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Sacha inchi (*Plukenetia volubilis* L.): Its potential as foodstuff and traditional medicine

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Abstract

The search for natural, functional, and healthy products based on local knowledge continues, such as sacha inchi (SI) or *Plukenetia volubilis* L. (Euphorbiaceae). This plant has long been used by the Icha tribe in Peru because it has a high protein and vegetable oil content. This study aims to explain the potential use of SI as a food ingredient or traditional medicine. The method used in the study is library research using data obtained online at Google Scholar using the keywords sacha inchi, *P. volubilis* and uses *P. volubilis*. The SI is an indigenous Peruvian plant that has been cultivated in various parts of the world, including Indonesia. The nutritional value of SI is so high that it is considered a "super food" because it is high in polyunsaturated oils, high quality protein, essential amino acids, dietary fiber, minerals, tocopherols, phytosterols, and phenolic compounds. The seeds of *P. volubilis* are used for various anti-oxidants, anti-cancer, anti-hypercholesterolemia, anti-hypertensive and anti-microbial properties. The proportion of unsaturated fatty acids in SI seeds is high, including Ɣ and δ -tocopherol, but is relatively stable against oxidation, so storage needs to be developed. The SI seeds have the potential to be developed as a nutraceutical, namely healthy food, especially to overcome cholesterol and hypertension.

Keywords: Sacha inchi; *Plukenetia volubilis*; Tocopherol; Nutraceutical

1. Introduction

Current global challenges include climate change, increasing population size, lack of food security, malnutrition, and degradation of agricultural land [1], so that reforming food production systems is very important. Currently, people are looking for natural, functional, and healthy products including sacha inchi (SI) or *Plukenetia volubilis* because they contain high protein and vegetable oils [2]. Various types of wild plants that have the potential as alternatives to support resilience to climate change, nutritional benefits, cultivation on marginal lands, and increasing income opportunities for small farmers [1] such as SI. The SI is a food ingredient that grows in the Peruvian rainforest [1,3,4], that has been used for centuries as food for indigenous peoples of the Amazon rainforest [5]. The SI is also called the "lost plant" of the Incas [1] because information on its use is not heard even though it is rich in nutritional value.

The whole sacha inchi plant has been used to produce nutritional, cosmetic and pharmaceutical products [4,5], so it has promising economic value [7]. This has implications for SI cultivation in various countries including Indonesia because it has high economic value. Sacha inchi oil is a high-quality product with market potential and a wealth of bioactive compounds beneficial for food and health [8]. The seeds can be squeezed for oil production or roasted and served as a snack, while the dried leaves can be used to make a kind of tea [7]. The SI seed oil commercialized in Peru contains the range 0.16–1.86 (% a-linolenic acid) [8]. Oil from cold-pressed seeds, sold under the commercial name SI oil is actually

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widely preferred because it contains a high percentage of omega 3 and omega 6, and is therefore used as a dietary supplement [9].

This plant is so famous that almost all parts of it are used, starting from the leaves, fruit skin, fruit and seeds. The leaves of SI have been widely processed into herbal teas (Fig. 1) which are claimed to have many benefits, especially to treat diseases related to the circulatory system and heart, although scientific evidence is still very minimal. SI seeds and leaves after roasting however high consumption of fresh seeds and leaves should be avoided. Heat processing should be applied prior to consumption of Inca nut seeds and leaves to reduce phytotoxins and potential health risks [7]. The oil of SI is traditionally used for skin care, to maintain skin softness, and for the treatment of wounds, insect bites and skin infections, in tropical contexts where the skin is frequently damaged [9]. Currently SI seeds are being industrialized to obtain oil (rich in omega-3 and -6) [2]. Due to its high content of omega-3, omega-6, and omega-9 fatty acids, this oil is used in medical and cosmetic applications [10].

