Physicochemical properties of seed oil of the cardinal grape (Vitis vinifera L.) originated in Vietnam

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Abstract

Grape (Vitis vinifera L.) seed oil was studied for physicochemical characteristics and chemical composition. Through the gas chromatography-flame ionization (GC-FID) process, the fatty acid composition in the oil was analysed, revealing that the oil is very rich in linoleic (65.3%), linolenic (0.43%), and oleic (17.56%) acid. The physicochemical properties of the oil were also examined, including viscosity (87.8±2.75 cP), acid value (2.25±0.75 mg KOH/g), saponification content (185.5±7.45 mg KOH/g) and iodine value (176.4±5.85 g I₂/100 g). The results also indicated that grape seed is a health-beneficial oil due to the high contents of polyunsaturated fatty acids. This research also provided an important base for further investigations on the production of relevant high-value products, such as analysis of other minor nutrients of grape seed oil originated in Vietnam and study of the beneficial effects of grapeseed oil on human health and its application in the cosmetic industry.

1. Introduction

Grape (Vitis vinifera L.) is categorized in the Vitaceae family. Grape seeds are by-products of wine, vinegar and molasses production (Yalcin et al., 2017). For many decades, grape seeds were considered agricultural wastes and were mainly burnt and used for feeding cattle. Grape seed is a rich source of many useful components. Grape seed is mainly composed of fibres (40%), complex carbohydrates (29%), oil (16%), proteins (11%), and complex phenols (7%) (Felhi et al., 2016). Some approaches have been made to apply this waste in several other domains such as the production of biodiesel, cosmetic and food purposes to reduce environmental impacts and gain economic benefits. Nowadays, the identification and valorization of new vegetable oils (especially fruit oils) are the trend in the lipid industry (Madawala et al., 2012). According to many studies, grape seed oil can be a potential vegetable oil for the food industry (Dabicic et al., 2020; Shinagawa et al., 2015). Historical records showed that this oil was classified as minor vegetable oil (FAO, 1992), and was used in salad dressings, marinades, baking, and frying.

In general, the grape seed contains between 6 and 22% oil that depending on the grape variety, the maturation degree of the seeds as well as the environmental conditions during ripening and also on the method of extraction (Rubio et al., 2009; Tangolar et al., 2009; Pardo et al., 2011; Fiori et al., 2014; Tociu et al., 2017). The majority of biological activities of grape seed oils are due to the hydrophilic constituents. This fruit oil contains a large amount of phenolic compounds, including phenolic acids (gallic, ferulic, caffeic, vanillin acids), phenolic aldehydes (vanillin), hydroxyphenolic esters (caftaric, coumaric, fectaric acids), monomeric flavanols (catechin, epicatechin and epicatechin-3-O-gallate), flavonols and their glucoside derivatives (kampferol, quercetin, quercetin-3-glucose, quercetin-3-rhamnoside, quercetin-3-galactoside) and diverse oligomer procyanidins (procyanidin B1, procyanidin B2) (Karaman et al., 2015; Marci et al., 2015; Duba and Fiori, 2015; Bellili et al., 2018). The phenolic content of grape seed oil varies from 24–60 mg gallic acid equivalent/kg depending on the extraction method (Bellili et al., 2018). Moreover, grape seed oil is also rich in lipophilic constituents that often have an important role in the prevention of some cardiovascular diseases and can lower cholesterol levels. Besides vitamin E...
Grape seed oil is also among the favourite ingredients of cosmetic products due to its high content of antioxidant compounds that can protect the skin from free radical damage (Garavaglia et al., 2016). Antioxidant, anti-inflammatory, antimicrobial, anticarcinogenic, antimutagenic activities, prevention and delay of cardiovascular diseases are some examples of bioactivities reported for grape seed oil (Garavaglia et al., 2016; Cádiz-Gurrea et al., 2017). Many studies demonstrated the bactericidal activity of grape seed extracts against both spoilage and pathogenic bacteria (Aeromonas hydrophila, Bacillus cereus, Enterobacter aerogenes, Enterococcus faecalis, Escherichia coli, E. coli O157:H7, Mycobacterium smegmatis, Proteus vulgaris, Pseudomonas aeruginosa, Pseudomonas fluorescens, Salmonella enteriditis, Salmonella enterica serovar Typhimurium, S. aureus and Yersinia enterocolitica (Bellili et al., 2018). The antioxidant activity of grape seed oil is mainly characterized by the presence of unsaturated fatty acid and other lipophilic components including tocopherols, tocotrienols, carotenoids, and chlorophyll because the presence of double bonds in these constituents can trigger oxidation capacity (Felhi et al., 2016; Al Juhami et al., 2017; Cádiz-Gurrea et al., 2017; Bellili et al., 2018).

