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Full Length Research Paper

Oil content and fatty acid composition of dimorphic seeds of desert halophyte *Suaeda aralocaspica*

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***Suaeda aralocaspica*, a desert annual halophyte in the family Chenopodiaceae, produces two morphologically distinct types of seeds on the same plant. The two types of seeds were separated and analysed for oil content and fatty acid composition in order to evaluate and compare their potential as a source of edible oil. No significant differences in the oil content and statistically significant differences in fatty acid composition were found between dimorphic seeds. Seed oil content of this species was > 29% on a dry weight basis. Both types of seeds contain ca. 93% unsaturated fatty acids, with linoleic (> 68%) and oleic acid (> 20%) being the most abundant. High seed oil content and significant percentage of polyunsaturated fatty acids make *S. aralocaspica* a promising halophyte as a source of high-quality edible oil.**

Key words: Linoleic, seed oil, *Suaeda aralocaspica*, unsaturated fatty acid.

INTRODUCTION

With the rapid growth of human population and irreversible spread of soil salinization in the arid and semiarid regions, the competition for fresh water and arable land among agriculture, domestic use and industrial use has tremendously increased (Rozema and Flowers, 2008; Fedoroff et al., 2010). To resolve this conflict, experts propose developing salt-tolerant crops through two methods: breeding and domestication. The first method is to improve the salt tolerance of conventional crops through traditional breeding or molecular genetic modification. Nevertheless, difference between the upper limit of salt resistance exhibited by crops and that required to tolerate high soil salinity is great (Glenn et al., 1991). The second method is to domesticate halophytes. Many of these salt-adapted plants could potentially become oilseed crops (Weber et al., 2007). People try to find new sources of edible oils to meet nutritional, industrial and developmental needs (Nehdi, 2011). Growing oilseed halophytes would not compete with the growth of present crops in arable land and therefore not affect the regular food supply. Meanwhile, halophytes thrive under certain salinity level of soil and can be watered with saline water without harmful effects on growth and reproduction (Flowers and Colmer, 2008; Khan et al., 2009).

New sources of edible vegetable oils that can grow in saline soil have been surveyed and sifted during the past few decades (O'Leary et al., 1985; Weber et al., 2007). Seed yields of some halophytes equal or exceed traditional oilseed crops. Meanwhile, the seeds contain appreciable quantities of edible oil with high quality. For example, *Salicornia bigelovii*, a potential oilseed crop, produced 2 tons of seeds per hectra. The seed contained 26-33 percent oil and the oil was high in linoleic acid (> 73%) (Glenn et al., 1991). Weber et al. (2007) analyzed oil characteristics of six halophytes (*Arthrocnemum indicum*, *Alhaji maurorum*, *Cressa cretica*, *Halopyrum mucronatum*, *Haloxylon stocksii* and *Suaeda fruticosa*) to determine their potential as a source of edible vegetable oil. The results indicate that the oil derived from seeds of halophytes especially *S. fruticosa* could be used for human consumption (Weber et al., 2007). Their reports

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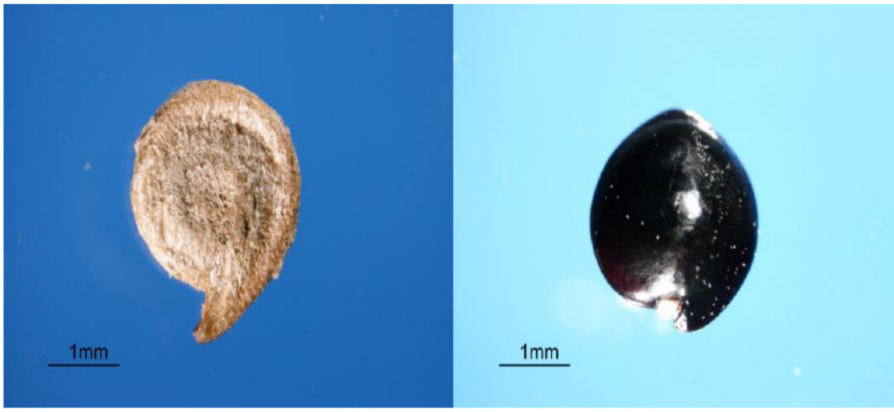

