

Extraction of oil from passion fruit seeds using surfactant-assisted aqueous extraction

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Article history:

Received: 1 October 2018

Received in revised form: 3 January 2019

Accepted: 12 January 2019

Available Online: 17 January 2019

Keywords:

Passion fruit seed oil, SAAE, Surfactant, Bioactive compound, IFT

DOI:

[https://doi.org/10.26656/fr.2017.3\(4\).146](https://doi.org/10.26656/fr.2017.3(4).146)

Abstract

Passion fruit (*Passiflora edulis*) has a distinctive aroma and flavour and is widely commercialized as fruit juice. A high amount of seeds waste is produced during the juice production. The seeds contain high amounts of oil which can be extracted by hexane or pressing. However, hexane is a hazardous chemical, while pressing generally results in low yield of oil. In this study, surfactant-assisted aqueous extraction (SAAE) was explored to extract the oil at room temperature (25°C) from the seeds by combining Tween 20 and Span 20 food-grade surfactants. It was determined that Hydrophilic-Lipophilic Balance (HLB 14 to 16) resulted in the lowest interfacial tension (IFT) between the oil and the surfactant solution. The extraction yield was found to correlate well with the interfacial tension whereby reduction in IFT causes an increase in the extraction yield. The highest extraction (80%) was found at 1% surfactant concentration which is at the critical micelle concentration (CMC) of the surfactant solution. The optimum parameter for extraction was 1:19 solid-liquid ratio, 15 mins extraction at 25°C. SAAE with food-grade surfactant can be a simple and viable technique to extract the waste passion fruit seed at low temperature, short time and low surfactant usage. The oil was found to contain phenols (26.3 mg GAE/g), squalene (0.65 mg/g), β -sitosterol (0.58 mg/g) and vitamin E (0.1 mg/g). The main free fatty acids present were linoleic (65.72%), oleic (17.9%) and palmitic (11.41%).

1. Introduction

Passion fruit (*Passiflora Edulis*) also known locally in Malaysia as Markisa is from *Passiflora* genus and *Passifloraceae* family. It has a distinct flavour and aroma that can be utilized for many purposes such as product flavouring and juice production. In the juice production, 40% of the processed fruits consisted of seeds and pulps are generally disposed and the seeds are identified as juice extraction's agricultural by-products (Chau and Huang, 2004). The seeds of passion fruit contain high amounts of oil which can be utilised in the food, pharmaceuticals and cosmetic industry. Passion fruit seed oil has started to find values particularly in the cosmetics industry and is incorporated into face cream, serum, face wash and shampoos due to several key characteristics. The fatty acid mainly consists of unsaturated fatty acids namely linoleic acids (C18:2) (Luehs *et al.*, 1994). Hence, it makes the passion fruit seed as a novel source of finest- grade edible oils (Nyanzi *et al.*, 2005). The oil also contains high amounts of natural anti-oxidant that comes from the tocopherols (Vitamin E) and its phenolic compound. Passion fruit

seed oil was reported to have a concentration of phenolic compound up to 1,314.13 mg GAE/kg which was comparable to others extracted oils from the sources of raspberry, blueberry and blackberry seeds (Parry *et al.*, 2005). According to Piombo *et al.* (2006), the major tocopherols composition analysed from the passion fruit seed oil was γ -tocopherol (217 mg/kg) and δ -tocopherol (243 mg/kg). Meanwhile, β -tocopherol was found as the minor component. The γ - and δ -tocopherol was claimed to be a more active antioxidant compared to α - and β -tocopherol (Schmidt and Pokorný, 2005). Hence, the phenolic compound and tocopherols composition give a huge impact on the antioxidant activity of the passion fruit seed oil. Besides, the oil also contains β -sitosterol up to 87.2 \pm 3.2 mg/100g (Piombo *et al.*, 2006), which helps to counter against the cardiovascular diseases and cancer as suggested by several authors before. This β -sitosterol may also protect against oxidative stress through the inflection of antioxidant enzymes (Awad *et al.* 2004) and helps against aging skin cells (Vivancos and Mopeno, 2005). In addition, the oil was found to contain piceatannol, a tetrahydric polyphenol that formed

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as an analogue of resveratrol. The piceatannol helps to constrain the synthesis of melanin (Yokozawa *et al.*, 2007) and also as an anti-allergic compound (Matsuda *et al.*, 2001). Hence due to its numerous benefits to the skin, the utilization of this oil in the cosmetic industry is growing.

