [31]. Juszkiewicz et al. [32] reported the use of creosol as a bactericide, pesticide, and disinfectant. Its use on the skin can prevent up to 90% of cases of skin cancer [33].

Considering the aforementioned drawbacks of the use of conventional disinfectant, the need for an alternative disinfectant that is less toxic and eco-friendly is highly desirable. In this study, the synthesis of 2,3-dihydroxyl propanal and ortho-cresol from dry leaves of the *Gmelina arborea* plant was investigated through hydrothermal conversion of the leaves. Figure 1 shows the conversion of the dry *Gmelina arborea* leaf to 2,3-dihydroxyl propanal and ortho-cresol.

Figure 1: Schematic showing ortho-cresol and 2,3-dihydroxyl propanal from *Gmelina arborea* leaf

Materials and Methods

The materials used in this study include dry leaves of the *Gmelina arborea* plant, ceramic mortar and pestle, GallenKamp hot plate magnetic stirrer, thermometer, 1000 mL Pyrex conical flask, 1000 mL Pyrex beaker, separating funnel, glass funnel, and distilled water. The analytical reagents were sodium sulphate and barium sulphate.

The dry leaves of *Gmelina arborea* were collected from the premises of Kaduna Polytechnic's main campus, Tudun-wada, Kaduna. The leaves were cleaned by removing stones and handpicking the dirt and then pulverized with ceramic mortar and pestle as done by Ibrahim and Ali [34]. A solution of 0.5 g of a barium chloride catalyst in 500 mL distilled water was prepared in a 1000 mL conical flask. A mass of 50 g of the pulverized leaves was poured into the catalyst solution placed on a hot plate magnetic stirrer and heated to 60 ^{o}C and then kept the temperature constant for 10 minutes with constant stirring at a rate of 250 rpm as done in [35]. The product was first filtered into a 1000 mL beaker using filter cloth and thereafter, with Whatmann filter paper. The filtrate was dehydrated with 0.2% sodium sulphate in a separating funnel. The upper organic layer was separated from the lower aqueous layer, weighed and analyzed using a GC-MS analyzer to determine the components and compositions in the product. The experiment was repeated for a constant temperature heating time of 20, 30, 40, 50, and 60 minutes, respectively.

Result and Discussion

The weights of the dehydrated bio-products obtained from the hydrothermal conversion of *Gmelina arborea* leaves at varying reaction times of 10, 20, 30, 40, 50, and 60 minutes were 295.50, 205.50, 208.20, 209.70, and 133.70 g, respectively. The yields of two bio-disinfectants, 2,3-dihydroxyl propanal and ortho-cresol, were obtained from the GC-MS results of the bio-products. The weight, in grams, of the bio-disinfectants and their mass ratio in milligrams per gram, with respect to the feedstock, were computed using equations 1 and 2 respectively and presented in Table 1.

Table 1: The yields of 2,3-hydroxyl propanal and ortho creosol from *Gmelina arborea* leaves

Reaction time (minutes)	Product weight	Product	Yield (%)	Weight (g)	Mass ratio (mg/g)
10	295.50	2,3-Dihydroxyl propanal	2.94	8.69	173.8
		Ortho creosol	4.76	12.53	250.72
20	205.50	2,3-Dihydroxyl propanal	5.51	11.34	226.59
		Ortho creosol	8.14	16.72	334.58
30	208.20	2,3-Dihydroxyl propanal	5.47	15.26	305.58
		Ortho creosol	8.40	23.44	468.89
40	208.20	2,3-Dihydroxyl propanal	5.55	11.56	231.37
		Ortho creosol	7.63	15.90	318.09
50	209.70	2,3-Dihydroxyl propanal	11.61	24.35	487.02
		Creosol	10.05	21.08	421.71
60	133.70	2,3-Dihydroxyl propanal	1.14	1.52	30.49
		Ortho creosol	18.31	24.48	489.75

$$w_c = \frac{Yield(\%) \times P}{100} \quad (1)$$

$$Y = \frac{w_c \times 1000}{m} \quad (2)$$

where w_c (in gram) is the weight of a bio-disinfectant, P (in gram) is the weight of dehydrated bio-product, yield (%) is the yield of the bio-disinfectant as revealed by GC-MS result, Y (mg/g) is the mass ratio of the bio-disinfectant, in mg/g of feedstock, m is the mass of the feedstock (50g) and 1000 is the conversion factor from gram to milligram.

