JFSP Vol.11, No.3, September-December 2025, Page: 163-176
pISSN: 2549-9068, eISSN: 2579-4558
Jurnal Farmasi Sains dan Praktis
(JFSP)
http://journal.unimma.ac.id/index.php/pharmacy

PHYSICOCHEMICAL CHARACTERISTICS AND PHARMACOLOGICAL ACTIVITY OF SACHA INCHI SEED OIL (*Plukenetia volubilis* L.): A LITERATURE REVIEW

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https://doi.org/10.31603/pharmacy.v%vi%i.12719

Article info:
Submitted : 26-11-2024
Revised : 23-09-2025
Accepted : 24-09-2025

Publisher:
University of Muhammadiyah Magelang

ABSTRACT
Sacha inchi (*Plukenetia volubilis* L.) of the family *Euphorbiaceae* is native to the Amazon rainforest of Peru. SaIn seeds are known to contain significant fatty acids such as linolenic acid (Omega-3), linoleic acid (Omega-6), and oleic acid (Omega-9). Several studies have revealed the pharmacological potential of Sacha inchi (SaIn) based on its bioactive compound profile. The purpose of this review article is to provide information on the pharmacological activities and describe the physicochemical characteristics of SaIn seed oil. This review article was conducted through a literature study of national and international journals published in the last ten years from Google Scholar, NCBI-Pubmed, and Crossref with search keys in the form "Plukenetia volubilis L.", "Sacha inchi", "pharmacological activities and physicochemical characteristics of Sacha inchi". Based on the literature review, the physicochemical characteristics of SaIn seed oil such as peroxide value, iodine number, saponification number, and acid number were found to vary depending on the extraction method. SaIn has pharmacological activities as an antioxidant, anticancer, antidiabetic, antiobesity, anticonvulsant, anti-aging, antihyperlipidemia, antibacterial and potential for alzheimer therapy. The novelty of this article lies in the integration of discussions on the variations in extraction methods and their effects on physicochemical characteristics, as well as the presentation of a broader scope of Sacha inchi's pharmacological activities in one comprehensive review.

Keywords: Sacha inchi (SaIn); Plukenetia volubilis L; Physicochemical Characteristics; Pharmacological Activities

1. INTRODUCTION

Sacha inchi (*Plukenetia volubilis* L.) of the family Euphorbiaceae is native to the Amazon rainforest of Peru. This plant has been known and used by the indigenous people of the Amazon for centuries as a source of food and medicine. The plant is also cultivated in Latin American countries like Colombia, Brazil, Ecuador, Bolivia, Nicaragua, Guatemala, Costa Rica, Mexico, and Cuba, as well as in Asian countries such as China, Cambodia, Laos, and Thailand, which are producers of SaIn. In Indonesia, the plant was first identified in Java, where it is locally known as "kacang inka" or "kacang gunung," and has traditionally been consumed as a vegetable. Considering its numerous health benefits, particularly from the oil-rich seeds, Sacha inchi has begun to be cultivated more extensively in Indonesia (Kong et al., 2023; Saras, 2023; Tianara et al., 2024).

Sacha inchi (SaIn) is a perennial, woody, climbing plant that is monoecious, bearing both male and female flowers on the same individual and can grow up to 2 – 4 m tall, its leaves are heart-shaped with a length of about 10 – 15 cm and a width of about 8 – 12 cm. SaIn fruits are round in shape with a diameter of about 2 – 3 cm and have a hard skin that protect the seeds. The seeds are flattened and light brown in color. The flowers are organized in axillary racemes, with the male flowers clustered toward the upper part and the female flowers located at the base. Male flowers are cream-colored, small-bracted, and deciduous, with a reduced protective bract, borne on pedicels, unisexual, and radially symmetrical. The Optimal growing conditions for SaIn include temperatures ranging from 10 to 37°C, and it flourishes in sandy, well-drained soils. The plant performs best at altitudes between 200 and 1500 m above sea level (Khine et al., 2020; Kong et al., 2023; Saras, 2023).

SaIn is known to have high nutritional content, including oil, fiber, protein, carbohydrates, and fats. Protein is the highest content found in SaIn seeds. In addition, SaIn seeds contain various types of minerals including potassium, phosphorus, calcium, sulfur, aluminum, chlorine, zinc, iron, titanium, vanadium, copper, magnesium, manganese, molybdenum, sodium, selenium, and zinc (Borges et al., 2018; Kim & Joo, 2019; Kong et al., 2023; Kyaw et al., 2019; Muangrat et al., 2018). SaIn seed oil is known as a nutritious supplement because it contains high levels of vitamins A and E that act as antioxidants. Several studies have been out have conducted of the fatty acids contained in SaIn seeds, including saturated fatty acids (butyric acid, myrystic acid, margaric acid, stearic acid, arachidic acid), monounsaturated fatty acids (palmitoleic acid, oleic acid, gondoic acid, nervonic acid) and polyunsaturated fatty acids (lenoleic acid, g-linolenic acid, a-linolenic acid, eicosatrienoic acid, doxosdienoic acid) (Kim & Joo, 2019; Kyaw et al., 2019; Muangrat et al., 2018).