Like most oilseeds, the typical industrial extraction method to extract the oil from passion fruit seed is using solvent extraction with hexane as the common solvent. This is because it has high solubility towards passion fruit seed oils and also due to the low cost of hexane itself (De Oliveira *et al.*, 2013). However, hexane is hazardous to health and flammable making the process not easily applicable, particularly to the small and medium-scale industry. Several other oil extraction techniques have been utilised including cold-press, supercritical fluid extraction, ultrasound-assisted extraction and pressurized liquid. However, these methods generally incur higher cost. Different extraction methods of oil from seeds also affect the quality of the oil. Extraction at low temperature is usually done at 40° C or lower such as during cold pressed. Extraction by hexane is usually done at the hexane boiling point of 68° C which is considered a relatively high temperature. Especially in the cosmetic and beauty industry, oil extracted at low temperature is valued more since the bio-active compounds that help to nourish the skin is better preserved than in oil extracted at a higher temperature.

In this study, surfactant-assisted aqueous extraction process (SAAEP) has been proposed as an alternative environmentally friendly method for effective extraction of oil from passion fruit seeds waste produced from juice extraction industry. In SAAEP, the surfactant is used to reduce the interfacial tension of oil and water allowing it to be released efficiently into the aqueous extraction medium. Several previous studies have used an extended-type of surfactant that allows an ultra-low interfacial tension to be developed promoting the efficient release of oil. However, the extended-surfactants are not food grade and its toxicity to human is questionable resulting in the extracted oil to be used mainly as non-food purposes such as biodiesel or lubricant (Do and Sabatini, 2010). In this study, Tween 20 and Span 20 which are food grade surfactants were used to extract passion fruit seed oil. Utilization of food-grade surfactants allows a safe product for human usage. Furthermore, as most cream requires emulsifiers in their preparation, any residual surfactants in the oil can be utilised in the cream preparation and do not need to be fully removed from the oil. This will simplify the separation and purification process.

This study attempts to investigate the effect of

surfactant concentration on the interfacial tension between passion fruit oil and water and correlation between interfacial tension and the oil extraction efficiency. Furthermore, the parameters of extraction such as surfactant concentration, solid to liquid ratio, and extraction time were optimized to achieve the highest extraction efficiency.

2. Materials and methods

Passion fruit seeds were obtained from a passion fruit juice producer in Kubang Kerian, Kelantan. The surfactants used were Polyoxyethylene (20) Sorbitan Monolaurate (Tween 20) and Sorbitan Monolaurate (Span 20). The fatty acid composition analysis was conducted with the materials and chemicals such as sodium chloride, sodium hydroxide, heptane and boron trifluoride-methanol (Evergreen Sdn. Bhd). Meanwhile, for the squalene and sterols analysis, the materials and chemicals used were pyridine (analytical grade), 5- α -cholestene $\geq 97\%$ C8003 (Sigma-Aldrich) obtained from LabChem Sdn Bhd and N-Trimethylsilyl-N-Methyl Trifluoroacetamide, MSTFA (Sigma-Aldrich). For total phenolic content analysis, the materials and chemicals used were Folin Ciocalteu Reagent and Sodium Bicarbonate (Evergreen Sdn. Bhd). Vitamin-E Analysis was conducted with the materials and chemicals of n-Hexane (HPLC Grade) and Methanol (HPLC Grade) obtained from LabChem Sdn. Bhd. The chemicals such as Hexane, Methanol, and Ethanol were being used for various processes throughout the research.

