

## Effect of maltodextrin concentration and drying temperature on the physicochemical characteristics of *Sacha inchi* (*Plukenetia volubilis*) extract powder

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Received: 25 October 2023; Accepted: 15 March 2024; Published: 3 April 2024

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ORIGINAL ARTICLE

### Abstract

*Sacha inchi* (*Plukenetia volubilis* L.) is an ancestral plant with various beneficial properties and has been used as a food source due to its high nutritional value for human health. The aim of this study was to assess the effect of the addition of maltodextrin concentration, the impact of the use of drying temperature, and the interaction of both on the physicochemical characteristics of powdered *Sacha inchi* extract. The results of this study would provide insightful information about the utilization of *Sacha inchi*, the optimal concentration of maltodextrin, and the drying temperature of powdered *Sacha inchi* extract. The experimental design used in this study is a Randomized Group Design with a 3x3 factorial pattern of two replications followed by Duncan's further test. The observed variation consisted of maltodextrin concentration (5%, 10%, and 15%) and drying temperature (50°C, 60°C, and 70°C). This study includes chemical and physical responses such as moisture content, antioxidant activity, yield, solubility, hygroscopicity, and scanning electron microscopy (SEM). The effect of maltodextrin concentration and drying temperature factor was significant on moisture content, hygroscopicity, yield, and solubility. The interaction between drying temperature and maltodextrin concentration significantly affected moisture content and solubility.

**Keywords:** drying temperature, maltodextrin, *Sacha inchi*, shrub

### Introduction

From centuries medicinal plants have been used for therapeutic purposes as it contains plenty of potential bioactive compounds. Recently these plants have been under keen interest of various researchers due to their potential health benefits (Zahra *et al.*, 2024; Aziz *et al.*, 2024; Riaz *et al.*, 2023; Waqas *et al.*, 2023; Ahmad *et al.*,

2023a; Ahmad *et al.*, 2023b; Ammara *et al.*, 2023; Aqib *et al.*, 2023; Ejaz *et al.*, 2023; Aziz *et al.*, 2023; Gul *et al.*, 2023). Extracts of various medicinal plants are used in different industries such as pharmaceuticals, food industries and for nanomedicine (Hayat *et al.*, 2023; Hussain *et al.*, 2023; Iram *et al.*, 2023; Riasat *et al.*, 2023; Saleem *et al.*, 2023; Sana *et al.*, 2022; Syed *et al.*, 2023; Zahra *et al.*, 2023; Zawar *et al.*, 2023; Rauf *et al.*, 2023;

Naveed *et al.*, 2022a; Naveed *et al.*, 2022b). *Sacha inchi* (*Plukenetia volubilis* L.) is a shrub that grows vines and is commonly known as Sacha beans, mountain beans, or Inka beans (Puangpronpitag *et al.*, 2021). *Sacha inchi* is an annual plant with slightly hairy textured leaves and belongs to the Euphorbiaceae family. The plant is widely cultivated commercially in South Asia and Southeast Asia, especially in Thailand (Puangpronpitag *et al.*, 2021). *Sacha inchi* in Indonesia has developed a lot, such as in the Central Java and Majalengka regions, West Java. Several studies have reported the potential benefits of *Sacha inchi* and its uses in different industries (Cárdenas *et al.*, 2021; Cisneros *et al.*, 2014; Mhd Rozi *et al.*, 2022). The chemical characterization of the major components of *Sacha inchi* demonstrated that it contains triacylglycerols (TAGs), polyphenols and tocopherols, especially from *Sacha inchi* oil via cold pressing of its seed (Fanali *et al.*, 2011; Gutiérrez *et al.*, 2017; Kodhal, 2020; Maurer *et al.*, 2012). The utilization of *Sacha inchi* in Indonesia still needs to be improved or more optimal because this *Sacha inchi* is only processed into oil. Then the seeds are processed through sun drying or roasting processes for seeding efforts. The processing of *Sacha inchi* has not yet reached the processing into functional food products, even though *Sacha inchi* seeds contain lipids (35%–60%) (including  $\omega$ -3, 6, and 9 fatty acids), protein (25%–30%) (including essential amino acids such as cysteine, tyrosine, threonine, and tryptophan), vitamin E, polyphenols, minerals, etc., the shell has a higher level of  $\alpha$ -tocopherol and the same amount of  $\omega$ -6 and  $\omega$ -3 fatty acids as the seeds. *Sacha inchi* leaves are a source of terpenoids, saponins, and phenolic compounds (flavonoids) (Wang *et al.*, 2018).