Due to the potential applications of grape seed oil, many studies were conducted to characterize the composition of grape seed oil (Wen et al., 2016; Shinagawa et al., 2018). However, most studies mainly focused on European varieties while the grape seed oil from the Cardinal variety has been rarely studied. Therefore, the study aimed to characterize the composition of seed oil from Cardinal grapes (cultivated in Vietnam).

2. Materials and methods

2.1 Sample

Fresh ripe grapes were collected in Ninh Thuan province, Vietnam and crude seed oil was extracted using a Soxhlet extractor. The grape seeds were dried under air drying at 50°C until the moisture of 15–18% db was obtained. Firstly, the dried grape seeds were ground using a mill and screened through a mesh size of 2 mm. After that, the seeds were subjected to a Soxhlet extractor and extracted with a mixture of hexane and acetone (ratio of 3/2, v/v). The ratio of material/solvent and the extraction time were 1/10 (w/v) and 8 hrs, respectively. The solvent was evaporated under reduced pressure. The separated oil was then filtered and evaporated completely. The extracted oil was transferred into dark bottles and stored in the refrigerator to keep it fresh for further analysis.

2.2 Physicochemical characteristics

The grape seed oil quality was evaluated by testing the principal indices used for edible oil including protein content (AOAC 945.01 - Kjeldahl method), total lipid content (AOAC method (920.39), saponification value (AOAC 920.160–2005), non-saponification value (AOAC 933.08-2005), acid value (ISO 660: 2009), peroxide value (ISO 3960: 2007) and iodine indices (AOAC 920.159-2005). The physical properties were analysed including viscosity at 20°C (Brookfield RVDV-E machine, USA), density (Mai et al., 2013), moisture content (ISO 662:1998), melting point (ISO 6321:2002) and refraction index (AOCS Cc7-25). The colour parameters were evaluated by Minolta Chroma colorimeter and expressed as the CIE value: lightness (L*), redness (a*, red to green axis) and yellowness (b*, yellow to blue axis). These characterizations were performed in triplicate.

2.3 Fatty acid composition

The fatty acid was analysed by using a flame ionization detector (GC-FID). First, the fatty acids were converted to fatty acid methyl esters (FAMEs) by incubating a mixture containing 100 mg grape seed oil and 2 mL of sodium methyleate in methanol for 15 mins at 100°C. Following that, 1 mL of boron trifluoride-methanol (20% BF3) was added and the mixture was heated at 100°C for another 15 mins. Then 1 mL of water and 1 mL of n-hexane were introduced into the mixture, followed by centrifugation. The resulting FAMEs were transferred into a vial and kept at 4°C. The study was carried out by using the Agilent 6820 gas chromatography. Each unit was analysed in triplicate. Data examination was carried out by using the Agilent ChemStation method.