2.1 Extraction of passionfruit seed oils using accelerated solvent extraction (ASE)

For the oil analysis, passion fruit seeds were dried using a freeze dryer and ground to powder form and sieved with a size of 6 mm sieve. The seeds were extracted using accelerated solvent extraction (ASE150, DIONEX) with hexane as the solvent. The seed sample was weighed 4 g and was extracted at 60°C for 7 mins of static time with a total volume of 11 mL and cycle repetition of five times under the pressure of 100 bars for 60 mins in each cycle (Piombo *et al.*, 2006). The hexane was then evaporated from the extract using the rotary evaporator at 60°C to obtain the oil yield.

2.2 Fatty acid composition determination

The fatty acid composition of oils was determined using Gas Chromatography (GC2010 Plus, SHIMADZU) with BP20 GC Capillary column following method Ce 2-66, preparation of methyl esters of fatty acids (AOCS 1998a). The oil was prepared into methyl esters through esterification before the GC analysis by mixing 0.1 g of oil sample with 4 mL of 0.5

N methanolic sodium hydroxide and boiling chip. The mixture was boiled on a steam bath with an attached condenser for 5 min until the fat globules moved into the solution. Next, 4 mL of boron trifluoride-methanol reagent and 3 mL of heptane was added into the boiling mixture through the condenser. After a minute, the heat was removed and a sufficient amount of sodium chloride was added into the mixture to float the heptane solution. The heptane solution was then transferred into GC vial to be injected into the gas chromatography following the method Ce 1-62, fatty acid composition by gas chromatography AOCS Official Method, 1997). The different type of fatty acid esters was identified by direct comparison with the standard mixture and the percentage of individual FAME was made in relation to the total area of the chromatogram. The analysis was done in triplicate to ensure reproducibility and mean data was reported.

2.3 Squalene and sterols determination

Squalene and β -sitosterols (sterols) were determined using Gas Chromatography (GC2010 Plus, SHIMADZU) with SGE-HT5 GC Capillary Column. In preparing the sample, 0.01 g of oil was weighed accurately into the GC Vial. After that, the oil sample was added into 15 μ L of 1000 ppm 5- α -cholestene which was further diluted into 50 ppm by using pyridine and 150 μ L of N-Trimethylsilyl-N-Methyl Trifluoroacetamide. Before injecting the vial into the gas chromatography, the mixture was mixed and heated at 40°C for 20 mins (Harrison *et al.*, 2005). The identifications of individual peaks were carried out using reference standards and quantification was done based on the pre-prepared calibration curve of reference standards. The analysis was done in triplicate to ensure reproducibility and mean data was reported.

2.4 Vitamin E determination

Vitamin E was determined using High-Performance Liquid Chromatography (HPLC) with II-NAP Cosmosil column. 0.02 g accurately weighed oil sample was dissolved with 1 mL of HPLC Grade n-hexane in a 1.5 mL centrifuge tube. The solution was then transferred into 1.5 mL vial using a 1 mL syringe that was filtered using a nylon syringe filter. Before starting the HPLC, the column used was washed with mobile phase (90% HPLC Grade MeOH: 10% Deionized Water) for 45 mins. The analysis time was 22 mins with the HPLC parameters set at 1.0 mL/min flowrate 30°C temperature and 295 nm UV detection wavelength. The value of Vitamin E was calculated based on standards tocopherol calibration curves. The analysis was done in triplicate to ensure reproducibility and mean data was reported.

2.5 Total phenolic content (TPC) determination

The total phenolic content of oil was determined using Folin-Ciocalteu reagent assay based on the method introduced by (Gutfinger, 1981). In preparing the sample, 0.1 g oil sample was mixed with 0.2 mL hexane by vortex and 0.12 mL of methanol/water (60:40, vol/vol). The methanol solution was used to extract the phenolic compound. The mixture was separated by centrifugation for 10 mins and the hexane was re-extracted again in the similar way (Fuentes and Bravo, 2012). The methanolic extracts were combined and 100 μ l of the supernatant was mixed with 0.5 mL of Folin-Ciocalteu reagent/distilled water (1:9, vol/vol). Next, 7 mL of distilled water was added. After 5 mins, 5 mL of sodium bicarbonate (60 mg/mL) solution was added into the mixture and left in dark place at room temperature for 2 hrs. Then, absorbance was checked using a UV-Visible spectrophotometer at 725 nm against a blank. TPC was expressed as gallic acid equivalents mg GAE/100 g extract using a standard solution of gallic ranged from 0.0 to 1.0 mg/mL (Mustafa *et al.*, 2016). The value of total phenolic content was calculated as follows:

