Seed characteristics and fatty acid composition of castor (*Ricinus communis* L.) varieties in Northeast China

Características y composición de ácidos grasos de la semilla en variedades de *Ricinus communis* L. en el Noreste de China

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Abstract. Oil content and fatty acid composition were investigated on 12 castor varieties and strains by using the soxhlet extraction method and capillary gas chromatography. This was made to provide a reference and theoretical basis for castorbean breeding with high oil content, determine variability of seed compounds for breeding purposes, and broaden chemical material choices. Results revealed that crude fat percentage in seeds ranged from 18.91 to 35.84% with an average of 25.91%; the absolute content of ricinoleic acid varied between 171.65 g/kg and 314.03 g/kg with an average of 222.43 g/kg, and kernel crude fat percentage was between 24.28 and 46.97% with an average of 34.30%. All these study variables were highest in the 2129 strain. The percentage of ricinoleic acid in crude fat was between 83.85 to 87.62%, and the highest value was found in the zhebi4 accession. The other fatty acids appeared in small concentrations, and showed small amplitude: 1.12 to 1.61%, 1.21 to 1.61%, 3.53 to 4.80%, 5.35 to 6.38%, 0.52 to 0.79%, 0.05 to 0.08% and 0.43 to 0.55%, for palmitic, stearic, oleic, linolic, linolenic, arachidic, and arachidonic acids, respectively. One hundred seed weight was determined for each accession. One hundred seed weight ranged from 25.7 g to 34.0 g with an average of 29.9 g. There was a significant correlation between seed weight and oil content, but the correlation value was low (r=0.51). Cluster analysis by SSPS based on the content of fatty acid composition revealed that the accessions were divided into three independent clusters. These findings will clearly provide useful information for further research in breeding and utilization of castor oil.

Keywords: Castor oil; Capillary Gas Chromatography; Crude fat; Ricinoleic acid; 100-seed weight.

Resumen. Se investigaron el contenido de aceite y la composición de ácidos grasos en 12 variedades y cepas de *Ricinus communis* L. usando un método de extracción y cromatografía gaseosa capilar. Esto se realizó con el fin de proveer una base teórica y de referencia para el cruzamiento de *Ricinus communis* L. con un alto contenido de aceites, determinar la variabilidad de compuestos de semillas con propósitos de cruzamiento, y ampliar la elección de materiales químicos. El porcentaje de grasa cruda en las semillas varió de 18,91 a 35,84% con un promedio de 25,91%; el contenido absoluto de ácido ricinoleico varió entre 171,65 g/kg y 314,03g/kg, con un promedio de 222,43 g/kg. El porcentaje de grasa cruda del grano varió entre 24,28 y 46,97% con un promedio de 34,30%. Los mayores valores para todas estas variables de estudio se obtuvieron en la cepa 2129. El porcentaje de ácido ricinoleico en la grasa cruda varió entre 83,85 a 87,62%, y el mayor valor se obtuvo en la variedad zhebi4. Los otros ácidos grasos aparecieron en menores concentraciones, y mostraron una pequeña amplitud: 1,12 a 1,61%; 1,21 a 1,61%; 3,53 a 4,80%, 5,35 a 6,38%, 0,52 a 0,79%, 0,05 a 0,08% y 0,43 a 0,55%, para los ácidos palmítico, esteárico, oleico, linoleico, linolénico, araquídico y araquidónico, respectivamente. Se determinó el peso de cien semillas para cada variedad. Dicho peso varió de 25,7 g a 34,0 g con un promedio de 29,9 g. Hubo una correlación significativa entre el peso y el contenido de aceite de la semilla, pero con un bajo coeficiente de correlación (r=0,51). El análisis de grupos usando SSPS basado en el contenido de la composición de ácidos grasos mostró que las variedades se dividieron en tres grupos independientes. Estos resultados proveen claramente una información muy útil para futuras investigaciones sobre el cruzamiento y la utilización de aceite de ricino.

Palabras clave: Aceite de ricino; Cromatografía gaseosa capilar; Grasa cruda; Ácido ricinoleico; Peso de cien semillas.

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INTRODUCTION

Castor (*Ricinus communis* L., 2n = 2x = 20) belongs to the Euphorbiaceae family (Anjani, 2012). It is one of the ten greatest oil crops in the world (Ogunniyi, 2006; Fenglan Huang, 2012). Under different climatic conditions, the castor oil plant can grow into large shrubs or trees, and it chiefly grows in arid and semi-arid regions (Govaerts et al., 2000). The oil produced from castor plants is non-volatile, non-drying and viscous. It is pale yellow, with a bland taste and a slight characteristic odor. Castor seeds are poisonous to humans and animals because they contain toxic compounds such as ricin, ricinine and certain allergens (Ogunniyi, 2006; Fenglan Huang, 2012). Accidental ingestion causes vomiting and abdominal pain. Although castor oil is non-edible, its chemical structure and properties are useful in many chemical industries. In contrast with other vegetable oils, ricinoleic acid has a longer shelf-life and it does not turn rancid unless it has been subjected to strong heat. Therefore, castor oil plants have become a valued industrial oil crop (Princen, 1979; Ogunniyi, 2006). As it can replace some edible industrial oils, the cultivation area has increased recently, especially in developing countries.

