Vol. 11(3), pp. 40-47, July-December 2019
DOI: 10.5897/JABSD2019.0354
Article Number: ECC279862125
ISSN: 2141-2340

http://www.academicjournals.org/JABSD

ACADEMIC JOURNALS

Journal of Agricultural Biotechnology and Sustainable Development

Full Length Research

The influence of solvent's polarity on physicochemical properties and oil yield extracted from pumpkin (*Cucurbita maxima*) seed

Lesten Eliez Chisomo Chatepa[1*] and Kingsley Masamba[2]

[1]Basic Science Department, Faculty of Agriculture, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P. O. Box 219, Lilongwe, Malawi.
[2]Department of Food Science and Technology, Faculty of Food and Human Sciences, Lilongwe University of Agriculture and Natural Resources, Bunda Campus, P. O. Box 219, Lilongwe, Malawi.

Received 31 May, 2019; Accepted 16 July, 2019

The effect of solvent polarity, polar and non-polar solvents, on pumpkin (*Cucurbita maxima*) seed oil yield and quality based on selected physicochemical properties was investigated. Five different solvents, like petroleum ether, hexane, cyclohexane, acetone and ethanol were used on a laboratory scale in this study. Results showed that both physicochemical properties and oil yield extracted from the pumpkin seed were influenced by solvent polarity. Oil yield ranged from 4.12 to 27.93%, with higher yield registered in petroleum ether and lowest in ethanol. Results on the physicochemical properties were as follows: Refractive index ranged from 1.437 (cyclohexane) to 1.466 (hexane), acid value, in mg KOH/g oil, ranged from 1.80 (cyclohexane) to 43.54 (ethanol), Peroxide value ranged, in meq O_2/kg, from 6.70 (hexane) to 58.11 (ethanol), Iodine value, in g I_2/g, ranged from 1.20 (petroleum ether) to 36.73 (ethanol), Saponification value, in mg KOH/kg, ranged from 30.54 (hexane) to 121.14 (acetone). The findings have demonstrated that solvent polarity significantly influenced physicochemical properties and oil yield extracted from pumpkin seed and therefore can assist in selecting solvents required in oil extraction to maximize yield and enhance or maintain oil quality.

Key words: *Cucurbita maxima,* dielectric constant, oil, polarity, phytochemical properties, soxhlet extraction.

INTRODUCTION

Plant seeds contain nutrients and energy rendering them significant in humans' and animals' diet. Seeds are sources of edible oil and fats providing energy twice more than a unit carbohydrate and protein (Ali et al., 2001). Pumpkin (*Cucurbita maxima*) seeds have significant nutritional content providing high quality oil and proteins (Mahasneh and El-Oqlah, 1999; Montesano et al., 2018). The oil content in pumpkin seeds has been reported to be 37.8-45.4% (Lazos, 1986) and 47.03% with some variations based on species and genetic diversity (Younis et al., 2000). *C. maxima* seeds produce good quality oil and are excellent sources of proteins in the range of 25.2-37% (Lazos, 1986; Kim et al., 2012).

The techniques for recovering oil from plant oilseeds

*Corresponding author. E-mail: lecchatepa@yahoo.com; lchatepa@luanar.ac.mw.

include soxhlet extraction using solvents, mechanical and enzyme extraction (Atabani et al., 2013). The amount of oil and antioxidants extracted from oilseeds depends on the type and polarity of the solvents used (Turkmen et al., 2006). Polar and non-polar aqueous solvents like hexane, acetone, ethanol, methanol and ethyl acetate are used in oil and antioxidants extraction from plant materials (Becker, 1978; Johnson and Lusas, 1983; Efthymiopoulos et al., 2018).

Studies on the effect of solvent selection on oil extraction efficiency have been addressed by examining the efficiency of hexane, octane, ethanol, heptane, isopropanol, chloroform, toluene and mixtures of hexane and isopropanol (Al-Hamamre et al., 2012; Caetano et al., 2012). Non-polar solvents are excellent in oil extraction because either the low presence or absence of charges allows the solvent to penetrate into the non-polar matrix of the samples (Al-Hamamre et al., 2012; Pujol et al., 2013). Polar solvents such as alcohols extract high amount of free fatty acids (FFAs), proteins, carbohydrates, polyphenols and phosphatides (Johnson and Lusas, 1983; Kondamudi et al., 2008; Dai and Mumper, 2010; Al-Hamamre et al., 2012) culminating in high oil acidity, susceptibility to oxidation and reduced oil shelf life because of the presence of FFAs (Predojević, 2008; Al-Hamamre et al., 2012).

In many oil extracting industries, hexane has been used because it has low vaporization temperature, high stability, low corrosiveness and low greasy residual effects in oils (Becker 1978; Johnson and Lusas, 1983; Radziah et al., 2011) besides being less toxic (Ramalho and Suarez, 2013). In oilseed extraction, solvents with high oil (triglycerides) extraction efficiency compared to waxes, chlorophyll, phosphatides and FFAs are recommended because they have low oil refining costs (Johnson and Lusas, 1983). Therefore for low temperature oil extraction processes, alcohols like ethanol are not suitable solvents because of low oil yield extraction and high refining costs.