$$TPC = \frac{\frac{\text{Sample absorbance} - \text{Blank Absorbance}}{R^2} \times \frac{10}{\text{Extraction Volume}} \times \text{Dilution Factor}}{\text{Sample Weight}}$$

Where blank absorbance = 0; Extraction Volume = 100 μ l = 0.1 mL; R^2 (Based from Standard Curve) = 0.9891; Dilution factor = 1; and Sample weight = 100 mg = 0.1g

The analysis was done in triplicate to ensure reproducibility and mean data was reported.

2.6 Interfacial tension measurement

This experiment was performed to determine the interfacial tension between passion fruit oil and surfactants at various surfactant concentrations and hydrophilic-lipophilic balance (HLB). The IFT was measured using DataPhysics Instruments GmbH Spinning Drop Video Tensiometer 20N (SVT 20N). The surfactant was prepared at specified concentrations and injected into a glass capillary tube with an inner diameter of 2.45 mm and an outer diameter of 6.25 mm. Then, one drop of passion fruit oil was injected into the capillary. The capillary was rotated until an elongated cylindrical drop was obtained and measurement of IFT was taken at equilibrium. From preliminary observation, the IFT reached equilibrium within 30 mins to 1 hr. Therefore, the measurements were taken within this period. The IFT analysis was repeated twice for each sample.

2.7 Extraction of oil in seed using Soxhlet extractor

The analysis of oil removal content in SAAEP was carried out using the Soxhlet Extraction method. The

amount of oil extracted from the seeds using hexane was referred to as the total oil. Initially, the Soxhlet extractor was heated and 100 mL of hexane was filled in the round bottom flask. The freeze-dried seed samples were weighed 4 g with a size of 6 mm and were put into the thimble and extracted for 8 hrs until the hexane in the tube become colourless. Next, the hexane was evaporated from the extract by using rotary evaporator at 60°C to obtain the oil sample. An assumption was made whereas the oil extracted during Soxhlet extraction was to the utmost from the seed samples. Thus, it can be used to calculate the SAAEP oil extraction efficiency. The extraction was done twice to ensure reproducibility and mean data was reported.

2.8 Extraction of oil in seed using surfactant-assisted aqueous extraction process (SAAEP)

Seed sample with a size of 2 mm (obtained by sieving) was weighed 4 g and was mixed with the surfactant solution at 25°C for a predetermined time using a magnetic stirrer. Next, the suspension was centrifuged at 3500 rpm for 20 mins. The aqueous solution was removed and the solid part which is the surfactant-assisted aqueous extracted seed sample was further processed to determine the residual oil (Kadioglu *et al.*, 2011).

The seed sample obtained from the aqueous extraction process was evaporated for dryness at 80°C until constant weight was achieved. Then, 20 mL of hexane was added to the dried seed sample. The mixture was mixed for 20 mins and was repeated twice to ensure full hexane extraction. The suspension was then centrifuged at 3500 rpm for 10 mins. The hexane phases were removed from the solid part by using micropipette and evaporated at 60°C to obtain the residual oil. The extraction was done twice to ensure reproducibility and mean data was reported.