The yield of the two bio-disinfectants, ortho-cresol and 2,3-dihydroxyl propanal, as observed in Figure 2 showed a gradual increase when the reaction time was increased from 0 to 50 minutes. A sharp increase in the yield of ortho-cresol was observed when the reaction time was further increased to 60 minutes. However, in the case of 2,3-hydroxyl propanal, the yield was observed to decrease sharply when the reaction time exceeded 50 minutes. The reverse trend observed in the case of 2,3-hydroxyl propanal may be due to conversion reactions of the 2,3-dihydroxyl propanal to other products.

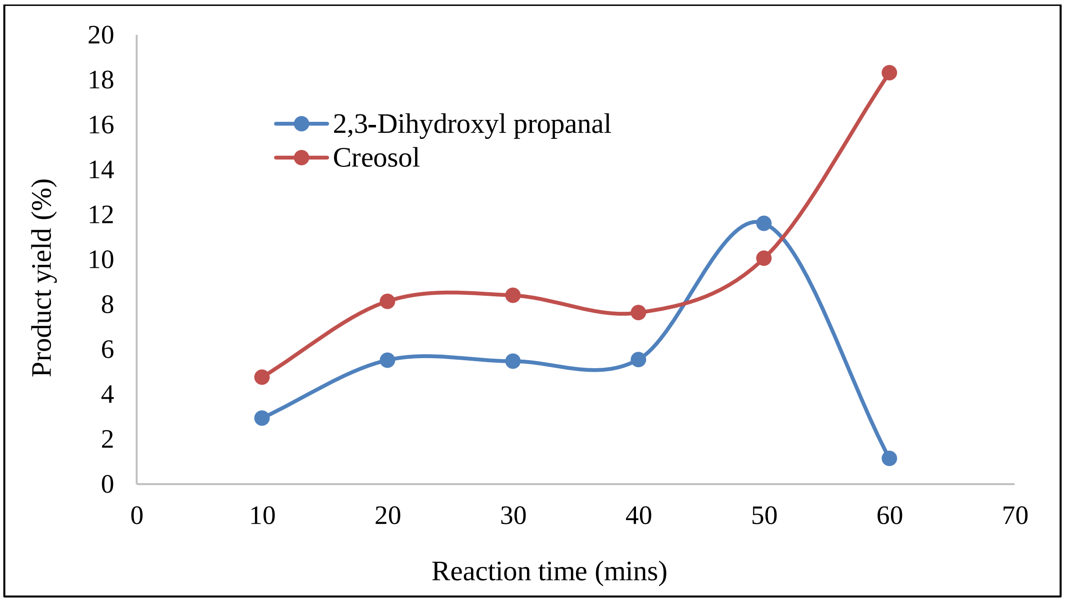

Figure 2: Effect of reaction time on the yield (%) of bio-disinfectants

Figure 3 displays the effect of reaction time on the mass ratio of the bio-disinfectant. The two bio-disinfectants exhibited an increasing trend in mass ratio when the reaction time was increased from 0 to 30 minutes. Between 30 to 40 minutes of reaction time, a decreasing trend was observed in both products. However, beyond 40 minutes of reaction time, different behaviours were displayed by the two products. Whereas ortho-cresol displayed an increasing trend in mass ratio when the reaction time was increased from 40 to 60 minutes, the mass ratio of 2,3-dihydroxyl propanal increased from 40 to 50 minutes reaction time and sharply fell thereafter when the reaction time was increased from 50 to 60 minutes. The sharp drop in the mass ratio of 2,3-dihydroxyl propanal could be attributed to a series of reactions that might have converted it to other products.