The composition of the fatty acids contained in SaIn seeds are important fatty acids, including linolenic acid (Omega-3), linoleic acid (Omega-6), and oleic acid (Omega-9). In the research conducted by (Maya et al., 2023), SaIn seed oil obtained through the pressing method obtained linolenic acid content of 48.5%, linoleic acid at 34.8%, and oleic acid at 7.7%. By the same method (Soimee et al., 2020) obtained linolenic acid content of 42.3% and 39.5% for linoleic acid. The bioactive content of SaIn seed oil, such as omega-3 and omega-6, is beneficial for human health, including lowering the risk of diabetes mellitus, hypertension, hyperactivity disorder, coronary heart disease, and inflammatory skin diseases (Fanali et al., 2011; Gogus & Smith, 2010; Kyaw et al., 2019). Thus, this article review aims to provide information about the physicochemical properties and pharmacological activities of SaIn seed oil.

2. METHOD

The data sources for this review consisted of national and international peer-reviewed journals, with literature searches conducted in Google Scholar, NCBI-PubMed, and Crossref using combinations of keywords and Boolean operators such as *"Plukenetia volubilis L." AND ("compound content" OR "pharmacological activity" OR "extraction method")*. The search was limited to articles published between 2014 and 2024, filtered by language (English or Indonesian) and article type (original research). The inclusion criteria were studies focusing on *Plukenetia volubilis L.* or its seed oil in terms of extraction methods, physicochemical properties, or pharmacological activities, while the exclusion criteria comprised articles without accessible full text, lacking original data, or published as non-research formats. The selection process involved duplicate removal, screening of titles and abstracts, and full-text assessment, resulting in 50 eligible articles, from which relevant data were extracted and thematically categorized into three domains: extraction methods, physicochemical characteristics, and pharmacological activities. The literature selection procces in this review followed the PRISMA flow diagram as illustrated in **Figure 1**.

