Revised JKS

by Nazir Uddin

Submission date: 07-Apr-2023 12:01AM (UTC+0800)
Submission ID: 2057659541
File name: Final_text_6_April2023.docx (14.28M)
Word count: 8286
Character count: 48960

Supercritical fluid extraction of torch ginger: encapsulation, metabolite profiling, and antioxidant activity

Abstract

Objectives

The objective of this study was first to perform the supercritical fluid extraction (SFE) and encapsulation of torch ginger *(Etlingera elatior)* inflorescences into a functional powder. Second objective was to evaluate the powder's characteristics, metabolite profiles, and antioxidant activity.

Methods

Torch ginger inflorescences were extracted via SFE technique, and the obtained extract was encapsulated by a spray-drying process with maltodextrin as an encapsulating agent. Subsequently, the powder was evaluated for its physical characteristics, determination of metabolite profiles by using a Fourier Transform Infrared Spectrophotometer (FTIR) and Gas Chromatography-Mass Spectrometry (GC-MS), and antioxidant activity.

Results

Spray drying encapsulation process managed to yield around 59.8% of torch ginger extract powder (TGEP) by using 10% of extract, which the obtained yield was twice higher than in another study. TGEP showed inconsistent agglomeration behaviour in particle size examination with distinct sizes concentrating at 2.2 µm and 17.4 µm, respectively. Brunauer-Emmett-Teller (BET) analysis of TGEP unveiled a considerably high surface area (1.13 m2/g), pore volume (0.218 cm3/g), and pore size (384.6 nm). The metabolites profile of TGEP was studied and characterized using two spectroscopic analyses. Analysis by the FTIR showed the presence of O-H, C-H, C=C, C=O, CO-O-CO, C-N, and C-O functional groups in the sample. Subsequently, the result of the GC-MS characterization revealed about 59 metabolites that predominantly fatty acids (30.5%), terpenes and derivatives (20.3%), fatty acid esters (16.9%), and alcohols (8.47%) were present in TGEP. The powder also demonstrated a high antioxidant activity based on the evaluation of its total phenolic content (23.3 ± 0.662), 2,2-diphenyl-

1-picrylhydrazyl radical scavenging capacity (1.31 ± 0.002), and ferric reducing antioxidant power (2919.5 ± 19.9), which were better than previous studies.

Conclusion

Therefore, this study unveiled TGEP as a functional powder with a high content of bioactive compounds with excellent bioactivity.

Keywords: *Etlingera elatior*, Encapsulated torch ginger extract powder, Supercritical fluid extraction, Spray drying, Encapsulation, Metabolite

1. Introduction

Torch ginger or scientifically known as *Etlingera elatior* is a perennial herbaceous plant belong in the *Zingiberaceae* family which is endemic to the Southeast Asian region. It grows in a large colonies and has a pink, ovoid-shaped, inflorescence with a unique fragrance (NParks, 2019). In the Southeast Asian gastronomy, torch ginger is synonymous in various cuisine such as *Asam Laksa* in Malaysia, *Pecel* in Indonesia, and added to traditional Thai meat dishes in Thailand (Rachkeeree et al., 2018).

Torch ginger has been receiving major traction among researchers and various studies have been conducted to unveil its promising medicinal value. Torch ginger has been reported to contains various phytochemical constituents specifically secondary metabolites that serve a multitudes of biological functions. Secondary metabolites in the class of lipids, phenolics, and terpenes are often found in torch ginger's extract and its metabolites profile was well documented in literature (Ghasemzadeh et al., 2015; Marzlan et al., 2020; Wijekoon et al., 2011; Wijekoon et al., 2013). As mentioned earlier, these classes of secondary metabolites have been scientifically proven to render various biological functions namely, as antioxidant, antimicrobial, and antibiotic (Hussein & El-Anssary, 2018; Lachumy et al., 2010). Furthermore, torch ginger also distinctively known as an aromatic flower and this aroma is fundamental in the Southeast Asian gastronomy (Oh et al., 2019; Raji et al., 2017). Hence, apart from elevating the sensory experience of food, the inclusion of torch ginger in daily diet is presumed to elicit the functional importance of bioactive compounds, which are vital for optimal human health (Abdelwahab et al., 2010; Lachumy et al., 2010).

In recent decade, supercritical fluid extraction (SFE) has been well reported as a safe and efficient extraction technique for various plant-based natural products in broad array of application. SFE utilise supercritical carbon dioxide (SCO_2) as a solvent in which this unique state delivers a gas-like diffusivity and liquid-like solubility throughout the extraction process (Sunol et al., 2019). These properties are important to induce the penetration of solvent deep into the plant matrices which it will increase the rate of mass transfer between the extracted material and the solvent used (Arumugham et al., 2021). Additionally, the use of CO_2 also provides an added advantage to this technique as the Food and Drug Administration (FDA) has classified the substance as Generally Recognized as Safe (GRAS) (FDA,

27 2020). Hence, this unique mechanism of SFE promotes the extraction, isolation, and retention of plant's
28 beneficial compounds, such as terpenes, flavonoids and phenolics in the obtained extract (Caballero et
29 al., 2020).
30 The encapsulation technique has ushered in a multifaceted benefit to the plant extract. This technique
31 has been claimed to protect bioactive compounds against oxidation, creates a thermal barrier, preserve
32 the physical structure of the compounds, and conserve the organoleptic attributes of the compound
33 (Mooranian et al., 2014). The aforementioned benefits are made possible via this technique as the
34 bioactive compounds are trapped in a capsule-like structure with a shell made up of biomaterials or
35 synthetic polymer that serves as a protective layer (Onsaard & Onsaard, 2019). Therefore, researchers
36 and industry players have preferred the encapsulation technique to produce bioactive compound-rich
37 extract suitable for various applications.
38 Several studies have been conducted on developing plant-extract-based powder from various herbal
39 plant species in literature (Rajabi et al., 2015; Simon-Brown et al., 2016). However, to the authors'
40 knowledge, only one study on developing torch ginger extract powder using the encapsulation
41 technique exists in the literature, which has been published by Anuar et al. (2021). Consequently, due
42 to insufficient studies on torch ginger-extract powder, information about its phytochemical composition
43 and bioactivity remain scarce in the literature. In this study, the torch ginger extract powder (TGEP)
44 was developed, the retention of bioactive compounds in the powder was evaluated, and its bioactivity
45 was tested. Therefore, the objective of this study was first to perform the supercritical fluid extraction
46 (SFE) and encapsulation of torch ginger (*Etlingera elatior*) inflorescences into a functional powder.
47 Meanwhile, the second objective was to evaluate the powder's characteristics, metabolite profiles, and
48 antioxidant activity.
49

50 2. Materials and methods

51 2.1. Torch ginger sample and chemicals

52 Torch ginger *(Etlingera elatior)* inflorescences were procured from a farm in Kuala Pilah, Negeri
53 Sembilan, Malaysia. The sample was harvested and delivered to the authors' laboratory within the same
54 day. Subsequently, the sample was stored in the laboratory's refrigerator for storage under refrigerated

55 conditions (± 4 °C). Analytical grade organic solvents and chemicals were used in the experiments for
56 an optimum precision. The N-Methyl-N-(trimethylsilyl)trifluoroacetamide (MSTFA) used for the
57 analysis was bought from Thermo Fisher Scientific (Waltham, MA, United States of America).
58 Denatured ethanol (99% purity) and acetic acid (glacial, ≥99% assay) were obtained from HmbG
59 Chemicals (Hamburg, Germany). Additionally, hydrochloric acid (fuming 37%), gallic acid, Folin-
60 Ciocateu phenol reagent, and ferric chloride hexahydrate were purchased from Merck (Darmstadt,
61 Germany). Meanwhile, anhydrous pyridine (99.8%), methoxyamine hydrochloride (98%), sodium
62 acetate (anhydrous), sodium carbonate (anhydrous), gallic acid (TraceCERT®), 2,2-Diphenyl-1-
63 picrylhydrazyl radical (DPPH), and (±)-6-Hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid
64 (Trolox) were procured from Sigma-Aldrich (St. Louis, MO, United States of America).
65

66 **2.2. Preparation**

67 **2.2.1. Pre-processing of torch ginger**

68 The inflorescences were separated from its stalk and later, they were cut into smaller pieces.
69 Subsequently, the sample was lyophilized by using the Labconco FreeZone Benchtop freeze dryer
70 (Missouri, United States of America) that was operated at -40 °C and the vacuum level was set at 133
71 x 10^{-3} mBAR. The drying process was conducted until the sample was sufficiently dried (± 10%
72 moisture content) which it took approximately four days to complete. Using a RT-CR30S 3HP cutting
73 mill with a cyclone powder collector (Rong Tsong Precision Technology Co., Dawei Rd., Taichung,
74 Taiwan), the dried sample was pulverized into powder with particles approximately 0.22 mm in size.
75 Following that, the remaining debris were removed from the powder by sieving it using a 200 x 50 mm
76 sieve with the aperture size of 0.220 mm and the powder was stored in an airtight container.
77

78 **2.2.2. Supercritical fluid extraction of torch ginger**

79 Supercritical fluid extraction (SFE) technique was performed to extract and isolate essential oil from
80 torch ginger by using a laboratory scale extraction plant (Deven Supercritical Pvt. Ltd., Phatak Baug,
81 Navi Peth, Pune, India). The extraction process was carried out according to method used in our

82 previous study with some modifications (Naziruddin et al., 2022). In brief, a filter bag with a pore size

83 of 45.0 μm was filled with approximately 200 g of torch ginger powder and subsequently positioned

84 within the high-pressure extraction vessel of the SFE unit. Stream of liquid CO_2 (99.8% purity, 1.2 kg/h)

85 was flowed into the chiller for it to be cooled at 5 °C and it was later pressurised by a high-pressure

86 pump before entering the extraction vessel. Inside the extraction vessel, liquid CO_2 was converted to a

87 supercritical state (SCO_2) upon being pressurised to 28 MPa at 50 °C. Consequently, the SCO_2

88 penetrated the sample's microporous matrix to induce the extraction and isolation of the desired

89 compounds. The entire extraction process took about six hours to complete, by which the yield was

90 collected every consecutive hour and dispensed into an amber glass bottle. The bottle was tightly capped

91 and hermetically sealed by wrapping it with a sheet of parafilm for storage at 4 °C.

