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Assessment of seed oil yield and characteristics of ten castor plant (*Ricinus communis L.*) Accessions in Ogbomoso, Nigeria

Raheem, W. A.[1], Lawal, B. A.[1*], Akanbi, W.B.[1] and Ojo, A. M.[2]

[1]Department of Crop Production and Soil Science, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.
[2]Raw Material Research and Development Council, Abuja, Nigeria.

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Experiment was conducted to assess the seed oil yield and physical and chemical characteristics of ten castor plant accessions. The experiment was laid out in a Randomized Complete Block Design replicated three times. At maturity, the racemes were harvested and seeds were extracted. One hundred gram of seed was taken from each accession for oil extraction. The extracted oils were analysed for physical properties and chemical properties. Data collected were subjected to analysis of variance and means were separated using least significant difference at 5% probability. Significant variations (Pc0.05) occurred among the accession's oil yield, physical and chemical properties. CASGPMAN produced highest oil content (51.90%) which was significantly higher than values obtained for other accessions. Specific gravity (0.97) obtained from IARCAS001 was significantly higher than others. Viscosity (9.4) and refractive index (1.43) obtained from NCRICAS056 were significantly higher than the values obtained from others. The highest saponification value (184.20 mg KOH/g) obtained from NCRICAS057 was significantly higher than 165.10 mg KOH/g obtained from IARCAS001. The highest free fatty acid (2.6 mg KOH/g) was obtained from NCRICAS057 while the least (1.8 mg KOH/g) was obtained from NCRICAS041. The study therefore concludes that NCRICAS057 produced oil with best physical and chemical properties.

Key words: Castor plant, oil yield, moisture content, viscosity, free fatty acid.

INTRODUCTION

Castor oil plant (*Ricinus communis* L.) is an inedible, drought resistant, and biofuel plants grown in many parts of the world. It is an important medicinal oilseed crop with large palmate lobed leaves (Hussein et al., 2010). Approximately 11,300 accessions of castor seed can be found in germplasm banks in 11 countries with the most extensive collections in India, China, Brazil and the US (Severino et al., 2012). When the fruits are harvested, they are allowed to dry after which they split open and the seed fall out. The seeds contain 40 to 60% oil, which isused together with its derivatives in industries for the production of paints, varnishes, lacquers, lubricants,

*Corresponding author: lawalba@ymail.com

greases, hydraulic fluids, soaps, printing inks, linoleum, oil cloth, protective coatings, and as raw material in the manufacturing of various chemicals as well as in the production of plasticizers and nylons (Oyeyemi et al., 2007). Results of extensive evaluation and breeding have produced castor oil plant with high oleic acid mutants (Rojas-Barros et al., 2004) and low ricin cultivars (Auld et al., 2009). High oleic acid mutants are better suited for biodiesel production and low ricin varieties are less toxic.

Ricin is not found in the processed castor oil because it is insoluble in oil, but is retained in the meal after the refining process. Seed maturation takes approximately 44 days and ricin loading begins around 28 days after pollination and present in the endosperm of the seed until approximately 6 days after the radicle emerges (Barnes et al., 2009). Due to the high toxicity of ricin in castor, Audi et al. (2005) recommended low ricin cultivars which inherently result in a reduced risk for growers and processors of castor seed and meal. Improved low ricin cultivars have a range of 0.10 to 5.60 mg/g (Auld et al., 2009) compared with one of its genetic parents and a commonly studied cultivar, with an average of 12.2 mg/g ricin (Pinkerton et al., 1999). Over years, India, China, Brazil, and USA supplied high percentage of castor oil globally. They had improved the oil qualities and production potential on yield per hectare basis

Castor plant is often seen along the road sides and on dumpsites throughout the tropics and subtropics. Its production varies widely from year to year due to fluctuation in rainfall and the size of the areas utilized for planting (Severino et al., 2012). In Nigeria, there is no available statistics suggesting the level of production, but experts observed that the plant grows well in the Northwestern states of Yobe, Borno, Adamawa, and Gombe, because of their Sahelian weather and prolong dry season. Although many scholars have contributed immensely on castor oil seed, little or no interest of government and inadequate empowerment fund has discouraged Nigerians farmers to planting castor oil plant. Nigeria spends between four to six hundred million dollars annually importing castor oil despite the abundant land, ecological and climatic conditions which are favourable to castor production (Oyeyemi et al., 2007). Improvement program on local accessions of castor are being carried out at the National Cereals Research Institute (NCRI), Badeggi and other research centers across the country. Through the improvement programs, different accessions are introduced for trials. Since oil is the economic yield of castor, there is a need to identify accessions with good physical and chemical qualities oil, hence the aim of this work is to determine the oil yield potential and the physical and chemical properties of tried castor oil plant accessions.