Due to a high demand for industrial oil, the major target of castor breeding was to achieve high yield and increased oil content. Some researchers studied methods of increasing castor oil by inducing productive semi-dwarfs with higher yield potential and earlier maturity, loss of day-length sensitivity (Lavanya & Chandramohan, 2003; Akande & Odunsi, 2012). Studies on castor breeding for improving oil quality have been recently initiated. Generally, only the relative content of crude fat in castor oil plants was considered as the indicator of oil quality (Akpan et al., 2006). Ricinoleic acid is a unique hydroxy fatty acid, which has been widely reported to be the major component in castor oil with a wide distribution, ranging from 70 to 90% (Gupta et al., 1951; Foglia et al., 2000; Conceição et al., 2007). Fatty acids in castor seeds have been studied since the 1970s (Cooper, 1971; Lin & Arcinas, 2007; Van Erp et al., 2011). Most often, however, only the relative content of fatty acid composition in castor seeds has been reported, and the absolute content has been ignored. In this study, the absolute contents of fatty acids in castor seeds were assayed by using capillary gas chromatography to update the database about this important industrial crop and also find out the variability for fatty acid and oil contents.

Asia can be considered as the main producing area of castor oil and fat for industrial use. India is the world's largest exporter of castor oil followed by China and Thailand (Wang et al., 2013). Tongliao, Inner Mongolia, is an important castor producing area in China with culturing castor varieties widely spread in Asia. Located in the east of the Asian continent (42° 15′ to 45° 41′ N, 119° 15′ to 123° 43′ E), Tongliao belongs to the continental monsoon climate. In this district, the annual precipitation ranges from 350 to 450 mm; the annual effective windy time (wind speed is about 3 to 20 m/s) varies from 5000 to 6000 h, and the annual effective wind power density changes from 100 to 150 W/m² (He Junyan, 2011). This paper was intended to detect and analyze fatty acid contents and seed characteristics in 12 castor varieties which are the largest planting in Northeast China. Based on the analysis, it can provide a reference for castorbean breeding purposes with high oil quality or content, for chemical composition in order to find out the variability for fatty acid and oil content.

MATERIALS AND METHODS

Castor seeds. Seeds of eight castor varieties and four strains were used in this study. The varieties included zhebi3, zhebi4, tongbi5, tongbi6, tongbi7, tongbi8, tongbi9 and tongbi10, which were cultivated by crossbreeding in the Academy of Agricultural Science in Tongliao, China. The strains determined in the experiment were 1987, 2129, 4019 and 06404, respectively. Twelve castor accessions were obtained and grown at the Academy of Agricultural Sciences. Seed samples were taken from the first racemes, when they reached the harvest point for chemical analysis.

Measuring methods
Measurement of 100-seed weight, 100-kernel weight and kernel percentage. One hundred seeds were collected from each variety to measure 100-seed weight. The seed-coat was peeled to determine 100-kernel weight. All the measurements were carried out in triplicate. The kernel percentage was calculated as follows:

$$\text{Kernel ratio} = \frac{\text{100-kernel weight}}{\text{100-seed weight}} \times 100\%$$

Measurement of crude fatty acid content. The crude fatty acid content in the seeds was determined with three replications by the soxhlet extraction method on a dry weight basis (Chemists & Horwitz, 1980). Hence, homogenized 2-4g samples were dried in an oven at 105±2 °C for 1 h and then inserted into the soxhlet extraction system (SXT-06, Shanghai Hongji Instrument CO., LTD). Extraction was carried out with 60ml anhydrous ether for 10 h at 70 °C. Then the solvent was removed under oven-drying and the residual lipid was determined gravimetrically.

The ratio of crude fat in seed was calculated as:

$$\text{Crude fat in seed} = \frac{\text{S1}}{\text{S2}} \times 100\%$$

Where S2 (g) is the content of crude fat in 100-seed, and S1 (g) is the weight of 100-seed. Similarly, the ratio of crude fat in kernel was calculated as:

$$\text{Crude fat in kernel} = \frac{K1}{K2} \times 100\%$$

Where K2 (g) is the content of crude fat in 100-kernel and K1 (g) is the weight of 100-kernel.

Measurement of fatty acid composition and absolute content. The fatty acid composition of the oil was performed by gas chromatography (GC) according to the National standard GB/T 17377-2008/ISO 5508: 1990 (China, 2008), whereas the methyl esters were prepared by the National standard GB/T 17376-2008/ISO 5509: 2000 (Reserve, 2008). Sodium hydroxide in methanol solution (0.5 mol/L, 6 mL) was added to the crude fat (0.5 g) that was saponified for 10 min with N_2 flux. Then boron trifluoride in methanol solution (12-15%, 7

mL) was added for refluent esterification for 5 min. Isooctane (5 mL) was added to the blender from the top of the condenser. Thereafter the condenser was taken down with NaCl solution (6 mol/L, 20 mL) added immediately, which was violently shaken for at least 15 s. NaCl solution was then infused to the flask neck. The mixture was demixed and the Isooctane solution in the upper layer (1-2 mL) was collected. The supernatant was dried with an excess of anhydrous sodium sulfate prior to analysis with gas chromatography.

