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The Potential of Charcoal and Wood Vinegar as Sustainable Natural Medicine

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Abstract
Forest biomass, such as *Dyera costulata* (Jelutong), mangroves and bamboo, can be converted through pyrolysis to produce charcoal as the main product and wood vinegar as the by-product. Due to charcoal's large surface area, it functions as an efficient adsorbent. Besides being a food additive, charcoal can cure diarrhea, lower cholesterol, and prevent gas and bloating. Furthermore, wood vinegar containing organic acids, phenols, and other compounds may support the antioxidant properties and thus can be a viable substitute for synthetic antioxidants. It may have adverse consequences due to its possible antioxidant function. Food and medicine have both included natural antioxidants. The phenolic compounds can also be used as food additives and as intermediates in the production of pharmaceuticals due to their anti-diarrheal and germicidal effects, among other benefits. However, because wood vinegar includes certain carcinogens, like phenol and 2-methylphenol, the phenolic chemicals extracted from it cannot be used directly. Therefore, to assess the antioxidant activity and refine wood vinegar, it is imperative to determine the primary antioxidant present in the chemical.
Keywords: Charcoal; wood vinegar; natural; medicine

Introduction

Biochemical and thermochemical processes can transform biomass into high-value products, which are renewable, environmentally friendly, and abundant, into chemicals, liquid fuels, combustible gas, and bio-ethanol. Pyrolysis is a viable method for turning biomass into solids, liquids, and gases (Hou *et al.*., 2018). Wood is gradually heated to its maximum temperature in the slow pyrolysis procedures to form a char within a longer vapour residence times and lower process temperatures around 400 °C. The thermal process is also referred to as carbonization, destructive distillation, and dry distillation, where charcoal becomes the main product of carbonization. The average yield is about 30-35 wt%, which varies depending on the kind and size of wood, the carbonization method, the processing time, and the final temperature (Lung Ho *et al.*., 2018).

The resultant smoke or vapours from the manufacturing of wood charcoal condensed to create an aqueous layer known as pyroligneous acid, often referred to as wood vinegar (WV), wood tar, and gases. From the sedimentation tar, this liquid is first settled and subsequently decanted. The main ingredients of raw WV are soluble tar, acetic acid, and methanol. WV is a translucent liquid with a brownish-red colour produced by the pyrolyzing process. It contains over 200 chemical molecules, including alkane, alcohol, aldehyde, phenolic, and acetic acids. Its pH range is 2.5 to 2.8, and it has a sour and smoky smell (Lung Ho *et al.*., 2018; Hou *et al.*., 2018). **Figure 1** summarizes the pyrolysis products derived from plant biomass.

However, Lin (2017) found that various carcinogenic polycyclic aromatic hydrocarbons (PAHs), like naphthalene and phenanthrene, are produced by vinegar collected at a carbonization temperature of over 500°C. Along with temperature, these toxic substances also have higher concentrations. The collection of vinegar must occur between 150°C and 350°C. The vinegars collected above this temperature range are required to assess the possibility of mutagenic and carcinogenic agents because they are ubiquitous in the human environment and appear to be hard to eradicate.

Wood vinegar can be made from various woods and forest biomass, such as eucalyptus, bamboo, mangrove, coconut shell, and *Dyera costulata* (Jelutong), by carbonizing them. Wood vinegar comes from various sources identified as natural, safe inhibitors with a range of bioactivities, making them appropriate for use in termiticide, antifungal, and repellent applications. Furthermore, wood vinegar demonstrates notable antioxidant activity in addition to strong antibacterial activity against a variety of microorganisms (Yang *et al.*., 2016; Souza *et al.*., 2018)

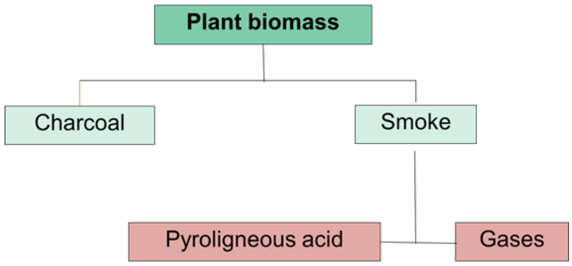

Figure 1 Pyrolysis Products from plant biomass.

