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Effect of Extraction Methods on the Storage and Physico-Chemical Properties of Castor Bean (*Ricinus communis*) and physic Nut (*Jatropha curcas*) Oils

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ABSTRACT

Castor bean (*R. communis*) and Physic nut (*J. curcas*) are multipurpose shrub with a variety of applications and enormous economic potential for seeds oils, which can be converted into biodiesel (an alternative to petrol diesel), biolubricant, transformer oil etc. . This study investigates the effect of extraction methods on the properties of Castor and physic nut oils obtained from two non-edible indigenous plants in Idah, Kogi state, Nigeria. The oils of Castor bean and Physic nut were extracted by two different methods; solvent using soxhlet extractor and mechanical press. The physico- chemical properties of the oils such as moisture content (%), specific gravity, acid value (mg KOH/ g), refractive index, saponification value (mg KOH/ g), peroxide value (meq/kg) and iodine value (g/100g) were also determined within a period of six months. For castor oil the values ranged from 11.77-13.33; Nil - 2.86 (%); 0.8852 - 0.8900; 0.9507-0.9572; 5.07-8.67; 0.87-2.10 (mg KOH/ g); 1.4680-1.4586; 1.4770-1.4694; 178.03-154.90; 173.91-146.68 (mg KOH/ g); 3.57-7.77; 1.18-2.80 (meq/kg); 82.83-90.35; 81.24-89.64 (g/100 g) for solvent and mechanical press extraction methods respectively. For *J. curcas* oil, values range from 12.96-14.00; 2.00-3.77(%); 0.8778-0.8850; 0.9177-0.9246; 10.37-18.52; 11.50-19.66 (mg KOH/ g); 1.4646-1.4541; 1.4688-1.4587; 208.55-176.45; 203.06-170.68 (mg KOH/ g); 6.31-9.65; 6.73-10.32 (meq/kg); 95.11-100.92; 93.35- 98.51 (g/100g) for solvent and mechanical press extraction methods respectively. The values obtained in this study are within the standard range, whereas some have about 1% variation. The oils of castor bean and physic nut are non edible because they contain toxic substances; ricin, ricinine and phorbol esters respectively; but can be used for energy application, soap production, shampoo production, lubricant e.t.c.

INTRODUCTION

The vegetable fats or oil have essential functions in the industrial economy of a developing country as the seed oil provides a huge use in human daily life in order to complete and make the nowadays much easier. The seed oils are one of the vegetable oil family members. Vegetable oils are fat lipids materials that have been derived from natural plants which physical oils are in liquid state at room temperature. The vegetable oil is composed of triglycerides which lack glycerin in its structure (Wan, 2012). Oils that are extracted from plants have been used in the ancient times and already used in many cultures, for example, castor bean and physic nut have been known to man for ages. Castor and physic nuts have been found in ancient Egyptian tombs dating back to 4000 BC and during that time, the castor and physic nut oils were used thousands of years ago in the wick lamps for lighting. Basically, to obtain the oil from the seeds is through extraction process and then distilled to remove solvent used in order to get the pure oil. Several feedstock from vegetable source such as Soy bean, Rape seed, Canola, Palm, corn, Physic nut and Castor seeds have been studied as an alternative to oil candidate. Among these sources, castor seeds are potentially promising feedstock since among vegetable oils, its oil is distinguished by its high content (over 70%) of ricinoleic acid. There is no other vegetable oil that contains high proportion of fatty hydroxyacids, and also the most stable viscosity of any vegetable oil (Ogunniyi, 2006). *Jatropha curcas* has being identified among the promising non-edible oil bearing seeds for biodiesel production. Jatropha produces mainly a non edible oil due to phorbol esters that are toxic, even at very low concentration (Leonard *et al.,* 2005). There are various processes or the combination of the process to obtain the oils from the seeds: the hydrate presses, continuous screw press and also solvent extraction are the common methods to obtain the oil from the seeds. However, the most satisfactory approach to get the oil is hot pressing the seeds by using a hydraulic press and then followed by solvent extraction (Atabani *et al.,* 2013).