The assay was performed with a gas chromatography system (Agilent7890A, China) with the capillary column (DB-23, 30 m×320 μm, 0.25 μm) (Agilent, China). N_2 was used as the carrier gas with a flux of 25 mL/min. The initial column temperature was kept at 180 °C for 5 min and gradually increased at 3 °C/min to 230 °C. The sample (10 μL) was directly injected to the column at 230 °C and then separated. The
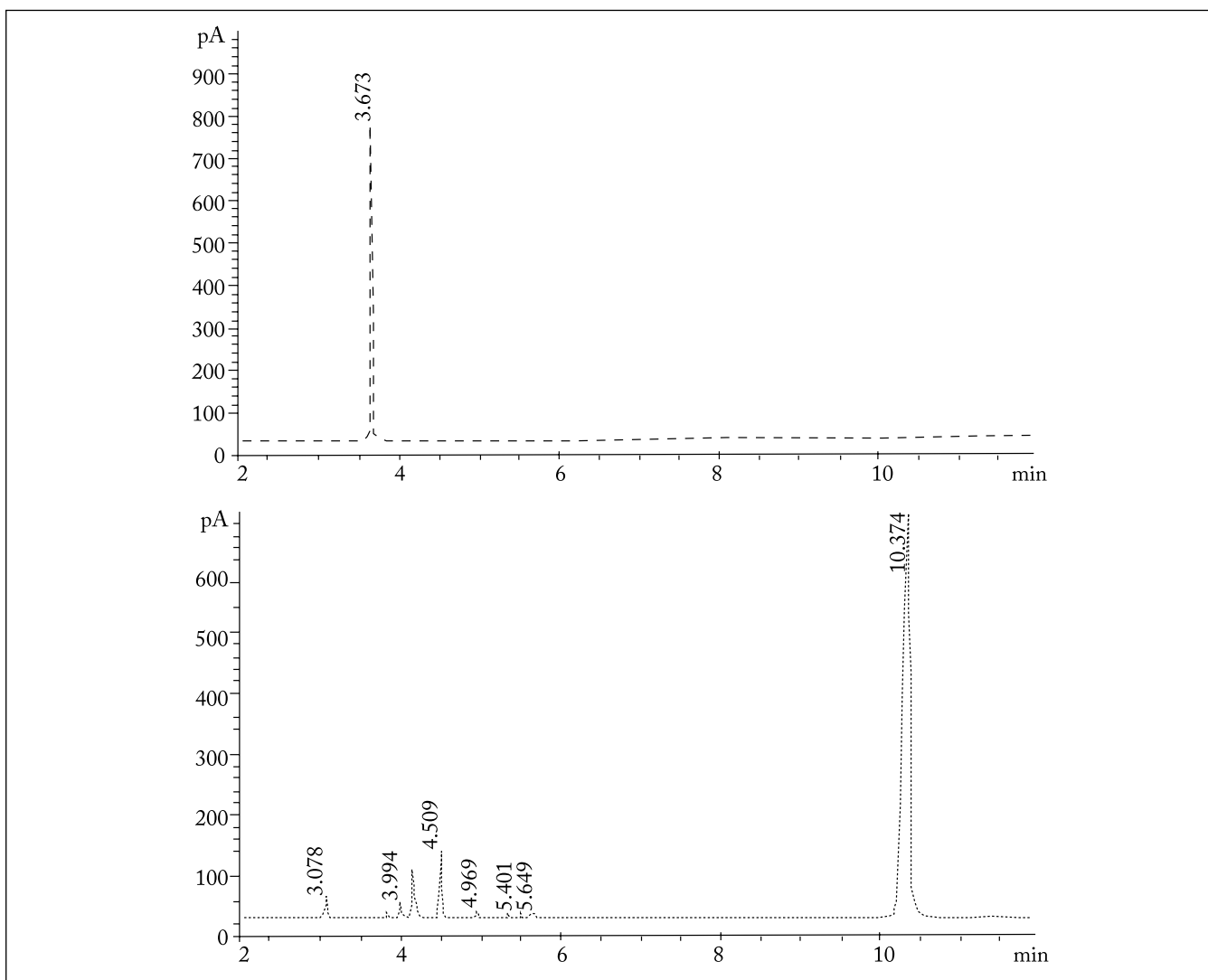

Fig. 1. Chromatogram of fatty acid methyl ester in castor varieties (first: standard substance; second: zhebi3).
Fig. 1. Cromatograma de éster de metilo en ácidos grasos de variedades de *Ricinus communis* (primero: sustancia estándar; segundo zhebi3).

composition ratio of fatty acid was then calculated according to the corresponding chromatographic peaks. The character and structure of fatty acid compositions in each castorbean materials were distinguished by the total ion current (TIC) of mass spectrometer (Fig. 1). By applying the computer automatic and manual retrieval with NIST98 and Wiley of Mass Spectral Data, fatty acid composition of the 12 castor accessions was analyzed and measured.