*Sacha inchi* needs to be developed into functional food; one of the products, *Sacha inchi*, is processed into powder to facilitate its use. In making powder there are many kinds of drying methods, namely cabinet drying, air-lift, tunnel dryer, conveyor dryer, spray dryer, and pan dryer (Wirakartakusumah *et al.*, 1992), one of which is a rotary vacuum dryer. Temperature in the drying process plays a vital role. If the drying temperature is too high, it will decrease the nutritional value and discoloration of the dried product. Meanwhile, if the temperature is too low, the resulting product will be wet, sticky, or smelly, requiring a long drying time (Sahupala *et al.*, 2019). Making powder from a liquid requires a filler that functions as a binder (Arsyad *et al.*, 2021) and one of the fillers is maltodextrin. This maltodextrin has several advantages, including its non-sweet taste and is easily soluble in water (Indri Paramita *et al.*, 2015). However, according to Rodríguez-Cortina *et al.* (2022), the main disadvantage of *Sacha inchi* is containing oil with compounds rich in fatty acids is the rapid oxidation, which due to this oxidation will result in the formation of peroxides with marked odor and unpleasant taste. Among

the strategies to prevent this is the encapsulation process with coating materials to increase oil stability, reduce lousy taste, delay lipid oxidation and enzyme hydrolysis, and allow controlled release of the encapsulated material (Rodríguez-Cortina *et al.*, 2022). The composition of the ingredients in the preparation of this powdered *Sacha inchi* extract includes the use of gum arabic as a stabilizer and tween 80 as a surfactant. Based on this, a study was conducted to determine the effect of maltodextrin concentration and dry temperature on the physical and chemical characteristics of powdered *Sacha inchi* extract and to determine the optimal maltodextrin concentration and drying temperature to produce powdered *Sacha inchi* extract products with the best characteristics.

## Materials and Methods

### Materials

The materials used in this study were *Sacha inchi* from a privately owned plantation in Cihanjuang, West Java, maltodextrin with the brand Qinhuangdao Lihua Starch with DE 10-12, and 96% ethanol purchased at Kimia Market Bandung. Chemical analysis materials used in this study were 75% NaCl RH, filter paper, silica gel, aluminum foil, 96% ethanol, petroleum ether, n-hexane, KOH, distilled water, carbon tape, NaOH, HCl, methanol, diethyl ether, 50  $\mu$ M DPPH solution, and chemicals needed for analysis came from the Bandung Research and Innovation Agency Research Laboratory, Padjajaran University Central Laboratory and Pasundan University Food Technology Laboratory.

### Preparation of *Sacha inchi* powder extract

The *Sacha inchi* fruit is harvested, after which it is washed and trimmed to get the seeds. The *Sacha inchi* seeds will be dried first using a cabinet dryer with a temperature of 70°C for 24 h. After drying the seeds, grinding was carried out using a Mitochiba ch 200 chopper for 3–5 min. *Sacha inchi* seeds that have become powder will be extracted using 96% ethanol solvent for 2 h with an ultrasonic-assisted extraction (UAE) instrument. After obtaining the *Sacha inchi* seed extract, a filtration process will be carried out, and then a centrifugation process at a speed of 8000 rpm for 10 min followed by evaporation for 30 min. *Sacha inchi* extract which has been evaporated is then mixed with tween 80, maltodextrin, gum arabic, and distilled water in the ratio (1:2:2:10) (w/v). The mixing process was carried out using a magnetic stirrer with a stirring speed of approximately 600 rpm for 60 min. After obtaining a homogeneous mixture of *Sacha inchi* powder extract emulsion, this emulsion mixture will be subjected to a second drying process using a rotary vacuum dryer

Machine SUS304 Material 50HZ / 60HZ, 1.5 rpm, and 25 in hg. Which was carried out in the chemical and physical analysis stages.