Figure 1. Brown (left) and black (right) seeds of *S. aralocaspica*.

suggest that the quality of extracted oil from seeds of some halophytic species particularly *Salicornia* spp. and *Suaeda* spp. are almost similar with the regular edible oils.

There are approximately 100 species in the *Suaeda*, which is a multipurpose species with many traits and considerable potential (Commissione and Florae, 1994). In the recent years, the economic importance of *Suaeda* has been increasing because of the use of its oil for human health.

According to the existing data, except for *Salicornia*, *Suaeda* may be the optimal candidate to produce edible vegetable oil in saline soil (Glenn et al., 1991; Yu et al., 2005; Li and Fan, 2010).*S. aralocaspica* can grow well under adverse edaphic conditions in central Asia because of its tolerance to high salinity and low nutrient requirements (Wang, 2010).

This species is an annual plant that grows up to 50 cm in height and is commonly found in the Gobi desert, where it grows in saline-alkaline sandy soils (Commissione and Florae, 1994). Plants bloom in August and produce two types of seeds on the same plant in September. The brown seed has a soft seed coat and the black seed has a rigid seed coat (Figure 1).

The two seed morphs also differ in size and weight. Brown seeds have a mean length of 3.17 mm and a mean dry mass of 2.51 mg. Black seeds have a mean length of 2.45 mm and a mean dry mass of 2.33 mg. For both seed morphs, the embryo is fully developed and planospiral (Wang et al., 2008).

Although detail studies on germination and growth of halophytes were reported, little work has been done on evaluation of chemical composition, especially fatty acid composition of seeds of halophytic species in China (Li et al., 2005; Yu et al., 2005; Song et al., 2009; Li and Fan, 2010). Very little is known about the difference of oil characteristics between different types of seeds on a single plant (Siddiqui and Khan, 2011). In the present work we analyzed oil content and fatty acid compositions of dimorphic seeds of *S. aralocaspica* collected from Xinjiang province of China., in order to compare oil characteristics between the two seed morphs, and to evaluate its potential as source of edible oil.

MATERIALS AND METHODS

Seeds

Freshly matured seeds of *S. aralocaspica* were randomly collected from ca. 100 plants growing in saline soils in Fukang, Northern Xinjiang, China, in October 2010. The fruits were allowed to dry for two weeks, and then the seeds were cleaned and air-dried at ambient temperature, and then separated by their color. Dry seeds were stored at room temperature for experimental use.

Oil extraction

The oil contents were analyzed with Soxhlet apparatus. In the Soxhlet extraction procedure, 10-g sample of the crushed seeds was packed in a thimble and the oils were extracted with hexane (99%) for 6 h. After extraction, concentrated oil was kept at 80°C for 12 h. The oil was stored at -18°C in sealed tubes prior to analysis.

Fatty acid analysis

The fatty acid compositions in samples were determined by gas chromatography of the fatty acid methyl esters (FAMEs). The FAMEs were obtained by transesterification with a cold methanolic solution of potassium hydroxide. Oil samples solubilized in hexane, esterified using potassium methoxide and analyzed on Agilent 6890N gas chromatograph equipped with a flame ionization detector (FID) and a polar capillary column: Supelcowax 10 (0.25 mm internal diameter, 60 m length and 0.25 µm film thickness). The operational conditions were: oven temperature programme, the column held initially at 100°C for 2 min after injection, then increased to 200°C at a rate of 4°C/min. The final temperature was increased to 240°C at a rate of 6°C/min and held for 43 min; The operational conditions were: injector temperature 250°C; detector (FID) temperature 260°C; carrier gas was nitrogen at a flow of 1 ml/min; inlet pressure was 25 psi and linear gas velocity was 22 cm/s;

Table 1. Oil contents and percentages of saturated, monounsaturated and polyunsaturated fatty acids of different seed morphs of *S. aralocaspica*. Different letters followed in each row indicate significant differences in each type of fatty acids between the two seed morphs.

