Journal of the Saudi Society of Agricultural Sciences 22 (2023) 149–157

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Journal of the Saudi Society of Agricultural Sciences

journal homepage: www.sciencedirect.com

Full length article

Microwave-assisted extraction of dragon fruit seed oil: Fatty acid profile and functional properties

Tejaswi Boyapati [a], Sandeep Singh Rana [b], Payel Ghosh [c,*]

[a] Department of Food Technology (Chemical Engineering), Vignan's Foundation of Science Technology and Research, Vadlamudi, Andhra Pradesh 522213, India
[b] School of Bioscience and Technology, Vellore Institute of Technology, Vellore, Tamil Nadu 632014, India
[c] Department of Food Technology (Chemical Engineering), Vignan's Foundation of Science Technology and Research, Vadlamudi, Andhra Pradesh 522213, India

ARTICLE INFO

Article history:
Received 25 April 2022
Revised 15 August 2022
Accepted 15 August 2022
Available online 18 August 2022

Keywords:
Dragon fruit seed oil
Microwave assisted extraction
Optimization
Fatty acid profiling
Antioxidant activity
Tocopherol

ABSTRACT

Dragon fruit is gaining its popularity in all over the world. The seed of the dragon fruit is highly nutritious in terms of essential fatty acid. The utilization of seed oils is getting increasingly common these days. In this work, a comparative analysis was undertaken for control and microwave-assisted extraction (MAE) samples, using the RSM-CCD (Response Surface Methodology – Central composite Design) design, to determine the influences power and time on dragon fruit seed oil's Yield, PV, DPPH, and polyphenol content. The optimization was done, where the extraction yield (34.30 %), PV (3.23 me quiiv O_2/kg), DPPH (69.65 %), and polyphenol (96.71 mg GAE/g) was observed. While comparing with the control sample the antioxidant activity of the seed oil in terms of (%DPPH, FRAP and ORAC) was better in microwave treated sample. The saturated fatty acid is 25 % with a monounsaturated fatty acid 20 % and Polyunsaturated fatty acid of 55 %. High amount of tocopherol content was determined having 93 % of γ -tocopherol. Dragon fruit seed oil has the possibility to be a good source for the functional components in the near future due to the presence of antioxidant compounds and essential fats.

1. Introduction

Hylocereus spp., commonly known as dragon fruit, generally grows in the equatorial region is a climber. In India it is called as Nagajamudu, Pitaya or Brahmajamudu. Pitaya is native to South, Central, and North America, and it thrives in tropical and subtropical regions (Vincent, 2009). Due to its unusual look, dragon fruit is quite appealing. The flesh is delicious, with a lot of tiny black seeds. Experts say it's also a wonderful source of minerals and antioxidants. *Hylocereus polyrhizus* (red pitaya with crimson meat) and *Hylocereus megalanthus* (yellow pitaya) are two more commercialized varieties (Ariffin et al., 2009). The fruit can be consumed fresh or made into dessert, pastries, sweets, jam, wines, shakes, and other speciality drinks, or used as flavourings in other drinks and cuisines. These are generally used to make flavor soups, lumpia, and other Filipino dishes. Skin pulps are used to make pickles, jam, and cleaning beverages. Although the fruit is native to America, several countries are growing (Merten, 2003; Pagliaccia et al., 2015).

The fruits consist of plenty of grainy seeds. Like other fruit seeds, dragon fruit seeds contain oil mainly poly unsaturated fatty acids (PUFA). Dragon fruit has more minerals than mangosteen and other tropical fruits like mango and pineapple, including potassium, phosphorus, sodium, and magnesium. The fruit is said to have a more significant amount of antioxidants when compared to other subtropical fruits (Farid Hossain et al., 2021). It is said to be good source of Ascorbic acid, retinol, and trace amounts of Thiamine and Riboflavin (C. et al., 2015). Because of its high lipid content and functional properties, dragon fruit oil extracted is viewed as a high value product (Liaotrakoon et al., 2013). The oil has anti-aging properties, so it smoothens and tightens the skin. It has greater amounts of antioxidants and unsaturated fatty acids, making it a great addition to creams, lotions and moisturizers. Several oil extraction techniques (mechanical compression, solvent extraction, supercritical fluid extraction, Enzymatic oil extraction, microwave-assisted oil extraction) are available for increasing the Yield of the oil by maintaining its quality from different fruit seeds (grapeseed, hemp seed, watermelon seed, passion fruit,

* Corresponding author.
E-mail address: payelghoshrana@gmail.com (P. Ghosh).

Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

https://doi.org/10.1016/j.jssas.2022.08.001
1658-077X/

etc.) (Aladić et al., 2015; De Oliveira et al., 2013; Ibrahim & Onwualu, 2005; Rai et al., 2015; Savoire et al., 2013). Among all such treatments microwave-assisted treatment gives promising results in different researches. The effect of microwave pre-treatment (before cold pressing) improves rapeseed oil's chemical stability, nutritional and functional content. There was no significant change in fatty acid composition upon microwave pre-treatment (Rezvankhah et al., 2019). In general, all modern research shows that using a microwave helps extract oil and increase production. Shorter extraction durations result in greater amount of oxidative stability, which is directly connected to reduced physical and chemical impacts (when compared to Soxhlet extraction utilising an accelerated temperature scenario), and efficient elution of antioxidants and preseravance of the nutritional properties (Li et al., 2013).

Dragon fruit seed oils contain a wide range of nutritional and antioxidant qualities; however, there seems to be little information on the pre-treatment methods for dragon fruit seed oil. The oil may fulfil a high industrial demand due to its quality. The work's objective is to optimize microwave pre-treatment parameters for increasing the yield of extraction of seed oil from dragon fruit and comparison of the antioxidant characteristics, fatty acid profile and tocopherol content for the extracted seed oil.

2. Materials and procedures

2.1. Sample collection

In Guntur– Andhra Pradesh (Latitude: 16.235741^0, Longitude: 80.397106^0), India, fresh dragon fruits were harvested and brought from a neighbouring farm on 34 days of flowering (DAF) (Jalgaonkar et al., 2020). Fruit is selected according to its physical ripeness. The produce is peeled and separated after being forcefully smashed with a soft spatula or while wearing gloves, the pulp is suspended in water, and the seeds and pulp are separated. The seeds will have settled inside the jar after about an hour. The pulp at the jar's rim can be manually removed. The seeds are filtered before being spread out on a wide dish or tray. Because the flesh surrounding the pulp is exceedingly gelatinous, it must be dried to eliminate moisture. Drying was done overnight in the shade. To acquire the final sample, the seeds are further dried at 40 °C for 4 h and pulverized into powder. Dragon fruits are gathered fresh each time for treatment to minimize the wasting of raw materials (Fig. 1a & Fig. 1b).