Earlier research has revealed that wood vinegar, a by-product of forest biomass pyrolysis, has potential as a natural antioxidant and antibacterial agent. The investigations also reported that wood vinegar generated using different source materials may provide variable quantities and levels of bioactive components. This study uses GC-MS to analyze the chemical composition of wood vinegar and explore the connection between its ingredients and its bioactivity. The safety and bioactivity of wood vinegar make it a promising candidate for natural medicine, particularly in the context of its antioxidant and antibacterial properties.

Materials and methods

Generally, the biomass offcut was prepared for charcoal production using a pyrolyzer. The pyrolysis process takes about 2-3 hours at a temperature of 350-450°C with input capacity depending on the capacity of the pyrolyzer. The top of the vessel was closed with a flange with a vapour outlet and an entry for the thermocouple. The vapour outlet was connected to a water-cooled condenser, a tar and water receptacle, and an gas outlet. The vessel fixed on a stand was placed in an insulated furnace heated by a burner. **Figure 2** depicts the process flow of charcoal and wood vinegar production via carbonization or pyrolysis process.

Figure 2 R&D in charcoal production.

Potential in industrial applications

Charcoal, which is typically utilized as fuel, is used extensively in both industry and daily life. It is a highly specific surface area porous material that can be used for various purposes, such as better water quality, indoor deodorization, humidity control, and air filtration. It is used in a wider range of applications, such as in medicine (antibacterial agent, gastrointestinal absorbent in overdoses and poisoning, reducing flatulence, diarrhea treatment, oral hygiene), pharmaceuticals (antimicrobial agent), agriculture (growth stimulation, organic fertilizer), wastewater treatment, food (food preservation) and boiler industry (Quattara et a., 2024). A recent trend has been using food products to stay healthy. These materials are advertised as having the capacity to absorb unclean pollutants like heavy metal ions and to cleanse the stomach and intestines after eating (Lin 2017).

The translucent and brown-red liquids of bamboo vinegar can be divided into three main categories: acid, phenol, and neutral chemicals. There are approximately 80–200 components in vinegar: 3% aldehyde, 5% alkone, 5% alcohol, 4% ester, 40% phenolic, and 32% organic acid. Typically, 80% of dehydrated vinegar is water (Lin 2017). Even at minimal concentrations, the organic compounds found in vinegar can be useful for a variety of applications, including insect repellent, an ingredient in medicines, cosmetic and personal care products, wood preservative and termite, mordant in the dyeing process, soil fertilizer, plant growth promoter or inhibitor, animal feed additive and odour remover. **Figure 2** depicts some of the potential of charcoal and wood vinegar in industrial applications.

Figure 3 The potential of charcoal and wood vinegar in Industrial applications.

FRIM' s R&D in developing antiseptic liquid soap using bamboo vinegar

FRIM has researched developing an antiseptic liquid soap using bamboo vinegar as a potential precursor in medicinal applications. Chemical compounds in bamboo vinegar were extracted by a liquid-liquid extraction. The extraction was carried out by adding ethyl acetate into a vial containing bamboo vinegar, which was mixed using a vortex mixer three times and left to settle. The ethyl acetate extract was collected in a test tube, and sodium anhydrase was added to remove the excess water. A gas chromatography-mass spectrum study was performed using a DB-5 fused silica capillary column. The temperature of the column was maintained at 50°C for two minutes, after which it was programmed to rise at 2°C/min to 100°C for one minute, to rise at 8°C/min to 180°C for one minute, and to rise at 10°C/min to 250°C for two minutes. Mass spectral data and peak retention durations were used to make tentative identifications of volatile components. **Table 1** summarizes the chemical composition of bamboo vinegar.