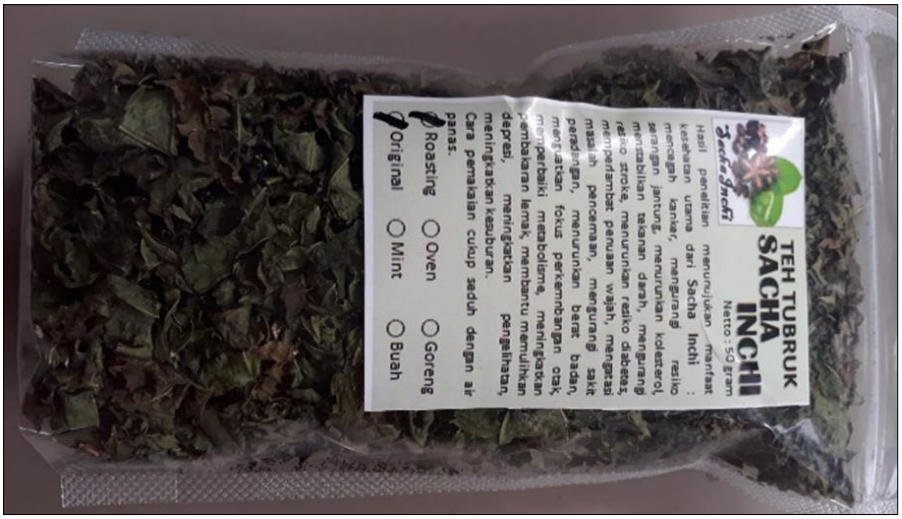

Figure 1 The processed leaves of sacha inch (*Plukenetia volubilis* L.) in the form of "tubruk tea"

Interest in cultivating and developing as a new source of oil rich in unsaturated fatty acids is increasing [4] in various countries including Indonesia. When compared with sunflower oil, the linolenic content of SI seed oil is higher. The proportion of ALA/linoleic acid was 1.37 in SI oil and 0.01 in sunflower oil [11]. The SI oil appears to have a beneficial effect on the lipid profile of patients with dyslipidemia, but its efficacy and safety should be evaluated in randomized clinical trials [12]. This study aims to explain the botany and benefits of P. volubilis as foodstuff and traditional medicine.

2. Methods

The method used in this study is library research through literature study. Libraries are obtained online, especially from Google Scholar by using the keywords *P. volubilis*, sacha inchi, and uses *P. volubilis*. The results obtained were synthesized so that the botany and utilization of *P. volubilis* were explained in a comprehensive manner.

3. Results and discussion

3.1. Botany of *Plukenetia volubilis* L.

The genus *Plukenetia* is a genus belonging Euphorbiaceae which is estimated to have nineteen species and is distributed in the pantropical area. Species in the genera *Plukenetia* are climbing plants or lianas; only rarely do they creep, perennial herbs. This genus is characterized by ovaries with four carpels. The most striking character for identifying this genus in the field is the presence of basilaminer, round, or elliptical glands on the adaxial side of leaves and tetramerous fruits. One species that is widely used as food and traditional medicine is *Plukenetia volubilis* or known as sacha inchi. *Plukenetia volubilis* is synonymous *Fragariopsis paxii* Pittier; *Plukenetia macrostyla* Ule; *Plukenetia peruviana* Müll.Arg.; and *Sajorium volubile* (L.) Baill [13].

Morphology: *P. volubilis* is a single-dwelling, climbing plant (Fig. 2A). The leaves are single and scattered (Fig. 2A.). The leaf blade is triangular-ovoid, 6 cm – 13 (-20) cm long and 4 cm – 10 (-12) cm wide, with a truncated or heart-shaped

base. Margins are crenate or jagged; there is one glandular protrusion on the adaxial side at the tip of the petiole. Inflorescence, 5 cm – 18 cm long, racemose-shaped, elongated, and single (bisexual). The number of female flowers is much less than that of male flowers (Fig. 2B), that is from 60 male flowers only 1-2 female flowers per inflorescence [14]. Flowers with a solitary pistil at the base node; stilar column partially or completely conate, 15 mm – 30 mm long; numerous sub-globular masculine flowers clustered at the distal node; there are 16 – 30 stamen cones (0.5 mm long) with visible filaments. The capsules are tetra (Fig. 2C) or pentamerous, glabrous, and 2.5 cm – 6 (- 7) cm in diameter [15]. Seeds, 1.5 cm – 2 cm x 0.7 cm – 0.8 cm, are lenticular in shape, laterally compressed, and brown in color with dark irregular patches [15]. This plant is distributed from the highland Andean rain forests to the lowlands of the Peruvian Amazon [9].