### Chemical analysis of *Sacha inchi* powder extract

#### Moisture content analysis

This moisture content analysis uses the thermogravimetric method with the MB45 Ohaus instrument, which refers to the technique (Anggo *et al.*, 2014). The sample is weighed as much as 2 g, then it is stored in an aluminum cup, after which the aluminum cup is inserted into the moisture analyzer; and then the moisture analyzer is closed, press the “start” button to start the analysis. The results of the water content analysis were shown on the moisture analyzer screen. If the analysis process has been completed, press the “stop” button.

#### Analysis of fatty acids

The analysis of fatty acids used an Agilent 5977C GC/MSD Gas Chromatography-Mass Spectrophotometry (GC-MS) instrument, which refers to the method (Brotas *et al.*, 2020) with the column temperature program is 100°C for 2 min, increasing at 5°C per minute to 240°C and remaining at 240°C for 8 min, with a total run time of 38 min. Ultra High Purity (UHP) helium was used as the carrier gas (0.8 mL per minute) and the injector was operated in split mode (20:1) at 240°C. The mass spectrometer was operated under the following conditions: trap temperature, 240°C; assortment temperature, 70°C; transfer line temperature, 240°C; ionization energy, 70 eV. Samples were analyzed in full scan mode (SCAN), with a mass range of 10 to 400 a.m.u.

#### Antioxidant activity analysis

This antioxidant activity analysis uses the DPPH method, which refers to the method by Molyneux (2004). Preparation of DPPH solution by weighing 0.04 mg of DPPH dissolved in 25 mL of methanol to obtain a concentration of 0.0004 M. Determination of antioxidant activity of the sample using a sample stock solution made by weighing the sample that has been macerated by methanol and evaporated as much as 8 g and dissolved with 10 mL of methanol so that the sample stock solution has a concentration of 1000 ppm. Subsequently, dilutions were made to make four solution concentrations (200, 400, 600, and 800 ppm). Determination of antioxidant activity is done by adding the sample, methanol, and DPPH solution into a test tube according to the formulation and predetermined concentration. The mixture was homogenized and left for 30 min in a dark place and the absorbance was measured by a UV-Vis spectrophotometer at a wavelength of 515 nm. The IC<sub>50</sub> value is

determined using the linear regression equation formula, with percent inhibition as the ordinate (y) and concentration as the abscissa (x) (Molyneux, 2004):

$$\% \text{ inhibition} = \frac{\text{control absorbance} - \text{sample absorbance}}{\text{control absorbance}} \times 100\%$$

### Physical analysis of *Sacha inchi* extract powder

#### Solubility analysis

This solubility analysis refers to Susanti *et al.*'s (2014) method. Samples with known water content are weighed as much as 2 g and dissolved in water at a temperature of 50°C. Next, the sample is filtered using fine filter paper with the help of a vacuum pump that has been dried in an oven at 105°C for 30 min and weighed. The filter paper and the residue are weighed and dried in an oven at 105°C for 3 h. Then, the filter paper is cooled in a desiccator and weighed. The solubility percent is calculated using the formula:

$$\% \text{ insoluble} = \frac{(c - b) \times 100}{\frac{100 - \%KA}{100} \times a}$$

$$\% \text{ solubility} = 100 - \% \text{ insoluble}$$

#### Yield

To determine the yield of *Sacha inchi* powder extract, we followed the method developed by Sayuti (2017). Determination of the yield of *Sacha inchi* powder extract is done by weighing the initial weight of the *Sacha inchi* and the weight of the resulting *Sacha inchi* powder extract and then dividing the weight of the total material used, after that, the yield is calculated using the following formula:

$$\% \text{ Yield} = \frac{\text{weight of Sacha inchi powder extract (g)}}{\text{base weight}} \times 100\%$$