	Brown seeds	Black seeds
Total oil	29.64 ± 0.22a	29.92 ± 0.27a
Saturated	6.53 ± 0.19a	6.71 ± 0.06a
Monounsaturated	22.11 ± 0.08a	23.87 ± 0.26b
Polyunsaturated	70.85 ± 0.16a	69.19 ± 0.15b
Total unsaturated	92.96 ± 0.10a	93.06 ± 0.27a
Unsaturated/saturated	14.23	13.88
Polyunsaturated/saturated	10.85	10.32

split ratio was 50:1 and injected volume was 1 μL. Identification of the components was assigned by comparison of their retention times of FAME with the known standard mixture (Supelco 37 Component FAME Mix) (Ariffin et al., 2009).

Data analysis

Data were expressed as means ± standard error (n=3). Seed oil content is expressed as percentage on a seed dry weight basis. Fatty acids are expressed as the relative percentage of each individual fatty acid of the total fatty acids available in the sample. All determinations were performed in triplicate. Differences between seed morphs in all the analysis were tested using one-way ANOVA with seed morph as the factor. The level of significance was set at P<0.05.

RESULTS AND DISCUSSION

The average percentages of oil for brown and black seeds were 29.64 and 29.92%, respectively. There were no significant differences of the oil content between the two seed morphs of seeds (P=0.475) (Table 1).

Fatty acids for both seed morphs were composed of saturated, monounsaturated and polyunsaturated fatty acids (Table 1). The predominant fatty acids were polyunsaturated and their amount was ca. 70% of the total fatty acids. Significant difference was observed between brown and black seeds in monounsaturated and polyunsaturated fatty acids. Ratio of unsaturated to saturated fatty acids was ca. 14, and ratio of polyunsaturated to saturated fatty acids was > 10 for both seed morphs (Table 1). Analysis of seed oil showed the presence of 16 fatty acids of which ten were saturated and six were unsaturated fatty acids (Table 2). The predominant fatty acid was linoleic acid (18:2), followed by oleic acid (18:1), palmitic acid (16:0), stearic acid (18:0), r-linolenic acid (18:3) (Table 2). Seeds of halophyte *S. bigelovii* contained ca. 30% oil (Glenn et al., 1991). Other species of *Suaeda* (*S. corniculata*, *S. fruticosa*, *S. glauca*, *S. moquinii*, *S. physophora*, *S. salsa*) contain 16 to 27% oil (Table 3). Oil content varied from 1 to 51% in different halophytes of previous studies (O'Leary et al., 1985; Weber et al., 2007). Oil content of traditional oilseed plants (soybean, safflower, sesame, sunflower, etc.) ranged from 19 to 49% (Weiss, 1983; Fayyaz-ul-Hassan et al., 2011).

The data presented here clearly indicate the potential to extract high-quality edible oil from seeds of desert halophyte *S. aralocaspica*. Oil quality is related to its degree of unsaturation (Ariffin et al., 2009). Oil with high unsaturation is considered to be healthy. Ratio of unsaturated to saturated fatty acids is an important index of the nutritional value of edible oil. The oil of *S. aralocaspica* seeds was characterized by a high polyunsaturated/saturated ratio of 14, which is higher than common edible oils. Unsaturation in the seeds of various halophytes (*Halopyrum*, *Haloxylon*, *Suaeda*, etc) has been reported to range from 54 to 96% (Yu et al., 2005; Mu et al., 2006; Weber et al., 2007; Cui et al., 2010; Li and Fan, 2010). A high ratio of polyunsaturated to saturate is regarded to be favourable for the reduction of serum cholesterol and atherosclerosis and may result in the prevention of heart diseases. The oil is not fit for human consumption if it contain undesirable component such as high level of erucic acid. The oil from the seeds of *S. aralocaspica* was free from any such undesirable components and could safely be recommended for human consumption.

