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Full Length Research Paper

Influence of water deficit and genotype on protein, oil contents and some physical characteristics of sunflower seeds

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Water deficit stress and genotype effects on crude protein, oil content and some physical properties of sunflower seeds were investigated. The analyses indicated that, water deficit stress and varietal difference influenced the proximate composition of sunflower seeds. The seeds from Azargol and Hysun 33 cultivars were found to have the highest and lowest oil contents of 45 and 42% respectively, while the seeds from Hysun 25 and 33 cultivars had the highest and lowest protein contents of 39 and 32% respectively. In general, as the water supply decreased oil content and physical characteristics of each cultivar were negatively affected, but protein content of each cultivar was positively affected. The cultivar with the highest protein content in well-watered and water deficit stress condition (irrigation after 50 and 150 mm cumulative evaporation from class A evaporation pan, respectively) had the following mean physical properties: length of 9.68 ± 0.5 and 7.44 ± 0.6 mm, width of 6.52 ± 1.3 and 4.21 ± 0.4 mm, thickness of 4.08 ± 0.51 and 3.11 ± 0.004 mm, volume of 142.7 ± 18.6 and 52.11 ± 1.8 mm^3, surface area of 105.7 ± 5.6 and 55.9 ± 1 mm^2, mass of 55.7 ± 1.2 and 28.4 ± 1.3 g and moisture content of 11.4 and 9.8% (d.b). However, the cultivar with the highest oil content in well-watered and maximum water deficit stress condition had the following mean physical properties: length of 12.73 ± 0.7 and 9.37 ± 0.3 mm, width of 5.76 ± 0.33 and 2.98 ± 0.02 mm, thickness of 3.33 ± 0.4 and 2.06 ± 0.05 mm, volume of 137.69 ± 6.8 and 31.35 ± 1.5 mm^3, surface area of 105.4 ± 5.2 and 42.1 ± 1.7 mm^2, mass of 53 ± 1.8 and 25.3 ± 0.2 g and moisture content of 9.9 and 9% (d.b).

Key words: Sunflower seed, water deficit stress, physical properties, protein content.

INTRODUCTION

Sunflower, with a world production of grain and oil, respectively over 28.5×10^6 and 10.5×10^6 Mg achieved on around 22.6×10^6 ha with a grain yield of 1.3 Mgha^{-1} (2003 to 2007 means), is one of the most common grown oilseed species (FAO -STAT Agriculture, 2009). Sunflower seeds contain a high amount of oil (40 to 50%) which is an important source of polyunsaturated fatty acid (linoleic acid) of potential health benefits (Monoti, 2004; Leon et al., 2003; Lopez et al., 2000). The growth, development and spatial distribution of plants are severely restricted by a variety of environmental stresses. Among different problems faced by crop plants, water stress is considered to be the most critical one (Boyer, 1982; Sinclair, 2005; Soriano et al., 2004). Reduced precipitation together with the higher evapotranspiration is expected to subject natural and agricultural vegetation to a greater risk of drought in those areas (Samarakoon and Gifford, 1995). D'Andria et al. (1995) reported that, the ability of sunflower to extract water from deeper soil layers "when water stress during the early vegetative phase causes stimulation of deeper root system" and a tolerance of short periods of water deficit, are useful traits of sunflower for producing acceptable yields in dry land farming. On the other hand, some evidences have indicated that, water stress deficit causes considerable decrease in yield and oil content of sunflower (Stone et al., 2001). Even a short term water deficit stress can cause substantial change in physical properties and biochemical composition of sunflower seed (Ashraf and Mehmood, 1990). Some physical properties of this seed and their comparison with other seeds are considered to

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be necessary for the proper design of equipment for handling, conveying, separation, dehulling, drying, mechanical expression of oil, storage and other processes (Kachru et al., 1990; Mohsenin, 1978).

Despite an extensive search, no published literature was found on the detailed physical properties, protein and oil content of sunflower seed and their dependency on operational parameters, which would be useful for the design of agricultural equipments systems. Various physical properties of seeds and their fractions are dependent on environmental condition and genotype, and appear to be important in the design of handling and processing equipment. Thus, a better knowledge of the response to water deficit stress in sunflower cultivars and their effect on physical and chemical properties of seeds would allow identifying the detailed reaction of different genotype and would provide suitable information for the improvement of sunflower by selection and design of adapted equipments. In this study, some chemical and physical properties were investigated, namely, length, width, thickness, volume, surface area, mass of 1000 seeds and moisture content of sunflower seeds.