2.4 Analysis of total phenolic contents

Total phenolic content (TPC) was determined with the Folin-Ciocalteu reagent according to a procedure described by Singleton and Rossi (1965). TPC of the oil extracts was isolated from a solution of oil extract in hexane by triple-extraction with water: methanol (60:40, v/v). The concentration of TPC was estimated spectrophotometrically using Folin-Ciocalteu reagent. First, an extract (0.5 mL) was pipetted into a test tube containing 2.5 mL of Folin-Ciocalteu reagent 10% v/v. After 5 mins, 2 mL of Na2CO3 20% (w/v) was added to the sample. Next, the mixture was vigorously shaken and...
incubated for 30 min in the dark. Finally, the absorbance was spectrophotometrically measured at 765 nm and the results were shown in mg gallic acid equivalents per 100 g of dried weight (mg GAE/100 g DW). The data presented are the average of three measurements.

2.5 Total antioxidant activity determination

To determine the antioxidant activity of the samples, the scavenging free radical using 1,1-diphenyl-2-picrylhydrazyl (DPPH) method described by Brand-Williams was carried out (Cadiz-Gurea et al., 2017). The general principle of the method is based on the ability of antioxidants to scavenge free radicals, in turn causing the change of DPPH solution from colourless to purple. The extract was first diluted to a reasonable concentration. Then 0.5 mL of the diluted sample was taken into a test tube. The control sample was ethanal (99.5%). DPPH solution (1.5 mL; OD 517 nm = 1.1±0.02) was added to the test tube, which was then allowed to stand in the dark for 30 min. Optical absorbance was measured at 517 nm on a UV-Vis spectrophotometer (Iqbal et al., 2015). Vitamin C (ascorbic acid) was used as the reference standard. The blank was 500 µL solution replaced with EtOH 99.7%. Standard sample: Vitamin C (0.1± 0.01 g) was dissolved EtOH 99.7% into volume flask 100 mL, in the dark (C = 100 µg/mL).

DPPH free radical scavenging activity (IC%) was determined by the following formula:

\[ IC\% = \frac{Abs_c - Abs_T}{Abs_c} \times 100 \]

Where AbsC is the optical absorbance of the control sample and AbsT is the optical absorbance of the sample. The result is reported based on the IC concentration at which the sample removes 50% of DPPH free radicals. Therefore, IC50 values are negatively correlated to the antioxidant activity, the lower IC50 value means the highest antioxidant activity of the tested sample.

2.6 Statistical analysis

All studies were completed in triplicate. The results were presented as mean value±standard deviation (SD). The study was examined by Statgraphics Centurion XV software.

3. Results

3.1 Physicochemical characteristics

The extraction oil yield was 16.6%, which was slightly higher than those (5.8–13.6%) reported by Beveridge et al. (1999) and Cao and Ito (2003). This result is in agreement with that obtained by Ohnishi et al. (1990), and Göktürk Baydar and Akkurt (2001). They reported that the oil content of seeds obtained from 9.9 to 20% depends on different grape cultivars. The physicochemical characteristics of grape seed oil were summarized in Table 1. Grape seed oil had a slightly higher density (0.965±0.015 g/cm³ at 25°C) than that of other fruit oils such as gac oil (0.955±0.012 g/mL) (Mai et al., 2013) and sacha inchi oil (0.90–0.921 g/cm³) (Mai et al., 2019). The refractive index at 25°C of grape seed oil (1.55) was also slightly comparable to that of gac oil (1.47) (Mai et al., 2013) and sacha inchi oil (1.525) (Mai et al., 2019).

The chemical properties of the grape seed oil include oxidative stability and fatty acid profile. The oxidative level is reflected by iodine value, acid value and saponification value. The viscosity at 20°C and the iodine value of grape seed oil is 87.8±2.75 cP and 176.4±5.85 gI2/100 g oil, respectively. The high iodine content of the grape seed oil suggested that the oil chains are slightly rich in unsaturated fatty acids. The iodine level of grape seed oil was significantly higher than that of gac oil (76.58±1.90 I2/100 g) (Mai et al., 2013) and soybean oil (132 g I2/100 g) and corn oil (116 g I2/100 g) (Knothe, 2002).