Solvent oil extraction produces higher yield and less turbid oil with less operating costs than mechanical extraction and supercritical fluid extraction (Liauw et al., 2008). However, the quality of the crude oil from solvent extraction is dependent on the type of solvent, temperature and pretreatment of the oil seed prior to extraction process (Tasan et al., 2011). From the available literature, it is evident that studies on physical, physicochemical and phytochemical characteristics of oil extracted from *C. maxima,* using solvents of varying polarity, have not been extensively conducted and have been reported by limited number of authors (Montesano et al., 2018; Srbinoska et al., 2012; Tsaknis et al., 1997). In addition, there is existence of limited literature on the quality characteristics of oil extracted by solvents of varying polarities. Therefore, the main objective of this current study was to investigate the effect of various oil extracting solvents of different polarities on selected physicochemical properties and oil yield of pumpkin (*C. maxima)* seed oil.

MATERIALS AND METHODS

Sample collection and preparation

Locally produced mature pumpkin (*C. maxima*) fruits were bought from a local market, Mitundu market, in Lilongwe district, Malawi. The pumpkin fruits were cut into two pieces with a knife and the seeds were collected, washed in distilled water and sundried for four consecutive days. The seeds were then dried in the laboratory oven at 60°C to constant weight (Ali et al., 2001). The dried samples were ground through a 1 mm sieve using a Thomas-WILEY model 4 Laboratory Mill before analyzing the physicochemical properties. The ground samples were used in oil extraction and quality characteristics of the oils were analyzed using Association of Official Analytical Chemists (AOAC), 1996 methods with minor modifications.

Solvents used and their physical characteristics

Five solvents were used to examine the effect of solvent properties on oil yield and composition. Table 1 presents the solvents and their physical properties and those solvents with dielectric constant below 15 are considered as non-polar. The solvent polarity was used to evaluate solvent efficiency in oil extraction and boiling point, latent heat of vaporization and specific heat values were used to evaluate solvent effect on oil production (Jonson et al., 1983; Efthymiopoulos et al., 2018).

Oil extraction procedure

100 g of the finely ground samples was weighed in sterilized glass bottles and soaked in 100 mL of solvents (95% petroleum ether, 95% hexane, 98.5% cyclohexane, 95% acetone and 95% ethanol) representing a 1:1 w/v ratio at 25°C for 24 h. The sample and solvent mixture were manually shaken at 5 h Interval to speed up the oil extraction process. The mixture of solvent sample was finally filtered through a whatman no 41 filter paper and was desolventized by using a rotary evaporator (Odewole et al., 2015). The flask containing the crude oil was then dried to constant weight at 105°C in the laboratory oven for 2 h to constant weight. The crude oil was then refrigerated at 10°C in tight closed plastic bottles with no further treatment waiting for some analysis (Adegbe et al., 2016). The oil was left on the laboratory bench to melt into liquid at room temperature for 60 min before conducting the physicochemical parameters.

Determination of physical properties of the extracted oil

The determination of the physico-chemical properties of the oil followed the AOAC, 1996 methods with minor modifications.

Oil yield

Following oil extraction method described above, the oil percentage was calculated using Equation 1 as shown below:

$$\text{Oil } \% = \left(\frac{A-B}{W}\right) \times 100 \quad (1)$$

Where A= weight of flask and oil after extraction (g), B= weight of flask only (g), W = weight of sample (g)

Table 1. Chemical and physical properties of used extraction solvents at 20°C.

Solvent	Boiling point (°C)	Latent heat of vaporization (Cal/g)	Specific heat value (Cal/g/°C)	Dielectric constant
Hexane	65-69	80	0.533	1.89
Cyclohexane (as petroleum fraction)	65-85	85.4	0.29	2.02
Cyclohexane (as alkane)	80	77.2	0.433	2.02
Petroleum ether	35-60	-	-	1.9
Acetone	56.1	124.5	0.58	20.7
Ethanol	78.3	204	0.61	26.6

Source: Boiling point (Johnson and Lusas, 1983; Berthod and Carda-brotch www.mariecurie.org/annals/volume3/berthod.pdf); Latent heat of vaporization (Wan et al., 1994); dielectric constants (Haidekker et al., 2005; Berthod and Carda-brotch www.mariecurie.org/annals/volume3/berthod.pdf)

Determination of oil refractive index

Refractive index was measured using Bellingham and Stanley No.A83304 refractometer. A drop of oil was put on the lower prism and the prism box was closed. The water flowed through the equipment jacket at 25 ^{o}C, with the light adjusted and thereafter the compensator knob was moved to get a dark borderline on the cross wires which was viewed through the refraction view piece. The reading was recorded from the scale view through the eyepiece (Ogungbenle, 2014).