Fatty acid methyl ester in castor seeds was determined using a standard curve plotted against known concentration of the standard substance (C17:1) (NU-CHEK, USA). The absolute content of fatty acid was calculated as:

$$\text{Absolute content} = C_1 \times C_2 \times 1000 / g$$

Where C_1 (mg) is the composition of the fatty acid, and C_2 (mg) is the composition of crude fat.

Statistical data analysis. All the measurements were taken in triplicate. Analysis of variance (ANOVA) and correlation analysis among fatty acids was done by SPSS V13.0. Hierarchical Cluster was performed basing on absolute fatty acid contents of castor varieties using SPSS.

RESULTS

One hundred-seed weight, 100-kernel weight and kernel percentage of castor seeds. The 100-seed weight of the selected castor seeds varied from 25.7 g to 34.0 g with an average of 29.9 g, and the highest and lowest weights were found in 4019 and 1987, respectively (Table 1). For the 100-kernel weight, it ranged from 19.2 g to 25.7 g in these castor varieties, with highest values for 1987 and lowest ones for zhema3. In these castor seeds, the percentage of kernel ranged between 69.32% for 4019 and 77.89% for tongma7 with an average of 75.18%. In addition, there was a large variation in the crude fat content of seeds, which varied from 18.91 to 35.84% with an average of 25.91%; highest values were found on zhema4. Crude fat content in kernel ranged from 24.28 to 46.97% with an average of 34.30%; once again, highest values were found in zhema4. The 17.86% amplitude found for oil content within the 12 varieties shows the potential of selection or breeding for this characteristic.

Fatty acid composition and content in castor seeds. The fatty acid composition of the 12 castorbean varieties is shown in Fig. 1 and Table 2. Regarding fatty acids, little variability was found for ricinoleic acid, which is the main component of castorbean oil, varying from 83.85 (tongbi5) to 87.62% (zhebi4). The other fatty acids figured in low concentrations, with a small range: 1.12 to 1.61%, 1.21 to 1.61%, 3.53 to 4.80%, 5.35 to 6.38%, 0.52 to 0.79%, 0.05 to 0.08% and 0.43 to 0.55%, for palmitic, stearic, oleic, linolic, linolenic, arachidic, and arachidonic acid, respectively.

Fatty acids absolute content distributed differently in castor varieties (Fig. 2). Some variability were surveyed for palmitic, stearic, oleic, arachidonic and ricinoleic acid with 3.1 to 4.2 g/kg, 2.3 to 4.4 g/kg, 7.9 to 14.0 g/kg, 0.9 to 1.5 g/kg and

Table 1. Crude fatty acid percentage of castor varieties.
Tabla 1. Porcentaje de ácidos grasos totales en *Ricinus communis*.

Varieties	100-seed weight (g)	100-kernel weight (g)	Kernel percentage (%)	Crude fatty acid content in 100 seeds (g)	Crude fatty acid percentage in seed (%)	Crude fatty acid percentage in kernel (%)
zhebi3	33.3 ± 0.9	25.7 ± 0.6	77.04	10.7 ± 0.5	32.05	41.60
zhebi4	31.9 ± 0.5	24.4 ± 0.6	76.31	11.4 ± 0.5	35.84	46.97
tongbi5	28.1 ± 0.4	21.7 ± 0.8	77.18	6.8 ± 0.5	24.11	31.24
tongbi6	30.8 ± 0.8	23.4 ± 0.5	75.99	8.9 ± 0.9	29.17	38.39
tongbi7	31.6 ± 0.4	24.6 ± 0.5	77.89	5.9 ± 0.9	18.91	24.28
tongbi8	27.8 ± 0.9	21.4 ± 0.6	76.80	7.4 ± 0.5	26.64	34.69
tongbi8	26.3 ± 0.4	19.6 ± 0.6	74.68	6.9 ± 0.4	26.45	35.42
tongbi10	28.9 ± 0.5	20.8 ± 1.0	72.11	6.7 ± 0.6	23.17	32.13
1987	25.7 ± 0.2	19.2 ± 0.2	74.38	6.9 ± 1.4	26.85	36.10
2129	33.2 ± 0.8	25.2 ± 1.7	76.04	8.9 ± 0.9	27.01	35.52
4019	33.9 ± 0.9	23.6 ± 1.0	69.32	6.9 ± 0.8	20.18	29.11
06404	28.1 ± 0.5	21.2 ± 1.5	75.20	5.8 ± 0.3	20.55	27.33
Mean	29.9	22.5581	75.18	7.7864	25.91	34.30
Standard deviation	2.8357	2.1958	2.53	1.8190	4.96	6.23