Table 1: Chemical composition of bamboo vinegar

Compound	Concentration
Propanoic acid	0.01
1-hydroxy-2-butanone	0.12
3,4-dihydropyran	0.08
Butanoic acid	0.09
Furfural	0.19
2-furanmethanol	0.04
2-cyclopenten-1-one	0.02
1-methylbicycloheptane	0.02
Phenol	0.09
2-methoxy-phenol	0.24
3-methyl-phenol	0.04
2-methoxy-4-methylphenol	0.02
4-ethyl-phenol	0.02
4-ethyl-2-methoxy-phenol	0.15
2,6-dimethoxy-phenol	0.04
Benzene	0.02
Vanillin	0.03
3-furancarboxylic acid	0.04
Ethanone	0.02
2-pentanone	0.01
Cyclohexane	0.01
Iron	0.01
Pyridine-3-carboxamide	0.01

The anti-microbial activity was carried out against Staphylococcus aureus ATCC 33591 (Methicillin-susceptible *S. aureus*), S. ATCC 25923 (Methicillin-resistant *S. aureus*), *S. aureus* ATCC 700699 (Vancomycin intermediate *S. aureus*) and *S. aureus* US300 (a strain of community-associated methicillin-resistant *S. aureus*). The anti-microbial activity of bamboo vinegar was carried out by determining the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) using thiazolyl blue tetrazolium bromide (MTT) (Table 2). MIC less than 1 µg/µl is considered good activity (Mastura *et al.*, 2019). **Figure 3** shows the overall process flow of the development of antiseptic liquid soap using bamboo vinegar.

Table 2: Antimicrobial properties of bamboo vinegar.

Microbes	Bamboo Vinegar	
	MIC (µl/ml)	MBC (µl/ml)
S. aureus ATCC 33591	25	25
S. aureus ATCC 25923	12.5	25
S. aureus ATCC 700699	25	25
S. aureus US300	25	25