Calculation of specific gravity

The specific gravity of the extracted oils was determined by calculation using the Lund equation as described by Halvorsen et al. (1993) as follows:

$$\text{Specific gravity} = 0.8475 + 0.0003\text{SV} + 0.00014\text{IV} \quad (2)$$

Where SV is saponification value and IV is iodine value.

Determination of oil physicochemical properties

Determination of saponification value (SV)

1.0 g of the oil was weighed in a flat bottomed quick fit flask and 50 ml of 1.0 M ethanolic potassium hydroxide (KOH) was added. The flask was connected to a reflux condenser and was refluxed for 1 h until the solution became clear. A blank sample containing only 50 ml ethanolic potassium hydroxide was similarly treated as the sample. The solution was then titrated to a faint pink colour end point against 1.0 M hydrochloric acid (HCl) using phenolphthalein indicator (Ogungbenle and Sanusi, 2015). Saponification value (SV) was calculated using Equation 3:

$$\text{SV (mg KOH g}^{-1}\text{ oil)} = \frac{(\text{A}-\text{B})\text{ x N x } 56.02}{\text{W}} \quad (3)$$

Where A= Blank ethanolic HCl volume in ml, B= sample ethanolic HCl volume in ml, N= Normality of HCl, W=Weight of sample / oil in grams.

Determination of acid value (AV)

1.0 g of oil was weighed in a 250 ml conical flask containing 25 ml of absolute ethanol and diethyl ether (1:1) solution. The mixture was heated in a warm water bath (40°C) for 5 min and 3 drops of phenolphthalein indicator was added. The mixture was titrated against 0.1 M Potassium hydroxide (KOH) to a faint pink color that persisted for 30 s. Acid value was then calculated using equation 4.

$$\text{Acid Value (mg KOH g}^{-1}\text{ oil} = \frac{\text{ml (KOH) x N x } 56.1}{\text{W}} \quad (4)$$

Where N = normality of KOH, W = weight of oil sample in grams

Determination of free fatty acids (FFA)

Free fatty acids are the resultant of glycerin decomposition in oils and is measured as the number of milligrams of KOH required to neutralize a unit mass of oil. Therefore, FFA value was analyzed by titrating 1.0 g of oil dissolved in 25 ml of absolute ethanol: diethyl ether (1:1 V/V) against 0.1 M ethanolic KOH to a faint pink color using phenolphthalein indicator. FFA is expressed as oleic acid equivalent and 0.1 M KOH = 28.2 g oleic acid as presented in Equation 4 (Okene and Evbuomwan, 2014).

$$\text{FFA (gg}^{-100}\text{ oil as oleic acid)} = \frac{\text{Titre volume (ml) of KOH x 0.1 N x } 28.2}{\text{W}} \quad (5)$$

Where N = Normality of ethanolic KOH, W = weight of sample of oil in grams

Determination of peroxide value (PV)

1.0 g of oil sample was weighed into a 250 ml conical flask containing 20 ml of glacial acetic acid: chloroform solvent (3:2 v/v). 1.0 ml of saturated Potassium hydroxide was then added to the mixture in the conical flask and kept in the dark for 1 min. 30 ml of distilled water was added and the solution was titrated against 0.1 M sodium thiosulphate ($Na_2S_2O_3$) solutions using 5 ml of starch as an indicator. A blank sample was prepared and treated the same way as with the other samples. Equation 5 was used to obtain results which were expressed as meq per kilogram (Ogbunugafor et al., 2011).

$$\text{PV (meqO}_2\text{ kg}^{-1}\text{ oil)} = \frac{((\text{V}_2-\text{V}_1)\text{ x M})\text{ x } 100}{\text{W}} \quad (6)$$

