Journal of Food and Nutrition Research, 2017, Vol. 5, No. 1, 22-26
Available online at http://pubs.sciepub.com/jfnr/5/1/4

DOI:10.12691/jfnr-5-1-4

Chemical Composition and Nutritional Evaluation of the Seeds of *Suaeda salsa* (L.) Pall

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Abstract Chemical composition and nutritional evaluation of the seed of *Suaeda salsa* were studied. The results indicated that seeds contained 5.35% moisture, 4.76% ash, 25.68% fat, 15.27% fiber, 27.32% protein and 20.11% carbohydrates. Sodium was the predominant element followed by potassium and then calcium. Vitamin C and vitamin E were detected. The amino acid profile compared good with FAO/WHO recommended pattern except for cystine/methionine, isoleucine, tyrosine/phenylalanine and tryptophane. Also, the first limiting amino acid was cystine/methionine. Fatty acid composition showed that linoleic acid was the major fatty acid, followed by oleic acid, palmitic acid, linolenic acid, stearic acid and palmitoleic acid. *S. salsa* seed was a kind of oil source that could satisfy the standards of modern nutrition towards healthy food and it possesses the development and utilization values.

Keywords: *proximate composition, vitamins, mineral, amino acids, fatty acids, Suaeda salsa seed*

Cite This Article: Chaofeng Li, Boping Tang, and Senhao Jiang, "Chemical Composition and Nutritional Evaluation of the Seeds of *Suaeda salsa* (L.) Pall." *Journal of Food and Nutrition Research*, vol. 5, no. 1 (2017): 22-26. doi: 10.12691/jfnr-5-1-4.

1. Introduction

Population explosion, land degradation, resource short and environmental pollution have attracted wide concerns and worries. Soil compaction and pollution were the worldwide problem of resources and ecology, has become the biggest obstacle to restricting the agricultural production, and then threatened the human survival.

Suaeda salsa (L.) Pall is an annual herb and euhalophyte [1], which occurs both on saline soil and in the intertidal zone [1], and the typical halophyte growing in soil which is higher than 2% in salt [2]. *S. salsa* was the most luxuriant in the humid soil which was 1% in salt and usually formed the single dominant plant community [2]. *S. salsa* showed the salt-tolerance ability, and then could effectively reduce salt content, increase soil organic matter and improve N, P, K in soil surface. Therefore, *S. salsa*, which could improve saline soil, was the preferred plant improving saline alkali soil and could obtain good economic, ecological and social benefits [2,3].

The fresh branches of *S. salsa* were a highly valuable vegetable and its seeds could produce an edible oil, especially for the Chinese peasants in a time of serious famine [4]. Also, *S. salsa* was frequently used as medicine to treating fever, food retention, blood sugar and pressure, expanding blood vessel, preventing cardiovascular system diseases and improving body immunity [5]. In addition, the seed of *S. salsa* was an important food source for animals and recognized as the economic potential resource due to the high amount of protein and crude fiber [5]. Therefore, this study investigated the chemical composition and nutritive value of *S. salsa* seed. This study would provide information on whether or not advisable to incorporate this seed into the oil source and the feed additives.

2. Material and Methods

Dry mature seeds of *S. salsa* were collected from coastal beach in Dafeng district, Yancheng city, Jiangsu Province. Seeds were ground using an electric mill then used for chemical composition analyses. The coarsely ground seeds were passed through a 0.25 mm sieve to obtain the flour which will be used for chemical composition determination. N-Hexane was of chromatographic grade and purchased from Fisher Scientific. Linoleic Acid was of chromatographic grade and purchased from Sigma-Aldrich Co. (St. Louis, Mo., USA). All the other chemicals and reagents used in this study were of analytical grade and purchased from China.

2.1. Proximate Analysis

Proximate composition of the *S. salsa* seeds power was determined by using the standard Association of Official Analytical Chemists procedures [6]. Moisture content was evaluated by the loss of weight upon drying in an oven at 100°C to a constant weight. Ash was assessed by incineration at 550°C of known weights of the samples in a muffle furnace (Method No. 930.05). Crude fat was found out by exhaustively extracting a known weight of sample in petroleum ether (boiling point, 30-60°C) in a Soxhlet extractor (Method No. 930.09). Protein amount

(N× 6.25) was measured by the Kjeldahl method (Method No. 978.04). Crude fiber quantity was ascertained after digesting a known weight of fat-free sample in refluxing 1.25% sulfuric acid and 1.25% sodium hydroxide (Method No.930.10). Carbohydrates were calculated by difference.