A **B** **C**

Figure 2 The sacha inchi (*Plukenetia volubilis* L.). A. Habitus; B. Flowering with female flowers and male flowers); C. The fruit is still young in the form of tetramerous

3.2. Uses of Sacha Inchi

3.2.1. Foodstuff

The seeds of SI have been used for centuries as food for indigenous peoples of the Amazon rainforest [4,5] which are used as functional food [4] so they have considerable commercial value [5]. Due to its high nutritional value, SI is considered a "superfood" because it is high in polyunsaturated oils, high quality protein [5,16], essential amino acids, dietary fiber, minerals, tocopherols, phytosterols. and good phenolic compounds [5]. The seeds of SI are rich in α-linolenic acid (ALA) (an omega-3 fatty acid) [10,11,17] so it is classified as a vegetable oil with the highest proportion of unsaturated fatty acids [10]. The protein content and all essential amino acids contained in SI seeds are sufficient when compared to the FAO/WHO recommended pattern for adult humans and are easily digested [16]. Seed protein is stored in the form of albumin which is about 25% (w/w) by weight of defatted seed flour, representing 31% of total seed protein [16]. The content of polyunsaturated fatty acids omega-3 and omega-6 seeds (~85% of total fatty acids) [18], tocopherol, and α-tocopherol (more than 50%) [19].

The SI has been used in the pharmaceutical food industry [17], cosmetics [10] as a new oil source rich in unsaturated fatty acids [4], carbohydrates and proteins [16]. The high content of omega-3, omega-6, and omega-9 fatty acids of SI seeds cause their use for medicine and cosmetics [10]. In Peru SI oil has been commercialized and its oil exports are used for consumption, in the food, cosmetics and pharmaceutical industries thereby increasing significant economic income for the producers [20]. In the food industry, SI seeds are squeezed for oil production or roasted to serve as a snack, while the dried leaves can be used to make tea [7]. Besides containing fat, SI seeds also contain vitamins A and E, and phytosterols, especially stigmasterol, campesterol, and 5-avenasterol [10]. The seeds of SI are rich in oil (41.4%) and protein (24.7%). The main minerals in SIS are potassium (5563.5 ppm), magnesium (3210 ppm) and calcium (2406 ppm). Fatty acid analysis SI oil contains a-linolenic acid (50.8%) and linoleic acid (33.4%) as the main fatty acids [6].

The SI oil that is traded contains main components such as triglycerides, fatty acid methyl esters, tocopherols, sterols and hydrocarbons [21]. Various researchers reported that the quality of SI oil was highly variable and various other plants were found as additives. Palmitic acid, oleic acid, α-tocopherol, d-tocopherol, campesterol and stigmasterol are compounds that indicate the authenticity of commercial SI oils [20]. Some commercialized SI oil samples contain high levels of tocopherol and d-tocopherol and also contain fatty acids, especially a-linolenic, linoleic, oleic and palmitic acids. Fourteen sterols and eleven alcohols were identified (b-sitosterol, stigmasterol, campesterol, D5-avenasterol, triterpene alcohol, lanosterol isomer 1 and cycloartenol) as major components of SI oil [20]. Some commercialized SI oils do not

meet the basic requirements because it is often found that various additional compounds such as the flavones sesamin and sesamolin indicate the addition of compounds from sesame oil [21].

Although the nutritional content of SI seeds is high, the content is greatly influenced by the processing process. Roasting seeds reduces the tocopherol content, but does not affect the fatty acid profile of the seeds [22]. Roasting can reduce bitter taste and eliminate anti-nutritional and anti-nutrient compounds in SI seeds which continue to decrease with increasing roasting temperature because these compounds are not heat-resistant except for saponins [23]. Various methods were developed to obtain oil from SI seeds such as supercritical carbon dioxide (SC-CO_2) [24] and cold-pressed [7]. Tocopherol content decreased significantly in the storage process, however the rate of oxidation of each type of fat varied. The α-linolenic acid is more easily oxidized than other fatty acids present [22]. SI seeds extracted by SC-CO2 contained 54.3% oil, of which 50.5% was linoleic acid (omega-3) and high tocopherol content of about 2-3 g/kg oil [24]. Temperature drying (30°C), roasting (120°C in 20 minutes), vacuum packaging in the laminate and storage at 4°C are recommended to maintain the tocopherol content [17]. Although the tocopherol concentration is relatively high, this oil is relatively stable against oxidation [10].

3.2.2. Traditional Medicine and Bioactivity of Sacha Inchi

The use of SI seeds as traditional medicine has also been widely reported, although it is not comparable to the reported nutritional value. The SI has been long used in the food, cosmetic and pharmaceutical industries [4]. In traditional medicine SI oil is used for skin care, treatment of wounds, insect bites and skin infections [9]. The SI oil has also been applied and has potential in the treatment of coronary heart disease, arthritis, diabetes, attention deficit hyperactivity disorder (ADHD), and inflammatory skin diseases [10]. The use of SI as a traditional medicine is related to its bioactivity. The following will explain further the bioactivity of SI as an antioxidant, anti-cancer.

