Oilseeds and Seed Oils of *Shorea macrophylla* and *Shorea palembanica*: Evaluation of Proximate, Antinutritive Factors and Chemical Composition

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Shorea macrophylla (*S. macrophylla*) and *Shorea palembanica* (*S. palembanica)* are known as "*Engkabang Jantung*" and "*Engkabang Asu*", respectively, by natives in Sarawak, Malaysia. The oilseeds remain underused due to a lack of scientific approach. This study aimed to determine proximate compositions and antinutritional factors of *S. macrophylla* and *S. palembanica* seeds and compare the fatty acid profiles, chemical properties and antioxidant activity between mechanical extraction (ME) and Soxhlet extraction (SE). The proximate compositions of *S. macrophylla* and *S. palembanica* seeds were 21.47% and 27.25% (moisture); 0.67% and 1.98% (ash); 41.37% and 49.06% (total lipid); 79.44% and 82.37% (total carbohydrate); 15.67% and 7.72% (crude fiber), respectively. Seeds of *S. macrophylla* and *S. palembanica* contained high levels of K (1186.50 and 400.17 mg/100 g), Ca (238.31 and 128.62 mg/100 g), Mg (300.50 and 117.17 mg/100 g), and Na (75.12 and 30.14 mg/100 g). The antinutritional factor phytate was detected in small concentrations in both species. At the same time, oxalate was found at a higher concentration in *S. palembanica* (2.43 mg/100 g) than in *S. macrophylla* (1.91 mg/100 g). The bioavailability of Ca and Zn influenced by antinutritional factors phytate and oxalate was calculated based on their molar ratios. The bioavailability of minerals affected by phytate did not exceed the critical value, suggesting adequate mineral absorption. However, high oxalate content exceeded the critical value of bioavailability (2.5), indicating insufficient mineral availability. SE was more efficient in extracting *Shorea* oils. Stearic, oleic and palmitic acids were the major fatty acids in *S. macrophylla* and *S. palembanica* oils, with no significant difference in fatty acid profiles between types of extraction ($p>0.05$). The acid (AV) and peroxide (PV) values of ME oils (AV: 3.47 to 4.75 mg NaOH/g; PV: 7.96 to 10.62 meq O_2/kg) were lower than SE oils (AV: 4.69 to 8 mg NaOH/g; PV: 9.92 to 14.58 meq O_2/kg). Therefore, mechanical extraction is considered the method of choice to extract *Shorea* oils. The iodine value (IV), AV, and PV of *Shorea* oils do not meet the required standards of the Indonesian National Standard (SNI) of Tengkawang butter and Cocoa Butter standards. Thus, a further refining process is suggested to increase the quality of *S. macrophylla* and *S. palembanica* oils.

Keywords: *Shorea;* mineral content; anti-nutritive; extraction method; antioxidant activity

Received: August 2022; Accepted: September 2022

Oilseeds are mainly derived from oil-producing plants such as rapeseed-mustard, soybean, sunflower, and oil palm [1]. Oilseeds contain fats, vitamins, minerals, carbohydrates, fiber, and protein [2]. Consuming oilseeds can have health benefits. Oilseeds yielding 20% to 40% oil can be categorized as edible or non-edible depending on the use [2]. In response to population growth, the need for seed oils continues to rise, and food scientists continue to research seed oils' nutritional and functional properties [3]. Several countries have examined underutilized plant resources to produce valuable oils. Morocco's argan oil has been utilized in various culinary, medicinal, and cosmetic uses worldwide [4].

Malaysia is one of the biodiversity hotspots with the richest floral diversity, particularly in Sarawak and Sabah, which house an estimated 12,000 species [5]. Several oil-producing plant species within the genus *Shorea* [6] are underutilized, and research on this genus is still scarce. *Shorea macrophylla (S. macrophylla*) and *Shorea palembanica* (*S. palembanica)* (Fig. 1(a) and (b)) can be found in Borneo (Malaysia, Indonesia and Brunei) [7]. These species, named locally as "*Engkabang Jantung*" [8] and "*Engkabang Asu*" [9], are closely related to *Shorea stenoptera (S. stenoptera)* (Borneo tallow) and *Shorea robusta (S. robusta)* (Sal). *Shorea* seed oils have been utilized as cooking oil and butter in traditional Sarawak cuisine [10]. Despite their popularity among Sarawak locals, the usage of *S. macrophylla* and *S. palembanica* oils on a larger scale has not been explored. Research on oil extraction from these two *Shorea* seeds is currently limited.

Figure 1(a). *S. macrophylla* seed

Figure 1(b). *S. palembanica* seed

Studies on *Shorea* species have been reported, including *S. robusta* as a native species of India [11] and *S. stenoptera* as an Indonesian species [12-13]. *S. macrophylla* and *S. palembanica* seeds from Sarawak, Malaysia, may differ compared to the aforementioned *Shorea* species due to differences in the species, geographical location, and environment affecting the oilseed content [14-18]. Nesaretnam & Ali [10] and Shashi Kumar et al. [11] employed the Soxhlet extraction method, while Gusti & Zulnely [12] and Darmawan et al. [13] extracted *Shorea* oils using the traditional "*apit*" extraction process. Extraction method influences oil yield and types of minor lipids [19], tocopherol content, and antioxidant activity in oil [20]. Antioxidants are significant in oil because they can inhibit oxidation and prevent oil degradation [21]. Reports on antioxidant activity and total phenolic content of *Shorea* oil are still scarce.

Vegetable oil production generates a large number of by-products [22], putting a significant amount of social and environmental pressure on efficient reutilization [23] since oilseed cakes have substantial proportions of carbohydrates, protein, fiber and minerals [22, 24]. The study on proximate composition, minerals, and antinutritive factors on *Shorea* oilseeds from Borneo is minute [10]. Therefore, this study compares oil production, chemical characteristics, and antioxidant activity of *S. macrophylla* and *S. palembanica* oils extracted using Soxhlet and mechanical extraction methods and their proximate compositions, mineral content, and antinutritive factors.

EXPERIMENTAL

Chemicals and Materials

H_2SO_4 (18 M, HmbG), NaOH (EMSURE™, ACS Reagent), ethanol (~99.8% undenatured, R&M Chemicals), desiccant beads (SiO_2, Sigma-Aldrich), D(-)-fructose (MERCK), HNO_3 (69-70%, HmbG), HCl (Mallinckrodt Chemicals, ACS grade), methyl red (R&M Chemicals), concentrated ammonia (25%, PC Laboratory), $CaCl_2$ (anhydrous, UNI CHEM), $KMnO_4$ (UNIVAR, Analytical reagent), NH_4SCN (EMSURE™, ACS, ISO, Reag. Ph Eur), $FeCl_3$ (Bendosen), gallic acid (Sigma Life Science), iodine (resublimed, SYSTEM), chloroform (J.T.Baker, ACS Reagent), Wijs solution (Merck), KI (Bendosen), $Na_2S_2O_3$ (Fischer Scientific, Analytical reagent), starch (China National Chemicals Import), diethyl ether (BDH Analar®), phenolphthalein (UNIVAR, Analytical reagent), glacial acetic acid (J.T.Baker,