92

93 **2.2.3. Spray drying encapsulation of torch ginger extract**

94 Prior to the process, a mixture made up of torch ginger extract (10%), water (80%), maltodextrin as an

95 encapsulating agent (7%), and emulsifiers (glyceryl monostearate and sodium stearoyl lactylate) each

96 at 1.5% was prepared. Subsequently, the prepared mixture was evenly mixed and homogenised for 15

97 minutes at 6000 rpm by using a Silverson L5M-A laboratory mixer (Silverson Machines, Inc., East

98 Longmeadow, Massachusetts, United States of America). The aforementioned machine was operated

99 with a short stop at every consecutive 5-minute to allow the cool down of the rotor blades. The mixture

100 was further homogenised for 30 minutes by applying speed at 5800 rpm using a GEA Lab Homogeniser

101 PandaPLUS 2000 (GEA Group Aktiengesellschaft, Düsseldorf, Germany). The formed emulsion was

102 dried using a Büchi B-290 spray dryer (Büchi Labortechnik AG, Flawil, Switzerland) which equipped

103 with an atomiser nozzle (0.5 mm in diameter) at 15 MPa. The spray drying process was conducted

104 under the following conditions: inlet air temperature at 130 °C, outlet air temperature at 50 ± 1 °C, flow

105 rate fixed at 150 L/h, and feed suspension rate set at 180 mL/h. Upon completion, the obtained powder

106 was transferred into an amber glass bottle and tightly sealed. The bottle was stored in a refrigerator for

107 storage at a refrigerated condition (± 4 °C). Schematic diagram of the supercritical fluid extraction

108 (SFE) process and the encapsulation of torch ginger extract by spray drying is showed in Fig. 1.

109

110 [Fig. 1 about here]

111

112 Yield of the encapsulated torch ginger extract powder (TGEP) obtained from the process was

113 determined according to the equation used by Navarro-Flores et al. (2020) which given as follows:

114

115 $Yield_{TGEP}$ (%) = Powder obtained (g) / Solids in the feed solution (g) x 100 % (1)

116

117 **2.3. Analysis of Powder Characteristics**

118 **2.3.1. Particle size analysis and BET analysis**

119 The particle size distribution of TGEP was studied using a Mastersizer 2000 particle size analyser

120 equipped with Scirocco 2000 sample dispersion unit (Malvern Instruments Ltd., Malvern, United

121 Kingdom). Prior to analysis, the refractive index of TGEP was determined at 1.52 by using a PAL-RI

122 refractometer (ATAGO Co., Ltd., Tokyo, Japan). TGEP was precisely weighed at 2.0 g, and it was

123 loaded into the hopper attached to the Scirocco 2000 sample dispersion unit, and the pressure was set

124 at 4 bar. In addition, the specific surface area and porosity distribution of TGEP were investigated with

125 Brunauer-Emmett-Teller (BET) analysis through a Micromeritics ASAP 2000 equipment. Before

126 analysis, the sample was degassed for 30 min at 60 °C under a continuous nitrogen gas flow.

127

128 **2.3.2. FTIR spectroscopy analysis**

129 The metabolite screening of TGEP was performed using a Spectrum 100 Fourier Transform Infrared

130 Spectrophotometer (FTIR) (PerkinElmer Inc., Waltham, United States of America) by using method

131 used in our previous study (Naziruddin et al., 2021). The scanning range of the FTIR was set from 4000

132 – 600 cm^{-1} with a scanning resolution of 4 cm^{-1}. By grinding, potassium bromide (KBr) was combined

133 with TGEP and the powder mixture was pelletised before analysis.

134

135 **2.4. Metabolites Profiling by GC-MS**

136 Prior to Gas Chromatography-Mass Spectrometry (GC-MS) analysis, TGEP was derivatized according

137 to the method used by Robinson et al. (2005). Briefly, 25.0 mg of TGEP was placed inside a 2.0 mL

centrifuge tube, and about 50.0 µL of anhydrous pyridine was then added into it. The mixture was subjected to sonication for a duration of 10 minutes at 30 °C by using an Elmasonic S 30 (H) ultrasonic device (Elma Schmidbauer GmbH, Singen, Germany). Subsequently, about 100 µL of methoxyamine HCl (20 mg/mL in pyridine) was pipetted into the solution and it was vortexed for one minute. Two consecutive incubation was conducted by which the solution was initially incubated for 2 hours at 60 °C and it was again incubated for 30 minutes at 60 °C upon the addition of 300 µL of MSTFA. Lastly, the solution was filtered using a 0.22 µm nylon syringe filter, and the filtered liquid was then transferred to an amber vial to be left at room temperature overnight.

The GC-MS method used in our previous study was followed for the identification of metabolites in TGEP and some modifications were made to improve the detection (Naziruddin et al., 2022). The derivatized fraction of TGEP was analysed by using a TSQ Quantum XLS GC-MS system (Thermo Scientific, United States of America). TGEP's aliquot was injected (1 µL injection volume) into an Agilent J&W DB-5MS column (length: 30 m, inner diameter: 0.25 mm, and film thickness: 0.25 mm) (Agilent Technologies, California, United States of America) in split-less mode and the carrier gas used was helium at 1.0 mL/min. The column was first held at 80 °C for 5 min and afterwards increased at 8 °C/min to 200 °C. Subsequently, the temperature of the oven was gradually raised to 280 °C at a ramp rate of 4 °C/min, and maintained at that level for 15 minutes. The temperature of the ion source and interface were regulated at 280 °C and 250 °C, respectively. The GC-MS analysis was performed in a total ion chromatography (TIC) mode and the full scan data was collected within a mass scan range of 40 to 600 m/z. To identify the compounds present, the acquired mass spectra for each chromatographic peak were compared with a retention time index and mass spectral libraries for GC-MS that were created by the National Institute of Standards and Technology (NIST). The data version used for this analysis was NIST17 (NIST, 2017).

2.5. Analysis of Antioxidant Activity

2.5.1. Quantification of the Total Phenolic Content

Total Phenolic Content (TPC) in TGEP was quantified using the Folin-Ciocalteu method (Xiao et al., 2020). TGEP (precisely weighed at 0.5 mg) was dissolved in 1 mL ethanol and shaken for 1 minutes.

Meanwhile, ethanolic gallic acid (GA) calibration solutions were prepared at five concentration levels which ranging from 6.25 x 10^{-3} mg/mL – 0.1 mg/mL. Briefly, approximately 0.1 mL of the extract was pipetted into a test tube and mixed with 0.5 mL of 50% Folin-Ciocalteu reagent. Subsequently, the solution was mixed using a vortex mixer (OHAUS Corporation, New Jersey, United States of America) for 3 minutes and about 7.9 mL of distilled water was added to the tube. The solution was allowed to set at room temperature for 5 minutes. Following that, 7.5% sodium carbonate solution was added to made the final volume of 10 mL and later it was incubated in a dark room (± 28 °C) for 2 hours. Throughout the incubation, the tube was periodically shaken at every 30 minutes to ensure it was fully reacted. Both sample and calibration standard solutions were determined for its absorbance at the wavelength of 765 nm by using a ultraviolet-visible (UV-Vis) spectrophotometer of the GENESYS™ 10S model (Thermo Fisher Scientific, Waltham, United States of America). The TPC's result was expressed as milligram (mg) of gallic acid equivalents (GAE) per gram (g) of TGEP (mg GAE/g TGEP). Calibration curve of the gallic acid standard was constructed and its linear equation was used to estimate the TPC value of TGEP.

2.5.2. DPPH radical scavenging capacity assay

The DPPH assay was performed based on previously reported methods with minor alterations (Trucillo et al., 2018). Sample was prepared by dissolving TGEP in ethanol at five different concentrations (0.1 mg/mL, 0.05 mg/mL, 0.025 mg/mL, 0.0125 mg/mL, and 6.25 x 10^{-3} mg/mL in ethanol). Meanwhile, all five levels of GA calibration solutions were also prepared in ethanol which ranging from 0.05 mg/mL to 3.125 x 10^{-3} mg/mL in concentration. Precisely weighed DPPH at 0.0197 g was dissolved in 500 mL ethanol to make a 10^{-4} M solution. Briefly, about 1 mL of the diluted TGEP was mixed with 3.0 mL DPPH solution in a test tube and intensely shaken for 1 minutes. The test tube was allowed to incubate for 30 minutes in a dark environment at ambient temperature. A UV-Vis spectrophotometer (similar model used for TPC assay) was used to measure the absorbance at a wavelength of 517 nm for the sample, standard, and control (diluted DPPH in ethanol absolute). Scavenging capacity (%) of the sample and standards were estimated by solving the equation (2) as follows:

Scavenging capacity (%) = [1 − (*abs*. *A* / *abs*. *B*)] x 100 % (2)

Where *abs*. *A* is the absorbance of sample or standards and *abs*. *B* is the control's absorbance. Reduction of the initial DPPH radical concentration by 50% based on its respective TGEP's concentration was represented by EC_{50} value.

2.5.3. Ferric reducing antioxidant power (FRAP) assay

FRAP assay was conducted by applying methods described by Benzie and Strain (1996) and Tomasina et al. (2012) with slight modifications. Freshly prepared FRAP reagent solution was prepared by combining 300 mM acetate buffer (pH 3.6), 10 mM TPTZ solution (in 40 mM hydrochloric acid), and 20 mM ferric chloride hexahydrate ($FeCl_3$) with a volume (mL) ratio of 25: 2.5: 2.5. Ethanolic TGEP's extract was prepared by dissolving the sample (1 mg) in 1 mL of ethanol. Meanwhile, Trolox calibration solutions in the concentration of 19.977 µM, 9.988 µM, 4.994 µM, 2.497 µM, and 1.251 µM were also prepared in ethanol. The assay was performed by mixing 8.7 mL of FRAP reagent with 0.3 mL TGEP's ethanolic extract and it was put aside to incubate at 50 °C for 1 hour. Using a UV-vis spectrophotometer, the absorbance at 593 nm was measured to monitor the reduction of ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}) by the antioxidants present in both TGEP and the standard. Results were expressed as micromolar (µM) of Trolox equivalents (TE) per g of TGEP (µM TE/g TGEP). Calibration curve based on the Trolox standards was constructed and the obtained equation was used to calculate the FRAP value.