#### Hygroscopicity

The hygroscopicity is determined by the method of Indah *et al.* (2019). The sample was weighed as much as 1 g and then put into an applicator containing a saturated NaCl solution with 75% RH at 25°C for 4 h. After 4 h, the sample was weighed to obtain a constant weight. The calculation of hygroscopicity is expressed in units of grams of absorbed moisture per 100 g of dry solids (g/100 g). The following formula is used for the calculation:

$$\text{Hygroscopicity} = (W_{\text{final}} - W_{\text{Starting}}) \times 100$$

## Scanning Electron Microscope (SEM)

The scanning was recorded with two electron microscopes, namely one instrument with a segmented STEM (transmission mode) detector, and another instrument with a secondary electron (SE) detector (Bals and Epple, 2023). The SEM tools used in this analysis are SEM JEOL JSM IT300 and EDX Oxford XMax 20. The procedure for this analysis is that the sample in powder form will be placed on a carbon-coated copper grid, and then the sample will be coated with gold (Au) for 2 min using a sputter, the sample that has been coated with gold will then be inserted into the SEM tool for analysis.

## Statistical analysis

The experimental design model used in this research is a Randomized Group Design (RAK) with a 3x3 factorial pattern where each design consists of 3 (three) factors with 2 (two) replications, resulting in 18 experimental units. The treatment design in this study consisted of two factors: maltodextrin concentration (M) and drying temperature (T). The maltodextrin concentration (M) treatment factor consists of three levels, namely 5%, 10%, and 15%, and the drying temperature (T) consists of three levels, namely 50°C, 60°C, and 70°C.

## Results and Discussion

### Moisture content

Moisture content analysis can be seen in Table 1. The results of the ANOVA calculations show that the maltodextrin concentration factor (M), drying temperature factor (T), and the interaction of both (MT) significantly affect the water content in *Sacha inchi* powder extract.

The concentration of maltodextrin and drying temperature in each treatment are very different, with the highest average water content of  $8.15 \pm 0.00\%$  in the treatment with maltodextrin 10% and temperature 50°C, and the lowest moderate water content of  $4.83 \pm 0.01\%$  in the treatment with maltodextrin 5% and temperature 70°C. This is following the research conducted by Rayhani *et al.* (2018). The more the addition of maltodextrin concentration increases, the more the moisture content of the product will increase; this is because maltodextrin has hygroscopic properties and can bind water better. The research by Turkmen *et al.* (2020) shows that drying temperature significantly affects the moisture content of cement leaf powder. The lowest moisture content of cement leaf powder was obtained at a 70°C drying temperature treatment of 7.24%. In comparison, the highest moisture content of cement leaf powder was obtained at a 40°C drying temperature treatment of 8.77%. The results of this study indicate that the higher the drying temperature, the smaller the water content of the *Sacha inchi* powder extract produced.

### Yield

The yield analysis can be seen in Table 1. The ANOVA calculations show that variations in maltodextrin concentration (M) and drying temperature (T) significantly affect the *Sacha inchi* powder extract yield. It can be concluded that each treatment is significantly different, with the highest average yield value of  $27.45 \pm 0.05\%$  in the treatment (maltodextrin 15%, temperature 70°C) and the lowest average yield of  $12.02 \pm 0.02\%$  in the treatment (maltodextrin 5%, temperature 50°C). This is because the increasing concentration of maltodextrin in the treatment results in a greater volume of yield produced in the extract of *Sacha inchi* powder because maltodextrin can increase yield and total soluble solids. The research

Table 1. The results of analysis of *Sacha inchi* extract powder's moisture content, yield, solubility, and hygroscopicity.