2.2. Vitamins Analysis

The vitamin C and vitamin E were determined by the methods of Li, *et al* [7] and Yang, *et al* [8] with some modifications.

S. salsa seeds power (1.00 g) was mixed with 80 mL 25 mmol/L metaphosphoric acid at an ice bath, extracted by ultrasonic at 400 W for 30 min, centrifuged at 15000 rpm for 10 min at 4°C. The supernatant was made up to 100 mL by 25 mmol/L metaphosphoric acid, and then filtered by 0.22 μm membrane and stored with airtight and light-free. Vitamin C was performed using an Ultimate 3000, equipped with a UV detector and a column, Diamonsil C18 (250 mm × 4.6 mm, 5 μm); The mobile phase was 0.005 mol/L sodium ethanesulphonate (pH 3.2) - methanol (7:3, v/v). The flow rate was 1.0 mL/min. The injection volume was 10 μL. The detection wavelength was 254 nm and the column temperature was 30°C.

S. salsa seeds power (1.00 g) was mixed with absolute alcohol at room temperature, extracted by ultrasonic at 400 W for 20 min, centrifuged (15000 rpm, 10 min, 4°C) at 15000 rpm for 10 min. The supernatant was made up to 50 mL by absolute alcohol, and then filtered by 0.22 μm membrane. Vitamin E was performed using an Ultimate 3000, equipped with a UV detector and a column, Diamonsil C18 (250 mm × 4.6 mm, 5 μm); The mobile phase was methanol. The flow rate was 1.0 mL/min. The injection volume was 10 μL. The detection wavelength was 275 nm and the column temperature was 35°C.

2.3. Minerals Analysis

The analysis of mineral elements was performed according to the method of Xie, *et al* [9] with some modifications. Briefly, approximately 1.00 g of *S. salsa* seeds power was digested by dry incineration in porcelain containers by adding 10 mL of concentrated HNO_3 (10% solution, w/v). The mixture was first maintained over a hot plate until dryness and then in muffle furnace at 450-500°C for 16 h. The incinerated sample was then treated with 1 mL of concentrated HNO_3 for ash whitening and this mixture was digested again for 6 h. Then, the residue was dissolved in 5 mL of 10% (v/v) HNO_3 and filtered through a filter paper. The sample was diluted to 25 mL with ultra pure water. Blank solutions were prepared in the same way as the *S. salsa* seeds samples. The contents of the elements were determined by an inductively coupled plasma atomic absorption spectrometer (FEI, Quanta 200) with axial viewing of the emitted radiation. The flow rate of sample uptake was 1.5 mL/min. Operating parameters for the instrument included forward power 1300 W, coolant gas flow rate 15.0 L/min, auxiliary gas flow rate 0.2 L/min and nebulizer gas flow rate 0.9 L/min.

2.4. Amino Acids Analysis

Amino acids were determined by HPLC (Thermo-Fisher, Ultimate 3000, USA) according to the method of Yang, *et al* [10]. The *S. salsa* seeds power (1.00 g) was hydrolyzed with 5 mL of 6 mol/L HCl or 4.2 mol/L NaOH in a sealed tube at 110°C in an oven for 24 h. The hydrolyzed sample was made up to 50 mL and filtered using a 0.45 μm membrane filter. Sample solution (200 μL) was completely mixed with 10 μL 0.5 g/L leucine, 100 μL 0.1 mol/L isothiocyanate phenyl - acetonitrile solution, 100 μL 1 mol/L triethylamine - acetonitrile solution, and then placed at room temperature for 1 h, added 400μL n-hexane. Vibrated for 1 min, the mixture was placed for 10 min. The lower solution was absorbed by the syringe and filtered by 0.45 μm membrane filter.