3. Results and Discussion

3.1. Yield of the encapsulated torch ginger-extract powder

In the process, about 400 g of the prepared emulsion with a total solid mass of 80.0 g (50:50 torch ginger's extract and encapsulating agent) was fed into the spray dryer, which produced 47.8 g of TGEP. Hence, based on the determination by equation (1), the process managed to yield around 59.8% of TGEP. The obtained yield in this study was found to be substantially higher than the yields reported by Anuar et al. (2021) which were in the range of 15 % – 36 % based on various formulations tested.

222 **3.2. Particle size analysis and BET analysis**

223 Fig. 2 displays the distribution of particle size for encapsulated torch ginger-extract powder. The median
224 diameter, $D_{0.5}$ for TGEP was measured at 6.188 ± 0.771 µm. Meanwhile, the sample revealed two
225 distinct particle sizes concentrating at 2.2 µm and 17.4 µm, respectively. This non-uniform size
226 distribution was likely due to the formation of large agglomerates as a result of spray drying at low inlet
227 air temperature (≤ 140 °C) (Both et al., 2020). Additionally, Siccama et al. (2021) also mentioned that
228 the presence of high residual moisture content and low glass transition temperature of the spray dried
229 powder might increase its stickiness which leads to agglomeration. Nonetheless, the produced TGEP
230 showed relatively small size of particles which was less than 50 µm.

231

232 [Fig. 2 about here]

233

234 In BET analysis (Table 1), TGEP was examined with the presence of considerably high surface area,
235 pore volume, and pore size features. Surface area purportedly affected the functionality of powders:
236 solubility, flowability, rehydration, and wetting characteristics. Furthermore, high surface area of
237 functional powder also contributed to a high degree of solvation which is paramount for the absorption
238 of retained compounds (Burgain et al., 2017; Koç & Kaymak-Ertekin, 2014). The outcomes' trend of
239 BET analysis were in agreement with results reported by Zhang et al. (2018), as the spray-dried powder
240 obtained from their research exhibited higher surface area (ranging from 1.54 to 2.18 m^2/g) with greater
241 porosity. The authors also reported that the physical characteristics of spray-dried powder often affected
242 by the spray drying inlet air temperature and type of atomiser. Zhang et al. (2018) also reported that the
243 inlet air temperature in between 120 °C to 160 °C can induced the increased of powder's surface area
244 due to formation of particles with dryer and harder coating. The aforementioned inlet air temperature
245 reflected to this study as the spray drying process was conducted at 130 °C. Hence, similar powder
246 characteristics reported by Zhang et al. (2018) were expected

247

248 [Table 1 about here]

249

3.3. FTIR analysis

The FTIR spectrum of TGEP is displayed in Fig. 3, and the peaks in the fingerprint region were assigned based on their corresponding functional groups in Table 2. A wide band was observed extending from 3000 cm^{-1} to 3600 cm^{-1}, which corresponded to the O-H stretching vibration of alcohols and carboxylic acids in the sample. Several researchers have been reported the present of alcohols, such as 1-Dodecanol, Tetradecanol, and 1-Undecanol in the torch ginger extract. Meanwhile, carboxylic acid that predominantly fatty acids such as Hexacosanoic acid, Decanoic acid, and Hexadecanoic acid also has been reported to present in torch ginger extract (Al-Mansoub et al., 2021; Anzian et al., 2020; Marzlan et al., 2020). The spectra showed two intense sharp peaks at 2853 cm^{-1} and 2925 cm^{-1} which were in relation to the C-H stretching vibration of alkyl group. Additionally, the presence of alkene in TGEP can be identified by a medium peak formed at 1463 cm^{-1} which corresponded to C-H bending of methylene group and a 1652 cm^{-1} shoulder band which representing the double bonds (C=C) vibrational stretching of alkenyl group. Alkane and alkene which belong to the class of hydrocarbons also has been reported by Al-Mansoub et al. (2021), as the author managed to identify the presence of Cyclododecane, Heptadecane, 1-Decene, and 1-Tetradecene in the ethanolic torch ginger extract. The sample also exhibited a sharp peak at 1727 cm^{-1} which indicating the C=O stretching of carbonyl group such aldehyde, ester, and carboxylic acid. This finding was in agreement with results reported by Marzlan et al. (2020), as the authors identified esters such as Lauryl acetate, Myristyl myristate, and (E)-9-Tetradecen-1-ol acetate in torch ginger oil extracted by supercritical fluid extraction. Anhydride group also potentially present in TGEP as indicated by the intense peak formed at 1025 cm^{-1} which attributing to the CO-O-CO stretching of the functional group. Subsequently, a sharp peak present at 1200 cm^{-1} signalled the C-N stretching of amine, while a broad peak formed at 1250 cm^{-1} to 1310 cm^{-1} might be corresponded to the C-O stretching of aromatic ester. Lastly, a noticeable peak formed at 750 cm^{-1} could be associated to C-H bending of 1,2-disubstituted and monosubstituted compounds that present in TGEP. Hence, the results proved that the presence of chemically-diverse compounds in TGEP was valid.

[Fig. 3 about here]

[Table 2 about here]

3.4. Metabolite profiling and identification by GC-MS

GC-MS chromatogram of the detected metabolites in TGEP was showed in Fig. 4. Broad array of masses was acquired (scan range 40 – 600m/z) within the scan time of 5.0 to 55.0 minutes and presence of metabolites were monitored at various retention times (RTs). The metabolites' identities were confirmed by comparing the generated spectral pattern with those of established spectral library developed by National Institute of Standards and Technology (NIST), data version NIST17 (NIST, 2017). Additionally, the detected metabolites were classified by referring to the comprehensive database of FooDB which was developed by the renounce research teams specialising in metabolomics (TMIC, 2021).

[Fig. 4 about here]

Altogether, about 59 metabolites belong to the 19 different classes of compounds were identified in TGEP as listed in Table 3. The number of metabolites able to be detected in this study is substantially higher and more diversified than other reported torch ginger's metabolite studies. In literature, studies conducted by Marzlan et al. (2020) and Anzian et al. (2020) reported the numbers of metabolite found in torch ginger's essential oil at 20 and 33 respectively. In brief, most of the detected metabolites were belong to four major classes which were fatty acids (30.5%), terpenes and derivatives (20.3%), fatty acid esters (16.9%), and alcohols (8.47%).

[Table 3 about here]

Among these major classes of metabolites, alcohols particularly 1-Dodecanol was reported to render a potent antibacterial activity against several bacterial species (Marzlan et al., 2022; Marzlan et al., 2020). Additionally, the pharmacological activities of terpenoids were also well-known and heavily studied in

306 the literature. Uvaol, a triterpene, was reported by Agra et al. (2016) to be effective as an active
307 ingredient for the treatment of inflammation caused by allergic reaction.
308
309 Torch ginger notoriously known for its distinctive aroma which is a vital characteristic of Southeast
310 Asian's cuisine. Expert described that torch ginger embodies a sweet, tangy, and lemongrass-like aroma
311 profile (Khor et al., 2017). Although the key aromatic compounds that responsible for torch ginger's
312 aroma have never been reported in literature, such study was already being conducted for ginger
313 (*Zingiber officinale* Roscoe) and galangal (*Kaempferia galanga* L.) which also belong in the
314 *Zingiberaceae* family. The researchers identified the presence of metabolite composition that consist of
315 aldehyde, alcohol, hydrocarbon, ketone, terpene, and ester to be accountable for the distinctive aroma
316 of both herbs (Hasegawa et al., 2016; Pang et al., 2017). In spite of the differences in species, similar
317 composition as previously mentioned was also found in TGEP and the aroma profiles exude by the
318 compounds could be assumed similar to torch ginger. Pang et al. (2017) mentioned that the presence of
319 primary odorants in ginger namely, monoterpenes and sesquiterpenes could be associated to the woody,
320 minty, citrusy, and herbal-like aroma. The researchers also attributed the sweet notes (balsamic and
321 floral) of ginger to the presence of metabolites in the class of alcohol, aldehyde, terpene and terpene
322 derivative. Additionally, humulene, a sesquiterpene found in TGEP was also reportedly presence in
323 galangal and it was presumed to emits the unique galangal-like aroma (Hasegawa et al., 2016). The
324 formerly defined aroma profile of ginger and galangal are noticeably similar to the general description
325 of torch ginger's aroma. Therefore, it is presumed that the key aromatic compounds of torch ginger
326 were retained in the TGEP, which would be beneficial for the application in food.
327
328 **3.5. Antioxidant activity**
329 The antioxidant capacity of TGEP was evaluated based on the performance of TPC, DPPH, and FRAP
330 as showed in Table 4. The quantified value of TPC for TGEP was found to be higher than other reported
331 values in literature which were in the range of 2.12 – 19.4 mg GAE/g (Anzian et al., 2017; Yan &
332 Asmah, 2010). The TPC values of the aforementioned studies were based on the quantification in the
333 fresh and dried forms of torch ginger. Therefore, it indicates that the phenolic compounds present in