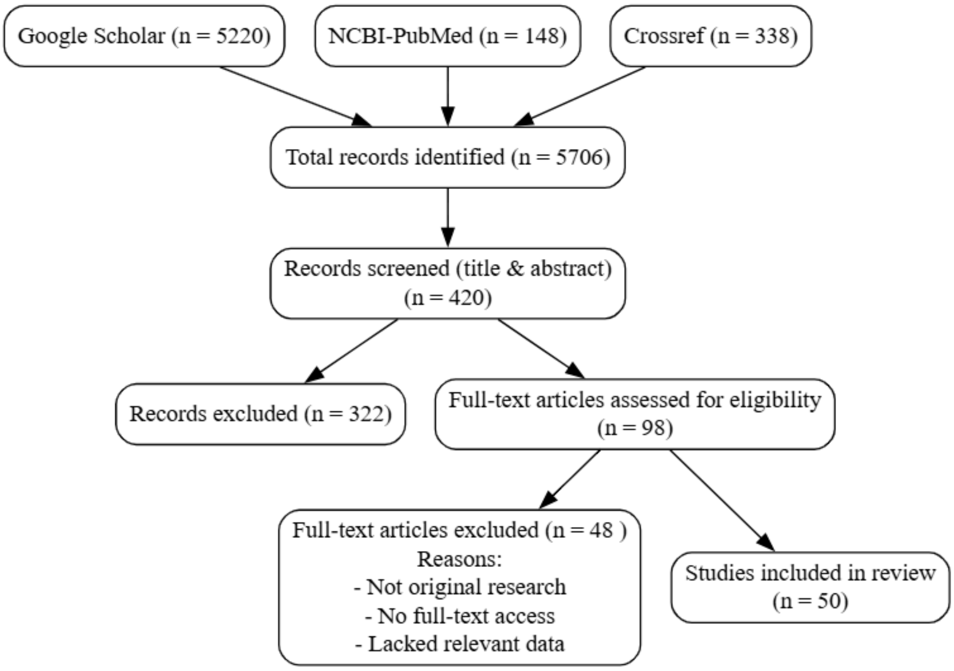

Figure 1. PRISMA flow diagram

3. RESULTS AND DISCUSSION

3.1 Sacha Inchi Seed Oil Extraction

Several extraction techniques have been employed to obtain SaIn seed oil, with Soxhlet extraction being one of the most commonly used methods. Despite its ability to generate relatively high oil yields, this method requires extended processing times and the use of organic solvents, which may result in residual contaminants and thus limit its suitability for pharmaceutical and nutaceutical applications (Borges et al., 2018; Jitpinit et al., 2022; Kong et al., 2023; Kyaw et al., 2019). Supercritical carbon dioxide (CO_2) can also be employed to extract SaIn, offering a highly effective method for obtaining essential oils and compounds used in the food, nutraceutical industries, and pharmaceutical. This method uses the properties of dissolution (solvation) and the transport capacity of supercritical CO_2 to separate the components present in the extract. By changing the temperature and pressure, it can change the density of CO_2 and the solubility of the solute in it, allowing for the separation of the desired components (Triana-maldonado et al., 2017). Supercritical fluids have the properties of liquid density, viscosity, low surface stress, and gas-like diffusion that are able to penetrate solid materials more effectively than ordinary liquids. Unlike conventional extraction, supercritical CO_2 extraction is a solvent-free method, eliminating the need to remove organic solvents from the final product (Manjare & Dhingra, 2019).

The extraction of SaIn may also involve the use of hydrolytic enzymes, including proteases and cellulases, which facilitate oil release by degrading the structural components of seed cells (Chinh et al., 2020). While enzymatic extraction can enhance yields and preserve thermolabile compounds, its industrial application is limited by the high cost of enzymes. To maximize SaIn yields, conditions such as time, temperature, solvent-to-sample ratio, and enzyme loading greatly influence. The variation of SaIn results in various methods can be seen in **Table 1**. Furthermore, the pressing method is a widely employed technique in the industrial sector. The results show that pressure and pressing time are factors that significantly affect the efficiency of SaIn extraction (Kong et al., 2023). For example, the extraction of SaIn by the screw pressing method carried out by Muangrat et al., (2018), this method has several advantages including cost-effectiveness, shorter extraction time than the extraction process with solvents, and does not leave solvent residues in oil products. The temperature of the press uses a variety of temperatures to extract the oil from the SaIn seeds. Mechanical screw pressing generally produces 75–95% of the oil from seeds and is capable of preserving more bioactive compounds such as antioxidants, thereby improving the oil's nutritional quality.

Although the oil yield obtained through mechanical pressing is comparatively lower than that achieved by Soxhlet or supercritical CO_2 extraction, this approach holds significant relevance for industrial-scale applications, particularly in the production of natural oils free from solvent residues. In a broader context, solvent-based techniques such as Soxhlet remain useful for laboratory-scale investigations; however, supercritical CO_2 extraction is more advantageous when high-purity oils are required for pharmaceutical and nutraceutical applications. Enzymatic extraction, despite its higher operational costs, offers notable benefits in preserving thermolabile bioactive constituents, while mechanical pressing continues to be the preferred method for large-scale industrial production, where the emphasis lies in maintaining natural quality, safety, and cost-effectiveness.

Table 1. SaIn Seed Oil Extraction Method

Extraction method	Operating conditions	Oil yield percentage (%)	Reference
Screw press	Dried seeds (60–90°C) Press temp. 60–90°C	18.14 - 40.63	(Muangrat et al., 2018)
Soxhlet	Seeds were extracted using n-hexane, ethanol and propanol.	45	
Solvent extraction	SaIn seeds are extracted using n-hexane while stirring for 4 hours.	38	(Borges et al., 2018)
Carbon dioxide (CO_2) extraction	Temperature conditions: 40°C, 50°C, and 60°C. Pressures: 300 bar and 400 bar. The extraction process lasts up to 6 hours with a constant CO_2 flow rate of 1.5 L/min.	38.1	(Jitpinit et al., 2022)
Soxhlet	Seeds are extracted using ethanol, i-propanol, and n-butanol solvents. Soxhlet for 0.5, 1, 3, 6 and 9 hours at 25°C	51.8 - 53.9	
Soxhlet	Seeds are extracted using petroleum ether solvents	42.30	(Kyaw et al., 2019)
Hydraulic Cold-Pressed Extraction (HCPE)	Extraction was carried out at 25°C at a pressure of 30, 40, 50 MPa for 10, 20, and 30 minutes.	28.90 - 42.12	(Kong et al., 2023)
Solvent extraction	Extraction using ethanol and n-hexane at a ratio of 1:20	43	
Ultrasonogrfi-assisted extraction (UAE)	The extraction using n-hexane at ratios of 1:20 and 1:30, with the temperature set at 60°C for 75 minutes.	44	
Enzymatic extraction	1% enzymes (chamzyme FP, flavourzyme, protamex, bromelain, papain, cellulase A, or a mixture of papain and cellulase A) at 40°C for 4 hours with stirring (600 rpm).	28.45	(Chinh et al., 2020)
Subcritical fluid extraction	SaIn was extracted using n-propane with a flow of 1 mL min^{-1} for 60 min at various temperatures and pressures	26.7 – 29.7	(Zanqui et al., 2016)
Soxhlet	Using a mixture of ethyl ether solvents: petroleum ether (1:1) for 16 hours.	42	