Chromatographic conditions: Amino acids analysis were performed using an Ultimate 3000, equipped with a UV detector and a column, Venusil XBA-AA column (250 mm × 4.6 mm, 5 μm); The mobile phase was consisted of solvents A (0.1mol/L sodium acetate -acetonitrile 97:3, v/v) and solvent B (acetonitrile - ultra pure water 4:1, v/v). The elution was performed as a linear gradient as follows: 0 min, 0% B; 13 min, 7% B; 23 min, 23% B; 29 min, 35% B; 35 min, 40% B; 40 min, 100% B; 45 min, 100% B; 47 min, 0% B; The column temperature was 40°C. The quantification of analysis was performed by UV detector at 254 nm. The injection volume was 2 μL. The flow rate was 1.0 mL/min.

2.5. Fatty Acids Analysis

Accurately weighed 200 mg *S. salsa* seeds power, added 2 mL 1mol/L KOH/methanol solution to saponify for 10 min at 70°C water bath and then cooled down, added 3 mL 1mol/L boron trifluoride/methanol solution to methyl esterification for 10 min at 70°C water bath. After cooling down, accurately added 0.5 mL n-hexane and the supernatant of organic phase was determined by gas chromatography (Agilent 7890B) according to the method of Liang, *et al* [11]. Fatty acids analysis was performed using a Gas Chromatograph (GC-17A), equipped with a flame ionization detector and a column, HP-88, (100 m, 0.25mm i.d. x 0.2 μm). The column temperature was programmed from 70°C for 1 min then elevated to 280°C at a rate of 25°C /min and hold at 280°C for 10 min. All the injector and detector temperatures were 250°C. Nitrogen was the carrier gas at a flow rate of 1.5 mL/min.

2.6. Statistical Analysis

All the analyses were performed in triplicate. Data were expressed as mean ± standard deviation (SD). Statistical analysis was done using Microsoft office excel 2007.

3. Results

3.1. Proximate Composition

The results presented in Table 1 showed that the moisture content of *S. salsa* seeds was low (53.57 g/Kg) indicating excellent storing quality for this seeds. Ash content of *S. salsa* seeds was 47.61 g/Kg. The crude fat yield (256.89 g/Kg) was higher than that reported for soybean, and basically equal in *Oenothera biennis* L. which was health care oil widely concerned by the world

[12]. The relatively high level of crude fat in *S. salsa* seeds indicated that the seeds would be a good source of energy. The content of crude fiber was 152.75 g/Kg. Therefore, *S. salsa* seeds could be considered as a good source for dietary fiber. In fact, the dietary fiber had an important role in the human nutrition in that fiber helped to maintain the health of the gastrointestinal tract, but in excess may bind trace elements, leading to deficiencies of iron and zinc [13].

The results showed that *S. salsa* seeds contained the abundant protein (273.20 g/Kg). These results indicated that *S. salsa* seeds could be included in food formulations as a source of protein. Regarding the carbohydrate content, *S. salsa* seeds contained 201.18 g/Kg carbohydrate. This level of the carbohydrate was low, due to the higher levels of crude protein, crude fat and fiber in the seed. Therefore, the chemical composition of *S. salsa* seeds was determined to be nutritious and incorporating this seeds into the human diets would improve the nutrition status.

3.2. Minerals

Plants were known to provide the required minerals important for human health. Table 1 showed the minerals composition of *S. salsa* seeds. Sodium was the predominant mineral, the other elements in descending order by quantity were K, Ca, P, Fe, Zn, Mn, Cu and Se. Based on the above results, *S. salsa* seeds were a good source for minerals, especially Na, K, Ca, P, Fe and Zn. Specially, Se was abundant in *S. salsa* seeds. Since some flours used in commercial feed for livestock were deficient in one or more element and protein, addition of *S. salsa* seeds flour might improve their nutritional properties. Moreover, *S. salsa* could be used as the material of plant salt extraction.

3.3. Vitamins

Vitamins were important indexes for evaluation of nutritive value and essential to human health. In this paper, fat-soluble vitamin E and water-soluble vitamin C were determined. Results were shown in Table1. As the results showed vitamin E was richer than the water-soluble vitamin C in *S. salsa* seeds and the content reached 2000 mg/Kg.