Castor bean and *Jatropha curcas* has been considered as the best sustainable source. They are native of tropical America, has been later introduced into Africa and Asia and now cultivated worldwide. They are multipurpose, drought resistant shrub Asia and now cultivated worldwide. They are multipurpose, drought resistant shrub belonging to the family Euphobiaceae seeds. The seeds of *Jatropha curcas* contains up to 40% mass of oil whereas the seeds of castor contained approximately 46% to 55% of oil by weight (Ogunniyi, 2006). This makes their use as an energy source very attractive .When the seeds are crushed and processed, the resulting oil can be in standard diesel engine when measures are taken to decrease the viscosity: preheating of the oil, blending with fossil diesel fuel or converting the oil to biodiesel using the esterification reaction .In addition, the oil from the seeds have been found useful in the manufacture of candles, soaps, in cosmetic industries and for medicinal purposes (Ardebili, 2012). In Nigeria, the current focus of the two prominent plants is mainly on biodiesel. *Ricinus communis* and *Jatropha curcas* has been identified as a novel bio-energy crops in fifteen Economic Countries of West Africa States (ECOWAS) in which Nigeria is one. Currently, there are widely spread abundance of castor and physic nut plants in Nigeria states of Kebbi, Kano, Sokoto etc (Galadima *et al.,* 2011).A transition to these renewable fuels requires profound knowledge on the biofuels, their chemical and physical characteristics such as peroxide value, acid value, iodine value, saponification value, Refractive Index, moisture content, specific gravity, behavior and effects on storage, durability etc which can affect the usefulness of oil. The storing of large volume of oil for long periods under diverse conditions is not an easy task, since many of its characteristics (colour, flavour and clarity) which are necessary to be maintained, deteriorate. Therefore there is lack of information on the storage properties of these two prominent oil seeds.

In recent times, the world has been confronted with energy crisis due to depletion of resources and increased environmental problems. This situation has led to the search for alternative fuel, which should not be only sustainable, but also environmentally friendly (Shivani *et al.,* 2011).A promising alternative to imported fossil fuels is the use of

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renewable sources such as wind or solar power for electricity generation. For the transportation sector the application of renewable fuels from non-edible crops and waste products offers alternative to biodiesel and gasoline (Leonard *et al.,* 2005). Due to the importance of vegetable oils in industries, pharmaceutical, food industries and also medical, there is an urgent need to produce more oil from the natural plants .For this reasons, Castor and physic nut are promising vegetable oils because they have several advantages; it is renewable, environmentally friendly and produced easily in rural areas, where there is an acute need for modern forms of energy. The primary use of the castor and physic nut oils is as the basic ingredient in the production of nylon 11, sebacic acid, plasticizers and engine jet lubricants. Castor and physic nut oil's high lubricity which reduces the friction is superior to other vegetable oils and petroleum based lubricants (Ogunniyi, 2006). It really clings to metal, especially hot metal, and are used in production of nylon 6-10, heavy duty automotive greases, coating and inks, surfactant, polyurethanes, soaps, polishes, synthetic resins, fabrics paints, varnishes, dyes, leather treatments, hydraulic fluids and also sealants (Wan, 2012). This study is aimed at investigating the effects of extraction methods on the storage and physico- chemical properties of oils from castor and physic nut at ambient conditions.

MATERIALS AND METHODS

Sample preparation

The matured and dried seeds of Castor bean and Physic nut were obtained within Idah, Kogi state, Nigeria. They were dehaulled manually, sundried for 6 hours, pounded with a mortar and pestle into kernel, tied in a nylon prior to extraction.

Oil extraction

Mechanical Press

Three hundred gram of each kernel sample were tied in a 40 mesh sieve and subjected to pressure of mechanical press machine for 6 hours. Then, 80 ml of oil from Jatropha was obtained while 50 ml of oil from castor was obtained and were stored in a screw-cap plastic bottle till required for analysis.

Solvent Extraction

Sixty gram of each sample were weighed using electronic weighing balance. It was tied in a plane sheet of paper and placed inside a soxhlet extractor. 300 ml of n-hexane was measured using a measuring cylinder into a round bottom flask. The soxhlet extractor was set upon heating mantle while connected to the source of electricity. The n-hexane was allowed to boil for 3 hours continuously at a temperature of 60-80°C. The oil obtained was left opened for 1hour so that trace solvent could evaporate. The oil obtained were stored in screw cap plastic bottle prior to analysis (Azadmard et *al.,* 2005).

Analysis of some Physico-Chemical Parameters

Moisture content was determined using AOAC (1990) method. Iodine value (IV), Acid value (AV), Saponification value (SV) and Peroxide value (PV) were determined by the methods of Pearson (1976). Refractive index was determined with Abbe Refractometer – bench type (Model: WAY – 2S, Searchtech Instruments). Specific gravity was determined for each of the oil as the ratio of the density of oil to the density of water at the same room temperature of 28°C. This was done using a density bottle of 20 ml capacity. The procedure were replicated three times and average evaluated.

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Table 1: Physico-chemical properties of Castor and *Jatropha curcas* oils by solvent and mechanical methods of extraction for a period of six months.