Table 1. Physico-chemical characterization of grape seed oil

| Parameter                      | Grape seed oil |
|--------------------------------|----------------|
| 1 Protein content (%)          | 0              |
| 2 Viscosity at 20°C (cP)       | 87.8±2.75      |
| 3 Refractive index nD at 25°C  | 1.55±0.002     |
| 4 Density (g/mL)               | 0.965±0.02     |
| 5 Acid value (mg KOH/g oil)    | 2.25±0.75      |
| 6 Saponification value (mg KOH/g oil) | 185.5±7.45 |
| 7 Iodine value (g I2/100 g oil) | 176.4±5.85    |
| 8 Peroxide value (meq O2 per kg of oil) | 0.72±0.82 |
| 9 Unsaponification matter (g/kg) | 2.2±0.15     |

Values are presented as mean±SD, n = 3.

The acid value of grape seed oil was 2.25±0.75 mg KOH/g oil, lower than that of gac oil (about 2.55±0.57 mg KOH/g oil) (Mai et al., 2013). This is a low acidity value in accordance with Codex Alimentarius Commission, 1999. Similar values have been reported by Navas (2010) for the oil of a red grape variety and by Bosco for the oils of white grape varieties (from 1.9 to 2.5 mg KOH/g oil) (Boso et al., 2018).

The saponification value of grape seed oil, at 185.5±7.45 mg KOH/g, was comparable to that of olive oil of about 185 mg KOH/g and sacha inchi oil (183.5±1.45 mg KOH/g).

3.2 Fatty acid composition

In order to evaluate the nutritional property and stability of grape seed oil, the fatty acid composition was analysed and compared with those reported in different...
studies. The fatty acid profile distribution of grape seed oil was presented in Table 2. In general, the fatty acid profile of our grape seed oil is in accordance with that described by other works (Wen et al., 2016; Al Juhaimi and Özcan, 2017; Mai et al., 2019). The results revealed that the total saturated fatty acid composition of grape seed oil (about 14%) was significantly lower than that of other common vegetable oils such as coconut oil (80%) and olive oil (15%). Dominant saturated fatty acids recognized in grape seed oil are palmitic acid (8.91%), stearic acid (4.75%), eicosanoic acid (0.15%) and heptadecanoic acid (0.11%).

Table 2. The comparisons of fatty acids in grape seed oils

| Fatty acid composition | Grape seed oil |
|------------------------|---------------|
| Saturated FA (%)       |               |
| Myristic acid (C14:0)  | 0.05          |
| Palmitic acid (C16:0)  | 8.91          |
| Pentadecanoic acid (C15:0) | 0.04      |
| Heptadecanoic acid (C17:0) | 0.11      |
| Stearic acid (C18:0)   | 4.75          |
| Arachidic acid (C20:0) | 0.15          |
| Monounsaturated FA (%) |               |
| Palmitoleic acid (C16:1) | 0.13      |
| Oleic acid (C18:1)     | 17.50         |
| Eicosenoic acid (C20:1) | 0.19      |
| Erucic acid (C22:1)    | 0.05          |
| Polyunsaturated FA (%) |               |
| Linoleic acid (C18:2)  | 65.3          |
| Linolenic acid (C18:3) | 0.43          |
| Eicosadienoic acid(C20:2) | 0.25   |
| Dihomogamma-linoleic acid (20:3) | 0.04 |