3.2 Physicochemical Characteristics of Sacha Inchi (SaIn) Seed Oil

An overview of the physicochemical characteristics of SaIn seed oil can be seen in **Table 2**. The parameters observed are peroxide value, iodine value, saponification value, and acid value. The acid value represents the level of free fatty acids formed due to the hydrolysis process of the oil or fat. The acid number is equivalent to the amount of KOH in milligrams needed to neutralize free fatty acids in 1 gram of oil or fat. A high acid value indicates poor handling or storage, as free fatty acids are typically produced through enzymatic or oxidative degradation. Oils with elevated acid values generally have reduced quality and stability (Hidalgo et al., 2019). The value of acids obtained from the Soxhlet method is 0.59 mg KOH/g oil (Kyaw et al., 2019). In contrast to the value obtained from the machine pressing method, which is around 0.38 ± 0.02 mg KOH/g oil (Maya et al., 2023). This difference in values is likely associated with the extraction methods employed. In Soxhlet extraction, variables such as solvent type, temperature, and extraction time can influence the extent of hydrolysis and the release of free fatty acids. Elevated acid values not only reflect poor oil quality but also shorten shelf life, as free fatty acids accelerate oxidation and can contribute to the formation of potentially toxic degradation products that threaten consumer safety.

The determination of peroxide value is ussed to assess the degree of oxidation or degradation of oil. The peroxide value obtained from the Soxhlet method is 2.00 meq O2/kg oil (Kyaw et al., 2019), and the method of pressing the machine ranges from 1.95 ± 0.26 meq O2/kg oil (Soimee et al., 2020). Extraction temperature can influence the peroxide value, as elevated temperatures tend to increase peroxide levels due to enhanced oxidation of fatty acids (Haile et al., 2019). Meanwhile (Maya et al., 2023) obtained a peroxide value of 11.01 meq O2/kg oil by the machine press method. Oil with high peroxide values indicates extensive lipid oxidation. This oxidative degradation reduces oil quality by producing rancid flavors and damaging essential fatty acids. Oils with peroxide values exceeding 9 meq O_2/kg are potentially harmful to health, due to high levels of reactive oxygen species (ROS) and secondary lipid oxidation products, which can induce oxidative stress, inflammation, and increase the risk of chronic diseases, including cardiovascular disorders. Therefore, oils with peroxide value greater than 10 meq O_2/kg are considered unstable and have a limited shelf life, making them less safe for long-term consumption (Konuskan et al., 2019).

The iodine value test is conducted to determine the concentration of unsaturated fatty acids present in the oil. The oil becomes more saturated as more iodine is absorbed (Muangrat et al., 2018). The iodine value obtained from the Soxhlet extraction is 183.69 g I_2/100 g oil, while the iodine value from the pressing method ranged from 203.00 ± 0.04 g I_2/100 g oil (Kyaw et al., 2019; Maya et al., 2023; Soimee et al., 2020). Based on the values obtained, the two extraction methods do not have significant differences. The iodine value is a critical parameter for evaluating oil quality, as it reflects the degree of unsaturation and influences oxidative stability and shelf life. Roasting seeds and extraction at elevated temperatures can induce partial oxidation of unsaturated fatty acids, leading to a reduction in iodine value. Oils with high iodine values, indicative of greater unsaturation, are more prone to oxidation, resulting in the formation of peroxides and other potentially toxic secondary compounds. Therefore, although elevated iodine values may suggest nutritional benefits due to unsaturated fatty acid content, they also raise concerns regarding storage stability and safety. Proper handling, the addition of antioxidants, or controlled storage conditions may be necessary to minimize oxidative damage in oils with high iodine values (Konuskan et al., 2019).

Saponification value is the amount is of milligrams of KOH needed to saponify 1 gram of oil or fat. The saponification values of the SaIn for the Soxhlet and pressing methods range from 1.55 – 168.58 mg KOH/g oil (Kyaw et al., 2019; Soimee et al., 2020). The saponification value is an important parameter for assessing the physicochemical characteristics of oils. A relatively low saponification value indicates that the oil is dominated by long-chain fatty acids, whereas oils rich in short-chain fatty acids (with relatively low molecular weight) exhibit higher saponification values. Oils with excessively high or low saponification values may have different susceptibilities to oxidation, which can affect shelf life and consumer safety. Oils with high unsaturated fatty acids are particularly prone to oxidation, requiring special attention during storage to prevent the formation of toxic compounds due to peroxidation. Physicochemical properties, this parameter is significantly influenced by various factors such as temperature, compression time, extraction method, and others (Kong et al., 2023).