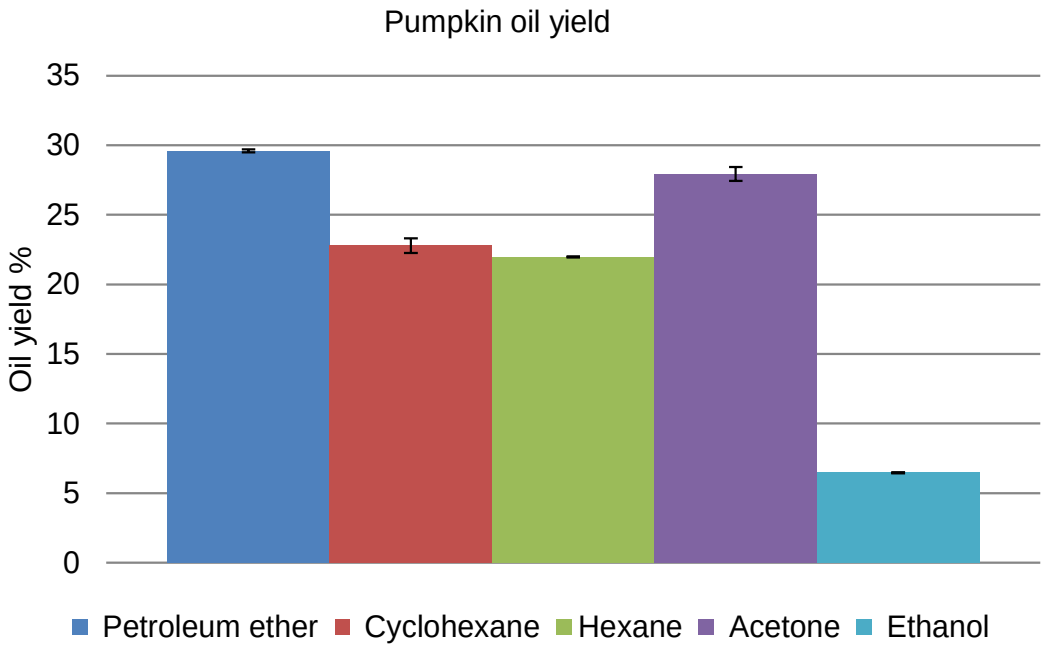

Figure 1. Effect of solvent type and polarity on oil yield extracted from pumpkin seeds.

Where V_1= titre volume in ml of 0.1 M $Na_2S_2O_3$ for blank, V_2 = titre volume in ml for sample, W = weight of oil sample in grams.

Determination of iodine value (IV)

In determination of the iodine value (IV) of the oil, the methods described by the Association of Official Analytical Chemists (AOAC), 1996 and Choudhary and Pande (2000) methods were used with some modifications in replacing Carbon tetrachloride with cyclohexane. 0.5 g of oil was weighed in a 250 ml conical flask and 20 ml of cyclohexane: glacial acetic acid (1:1 V/V) solution was added into the flask. 10 ml of Wijs reagent was added to the flask, thoroughly mixed and kept in the dark for an hour. 15 and 100 ml of 15% Potassium iodide (KI) and distilled water were added to the flask and the solution was titrated against 0.1 M sodium thiosulphate ($Na_2S_2O_3$) solution to colorless end point using starch as an indicator. The IV was calculated using Equation 7.

$$\text{Iodine Value (g I}_2\text{ g}^{-100}\text{ oil)} = \frac{(\text{B}-\text{S})\text{ x M x }126.9\text{ x }100}{\text{W (g)x }1000} \quad (7)$$

Where B= volume 0.1 M sodium thiosulphate used in titrating the blank, S = volume of 0.1 M sodium thiosulphate used in titrating the sample, 126.9 = molar mass of iodine, M= Molarity of sodium thiosulphate, W=sample weight in grams

Ester value (EV)

This is the milligram of KOH that reacts with glycerin after saponification of a unit gram of oil. Therefore the EV was calculated as the difference between the saponification value (SV) and acid value (AV) as shown in the equation below:

$$\text{Ester Value} = \text{Saponification Value} - \text{Acid Value} \quad (8)$$

Statistical analysis

Laboratory chemical analyses were done in triplicate and the mean value of each chemical parameter was calculated using Microsoft excel. The data were statistically analyzed using analysis of variance (ANOVA) in Microsoft Excel ToolPak. Two sample T-tests with unequal variances were used to compare mean values and significance was accepted at P≤0.05 level.

RESULTS AND DISCUSSION

Effects of solvent selection on oil yield

The results showed that crude oil extraction efficiency ranged from 21.97 to 29.59% for non-polar solvents with 95% petroleum ether registering the highest and 95% hexane registering the lowest value as presented in Figure 1. Cyclohexane extracted oil yield was comparably similar to 22.78% for 95% hexane. Acetone, a dipolar aprotic solvent, extracted 27.93% more oil than non-polar cyclohexane and hexane. The polar solvent, 95% ethanol extracted 6.46% oil less than both non-polar and dipolar aprotic solvents. The highest crude oil yield from petroleum ether extraction means that petroleum ether is more efficient in extracting non polar pumpkin seeds fractions than hexane and cyclohexane despite being non polar. Hexane and cyclohexane, with dielectric constants of 1.89 and 2.02 extracted less oil than the more non-polar petroleum ether with a dielectric constant of 1.9. However, acetone, a high dipolar aprotic solvent, with a dielectric constant of 20.7, extracted more crude oil than non-polar hexane and cyclohexane in this study.

Table 2. Physicochemical properties of pumpkin oil extracted using various solvents.