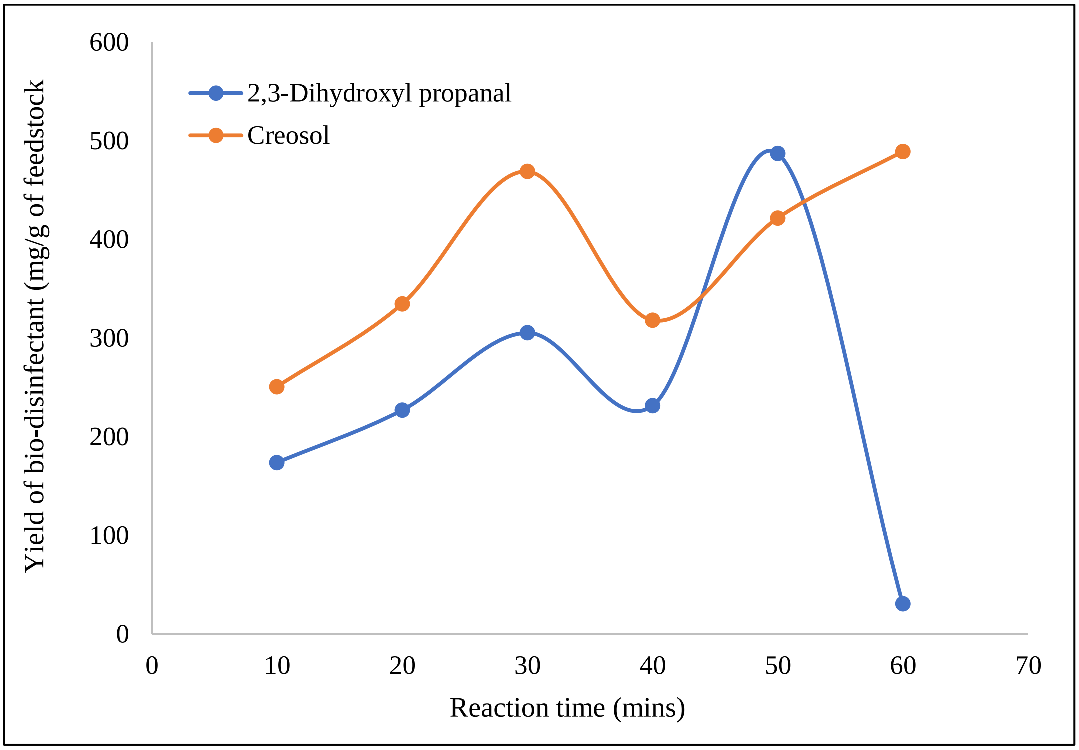

Figure 3: Effect of reaction time on the mass ratio of bio-disinfectants

The production of 2,3-dihydroxyl propanal has been majorly by the oxidation of glycerol [36]. Glycerol on the other hand is a very valuable and expensive product with a volatile market price that depends on supply [37]. Hence, its production from waste *Gmelina arborea* leaves would be a viable project. Ortho-cresol is produced by the catalytic thermal cracking of naphtha [38]. It is also usually extracted from the fractional distillation of coal tar [39]: [40]. Comparing the fractional distillation from coal tar with the hydrothermal conversion of *Gmelina arborea* at 60 ^{o}C, the latter is less energy-consuming. The use of *Gmelina arborea* leaves adds value to the waste leaves. It is, therefore, cheaper to produce 2,3-dihydroxyl propanal and ortho-cresol from waste *Gmelina arborea* leaves than their conventional methods.

Conclusion

Two bio-disinfectants, 2,3-dihydroxyl propanal and ortho-cresol were successfully synthesized from waste leaves of *Gmelina arborea* via hydrothermal conversion using barium chloride catalyst. The process yielded 11.61% amounting to 487.02 mg/g 2,3-dihydroxyl propanal in 50 minutes reaction time and 18.31% amounting to 489.75 mg/g ortho-cresol in 60 minutes reaction time, respectively. Even though the yields are lower than the literature values, the process is more economical and less harmful considering the raw material used. The production of 2,3-dihydroxyl propanal and ortho-cresol from waste material, *Gmelina arborea* leaves, via hydrothermal conversion using a barium chloride catalyst is viable.

Recommendation

i. This study considered the effect of reaction time on the yield of bio-disinfectants. The time range was limited to 10,20, 30 40 50 and 60 minutes. There is a need for further investigation beyond the 60 minutes.
ii. The study did not look at the effect of temperature variation on the yield of these bio-disinfectants. There is a need for further investigation in this regard.
iii. Other catalyst of interest, like zinc chloride, calcium oxide, zirconium oxide, etc., should be explored.