Table 2. Physicochemical Characteristics of SaIn Seed Oil

Extraction Method	Peroxide Value (meq O2/kg oil)	Iodine Value (g 12/100 g oil)	Saponification Value (mg KOH/ g oil)	Acid Value (mg KOH/g oil)	% FFA	Reference
Screw press	1.94 - 2.27	102.66 - 104.05	182.18 - 195.11	1.94 - 5.90	0.97 – 2.97	(Muangrat et al., 2018)
Carbon dioxide (CO2) extraction	-	191.8 ± 1.7	190.2 ± 3.2	-	-	(Jitpinit et al., 2022)
Soxhlet	2.00	183.69	190.85	0.59	-	(Kyaw et al., 2019)
HCPE	5.71 – 9.07	176.22 – 197.76	-	1.82 – 2.16	0.91 – 1.08	(Kong et al., 2023)
Enzymatic Extraction	2.05 ± 0.06	193.40 ± 1.22	197.31 ± 3.10	2.73 ± 0.13	-	(Chinh et al. 2020)
Press Machine	11.01	179.32	-	0.38 ± 0.02	-	(Maya et al., 2023)
Press Machine	1.95 ± 0.26	203.00 ±0.04	168.58 ± 1.55	1.68 ± 0.03	-	(Soimee et al., 2020)
Cold *Pressing*	0.890 ± 0.05	93.80 ± 0.40	185.50 ± 0.20	-	0.200 ± 0.02	(Herrera-calderon et al., 2019)
Soxhlet	2.90 ± 0.2	-	-	0.37 ± 0.01	0.19 ± 0.0	(Chirinos et al., 2015)
Cold *Pressing*	1.92 ± 0.46	-	-	0.39 ± 0.04	-	(Gutiérrez et al., 2019)
Press machine	5.81 ± 0.5	192.5 ± 0.7	-	0.38 ± 0.02	-	(Hidalgo et al., 2019)

3.3 Pharmacological Activity of Sacha Inchi Seed Oil

The large amount of compound content contained in SaIn oil has led to many tests on the pharmacological activity of SaIn, including:

3.3.1. Antioxidants

The antioxidant activity test carried out showed the potential of SaIn oil as an antioxidant. Research conducted by (Kittibunchakul et al., 2023) shows the same FRAP, ORAC and DPPH values 4.27 µmol TE/100 g DW, 284.48 µmol TE/100 g DW, and 0.018 µmol TE/100 g DW. Where SaIn seeds those that underwent roasting showed antioxidant potential 1.5 to 2.7 times higher than raw seeds. It also shows the same results in research conducted by (Cisneros et al., 2014), where baked SaIn oil has a higher DPPH value of 0.38 µmol TE/g of oil compared to unbaked SaIn oil, which is 0.073 µmol TE/g of oil. According to the research by

(Borges et al., 2018) reported that the antioxidant activities of SaIn oil fluctuates depending on the roasting temperature. In measurements using DPPH, the control extract activity was 0.49 μmol TE/g seeds, 0.37 μmol TE/g seeds at 120°C, and 0.61 μmol TE/g seeds at 160°C, which showed an increase of 13% compared to other samples.

Phenolic compounds naturally occur in both free forms and covalently bound forms with functional groups or other molecules. Roasting can break these covalent bonds, rendering previously inaccessible phenolic compounds more readily extractable and allowing them to contribute to antioxidant activity. Moreover, the Maillard reaction that takes place during roasting generates novel compounds with antioxidant properties. The synergistic effect of releasing bound phenolic compounds and forming new antioxidant compounds via the Maillard reaction is proposed to be the primary mechanism responsible for the observed enhancement of antioxidant activity in Sacha Inchi seeds at specific roasting temperatures (Morales & Garcia, 2023). The 15-minutes roasting process significantly reduced the overall antinutrient content and enhanced antioxidant activity. Oxidative changes resulting from roasting remained within generally acceptable limits for oil quality (Borges et al., 2018).

3.3.2. Anticancer

The anticancer activity of SaIn has been studied. Research by (Permadi et al., 2025) in vitro on HeLa cervical cancer cells has found that alpha-linolenic acid (ALA) isolated from SaIn oil has stronger cytotoxic activity than cisplatin, with an IC_{50} value from 23 – 28 μg/mL, whereas cisplatin showed higher IC_{50} values (>30 μg/mL), This indicates that ALA from SaIn oil is more effective in inhibiting HeLa cell growth. Meanwhile, in vitro studied by (Vargas et al., 2025) reported that treatment with SaIn oil in AGS gastric cancer cells reduced cell viability by 46.7% (CC_{50}) and at a concentration of 1% induced up to 95% cancer cell death. The anticancer mechanisms of SaIn oil involve an increased proportion of cancer cells in the sub-G1 phase, indicating DNA fragmentation, increased production of ROS and NO as triggers of oxidative stress, activation of the apoptosis enzymes caspase-3, -8, and -9, which play a role in programmed cell death. Additionally, this oil can inhibit cancer cell migration, thereby preventing spread to other tissues.

