Oil Content and Fatty Acid Composition of Chia (*Salvia hispanica* L.) from Five Northwestern Locations in Argentina

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ABSTRACT: Any new crop for which there is a market, and which appears to be adapted to the region, would be attractive to replace nonprofitable traditional crops in Northwestern Argentina. Chia (*Salvia hispanica L.*) is especially attractive because it can be grown to produce oil for both food and industry. The fatty acids of chia oil are highly unsaturated, with their main components being linoleic (17–26%) and linolenic (50–57%) acids. Seeds from a chia population harvested in Catamarca were sown in five Northwestern Argentina locations. The oil from the chia seeds produced under these five field conditions was measured. Linolenic, linoleic, oleic, palmitic, and stearic fatty acid contents of the oil were determined by gas chromatographic analysis. The results showed variations in oil content, and the oleic, linoleic, and linolenic fatty acid concentrations of the oil were significantly affected by location.
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KEY WORDS: Argentina, chia, fatty acids, linolenic acid, location influence, new crops, oil, polyunsaturated, *Salvia*, temperature influence.

The low price of traditional crops, which is due to worldwide over-production, increases the process of desertification and the migration of people, who abandon their lands looking for a better income. The absence of profits also obstructs the application of environmental practices and the continuity of agricultural businesses.

Any new industrial crop for which there is a market, and which appears adapted to the region, would be attractive. Chia (*Salvia hispanica* L.) is a possible new crop for food and industry. This plant was used by the Aztec tribes in the early history of Mesoamerica. This grain crop was important not only for food, but also for medicines and paints. Chia oil is a centuries-old ingredient that has been rediscovered for today's cosmetics and nutritional applications (1).

Although chia has been cultivated for several centuries by Aztec Indians (2), at present it is only cultivated in the Los Altos region, Jalisco State, Mexico. The total area cultivated is less than 450 hectares per year. On average, production fields are no bigger than 6.3 hectares. All of the work is done by hand. The current trend is to replace the crop with corn, which has a fixed price and is subsidized by government programs (3).

Chia oil is extremely high in polyunsaturated fatty acids, particularly ω3 linolenic acid. The main components are linoleic (17–26%) and linolenic (50–57%) acids (4).

The composition of vegetable oils plays an important part in their chemistry. This is determined by the ratio between saturated and unsaturated fatty acids. A high proportion of monounsaturated and polyunsaturated fatty acids is particularly desirable in food products (5,6).

Human diets with high fat content have been associated with cancer and cardiovascular diseases. However, populations that consume increased amounts of fats rich in ω3 fatty acids have been shown to have a much lower incidence of coronary heart disease than populations that consume primarily ω6 fatty acids (6).

Climatic conditions and geographical location are known to influence fatty acids in soybean, sunflower, and safflower oil (7,8). Early plantations in Argentina showed variation in oil content and in fatty acid composition compared to native chia plantations (9). Except for this reference, no information in the literature concerning the effects of environmental and geographic factors on the levels of fatty acids in chia oil was found. Thus, the objective of this study was to examine the influence of location on the fatty acid composition of chia oil.

MATERIALS AND METHODS

Seeds from Chia harvested in June 1993 in Catamarca, Argentina, were sown in five Northwestern Argentina locations. The latitude, longitude, elevation, date of planting, and date of the first frost are shown in Table 1. The climatic variables measured were: maximum and minimum average temperatures and rainfall (Table 2). Each plot was grown under dryland conditions, except for Sumalao, where irrigation was applied twice a month.

The chia seed was collected by hand from random plants, then divided into four subsamples. Seed was harvested after frost, then cleaned and dried in the shade. The seeds were stored until September 1994 when the oleic, linoleic, linolenic, palmitic, and stearic acid content were determined. This analysis was done in the laboratories of the Argentine

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TABLE 1
Characteristics of the Five Locations in Northwestern Argentina Where Chia Was Planted

Location (province)	Latitude	Longitude	Elevation (meters)	Planting date (1993)	Date of frost (1993)
Sumalao (Catamarca)	28° 28′	65° 44′	500	12/30	6/24
Yuto (Jujuy)	23° 28′	64° 27′	345	1/20	6/26
Metan (Salta)	25° 30′	64° 58′	859	1/20	6/26
R. de Lerma (Salta)[a]	24° 29′	65° 34′	1332	12/30	6/25
Pichanal (Salta)	23° 20′	64° 13′	306	1/20	6/26

[a]R. Rosario.