Variable	Solvent				
Parameter (25°C)	Petroleum ether	Cyclohexane	Hexane	Acetone	Ethanol
State at 25°C	Liquid	Liquid	Liquid	Liquid	Liquid
Specific gravity	0.860 ± 0.08[a]	861 ± 0.09[a]	0.859 ± 0.08[a]	0.886 ± 0.09[a]	0.887 ± 0.09[a]
Refractive Index	1.464 ± 0.00[a]	1.437 ± 0.00[b]	1.466 ± 0.00[a]	1.465 ± 0.00[a]	1.457 ± 0.00[a]
Acid value (mg KOH/g)	2.58 ± 0.02[a]	1.80 ± 0.00[b]	4.47 ± 0.22[c]	2.45 ± 0.08[d]	43.54 ± 0.22[e]
Free fatty acid (mg/100 g as oleic acid)	1.30 ± 0.01[a]	0.91 ± 0.00[b]	2.24 ± 0.11[c]	1.23 ± 0.04[d]	21.89 ± 0.11[e]
Saponification value (mg KOH/kg)	41.56 ± 0.31[a]	40.88 ± 1.36[b]	30.54 ± 0.04[c]	121.14 ± 0.00[d]	114.26 ± 0.00[e]
Iodine value (g I_2/g)	1.20 ± 0.01[a]	10.30 ± 0.06[b]	14.56 ± 0.05[c]	15.30 ± 0.21[d]	36.73 ± 0.62[e]
Peroxide value (meq O_2/kg)	19.15 ± 0.03[a]	8.10 ± 0.22[b]	6.70 ± 0.02[c]	24.15 ± 0.13[d]	58.11 ± 0.28[e]
Ester value (mg KOH/g)	38.98 ± 0.32[a]	39.07 ± 1.36[b]	26.07 ± 0.25[c]	118.77 ± 0.01[d]	70.52 ± 0.20[e]

Ethanol, high polar solvent, extracted 6.46% oil less than both non–polar and dipolar aprotic solvents used in this study because high polar solvents, with high dielectric constants like ethanol have lower oil miscibility (Johnson and Lusas, 1983). However, oil extraction efficiency of alcohols like ethanol is temperature and water content dependent. The extraction efficiency increases with the increase in temperature and water content reduction (Johnson and Lusas, 1983). Oil yield of 6.46% from ethanol extraction was comparable to 5.71 and 5.92% of oil extracted using ethanol in soxhlet apparatus method (Srbinoska et al., 2012) for *C. maxima* and *C. pepo* seeds reported in Macedonia. C*. maxima* seeds oil extracted using petroleum ether was comparably similar to 29.0% extracted using petroleum ether in soxhlet apparatus method (Montesano et al., 2018) reported in Italy.

Effects of solvent selection on physicochemical properties of the extracted oils

The physicochemical properties of *C. maxima* seeds extracted using five different solvents in the ratio of 1:1 v/w at 25°C with respect to solvent and solid samples are presented in Table 2.

Effect of solvent type and polarity on refractive index

According to FAO/WHO (1999) the recommended refractive index for crude soy bean oil should be1.466-1.470 at 40°C and it was found out that the values obtained in this study are comparable to the recommended values. The refractive indices of the oils were similar ($P>0.05$) but were higher ($P<0.05$) than the oil extracted using cyclohexane. Furthermore, the obtained values for refractive index of the crude oil were in line with those previously reported by other authors for pumpkin maxima seed oil (1.4656±0.004) (Alfawaz, 2004) and oil from other *Cucurbita* spp. seed oil extracted using petroleum ether and n-hexane in soxhlet apparatus (Tsaknis et al., 1997; Srbinoska et al., 2012).

Effect of solvent type and polarity on acid value

Acid value indicates the amount of free fatty acids present in the oil and the low values except that of oil extracted with ethanol means pumpkin oil extracted with the other solvents used in this study is stable from spoilage during storage (Borhade, 2012). Acid value was the least ($P<0.05$) in oils extracted using cyclohexane (1.80 mg KOH/g) followed by acetone (2.45 mg KOH/g), petroleum ether (2.58 mg KOH/g), hexane (4.47 mg KOH/g) and ethanol (43.54 mg KOH/g). The high ($P<0.05$) acid values in oils extracted using ethanol could be attributed to the high amount of FFAs in oils from alcohol (ethanol) extraction process (Johnson and Lusas, 1983). The acid values extracted using petroleum ether, hexane, cyclohexane and acetone were lower as compared to those extracted using ethanol which could be attributed to the properties of the solvents. The findings in this study have shown that the choice of solvents, with respect to solvent polarity, influences the oil quality in terms of acid value. The acid value of oil extracted using cyclohexane was similar to 2.05 for *Cucurbita mixta* oil (Borhade, 2012) but lower compared to values of 4.07 and 4.71 mg KOH/g reported by other authors (Srbinoska et al., 2012) for *C. maxima* and *Cucurbita pepo* seed oil extracted using n-hexane in soxhlet apparatus. The Codex Alimentarius Commission (1982) recommended the maximum acid value of 10 and 4 mg KOH/g oil for virgin palm and coconut oil respectively. Therefore the acid values are agreeable to the recommendation of Codex Alimentarius Commission (1982) except for that of ethanol extracted oil.