Method of Extraction	Oil Sample	Period of Storage	MC (%)	SG ($^m/_v$)	AV (mgKOH/g)	RI	SV (mgKOH/g)	PV (meq/kg)	IV (wijs')
Mechanical	*J. curcas*	Commencement (March)							
		April	2.00	0.917	11.50	1.4688	203.06	6.73	93.35
		July	3.23	0.9194	13.97	1.4645	196.35	7.14	95.24
		August	3.45	0.9210	16.19	1.4610	182.23	9.55	96.88
		September	3.77	0.9246	19.66	1.4587	170.68	10.32	98.51
		Mean	3.11	0.9207	15.33	1.4633	188.08	8.44	95.99
		Standard deviation	0.77	0.00294	3.46	0.00440	14.49	1.77	2.21
		Coefficient of variation	24.87	0.32	22.60	0.30	7.70	20.96	2.30
Solvent	*J. curcas*	Commencement (March)							
		April	12.96	0.8778	10.37	1.4646	208.55	6.31	95.11
		July	13.33	0.8790	12.49	1.4610	204.66	6.90	96.88
		August	13.46	0.8804	15.60	1.4586	189.34	8.39	99.01
		September	14.00	0.8850	18.52	1.4541	176.45	9.65	100.92
		Mean	13.44	08806	14.25	1.4596	194.75	7.813	97.98
		Standard deviation	0.43	0.00315	3.57	0.00440	14.75	1.506	2.53
		Coefficient of variation	3.23	0.36	25.05	0.30	7.57	19.27	2.58
Mechanical	*R. communis*	Commencement (March)							
		April	Nil	0.9507	0.87	1.4770	173.91	1.18	81.24
		July	1.92	0.9516	1.12	1.4751	170.76	1.70	83.00
		August	2.00	0.9539	1.68	1.4725	159.57	2.00	85.78
		September	2.86	0.9572	2.10	1.4694	146.68	2.80	89.67
		Mean	2.26	0.9534	1.44	1.4735	162.73	1.92	84.92
		Standard deviation	0.52	0.0029	0.55	0.0033	12.34	0.68	3.68
		Coefficient of variation	23.06	0.30	38.40	0.22	7.59	35.28	4.33
Solvent (n-hexane)	*R. communis*	Commencement (March)							
		April	11.77	0.8852	5.07	1.4680	178.03	3.57	82.83
		July	12.50	0.8876	5.95	1.4632	175.05	4.39	84.01
		August	12.73	0.8891	7.29	1.4601	166.32	6.09	87.21
		September	13.33	0.8900	8.67	1.4586	154.90	7.77	90.35
		Mean	12.58	0.8880	6.75	1.4625	168.58	5.45	6.16
		Standard deviation	0.65	0.0021	1.58	0.0042	10.38	1.87	34.21
		Coefficient of variation	5.12	0.24	23.35	0.28	6.16	34.21	3.93

MC – Moisture Content, SG - Specific Gravity, AV – Acid Value, RI – Refractive Index, SV – Saponification Value, PV – Peroxide Value, IV – Iodine Value

RESULTS AND DISCUSSION

Table 1 shows the moisture content (%) of Castor oil obtained by solvent method range from 11.77 to 13.33% whereas oil obtained by mechanical press ranged from NIL to 2.86% within the period of six months. The moisture content obtained by solvent method is slightly higher than ones reported in literature by Mgudu *et al.*,2012; Ibeto *et al.*, 2012; Edison *et al.*, 2012 (3.16-3.72;3.50-8.27;3.6)% respectively. The moisture content of *Jatropha curcas* oil obtained by solvent method ranged from 12.96 to 14.00% whereas oil obtained by mechanical press range from 2.00 to 3.77%.The value obtained by solvent method is higher than the value obtained by mechanical press. The value obtained is higher than ones reported in Literature by Belewu *et al.*, 2010 (0.101-0.102) %.This high moisture content creates problem in transesterification, reduces shelf life and may also cause corrosion in internal combustion engine. Oils obtained by mechanical press will have more shelf life due to smaller moisture content than those obtained by solvent method. The reason for high moisture of both oils obtained by solvent method could be due to the solvent and heat involved during extraction.