Another study by (Schiessel et al., 2015) conducted in vivo and ex vivo tests on male Wistar rats induced with Walker 256 tumor cells and found that SaIn oil supplementation at a dose of 1 g/kg BW/ day for 4 weeks significantly reduced tumor mass from 19.1 ± 2.0 g to 8.3 ± 0.7 g, suppressed tumor cell proliferation from 867 cpm to 300-340 cpm, increased lipoperoxidation to 82.5 μmol/mg protein, and reduced COX-2 expression by 20%. Furthermore, SaIn treatment promoted lipid peroxidation in tumor tissue, improved hypertriglyceridemia and hypoglycemia, prevented body weight loss, and decreased plasma concentrations of pro-inflammatory cytokines, including TNF-α and IL-6.

The content of omega-3 fatty acids SaIn plays an important role in its activity as an anticancer. Omega-3 fatty acids can inhibit estrogen-induced cell proliferation, which is fugnant as an inhibitor of COX-2, which plays a role in inflammation and can affect tumor development, as well as reduce the density of microblood vessels in tumors which can inhibit tumor growth. In addition, omega-3 also affects the signaling pathways involved in cell cycle control and apoptosis, both of which play an important role in controlling cancer progression. This is supported by epidemiological studies that show a reduced prevalence of cancer in populations that consume foods rich in omega-3 fatty acids (Dydjow-bendek & Zagozdzon, 2020; Klek, 2016).

3.3.3. Antidiabetics

Antidiabetic evaluation is conducted through the inhibition of essential enzymes linked to type II diabetes (α-amylase and α-glucosidase). Inhibiting α-glucosidase and α-amylase will inhibit starch degradation, glucose release is delayed, resulting in lower sugar production, which in turn reduces glucose absorption and blood glucose levels (Papoutsis et al., 2021). Research

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by (Kittibunchakul et al., 2023) has found that all SaIn oils inhibited lipase activity by 14.63 – 24.19% at an extract concentration of 0.4 mg/mL, with an estimated IC_{50} value higher than 0.4 mg/mL. Other results showed a decrease in blood glucose levels, an increase in insulin levels in the pancreas and serum, a decrease in damage to the Langerhans islands of the pancreas, and a decrease in MDA (malondialdehyde) levels. Clinical studies found that administration of sacha inchi seed oil for 16 weeks at 5 or 10 ml (equivalent to 2 and 4 g ω-3/day) can reduce serum cholesterol and LDL-C level and increase HDL-C in patients with hypercholesterolemia. Moreover, daily consumption of 15 mL of sacha inchi oil has a beneficial effect on postprandial insulin sensitivity in healthy adults, which correlates with increased sirtuin-1 expression. In a study by (Wongmanee et al., 2024), a dose of 2 ml/kg/day was significantly more effective in improving hyperglycemia and pancreatic β-cell dysfunction, and death in diabetic rats compared to doses of 0.5 and 1 mL/kg/day. Using an allometric scale to calculate and convert the dose from rats to humans, the human equivalent dose of 2 ml/kg/day (0.84 g ω-3/kg/day) of oil is approximately 20 ml/day (8.4 g ω-3/day) for a 60 kg individual.

3.3.4 Antiobesity

The administration of omega-3 supplements in some studies has been effective for weight loss. Where omega-3s can affect gene expression and the number of neurotransmitters in the brain, which in turn can affect body composition, especially with reduced fat mass and Increases fat-free mass (Moradi et al., 2020). SaIn itself has a high omega-3 content. Testing of SaIn oil as an anti-obesity was carried out by inhibiting of the lipase enzyme. Blocking the activity of lipase, an enzyme that breaks down lipids, can cause a reduction in fat absorption, which is considered as one of the strategies for managing obesity (Liu et al., 2020). In vivo studies (Li et al., 2020), administering SaIn oil at a dose of 0.5 – 1.5 mL/kg to Sprague Dawley rats fed a high-fat diet for eight weeks significantly reduced adipocyte size, liver steatosis, and inflammation. These effects may be associated with an increase in hepatic lipase expression following SaIn oil administration. Hepatic lipase is an important lipolytic enzyme that plays a role in the absorption of lipoproteins through the de novo lipid synthesis pathway. In addition, SaIn oil is able to inhibit the production of lysophosphatidylcholine (LysoPC) and lysophosphatidylethanolamine (LysoPE), pro-inflammatory phospholipids commonly elevated in hyperlipidemia and diet-induced obesity. SaIn oil also reduces the expression of phosphatidylglycerol phosphate synthase 1 (PGS1), an enzyme that catalyzes the synthesis of phosphatidylglycerol, a potent inhibitor of lipolysis in rats fed a high-fat diet. While SaIn oil has shown potential in improving lipid profiles in humans, direct evidence of its effects on weight reduction remains limited. Therefore, more research is needed to evaluate the potential of sacha inchi seed oil in directly reducing body weight (Kayser et al., 2019).