The following equation was used to calculate the oil removal efficiency:

$$\text{Oil removal efficiency (100\%)} = \frac{\text{Soxhlet extracted oil} - \text{residual oil}}{\text{soxhlet extracted oil}} \times 100\%$$

2.9 Parameters optimization for surfactants assisted aqueous extraction process

Along with these parameters optimization process, the parameters such as particle size and temperature were kept constant at 2 mm and 25°C respectively. A total of 4 g of seed was used in all studies

2.10 Effect of surfactant concentration

To study the effect of surfactant concentration, the SAAEP was conducted by varying the surfactant

concentration for 0%, 0.1%, 0.5%, 1.0% and 10%. The solid-liquid ratio (SLR) and the extraction time set were 4:75 and 45 mins respectively.

2.11 Effect of solid to liquid ratio (SLR)

To study the effect of solid-liquid ratio, the SAAEP was conducted by varying the volume of surfactant mixture at 50 mL, 75 mL, 100 mL, and 125 mL. The concentration used was the optimum concentration identified from the previous step and the extraction time used was 45 mins.

2.12 Effect of extraction time

To study the effect of extraction time, the SAAEP was conducted by varying the extraction time at 40 mins, 50 mins and 60 mins. The optimum concentration of surfactant and solid-liquid ratio identified from previous steps was used.

3. Results and discussion

The average oil content in the seed was 23.32% extracted using Soxhlet extractor. This amount was found to be higher than that reported by Piombo *et al.* (2006) which was 18.4%. This could be due to the different extraction technique used by Piombo which was using accelerated solvent extraction (ASE). Even though the same solvent was being used, the parameters in ASE such as time, temperature and pressure were different in comparison to Soxhlet extraction method. The value of oil weight obtained from the passion fruit seeds was used as a reference to calculate the oil extraction efficiency using SAAEP.

3.1 Suitable Hydrophilic-Lipophilic Balance (HLB) value of Tween 20/Span 20 surfactant mix

Tween 20 or also known as Polysorbate 20 was a polysorbate-type non-ionic surfactant formed by ethoxylated sorbitan and lauric acid. It was a surfactant frequently used in food and cosmetic application with a HLB of 16.7 and hence was easily soluble in water. Span 20 or sorbiton monolaurate, on the other hand, has a HLB of 8.7 was more soluble in oil. Previous research has shown that combination of surfactants with a high and low HLB can provide synergism on the interface and reduced the interfacial tension much more than a single surfactant alone (Nesterenko *et al.*, 2014). The interfacial tension between the passion fruit oil and surfactants at several HLB was shown in Figure 1. The surfactant with HLB below 13 cannot be dissolved properly in an aqueous solution. It can be seen that increasing the HLB from 13 to 14 reduced the IFT from 0.5 mN/m to 0.34 mN/m. The IFT at HLB 15 and 16 were similar to that of 14. Hence for passion fruit oil, surfactants mixture with

HLB between 15 and 16 were suitable to reduce the IFT to the lowest possible.

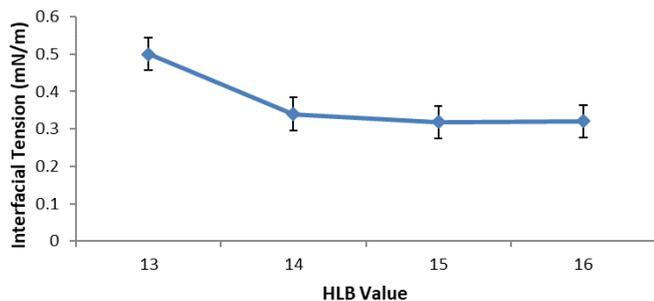


Figure 1. Graph of IFT vs HLB value of surfactant mixture. The concentration of surfactant is 1% and conducted at $25\pm 2^\circ\text{C}$

3.2 Effect of surfactant concentration on interfacial tension and extraction yield with varying surfactant concentration

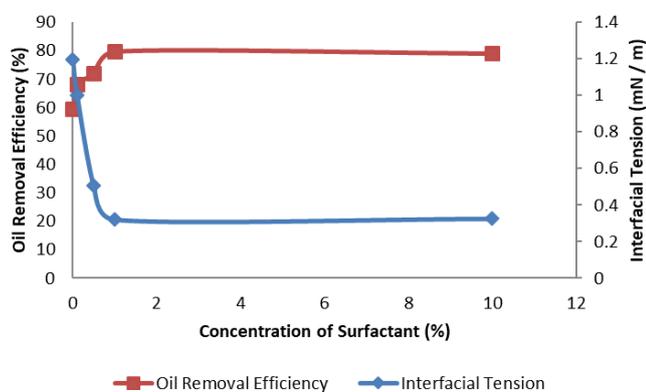


Figure 2. Correlation between oil removal efficiency and interfacial tension with varying surfactant concentration