Effect of solvent type and polarity on free fatty acids

Results on Free fatty acids (FFAs), as oleic acids, ranged

from 0.91 to 21.89 mg/100 g with cyclohexane extracted oil registering the lowest (P<0.05) value and ethanol extracted oil the highest (P<0.05) value. Free fatty acids measures amount of fatty acids in the oil and high concentration of FFAs in crude oil results in high losses in the neutralization with alkaline solution during refining process (Okene and Evbuomwan, 2014). Free fatty acid (FFA) was highest (P<0.05) in ethanol extracted oil whereas oil extracted using cyclohexane registered the lowest (P<0.05) FFA value. The free fatty acid values from acetone and petroleum ether extracted oils were lower (P<0.05) than that of hexane extracted oil in this study. The highest FFAs values obtained using polar solvents such as ethanol suggest that solvent polarity influences oil quality and non-polar solvents produce oil with high quality based on FFAs. The high FFA value in ethanol extracted oil is in agreement with what has been previously reported that ethanol extracts more FFAs than non-polar and dipolar aprotic solvents (Johnson and Lusas, 1983). The high FFAs in ethanol extracted oil are attributed to the high dielectric constants of ethanol which accounts for its polarity (Johnson and Lusas, 1983).

Effect of solvent type and polarity on saponification value

Saponification value measures the length of the fatty acid chain in the oil as well as indicating the nature of fatty acid chains esterified to glycerol (Garret and Grisham, 2012; Zahir et al., 2014). The high (P<0.05) saponification values in acetone and ethanol extracted oils could be attributed to the effects of the solvent properties as more FFAs are extracted by polar and dipolar aprotic solvents (Johnson and Lusas, 1983).

The lowest (P<0.05) saponification values were determined in polar solvents, hexane, 30.54 mg KOH / kg, cyclohexane, 40.88 mg KOH/kg, and petroleum ether, 41.56 mg KOH/kg, respectively. Acetone, a dipolar aprotic solvent extracted oil, registered the highest (P<0.05) saponification value (121.14 mg KOH/kg) followed by the polar solvent, ethanol, with saponification value of 114.26 mg KOH/kg respectively. It is recommended that in sunflower and *Arachis hypogaea* oil, the saponification value should be 188-194 and 187-196 mg KOH/g oil respectively (MBS, 1988; FAO/WHO, 2009). Therefore the saponification values observed in this study were below MBS, (1988) and FAO/WHO (2009) recommended values indicating high quality oils. The saponification values of the oils were increasing with respect to the increasing polarities of the solvents signifying the influence of the solvent polarity on oil quality. The saponification values obtained in this study are in agreement with what other authors previously reported on pumpkin *spp* seed oil extracted using n-hexane by shaking and in soxhlet apparatus (Ardabili et al., 2011; Srbinoska et al., 2012). However, saponification values for acetone and ethanol extracted oils were more than 91.16±3.63 mg KOH/kg for pumpkin (*Telfairia occidentalis*) seeds oil extracted using petroleum ether in a soxhlet apparatus (Eddy et al., 2011) and 44.88 mg KOH/kg (Eze, 2012) using n-hexane in a soxhlet apparatus reported in Nigeria.

Effects of solvent type and polarity on iodine value

Iodine value indicates the degree of unsaturation which determines the stability of oils to oxidation (Asuquo et al., 2012). Iodine values ranged from 1.20 to 36.73 g I_2/g for petroleum and ethanol extracted oils respectively. It has been reported that the iodine value for *Arachis hypogaea* oil should be 86-107 (FAO/WHO, 2009) and 80-106 g I_2/g (MBS, 1988). The iodine values obtained in this study signified high oil quality because the values were below the recommended FAO/WHO (2009) and MBS (1988) values. The low iodine values in oils extracted by non-polar and dipolar solvents renders the oils more stable and less susceptible to oxidation than those extracted by polar solvents like ethanol. The iodine values obtained in this study were found to be lower than the values reported by other authors; 129.23 g I_2/g, 133.03 g I_2/g (Moo-Huchin et al., 2013) and 105.12 g I_2/g (Alfawaz, 2004) for oils extracted using n-hexane and hexane respectively for *Cucurbita* spp. and *C. maxima* seed oil. The low iodine values indicate that pumpkin seed oil, extracted using these solvents, is saturated (Alfawaz, 2004) and therefore has long shelf life.