2.2. Determination of physicochemical characteristics of dragon fruit seeds

All procedures for determining moisture, total carbohydrates, dietary fiber, protein, and ash were measured based on method given by Nielsen (1998), Mengeş et al. (2019). A Hunter Lab Colorimeter was used to determine the L, a*, b*, and colour readings of the fruit. The L value has been used to describe the brightness to darkness (100–0) ratio, where a represents red (+ve) and green (–ve) colour and b represents yellow (+ve) and blue (– ve) colour. The chroma (C) value and hue angle were computed using the formulas (h), hue value has been used to determine the colour's purity, while the chroma value (C) was used to determine the appearance of the different shades.

$$C = \sqrt{a^2 + b^2}$$

$$h = tan - 1(b/a)$$

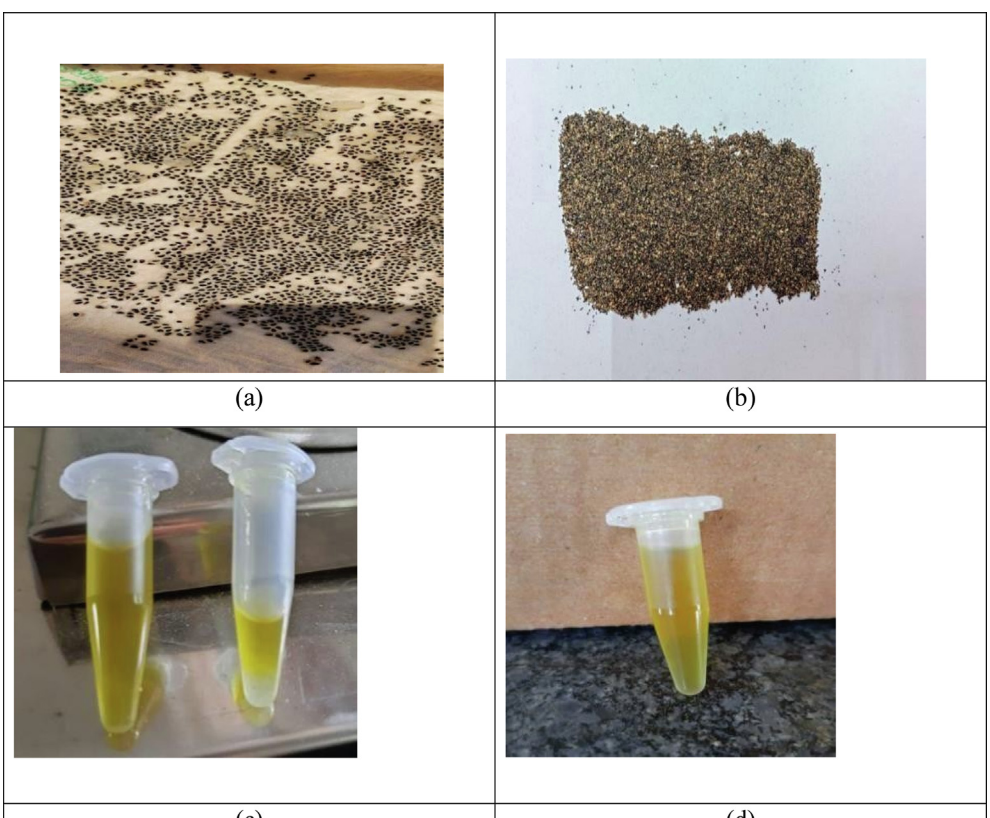

Fig. 1. (a) Wet seeds before sun-drying; (b) Dried seed powder; (c) Dragon fruit seed oil – Solvent extraction; (d) Dragon fruit seed oil – Microwave assisted solvent extraction.

After separating the non-edible (skin) component of the fruit from the edible section, the weight of the edible portion (pulp + seeds) and the weight of the non-edible portion (skin) is taken. The product is peeled and divided into pulp to separate and assess the proportion of seeds.

2.3. Dragon fruit seed oil characterization

The fat percentage in dragon fruit seeds was assessed using the solvent extraction technique **(**Fig. 1c & Fig. 1d**)**, which involves isolating fat using non-polar solvents such as *n*-hexane (Nielsen, 1998). The yield percentage is calculated by taking (actual yield/total weight of the sample) * 100. Refractive Index, Iodine Value, Peroxide value, and saponification are measured based on the procedures mentioned in the (AOAC 2017; AOCS 2017). The quantity of free fatty acid in the sample that neutralizes the KOH is calculated as the acid value, and the FFA's content in the oil extracted from dragon fruit seeds is reported in terms of (mg KOH/g). This parameter is computed using a method given by Win et al. (2018) which is discussed in detail under Section 2.5.

Antioxidant activity was measured by spectrophotometric analysis. The sample's antioxidant activity is measured in % DPPH, and the process uses methanolic extract, which has been used by other researchers (Ghosh et al., 2021). FRAP is an abbreviation for ferric reducing antioxidant power. This FRAP is measured in terms of μmol Trolox/g dry weight. The method utilised for this FRAP study was adapted from (Pal et al., 2015), in which acetate buffer with a pH of 3.6, 2, 4, 6-tripyridyl-s-triazine solutions were combined in HCl, and $FeCl_3{\cdot}6H_2O$ solutions is being used as standard stock solution. Acetate buffer, TPTZ solution, and $FeCl_3{\cdot}6H_2O$ solution were combined in a specific ratio to generate a new working solution, which was warmed to 37 °C before use. Fruit preparations were prepared by reacting in the dark with FRAP solution for 0.5 h and the absorbance of the coloured product (ferrous tripyridyl triazine complex) is measured at 593 nm. A FRAP calculation is performed using graph by plotting a calibration curve (10–100 M) established by adding Trolox to the FRAP buffer solution, and the results are presented in Trolox equivalents (M Trolox/g FW).

Antioxidant activity was also measured by Oxygen Radical Absorbance Capacity Assays (ORAC). Fluorescein, phosphate buffer was used to make a 0.12 mM fluorescein solution (75 mM, pH 7.4). Before each assay, a 1:100 dilution of this solution with phosphate buffer was used to make the final fluorescein working solution. The stock solution of 2,2′-azobis(2-methylpropionamidine) dihydrochloride (AAPH) (c = 129 milli molar) was prepared by dissolving AAPH in phosphate buffer. Trolox was also used for calibration. A 96-well microtiter plate was filled with 10 μL of each sample in various dilutions, Trolox or water. Following that, 100 L of phosphate buffer (75 mM, pH 7.4) or 250 L of negative control phosphate buffer (75 mM, pH 7.4) were added. 150 μL of the AAPH stock mixture was taken to the blank value, standards, and samples after a 10-minute incubation period at 37 °C. The fluorescence quenching experiment was carried out at 37 °C with an excitation wavelength of 485 nm and an emission wavelength of 528 nm. The reaction's progress was tracked for a time period of 2 h, with 1 observation every 2 min (Groth et al., 2020).

Table 1
Results of the Physicochemical characteristics of the control dragon fruit seed.

Sl. No	Control Seed parameters	Value
1.	Moisture (% wb)	67 ± 1.22
2.	Carbohydrate (g/100 g seed)	3.48 ± 1.55
3.	Dietary Fibre (g/100 g seed)	3.00 ± 1.23
4.	Protein (g/100 g seed)	2.00 ± 1.43
5.	Fat/Oil (%)	24.2 ± 0.73
6.	Ash (g/100 g seed)	0.25 ± 0.22
7.	L	31.61 ± 0.53
8.	a*	0.76 ± 0.002
9.	b*	10.61 ± 0.32
10.	Edible part of the fruit (%)	39.75 ± 3.45
11.	Non edible part of the fruit (%)	51.92 ± 4.73
12.	Seed (%)	7.89 ± 1.21

2.4. Experimental design for Microwave pre-treatment extraction by design expert RSM-CCD

The Microwave aided extraction of the dragon fruit seed oil was optimized using the RSM CCD design, where independent parameters were power (w) and Time (min), and the dependent parameters were yield (%), PV (me quiv Oxygen/kg), DPPH (%), and Polyphenol (mg GAE/g). The microwave used here is Samsung (MC28M6036CC Convention MWO – 28 L). Power was varied from 300 to 600 W, represented in the coded format (−1 to +1), and time was varied from 5 to 15 min, which was also represented in the coded form (−1 to +1). A total of 13 trials, including the five replicates at the centre point, were carried out in a randomized fashion for the three variables using a CCD setup (Table 2). Analysis of variance (ANOVA) has been employed to validate this model. After the pre-treatment, the oil extraction used to carry out by using solvent extraction mentioned in Section 2.3.