The total unsaturated fatty acid content of grape seed oil is more than 80% including both monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA). The MUFA content in grape seed oil accounted for about 18% of total content and is largely dominated by oleic acid whose content reached 17.5% of total content, higher than that found in coconut oil (7.5%) (Karaman et al., 2015) and much lower than in olive oil (70%). For PUFA, its content was 68% and mainly included linoleic acid (65.3%). In general, grape seed oil has more linoleic acid than other vegetable oils such as safflower and sunflower oils (Lampi and Heinonen, 2009). This result is in accordance with those reported in previous studies. For example, the fatty acid profile of grape seed oil from several grape varieties grown in different countries was dominated by 61–75% linoleic acid (Beveridge et al., 1999; Crews et al., 2006). The most abundant fatty acid of different grape seed oils in China was linoleic acid ranging from 63.5 to 76.77%, followed by oleic acid (13.63–22.03%), palmitic acid (6.56–8.55%) and stearic acid (2.06–4.59%) (Wen et al., 2016). A study by Garavaglia et al. (2016) also showed that linoleic acid is the most abundant fatty acid in cold-pressed grape seed oils, contributing between 66% and 75% of total fatty acid. Therefore, grape seed oil could be classified in the linoleic acid or the (n-6) polyunsaturated fatty acid class (Dubois et al., 2007). Both oleic acid and linoleic acid have great importance in terms of nutritional implications because they can help to decrease total serum cholesterol and LDL-c (Dhavamani et al., 2014) resulting in inhibiting vascular disorders as well as heart attack (Prado et al., 2011). However, grape seed oil was rather poor in linolenic acid (<1%) in comparison with other seed oils (Goffman and Gallietti, 2001; Castillo et al., 2002; Castillo et al., 2004). For example, the linoleic acid content of black currant seed oil ranged from 43% to 58%. Although linolenic acid has positive effects on cardiovascular health and immune responses, a high level of this fatty acid can produce an unfavourable odour and taste in oil. Linolenic acid is oxidized easily due to having three double bonds on its hydrocarbon chain. The quality of oil rich in linolenic acid during processing and preservation would be unstable and have a short shelf-life (Madawala et al., 2012).

The fatty acids composition of edible oils differs in the variety, environmental cultivation and extraction methods (Al Juhaimi and Özcan, 2017). The fatty acid composition of the seeds remained relatively constant during the harvesting period, but the origin of berries had a significant effect on the fatty acid composition and the level (Yang and Kallio, 2002; St George and Cenkowski, 2007). In comparison with Brazilian cold pressed grape seed oil, Vietnamese grape seed oil exhibited higher contents of monosaturated oleic (C18:1 n-9) (17.5% versus 14.8%) and palmitic acid (C16:0) (8.91% versus 6.26%). However, the linoleic acid (C18:2 n-6) of Vietnamese grape seed oil was lower than that of Brazilian grape seed oil (65.3% versus 74.15%) (Shinagawa et al., 2018). The portion of saturated fatty acid and unsaturated fatty acid in grape seed oil from Vietnam was about 15% and 85%, respectively, which was equivalent to those of the grape seed oil from Brazil. In comparison with grape seed oils from China, which were characterized by high contents of unsaturated fatty acids (86.41–91.08%) including 63.88% to 77.12% of polyunsaturated fatty acids (Wen et al., 2016), Vietnamese grape seed oil demonstrated an equivalent content of total unsaturated fatty acid (85%).

3.3 Total phenolic content and antioxidant activity of grape seeds oil

Phenolic compound plays a vital role in plants due to their scavenging ability. The previous result illustrated that the total phenolic content (TPC) of the grape seed oil ranged from 50.51±3.21 mg/100 g to 560.21±6.22 mg/100 g. Our study showed that the TPC value of
Vietnamese grape seed oil was 609.08±5.82 mg GAE/g. Figure 1 illustrates shows the DPPH radical scavenging activity of the grape seed oil from Vietnam and that of vitamin C. The free radical scavenging capacities of the grape seed oil were presented using an IC₅₀ value of 25 µg/mL while vitamin C had activities with IC₅₀ values of 4.48 µg/mL. The smaller the reading value of IC₅₀, the stronger the catching ability of free radicals. The results showed that grape seed oil has 5 times higher catching ability of free radicals than in that vitamin C. Oxidation resistance also depends on the characteristics and extraction conditions of each type of material (Madawala et al., 2012). Nevertheless, this result also shows great potential in exploiting the antioxidant capacity of grape seed oil from Vietnam.