The effect of surfactant concentration on IFT and yield can be seen in Figure 2. At first, the experiment was done with 0% surfactant concentration (as control) and the resulting IFT value was 1.2 mN/m. Then, as the surfactant concentration was increased to 1%, the value of IFT decreased to 0.32 mN/m. However, when the concentration of the surfactant was increased to 10%, the IFT value stabilised. The critical micelle concentration (CMC) can be defined as the concentration where micelle was formed and the IFT value has stabilised. Hence, in this experiment, it can be concluded that the CMC was achieved at 1% of surfactant concentration. It also can be seen clearly that the extraction yield increases with the increase in surfactant concentration until the CMC value was reached. After 1%, the yield plateau was at about 80% efficiency. Hence, the yield of extraction can be clearly correlated with interfacial tension whereby decreased in IFT increased the yield of extraction. The study on surfactant extraction of canola using showed a similar amount of sodium dodecyl sulphate (0.57%) was needed for optimum extraction, where the extraction efficiency achieved was up to 80%. The optimum extraction of the canola was also supported with the optimum extraction time needed which was 30

mins and above. This was due to the phenomenon of stable decrement of IFT readings observed after 30 mins of canola extraction from the previous study (Tuntiwattapanun *et al.*, 2013). The IFT value is very important in promoting oil extraction whereby lower IFT value with low CMC will enhance oil liberation mechanism while using less surfactant, which is safer for the consumer as this, may avoid irritation and toxicity.

3.3 Effect of varying Solid to Liquid Ratio (SLR)

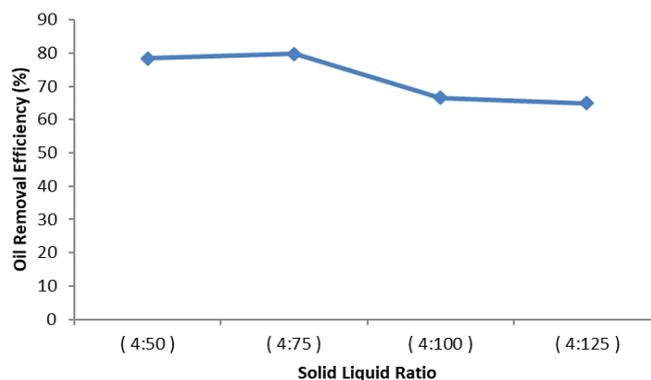


Figure 3. Graph of oil removal efficiency with solid to liquid ratio with surfactant HLB value of 16 and concentration of 1%. The contact time is 45 min. The temperature and particle size are kept constant at $\pm 25^\circ\text{C}$ and 2 mm, respectively.

From the result shown in Figure 3, the optimum SLR was 4:75 with 79.82% of oil removal efficiency. Decreased in the solution volume to SLR ratio of 4:50 seems to reduce the efficiency to 78.36% and when the volume was increased to SLR ratio of 4:100 and 4:125 ratios, the efficiency reduced to 66.52% and 64.96% respectively. This situation can be explained as per reported by Sabatini *et al.* (2011), where high SLR was reported to be related to the increase of viscosity which caused the difficulty in achieving surfactant-oil seed contact. On the other hand, low SLR will cause less impact on the seeds particles during mixing and reducing the extraction efficiency. Therefore, an optimum value of SLR was crucial in SAAEP.