2.5. Fatty acid profiling

The gas chromatographic technique was used to do fatty acid profiling. The GC instrument was a Gas Chromatograph equipped with an FID (Flame Ionized Detector). Fatty acids were separated using it. 50 g sample was taken and is raised to a temperature of 80 °C in the mixture of chemicals (methanol, tetrahydrofuran, heptane, 2,2–dimethoxy propane and sulphuric acid (37:20:36:5:2)) where the parallel hydrolysis and extraction of methyl derivatives took place in a single step. H_2 was employed as a variable phase and at a flow rate of 0.06 L/hour. Agilent HP 50 + separation column (0.03 km length, 0.32ID mm, 0.25 μm Film) has been utilised as the adsorbate or column for the partitioning. The oven temperature with gradient mode of separation have been used, first with overall total time of 0.417 h, by an starting temp of 4 °C for four minutes, that was then raised to a temp of 150 °C at a level of 25 °C/min by an attempt to hold for a period of 60 s, again increasing it to a temperature of 220 °C at a raise of 4 °C/min by retaining it for 300 s, and ultimately to a temperature of 240 °C at an increase of 4 °C/min with a retention period of 900 s, where the process for determining the fatty acids contained in seed oil is based on the method used by Ghosh et al. (2021).

2.6. Tocopherol content

HPLC was used to determine the amount of tocopherol in the sample. The procedure to estimate the tocopherol content is taken from (Piombo et al., 2006) and is used in our study for the estimation of tocopherol content, at a 0.06 L/hour flow rate, the solvents was made up entirely from a mixture of hexane and dioxane. Using a spectrofluorimetric detector and the excitation wavelength was set at 290 nm and the emission wavelength was set at 330 nm. To assure accuracy, the analysis was performed three times(triplicates) for accuracy and confirmatory purpose.

2.7. Statistical evaluation

The statistical analysis was performed here as mean ± SD of three independent evaluation and had been statistically analysed employing SPSS statistics 20 (SPSS, Inc., Chicago). Turkeys Test

Table 2
The CCD real variables and experimental responses.

Diagnostics Case Statistics												
					Yield (%)		PV (me quiiv Oxygen/kg)		DPPH (%)		Polyphenol (mg GAE/g)	
Standard Order	Power (Watt)	Power (Watt) - Coded	Time (Min)	Time (Min)-Coded	Actual Value	Predicted Value	Actual Value	Predicted Value	Actual Value	Predicted Value	Actual Value	Predicted Value
1	300	−1	5	−1	21.6	24.13	2.94	2.97	59.41	60.35	71.36	74.82
2	600	1	5	−1	32.8	34.04	3.11	3.13	68.21	67.67	90.13	90.75
3	300	−1	15	1	24.3	26.78	2.98	2.99	60.03	61.05	75.34	79.79
4	600	1	15	1	33.1	34.30	3.23	3.23	70.11	69.65	95.11	96.71
5	237.87	−1.414	10	0	22.5	19.73	2.91	2.89	60.14	58.85	74.61	70.06
6	662.13	1.414	10	0	33	32.05	3.18	3.17	69.31	70.11	93.81	93.29
7	450	0	2.93	−1.414	34.6	32.71	3.13	3.09	64.11	63.93	87.33	85.49
8	450	0	17.07	1.414	36.6	34.77	3.16	3.17	66.13	65.83	96.46	93.23
9	450	0	10	0	34.8	34.88	3.14	3.14	64.15	64.15	93.41	93.32
10	450	0	10	0	35.1	34.88	3.15	3.14	64.13	64.15	93.4	93.32
11	450	0	10	0	35	34.88	3.14	3.14	64.15	64.15	93.39	93.32
12	450	0	10	0	34.8	34.88	3.14	3.14	64.15	64.15	93.2	93.32
13	450	0	10	0	34.7	34.88	3.14	3.14	64.15	64.15	93.2	93.32

and ANOVA were also used to determine statistical significance. For all differences, the significance level was set at $P < 0.05$.

3. Results and discussion

3.1. Physicochemical properties of dragon fruit seed

When compared to the moisture content of a few other date seeds, which was reported to be 2.33 percent, 1.66 percent, and 1.66 percent for Mazafati Bam, Mazafati Jiroft, and Kalutah varieties, respectively, the dragon fruit seed has a moisture level of around 67 % when measured on a (% wb) (Dehdivan & Panahi, 2017). Table 1 lists the physico-chemical parameters of the dragon fruit seed. The moisture content of red pitaya seeds is around 126 ± 6 g/kg seed (fresh weight base) by Villalobos-Gutiérrez et al. (2012). The control dragon fruit seed has a total carbohydrate content of 3.48 ± 1.55 g/100 g seed. The carbohydrate content of the dragon fruit, as estimated by Kurnia et al. (2021), is found to be around 10.8 %, and the carbohydrate content ranges from 79.32 to 82.97 % among different varieties of date seeds (Dehdivan & Panahi, 2017) and 352 ± 15 mg/kg in red pitaya seeds of Central American origin by Villalobos-Gutiérrez et al. (2012). Dietary Fibre is estimated to be 3.00 ± 1.23 g/100 g seed in the control dragon fruit seed. The dietary fibre content of red pitaya seeds from Central America is estimated to be around 302 ± 19 mg/kg seed (fresh weight base), while the amount of protein present in the control dragon fruit seed was observed to be 2.00 ± 1.43 g/100 g seed, and the protein content of the red pitaya seeds from Central America was reported to be around 206 ± 6 mg/kg seed (FW basis) (Villalobos-Gutiérrez et al., 2012). The control dragon fruit seed is reported to have a fat percentage of around 24.2 ± 0.73 %. The control dragon fruit seed contains 0.25 ± 0.22 g of ash per 100 g of seed which is found to be higher when compared with the ash content reported by Villalobos-Gutiérrez et al. (2012), which is 21 ± 1 mg/kg seed (fresh weight base). The L value for the control dragon fruit seed was determined to be 31.61 ± 0.53, the a* value for the control dragon fruit seed was 0.76 ± 0.002, and the b* value for the control dragon fruit seed was found to be 10.61 ± 0.32. The percentage of the edible fruit is approximately 39.75 ± 3.45 %, the portion of the fruit that is non-edible is around 51.92 ± 4.73 %, and the percentage of seeds is around 7.89 ± 1.21 %.

3.2. Optimization and effects of variables

The solvent extraction approach was used to determine the solvent extraction for the dragon fruit seeds, which used organic solvents like *n*-hexane. The CCD design for the Microwave treated extraction of the samples was made as mentioned in Table 2. The CCD design was employed for optimizing the Yield. The ANOVA model showed that all the proposed things had an excellent R^2 value. The Yield was observed to have an R^2 value of 0.9053(Quadratic), PV with 0.9664(Quadratic), DPPH with 0.9539(linear), and Polyphenol of 0.9240(Quadratic). The suggested model is fit if the R^2 for all responses is >90. This regression model shows that the conditions are favourable for attaining the highest Yield (Abdullah et al., 2007). Where the equations for Yield (1), PV (2), DPPH (3), and Polyphenol (4) are as follows:

$$\text{Yield} = -25.99 + 0.21A + 0.96B - 0.0008AB - 0.0002A^2 - 0.022B^2 \tag{1}$$

$$\text{PV} = +2.38 + 0.002B + 0.00002AB - 0.000002A^2 - 0.0002B^2 \tag{2}$$

$$\text{DPPH} = +55.76 + 0.02A - 0.35B + 0.0004AB + 0.000007\,A^2 + 0.015B^2 \tag{3}$$

$$\text{Polyphenol} = +4.40 + 0.28A + 1.98B + 0.0003AB - 0.0002A^2 - 0.08B^2 \tag{4}$$

The research was done in triplicates for confirmation, and the results were reported as an average using the three-dimensional graphs. The R^2 value is determined to validated the model. The details of the effect of independent parameter on the dependent parameter has been mentioned in the Table 2.