Table 1. The Proximate Composition of *S. salsa* Seeds

Components	Content	Components	Content (mg/Kg)
Moisture (g/Kg)	53.57±1.34	Ca	840.39±5.72
Ash (g/Kg)	47.61±2.06	K	1260.10±9.37
Crude protein (g/Kg)	273.20±4.15	Na	4460.41±15.83
Crude fat (g/Kg)	256.89±5.01	P	380.24±6.20
Fiber (g/Kg)	152.75±3.60	Zn	57.83±3.16
Carbohydrate (g/Kg)	201.18±2.74	Fe	140.90±5.61
Vit C (mg/Kg)	141.08±*15.38*	Cu	15.57±2.14
Vit E (mg/Kg)	2000.49±27.13	Mn	52.08±4.15
		Se	1.1±0.54

Values were mean ± SD of mean of triplicate analyses.

Table 2. Amino Acids Composition of *S. salsa* Seeds

EAA	Content (mg/g)	NEAA	Content (mg/g)
Thr	7.42±0.11	Asp	17.21±0.26
Val	9.84±0.09	Ser	11.67±0.15
Met	4.57±0.05	Glu	32.87±0.31
Ile	7.90±0.07	Pro	7.84±0.22
Leu	12.68±0.23	Gly	11.31±0.50
Phe	9.43±0.09	Ala	7.86±0.00
Lys	11.39±0.14	Arg	22.53±0.20
Trp	8.61±0.31	Cys	2.19±0.00
His	5.79±0.08	Tyr	8.70±0.03
EAA	71.84±1.08	NEAA	127.97±1.59
TAA	199.81±2.64	NEAA/TAA	0.64
EAA/TAA	0.36	EAA/NEAA	0.56

Values were mean ± SD of mean of triplicate analyses.

Table 3. AAS and CS in the protein from *S. salsa* seeds

EAA	Content (mg/g)	WHO pattern	Whole egg pattern	AAS	CS
Thr	7.42±0.11	7	6	0.71	123.7
Val	9.84±0.09	10	7	0.72	140.6
Met+Cys	4.57±0.03	13	4.9	0.34	138.0
Ile	7.90±0.07	10	7.2	0.56	109.7
Leu	12.68±0.23	14	10.8	0.63	117.4
Phe+Tyr	9.43±0.07	14	11.9	0.71	152.4
Lys	11.39±0.14	12	8.4	0.68	134.5
Trp	8.61±0.31	3.5	2	0.91	430.0

Values were mean ± SD of mean of triplicate analyses.

3.4. Amino Acids

The amino acid profile and essential amino acid score (AAS) for *S. salsa* seeds were listed in Table 2 and Table 3. The potential food value of the seeds proteins (as a source of amino acids) could be justified by comparison with the FAO reference pattern [14]. In *S. salsa* seeds, the essential amino acids/total amino acids (EAA/TAA) was 0.36 and the essential amino acids/non-essential amino acids (EAA/NEAA) was 0.56. According with the ideal model recommended by FAO/WHO, the quality of protein was excellent when EAA/TAA was about 0.40 and EAA/NEAA was more than 0.60. Therefore, the *S. salsa* seeds were a good source of protein and used as the feed for livestock.

The amino acid profile of *S. salsa* seeds revealed that both threonine and tryptophan had higher levels than those listed in FAO/WHO reference pattern. Also, the level of valine and lysine were very similar to that of the FAO/WHO reference pattern. However, the other essential amino acids had lower levels when compared with those of the FAO/WHO reference pattern. Moreover, the result of AAS indicated that the most limiting amino acids were cystine/methionine (0.34) and isoleucine (0.56).

3.5. Fatty Acids

The fatty acid profile of *S. salsa* seeds was shown in Table 4. Linoleic acid was the predominant fatty acid (1769.47 mg/Kg), followed by oleic acid (355.84 mg/Kg), palmitic acid (193.54 mg/Kg), linolenic acid (114.94 mg/Kg),

stearic acid (50.43 mg/Kg) and palmitoleic acid (49.92 mg/Kg). These results indicated that linoleic acid in *S. salsa* seeds was richer than that of *Perilla frutescens* seeds and slightly less than those of *O. biennis* seeds and *Carthamus tinctorius* seeds. Also, the results of *S. salsa* seeds indicated that the seeds had relatively high levels of the essential fatty acid, linoleic acid, followed by oleic, palmitic and linolenic acid. The unsaturated fatty acids in *S. salsa* seeds were 2290.18 mg/Kg and more abundant than that of *O. biennis* seeds. Moreover, the higher index of mono- and polyunsaturated fatty acids would play an important role in human and animal health, and then the linoleic acid could play a significant role in reducing blood cholesterol levels when consumed regularly as a part of the diet [15]. Therefore, *S. salsa* seeds could be used as the material producing unsaturated fatty acids and linoleic acid. And then these indicated that the oil was highly nutritious.