MATERIALS AND METHODS

The experiment was conducted at the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Nigeria. Ogbomoso is on latitude 8°101N and longitude 4°101E in the guinea savannah zone of Southwest Nigeria. Ten accessions were assessed for their oil physical and chemical properties. Five of them were obtained from National Cereals Research Institute (NCRI), Badegi, Niger State, Nigeria. They are NCRICAS007, NCRICAS041, NCRICAS056, NCRICAS057 and NCRICAS081. Another four were collected from Institute of Agricultural Research (IAR), Samaru Nigeria which are IARCAS001, IARCAS011, IARCAS021 and IARCAS023 while the control, CASGPMAN was obtained locally in Ogbomoso, the trial location. After harvesting from field, 100 g grind seed was taken from each accession for assessment of physical and chemical properties of their oil.

Castor seeds preparation and processing

Castor seeds undergo various processes in the course of its preparation for laboratory procedures. The seeds were cleaned of foreign materials and dirt, they were sundried till when the capsules split, after which they were winnowed to obtain clean seeds. Mortar and pestle were used to crush seed into paste (cake) in preparation for oil extraction.

Extraction of castor oil

Oil extraction was carried out using Soxhlet extractor. Normal Hexane of 300 ml was put into round bottom flask. 5 g of the sample was placed in the thimble and was inserted in the centre of the extractor. The Soxhlet was heated at 60°C. When the solvent was boiling, the vapour rises through the vertical tube into the condenser at the top. The liquid condensate drips into the filter paper thimble in the centre, which contains the solid sample to be extracted. The extract seeps through the pores of the thimble and fills the siphon tube, where it flows back down into the round bottom flask. This was allowed to continue for 30 min. It was then removed from the tube, dried in the oven, cooled in the desiccators and weighed again to determine the amount of oil extracted. This was repeated until constant weight was obtained. At the end of the extraction, the resulting mixture containing the oil was heated to recover solvent. This was repeated three times for each accession; average oil yield was computed.

$$\text{Oil yield} = \frac{W1-W2}{W1} \times 100\%$$

Where, W1 = initial weight of milled castor seed; W2 = weight of leftover castor cake after extraction

Determination of the physical properties of the extracted castor oil

Determination of specific gravity

Density bottle was used to determining the density of the oil. A clean and dry bottle of 25 ml capacity was weighed (W_0) and then filled with the oil, stopper inserted and reweighed to give (W_1). The oil was substituted with water after washing and drying the bottle and weighed to give (W_2).

The expression for specific gravity = (W_1-W_0) / (W_2-W_0) = Mass of the substance / Mass of an equal volume of water.

Determination of viscosity

A clean, dried viscometer with a flow time above 200 s for the fluid to be tested was used. The sample was filtered through a sintered glass (fine mesh screen) to eliminate dust and other solid material in the liquid sample. The viscosity meter was charged with the sample by inverting the tube's thinner arm into the liquid sample and suction force was drawn up to the upper timing mark of the viscometer, after which the instrument was turned to its normal vertical position. The viscometer was placed into a holder and inserted to a constant temperature bath set at a 29°C and allowed approximately 10 min for the sample to come to the bath temperature at 29°C. The suction force was then applied to the thinner arm to draw the sample slightly above the upper timing mark. The afflux time by timing the flow of the sample as it flow freely from the upper timing mark to the lower timing mark was recorded.

Determination of refractive index

Refractometer was used in this determination. Few drops of the sample were transferred into the glass slide of the refractometer. Water at 30°C was circulated round the glass slide to keep its temperature uniform. Through the eyepiece of the refractometer, the dark portion viewed was adjusted to be in line with the intersection of the cross. At no parallax error, the pointer on the scale pointed to the refractive index. This was repeated and the mean value was computed as the refractive index.