3.2.1. Variables effect on yield

As shown in Table 3, power (A) ($P < 0.0001$) and time (B) ($P < 0.001$) had a considerable beneficial influence on juice output, whereas quadratic parameters had a significant negative effect

Table 3
ANOVA and F-Value for all Dependent Variables for MW assisted oil extraction from dragon fruit seed.

Regression Coefficient	Yield	PV	DPPH	Polyphenol
b_0	−25.99	+2.38	+55.76	+4.40
A(Power)	0.21	0.002	0.015	0.284
B(Time)	0.96	−0.002	−0.35	+1.98
AB	−0.0008	+0.00002	0.0004	0.0003
A^2	−0.0002	$-2.4*10^{-6}$	$7.50*10^{-6}$	−0.0002
B^2	−0.022	−0.0002	0.01	−0.079
F-Value	13.39	40.23	38.07	17.02

($P < 0.01$). In terms of their real level, the regression model describing the influence of power and temperature on the production of dragon fruit seed oil is as follows:

$$Yield = -25.99 + 0.21A + 0.96B - 0.0008AB - 0.0002A^2 - 0.022B^2$$

The coefficient of determination R^2 for the above equation is 0.90. This figure implies that the regression model is able to explain 90 % of variance in the data. Fig. 2a demonstrates that as the power and time rise, the Yield grows until it reaches a certain point, beyond which it drops. On the other hand, optimal power and time have the considerable influence on oil yield. The most considerable Yield was recorded at 450 w and 10 min. Because of the oil's deterioration and evaporation during the extraction process, a drop in yield is noted after a certain length of time. And it is at this power-time combination that the greatest yield is reached. Depending on the moisture content of the fruit seeds, the yield obtained from Passion fruit seeds collected using an oil press machine was determined to be in the range of 6–12 percent by Andasuryani et al. (2020). Our control oil produced a yield of around 24.2 ± 0.73[a], whereas the yield of the optimised sample was 33.6 ± 0.48[b]. Both of our samples yielded more oil than the oil obtained from the Passion fruit seed.

3.2.2. Variables effect on PV

As shown in Table 3, power (A) ($P < 0.0001$) and time (B) ($P < 0.001$) had a linear positive influence on PV of the juice, whereas quadratic parameters had a substantial negative effect ($P < 0.01$). The following is the regression model for the influence of power and temperature on the PV of dragon fruit seed oil in terms of their real level:

$$PV = +2.38 + 0.002B + 0.00002AB - 0.000002A^2 - 0.0002B^2$$

The coefficient of determination R^2 for the above equation is 0.96. According to this result, the regression model can explain for 96 % of the data variability. PV grows up to a point, then falls, as seen in Fig. 2b, as power and duration increase. On the other hand, optimal power and time have the considerable influence on oil PV. The greatest PV was observed at 450 w and 10 min. Because of the deterioration and evaporation of the oil during the extraction process, a drop in PV is noted after a certain length of time. And, it is at this power-time (450 w and 10 min) combination, the highest quantity of PV is achieved. The microwave-treated sample exhibited a lower PV value than the control, indicating that the proportion of oxidation in the treated sample is less. This is contrary to the findings of (Kaseke et al., 2020), who observed that the oil derived from pomegranate seeds exhibited that the un-microwaved sample (control) had a lower PV value than the microwaved extracted sample (treated). The lesser the PV the more the oil is oxidative stable.

3.2.3. Variables effects on DPPH

As shown in Table 3, power (A) ($P < 0.0001$) and time (B) ($P < 0.001$) had a considerable beneficial influence on the DPPH of the juice, whereas quadratic parameters had a notable positive influence ($P < 0.01$). The following is the regression model for the influence of power and temperature on the DPPH of dragon fruit seed oil in terms of their real levels:

$$DPPH = +55.76 + 0.02A - 0.35B + 0.0004AB + 0.000007A^2 + 0.015B^2$$

The coefficient of determination R^2 for the above equation is 0.96. According to this result, the regression model can explain for 96 % of the data variability. Fig. 2c demonstrates that as power and time rise, DPPH grows until it reaches a specific point, beyond which it drops. On the other hand, optimal power and time have the considerable influence on oil's DPPH. The highest DPPH content was reported at 650 w and 15 min. The deterioration happens at more elevated temperatures/power or more prolonged exposure to heat during the extraction process, resulting in a drop in DPPH after certain time period. And it is at this power-time (650 w and

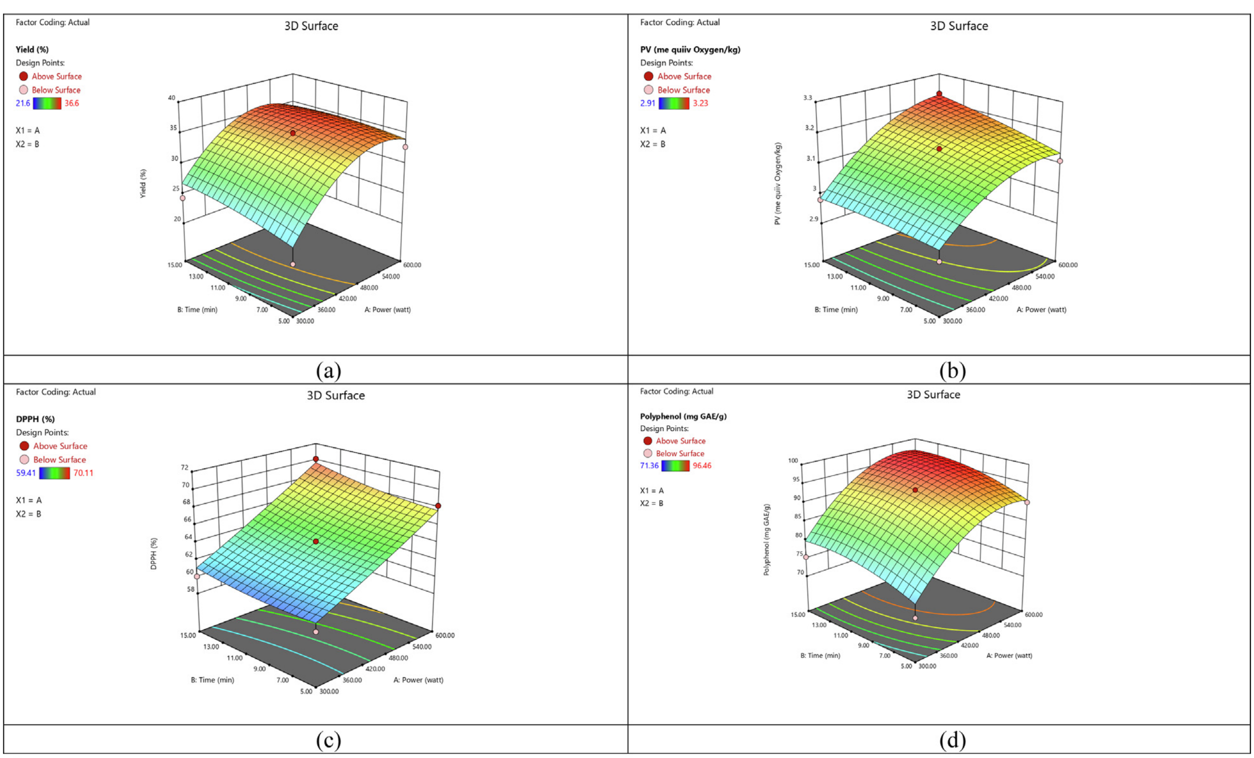

Fig. 2. (a) Effect of independent parameters on yield; (b) Effect of independent parameters on PV; (c) Effect of independent parameters on %DPPH; (d) Effect of independent parameters on polyphenol.