Maltodextrin concentration (M)	Drying temperature (T)	Code	Moisture content	Yield	Solubility	Hygroscopicity
5%	50°C	m1t1	$4.93 \pm 0.01^c$	$12.02 \pm 0.02^a$	$73.82 \pm 0.03^a$	$1.40 \pm 0.14^a$
5%	60°C	m1t2	$4.89 \pm 0.01^b$	$12.08 \pm 0.03^a$	$74.54 \pm 0.06^b$	$1.50 \pm 0.42^a$
5%	70°C	m1t3	$4.83 \pm 0.01^a$	$12.14 \pm 0.01^a$	$75.06 \pm 0.08^c$	$1.50 \pm 0.14^a$
10%	50°C	m2t1	$8.15 \pm 0.00^j$	$19.33 \pm 0.04^a$	$86.42 \pm 0.13^d$	$3.00 \pm 0.14^a$
10%	60°C	m2t2	$8.12 \pm 0.02^h$	$19.47 \pm 0.01^a$	$86.60 \pm 0.14^e$	$2.90 \pm 0.14^a$
10%	70°C	m2t3	$8.08 \pm 0.01^g$	$19.52 \pm 0.02^a$	$86.76 \pm 0.04^f$	$3.30 \pm 0.14^a$
15%	50°C	m3t1	$7.52 \pm 0.01^f$	$27.22 \pm 0.02^a$	$96.80 \pm 0.06^g$	$0.15 \pm 0.07^a$
15%	60°C	m3t2	$7.47 \pm 0.01^e$	$27.36 \pm 0.03^a$	$96.93 \pm 0.04^h$	$0.35 \pm 0.07^a$
15%	70°C	m3t3	$7.44 \pm 0.01^d$	$27.45 \pm 0.05^a$	$97.28 \pm 0.11^i$	$0.35 \pm 0.21^a$

Note: Different letters (a, b, c, d, e, f, g, h, i) in the table indicate a significant difference in level 5%.

results by Tresna Yuliawaty and Susanto (2015) show that the treatment of drying time and maltodextrin concentration on the yield value tends to increase. The analysis of variance showed that the treatment of maltodextrin concentration had a significant effect on the yield value of the resulting mengkudu leaf instant drink. The increase in total yield produced indicates that maltodextrin can function as a mass enhancer. The greater the amount of maltodextrin added, the higher the product yield. This is because using maltodextrin in instant beverage products increases the volume and the total solid material, so the yield is higher (Table 1).

The results of data analysis of the effect of drying temperature factors on yield as shown in Table 1 are not in line with the results of research by Hariyanto *et al.* (2022) which states that the lowest yield value is in the treatment of drying temperature 70°C and time for 5 h with a yield value of 8.07%, while the highest yield value is in the treatment of temperature 50°C and time for 3 h with a yield value of 10.48% with a yield response desirability value of 0.4063.

### Solubility

The solubility analysis can be seen in Table 1. The statistical analysis showed that variations in maltodextrin concentration (M), drying temperature (T), and the interaction of both (MT) had a significant effect on the solubility of *Sacha inchi* powder extract. The maltodextrin concentration factor in each treatment is significantly different, with the highest average solubility value of  $97.28 \pm 0.11\%$  in the treatment (15% maltodextrin, 70°C temperature) and the lowest intermediate solubility of  $73.82 \pm 0.03\%$  in the treatment (5% maltodextrin, 50°C temperature). This is because maltodextrin is easily soluble in water; therefore, the higher the concentration of maltodextrin, the more solubility will increase. These results align with research by Tresna Yuliawaty and Susanto (2015), which shows the solubility of noni leaf instant drinks tends to increase along with the addition of maltodextrin concentration. This is because when the noni leaf powder is dissolved, the hydroxyl groups contained in maltodextrin will interact with water so that the solubility of the powder increases. The more free hydroxyl groups in the filling material, the higher the solubility level. This means that if the solubility value obtained is higher, it shows the better quality of the resulting product because the presentation process will become easier.