The specific gravity of castor oil obtained by solvent method ranged from 0.8852 to 0.900 whereas oil obtained by mechanical press ranged from 0.9507 to 0.9572. The specific gravity obtained by mechanical press is slightly higher than the value by solvent method and falls within the ASTM standard at 25°C (0.86-0.90), Mgudu *et al.*, 2012 (0.950-0.965). The solvent has insignificant effect on the specific gravity. Jatropha oil obtained by solvent method ranged from 0.8778 to 0.8850 whereas oil obtained by Mechanical press range from 0.9177 to 0.9242. The value obtained by mechanical press is slightly higher than the value obtained by solvent method. The specific gravity of the oil falls within the ASTM and EN standard range of 0.86 to 0.92 for biodiesel. Similar value has been reported in literature by Inekwe *et al.*, 2012; Ugbogu *et al.*, 2014; Belewu *et al.*, 2010; Ibeto *et al.*, 2014; Mgudu *et al.*, 2012 (0.91;0.92;0.9010;0.93;0.950-0.965)respectively. This characteristic relates to the ratio of the weight of the oil to the weight of an equal volume of water. The acid value (mg KOH/ g) for castor oil obtained by solvent method range from 5.07 to 8.67(mg KOH/ g) whereas the oil obtained by mechanical press range from 0.87 to 2.10(mg KOH/ g).The value obtained by mechanical press was smaller than the value obtained by solvent method and falls within ASTM standard (0.4 to 4.0mg KOH/ g) but varies slightly by the work reported by Mgudu *et al.*, 2012; Borchani *et al.*, 2012 (0.4-4.0;1.12-1.64) mg KOH/ g respectively. Jatropha oil obtained by solvent method ranged from 10.37 to18.52 (mg kOH/ g) whereas the oil obtained by mechanical press range from 11.50 to 19.66(mg KOH/ g). The value obtained by mechanical press was slightly higher than the value obtained by solvent method. Acid value of Jatropha oil was very high and exceeded the ASTM standard of 0.8 mg KOH/ g. Similar value has been reported in literature by Belewu *et al.*, 2010;Inekwe *et al.*, 2012 (18.76-23.87;11.22-18.09) mg KOH/ g respectively but slightly varies with the work reported by Ugbogu *et al.*, 2014 (9.48mg KOH/ g). Acid value measures

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the presence of corrosive free fatty acid and oxidation product. This is an important variable in considering the quality of oils.

The Refractive index of Castor oil obtained by solvent method ranged from 1.4680 to 1.4586 as shown in Table 1 whereas oil obtained by mechanical press ranged from 1.4770 to 1.4694. The value obtained by mechanical press is very slightly lower than value of solvent method. These values vary slightly with the ASTM castor oil quality specification range from 1.475 to 1.480. Similar values have been reported by Borchani *et al.,* 2010; Abolfazl *et al.,* 2011; Mgudu *et al.,* 2012 and Ariponnammal 2012 (1.471;1.404-1.426;1.475;1.475) respectively. These values are higher than the values reported in literature by Ibeto *et al.,* 2012 (0.73-0.91). *Jatropha curcas* oil obtained by solvent method has refractive index ranged from 1.4646 to 1.4541 whereas value of oil obtained by mechanical press ranged from 1.4688 to 1.4587. Both methods of extraction has insignificant effects on their values. These values fall within the range reported in literature by Ibeto *et al.,* 2012; Inekwe *et al.,* 2012 and Ariponnammal 2012 (1.46; 1.47; 1.4647-1.4670) respectively. The refractive index of a substance measure how the substance affect light passing through it and to an extent tells its degree of purity. The refractive index of light in a vacuum is 1.00. The refractive indices obtained in this work were observed to decrease with respect to long period of storage. The saponification value (mg KOH/ g) of Castor oil obtained were 178.03, 175.05, 166.32, 154.90 (mg KOH/ g) and 173.91, 170.76, 159.57, 146.68 (mg KOH/ g) by solvent and mechanical press respectively. The saponification value obtained by mechanical press was observed to be smaller than values obtained by solvent method which could be due to solvent. This values falls within the range reported by Abolfazl *et al.,* 2011 (164.50-178.53 mg KOH/ g) and lower than values determined in other study by Bonchani *et al.,* 2010 (186.60, 185.75 mg KOH/ g). Saponification value (mg KOH/ g) of *Jatropha curcas* oil obtained by solvent method ranged from 208.55 to 176.45(mg KOH/g) whereas oil obtained by mechanical press ranged from 203.06 to 170.68(mg KOH/g). The value obtained by mechanical press is smaller than values obtained by solvent method. The saponification value obtained in literature reported by Inekwu *et al.,* 2012; Emil *et al.,* 2009; Ugbogu *et al.,* 2014 (206.60, 210.84, 205.00; 193.55;195.10) (mg KOH /g) respectively,falls within the range obtained in this study. The values obtained in this work was observed to be lower than earlier reported by Belewu *et al.,* 2010 (240.53, 230.71 mg KOH/ g) and higher than reported by Ibeto *et al.,* 2012 (162.69 mg KOH/ g). The saponification value for the samples was observed to be decreasing with long period of storage. High saponification value indicated that oils are normal triglyceride and very useful in the production of liquid soap and shampoo industries.