15 min) combination the maximum level of DPPH is produced. The microwave assisted extracted pomegranate seed oil has a DPPH value of 17.00 ± 0.21 IC_{50}/(mg/mL)(çavdar et al., 2017), which is much lower than our control and treated samples.

3.2.4. Variables effect on Polyphenol content

As shown in Table 3, power (A) ($P < 0.0001$) and time (B) ($P < 0.001$) had a linear positive influence on the Polyphenol in the juice, whereas quadratic parameters had a substantial negative effect ($P < 0.01$). The following is the regression model for the influence of power and temperature on the Polyphenol of dragon fruit seed oil in terms of their real level:

$$\text{Polyphenol} = +4.40 + 0.28A + 1.98B + 0.0003AB - 0.0002A^2 - 0.08B^2$$

The coefficient of determination R^2 for the above equation is 0.92. This figure clearly shows that the regression design can describe for 92 percent of the variance in the data. Fig. 2d shows that the polyphenol content rises as the power increases, but there is no discernible variation over time. On the other hand, optimal power and time have the considerable influence on oil's Polyphenol. The consistent yield is seen at every power and time combination during the extraction process. The polyphenol yield from grape seed oil with various treatments has been found to be between 49 and 83 mg/g (Dang & Xiu, 2013).

The constraints for optimization were considered as Power and Time in range, whereas yield was maximized, PV in range, DPPH and polyphenol was in maximization condition. The best combination effect of Power and Time was observed at 600 W for 15 min. The PV (me quiiv Oxygen/kg) at 600 W is found to be (>3 me quiiv Oxygen/kg)), the DPPH (%) at 600 W is found to be (>67 %), and the polyphenol content is found to be (>90 mg GAE/g). The maximum Yield is obtained at a treatment time of 15 min. The yield % is (>34 %), the PV me quiiv Oxygen/kg (>3 me quiiv Oxygen/kg), the DPPH % (>65 %), polyphenol (>75 mg GAE/g).

3.3. Characterisation and qualitative analysis for the seed oil extracted in different methods

The comparative analysis for the extracted oil sample using the solvent and microwave extraction is given in Table 4.

The optimal and selected parameters for the Microwave aided extraction of the dragon fruit seed oil is 600 W of power and 15 min, with a yield of 34.297 % according to the optimized design, and a yield obtained was in the range of 24.2 ± 0.73 for the solvent extracted dragon fruit seed oil. This demonstrates that the microwave-assisted extraction of dragon fruit seed oil yields more. The obtained DPPH % is around 69.654, and the polyphenol content is 96.714 mg GAE/g. The Optimized Microwave-Assisted Extracted seed oil has a refractive index of 1.41 ± 0.02, higher than the Control Seed oil (Solvent Extraction) refractive index of 1.33 ± 0.01.

3.3.1. Iodine value

The iodine value is used to identify the extent of unsaturation of the oils. The Optimized Microwave-Assisted Extracted seed oil has a higher Iodine value of 131 ± 1.01 (g I_2/100 g) than the Control Seed oil (Solvent Extraction), which has a value of 127 ± 0.98 (g I_2/100 g). Due to the obvious prevalence of more polyunsaturated fats, the Iodine value of the Chia seed oil derived by solvent extraction was 210.5 ± 0.02 (g I_2/100 g), which was substantially greater

Table 4
Analysis for the extracted oil from Dragon fruit seeds.

Sl No	Characteristics	Control Seed oil (Solvent Extraction)	Optimized Microwave Assisted Extracted seed oil
1.	Yield (%)	24.2 ± 0.73[a]	33.6 ± 0.48[b]
2.	Refractive Index	1.33 ± 0.01[a]	1.41 ± 0.02[a]
3.	Iodine Value (g I_2/100 g))	127 ± 0.98[a]	131 ± 1.01[b]
4.	Peroxide Value (me eqiv O_2/kg)	3.16 ± 0.002[a]	3.01 ± 0.001[a]
5.	FFA (mg KOH/g)	1.7 ± 0.13[a]	1.4 ± 0.16[b]
6.	Saponification (mg KOH/g)	241.6 ± 1.23[a]	250.2 ± 1.43[b]
7.	Antioxidant Activity (% DPPH)	65.3 ± 0.98[a]	68.4 ± 0.46[b]
8.	FRAP (μmol Trolox/g DW)	310 ± 0.88[a]	325 ± 0.94[b]
9.	ORAC (μmol Trolox/g DW)	13.61 ± 0.03[a]	14.23 ± 0.02[b]
Sl No	Fatty Acid Composition (g/100 g)	Control Seed oil (Solvent Extraction)	Optimized Microwave Assisted Extracted seed oil
1.	Myristic Acid (C14:0)	0.13 ± 0.00[a]	0.11 ± 0.00[b]
2.	Palmitic Acid (C16:0)	15.31 ± 0.02[a]	14.69 ± 0.01[b]
3.	Margaric acid (C17:0)	0.10 ± 0.00[a]	0.11 ± 0.01[a]
4.	Stearic acid (C18:0)	7.31 ± 0.01[a]	7.30 ± 0.03[a]
5.	Arachidic acid (C20:0)	0.93 ± 0.04[a]	0.90 ± 0.04[b]
6.	Behenic acid (C22:0)	0.86 ± 0.02[a]	0.88 ± 0.03[b]
7.	Lignoceric acid (C24:0)	0.51 ± 0.00[a]	0.51 ± 0.00[a]
	∑ Saturated Fatty Acid	25.15	24.61
8.	Palmitoleic acid (C16:1)	0.81 ± 0.02[a]	0.79 ± 0.03[b]
9.	Oleic acid (C18:1)	19.21 ± 0.06[a]	18.66 ± 0.07[b]
10.	Godonic acid (C20:1)	0.11 ± 0.00[a]	0.10 ± 0.00[a]
11	Erucic acid (C22:1)	0.06 ± 0.01[a]	0.05 ± 0.01[b]
	∑ Monounsaturated Fatty Acid	20.19	19.6
12.	Hexadecadienoic acid (C16:2)	0.18 ± 0.00[a]	0.17 ± 0.00[b]
13.	Linoleic Acid (C18:2)	54.81 ± 0.07 [a]	52.14 ± 0.08[b]
14.	Linolenic Acid (C18:3)	0.20 ± 0.01 [a]	0.14 ± 0.01[b]
15.	Eicosanoic acid (C20:3)	0.05 ± 0.00 [a]	0.04 ± 0.00 [a]
16.	Arachidonic acid (C20:4)	0.04 ± 0.00 [a]	0.04 ± 0.00 [a]
	∑ Polyunsaturated Fatty Acid	55.64	52.89
	Essential Fatty Acid (C18:2 + C18:3)	55.01	52.28
	Tocopherol Content (mg/kg)		
17.	α-tocopherol	10.43 ± 0.9[a]	52.19 ± 1.4[b]
18.	γ-tocopherol	830.26 ± 6.87[a]	921.58 ± 7.9[b]
19.	δ-tocopherol	51.75 ± 2.7[a]	76.6 ± 3.2[b]
20.	Total tocopherol content	892.44	1050.37

than the control and treated samples used in this study(Ixtaina et al., 2011). The sample has a higher iodine value than the peanut oil (86–107 g I_2/100 g), Coconut oil (6–11 g I_2/100 g), cocoa butter (34–40 g I_2/100 g), Canola (105–126 g I_2/100 g), Maize oil (102–135 g I_2/100 g) and is almost equal with the Wheat germ oil (115–126 g I_2/100 g) as reported in the (Tiefenbacher, 2017). The greater the iodine value, the higher the content of unsaturated fats in the oil.