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References

1. Eryilmaz M. New generation disinfectants. Journal of Pharmaceutical Microbiology. 2016;2(1):6.
2. Khobragade DS. Health care waste: Avoiding hazards to living and nonliving environment by efficient management. Fortune Journal of Health Sciences. 2019;2(2):14-29.
3. Makhoahle P, Gaseitsiwe T. Efficacy of Disinfectants on Common Laboratory Surface Microorganisms at RS Mangaliso Hospital, NHLS Laboratory, South Africa. Bull Pioneer Res Med Clin Sci. 2022;1(1):1-2.
4. Kumar M, Tandel K. Chapter Overview. Prevention of Healthcare-Associated Infections: Infection Prevention and Control. 2021 Jan 31:326.
5. Akhairi MA, Kamarudin SK. Catalysts in direct ethanol fuel cell (DEFC): An overview. International journal of hydrogen energy. 2016 Feb 23;41(7):4214-28.
6. Kocak E, Bilgili F, Bulut U, Kuskaya S. Is ethanol production responsible for the increase in corn prices? Renewable Energy. 2022 Nov 1; 199:689-96.
7. Parveen N, Chowdhury S, Goel S. Environmental impacts of the widespread use of chlorine-based disinfectants during the COVID-19 pandemic. Environmental Science and Pollution Research. 2022 Dec;29(57):85742-60.
8. Sedlak DL, von Gunten U. The chlorine dilemma. Science. 2011 Jan 7;331(6013):42-3.
9. Rangkooy HA, Marghzari L, Dehaghi BF, Angali KA. Survey effect of exposure to formaldehyde on pulmonary function test in hospital staffs. Asian Journal of Pharmaceutics. 2018 Apr 1;12(2): S580-S4.
10. El Zawi NR, Elyasseri AM. A review of toxicity, genotoxicity and teratogenicity of formaldehyde. Cancer. 2021; 15:43.
11. Takigawa T, Endo Y. Effects of glutaraldehyde exposure on human health. Journal of Occupational Health. 2006;48(2):75-87.
12. Copeland S, Nugent K. Persistent and unusual respiratory findings after prolonged glutaraldehyde exposure. The International Journal of Occupational and Environmental Medicine. 2015 Jul;6(3):177.
13. Hesam G, Vahabi Shekarloo M, Atamaleki A, Jalali M, Hajipour-Verdom B, Moradpour Z. Health risk assessment of inhalation exposure to dry fogging of hydrogen peroxide in a dental clinic during the COVID-19 pandemic. Environmental Science and Pollution Research. 2022 Oct;29(50):75338-43.
14. Yang XY, Liu HY. Hydrogen peroxide is a risk factor for occupational chemical poisoning. Chinese Medical Journal. 2021 Apr 5;134(07):881-2.
15. De Matteis S, Ronsmans S, Nemery B. Respiratory health effects of exposure to cleaning products. Clinics in chest medicine. 2020 Dec 1;41(4):641-50.
16. Johnson VJ, Reynolds JS, Wang W, Fluharty K, Yucesoy B. Inhalation of ortho-phthalaldehyde vapour cause respiratory sensitization in mice. Journal of Allergy. 2011;2011.
17. Cavalcanti LW, Nepomuceno AB, Ferreira JD. Unexpected Ocular Manifestations Due to Exposure to Highly Concentrated Peracetic Acid: A Case Report. The American Journal of Case Reports. 2023;24: e940114-1.
18. Alamsyah DP, Syarifuddin D, Mohammed HA. Green customer behaviour on eco-friendly products: Innovation approach. JDM (Jurnal Dinamika Manajemen). 2018 Sep 27;9(2):159-69.