Table 2. Fatty acid composition and percentage on castorbean varieties.
Tabla 2. Composición y porcentaje de ácidos grasos en variedades de *Ricinus communis.*

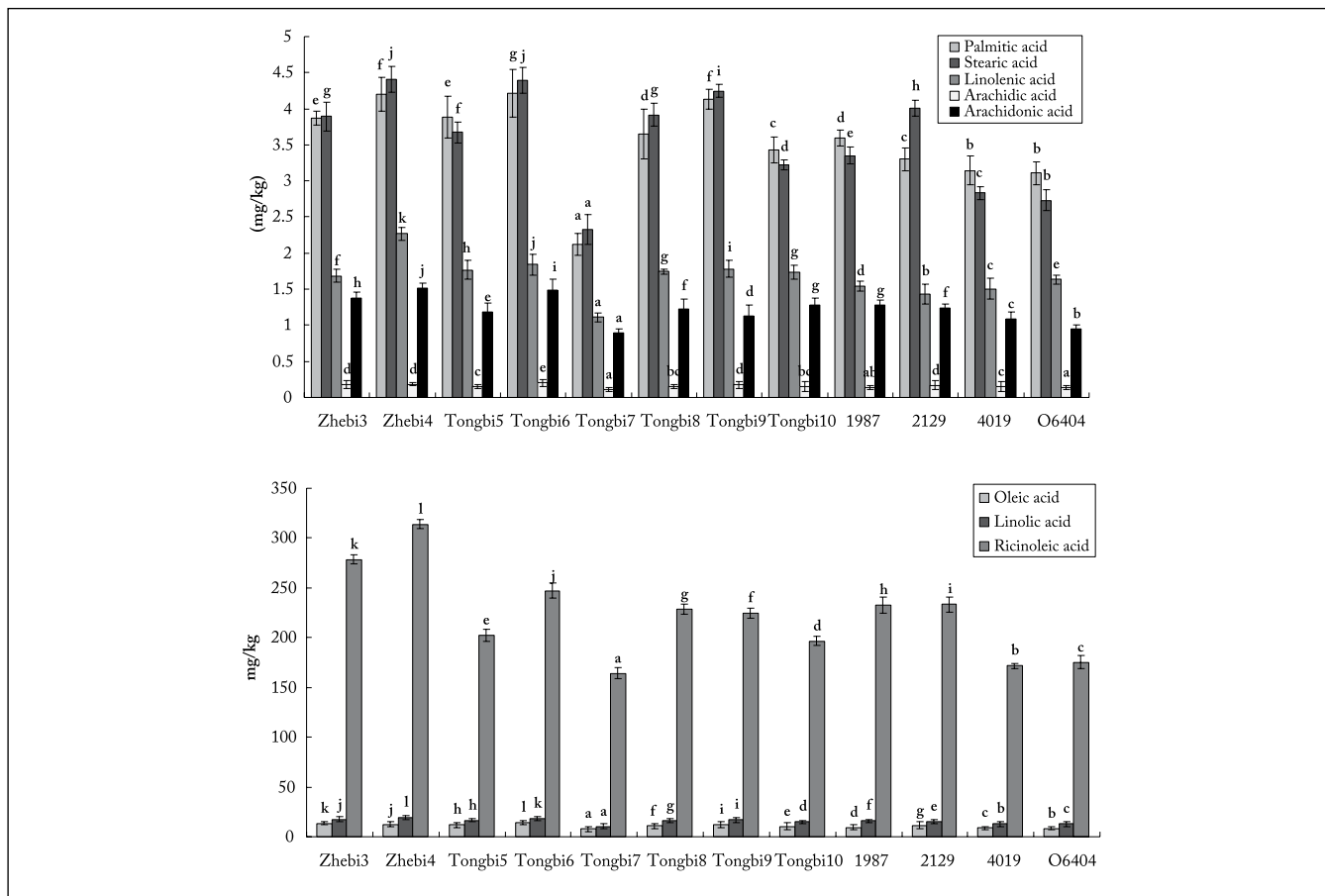| Varieties	Palmitic acid (%)	Linolenic acid (%)	Oleic acid (%)	Stearic acid (%)	Arachidonic acid (%)	Linolic acid (%)	Arachidic acid (%)	Ricinoleic acid (%)
Zhebi3	1.21 ± 0.02	0.52 ± 0.03	4.26 ± 0.08	1.21 ± 0.07	0.43 ± 0.01	5.49 ± 0.13	0.06 ± 0.01	86.82 ± 0.41
Zhebi4	1.17 ± 0.01	0.63 ± 0.04	3.53 ± 0.20	1.23 ± 0.01	0.42 ± 0.02	5.35 ± 0.22	0.05 ± 0.009	87.62 ± 0.19
Tongbi5	1.61 ± 0.02	0.73 ± 0.04	4.92 ± 0.08	1.52 ± 0.05	0.49 ± 0.05	6.81 ± 0.06	0.06 ± 0.01	83.85 ± 0.29
Tongbi6	1.44 ± 0.08	0.63 ± 0.01	4.80 ± 0.07	1.51 ± 0.08	0.51 ± 0.03	6.27 ± 0.14	0.07 ± 0.07	84.77 ± 0.33
Tongbi7	1.12 ± 0.10	0.59 ± 0.02	4.15 ± 0.10	1.23 ± 0.07	0.47 ± 0.04	5.57 ± 0.11	0.06 ± 0.08	86.81 ± 0.16
Tongbi8	1.37 ± 0.05	0.66 ± 0.04	4.00 ± 0.30	1.47 ± 0.10	0.46 ± 0.005	6.09 ± 0.13	0.06 ± 0.09	85.89 ± 0.44
Tongbi9	1.56 ± 0.10	0.67 ± 0.04	4.51 ± 0.09	1.61 ± 0.10	0.43 ± 0.07	6.33 ± 0.12	0.06 ± 0.01	84.82 ± 0.07
Tongbi10	1.48 ± 0.06	0.75 ± 0.02	4.49 ± 0.10	1.39 ± 0.01	0.55 ± 0.07	6.36 ± 0.11	0.07 ± 0.01	84.91 ± 0.38
1987	1.34 ± 0.04	0.57 ± 0.03	3.55 ± 0.20	1.25 ± 0.09	0.48 ± 0.08	6.00 ± 0.16	0.05 ± 0.06	86.76 ± 0.53
2129	1.22 ± 0.03	0.53 ± 0.04	4.27 ± 0.13	1.49 ± 0.14	0.46 ± 0.02	5.56 ± 0.13	0.06 ± 0.09	86.41 ± 0.12
4019	1.56 ± 0.07	0.75 ± 0.06	4.26 ± 0.11	1.40 ± 0.028	0.54 ± 0.08	6.34 ± 0.08	0.08 ± 0.08	85.08 ± 0.21
06404	1.51 ± 0.03	0.79 ± 0.06	4.17 ± 0.093	1.33 ± 0.15	0.46 ± 0.06	6.38 ± 0.13	0.06 ± 0.09	85.29 ± 0.17
Mean	1.38	0.65	4.24	1.39	0.48	6.05	0.06	85.75
Standard deviation	0.17	0.90	0.42	0.14	0.04	0.45	0.008	1.13