The seed oil of *S. aralocaspica* can be regarded as linoleic-oleic oil because of the abundance of linoleic acid, followed by oleic acid. While canola and olive oil are dominated by monounsaturated oleic acid, the fatty acid fractions of *S. aralocaspica* such as high linoleic acid are generally comparable with oil crops. The present fatty acid composition of seed oil makes it desirable in terms of nutrition and it may be used as high-quality edible oil.

It is not necessary to separate dimorphic seeds when producing oil because there is no significant difference in oil content and just slight difference in fatty acid composition between the two types of seeds. Meanwhile, Cultivation of *S. aralocaspica* in experimental fields is necessary to assess the actual seed yield and the effect of environmental conditions on oil characteristics.

Table 2. Fatty acid composition (% of total fatty acids) of *S. aralocaspica* seed oil. Different letters followed in each row indicate significant differences in each type of fatty acids between the two seed morphs.

% Fatty acid	Brown seed	Black seed
Saturated fatty acid		
Myristic acid (C14: 0)	0.065 ± 0.001a	0.052 ± 0.001b
Palmitic acid (C16: 0)	3.905 ± 0.004a	3.880 ± 0.007b
Stearic acid (C18: 0)	1.377 ± 0.011a	1.487 ± 0.008b
Arachidic acid (C20: 0)	0.740 ± 0.195a	0.992 ± 0.054a
Behenic acid (C22: 0)	0.339 ± 0.031a	0.275 ± 0.088a
Lignoceric acid (C24: 0)	0.105 ± 0.007a	0.020 ± 0.020b
Monounsaturated fatty acid		
Palmitoleic acid (C16: 1)	0.090 ± 0.001a	0.093 ± 0.002a
cis-Palmitoleic acid (C16: 1)	0.063 ± 0.000a	0.073 ± 0.001b
Oleic acid (C18: 1)	20.805 ± 0.053a	22.427 ± 0.051b
tra- Elaidic acid (C18: 1)	0.687 ± 0.012a	0.576 ± 0.078a
Eicosenoic acid (C20: 1)	0.136 ± 0.073a	0.525 ± 0.289a
cis-Eicosenoic acid (C20: 1)	0.332 ± 0.074a	0.180 ± 0.117a
Polyunsaturated fatty acid		
Linoleic acid (C18: 2)	69.627 ± 0.164a	68.431 ± 0.147b
g-Linolenic acid (C18: 3)	0.055 ± 0.000a	0.078 ± 0.001b
r-Linolenic acid (C18: 3)	1.103 ± 0.010a	0.615 ± 0.006b
cis-Eicosadienoic acid (C20: 2)	0.064 ± 0.013a	0.064 ± 0.018a

Table 3. Oil content and average percentages of unsaturated fatty acids of *Suaeda* seed.

Specie	Oil content (% dry seed weight)	Unsaturated (% fatty acids)
S. aralocaspica	30	93
S. corniculata	16-25	88-94
S. fruticosa	25	74
S. glauca	24	89
S. moquinii	25	74
S. physophora	27	96
S. salsa	16-20	89-91

Conclusion

There were no differences in the oil content and in the fatty acid compositions between both types of seeds of *S. aralocaspica*. The oil from *S. aralocaspica* could be considered alternative source of high-quality edible oil due to presence of all saturated and unsaturated fatty acids required for human health, and available high percent of polyunsaturated fatty acids. The *S. aralocaspica* appears to be a potentially valuable oilseed crop, which grows well in inland saline deserts.

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