334 torch ginger retained at an exceptional level in TGEP. Additionally, this claimed also supported by the
335 presence of Hexadecyl-(E)-p-coumarate which is a phenolic acid identified in TGEP by the GC-MS.
336
337 [Table 4 about here]
338
339 The free radical scavenging capacity of TGEP was predicted based on its antioxidants ability to reduce
340 DPPH radical. The activity of scavenging DPPH radicals was measured by the EC_{50} value in which it
341 indicates the effective TGEP's concentration needed to reduce the DPPH radical's absorbance by 50%.
342 The value of EC_{50} for TGEP was determined at 1.31 ± 0.002 mg/mL, which was substantially lower
343 than such value reported by Nurain et al. (2013) at 3.47 ± 0.420 mg/mL based on the determination in
344 ethanolic torch ginger's extract. This low value of EC_{50} for TGEP signified its high antioxidant activity
345 which could potentially linked to its high TPC value. Additionally, the quantified FRAP value of TGEP
346 also was found to be substantially higher as compared to such values reported by Bunleu and Buavaroon
347 (2018) and Wijekoon et al. (2011) which were in the range of 9.0 – 130 µM Fe(II)/g. The excellent
348 performance of TGEP's antioxidants in the assay demonstrated its high reactivity against the Fe^{3+} -
349 TPTZ and effectively reduced it to Fe^{2+} - TPTZ. Hydroxyl and carbonyl-rich compounds in plants have
350 been associated with excellent reducing capabilities and stabilisers (Mohamad et al., 2014; Pradeep et
351 al., 2022). Based on Table 3, TGEP possessed abundant compounds with sufficient hydroxyl and
352 carbonyl groups present, such as dodecanal (aldehyde), xanthophyll, and β-Sitosterol (terpene)
353 (Mahavy et al., 2022; Tovey, 2019). The oxidation-reduction abilities of these compounds allow the
354 binding of metals and inactivate them via chelation (Azri et al., 2019).
355
356 The outstanding performance of TGEP in the aforementioned antioxidant assay could be linked to the
357 existence of various metabolites in the class of terpenoids as profiled in Table 3. Terpenoid has been
358 vastly studied in literature and the evidences for its potency as an antioxidant were well recorded.
359 Terpenoids, namely humulene and uvaol found in TGEP have been reported in multiple studies able to
360 induce the reduction of oxidative stress by effectively control the autoxidation reaction (Allouche et al.,
361 2010; Gunawan et al., 2016). Additionally, the abundance of TGEP's metabolites with a hydroxyl,

362 methoxy, and carboxylic acid groups could potentially contribute to the high antioxidant capacity as
363 these functional group were reported to render a vital effect on the antioxidant ability (Chen et al.,
364 2020).
365
366 **3.6. Potential future as a plant-based functional food additive**
367 The development of functional food additives derived from plants has aroused the interest of consumers
368 for a much healthier alternative and reduced the dependency on its artificial counterparts (Domínguez
369 et al., 2021). However, various shortcomings in applying plant extract at the industrial scale might
370 induce complexity in the manufacturing process and not be economically sound. Plant extract must be
371 handled with the utmost care as it is highly volatile, hydrophobic, and prone to stability issues when
372 exposed to environmental stressors (e.g., extreme temperature, light) (Kfoury et al., 2016; Rezaei &
373 Nasirpour, 2019). The encapsulation technique has been known to offset these problems as it can trap
374 the plant's bioactive compounds in an encapsulating agent and makes it more stable (Muñoz-Shugulí
375 et al., 2021). Based on the evaluations, TGEP has demonstrated the retention of various metabolites
376 with different bioactive functions and maintained its antioxidant capability. This technique also captures
377 the key aromatic compounds of torch ginger, which would be vital for its application as a food additive.
378
379 **4. Conclusion**
380 Present study revealed the extraction, encapsulation and comprehensive metabolite profiling of torch
381 ginger-extract powder. Spray drying encapsulation process managed to yield around 59.8% of TGEP
382 by incorporating 10% supercritical fluid-torch ginger extract into encapsulating agent mixture, which
383 the obtained yield was twice higher than other study. Based on the performed analyses, the developed
384 powder showed the present of varying valuable bioactive compounds. From the particle size analysis,
385 TGEP revealed aggregated feature, which shown by two distinct particle sizes concentrating at 2.2 μm
386 and 17.4 μm, respectively. BET analysis of TGEP unveiled a considerably high surface area (1.13 m^2/g),
387 pore volume (0.218 cm^3/g), and pore size (384.6 nm) which were purportedly affected by the spray
388 drying inlet air temperature. The FTIR analysis revealed the presence of O-H, C-H, C=C, C=O, CO-O-
389 CO, C-N, and C-O functional groups in the sample. Meanwhile, based on the GC-MS analysis, about

390 59 metabolites that predominantly fatty acids (30.5%), terpenes and derivatives (20.3%), fatty acid
391 esters (16.9%), and alcohols (8.47%) were identified in TGEP. TGEP also demonstrated an excellent
392 antioxidant capacity based on its high activity in the DPPH radical scavenging capacity (1.31 ± 0.002),
393 ferric reducing antioxidant power assay (2919.5 ± 19.9), and high value of total phenolic content (23.3
394 ± 0.662) in comparison to the previous studies. Therefore, this study has indicated that the developed
395 encapsulated torch ginger extract powder able to retain the beneficial bioactive compounds which
396 makes it a promising functional powder.
397
398 **Conflict of Interest**
399 Authors declared no conflict of interest
400
401 **Data Availability**
402 All data generated or analysed during this study are included in this published article.
403

404 **Tables and figures**

405 **Table 1.** BET analysis data of TGEP

Sample	Surface Area (m^2/g)	Pore Volume (cm^3/g)	Pore Size (nm)
TGEP	1.131	0.218	384.6

406

407 **Table 2.** Assignment of FTIR spectra peaks and corresponding functional groups

Wavenumbers (cm^{-1})	Band assignment
3000 cm^{-1} to 3600 cm^{-1}	O-H stretching vibration of alcohols and carboxylic acids
2853 cm^{-1} and 2925 cm^{-1}	C-H stretching vibration of alkyl group
1463 cm^{-1}	C-H bending of methylene group
1652 cm^{-1}	Double bonds (C=C) vibrational stretching of alkenyl group
1727 cm^{-1}	C=O stretching of carbonyl group
1025 cm^{-1}	CO-O-CO stretching of anhydride group
1200 cm^{-1}	C-N stretching of amine
1250 cm^{-1} to 1310 cm^{-1}	C-O stretching of aromatic ester
750 cm^{-1}	C-H bending of 1,2-disubstituted and monosubstituted compounds

408

409 **Table 3.** Metabolites composition in TGEP as identified by GC-MS.

Nr.	Metabolite	Retention time (min)	Molecular formula	Molecular weight (g/mol)	Probability (%)
	Acetate Esters				
1.	1-Tetradecyl acetate	20.14	$C_{16}H_{32}O_2$	256	23.72
2.	Lauryl acetate	17.39	$C_{14}H_{28}O_2$	228	36.04
	Acid anhydride				
3.	2,5-Furandione, 3-dodecyl-	32.45	$C_{16}H_{26}O_3$	266	10.42
	Alcohols				
4.	1-Dodecanol	15.35	$C_{12}H_{26}O$	186	13.35
5.	11-Tetradecen-1-ol, (E)-	18.22	$C_{14}H_{28}O$	212	11.34
6.	cis-9-Tetradecen-1-ol	18.22	$C_{14}H_{28}O$	212	10.46
7.	cis-11-Tetradecen-1-ol	18.22	$C_{14}H_{28}O$	212	10.06
8.	1-Heptatriacotanol	29.96	$C_{37}H_{76}O$	536	24.73
	Aldehyde				
9.	Dodecanal	10.09	$C_{12}H_{24}O$	184	44.48
	Amine				
10.	2,6-Octadien-1-amine, 3,7-dimethyl-	11.76	$C_{10}H_{19}N$	153	12.92
	Carboxylic esters				
11.	4-Azido-2-nitrobutyric acid, 2,6-di-t-butyl-4-methoxyph	34.96	$C_{19}H_{28}N_4O_5$	392	21.06

	enyl ester				
	Coumaric acid ester				
12.	Hexadecyl-(E)-p-coumarate, trimethylsilyl ether	38.38	$C_{28}H_{48}O_3Si$	460	36.63
	Dithiane				
13.	2-[3-(1-Ethoxyethoxy)prop yl][1,3]dithiane	24.29	$C_{11}H_{22}O_2S_2$	250	28.96
	Fatty acids				
14.	Dodecanoic acid, 3-hydroxy-	10.43	$C_{12}H_{24}O_3$	216	12.20
15.	Dodecanoic acid	16.04	$C_{12}H_{24}O_2$	200	63.76
16.	Dodecanoic acid, TMS derivative	17.59	$C_{15}H_{32}O_2Si$	272	56.20
17.	Undecanoic acid, TMS derivative	18.06	$C_{14}H_{30}O_2Si$	258	10.35
18.	Tetradecanoic acid	19.55	$C_{14}H_{28}O_2$	228	39.02
19.	Myristic acid, TMS derivative	20.71	$C_{17}H_{36}O_2Si$	300	68.45
20.	Tridecanoic acid	22.34	$C_{13}H_{26}O_2$	214	30.30
21.	Pentadecanoic acid	22.34	$C_{15}H_{30}O_2$	242	18.22
22.	Palmitelaidic acid, TMS derivative	23.22	$C_{19}H_{38}O_2Si$	326	58.40
23.	Petroselinic acid, TMS derivative	23.22	$C_{21}H_{42}O_2Si$	354	11.55
24.	Palmitic Acid, TMS derivative	23.68	$C_{19}H_{40}O_2Si$	328	45.52
25.	Tridecanoic acid, TMS derivative	11.42	$C_{16}H_{34}O_2Si$	286	11.42
26.	Pentadecanoic acid, TMS derivative	10.98	$C_{18}H_{38}O_2Si$	314	10.98
27.	Octadecanoic acid	25.54	$C_{18}H_{36}O_2$	284	11.19
28.	9,12-Octadecadienoic acid (Z,Z)-, TMS derivative	26.42	$C_{21}H_{40}O_2Si$	352	22.10
29.	Stearic acid, TMS derivative	26.90	$C_{21}H_{44}O_2Si$	356	37.56
30.	Heptadecanoic acid, TMS derivative	26.90	$C_{20}H_{42}O_2Si$	342	25.76
31.	2-Oleoylglycerol, 2TMS derivative	35.50	$C_{27}H_{56}O_4Si_2$	500	16.18
	Fatty acid esters				
32.	9-Octadecenoic acid (Z)-, oxiranylmethyl ester	25.54	$C_{21}H_{38}O_3$	338	12.67
33.	9(E),11(E)-Conjugated linoleic acid, trimethylsilyl ester	26.42	$C_{21}H_{40}O_2Si$	352	36.47
34.	Butanoic acid, 4-cyano-2-nitro-, 2,6-bis(1,1-dimethylethyl)-4-methoxyphenyl ester	34.96	$C_{20}H_{28}N_2O_5$	376	13.18
35.	cis-9-Tetradecenoic acid,	43.13	$C_{21}H_{40}O_2$	324	43.13