The peroxide value (meq/kg) of both castor and *Jatropha curcas* oil obtained by two different methods. Castor oil obtained by solvent method are in the range of 3.57 to 7.77 meq/kg and the oil obtained by mechanical press are in the range of 1.18 to 2.80 (meq/kg). The peroxide value of Castor oil obtained by mechanical press was observed to be smaller compared to values obtained by solvent method. The value obtained by solvent method falls within the range reported by Akinoso *et al.,* 2010 (3.9,15.4 meq/kg) but both values are far higher than reported in other studies of Borchani *et al.,*2010; Abolfazl *et al.,* 2011 (0.14-0.99; Nil-0.50) (meq/kg). The peroxide values (meq/kg) of Jatropha oil obtained by solvent method range from 6.31 to 9.65meq/kg whereas oil obtained by mechanical press range from 6.73 to 10.32 meq/kg. The peroxide value obtained by solvent method is slightly smaller than values obtained by mechanical press. The values obtained falls within the range reported in literature which ranges from 4.36 - 9.82meq/kg by Ibeto *et al.,* 2012 and higher than reported in other studies of Inekwe *et al.,* 2012; Emil *et al.,* 2009 and Ugbogu *et al.,* 2014 (1.31-2.34; 1.93; 3.20) (meq/kg) respectively and also lower than the values reported by Belewu *et al.,* 2010 (44.00, 56.00) (meq/kg). These oils have low peroxide value which makes them suitable for food industries and other industrial application as a source of bio-energy as soon as they are produce because the long storage period increases their peroxide value.

The iodine value of Castor and *Jatropha curcas* oil obtained by two methods of extraction. The castor oil obtained by solvent method are in the range of 81.83 to 90.35g / 100g whereas the oil obtained by mechanical press are in the range of 81.24 to 89.67 g / 100g.The value obtained by mechanical press is slightly smaller than the value obtained by solvent method. The iodine value (g / 100 g) was smaller than the standard iodine value of 120 by Europe's EN14214 specification (Ibeto *et al.,* 2012). The value obtained in this work falls within the range of values reported in other study Abolfazl *et al.,* 2011; Borchani *et al.,* 2010 (75.75-85.62;81.23-113.35) g / 100 g. Also iodine value of *Jatropha curcas oil* obtained by solvent method range from 95.11 to 100.92g / 100 g whereas the oil obtained by mechanical press range from 93.35 to 98.51 g /100 g. The value obtained by mechanical method is slightly smaller than the value obtained by solvent method. These values falls within the range reported in other study ugbodu *et al.,* 2014 (95.00 g/ 100 g) and has higher values than earlier studies of Belewu *et al* 2010; Inekwu *et al.,* 2012 (20.30, 26.09; 86.32, 70.08) g / 100 g.The value obtained in this study was observed to be lower than reported in other study of Emil *et al.,* 2009 (103.62 g /100 g). Iodine value which is a measure of the unsaturation of fats and oil, high iodine value shows high unsaturation of oil. The limitation of unsaturation of fatty acids is vital due to the fact that heating highly unsaturated fatty acids results in polymerization of glycerides which could lead to the formation of deposits.

CONCLUSION

The soxhlet extraction method gave higher oil yields than mechanical press method of extraction. This was probably due to continuous extraction for approximately 3 hours. The physico-chemical properties such as saponification value, moisture content, acid value, specific gravity, peroxide value, iodine value, and refractive index of the Castor and Jatropha oils obtained by mechanical press method of extraction has considerably lower value compared to the solvent method. As a result, oil obtained by mechanical press method is likely to be less susceptible to oxidation. The result of the physico-chemical properties such as saponification value (mg KOH /g), Acid value (mg KOH/ g) and Refractive index obtained in this work falls within the ASTM standard for biodiesel production whereas there are slight variations in moisture content (%), peroxide value (meq/kg), Iodine value(g/100g) and specific gravity with standards. This work has shown both oils to contain a low peroxide value which makes them suitable for food industries and other industrial application especially as a source of bio-energy as soon as they are produced, because long storage increases the peroxide value. In many countries with little or no petrochemical feedstock, castor and physic nut oils will come in handy as a versatile renewable resources, such oils with a variety of uses will be suitable industrial production where many edible oils are being used. Generally, it is considered that non-edible oils should be exploited as far as it is possible so that edible oils can be freed for human consumption. This is especially important in developing countries where food security poses challenge.

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