4. Conclusion

Grape seed oil is a by-product of the winemaking industry which is rich in essential, high phenolic compounds and high antioxidant activity, with good benefits to human health. Other minor nutrients of grape seed oil from Vietnam need to be studied in future research. Further research is also needed on the beneficial effects of grape seed oil on human health and its application in the cosmetic industry. The presence of total phenolic compounds and high antioxidant activity might emphasize the role of grape seed oil as an antioxidant and as an important ingredient to facilitate oxidative balance.

Conflict of interest

The authors declare no conflict of interest.

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References

Al Juhaimi, F. and Özcan, M.M. (2017). Effect of cold press and soxhlet extraction systems on fatty acid, tocopherol contents, and phenolic compounds of various grape seed oils. *Journal of Food Processing and Preservation*, 42(1), 136-145. https://doi.org/10.1111/jfpp.13417

Bellili, S., Jazi, S., Nasr, S.ben, Dhifi, W., Neves, M.A., Miguel, M.G.C. and Mnif, W. (2018). Grape seed oil: Chemical composition, biological properties and health benefits. In Nguyen, K.D.H (Ed.). Seed Oil: Production, Uses and Benefits. Baltimore, USA: Nova Sciences Publishers.

Beveridge, T., Li, T.S.C., Oomah, B.D. and Smith, A. (1999). Sea Buckthorn Products: Manufacture and Composition. *Journal of Agricultural and Food Chemistry*, 47(9), 3480-3488. https://doi.org/10.1021/jf981331m

Boso, S., Gago, P., Santiago, J.-L., Rodriguez-Canas, E. and Martinez, M-C. (2018). New monovarietal grape seed oils derived from white grape bagasse generated on an industrial scale at a winemaking plant. *LWT - Food Science and Technology*, 92, 388-394. https://doi.org/10.1016/j.lwt.2018.02.055

Cao, X. and Ito, Y. (2003). Supercritical fluid extraction of grape seed oil and subsequent separation of free fatty acids by high-speed counter-current chromatography. *Journal of Chromatography A*, 1021(1-2), 117-124. https://doi.org/10.1016/j.chroma.2003.09.001

Cádiz-Gurrea, M.D.I.L., Borrás-Linares, I., Lozano-Sánchez, J., Joven, J., Fernández-Arroyo, S. and Segura-Carretero, A. (2017). Cocoa and Grape Seed Byproducts as a Source of Antioxidant and Anti-Inflammatory Proanthocyanidins. *International Journal of Molecular Sciences*, 18(2), 376. https://dx.doi.org/10.3390%2Fijms18020376

Castillo, M.L.R.D, Dobson, G., Brennan, R. and Gordon, S. (2002). Genotypic Variation in Fatty Acid Content of Blackcurrant Seeds. *Journal of Agricultural and Food Chemistry*, 50(2), 332-335. https://doi.org/10.1021/jf010899j

Castillo, M.L.R.D, Dobson, G., Brennan, R. and Gordon, S. (2004). Fatty Acid Content and Juice Characteristics in Black Currant (*Ribes nigrum* L.)

![Figure. 1. DPPH radical scavenging activity](image-url)
Genotypes. Journal of Agricultural and Food Chemistry, 52(4), 948-952. doi:10.1021/jf034950q

Crews, C., Hough, P., Godward, J., Berereton, P., Lees, M., Guiet, S. and Winkelmann, W. (2006). Quantitation of the Main Constituents of Some Authentic Grape-Seed Oils of Different Origin. Journal of Agricultural and Food Chemistry, 54(17), 6261-6265. doi:10.1021/jf060338y

Dabetic, N.M., Todorovic, V.M., Djuricic, I.D., Antic Stankovic, J.A., Basic, Z.N., Vujovic, D.S. and Sobajic, S.S. (2020). Grape Seed Oil Characterization: A Novel Approach for Oil Quality Assessment. European Journal of Lipid Science and Technology, 122(6), 1900447. https://doi.org/10.1002/ejlt.201900447