	heptyl ester				
36.	cis-9-Tetradecenoic acid, isobutyl ester	35.88	$C_{18}H_{34}O_2$	282	10.33
37.	Tetradecanoic acid, 2-oxo-, ethyl ester	37.61	$C_{16}H_{30}O_3$	270	51.47
38.	Hexadecanoic acid, octadecyl ester	39.29	$C_{34}H_{68}O_2$	508	23.56
39.	Hexadecanoic acid, tetradecyl ester	39.29	$C_{30}H_{60}O_2$	452	16.16
40.	Hexadecanoic acid, hexadecyl ester	39.29	$C_{32}H_{64}O_2$	480	11.41
41.	Oleic acid, eicosyl ester	46.10	$C_{38}H_{74}O_2$	562	14.32
	Hydrocarbon				
42.	17-Pentatriacontene	41.55	$C_{35}H_{70}$	490	14.77
	Ketones				
43.	Cyclododecanol	10.09	$C_{12}H_{24}O$	184	16.24
44.	(Z)-18-Octadec-9-enolide	25.16	$C_{18}H_{32}O_2$	280	14.66
45.	15-Isopropenyl-3-(trimethy lsilyl)oxacyclopentadecan-2 -one	26.42	$C_{20}H_{38}O_2Si$	338	26.42
	Phytoestrogen and derivative				
46.	Estra-1,3,5(10)-trien-17β-ol	25.54	$C_{18}H_{24}O$	256	14.99
	Xanthophyll				
47.	.psi.,.psi.-Carotene, 1,1',2,2'-tetrahydro-1,1'-dimethoxy-	45.88	$C_{42}H_{64}O_2$	600	7.79
Terpenes and derivatives					
	Monoterpenes				
48.	3-Cyclohexene-1-methanol , 5-hydroxy-α,α,4-trimethyl-	13.79	$C_{10}H_{18}O_2$	170	14.18
49.	trans-3(10)-Caren-2-ol	13.79	$C_{10}H_{16}O$	152	13.79
	Monoterpene derivative				
50.	Sobrerol 8-acetate	13.79	$C_{12}H_{20}O_3$	212	14.18
	Sesquiterpenes				
51.	1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-	15.17	$C_{15}H_{24}$	204	33.15
52.	Humulene	15.17	$C_{15}H_{24}$	204	24.07
53.	Formic acid, 3,7,11-trimethyl-1,6,10-do decatrien-3-yl ester	15.68	$C_{16}H_{26}O_2$	250	11.47
	Triterpenes				
54.	ç-Sitosterol	46.47	$C_{29}H_{50}O$	414	15.68
55.	β-Sitosterol	46.67	$C_{29}H_{50}O$	414	30.42
56.	Uvaol, 2O-TMS	47.19	$C_{36}H_{66}O_2Si_2$	586	10.48
57.	β-Sitosterol, TMS derivative	47.51	$C_{32}H_{58}OSi$	486	10.54

58.	Stigmast-5-ene, 3β-(trimethylsiloxy)-, (24S)-	47.51	$C_{32}H_{58}OSi$	486	52.32
	Terpene alcohol				
59.	7,8-Epoxylanostan-11-ol, 3-acetoxy-	41.08	$C_{32}H_{54}O_4$	502	17.48

410

411 **Table 4.** Antioxidant activity of the encapsulated torch ginger-extract powder.

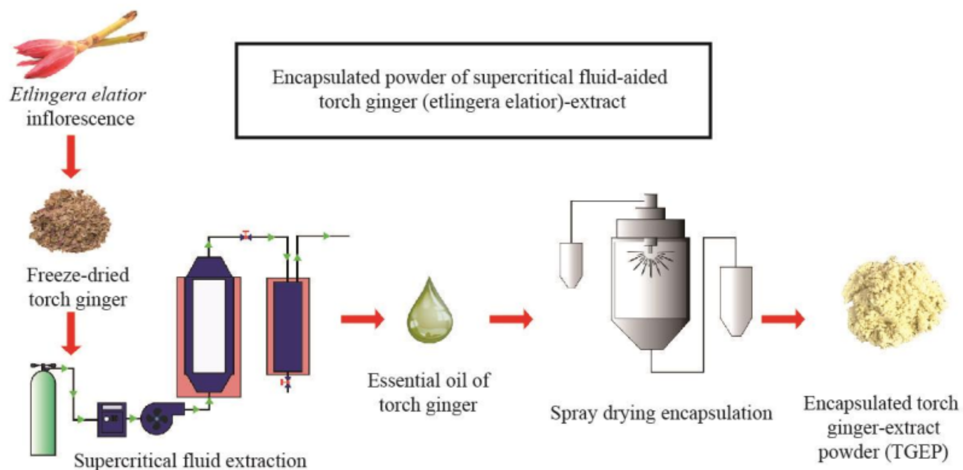
TPC (mg GAE/g TGEP)	EC_{50} of DPPH radical scavenging ability (mg/mL)	FRAP (μM TE/g TGEP)
23.3 ± 0.662	1.31 ± 0.002	2919.5 ± 19.9

412 Values are means of triplicate determination ± SD.

413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431

432 **List of figures**

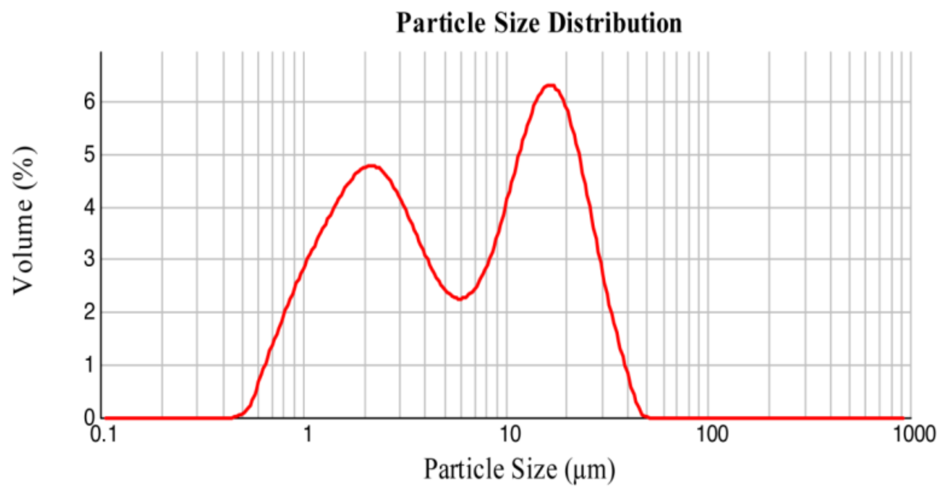
433 **1. Fig. 1.** A schematic representation illustrating the SFE and the encapsulation process of TGEP.
434
435 **2. Fig. 2.** Particle size distribution of TGEP.
436
437 **3. Fig. 3.** FTIR spectrum of TGEP.
438
439 **4**. **Fig. 4.** The chromatogram obtained by GC-MS (TIC) displays the metabolites that have been
440 identified in TGEP.
441
442



443
444 **Fig. 1.** A schematic representation illustrating the SFE and the encapsulation process of TGEP.

445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466

467

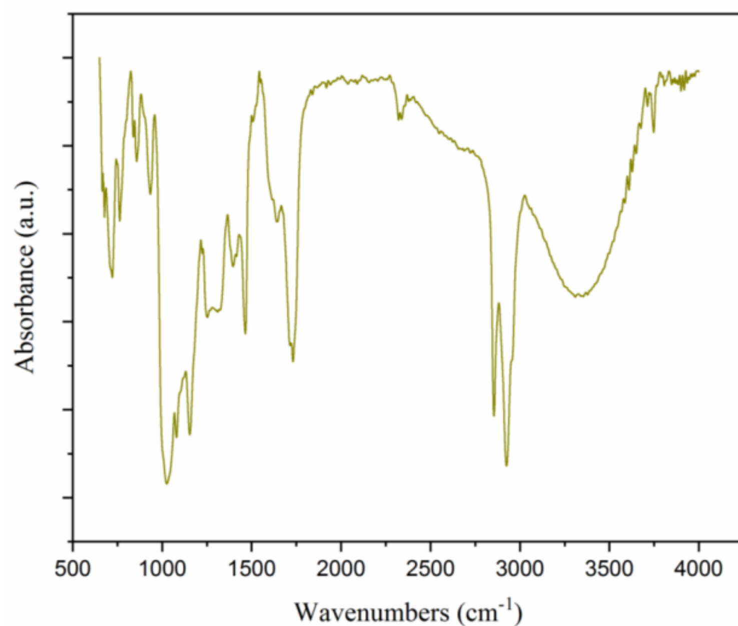


468 **Fig. 2.** Particle size distribution of TGEP.

469

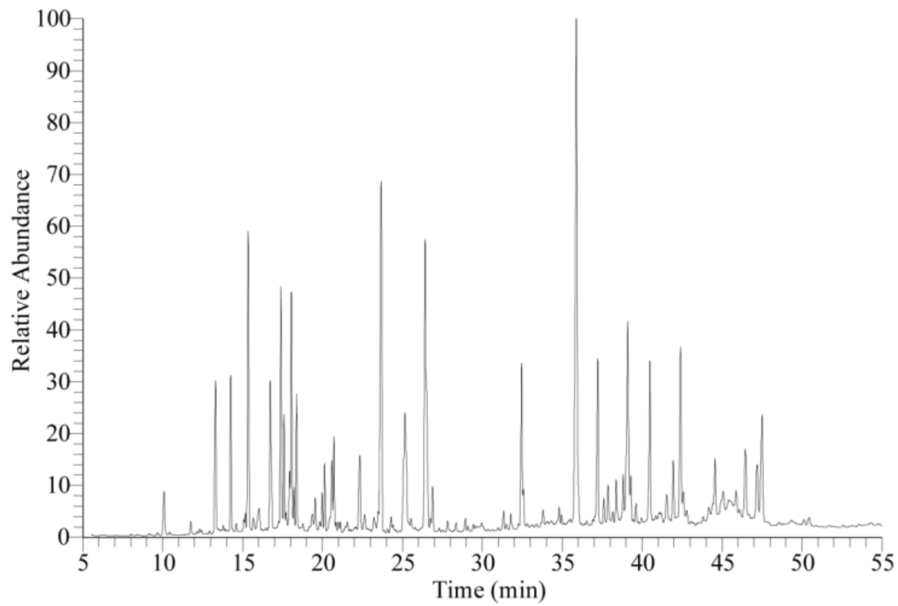
470
471
472
473
474
475
476
477
478
479
480

481



482 **Fig. 3.** FTIR spectrum of TGEP.