Determination of the chemical properties of the extracted castor oil

Determination of acid value

Twenty five milliliter of diethyl ether and 25 ml of ethanol were mixed in a 250 ml beaker. The resulting mixture was added to 10 g (W_0) of oil in a 250 ml conical flask and few drops of phenolphthalein were added to the mixture. The mixture was titrated with 0.1 M NaOH to the end point with consistent shaking for which a dark pink colour was observed and the volume of 0.1 M NaOH (V_0) was recorded. Fatty Acid (FFA) was calculated as $V_0/W_0*2.83*100$. Where: 100 ml of 0.1 M NaOH = 2.83 g of oleic acid.

Determination of iodine and saponification value

The method specified by ISO 3961 (2009) and ISO 3657 (2002) were used for iodine and saponification respectively.

Determination of peroxide value

One gram of castor seed oil, 1 g of potassium iodide and 20 ml of solvent mixture (glacial acetic acid/ chloroform, 3/2 by volume) were measured into Erlenmeyer flask of 250 ml capacity and the mixture was boiled for one minute. The hot solution was poured into a flask containing 20 ml of 5% potassium iodide. Thereafter, three drops of starch solution were added to the mixture and titrated with 0.025N standardized sodium thiosulphate and the peroxide value (PV) was determined following using the equation:

$$PV = \frac{SN \times 100}{W}$$

Where, S = ml of $Na_2S_20_3$; N = normality of $Na_2S_20_3$ and w = weight of oil sample (g).

Determination of percentage fatty acids

The percentage composition of fatty acids in the castor oil was determined using Shimadzu Gas Chromatograph - Mass Spectrometer (GCMS-QP 2010 plus) using standard fatty acid methyl esters.

Data analysis

Data on each parameter were taken in three replications. Data collected were subjected to analysis of variance and treatment means were separated using least significant difference at 5% probability level.

RESULTS

Oil yield of castor plant accessions

The percentage oil yield of castor plant was significantly varied (priedcenin different accession (Figure 1). Oil yield ranged between 31.2 and 51.9%. Accession CASGPMAN produced the highest yield (51.9%) which was significantly higher than others except NCRICAS057 (48.8%), IARCAS021 (45.8%) and IARCAS023 (45.9%). The least oil yield (31.2%) was obtained from NCRICAS041 accession and the average oil content of all the accessions was 41.21%.

Physical properties of castor plant oil accession

Physical properties of oil extracted from accessions of castor plant are presented in Table 1. All the physical characteristics of castor plant oil varied significantly (pcal chain accessions. Oil moisture content of the ten accessions ranging from 7.9 to 9.3% with NCRICAS041 have the highest (9.3%) which was not significantly different compared with 9.2% (CASGPMAN) and 9.1% (IARCAS021). Moisture contents of other accessions are statistically similar except 7.9% obtained from NCRICAS056. Specific gravity of the ten accessions at 25°C ranged from 0.84 to 0.97 with oil from IARCAS001 having the highest (0.97) while IARCAS023 had the least (0.84). Viscosity values at 28°C ranged from 8.4 to 9.4 with oil from NCRICAS056 accession having the highest (9.4) compared with the least (8.4) obtained from IARCAS023. Locally sourced accession (CASGPMAN) produced oil with highest refractive index 1.43 while accession IARCAS023 has the least (1.30). Relative density value ranged from 3.8 to 4.8 g/vol.

Chemical properties of castor plant oil accession

Chemical properties of oil extracted from the ten accessions of castor plant are presented in Table 2. There is no specific order across the accessions in