3.3.2. Peroxide value

One of the most widely used tests for determining oxidation in fats and oils is the peroxide value, which assesses oxidative degradation and the stability of the oil. When compared to the Control Seed oil (Solvent Extraction), which has a peroxide value of 3.16 ± 0.002 (me eqiv O_2/kg), the Optimized Microwave-Assisted Extracted seed oil has a peroxide value of 3.01 ± 0.001 (me eqiv O_2/kg). This indicates that the treated sample has more excellent oxidative stability than the control dragon fruit seed oil sample (Solvent Extraction). The Chia seed oils are reported to have a peroxide value of 1.80 ± 0.16^d (me eqiv peroxide/kg) (Imran et al., 2016). The free fatty acid in the Optimized Microwave-Assisted Extracted seed oil is 1.4 ± 0.16 (mg KOH/g) compared to 1.7 ± 0.13 (mg KOH/g) in the Control Seed oil (Solvent Extraction), indicating that the optimized sample had less FFA than the control (Solvent Extraction).

3.3.3. Saponification value

Higher triglyceride saponification values suggest more medium-chain FA's. The more the saponification number, the shorter overall average fatty acid sequence and the lesser the mean molecular weight of triglycerides. The Optimized Microwave-Assisted Extracted seed oil has a saponification value of 250.2 ± 1.43 (mg KOH/g), which is higher than the Control Seed oil (Solvent Extraction) of 241.6 ± 1.23 (mg KOH/g). The similar kind of findings by Afolayan et al. (2014) in melon seed oil has showed to had saponification value around 180.92 (mg KOH/g) which is said to be employed in soap making due to its greater saponification value. The control and treated samples have a more excellent saponification value than the chia seed oil. The saponification value for the chia seed oil is reported as 193.09 ± 0.07 (mg KOH/g) (Ixtaina et al., 2011). This means that this dragon fruit seed oil can be employed in making soaps with functional benefits.

3.3.4. Antioxidant activity (%DPPH)

The antioxidant activity of the Optimized Microwave-Assisted Extracted oil from the dragon fruit is found to be greater than that of the Control Seed oil (Solvent Extraction), with values of 68.4 ± 0.46 (% DPPH) and 65.3 ± 0.98 (% DPPH), respectively. The ability of pulp and peel extracts to scavenge DPPH free radicals was demonstrated. Because of the presence of betalain, the red dragon fruit's pulp had the highest antioxidant activity of 1266.3 g/ml, while the peel had the highest antioxidant activity of 445.2 g/ml (JerÃƒÂnimo & Costa Orsine, 2015). Both of these values are found to be greater than seed oil. Microwave aided drying of kiwi fruits has been found to have a higher antioxidant content than conventionally dried kiwi fruits, which is consistent with our findings (Özcan et al., 2020).

3.3.5. Antioxidant activity (FRAP)

The Optimized Microwave-Assisted Extracted seed oil has a greater FRAP when compared to the Control (Solvent Extraction), with values of 325.94 ± 0.94 (μmol Trolox/g Dry Weight) & 310.8 8 ± 0.88 (μmol Trolox/g DW), respectively. In comparison, the dragon fruit pulp was reported to have the FRAP of around 609 to 620 μmol Fe2+/g Dry Weight (Ramli et al., 2014).

3.3.6. Antioxidant activity (ORAC)

The Optimized Microwave-Assisted Extracted seed oil has a higher ORAC than the Control Seed oil (Solvent Extraction), with values of 14.23 ± 0.02 (μmol Trolox/g Dry Weight) & 13.61 ± 0.03 (μmol Trolox/g Dry Weight), respectively. Similar studies have been conducted on The Golden Delicious 2017 variety, which had an ORAC value of 4.82 to 6.3 [milli mol TE/100 g Dry Weight], and the Golden Delicious 2018 variety, which had an ORAC content of 6.3 to 9.6 [milli mol TE/100 g Dry Weight]. The cold-pressed black caraway seed oil has an ORAC value of 220 μmol trolox equivalents (TE) per gram of fat (Yu et al., 2005), and the cold-old-pressed hemp seed oil has an ORAC value of 28 μmol TE/g oil (Groth et al., 2020; Yu et al., 2005).

3.4. Fatty acid profiling

Numerous experts have mentioned the advantages of essential fatty acids such as linoleic acid and alpha-linolenic acid, that may be advantageous in avoiding various ailments such as diabetes, inflammatory responses, and coronary heart disease (Munshi et al., 2020). The fatty acid profiling of optimized Microwave-assisted extracted seed oil was compared to that of the fatty acid profile of control oil extracted from the dragon fruit seeds which is extracted using solvent extraction and this comparison revealed that among the saturated fatty acids, myristic acid (C14:0), palmitic acid (C16:0), margaric acid (C17:0), stearic acid (C18:0), arachidic acid (C20:0), behenic acid (C22:0) are present in greater amount in control sample. In contrast, lignoceric acid (C24:0), Arachidonic acid is found to be at the same level in each of the two samples. The saturates fatty acid content in control is found to be greater than the optimized Microwave-assisted extracted seed oil sample (Table 4). The monounsaturated fatty acids and polyunsaturated acids are higher in the control than the Microwave-assisted extracted dragon fruit seed sample. Our samples have a higher proportion of stearic acid (C18:0), while palmitoleic acid is nearly the same. Similar kind of data was obtained by Liaotrakoon et al. (2013) where the essential fatty acid percent was 56 % having linolenic acid maximum. The oxidative stability of the oil was found quite high up-to 12 weeks of storage period. This microwave pre-treatment on the mango seed by Kittiphoom and Sutasinee (2015) improved the yields of Linoleic, Linolenic, and Eicosanoic acid; however, our samples showed a slight reduction. Linolenic acid was the most abundant fatty acid in seed oil of Origanum, accounting for 34.4 percent to 67.4 percent (Matthäus et al., 2018).

3.5. Tocopherol content

Tocopherol is an antioxidant required for many human functions. It was detected in higher concentrations in the Microwave aided extracted dragon fruit seed oil sample than in the control sample. Tocopherol content is expressed in milligrams per kilogram. A similar type of research done by Górnaś (2015) on different apple seeds showed a total tocopherol content ranging from 130 to 339 (mg/100 g oil). The Microwave-assisted extracted dragon fruit seed oil has an entire tocopherol content of 1050.37 mg/kg, while the control sample has a total tocopherol value of 892.44 mg/kg. Unlike the results found in the plum fruit which is subjected to different heating temperatures by Ghafoor et al. (2019a). Individual groups of tocopherols such as α-tocopherol, γ -tocopherol, and δ -tocopherol are also discovered in higher concentrations in the optimized sample, with values ranging from 52.19 ± 1.4 mg/kg, 921.58 ± 7.9 mg/kg and 76.6 ± 3.2 mg/kg, respectively (Table 4). Fairly similar research on White-flesh dragon fruit seed oil extracted using the traditional solvent extraction is found that perhaps the δ-Tocopherol content was 38.70 ± 0.24, the γ-Tocopherol content was 75.62 ± 2.23, and the α -Tocopherol content was 292. 94 ± 9.88 (Liaotrakoon et al., 2013). The amount of tocopherol in the oil produced from poppy seeds after roasting the seeds was similarly reduced (Ghafoor, et al., 2019b). However, when comparing the microwave-treated sample to the conventional in our experiment, the tocopherol concentration was found to be higher in the microwave-treated sample.