The more the drying temperature increases, the smaller the water content value obtained in the powdered *Sacha inchi* extract; this will result in the powdered *Sacha inchi* extract being hygroscopic and easily soluble in water so that its solubility is higher. These results are in

line with the research by Hariyanto *et al.* (2022), which states that the lowest percentage value of solubility is in drying at a temperature of 50°C for 3 h with a value of 87.95% while the highest percentage value of solubility is drying with a temperature of 70°C for 5 h with a value of 96.1% and the desirability value of the solubility response is 0.6862. The results of the solubility value of tilapia fish head powder broth are getting higher as the temperature and drying time increase. Increasing temperature and drying time length can cause the material's water content to decrease, making the material more hygroscopic and more accessible to absorb water so that the solubility value is more significant.

### Hygroscopicity

The hygroscopy analysis can be seen in Table 1. The results of ANOVA calculations show that the maltodextrin concentration factor (M) significantly affects the level of hygroscopicity of *Sacha inchi* powder extract. The maltodextrin factor, each treatment is significantly different, with the highest average value of hygroscopicity level of  $3.30 \pm 0.14\%$  in the treatment (maltodextrin 10%, temperature 70°C) and the smallest average value of hygroscopicity is  $0.15 \pm 0.07\%$  in the treatment (maltodextrin 15%, temperature 50°C). This is in line with the study of Rodríguez-Cortina *et al.* (2022), who stated that the hygroscopicity values of *Sacha inchi* oil microcapsules varied from 2.32% to 5.07%. These results indicate that the hygroscopicity in Ultrasound Probe Homogenization (US) for both drying technologies is much better than Conventional Homogenization (CH). This may be due to the hygroscopicity of microcapsules in general, which is related to their composition, type, carrier concentration, and size. Microcapsules with values greater than 20% are considered to be highly hygroscopic. Different studies have found that high hygroscopicity results in stickiness of the powders, which contributes to decreased shelf stability. In this study, the value was less than 20%, indicating low hygroscopicity of the microcapsules, thus facilitating their shelf-life and stability during storage.

Based on the research results by Hariadi *et al.* (2023), it is known that the hygroscopicity results of telling flower milk powder are 0.006; this shows that the concentration of peanut powder and variations in drying temperature have a significant effect. The level of hygroscopicity has several categories, including the level of hygroscopicity <10% (less than 10%) included in no hygroscopic materials, the level of hygroscopicity 10.1%–15% having slightly hygroscopic materials, the level of hygroscopicity 15.1%–20% is classified as hygroscopic material, the hygroscopicity level of 20.1%–25% belongs to highly hygroscopic material, and the hygroscopicity level >25% belongs to highly hygroscopic material.

## Antioxidant activity

The results of antioxidant activity analysis on sample  $m_{1,t_1}$  (5% maltodextrin, temperature 50°C) showed a result of 0.075%, which is the antioxidant activity of this powdered *Sacha inchi* extract including a weak level category. According to Puangpronpitag *et al.* (2021), the  $IC_{50}$  result on *Sacha inchi* seed oil is  $0.007 \pm 0.001$  (mg/mL). Still, in this study at 50°C, the antioxidant activity is already weak, another factor that causes antioxidant levels in this powdered *Sacha inchi* extract may be due to the length of drying carried out. Based on research conducted by Ayu Martini *et al.* (2020) they were stated that the interaction between temperature and length of drying time had a genuine effect. The results showed that the higher temperature and longer time resulted in a higher  $IC_{50}$  value. A high  $IC_{50}$  value indicates a low antioxidant ability; otherwise, a low  $IC_{50}$  value indicates a high antioxidant ability (Ayu Martini *et al.*, 2020).