Fig. 2. Absolute content of fatty acid compositions in castor varieties.
Fig. 2. Contenido absoluto de composición de ácidos grasos en variedades de *Ricinus communis.*

164.2 to 314.0 g/kg, respectively. While the other fatty acids absolute content appeared in low concentrations, their amplitude was from 12.8 to 19.2 g/kg, 1.1 to 2.3 g/kg and 0.1 to 0.2 g/kg, for linoleic, linolenic and arachidic acid, respectively. From these data, we suggested zhema4 was the best accession for extracting castor oil.

Meanwhile, we analyzed unsaturated and saturated fatty acids content and percentage in the varieties. As shown in Figure 3, little variability was found in unsaturated (from 184.57 g/kg to 349.62 g/kg) and saturated (4.56 g/kg to 8.55 g/kg) fatty acids of varieties.

Some interesting correlations were observed among the fatty acids (Table 3). However, no significant correlations were surveyed between seed weight and fatty acid composi-

tion. This suggests that fatty acid content may be changed without significant modification in seed weight or volume of production. The percentage of one hundred seed weight was negatively correlated with palmitic, stearic and linoleic acids: r= -0.452, -0.290 and -0.529, respectively. Conversely, the percentage of 100-seed weight was positively associated with linolenic and fatty acid: r=0.486 and 0.51. Moreover, the percentage of fatty acids was highly associated with ricinoleic acid: r=0.523, while the percentage of linolic acid was highly correlated with palmitic acid (r=0.958**, p<0.01). The positive correlations suggested that the increase in ricinoleic acid would increase seed weight and oil content. Negative correlations, however, indicated that increases in seed weight might cause a decrease in the percentage of palmitic or linolic acid.
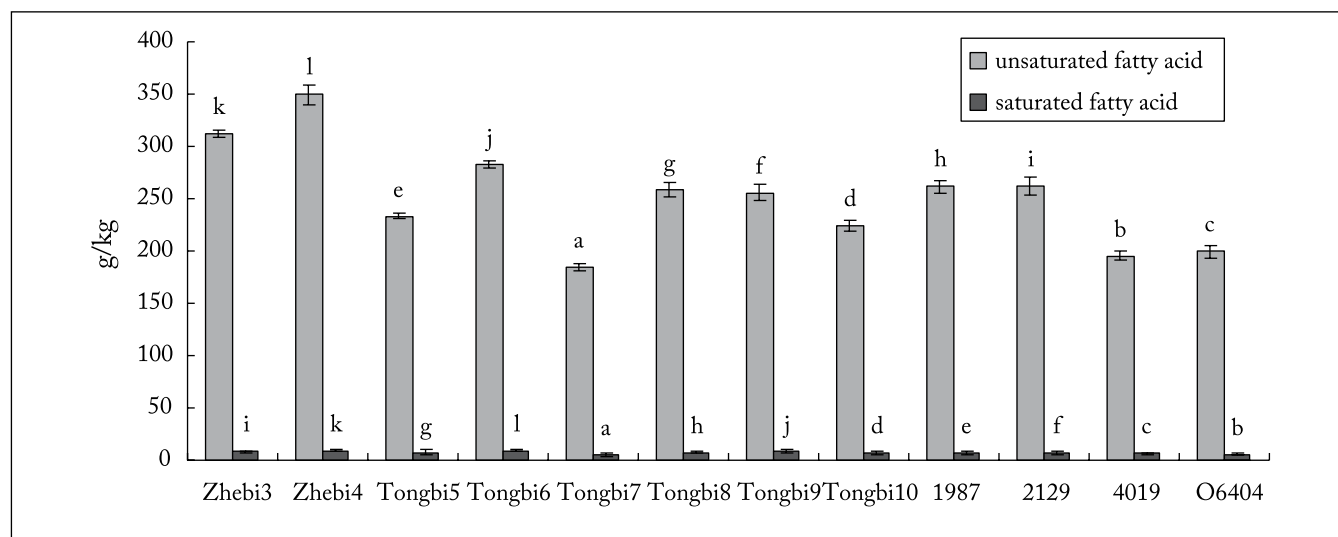