483
484
485
486
487
488
489
490
491
492
493
494
495



496
497 **Fig. 4.** The chromatogram obtained by GC-MS (TIC) displays the metabolites that have been
498 identified in TGEP.

499
500
501
502
503
504
505
506
507
508
509
510
511
512
513

514
515
516
517
518
519
520
521
522
523
524
525
526

527 **References**

528 Abdelwahab, S. I., Zaman, F. Q., Mariod, A. A., Yaacob, M., Ahmed Abdelmageed, A. H., &
529 Khamis, S., 2010. Chemical composition, antioxidant and antibacterial properties of
530 the essential oils of *Etlingera elatior* and Cinnamomum pubescens Kochummen.
531 Journal of the Science of Food and Agriculture. 90(15), 2682-2688.
532 https://doi.org/10.1002/jsfa.4140.
533 Agra, L. C., Lins, M. P., da Silva Marques, P., Smaniotto, S., Bandeira de Melo, C., Lagente,
534 V., & Barreto, E., 2016. Uvaol attenuates pleuritis and eosinophilic inflammation in
535 ovalbumin-induced allergy in mice. European Journal of Pharmacology. 780, 232-242.
536 https://doi.org/10.1016/j.ejphar.2016.03.056.
537 Al-Mansoub, M., Asif, M., Revadigar, V., Hammad, M., Chear, N., Hamdan, M. R., . . .
538 Murugaiyah, V., 2021. Chemical composition, antiproliferative and antioxidant
539 attributes of ethanolic extract of resinous sediment from *Etlingera elatior* (Jack.)
540 inflorescence. Braz. J. Pharm. Sci. 57. https://doi.org/10.1590/s2175-
541 97902020000418954.
542 Allouche, Y., Beltrán, G., Gaforio, J. J., Uceda, M., & Mesa, M. D., 2010. Antioxidant and
543 antiatherogenic activities of pentacyclic triterpenic diols and acids. Food and Chemical
544 Toxicology. 48(10), 2885-2890. https://doi.org/10.1016/j.fct.2010.07.022.
545 Anuar, N. H. S., Kormin, F., Isa, N. L. M., Iwansyah, A. C., Abu Bakar, M. F., Mohamad Fuzi,
546 S. F. Z., & Sabran, F., 2021. Spray Drying Microencapsulation of Kantan Extract
547 (*Etlingera Elatior*) with Various Wall Materials. IOP Conference Series: Earth and
548 Environmental Science. 736(1), 012007. https://doi.org/10.1088/1755-
549 1315/736/1/012007.
550 Anzian, A., Muhialdin, B. J., Mohammed, N. K., Kadum, H., Marzlan, A. A., Sukor, R., &
551 Meor Hussin, A. S., 2020. Antibacterial Activity and Metabolomics Profiling of Torch
552 Ginger (*Etlingera elatior* Jack) Flower Oil Extracted Using Subcritical Carbon Dioxide
553 (CO_2) Evidence-Based Complementary and Alternative Medicine. 2020, 4373401.
554 https://doi.org/10.1155/2020/4373401.
555 Anzian, A., Rashidah, S., Nazamid, S., Safraa binti Che Wan Sapawi, C. W. N., & Meor
556 Hussin, A. S. b., 2017. Chemical composition and antioxidant activity of Torch Ginger
557 (*Etlingera elatior*) flower extract. Food and Applied Bioscience Journal. 5(1), 32-49.
558 https://doi.org/10.14456/fabj.2017.4.
559 Arumugham, T., K, R., Hasan, S. W., Show, P. L., Rinklebe, J., & Banat, F., 2021. Supercritical
560 carbon dioxide extraction of plant phytochemicals for biological and environmental
561 applications – A review. Chemosphere. 271, 129525.
562 https://doi.org/10.1016/j.chemosphere.2020.129525.
563 Azri, F. A., Selamat, J., Sukor, R., Yusof, N. A., Ahmad Raston, N. H., Nordin, N., & Jambari,
564 N. N., 2019. *Etlingera elatior*-Mediated Synthesis of Gold Nanoparticles and Their
565 Application as Electrochemical Current Enhancer. Molecules. 24(17), 3141.
566 https://doi.org/10.3390/molecules24173141.
567 Benzie, I. F. F., & Strain, J. J., 1996. The Ferric Reducing Ability of Plasma (FRAP) as a
568 Measure of "Antioxidant Power": The FRAP Assay. Analytical Biochemistry. 239(1),
569 70-76. https://doi.org/10.1006/abio.1996.0292.
570 Both, E. M., Boom, R. M., & Schutyser, M. A. I., 2020. Particle morphology and powder
571 properties during spray drying of maltodextrin and whey protein mixtures. Powder
572 Technology. 363, 519-524. https://doi.org/10.1016/j.powtec.2020.01.001.
573 Bunleu, S., & Buavaroon, S., 2018. Antioxidant Activities, Acute Toxicity and Chemical
574 Profiling of Torch Ginger (*Etlingera elatior* Jack.) Inflorescent Extract.
575 Pharmacognosy Journal. 10(5), 979-982. https://doi.org/10.5530/pj.2018.5.166.

576 Burgain, J., Petit, J., Scher, J., Rasch, R., Bhandari, B., & Gaiani, C., 2017. Surface chemistry
577 and microscopy of food powders. Progress in Surface Science. 92(4), 409-429.
578 https://doi.org/10.1016/j.progsurf.2017.07.002.
579 Caballero, A. S., Romero-García, J. M., Castro, E., & Cardona, C. A., 2020. Supercritical fluid
580 extraction for enhancing polyphenolic compounds production from olive waste
581 extracts. Journal of Chemical Technology & Biotechnology. 95(2), 356-362.
582 https://doi.org/10.1002/jctb.5907.
583 Chen, J., Yang, J., Ma, L., Li, J., Shahzad, N., & Kim, C. K., 2020. Structure-antioxidant
584 activity relationship of methoxy, phenolic hydroxyl, and carboxylic acid groups of
585 phenolic acids. Scientific Reports. 10(1), 2611. https://doi.org/10.1038/s41598-020-
586 59451-z.
587 Domínguez, R., Pateiro, M., Munekata, P. E. S., McClements, D. J., & Lorenzo, J. M., 2021.
588 Encapsulation of Bioactive Phytochemicals in Plant-Based Matrices and Application
589 as Additives in Meat and Meat Products. Molecules. 26(13), 3984.
590 https://www.mdpi.com/1420-3049/26/13/3984.
591 FDA, 2020. Part 184 Direct Food Substances Affirmed as Generally Recognized as Safe.
592 https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=184.124
593 0 (accessed 13 June 2021).
594 Ghasemzadeh, A., Jaafar, H. Z. E., Rahmat, A., & Ashkani, S., 2015. Secondary metabolites
595 constituents and antioxidant, anticancer and antibacterial activities of *Etlingera elatior*
596 (Jack) R.M.Sm grown in different locations of Malaysia. BMC Complementary and
597 Alternative Medicine. 15(1), 335. https://doi.org/10.1186/s12906-015-0838-6.
598 Gunawan, I. W. G., Putra, A. A. B., & Widihati, I. A. G., 2016. The Response to Oxidative
599 Stress α-Humulene Compounds *Hibiscus Manihot* L Leaf on The Activity of 8-
600 Hydroxy-2-Deoksiquanosin Levels Pancreatic β-Cells in Diabetic Rats. Biomedical
601 and Pharmacology Journal. 9(2). https://doi.org/10.13005/bpj/956.
602 Hasegawa, T., Hashimoto, M., Fujihara, T., & Yamada, H., 2016. Aroma Profile of Galangal
603 Composed of Cinnamic Acid Derivatives and Their Structure-Odor Relationships. Nat
604 Prod Commun. 11(10), 1463-1469. https://doi.org/10.1177/1934578X1601101012.
605 Hussein, R. A., & El-Anssary, A. A., 2018. Plants Secondary Metabolites: The Key Drivers of
606 the Pharmacological Actions of Medicinal Plants, in: P. F. Builders (Ed.), Herbal
607 Medicine. IntechOpen Limited, London, UK.
608 Kfoury, M., Landy, D., Ruellan, S., Auezova, L., Greige-Gerges, H., & Fourmentin, S., 2016.
609 Determination of formation constants and structural characterization of cyclodextrin
610 inclusion complexes with two phenolic isomers: carvacrol and thymol. Beilstein
611 Journal of Organic Chemistry. 12, 29-42. https://doi.org/10.3762/bjoc.12.5.
612 Khor, P.-Y., Na'im, F., Ramli, I., Fatihah, N., Khatijah, S., Zainuddin, J., & Sahira, N., 2017.
613 Phytochemical, Antioxidant and Photo-Protective Activity Study of Bunga Kantan
614 (*Etlingera elatior*) Essential Oil. Journal of Applied Pharmaceutical Science. 7.
615 https://doi.org/10.7324/JAPS.2017.70828.
616 Koç, B., & Kaymak-Ertekin, F. (2014). The effect of spray drying processing conditions on
617 physical properties of spray dried maltodextrin. Original Paper presentation at the
618 meeting of the Foodbalt 2014. 9th Baltic Conference on Food Science and Technology,
619 Riga, Latvia.
620 Lachumy, S. J. T., Sasidharan, S., Sumathy, V., & Zuraini, Z., 2010. Pharmacological activity,
621 phytochemical analysis and toxicity of methanol extract of *Etlingera elatior* (torch
622 ginger) flowers. Asian Pacific Journal of Tropical Medicine. 3(10), 769-774.
623 https://doi.org/10.1016/S1995-7645(10)60185-X.
624 Mahavy, C. E., Mol, A., Andrianarisoa, B., Duez, P., Jaziri, M. E., Baucher, M., &
625 Rasamiravaka, T., 2022. The Xanthophyll Carotenoid Lutein Reduces the Invasive