Effects of solvents type and polarity on peroxide value

Peroxide value measures the degree of the occurrence of peroxidation / adulteration of oil (Okene and Evbuomwan, 2014) and could be used to evaluate the quality and stability of oils during storage (Adejumo et al., 2013; Okene and Evbuomwan, 2014). Peroxide values ranged from 6.70 meq O_2/kg to 58.11 meq O_2/kg with hexane extracted oil registering the lowest (P<0.05) value and ethanol extracted oil the highest (P<0.05) value. The peroxide value for cyclohexane extracted oil (8.10 meq O_2/kg) was lower (P<0.05) than that of acetone extracted oil (24.15 meq O_2/kg) and petroleum ether extracted oil (19.15 meq O_2/kg) respectively. The determined peroxide values were increasing with increasing solvent polarity; this indicates the influence of polarity on oil quality. The peroxide value of hexane and cyclohexane extracted oil were lower than 9.20 meq O_2/kg (Tsaknis et al., 1997) for *C. maxima* seed oil reported in Greece. Therefore the low peroxide values of oil from hexane and cyclohexane implies that these oils could be more stable during storage than oils extracted by petroleum ether, acetone and ethanol. Cyclohexane and hexane extracted oils had

lower peroxide values than 10 meq O_2/g oil whereas those of petroleum ether, acetone and ethanol had higher than 10 meq O_2/g oil for soybean, cottonseed and rapeseed oils (Codex Alimentarius Commission, 1982). The Malawi Standard specification recommended a maximum value of 2.5 O_2/g oil for refined sunflower oil (MBS, 1988) and the observed values from this study were all above Malawi oil specifications.

Conclusion

Results from the present study have revealed that the type and polarity of solvent significantly influenced the different physicochemical properties and oil yield extracted from pumpkin seed. The results have shown that cyclohexane and hexane produced less oil content but higher oil quality than petroleum ether with respect to selected physicochemical properties such as peroxide value. In addition, it has been found out that ethanol produced the least oil yield and quality compared with all the solvents used in this study. It can therefore be concluded that hexane and petroleum are the best solvents for oil extraction at low temperatures and therefore the findings from this study can be helpful in choosing the suitable solvents for oil extraction to maximize yield as well as maintain oil quality.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Adejumo BA, Inaede SG, Adamu TS (2013). Effect of moisture content on the yield and characteristics of oil from Moringa oleifera seeds. Academic Research International 4(4):160. www.savap.org.pk

Al-Hamamre Z, Foerster S, Hartmann F, Kruger M, Katsichmitt M (2012). Oil extracted from coffee spent grounds as a renewable source for fatty acid methyl ester manufacturing. Fuel 96:70-76.

Alfawaz MA (2004). Chemical composition and oil characterization of pumpkin (*Cucurbita maxima*) seed kernel. Food Science and Agriculture 2(1):5-18.

Ali Amanat, Nasser A. and Al-Asgah (2001). Effect of feeding different carbohydrate to lipid ratios on the growth performance and body composition of Nile Tilapia (Oreochromis niloticus) fingerlings. Animal Research 50:91-100.

Ardabili AG, Farhoosh R, Khodaparast HH (2011). Chemical composition and physicochemical properties of pumpkin seeds (*Cucurbita pepo subsp. Pep var*. *Styriaka*) grown in Iran. Journal Agricultural Science Technology 13:1053-1063.

Asuquo JE, Anusiem ACI, Etim EE (2012). Comparative study of the effect of temperature on the adsorption of metallic soaps of shea butter, castor and rubber oil onto hematite. International Journal Modern Chemistry 3(1):39-50.

Atabani AE, Silitonga AS, Ong HC, Mahila TMI, Masjuki HH, Badruddin IA, Fayaz H (2013). Non-edible vegetable oils: A critical evaluation of oil extraction, fatty acid composition, biodiesel production, characteristics, engine performance and emissions production. Renewable and Sustainable Energy Reviews 18:211-245.

Becker W (1978). Solvent extraction of soybean. Journal American Oil Chemist Society 55:754-761.

Borhade S (2012). Extraction and characterisation of pumpkin (*Cucurbita mixta*) seed oil. Life Sciences leaflets 7:45-47.

Caetano NS, Sihaa VFM, Mata TM (2012). Varolization of coffee grounds for biodiesel production. Chemical Engineering Transaction Volume 26. https://pdfs.semanticscholar.org/f0c6/e6efa94f40ed562f96beea3c56f5ed2398db.pdf

Codex Alimentarius Commission (1982). Recommended internal standards for edible fats and oils. (21st Ed.) XI. FAO/WHO, Rome.

Dai J, Mumper RJ (2010). Plant phenolics extraction, analysis and their antioxidant and anticancer properties. Molecules 15:731-752.

Eddy NO, Ukpong JA, Ebenso EE (2011). Lipids characterization and industrial potential of pumpkin seeds (*Telfairia occidentalis*) and cashew nuts (*Anacardium occidentale*). Journal of Chemistry 8(4):1986-1992.

Efthymiopoulos I, Hellier P, Ladommatos N, Russo-Profili A, Eveleigh A, Aliev A, Kay A, Mills-Lamptey B (2018). Influence of solvent selection and extraction temperature on yield and composition of lipids extracted from spent coffee grounds. Industrial Crops and Products 119:49-56.

Eze SOO (2012). Physico-chemical properties of oil from some selected underutilized oil seeds available for biodiesel production. African Journal of Biotechnology 11(42):10003-10007.

FAO/WHO (1999). Standard for named vegetable oils codex stan 210-1999. Codex Alimentarius Commission. Food and Agriculture Organisation of the United Nations, World Health Organisation, Rome pp. 1-13.