Table 4. Fatty acids composition of *S. salsa* seeds

Fatty acids	Formula	Molecular weight	Relative content (mg/Kg)
palmitic acid	C16H32O2	256	193.54±13.02
palmitoleic acid	C16H30O2	254	49.92±1.90
oleic acid	C18H34O2	282	355.84±12.38
linoleic acid	C18H32O2	280	1769.47±51.27
linolenic acid	C18H30O2	278	114.94±10.36
stearic acid	C18H36O2	284	50.43±3.23
saturated fatty acids (SFA)			243.97±15.49
unsaturated fatty acids			2290.18±76.52
polyunsaturated fatty acids (PUFA)			1884.42±62.21
PUFA/SFA			7.72

Values were mean ± SD of mean of triplicate analyses.

4. Discussion

In all the oil crops, soybean was one of the most important oil plants in the world. In soybean, the fat content was above 20%, which was similar with that of *S. salsa* seeds and a bit less than that of *S. salsa* seeds. However, *S. salsa* usually grew in the desert, wasteland, beach, and so on, did not occupy the cultivated land and need to manage, and then naturally grew and died. Therefore, *S. salsa* had the high value of development in oil source, which should be taken enough attention, especially in the case of desertification, salinization, and deforestation. Furthermore, when *S. salsa* was cultivated and grown in the soil salinity of 0.23% ~ 0.98%, the yield of *S. salsa* seeds might been increased by 1 or 2 times [16].

In the nutrition evaluation of fatty acids, PUFA/SAF was an important index. When the ratio of PUFA/SAF was more than 2, the fat might reduce blood lipids. Moreover, the greater the ratio was, the stronger the ability to reduce blood lipids was. The PUFA/SAF ratio was 7.72 and much more than 2 in the fatty acids of *S. salsa* seeds, so *S. salsa* seeds oil, which was used as health edible oil, had the high valve. Because of the abundant nutrition, *Oenothera biennis* and *Perilla frutescens* had been become the oil plants, and the linoleic acid was 73.5% ~ 81.9% [17] and 10.43% ~ 16.65% [18], respectively. In *S. salsa* seeds oil, the linoleic acid was far richer than that of *Perilla frutescens*, and was similar with that of *Oenothera biennis* and *Carthamus tinctorius* L.. Therefore, *S. salsa* seeds oil could meet the need of the market and the development value, and could be used as the high quality and cheap material for synthesizing conjugated linoleic acid which had the function of anti-cancer, anti-cardiovascular diseases, and participated in lipolysis, metabolism and other physiological activity.

S. salsa was a kind of halophyte accumulating salt in vivo, and then could desalinate, reduce soil salinity, increase nitrogen, phosphorus, potassium, organic matter, microbial in soils, and so on, thereby improve the soil quality[19]. *S. salsa* was conducive to saline environment and vegetation restoration, could eliminate the bare salt and alkali wasteland, prevent soil erosion, protect wetlands [20]. *S. salsa* was very developed in root and one of an excellent sand fixing plants, could prevent the desert migration [21]. Thus, the development *S. salsa* had also the good ecological effect and meet the requirement for environmental improvement.

5. Conclusions

The present study on the chemical composition of *S. salsa* seeds suggested that these seeds could be useful as a new source of edible oil especially for health care and a favorable livestock feed for adding protein, and so on.

Acknowledgements

We are grateful for financial support from Jiangsu Province Natural Science Research Foundation, No. BK20150422 and Jiangsu Provincial Key Laboratory of Coastal wetland Bioresources and Environmental protection open Foundation, No. JKCBE2012027.

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