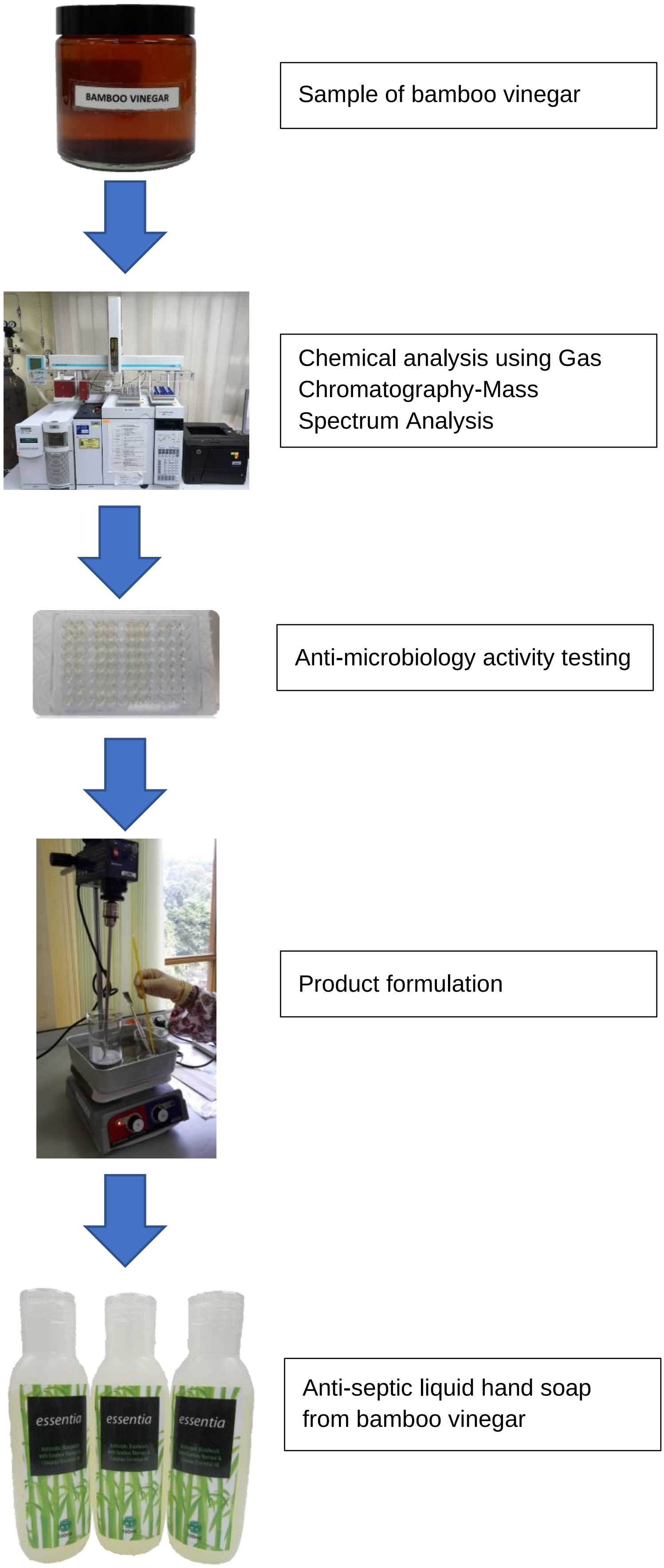

Figure 4 Process flow of development antiseptic liquid soap using bamboo vinegar.

Conclusion

Bamboo vinegar has antiseptic properties based on its chemical composition and antimicrobial activity. Therefore, bamboo vinegar can be developed as an antiseptic product, such as liquid hand soap. Antiseptic liquid hand soap was formulated by incorporating deionized water, surfactant, foam booster, chelating agent, preservative, bamboo vinegar as the active ingredient, essential oil and citric acid.

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References

Ho, C.L., Lin, C.Y., Ka, S.M., Chen, A., Tasi, Y.L., Liu, M.L., Chiu, Y.C. & Hua, K.F. (2013). Bamboo vinegar decreases inflammatory mediator expression and NLRP3 inflammasome activation by inhibiting reactive oxygen species generation and protein kinase C-α/δ activation. *PLoS One*, 8(10), 75738.

Hou, X., Qiu, L., Luo, S., Kang, K., Zhu, M. & Yao, Y. (2018). Chemical constituents and antimicrobial activity of wood vinegars at different pyrolysis temperature ranges obtained from Eucommia ulmoides Olivers branches. *RSC advances*, 8(71), 40941-40949.

Lin, H.C. (2017). Preliminary safety evaluation of bamboo pyrolysis products: Charcoal and vinegar. *In Bamboo-Current and Future Prospects*. IntechOpen.

Mastura, M., Saiful Azmi, J., Mazurah, M.I., Fadzureena, J., Nik Musaadah, M., Adiana, M.A., Tan, A.L., Madihah, M.N., Intan Nurulhani, B. & Norini, B. (2019). Meneroka potensi, memperkasa tradisi: inisiatif bioprospek entiti antimikrob berasaskan pengetahuan tradisi orang asli semenanjung Malaysia. *In Prosiding Seminar Pemuliharaan dan Pemerkasaan Pengetahuan Tradisi 2019*. Pp 92-95.

Ouattara, H.A.A., Niamke, B.F., Ahoke, M.E.M.F., N'guessan, J.L.L., Yao, J.C., Amusant, N. & Dumarcay, S. (2024). Physicochemical characterization, chemical composition and antioxidant activities of pyroligneous acids from cocktails of wood and agricultural residues from Ivory Coast. *Journal of Analytical and Applied Pyrolysis*, 181, 106629.

Souza, J.L.S.D., Guimarães, V.B.D.S., Campos, A.D. & Lund, R.G. (2018). Antimicrobial potential of pyroligneous extracts–a systematic review and technological prospecting. *Brazilian Journal of Microbiology*, 49, 128-139.

Yang, J.F., Yang, C.H., Liang, M.T., Gao, Z.J., Wu, Y.W. & Chuang, L.Y. (2016). Chemical composition, antioxidant, and antibacterial activity of wood vinegar from *Litchi chinensis*. *Molecules*, 21(9), 1150.