## Scanning Electron Microscope (SEM)

It can be seen that the surface morphology of the particles is highly polymorphic and agglomerated, with thick walls and hollow microcapsules. According to research by Alves *et al.* (2014), gum Arabic is an excellent encapsulating material due to its solubility, low viscosity, good emulsifying properties, mild taste, and oxidation resistance, and which provides oil and maltodextrin with common dextrose equivalents (DE), also stabilizes the emulsion and causes the formation of thicker microcapsule walls, which prevents moisture absorption by the system (Figure 1).

## Conclusions

Based on the results of research on the manufacture of powdered *Sacha inchi* extract using a rotary vacuum dryer machine, it can be shown that the addition of maltodextrin concentration and drying temperature can have a significant effect on the chemical and physicochemical characteristics of powdered *Sacha inchi* extract. The addition of maltodextrin concentration and drying temperature factor affects the moisture content, hygroscopicity, yield, and solubility. The interaction between drying temperature and maltodextrin concentration affected moisture content and solubility. The primary research is generally carried out through chemical and physical analysis to determine the best physicochemical characteristics of *Sacha inchi* extract powder. Based on this study, the best chemical analysis produced was 4.83% moisture content and 0.075% antioxidant activity. The best physical analysis results show a yield of 27.45%, solubility of 97.28%, and hygroscopicity of 0.15%. The above study obtained the best treatment results with a drying temperature of 50°C and adding 5% maltodextrin concentration.

## Conflict of interest

The authors declare no conflicts of interest.

## Acknowledgments

The authors are thankful to the Researchers Supporting Project number (RSP2024R335), King Saud University, Riyadh, Saudi Arabia.

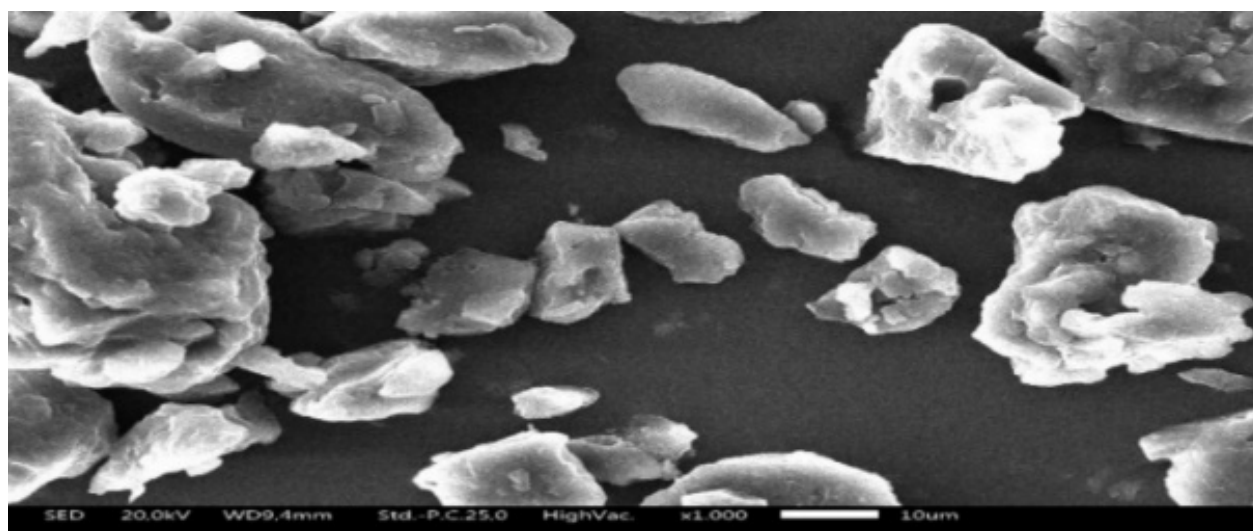


Figure 1. SEM Analysis results of *Sacha inchi* extract powder with 1000x magnification.

## Data availability statement

All the data generated in this study have been included in this manuscript.

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