Duba, K.S. and Fiori, L. (2015). Supercritical CO2 extraction of grape seed oil: Effect of process parameters on the extraction kinetics. Journal of Supercritical Fluids, 98, 33-43. https://doi.org/10.1016/j.supflu.2014.12.021

Dubois, V., Breton, S., Linder, M., Fanni, J. and Parmentier, M. (2007). Fatty acid profiles of 80 vegetable oils with regard to their nutritional potential. European Journal of Lipid Science and Technology, 109(7), 710-732. https://doi.org/10.1002/ejlt.200700040

Dhavamani, S., Rao, Y.P.C. and Lokesh, B.R. (2014). Total antioxidant activity of selected vegetable oils and their influence on total antioxidant values in vivo: A photochemiluminescence based analysis. Food Chemistry, 164, 551-555. https://doi.org/10.1016/j.foodchem.2014.05.064

Felhi, S., Baccouchi, N., Salah, H.B., Smaoui, S., Allouche, N., Gharsallah, N. and Kadri, A. (2016). Nutritional constituents, phytochemical profiles, in vitro antioxidant and antimicrobial properties, and gas chromatography-mass spectrometry analysis of various solvent extracts from grape seeds (Vitis vinifera L.). Food Science and Biotechnology, 25(6), 1537-1544. https://doi.org/10.1007/s10068-016-0238-9

Fiori, L., Lavelli, V., Duba, K.S., Sri Harsha, P.S.C., Mohamed, H.B. and Guella, G. (2014). Supercritical CO2 extraction of oil from seeds of six grape cultivars: Modeling of mass transfer kinetics and evaluation of lipid profiles and tocotol contents. The Journal of Supercritical Fluids, 94, 71-80. https://doi.org/10.1016/j.supflu.2014.06.021

Garavaglia, J., Markoski, M.M., Oliveira, A. and Marcadenti, A. (2016). Grape Seed Oil Compounds: Biological and Chemical Actions for Health. Nutrition and Metabolic Insights, 9, 59-64. https://dx.doi.org/10.14137%2FNML.32910

Goffman, F.D. and Galletti, S. (2001). Gamma-Linolenic Acid and Tocopherol Contents in the Seed Oil of 47 Accessions from Several Ribes Species. Journal of Agricultural and Food Chemistry, 49(1), 349-354. https://doi.org/10.1021/jf0006729

Göktürk Baydar, N. and Akkurt, M. (2001). Oil content and oil quality properties of some grape seeds. Turkish Journal of Agriculture and Forestry, 25, 163-168.

Iqbal, E., Salim, K.A. and Lim, L.B.L. (2015). Phytochemical screening, total phenolics and antioxidant activities of bark and leaf extracts of Goniothalamus velutinus (Airy Shaw) from Brunei Darussalam. Journal of King Saud University - Science, 27(3), 224-232. https://doi.org/10.1016/j.jskus.2015.02.003

Karaman, S., Karasu, S., Tornuk, F., Toker, O.S., Geçgel, Ü., Sagdic, Özcan N. and Gül, O. (2015). Recovery Potential of Cold Press Byproducts Obtained from the Edible Oil Industry: Physicochemical, Bioactive and Antimicrobial Properties. Journal of Agricultural and Food Chemistry, 63(8), 2305-2313. https://doi.org/10.1021/jf504390t

Knothe, G. (2002). Structure indices in FA chemistry. How relevant is the iodine value? Journal of the American Oil Chemists' Society, 79(9), 847-854. https://doi.org/10.1007/s11746-002-0569-4

Lampi, A.-M. and Heinonen, M. (2009). Berry seed and grapeseed oils. In Moreau, R.A. and Kamal-Eldin, A. (Eds). Gourmet and Health-Promoting Specialty Oils, p. 215-235. Baltimore, USA: Academic Press and AOCS Press.