3.3.5. Alzheimer Therapy

Two cholinesterases (AChE and BChE) and BACE-1 are targeted in efforts to enhance the treatment of Alzheimer's disease. Cholinesterase is responsible for breaking down acetylcholine, the neurotransmitter utilized by cholinergic neurons. The depletion of these neurons may result in impairments in attention and memory, ultimately causing Alzheimer's disease. The enzyme BACE-1 catalyzes the breakdown of amyloid precursor protein (APP), contributing to the formation of amyloid plaques characteristic of brain lesions in individuals with Alzheimer's disease (Moussa, 2017). Research by (Kittibunchakul et al., 2023) evaluated the activity of SaIn oil as an Alzheimer's therapy by testing its ability to inhibit AChE and BChE enzymes at a concentration of 0.4 mg/mL. The results found that AChE inhibition only reached 12.25% and BChE inhibition reached 22.48%. These findings indicate that this concentration was insufficient to exert a significant therapeutic effect, suggesting that the IC_{50} value is likely at a higher concentration than 0.4 mg/mL. This shows that SaIn oil has potential as an anti-Alzheimer’s agent, but further studies are needed to determine the effective dosage. Meanwhile, research by (Islam et al., 2022) using the SAMP8 mouse model revealed that SaIn oil supplementation was able to increase 2-arachidonoylglycerol (2-AG) levels by approximately 2 folds in non-stressed mice and 1.6 folds in stressed mice, particularly in the hypothalamus, midbrain, and hindbrain. This elevation in 2-AG represents an adaptive response of the endocannabinoid system, facilitating stress coping mechanisms by reducing anxiety, supporting memory function, and protecting neurons from damage. The sustained elevation of 2-AG levels maintained by SaIn oil has a neuroprotective effect, aids adaptation to stress, and has the potential to slow down the nerve damage that is characteristic of Alzheimer's disease.

3.3.6. Anticonvulsants

In animals with epilepsy, omega-3 fatty acids enhance GABAergic transmission, potentially through the promotion of new hippocampal interneuron formation or by modifying calcium-binding protein expression (Degiorgio & Taha, 2016). The test animals were divided into five groups, each consisting of six animals. Group I served as the control group and was administered pentylenetetrazole (PTZ) at a dose of 80 mg/kg subcutaneously. Group II received a combination of PTZ and diazepam at a dose of 1 mg/kg subcutaneously. Groups III to V were administered pentylenetetrazole (PTZ) along with SaIn oil at doses of 250, 500, and 1000 mg/kg orally. SaIn oil was given 30 minutes prior to pentylenetetrazole administration. Based on the test results, the experimental group treated with the highest dose of SaIn oil (1000 mg/kg) showed better responses to PTZ-induced seizures, as indicated by a lower seizure score, frequency, and duration. This suggests that SaIn oil exhibits anticonvulsant effects at the maximum tested dose, comparable to the effect of diazepam. Its primary mechanism is thought to involve the reduction of free radicals and the enhancement of GABA levels in the brain (Herrera-calderon et al., 2019). Sacha Inchi seed oil is rich in α-linolenic acid (ALA), which plays an important role in central nervous system function, partly by modulation of GABAergic neurotransmission. This modulation enhances neuronal inhibition in the hippocampus and amygdala, thereby reducing neuronal excitability and preventing seizures. In addition, ALA can increase the expression of BDNF (Brain-Derived Neurotrophic Factor), enhance GABA receptor sensitivity, and provide antioxidant and anti-inflammatory effects that protect neurons from oxidative stress (Pidoplichko et al., 2025).

3.3.7. Anti-Aging

The chemical components found in SaIn seed oil include omega-3 fatty acids, vitamins A, D, and E. These fatty acids contribute to skin health by stimulating the regeneration of new skin cells, maintaining moisture and elasticity, and enhancing collagen production (Lourith et al., 2024) reported that the inhibitory activity of SaIn is comparable to that of vitamin C against elastase. According to a study by (Maya et al., 2023) SaIn seed oil contains vitamin A at 123.42 mg/100 g and vitamin E at 145.06 mg/100 g. In addition, vitamin D was detected at a concentration of 899.46 mg/100 g, a finding that has not been reported in previous studies. Vitamin A functions as a regulator by modulating the activity of matrix metalloproteinases (MMPs), stimulating collagen synthesis, inhibiting collagenase production, and promoting skin regeneration.