Fig. 3. Composition analysis of fatty acid in castor varieties.
Fig. 3. Composición de ácidos grasos saturados y no saturados en variedades de *Ricinus communis*.

Table 3. Matrix of simple correlation coefficients for fatty acids and seed weight of castor varieties.
Tabla 3. Matriz de coeficientes de correlación simple para ácidos grasos y peso de semillas en variedades de *Ricinus communis*.

	Palmitic acid	Stearic acid	Oleic acid	Linolic acid	Linolenic acid	Arachidic acid	Arachidonic acid	Ricinoleic acid	Fatty acid
Palmitic acid	—								
Stearic acid	0.653*	—							
Oleic acid	0.574		—						
Linolic acid	0.958**			—					
Linolenic acid	0.784**	0.308	0.316	0.774**	—				
Arachidic acid	0.491	0.358	0.579*	0.448	0.457	—			
Arachidonic acid	0.483	0.194	0.398	0.558	0.486	0.758**	—		
Ricinoleic acid	-0.914**	-0.755**	-0.837**	-0.941**	-0.686*	-0.583*	-0.548	—	
Fatty acid	-0.526	-0.244	-0.241	-0.644*	-0.567	-0.271	-0.463	0.523	—
100-seed weight	-0.452	-0.290	0.015	-0.529	0.486	0.387	0.056	0.332	0.51

Interestingly, Cluster analysis by SPSS dendrogram based on absolute content of fatty acids revealed that the varieties were clearly divided into three independent clusters: 4019, 06404 and tongbi7 were grouped together, zhebi3, tongbi6 and zhebi4 were mainly clustered in the same group, while the rest were classified in the last group including tongbi5, tongbi9, tongbi8, 1987, tongbi10 and 2129 accessions (Fig. 4).
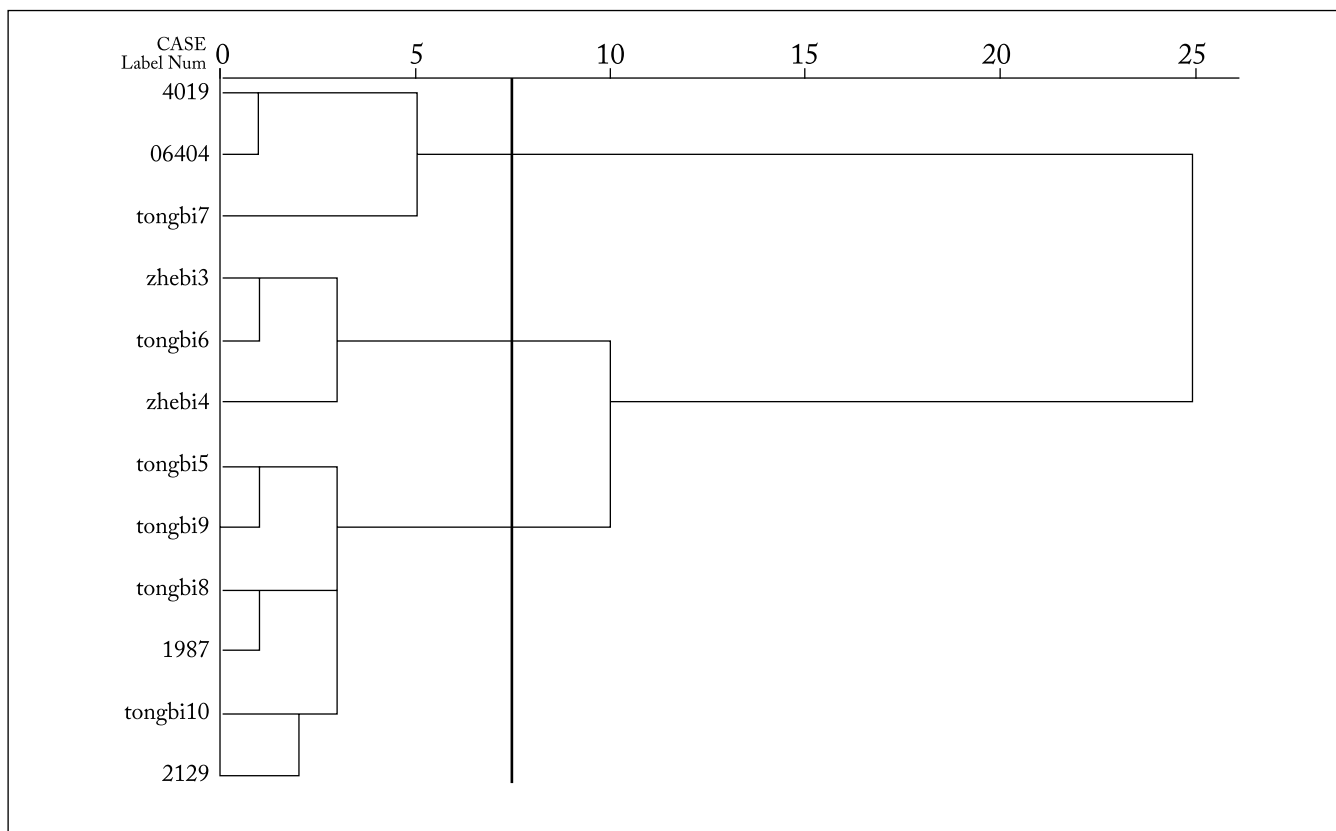