FAO/WHO (2009). Joint FAO/WHO Food Standard Programme. Codex Alimentarius Commission. Report of the 21st session of the Codex Alimentarius Commission on fats and oils. Kola Kinabalu, Malaysia, 16-20 February.

Garret RH, Grisham CM (2012). Biochemistry, 5th Edition, University of Virginia, Brooks/Cole, 20 Davis Drive, Belmont CA 94002-3098, USA.

Haidekker MA, Brady TP, Lichlyter D, Theodorakis EA (2005). Effects of solvent polarity and solvent viscosity on the fluorescent properties of molecular rotors and related probes. Bioorganic Chemistry 33:415-425.

Johnson LA, Lusas EW (1983). Comparison of alternative solvents for oil extraction. Journal of American oil Chemists Society 60:229-241.

Kim MY, Kim EJ, KIM YN, Choi CH, Lee BH (2012). Comparison of the chemical compositions and nutritive values of various pumpkin (Cucurbitaceae) species and parts. Nutrition Research and Practice 6:21-27.

Kondamudi N, Mohapatra SK, Misra M (2008). Spent coffee grounds as a versatile source of green energy. Journal of agricultural and food chemistry 56(24):11757-11760.

Lazos ES (1986). Nutritional, fatty acid and oil characteristics of pumpkin and melon seeds. Journal of Food Sciences 51:1382-1383.

Liauw MY, Natan FA, Widiyanti P, Ikasari D, Indraswati N, Soetaredjo FE (2008). Extraction of neem oil (*Azandirachta indica A. Juss*) using n-hexane and ethanol: studies of oil quality, kinetic and thermodynamic. Journal of Engineering and Applied Sciences 3(3):54-59

Mahasneh AM, El-Oqlah AA (1999). Antimicrobial activity of extracts of herbal plants used in the traditional medicine of Jordan. Journal of Ethno Pharmacology 64:271-276.

Malawi Standard Board (MBS) (1988). Groundnut oil -specification. Blantyre, Malawi pp. 77-78.

Montesano D, Blasi F, Simonetti MS, Santini A, Cossignani L (2018). Chemical and nutritional characterization of seed oil from *Cucurbita maxima* L. (*Var. Berrettina*) pumpkin. Food 7:30.

Odewole MM, Sunmonu MO, Obajemih OI, Owolabi TE (2015). Extraction of oil from fluted pumpkin seed (*Telfairia occidentalis*). Annals of Food Science and Technology 16(2):372-378.

Ogungbenle HN (2014). Chemical and amino acid composition of raw and defatted African mango kernel. British Biotechology Journal 4(3):244-253.

Ogungbenle HN, Sanusi DS (2015). Extraction, physicochemical, phytosterols and fatty acid of Celosia spicata leaves. British Journal of Research 2(1):009-020.

Okene EO, Evbuomwan BO (2014). Solvent extraction and characteristics of oil from coconut seeds using alternative solvents.

International Journal of Engineering and Technical Resources 2:135-138.
Radziah W, Miradatul MR, Nurfadilah MI (2011). Basic study on anti-bacterial properties of *Adenanthera pavoning* (saga) seed oil, business, engineering and industrial applications (ISBEIA) 2011EEE symposium, 25-28 September 2011, Langkawi, Malaysia.
Ramalho HF, Suarez PAZ (2013). The chemistry of oils and fats and their extraction processes and refining. Virtual Journal of Chemistry 5:2-15.
Srbinoska M, Hrabovski N, Rafajlovska V, Sinadinović-Fišer S (2012). Characterization of the seed and extracts of the pumpkins *Cucurbita maxima D* and *Cucurbuta pepo L*. from Macedonia. Macedonian Journal of Chemistry and Chemical Engineering 31(1):65-78.
Tsaknis J, Lalas S, Lazos ES (1997). Characterization of crude and purified pumpkin seed oil. Grasas y Aceites 48(5):267-272.
Tasan M, Gecgel U, Demirci M (2011). Effects of storage and industrial oilseed extraction methods on the quality and stability of characteristics of crude sunflower oil (*Helianthus annuus* L.). Grasas Y. Aceites 62(4):389-398.
Turkmen N, San F, Velioglu YS (2006). Effects of extraction solvents on concentration and antioxidants activity of black and black mate tea polyphenols determined by ferrous tartrate and Folin Ciocalteau methods. Food Chemistry 99:835-841.
Younis YMH, Ghirmay S, Al-Shihry SS (2000). African *Cucurbita pepo* L.: properties of seed and variability in fatty acid composition of seed oil. Phytochemistry 54:71-75.
Zahir E, Rehana S, Mehwish HA, Anjum Y (2014). Study of physicochemical properties of edible oil and evaluation of frying oil quality by Fourier transform – infrared (FT-IR) spectroscopy. Arabian Journal of Chemistry 10(2):3870-3876.