626 Potential of Pseudomonas aeruginosa and Increases Its Susceptibility to Tobramycin.
627 International Journal of Molecular Sciences. 23(13), 7199.
628 https://doi.org/10.3390/ijms23137199.
629 Marzlan, A. A., Muhialdin, B. J., Zainal Abedin, N. H., Manshoor, N., Ranjith, F. H., Anzian,
630 A., & Meor Hussin, A. S., 2022. Incorporating torch ginger (*Etlingera elatior* Jack)
631 inflorescence essential oil onto starch-based edible film towards sustainable active
632 packaging for chicken meat. Industrial Crops and Products. 184.
633 https://doi.org/10.1016/j.indcrop.2022.115058.
634 Marzlan, A. A., Muhialdin, B. J., Zainal Abedin, N. H., Mohammed, N. K., Abadl, M. M. T.,
635 Mohd Roby, B. H., & Meor Hussin, A. S., 2020. Optimized supercritical CO2
636 extraction conditions on yield and quality of torch ginger (*Etlingera elatior* (Jack) R.M.
637 Smith) inflorescence essential oil. Industrial Crops and Products. 154, 112581.
638 https://doi.org/10.1016/j.indcrop.2020.112581.
639 Mohamad, N. A. N., Arham, N. A., Jai, J., & Hadi, A., 2014. Plant Extract as Reducing Agent
640 in Synthesis of Metallic Nanoparticles: A Review. Advanced Materials Research. 832,
641 350-355. https://doi.org/10.4028/www.scientific.net/AMR.832.350.
642 Mooranian, A., Negrulj, R., Chen-Tan, N., Al-Sallami, H. S., Fang, Z., Mukkur, T. K., . . . Al-
643 Salami, H., 2014. Microencapsulation as a novel delivery method for the potential
644 antidiabetic drug, Probucol. Drug design, development and therapy. 8, 1221-1230.
645 https://doi.org/10.2147/DDDT.S67349.
646 Muñoz-Shugulí, C., Vidal, C. P., Cantero-López, P., & Lopez-Polo, J., 2021. Encapsulation of
647 plant extract compounds using cyclodextrin inclusion complexes, liposomes,
648 electrospinning and their combinations for food purposes. Trends in Food Science &
649 Technology. 108, 177-186. https://doi.org/10.1016/j.tifs.2020.12.020.
650 Navarro-Flores, M. J., Ventura-Canseco, L. M. C., Meza-Gordillo, R., Ayora-Talavera, T. d.
651 R., & Abud-Archila, M., 2020. Spray drying encapsulation of a native plant extract rich
652 in phenolic compounds with combinations of maltodextrin and non-conventional wall
653 materials. Journal of Food Science and Technology. 57(11), 4111-4122.
654 https://doi.org/10.1007/s13197-020-04447-w.
655 Naziruddin, M. A., Kian, L. K., Jawaid, M., Aziman, N., Yusof, N. L., Abdul-Mutalib, N. A.,
656 . . . Tverezovskaya, O. A., 2022. Development of encapsulated sage extract powder:
657 Inter-comparison with commercially available powder for physical properties and
658 metabolites composition. Journal of Supercritical Fluids. 184.
659 https://doi.org/10.1016/j.supflu.2022.105571.
660 Naziruddin, M. A., Kian, L. K., Jawaid, M., Fouad, H., Sanny, M., & Braganca, R. M., 2021.
661 Sage biomass powders by supercritical fluid extraction and hydro-distillation
662 techniques: a comparative study of biological and chemical properties. Biomass
663 Conversion and Biorefinery. https://doi.org/10.1007/s13399-021-02055-y.
664 NIST, 2017. NIST/EPA/NIH Mass Spectral Library with Search Program, (Data Version:
665 NIST v17, Software Version: 2.3). Gaithersburg, Maryland, USA: National Institute of
666 Standards and Technology (NIST).
667 NParks, 2019. Flora: *Etlingera elatior*.
668 https://www.nparks.gov.sg/florafaunaweb/flora/1/9/1990 (accessed 22 September
669 2021).
670 Nurain, A., Noriham, A., Zainon, M. N., Saidatul, W. S. K. W., & Khairusy, S. Z., 2013.
671 Comparative Study of Aqueous and Ethanolic Aromatic Malaysian Herbs Extracts
672 Using Four Antioxidant Activity Assays. International Journal of Agricultural
673 Research. 8(2), 55-66. https://doi.org/10.3923/ijar.2013.55.66.
674 Oh, Y., Razak, N. F. A. H. A., Wee, D. H. T., Ching, E. L., & Rahman, Z., 2019. The
675 development of Nyonya cuisine in the Malay Archipelago: Penang and Malacca

676 Nyonya cuisine. Journal of Ethnic Foods. 6(1), 17.
677 https://doi.org/https://doi.org/10.1186/s42779-019-0010-x.
678 Onsaard, E., & Onsaard, W., 2019. Microencapsulated Vegetable Oil Powder, in: F. Salaün
679 (Ed.), Microencapsulation - Processes, Technologies and Industrial Applications.
680 IntechOpen Limited, London, UK.
681 Pang, X., Cao, J., Wang, D., Qiu, J., & Kong, F., 2017. Identification of Ginger (*Zingiber*
682 *officinale* Roscoe) Volatiles and Localization of Aroma-Active Constituents by GC–
683 Olfactometry. Journal of Agricultural and Food Chemistry. 65(20), 4140-4145.
684 https://doi.org/10.1021/acs.jafc.7b00559.
685 Pradeep, M., Kruszka, D., Kachlicki, P., Mondal, D., & Franklin, G., 2022. Uncovering the
686 Phytochemical Basis and the Mechanism of Plant Extract-Mediated Eco-Friendly
687 Synthesis of Silver Nanoparticles Using Ultra-Performance Liquid Chromatography
688 Coupled with a Photodiode Array and High-Resolution Mass Spectrometry. ACS
689 Sustainable Chemistry & Engineering. 10(1), 562-571.
690 https://doi.org/10.1021/acssuschemeng.1c06960.
691 Rachkeeree, A., Kantadoung, K., Suksathan, R., Puangpradab, R., Page, P. A., & Sommano,
692 S. R., 2018. Nutritional Compositions and Phytochemical Properties of the Edible
693 Flowers from Selected Zingiberaceae Found in Thailand. Frontiers in Nutrition. 5.
694 https://doi.org/10.3389/fnut.2018.00003.
695 Rajabi, H., Ghorbani, M., Jafari, S. M., Sadeghi Mahoonak, A., & Rajabzadeh, G., 2015.
696 Retention of saffron bioactive components by spray drying encapsulation using
697 maltodextrin, gum Arabic and gelatin as wall materials. Food Hydrocolloids. 51, 327-
698 337. https://doi.org/10.1016/j.foodhyd.2015.05.033.
699 Raji, M. N. A., Ab Karim, S., Ishak, F. A. C., & Arshad, M. M., 2017. Past and present practices
700 of the Malay food heritage and culture in Malaysia. Journal of Ethnic Foods. 4(4), 221-
701 231. https://doi.org/https://doi.org/10.1016/j.jef.2017.11.001.
702 Rezaei, A., & Nasirpour, A., 2019. Evaluation of Release Kinetics and Mechanisms of
703 Curcumin and Curcumin-β-Cyclodextrin Inclusion Complex Incorporated in
704 Electrospun Almond Gum/PVA Nanofibers in Simulated Saliva and Simulated
705 Gastrointestinal Conditions. BioNanoScience. 9(2), 438-445.
706 https://doi.org/10.1007/s12668-019-00620-4.
707 Robinson, A. R., Gheneim, R., Kozak, R. A., Ellis, D. D., & Mansfield, S. D., 2005. The
708 potential of metabolite profiling as a selection tool for genotype discrimination in
709 Populus. Journal of Experimental Botany. 56(421), 2807-2819.
710 https://doi.org/10.1093/jxb/eri273.
711 Siccama, J. W., Pegiou, E., Eijkelboom, N. M., Zhang, L., Mumm, R., Hall, R. D., & Schutyser,
712 M. A. I., 2021. The effect of partial replacement of maltodextrin with vegetable fibres
713 in spray-dried white asparagus powder on its physical and aroma properties. Food
714 Chemistry. 356, 129567. https://doi.org/10.1016/j.foodchem.2021.129567.
715 Simon-Brown, K., Solval, K. M., Chotiko, A., Alfaro, L., Reyes, V., Liu, C., . . . Sathivel, S.,
716 2016. Microencapsulation of ginger (*Zingiber officinale*) extract by spray drying
717 technology. LWT - Food Science and Technology. 70, 119-125.
718 https://doi.org/10.1016/j.lwt.2016.02.030.
719 Sunol, A. K., Sunol, S. G., & Cogswell, K., 2019. 20 - SUBSTITUTION OF SOLVENTS BY
720 SAFER PRODUCTS, in: G. Wypych (Ed.), Handbook of Solvents (Third Edition).
721 Chemtec Publishing, Ontario, pp. 1455-1634.
722 TMIC, 2021. FooDB. https://foodb.ca/ (accessed 30 September 2021).
723 Tomasina, F., Carabio, C., Celano, L., & Thomson, L., 2012. Analysis of two methods to
724 evaluate antioxidants. Biochemistry and Molecular Biology Education. 40(4), 266-270.
725 https://doi.org/10.1002/bmb.20617.