4. Conclusion

Dragon fruit a type of cactus fruit is considered as a functional fruit. This research aimed to increase the yield of the dragon fruit seed oil using several processes and then choose the best among them based on various characteristics such as Yield, DPPH, PV, and Polyphenol. Due to its advantages in extracting high-quality oil, microwave-assisted extraction was used to extract dragon fruit seed oil. RSM with CC Design was used to investigate the impacts of power and time on Yield, DPPH, PV, and Polyphenol. Power and Time were found to be the best conditions for extractions at 600 w for 15 min. At these conditions, the Yield is 33.6 ± 0.48 %, refractive index 1.41 ± 0.02, Iodine value 131 ± 1.01 g I2/100 g, Peroxide value 3.01 ± 0.001 me eqiv O_2/kg, FFA 1.40.16 mg KOH/g, Saponification value 250.2 ± 1.43 mg KOH/g, Antioxidant activity 68.4 ± 0. 46 % DPPH, FRAP 325 ± 0.94 mol Trolox/g DW. In the fatty acid composition, the maximum amount of fatty acid will be PUFA with an essential fatty acid percent of 55. A high quantity of linoleic acid was obtained in the seed oil. The RSM and the three-dimensional counter plot (Fig. 2) provide a better understanding of the oil extracted. Because of the greater levels of Polyphenol and unsaturated fats in this oil, it has a great value and may be microencapsulated for usage extensively in various forms. Besides that, research studies are required to conduct on the use of dragon fruit seed oil in the food, pharma, and cosmeceuticals following processing and refinement in order to broaden the market reach and provide great possibilities.

5. Declarations

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Availability of data and material: Yes.

Code availability: No.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abdullah, A.G.L., Sulaiman, N.M., Aroua, M.K., Mohd, M.J.M., 2007. Response surface optimization of conditions for clarification of carambola fruit juice using a commercial enzyme. J. Food Eng. 81, 65–71. https://doi.org/10.1016/j.jfoodeng.2006.10.013.

Afolayan, M., Fausat, A., Idowu, D., 2014. Extraction and physicochemical analysis of some selected seed oils. Int. J. Adv. Chem. 2 (2) https://doi.org/10.14419/ijac.v2i2.2203.

Aladić, K., Jarni, K., Barbir, T., Vidović, S., Vladić, J., Bilić, M., Jokić, S., 2015. Supercritical CO2 extraction of hemp (Cannabis sativa L.) seed oil. Ind. Crops Prod. 76, 472–478. https://doi.org/10.1016/j.indcrop.2015.07.016.

Andasuryani, I., Derosya, V., Syukri, D., 2020. The Effect of Moisture on the Yield of Sweet Passion Fruit (Passiflora lingularis Juss cv. Gumanti) Seed Oil from Indonesia by Mechanical Extraction. In: IOP Conference Series: Earth and Environmental Science. https://doi.org/10.1088/1755-1315/515/1/012021.

Ariffin, A.A., Bakar, J., Tan, C.P., Rahman, R.A., Karim, R., Loi, C.C., 2009. Essential fatty acids of pitaya (dragon fruit) seed oil. Food Chem. 114 (2), 561–564. https://doi.org/10.1016/j.foodchem.2008.09.108.

Chandrasekhara, C., Rao, S.V.M., 2015. GJRA-Glob. J. Res. Anal. X 261 4 (10), 261–262 http://www.freepatentsonline.com/article/American-Journal-Applied-.

çavdar, H.K., Yanik, D.K., Gok, U., Gogus, F., 2017. Optimisation of microwave-assisted extraction of pomegranate (Punica granatum L.) seed oil and evaluation of its physicochemical and bioactive properties. Food Technol. Biotechnol. 55 (1), 86–94. https://doi.org/10.17113/ftb.55.01.17.4638.

Dang, Y., Xiu, Z., 2013. Microwave-assisted aqueous two-phase extraction of phenolics from grape (Vitis vinifera) seed. August. https://doi.org/10.1002/jctb.4241.

De Oliveira, R.C., Davantel De Barros, S.T., Gimenes, M.L., 2013. The extraction of passion fruit oil with green solvents. J. Food Eng. 117 (4), 458–463. https://doi.org/10.1016/j.jfoodeng.2012.12.004.

Dehdivan, N.S., Panahi, B., 2017. Physicochemical properties of seeds and seeds oil extracted from Iranian date palm cultivars. Biol. Forum – Int. J. 9 (1), 139–144.

Farid Hossain, M., Numan, S.M., Akhtar, S., 2021. Cultivation, Nutritional Value and Health Benefits of Dragon Fruit (Hylocereus spp.): A Review. Int. J. Horticult. Sci. Technol. J. Homepage 8 (3).

Ghafoor, K., Ahmed, I.A.M., Doğu, S., Uslu, N., Gbemisola Jamiu, F., al Juhaimi, F., Babiker, E.E., Özcan, M.M., 2019a. The Effect of Heating Temperature on Total Phenolic Content, Antioxidant Activity, and Phenolic Compounds of Plum and Mahaleb Fruits. Int. J. Food Eng. https://doi.org/10.1515/ijfe-2017-0302.

Ghafoor, K., Özcan, M.M., AL-Juhaimi, F., Babiker, E.E., Fadimu, G.J., 2019b. Changes in quality, bioactive compounds, fatty acids, tocopherols, and phenolic compositioninoven- and microwave-roastedpoppy seeds and oil. LWT 99, 490–496. https://doi.org/10.1016/j.lwt.2018.10.017.

Ghosh, P., Singh, S., Rana, S.S., 2021. Physicochemical, nutritional, bioactive compounds and fatty acid profiling of Pumpkin flower (Cucurbita maxima), as a potential functional foodSN. Appl. Sci. 3 (2). https://doi.org/10.1007/s42452-020-04092-0.

Górnaś, P., 2015. Unique variability of tocopherol composition in various seed oils recovered from by-products of apple industry: Rapid and simple determination of all four homologues (α, β, γ and δ) by RP-HPLC/FLD. Food Chem. 172, 129–134. https://doi.org/10.1016/j.foodchem.2014.09.051.

Groth, S., Budke, C., Neugart, S., Ackermann, S., Kappenstein, F., Daum, D., Rohn, S., 2020. Influence of a Selenium Biofortification on Antioxidant Properties and Phenolic Compounds of Apples (Malus domestica), pp. 1–22.

Ibrahim, A., Onwualu, A.P., 2005. Technologies for Extraction of Oil From Oil-Bearing Agricultural Products: a Review. J. Agric. Eng. Technol. 13, 58–89.

Imran, M., Nadeem, M., Manzoor, M.F., Javed, A., Ali, Z., Akhtar, M.N., Ali, M., Hussain, Y., 2016. Fatty acids characterization, oxidative perspectives and consumer acceptability of oil extracted from pre-treated chia (Salvia hispanica L.) seeds. Lipids Health Dis. https://doi.org/10.1186/s12944-016-0329-x.