Anti-oxidant and Anti-cancer

Plants used as antioxidants are plants that produce compounds that can suppress or inhibit free radicals. Free radicals are one of the causes of cancer, therefore antioxidants are often associated with anti-cancer. The fruit peel of SI is an alternative source of antioxidants for the food or nutraceutical industry [18]. The leaf of SI extract contains phenolic compounds, steroids, terpenoids which are related to their capacity as antioxidants which are declared equivalent to ascorbic acid (EEA/g) ranging from 59.31 to 97.76 EAA/g, while the 2,2-difenil-1-pikrilhidrazil (DPPH) test value is 62.8% to 88.3% [25].

The ability of SI as an antioxidant is strongly influenced by various factors such as temperature [22,23], cultivar [26], storage process [22] and the compounds used for extraction. The seeds of SI increase antioxidant activity higher than others [22,23] because they have a higher phenolic content [23] and lower oxidation states [22]. Various SI seed cultivars contained varying total phenolics, total hydrophilic and lipophilic carotenoids so that the antioxidant capacity varied from 64.6 to 80 mg [26].

Administration of salicylic acid increased the activity of antioxidant enzymes including superoxide dismutase, catalase, guaiacol peroxidase, ascorbate peroxidase, and glutathione reductase and decreased dehydroascorbate reductase activity of SI seeds. Pretreatment of SI seeds with SA can induce antioxidant enzymes that cause an increase in cold tolerance [27]. Cell viability test showed that SI leaf extract was able to reduce the viability of cancer cells such as HeLa and A549 cells. Methanol and hexane extract (250 g/mL) SI decreased HeLa cell proliferation by 54.3% and 48.5, respectively, and cell death was induced via the apoptotic pathway [25]. The bioactivity of SI as an antioxidant and anti-cancer is thought to be related to the content of its secondary metabolites, especially phenolics. Chirinos et al [18] reported that the main phenolic in SI seeds was 74.5 ± 5.1 mg g-1 of which 93.1% were condensed tannins, free phenolic acids, hydrolyzed tannins, flavonoids and flavonoids.

Anti-hyper cholesterol and Anti-hypertension

Hypercholesterolemia is a metabolic disorder that results in blood cholesterol levels above normal which directly or indirectly have implications for hypertension. The bioactivity of SI as anti-hypercholesterolemia has been reported by Gonzales and Gonzales [28], Hanssen and Schmitz-Hübsch [10], and Chirinos et al [2]. The consumption of SI oil causes total serum cholesterol and low-density lipoprotein (LDL) cholesterol levels and arterial blood pressure to decrease and increase high density lipoprotein (HDL) cholesterol so it is very good for health [28]. The oil SI appears to have a beneficial effect on the lipid profile of patients with dyslipidemia, but its efficacy and safety should be evaluated in randomized clinical trials [12]. After 2 hours consumption of SI oil showed a decrease in plasma cholesterol δ-triacylglycerol lipoprotein. Consumption of SI oil increased α-linolenic acid and docosahexaenoic acid (DHA) in plasma [11]. The consumption of SI oil resulted in a decrease in the mean values of total cholesterol, and non-esterified fatty

acids, and an increase in HDL. The SI oil appears to have a beneficial effect on the lipid profile of patients with dyslipidemia, but its efficacy and safety should be evaluated in randomized clinical trials [12]. Gonzales & Gonzales [28] reported that consumer acceptance (acceptability) when consuming SI oil was low, especially in the first week, and increased in line with the side effect of nausea.

Anti-Microbial

Microbes cause various infectious diseases in humans including skin infections. *Staphylococcus aureus* involved in many skin pathologies (impetigo, folliculitis, furuncles and subcutaneous abscesses) and is one of the main pathogens found on the skin. The SI oil is more active as an anti-adherent (preventive) than coconut oil on keratinocytes. There was no significant difference between the releasing (curative) effects of the two oils on keratinocytes but SI oil was almost 5 times more active on the release of *S. aureus* from human skin. The use of SI oil on skin cells is safe and efficient in inhibiting the attachment of S. aureus and supports the traditional use of pure SI oil in skin care [9].

4. Conclusion

The nutritional value of *Plukenetia volubilis* is so high that it is considered a "super food" because it is high in polyunsaturated oils, high quality protein, essential amino acids, dietary fiber, minerals, tocopherols, phytosterols, and phenolic compounds. The seeds of *P. volubilis* are used for various anti-oxidants, anti-cancer, anti-hypercholesterolemia, anti-hypertensive and anti-microbial properties.

Compliance with ethical standards

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