Madawala, S.R.P., Kochhar, S.P. and Dutta, P.C. (2012). Lipid components and oxidative status of selected specialty oils. Grasas y Aceites, 63(2), 143-151. http://dx.doi.org/10.3989/gya.083811

Mai, H.C., Nguyen, D.C., Nguyen, P.T.N. and Bach, L.G. (2019). Physico-Chemical Properties of Sacha Inchi (Plukenetia volubilis L.) Seed Oil from Vietnam. Asian Journal of Chemistry, 32(2), 335-338. http://dx.doi.org/10.14233/ajchem.2020.22233

Mai, H.C., Truong, V., Debaste, F. (2013). Optimization of enzyme aided extraction of oil rich in carotenoids from gac fruit (Momordica cochinchinensis Spreng.). Food Technology and Biotechnology, 51(4), 488-499. https://dipot.ubl.ac.be/dspace/bitstream/2013/69563/3/3282-in_press.pdf

Marci, F.D., Seraglia, R., Molin, L., Traldi, P., Rosso, M.D., Panighel, A., Vedova, A.D., Gardiman, M., Giust, M., Carraro, R. and Flamini, R. (2015).
Characterization of seed proanthocyanidins of thirty-two red and white hybrid grape varieties. *Vitis*, 54 (3), 121-128. https://doi.org/10.5073/vitis.2015.54.121-128

Navas, P.B.H. (2010). Physicochemical characterisation of grape, seed oil by solvent cold extracted. *Revista de la Facultad de Agronomía*, 27(2), 270-288.

Ohnishi, M., Hirose, S., Kawaguchi, M., Ito, S. and Fujino, Y. (1990). Chemical Composition of Lipids, Especially Triacylglycerol, in Grape Seeds. *Agricultural and Biological Chemistry*, 54(4), 1035–1042. https://doi.org/10.1080/00021369.1990.10870074

Pardo, J.E., Rubio, M., Pardo, A., Zied, D.C. and Álvarez-Ortí, M. (2011). Improving the quality of grape seed oil by maceration with grinded fresh grape seeds. *European Journal of Lipid Science and Technology*, 113(10), 1266-1272. https://doi.org/10.1002/ejlt.201000521

Prado, I.M.D, Giufrida, W.M., Alvarez, V.H., Cabral, V.F., Quispe-Condori, S., Saldana, M.D.A. and Cardozo-Filho, L. (2011). Phase Equilibrium Measurements of Sacha Inchi Oil (Plukenetia volubilis) and CO2 at High Pressures. *Journal of the American Oil Chemists’ Society*, 88(8), 1263-1269. http://dx.doi.org/10.1007/s11746-011-1786-z

Rubio, M., Alvarez-Ortí, M., Alvarruiz, A., Fernández, E. and Pardo, J.E. (2009). Characterization of Oil Obtained from Grape Seeds Collected during Berry Development. *Journal of Agricultural and Food Chemistry*, 57(7), 2812-2815. https://doi.org/10.1021/jf803627t

Shinagawa, F.B., Santana, F.C., Araujo, E., Purgatto, E. and Mancini-Filho, J. (2018). Chemical composition of cold pressed Brazilian grape seed oil. *Food Science and Technology*, 38(1), 164-171. https://doi.org/10.1590/1678-457X.08317

Shinagawa, F.B., Santana, F.C.de, Torres, L.R.O. and Mancini-Filho, J. (2015). Grape seed oil: a potential functional food? *Food Science and Technology (Campinas)*, 35(3), 399-406. https://doi.org/10.1590/1678-457X.6826

Singleton, V.L. and Rossi, J.A. (1965). Colorimetry of total phenolics with phosphomolybdic phosphotungstic acid reagents. *American Journal of Enology and Viticulture*, 16, 144-158.

St. George, S.D. and Cenkowski, S. (2007). Influence of Harvest Time on the Quality of Oil-Based Compounds in Sea Buckthorn (*Hippophae rhamnoides* L. ssp. sinensis) Seed and Fruit. *Journal of Agricultural and Food Chemistry*, 55(20), 8054-8061. https://doi.org/10.1021/jf070772f