3.4 Effect of varying extraction time

The contact time between the passion fruit seed and surfactant mixtures solution was varied to analyse the effect of different extraction period to the SAAEP. It can be seen in Figure 4 that the extraction reached about 90% of the maximum yield in just 10 to 15 mins extraction time. At 15 mins, the extraction yield is 73%. This extraction time was similar to that found by Do and Sabatini (2010) for the extraction of canola seed oils by surfactant sodium dodecyl sulphate. On the contrary, for aqueous extraction alone, the extraction time is found to be much longer at about 375 mins from pomegranate seed extraction (Ghorbanzadeh and Rezaei, 2017).

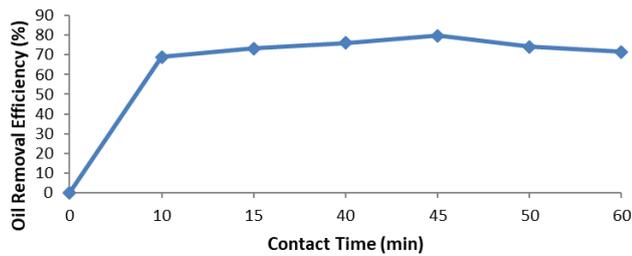


Figure 4. Graph of oil removal efficiency with varying contact time with surfactant HLB value of 16, surfactant concentration of 1% and SLR of 4:75. The temperature and particle size are kept constant at $\pm 25^{\circ}\text{C}$ and 2 mm, respectively.

The extraction time can be correlated with the time needed to reach equilibrium IFT whereby micelle was completely formed. Dynamic interfacial tension (IFT) between the surfactant solution and passion fruit oil shows that the equilibrium IFT was achieved within 15 mins. Less time of extraction with optimum yield will save time and produce a more efficient process for commercialization purpose.

3.6 Oil analysis

Fatty acid composition, squalene, sterol, vitamin E and total phenolic content analysis have been conducted. The values obtained were compared to the values reported for rosehip and olive oil as they were popular ingredients in cosmetics due to their high qualities.

3.7 Fatty acid profile

From the analysis, it was determined that passion fruit seed oils fatty acid composition was linoleic (C18:2) 65.72%, followed by 17.84% of oleic (C18:1) and also 11.41% of palmitic (C16:0). The full fatty acid analysis was shown in Table 1. This fatty acid profile was similar to corn oil and sunflower oil which was dominated by linoleic acids where it was claimed by previous authors, the linoleic acids analysed in passion fruit seed oils was about 68.68 to 70.06% (Sant'Anna *et al.*, 2001) and 72.69% (Liu *et al.*, 2008). The high amount of linoleic acid in the passion fruit seed oils indicated that the oil was a light-oil and can easily be penetrated into the human skin compared to saturated fatty acid. Due to numerous beneficial effects, linoleic acid found applications in many branches of industry, particularly in the cosmetic industry (Zielinska *et al.*, 2004). Linoleic acids also were reported to support the

healing process and speed up the regeneration of skin barrier (Lautenschlager, 2009). In comparison with rosehip oil, which is very popular oil in the cosmetic industry, it contains only about 44.4% of linoleic acid (Graizer *et al.*, 2015).

3.8 Squalene content

Squalene is triterpene compound and was one of the main components in skin sebum (Amarowicz, 2009). In cosmetic purpose, squalene was known as a component for its emollient and antioxidant properties (Gornas and Rudzinska, 2016). Squalene was known to be an effective agent of oxygen scavenger and also efficient preventer of the oxidative stress (Huang *et al.*, 2009). Among the plant oil that was found in the cosmetic utilization, olive oil was reported to have the highest amount of squalene which was up to 5.451 mg/g (Giacometti, 2001). Meanwhile, in this research, the passion fruit seed oil was found to contain about 0.646 mg/g of squalene. Hence, although passion fruit seed oil does not have a very high amount of squalene compared to olive oil, this amount was higher than that in other oilseeds such as apple, grape and watermelon as reported by Gornas and Rudzinska (2016).