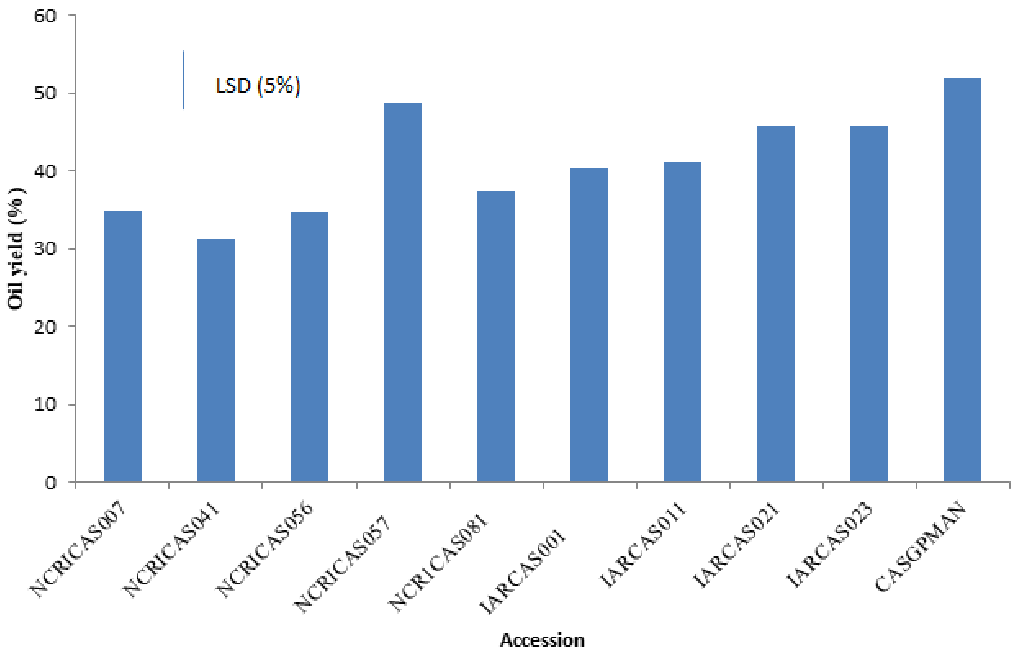

Figure 1. Influence of accession on oil yield of castor plant. The bar represents least significant difference value at 5% probability.

Table 1. Effect of accession on the physical properties of castor bean seed oil.

Accession	Moisture content (%)	Specific gravity at 25°C	Viscosity at 28°C	Refractive index at 28°C	Relative density (g/vol)
NCRICAS007	8.90^{b}	0.86^{b}	8.50^{b}	1.34^{b}	4.1^{ab}
NCRICAS041	9.30^{a}	0.87^{b}	8.80^{a}	1.38^{ab}	3.80^{b}
NCRICAS056	7.90c	0.92^{a}	9.40^{a}	1.43^{a}	4.60^{a}
NCRICAS057	8.80^{b}	0.94^{a}	8.90^{a}	1.39^{ab}	4.80^{a}
NCR1CAS081	8.60^{b}	0.95^{a}	8.70^{b}	1.38^{ab}	3.90^{ab}
IARCAS001	8.80^{b}	0.97^{a}	8.40^{b}	1.37^{b}	3.80^{b}
IARCAS011	8.90^{b}	0.92^{a}	8.40^{b}	1.38^{ab}	3.90^{ab}
IARCAS021	9.10^{a}	0.94^{a}	8.50^{b}	1.36^{b}	4.10^{ab}
IARCAS023	8.70^{b}	0.84^{b}	8.40^{b}	1.30c	3.90^{ab}
CASGPMAN	9.20^{a}	0.96^{a}	8.90^{a}	1.42^{a}	4.70^{a}

Means having the same letter in a column are statistically non-significant using LSD at 5% probability level. WAP = Week after planting.

exhibiting the properties. Iodine content is an indication of the level of unsaturation status of oil. Iodine content of the 10 accessions tried ranged between 81.5 and 85.4 g I/100 g oil. The highest iodine value (85.4 g I/100 g oil) was obtained from NCRICAS041 and the least (81.5 g I/100 g oil) was obtained from NCRICAS007. Saponification status of the oils of the 10 castor plant accessions was between 165.1 and 184.2 mg KOH/g oil. The acid values of all the oil from the ten accessions are between 4.9 and 5.9 mg KOH/g oil. The values are statistically similar except for 4.90 obtained from NCRICAS056. The results from Table 2 showed that all the oil from the ten accessions had peroxide values that ranged from 7.4 to 11.2 meq/kg oil. The highest peroxide value (11.2 meq/kg oil) was obtained for NCRICAS041 while the least (7.4 meq/kg oil) which was significantly lower than others was recorded for oil extracted from IARCAS001. The hydroxyl contents of oil from the ten accessions ranged from 156.9 to 163.4 mg KOH/g oil. Oil from IARCAS011 had the least hydroxyl content (156.9 mg KOH/g oil) which was significantly lower than others except IARCAS001. Free fatty acids are produced by triglyceride breakdown and are therefore good indicators of degradation. From Table 2, free fatty acids (FFA)

Table 2. Effect of accession on the chemical properties of castor seed oil.