726 Tovey, F., 2019. Chapter 8 - Duodenal Ulcer and Diet in Sub-Saharan Africa, in: I. Segal (Ed.),
727 Digestive Diseases in Sub-Saharan Africa. Academic Press, pp. 53-65.
728 Trucillo, P., Campardelli, R., Aliakbarian, B., Perego, P., & Reverchon, E., 2018. Supercritical
729 assisted process for the encapsulation of olive pomace extract into liposomes. Journal
730 of Supercritical Fluids. 135, 152-159. https://doi.org/10.1016/j.supflu.2018.01.018.
731 Wijekoon, M. M. J. O., Bhat, R., & Karim, A. A., 2011. Effect of extraction solvents on the
732 phenolic compounds and antioxidant activities of bunga kantan (*Etlingera elatior* Jack.)
733 inflorescence. Journal of Food Composition and Analysis. 24(4), 615-619.
734 https://doi.org/10.1016/j.jfca.2010.09.018.
735 Wijekoon, M. M. J. O., Bhat, R., Karim, A. A., & Fazilah, A., 2013. Chemical Composition
736 and Antimicrobial Activity of Essential Oil and Solvent Extracts of Torch Ginger
737 Inflorescence (*Etlingera elatior* Jack.). International Journal of Food Properties. 16(6),
738 1200-1210. https://doi.org/10.1080/10942912.2011.579674.
739 Xiao, F., Xu, T., Lu, B., & Liu, R., 2020. Guidelines for antioxidant assays for food
740 components. Food Frontiers. 1(1), 60-69. https://doi.org/10.1002/fft2.10.
741 Yan, S. W., & Asmah, R., 2010. Comparison of total phenolic contents and antioxidant
742 activities of turmeric leaf, pandan leaf and torch ginger flower. International Food
743 Research Journal. 17, 417-423.
744 Zhang, L., Zeng, X., Fu, N., Tang, X., Sun, Y., & Lin, L., 2018. Maltodextrin: A consummate
745 carrier for spray-drying of xylooligosaccharides. Food Research International. 106,
746 383-393. https://doi.org/10.1016/j.foodres.2018.01.004.
747

Revised JKS

ORIGINALITY REPORT

18%	16%	12%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

#	Source	%
1	www.mdpi.com Internet Source	1%
2	Submitted to Universiti Sains Malaysia Student Paper	1%
3	mdpi-res.com Internet Source	1%
4	core.ac.uk Internet Source	1%
5	www.researchgate.net Internet Source	<1%
6	Submitted to Universiti Putra Malaysia Student Paper	<1%
7	phcogj.com Internet Source	<1%
8	www.jmaterenvironsci.com Internet Source	<1%
9	www.shd.org.rs Internet Source	<1%

10	grasasyaceites.revistas.csic.es Internet Source	<1 %
11	edepot.wur.nl Internet Source	<1 %
12	patents.google.com Internet Source	<1 %
13	studentsrepo.um.edu.my Internet Source	<1 %
14	www.frontiersin.org Internet Source	<1 %
15	www.knowitall.com Internet Source	<1 %
16	"Food Powders Properties and Characterization", Springer Science and Business Media LLC, 2021 Publication	<1 %
17	www.freepatentsonline.com Internet Source	<1 %
18	www.biorxiv.org Internet Source	<1 %
19	www.science.gov Internet Source	<1 %
20	W. L. Boatright, Q. Lei. "Compounds Contributing to the “Beany” Odor of Aqueous	<1 %

Solutions of Soy Protein Isolates", Journal of Food Science, 2006
Publication

21	academic.oup.com Internet Source	<1 %
22	acp.copernicus.org Internet Source	<1 %
23	www.myfoodresearch.com Internet Source	<1 %
24	downloads.hindawi.com Internet Source	<1 %
25	ijpsr.com Internet Source	<1 %
26	psecommunity.org Internet Source	<1 %
27	Marko Mäkinen. "Ion spectrometric detection technologies for ultra-traces of explosives: A review", Mass Spectrometry Reviews, 2011 Publication	<1 %
28	Submitted to University of Queensland Student Paper	<1 %
29	ir.library.ui.edu.ng Internet Source	<1 %
30	Submitted to Liverpool John Moores University Student Paper	<1 %

31	Submitted to Mahidol University Student Paper	<1 %
32	Marta Wojciechowska, Piotr Stepnowski, Marek Gołębiowski. " The impact of insecticides containing deltamethrin and cyfluthrin on the composition of surface compounds in the larvae, females and males of ", Biomedical Chromatography, 2022 Publication	<1 %
33	fppn.biomedcentral.com Internet Source	<1 %
34	innovareacademics.in Internet Source	<1 %
35	ir.mu.ac.ke:8080 Internet Source	<1 %
36	www.scielo.br Internet Source	<1 %
37	Submitted to Kwame Nkrumah University of Science and Technology Student Paper	<1 %
38	Submitted to Universiti Tunku Abdul Rahman Student Paper	<1 %
39	res.mdpi.com Internet Source	<1 %
40	www.mybluetea.com.au	

Internet Source

<1%

---

41 Adriana Dutra Sousa, Edy Sousa de Brito. "Optimization of Condensed Tannin Aqueous Extraction from Cashew Tree Pruning Residue Using Response Surface Methodology and Its Drying", Waste and Biomass Valorization, 2015
Publication

<1%

---

42 Lam Xue Mei, Abdorreza Mohammadi Nafchi, Farzaneh Ghasemipour, Azhar Mat Easa, Shima Jafarzadeh, A.A. Al-Hassan. "Characterization of pH sensitive sago starch films enriched with anthocyanin-rich torch ginger extract", International Journal of Biological Macromolecules, 2020
Publication

<1%

---

43 Submitted to Loughborough University
Student Paper

<1%

---

44 Minh - Trung Nguyen, Hoang Van Chuyen, Minh Dinh Tran, Quang - Vinh Nguyen. " Microencapsulation of (L.) . extract using spray drying: Effects of wall materials on physicochemical characteristics and biological activities of the microcapsules ", Journal of Food Processing and Preservation, 2022
Publication

<1%

	Source	
45	academicjournals.org Internet Source	<1%
46	elea.unisa.it Internet Source	<1%
47	m.japsonline.com Internet Source	<1%
48	repository.i3l.ac.id Internet Source	<1%
49	ri.conicet.gov.ar Internet Source	<1%
50	1library.org Internet Source	<1%
51	Loo, A.Y.. "Antioxidant and radical scavenging activities of the pyroligneous acid from a mangrove plant, Rhizophora apiculata", Food Chemistry, 2007 Publication	<1%
52	assets.researchsquare.com Internet Source	<1%
53	docplayer.net Internet Source	<1%
54	eprints.utm.my Internet Source	<1%
55	itjfs.com Internet Source	<1%

56	japsonline.com Internet Source	<1 %
57	research.bangor.ac.uk Internet Source	<1 %
58	María Victoria Álvarez-Henao, Nataly Saavedra, Sonia Medina, Claudio Jiménez Cartagena et al. "Microencapsulation of lutein by spray-drying: Characterization and stability analyses to promote its use as a functional ingredient", Food Chemistry, 2018 Publication	<1 %
59	Schneider, S., A. Müller, and T. Wittek. "Concentration of Potassium in Plasma, Erythrocytes, and Muscle Tissue in Cows with Decreased Feed Intake and Gastrointestinal Ileus", Journal of Veterinary Internal Medicine, 2016. Publication	<1 %
60	cyberleninka.org Internet Source	<1 %
61	dspace.nm-aist.ac.tz Internet Source	<1 %
62	elibrary.trf.or.th Internet Source	<1 %
63	jjnpp.com Internet Source	<1 %

	Source	Type	Similarity
64	pure.rug.nl	Internet Source	<1%
65	riunet.upv.es	Internet Source	<1%
66	trace.tennessee.edu	Internet Source	<1%
67	www.grafiati.com	Internet Source	<1%
68	www.nottingham.edu.my	Internet Source	<1%
69	www.omicsonline.org	Internet Source	<1%
70	www.thegoodscentscompany.com	Internet Source	<1%
71	"Cyclodextrin Fundamentals, Reactivity and Analysis", Springer Science and Business Media LLC, 2018	Publication	<1%
72	Anis Asyila Marzlan, Belal J Muhialdin, Nur Hanani Zainal Abedin, Nameer Khairullah Mohammed et al. "Optimized supercritical CO2 extraction conditions on yield and quality of torch ginger (Etlingera elatior (Jack) R.M. Smith) inflorescence essential oil", Industrial Crops and Products, 2020	Publication	<1%

73	Gupta, Asmita, and Indu Shekhar Thakur. "Biodegradation of wastewater organic contaminants using Serratia sp. ISTVKR1 isolated from sewage sludge", Biochemical Engineering Journal, 2015. Publication	<1 %
74	Javadi, Neda, Faridah Abas, Azizah Abd Hamid, Sanimah Simoh, Khozirah Shaari, Intan Safinar Ismail, Ahmed Mediani, and Alfi Khatib. "GC-MS-Based Metabolite Profiling of Cosmos caudatus Leaves Possessing Alpha-Glucosidase Inhibitory Activity : GC-MS-based metabolite profiling...", Journal of Food Science, 2014. Publication	<1 %
75	M. Schwarz, J. A. Klun, E. C. Uebel. "European corn borer sex pheromone", Journal of Chemical Ecology, 1990 Publication	<1 %
76	Rajesh Dev Sarkar, Priyanka Lahkar, Mohan Chandra Kalita. "Glycosmis pentaphylla (Retz.) DC leaf extract mediated synthesis of selenium nanoparticle and investigation of its antibacterial activity against urinary tract pathogens", Bioresource Technology Reports, 2021 Publication	<1 %
77	dspace.ncl.res.in	

Internet Source <1 %

78	ifst.pericles-prod.literatumonline.com Internet Source	<1 %
79	journal.ipb.ac.id Internet Source	<1 %
80	jsat.rmutl.ac.th Internet Source	<1 %
81	patents.patsnap.com Internet Source	<1 %
82	pdfcoffee.com Internet Source	<1 %
83	www.hindawi.com Internet Source	<1 %
84	www.oecd.org Internet Source	<1 %
85	www.palawanscientist.org Internet Source	<1 %
86	www.sphinxsai.com Internet Source	<1 %
87	www.teses.usp.br Internet Source	<1 %
88	www2.hcmuaf.edu.vn Internet Source	<1 %

89 Eiki Satoh, Naoki Tohyama, Masakazu Nishimura. "Comparison of the antioxidant activity of roasted tea with green, oolong, and black teas", International Journal of Food Sciences and Nutrition, 2009 <1 %

Publication

---

90 Tanvir Kaur, Manju Bala, Gaurav Kumar, Ashish Vyas. "Biosynthesis of zinc oxide nanoparticles via endophyte Trichoderma viride and evaluation of their antimicrobial and antioxidant properties", Archives of Microbiology, 2022 <1 %

Publication

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		

Revised JKS

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26

PAGE 27

PAGE 28

PAGE 29

PAGE 30