3.9 β -sitosterol Analysis

The passion fruit seed oils were determined to have only about 0.582 mg/g of β -sitosterols and this was relatively lower compared to the previous result validated by Piombo *et al.* (2006) where the passion fruit oil was found to have 0.872 mg/g of β -sitosterols. One of the plant oil which having high β -sitosterols that were widely used in the cosmetic industry was rosehip oil with 5.297 mg/g (Graizer *et al.*, 2015). The sterols and phytosterols are valuable components in cosmetic because it help to heal the damaged skin effectively as it has high similar structure to cholesterol. Sterols are also a good component of sunburn curing and skin rejuvenation. Besides, according to Fatima *et al.* (2013), it also helps in monitoring skin diseases such as eczema and scabies.

3.10 Vitamin E

Vitamin E is known to be an antioxidant agent that fights free radicals which cause damage to the skin and premature aging. In this research, the passion fruit seed oil was found to have about 0.102 mg/g of the vitamin E

Table 1. Fatty Acid Composition of Passion Fruit Seed Oils

| Samples | Fatty Acid Composition (%) | | | | | |
|--------------------------|----------------------------|---------------------|-----------------|---------------------------|------------------------------|-------------------------------|
| | Palmitic (C16:0) | Palmitoleic (C16:1) | Stearic (C18:0) | Ω -9 Oleic (C18:1) | Ω -6 Linoleic (C18:2) | Ω -3 Linolenic (C18:3) |
| Passion Fruit | 11.41 | - | - | 17.84 | 65.72 | - |
| Rose hip (as *reference) | 4.2 | - | 2.1 | 14.7 | 44.4 | 31.8 |

*Reference: (Graizer *et al.*, 2015)

content.

3.11 Total phenolic content (TPC)

The total phenolic content in passion fruit seed oils was found to be 26.28 GAE/g. The phenolic content in passion fruit seed oils was lower compared to rosehip oil that contained up to 96 GAE/g of phenolic content (Ercisli, 2007). However, it is comparable to other seed such as grape, apple and citron (Da Silva and Jorge, 2017). In the cosmetic industry, the phenolic content of plant oil was used either through consumption of product or application in the skin as the phenolic help to retard the development of various skin disorders. It was also claimed to be able to eliminate the cause and effect of skin aging, skin damage, and wounds and also burns (Dzialo et al., 2016).

Since SAAEP is done at a lower temperature of 25°C (room temperature), the degradation of bioactive compound is expected to be less than oil extracted by hexane extraction as no heat is added during the SAAEP extraction. In comparison, oil extracted by hexane is done at 68°C and more degradation is expected. It is predicted that more bioactive compound will be preserved in the oil during SAAEP extraction although this need to be proven and will be analysed in our future work once the SAAEP process has been improvised to achieve higher yield. Similarly, the fatty acid composition is expected to vary with extraction temperature as oxidation of double bond in the fatty acid chain should increase with the increase in temperature. However, the degree of reduction needs to be confirmed with the analysis of the oil after SAAEP.

4. Conclusion

Surfactant-assisted aqueous extraction process is a safe and environmentally friendly extraction process compared to hexane extraction. The combination of surfactant Tween 20 and Span 20 with a HLB 14 to 16 was found to successfully reduce the interfacial tension between the passion fruit oil and water to the minimum compared to other HLB. The yield of extraction was correlated well with IFT whereby decreasing the IFT increases the extraction yield. The optimum condition to extract oil from passion fruit seeds is 1% of surfactant concentration with solid to liquid ratio of 4 g to 75 mL and the contact time of 15 mins. Therefore, it could be concluded that SAAEP has the potential to extract passion fruit seed oil up to 79% oil removal efficiency at only 1% surfactant concentration and low extraction temperature at 25°C.

Passion fruit seeds have high oil content which up to 20.22% with a high amount of fatty acid that high particularly omega-6-essential fatty acid. The squalene,

sterol, vitamin E and phenolic are comparable to many oilseeds although generally lower than oil known to be highly nutritious for skin such as olive and rosehip.

Acknowledgement

The authors would like to acknowledge the information and facilities provided by Universiti Putra Malaysia.

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