19. Kate AE, Singh A, Shahi NC, Pandey JP, Prakash O, Singh TP. Novel eco-friendly techniques for extraction of food-based lipophilic compounds from biological materials. Nat. Prod. Chem. Res. 2016;4(5):1000231.
20. Collins B, Guinane CM, Cotter PD, Hill C, Ross RP. Assessing the contributions of the LiaS histidine kinase to the innate resistance of Listeria monocytogenes to nisin, cephalosporins, and disinfectants. Applied and Environmental Microbiology. 2012 Apr 15;78(8):2923-9.
21. Ton SS, Chang SH, Hsu LY, Wang MH, Wang KS. Evaluation of acute toxicity and teratogenic effects of disinfectants by Daphnia magna embryo assay. Environmental pollution. 2012 Sep 1; 168:54-61.
22. Hauman CH, Love RM. Biocompatibility of dental materials used in contemporary endodontic therapy: a review. Part 1. Intracanal drugs and substances. International endodontic journal. 2003 Feb;36(2):75-85.
23. Ouyang J, Liu X, Wang BH, Pan JB, Shen S, Chen L, Au CT, Yin SF. WO3 Photoanode with Predominant Exposure of {202} Facets for Enhanced Selective Oxidation of Glycerol to Glyceraldehyde. ACS Applied Materials & Interfaces. 2022 May 12;14(20):23536-45.
24. Zhao YZ, Li X, Lu CT, Xu YY, Lv HF, Dai DD, Zhang L, Sun CZ, Yang W, Li XK, Zhao YP. Experiment on the feasibility of using modified gelatin nanoparticles as an insulin pulmonary administration system for diabetes therapy. Acta Diabetologia. 2012 Aug; 49:315-25.
25. Cherian S, Ryu SB, Cornish K. Natural rubber biosynthesis in plants, the rubber transferase complex, and metabolic engineering progress and prospects. Plant biotechnology journal. 2019 Nov;17(11):2041-61.
26. Demetra SI, Carmen GA, Daniela BE, Maria ST, Snezana CU, Gabriela PA, Cristina EN. Renewable Composites Based on Oak Acorn Extract, Collagen, and Whey, with Applications in Leather Processing. Annals of the University of Oradea. Fascicle of Textiles, Leatherwork. 2023 Jan 1;24(1).
27. Avilés-García O, Mendoza-Zepeda A, Regalado-Méndez A, Espino-Valencia J, Martínez-Vargas SL, Romero R, Natividad R. Photo-Oxidation of Glycerol Catalyzed by Cu/TiO2. Catalysts. 2022 Jul 29;12(8):835.
28. Singh S, Patel A. Selective green esterification and oxidation of glycerol over 12-tungstophosphoric acid anchored to MCM-48. Industrial & Engineering Chemistry Research. 2014 Sep 24;53(38):14592-600.
29. Parodi AR, Merlo C, Córdoba A, Palopoli C, Ferreyra J, Signorella S, Ferreira ML, Magario I. Application of metal complexes as biomimetic catalysts on glycerol oxidation. Molecular Catalysis. 2020 Feb 1; 481:110236.
30. Wojtunik-Kulesza KA. Toxicity of selected monoterpenes and essential oils rich in these compounds. Molecules. 2022 Mar 6;27(5):1716.
31. Bruze M, Zimerson E. Contact allergy to o-cresol—a sensitizer in phenol-formaldehyde resin. American Journal of Contact Dermatitis. 2002 Dec 1;13(4):198-200.
32. Juszkiewicz M, Walczak M, Woźniakowski G. Characteristics of selected active substances used in disinfectants and their virucidal activity against ASFV. Journal of veterinary research. 2019 Mar;63(1):17.
33. Torres-Contreras AM, Garcia-Baeza A, Vidal-Limon HR, Balderas-Renteria I, Ramírez-Cabrera MA, Ramirez-Estrada K. Plant secondary metabolites against skin photodamage: Mexican plants, a potential source of UV-radiation protectant molecules. Plants. 2022 Jan 15;11(2):220.
34. H. Ibrahim and Ali M. Abubakar. Facile Synthetical Method of Squalene from Vegetable Residue. Journal of Chemical Engineering and Industrial Biotechnology (JCEIB**)** ISSN: 2600-7347 e-ISSN: 0126-8139 VOL. 09, ISSUE 01, XXX – XXX DOI: https://doi.org/10.15282/
35. Haruna Ibrahim and Abubakar M. Ali. A New Strategy to Synthesize Pentyl 2-hydroxy Benzoate from Renewable *Gmelina arborea* Leaves. Asian Journal of Advances in Research, Volume 6, Issue 1, Page 232-236, 2023; Article no. AJOAIR.2538
36. Liu M, Liu H, Li N, Zhang C, Zhang J, Wang F. Selective oxidation of glycerol into formic acid by photogenerated holes and superoxide radicals. ChemSusChem. 2022 Oct 10;15(19): e202201068.
37. Tan HW, Aziz AA, Aroua MK. Glycerol production and its applications as a raw material: A review. Renewable and sustainable energy reviews. 2013 Nov 1; 27:118-27.

38. Kuznetsov PN, Kuznetsova LI, Buryukin FA, Marakushina EN, Frizorger VK. Methods for the preparation of coal-tar pitch. Solid Fuel Chemistry. 2015 Jul;49(4):213-25.
39. Li A, Zhu C, Zhang L, Ma Y, Xu D, Gao J, Wang Y. Efficient extraction and theoretical insights for separating o-, m-, and p-cresol from model coal tar by an ionic liquid [Emim][DCA]. The Canadian Journal of Chemical Engineering. 2022 Apr;100: S205-12.
40. Li A, Xu X, Zhang L, Gao J, Xu D, Wang Y. Separation of cresol from coal tar by imidazolium-based ionic liquid [Emim][SCN]: Interaction exploration and extraction experiment. Fuel. 2020 Mar 15; 264:116908.