Vitamin D enhances skin suppleness by promoting the synthesis of collagen (Danimayostu et al., 2023). By preventing unsaturated fatty acids from oxidizing, vitamin E demonstrates its antioxidant effect in biological systems (Puangpronpitag et al., 2021). Omega-3 can delay aging by inhibiting damage in keratinocytes induced by UV rays, possibly through controlling the COX-2, NF-κB pathways, as well as the MAPK or ERK pathways (Huang et al., 2018). The presence of such compound components in SaIn oil helps maintain collagen-rich tissue and effectively inhibits collagenase activity, disrupts the extracellular matrix, and improves skin wellness (Maya et al., 2023).

3.3.8. Anti-inflammatory

SaIn is recognized to contain omega-3, omega-6, omega-9, tocopherols, flavonoids, and phytosterols. Omega-6 and omega-3 fatty acids are known to modulate the release of pro-

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inflammatory cytokines, thereby regulating the inflammatory response. They also enhance the production of collagen by fibroblasts, effectively promoting skin wound healing and reducing inflammation (Guidoni et al., 2019). Administration of SaIn oil at doses of 1.35 mL/kg BB/day, 2.7 mL/kg BB/day, and 5.4 mL/kg BB/day significantly inhibited the increase in serum IL-6 levels in male Wistar rats fed a high-fat and high-fructose diet. Administration SaIn oil to rats significantly decreased serum pro-inflammatory cytokine levels, indicating its anti-inflammatory effect (Wijaya et al., 2024; Wongmanee et al., 2024).

3.3.9. Antihyperlipidemia

Omega-3 PUFAs found in SaIn oil. It is known to have benefits in preventing the development of Hyperlipidemia. Administration of SaIn oil at doses between 0.5 and 1.5 mL/kg over an 8-week period in obese rats resulted in a reduction of total cholesterol, triglycerides, and LDL cholesterol. Additionally, it helped reverse gut microbiota dysbiosis and increased the composition of bile acids. In humans, randomized controlled trials (RCTs) administering SaIn oil at doses of 5 and 10 mL daily showed decreases in total cholesterol and low-density lipoprotein cholesterol and increased levels of high-density lipoprotein cholesterol. These findings indicate that consumption of SaIn oil, which is rich in α-linolenic acid, can help alleviate dyslipidemia, hepatic steatosis, and inflammatory infiltration. Furthermore, SaIn oil modulates the gut microbiota metabolome, which means there are changes in the way bacteria in the gut process and produce molecules related to the body's metabolism. It also helps prevent bile acid dysmetabolism induced by a high-fat diet (Gonzales & Gonzales, 2014; Yu & Du, 2020).

3.3.10. Antibacterial

SaIn contains unsaturated fatty acids, particularly omega-3 and omega-6, which are recognized for their anti-inflammatory and antimicrobial properties. Traditionally, SaIn has been used in antibacterial treatments for various skin diseases. Topical administration of SaIn oil is effective in preventing the growth S. aureus. This is related to Effects of SaIn oil in reducing bacterial adhesion of S. aureus on human skin and keratinocytes. Unsaturated fatty acids, such as linoleic acid, have the ability to Increase the softness (fluidity) of cell membranes. Due to this change in fluidity, the membrane can reduce the ability of bacteria to attach to the surface of skin cells. This mechanism occurs because increased cell membrane fluidity interferes with the interaction between adhesion proteins on the bacterial surface and the cell membrane, thereby reducing the bacteria's ability to attach stably to skin cells (Gonzalez-aspajo et al., 2015). Testing of SaIn oil against S. aureus and E. coli carried out by (Khine et al., 2020) indicates the presence of antibacterial activity against both bacteria. This is evidenced by the presence of a 22 mm clear zone on the E. coli and a 24 mm clear zone on the S.aureus on the tests carried out. These results indicate that SaIn oil has antibacterial activity. However, to assess the potential antibacterial effectiveness of SaIn oil, further studies are required to directly compare its activity with that of standard antibiotics.

4. CONCLUSION

Sacha inchi (Plukenetia volubilis L.) contains essential fatty acids such as omega-3, omega-6, omega-9, vitamins A, D, and E wich very benefical for support their role in maintaining cardiovascular health, lipid metabolism, brain function and preventing degenerative diseases. The physicochemical characteristics of these oils, including the peroxide value, iodine number, saponification number, and acid number, are highly dependent on the extraction method used. SaIn seed oil posseses a boardspectrum of pharmacological activities, including as an antioxidant, anticancer, antidiabetic, anti-obesity, anti-aging, anticonvulsant, anti-inflammatory, antihyperlipidemia, and antibacterial. While current evidence is largely preliminary, further clinical studies are needed to confirm its effects in humans. With its rich nutritional profile, Sacha Inchi seed oil shows significant potential for pharmaceutical, cosmetic, and nutraceutical applications.

ACKNOWLEDGMENTS

The author would like to thank Halu Oleo University for the support of facilities and resources during the process of making this article, as well as all parties who have provided input, discussion, and relevant data to complete this article.

CONFLICTS OF INTEREST

There is no conflict of interest in this article.

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