TABLE 2
Weather Conditions of the Five Argentine Locations

Location	Variable	Jan.	Feb.	Mar.	April	May	June	Total
Sumalao	Maximum temperature °C	33.2	30.1	29.8	23.8	25.2	22.8	27.5
	Minimum temperature °C	21.5	19.0	18.1	12.6	12.3	8.4	15.3
	Rainfall (mm)	115	143	6	21	4	0	289
Metan	Maximum temperature °C	29.1	26.4	26.4	22.6	23.4	20.9	24.8
	Minimum temperature °C	17.5	16.7	14.8	12.5	12.1	9.1	13.8
	Rainfall (mm)	147	175	99	117	27	11	576
Rosario de Lerma	Maximum temperature °C	26.6	25.3	25.2	22.3	23.6	21.9	24.2
	Minimum temperature °C	16.3	15.7	13.9	11.8	10.1	7.1	12.5
	Rainfall (mm)	216	108	51	0	0	0	375
Yuto	Maximum temperature °C	33.0	29.7	30.6	24.7	27.0	25.1	28.4
	Minimum temperature °C	20.6	19.6	18.1	16.1	15.2	11.6	16.9
	Rainfall (mm)	311	196	32	37	23	4	603
Pichanal	Maximum temperature °C	34.4	30.5	32.8	26.4	28.6	27.2	30.0
	Minimum temperature °C	21.7	20.3	18.3	16.6	15.4	13.2	17.6
	Rainfall (mm)	223	200	31	6	45	3	508

Institute of Vegetable Health. The equipment used was a Hewlett-Packard 5840A gas liquid chromatograph (Palo Alto, CA), and procedures specified in International Standard ISO 5509-1978 item 6 (10) were followed.

Each variable was compared by analysis of variance. When the F value was significant, the means were separated with Duncan's New Multiple Range Test. Correlation coefficients were determined between the fatty acid composition and temperature.

RESULTS AND DISCUSSION

Chromatographic analysis of the oil composition showed the presence of linolenic, linoleic, oleic, stearic, and palmitic fatty acids in the seed from all locations (Table 3). Oil percentages and fatty acid relationships differed among locations, however.

The total percentage of oil was greater in Rosario de Lerma, Yuto, and Sumalao and comparable in Metan and Pichanal to the percentage of oil from chia seeds (35.7%) grown in Jalisco, Mexico, which is its native location. Except for Pichanal, all samples exceeded the oil percentage (33.0%) produced by seeds grown in Colonia del Valle, Catamarca, in 1992 (9).

Analysis of the fatty acid composition demonstrated that linolenic acid was predominant and varied from 63.4 to 60.7% of the total. The oil from Metan contained a statistically significant ($P > 0.05$) greater percentage of this fatty acid.

The oil from Pichanal contained the lowest percentage of linolenic acid and was statistically different from the other samples ($P > 0.05$). All of the oils analyzed had percentages of linolenic acid higher than 55.3%, the level obtained from seed grown in the region where it occurs naturally and the level from seed collected in Colonia del Valle, Catamarca in 1993 (9). The percentage of the other fatty acids also had significant differences ($P > 0.05$) among locations, especially oleic acid percentage.

The differences between locations are presumably due to effects of one or more environmental factors. The effects of temperature, light, soil type, and nutrition can affect seed oil quantity and quality. The effect of temperature on oil composition (11,12) was studied. Although some generalization is possible concerning the effects of temperature on the development of oils in oil seed crops, it is obvious that consideration must be given to the species and variety involved (13).

Negative correlation between linolenic acid and April and May maximum mean temperature was significant ($P > 0.05$)

TABLE 3
Seed Oil Content and Fatty Acid Composition

		Fatty acids[a]				
Place	Oil (%)	Linolenic (%)	Linoleic (%)	Oleic (%)	Stearic (%)	Palmitic (%)
Metan	35.6^{c}	63.4^{b}	19.8^{c}	7.3^{d}	3.3^{c}	6.2^{c}
Rosario de Lerma	38.6^{b}	62.7^{c}	$20.2^{b,c}$	7.8^{c}	3.1^{c}	6.3^{c}
Sumalao	35.9^{c}	$62.4^{c,d}$	20.8^{b}	7.3^{d}	3.1^{c}	6.4^{c}
Yuto	$37.4^{b,c}$	52.0^{d}	$20.3^{b,c}$	$7.6^{c,d}$	3.1^{c}	7.1^{b}
Pichanal	32.3^{d}	60.7^{e}	$20.3^{b,c}$	8.2^{b}	3.7^{b}	6.9^{b}

[a]Within a column, means followed by the same letter are not statistically different at the 0.05 probability level according to Duncan's New Multiple Range Test. All locations are in Argentina.

TABLE 4
Correlation Coefficients

Trait pairs	Coefficient[a]
Linolenic acid vs.:	
April maximum mean temperature	−0.879
May maximum mean temperature	−0.878
Palmitic acid vs.:	
April maximum mean temperature	0.898
May maximum mean temperature	0.884

[a]Significant at $P > 0.05$.

(Table 4). The chia seed was formed between the beginning of April and the end of May. The high temperatures could have affected the formation of linolenic acid, as is found in other oil crops (14).

Palmitic fatty acid percentage was positively correlated ($P > 0.05$) with April and May maximum mean temperature (Table 4). This positive correlation is opposite the behavior of saturated fatty acid content of rape, sunflower, flax, safflower, and castor bean oils, which remain constant when temperature increases during seed development (13).

This research showed that location influenced the oil content and the fatty acid composition of chia seeds. Except for Pichanal, Salta, all of the chia plots produced seed with a higher oil percentage and linolenic acid content than those obtained from the region where chia grows naturally. Additional studies should be conducted to determine the exact environmental influences on the formation of chia oil quantity and quality.

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