Accession	Iodine value (g I/100 g oil)	Saponification value (mg KOH/g oil)	Acid value (mg KOH/g oil)	Peroxide value (meq/kg oil)	Hydroxyl (mg KOH/g oil)	Free fatty acid (mg KOH/g oil)
NCRICAS007	81.50^{b}	173.40^{a}	5.50^{a}	10.40^{a}	162.30^{a}	1.90^{ab}
NCRICAS041	85.40^{a}	168.30^{b}	5.00^{ab}	11.20^{a}	161.10^{a}	1.80^{b}
NCRICAS056	84.40^{a}	175.30^{a}	4.90^{b}	8.40^{b}	160.20^{a}	1.90^{ab}
NCRICAS057	85.30^{a}	184.20^{a}	5.70^{a}	10.20^{a}	163.40^{a}	2.60^{a}
NCR1CAS081	82.10^{b}	176.0^{a}	5.40^{a}	9.30^{ab}	160.20^{a}	2.00^{ab}
IARCAS001	83.10^{ab}	165.10^{b}	5.60^{a}	7.40c	159.90^{b}	1.90^{ab}
IARCAS011	84.20^{a}	166.30^{b}	5.90^{a}	8.20^{b}	156.90^{b}	2.00^{ab}
IARCAS021	82.30^{b}	180.20^{a}	5.60^{a}	7.80^{a}	160.20^{a}	2.10^{ab}
IARCAS023	81.50^{b}	176.20^{a}	5.30^{a}	8.70^{b}	162.50^{a}	2.30^{a}
CASGPMAN	84.90^{a}	182.40^{a}	5.80^{a}	9.80^{b}	162.90^{a}	2.50^{a}

Means having the same letter in a column are statistically non-significant using DMRT at 5% probability level. WAP = Week after planting

values between 1.8 and 2.6 mg KOH/g oil were obtained from the ten accessions with an average value of 2.1 mg KOH/g oil. The highest FFA value (2.6 mg KOH/g oil) was recorded from NCRICAS057 while oil from NCRICAS041 had the least FFA value (1.8 mg KOH/g oil).

DISCUSSION

Oil yield range obtained from the tried accessions are within the earlier reported ranges of 40 to 60% (Akpan et al., 2006; Ogunniyi, 2006), while the differences in response of accession was earlier attributed to adaptation to soil fertility and climate by Salimon et al. (2010a). Moisture content of plant produce is of high essence especially for storage; Ace Commodity Exchange recommended 5% in 2013. The observed moisture contents across the accessions are higher than this recommendation and that of Bagali (2010). This pointed to the fact that the harvest should be allowed to dry more before storage for good shelf live. Other physical properties of extracted oil of the ten accessions of castor did not follow any specific order compared with ASTM standards. Specific gravity of oils from three accessions (NCRICAS081, NCRICAS056 and CASGPMAN) was within the range of specific gravity standard. Oil viscosity range obtained was similar to those reported by Makanju and Bello (2011) which were reported to be slightly higher and unusual for natural vegetable oils, this observation was attributed to hydrogen bond of its hydroxyl groups by Ogunniyi (2006). The refractive index obtained from the ten accessions were below the ASTM Standard at 30°C range (1.476 - 1.478). They also differ compared with Mensah and Ocham (2005) from cold pressed at 25°C and that of Omari et al. (2015). Also the pH range can be attributed to free fatty acids as explained by Omari et al. (2015) who reported similar range.

Iodine contents of the accessions were within the range reported by ASTM Standard (83 and 88 g I/100 g oil) and content reported from Malaysian accessions (Salimon et al., 2010b). With respect to saponification quality, the range obtained was within the reported range of ASTM standard. Also, the results were in agreement with that of Ogunniyi (2006) and Mensah and Ocharan (2005). Peroxide contents were with the range reported by Abitogun et al. (2009) but below that from the report of Udiandeye et al. (2011). Hydroxyl contents were in the range reported by Yusuf et al. (2015) from wild castor seed oil and met the general specification for industrial grade castor oil (WHC, 2012).

Conclusion

Highest oil yield was obtained from locally sourced accession CASGPMAN but NCRICAS056 and NCRICAS057 sourced from National Cereals Research Institute (NCRI), have better oil quality and are recommended.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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