Ixtaina, V.Y., Martínez, M.L., Spotorno, V., Mateo, C.M., Maestri, D.M., Diehl, B.W.K., Nolasco, S.M., Tomás, M.C., 2011. Characterization of chia seed oils obtained by pressing and solvent extraction. J. Food Compos. Anal. 24 (2), 166–174. https://doi.org/10.1016/j.jfca.2010.08.006.

Jalgaonkar, K., Mahawar, M. K., Bibwe, B., & Kannaujia, P. (2022). Postharvest profile, processing and waste utilization of dragon fruit (Hylocereus Spp.): A review. Food Reviews International, 38(4), 733-759

JerÃƒÂnimo, M.C., Costa Orsine, J.V., 2015. Chemical and Physical-Chemical Properties, Antioxidant Activity and Fatty Acids Profile of Red Pitaya [Hylocereus Undatus (Haw.) Britton & Rose] Grown In Brazil. J. Drug Metabolism Toxicol. 06 (04). https://doi.org/10.4172/2157-7609.1000188.

Kaseke, T., Opara, U.L., Fawole, O.A., 2020. Effect of microwave pretreatment of seeds on the quality and antioxidant capacity of pomegranate seed oil. Foods 9 (9). https://doi.org/10.3390/foods9091287.

Kittiphoom, S., Sutasinee, S., 2015. Effect of microwaves pretreatments on extraction yield and quality of mango seed kernel oil. Int. Food Res. J. 22 (3), 960–964.

Kurnia, N., Liliasari, Adawiyah, A.D.R., Supriyanti, F.M.T., 2021. Determin ation of carbohydrates content in red dragon fruit for food chemistry laboratory. AIP Conf. Proc. 2330 (March), 5–10. https://doi.org/10.1063/5.0043135.

Li, J., Zu, Y.G., Luo, M., Gu, C.B., Zhao, C.J., Efferth, T., Fu, Y.J., 2013. Aqueous enzymatic process assisted by microwave extraction of oil from yellow horn (Xanthoceras sorbifolia Bunge.) seed kernels and its quality evaluation. Food Chem. 138 (4), 2152–2158. https://doi.org/10.1016/j.foodchem.2012.12.011.

Liaotrakoon, W., De Clercq, N., Van Hoed, V., Dewettinck, K., 2013. Dragon fruit (Hylocereus spp.) seed oils: Their characterization and stability under storage conditions. JAOCS J. Am. Oil Chem. Soc. 90 (2), 207–215. https://doi.org/10.1007/s11746-012-2151-6.

Matthäus, B., Özcan, M.M., Doğu, S., 2018. Fatty Acid Composition and Sterol Contents of Some Origanum Seed Oils. Eur. J. Lipid Sci. Technol. 120 (7). https://doi.org/10.1002/ejlt.201800094.

Menges, H.O., Ünver, A., Özcan, M.M., Ertekin, C., 2019. The Effects of Drying Parameters on Drying Characteristics, Colorimetric Differences, Antioxidant Capacity and Total Phenols of Sliced Kiwifruit. Erwerbs-Obstbau. https://doi.org/10.1007/s10341-019-00417-5.

Merten, S., 2003. A review of Hylocereus production in the United States. J. Profess. Assoc. Cactus Develop. 5 (November 2002), 98–105.

Munshi, M., Arya, P., Kumar, P., 2020. Physico-chemical analysis and fatty acid profiling of fenugreek (Trigonella foenum-graecum) seed oil using different solvents. J. Oleo Sci. 69 (11), 1349–1358. https://doi.org/10.5650/jos.ess20137.

Nielsen, S.S., 1998. Food Analysis. In: Suzanne Nielsen, S. (Ed.), Instructor's Manual for Food Analysis, 2nd ed. https://doi.org/10.1007/978-1-4615-5439-4_8.

Özcan, M.M., al Juhaimi, F., Ahmed, I.A.M., Uslu, N., Babiker, E.E., Ghafoor, K., 2020. Effect of microwave and oven drying processes on antioxidant activity, total phenol and phenolic compounds of kiwi and pepino fruits. J. Food Sci. Technol. 57 (1), 233–242. https://doi.org/10.1007/s13197-019-04052-6.

Pagliaccia, D., Vidalakis, G., Douhan, G.W., Lobo, R., Tanizaki, G., 2015. Genetic characterization of pitahaya accessions based on amplified fragment length polymorphism analysis. HortScience 50 (3), 332–336. https://doi.org/10.21273/hortsci.50.3.332.

Pal, R.S., Kumar, V., Arora, S., 2015. Physicochemical and Antioxidant Properties of Kiwifruit as a Function of Cultivar and Fruit Harvested Month. March. https://doi.org/10.1590/s1516-8913201500371.

Piombo, G., Barouh, N., Barea, B., Boulanger, R., Brat, P., Pina, M., Villeneuve, P., 2006. Characterization of the seed oils from kiwi (Actinidia chinensis), passion fruit (Passiflora edulis) and guava (Psidium guajava). Oléagineux Corps Gras Lipides 13, 195–199.

Rai, A., Mohanty, B., Bhargava, R., 2015. Modeling and response surface analysis of supercritical extraction of watermelon seed oil using carbon dioxide. Sep. Purif. Technol. 141, 354–365. https://doi.org/10.1016/j.seppur.2014.12.016.

Ramli, N.S., Ismail, P., Rahmat, A., 2014. Influence of conventional and ultrasonic-assisted extraction on phenolic contents, betacyanin contents, and antioxidant capacity of red dragon fruit (Hylocereus polyrhizus). Sci. World J. 2014. https://doi.org/10.1155/2014/964731.

Rezvankhah, A., Emam-Djomeh, Z., Safari, M., Askari, G., Salami, M., 2019. Microwave-assisted extraction of hempseed oil: studying and comparing of fatty acid composition, antioxidant activity, physiochemical and thermal properties with Soxhlet extraction. J. Food Sci. Technol. 56 (9), 4198–4210. https://doi.org/10.1007/s13197-019-03890-8.

Savoire, R., Lanoisellé, J.L., Vorobiev, E., 2013. Mechanical Continuous Oil Expression from Oilseeds: A Review. Food Bioprocess Technol. 6 (1), 1–16. https://doi.org/10.1007/s11947-012-0947-x.

Tiefenbacher, K.F., 2017. Technology of Main Ingredients—Sweeteners and Lipids. In: Wafer and Waffle. https://doi.org/10.1016/b978-0-12-809438-9.00003-x.

Villalobos-Gutiérrez, M.G., Schweiggert, R.M., Carle, R., Esquivel, P., 2012. Chemical characterization of Central American pitaya (Hylocereus sp.) seeds and seed oil. CYTA – J. Food 10 (1), 78–83. https://doi.org/10.1080/19476337.2011.580063.

Vincent, S., 2009. Pitaya (Dragon Fruit) Production and Processing (Issue August).

Win, S.S., Trabold, T.A., Zhao, B., Munshi, M., Arya, P., Kumar, P., Gabriel, R., Luis, C., David, B., Zhao, B., Tulyathan, V., Tananuwong, K., Songjinda, P., Jaiboon, N., Thammarat, N.S., Dehdivan, N.S., Panahi, B., Boyapati, T., Ghosh, P., et al., 2018. Sustainable Waste-to-Energy Technologies : Transesterification. In: Sustainable Food Waste-to-Energy Systems, vol. 01, no. 02. Elsevier Inc. https://doi.org/10.1016/B978-0-12-811157-4.00006-1.

Yu, L.L., Zhou, K.K., Parry, J., 2005. Antioxidant properties of cold-pressed black caraway, carrot, cranberry, and hemp seed oils. Food Chem. 91 (4), 723–729. https://doi.org/10.1016/j.foodchem.2004.06.044.