Fig. 4. Hierarchical cluster for castor varieties based on absolute content of fatty acid compositions.
Fig. 4. Agrupación jerárquica para variedades de *Ricinus communis* basada en el contenido absoluto de composición de ácidos grasos.

DISCUSSION

Castor oil is identified as a potential feed-stock for biofuel production because of its proven technical and guaranteed sale (Anjani, 2012). Many researchers have measured and reported oil content ranging from 40 to 60% in a series of castor genotypes using the soxhlet extraction method (Da Silva Ramos et al., 1984; Rojas-Barros et al., 2004; Anjani, 2012). In this work, 20.18% to 35.84% in seed, and 29.11% to 46.97% in kernel of fatty acids were observed in 12 castor varieties (Table 1). The low contents and variability compared with other reports were most likely caused by small collections; more surveying may result in greater value amplitudes. As a result of the variability of oil content in the 12 castor accessions, selection and plant breeding technology can be applied to modify the oil content of castorbean. In addition, variability in fatty acid composition was also found, but most of it was within a narrow variation range (less than 1%; Table 2). It means that the fatty acid composition will not change only by using the selection process as a tool. More effective, modern methods should be used to make it on this plant species. Meanwhile, we must survey more varieties to verify if a greater variability is available.

Ricinoleic acid was often used as a surface-active agent, plasticizer and lubricant additive in industry with increasing demands in the world (Ory et al., 1962). Therefore, it is imperative to screen methods for improving the content of ricinoleic acid in castorbean. Approximately 86% of the fatty acid found in castorbean was ricinoleic acid, which distinguishes castor oil from other seed oils (Table 2). As the content of ricinoleic acid is much higher than that of the other fatty acids, it is difficult to increase only with traditional breeding methods. This viewpoint was identical with that of various authors (Da Silva Ramos et al., 1984; Rojas-Barros et al., 2004; Anjani, 2012). Hence, we suggest that RNAi technology may achieve this goal, and we were working with this technique in order to improve castor oil content.

Some tendencies were found, positive and negative on the correlations among fatty acid conmposition (Table 3). While the significant correlations could be concerned with the fatty acid biosynthesis pathway in castor, the mechanism underlying them is still not clear (Da Silva Ramos et al., 1984). Nevertheless, non-significant correlations were detected between seed weight and fatty acid. It means that selection for a specific fatty acid could increase the positive correlations, while reducing the negative ones.

Hierarchical Cluster of castorbean varieties based on absolute content of fatty acid compositions separated 12 individual varieties into three independent clusters (Figs. 2 and 4) which related to a seed character (i.e., fatty acid composition and percentage). Group I represented the accessions coming from a common ancestor with low content of fatty acids. While Group II included the varieties with higher content, Group III were the accessions with the highest content. It would be necessary to breed superior strains with higher oil and unsaturated fatty acid contents. It is useful for castor breeders to seek germplasm accessions with high oil content in the collection.

Our preliminary results suggest that some variability in oil content and 100-seed weight was found among the 12 accessions of castor varieties and strains. This information could help breeders to develop high castor oil varieties for biofuel production and conservation of castor beans.

ACKNOWLEDGMENTS

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