MATERIALS AND METHODS

The experimental factors were irrigation regimes consisting of three levels of irrigation after 50, 100 and 150 mm cumulative evaporation from class A evaporation pan, respectively, and genotype, represented by four sunflower hybrids (Azargol, Alstar, Hysun33 and Hysun 25). Sunflower seeds were obtained from the Plant Improvement Institute in Karaj, Iran. All combinations of the aforementioned treatments were laid out in the field according to a split-plot randomized complete block design with three replicates, assigning water supply treatments to the whole units and genotypes to the subunits. At ripening, the plants of a 5.2 m^2 area in the middle of each subplot were harvested and their seed were separated manually from heads to determine their protein, oil content and physical properties. The seeds were cleaned manually for foreign matter, broken and immature seeds. Representative undehulled fruit samples per replicate plot were ground and utilised to determine oil content (% of d.m.) by a Soxhlet apparatus using petroleum ether 40 to 60°. The protein content of each cultivar was determined by Lowary et al. (1951). The moisture content of the seed was determined by the vacuum oven method 2 (temperature 70°C and pressure 100 mmHg). The sample was kept at 5.8°C in a refrigerator for a week to enable the moisture to distribute uniformly throughout the product. Before starting the experiment, the pouches were taken out of the refrigerator and allowed to warm up to the room temperature for 2 h.

In order to determine the size and shape of the seed, three sub-samples, each weighing 0.5 kg, were randomly drawn from the bulk sample. From each of the three 0.5 kg sub-samples, 200 seeds were picked out and the 600 seeds thus obtained were mixed thoroughly. Finally, 120 seeds were randomly selected of each treatment and labelled for easy identification. This method of random sampling was similar to the one followed by Joshi et al. (1993) and Dutta et al. (1988). For each individual seed, three principal dimensions, namely length, width and thickness were measured using a micrometer (least count 0.01 mm). As a result of the irregular shape of the sunflower seed, only the greatest values of both width and thickness have been taken. To obtain the mass, each seed was weighed with a precision electronic balance reading to 0.001 g. Grain volume (V) and surface area (S) were calculated using Jain and Bal (1997):

$$V = 0.25[(\frac{\pi}{6})L(W+T)^2]$$

$$S = \frac{\pi B L^2}{(2L - B)}$$

Where:

$$B = (WT)^{\frac{1}{2}}$$

Where:

L, W and T are length, width and thickness of seeds in mm, respectively.

RESULTS AND DISCUSSION

Effect of water deficit stress and genotype on protein and oil contents

The results of protein and oil contents of the seed of the different cultivars are shown in Figures 1 and 2 respectively. The well watered treatments generally had the least protein contents (28 to 39%) while the mean water deficit stress (irrigation after 100 mm evaporation) had the highest protein contents (41 to 42%) for all the cultivars studied. This suggests that, water stress treatments significantly increased protein content in all the sunflower cultivars, although the result of this study indicated that maximum water deficit stress (irrigation after 150 mm evaporation) decreased protein content (Figure 1). However, there are significant differences ($P \leq 0.05$) in the protein contents among the various cultivars with cultivar

Hysun 25 having the highest protein content (39%) in the seed while cultivar Hysun 33 had the least values of protein in the seed (Figure 1). The protein content in the seed of the different cultivars in the well watered treatments ranged from 28 to 39% with cultivar Hysun 25 having the highest and Azargol having the least value. However, in the irrigation after 100 mm evaporation (mean water deficit stress) the protein contents ranged from 30 to 42% with cultivar Hysun 25 having the highest value and Hysun 33 had the lowest value and in the intense water deficit stress (irrigation after 150 mm evaporation) the protein content ranged from 32 to 40% with cultivar Alstar having the highest value and Azargol having the lowest value (Figure 1). Therefore, in the water deficit condition the sunflower cultivar Alstar showed the highest protein content (40%) than that of the other cultivar (Figure 1). It is evident that, water deficit stress enhanced the protein content in all the cultivars

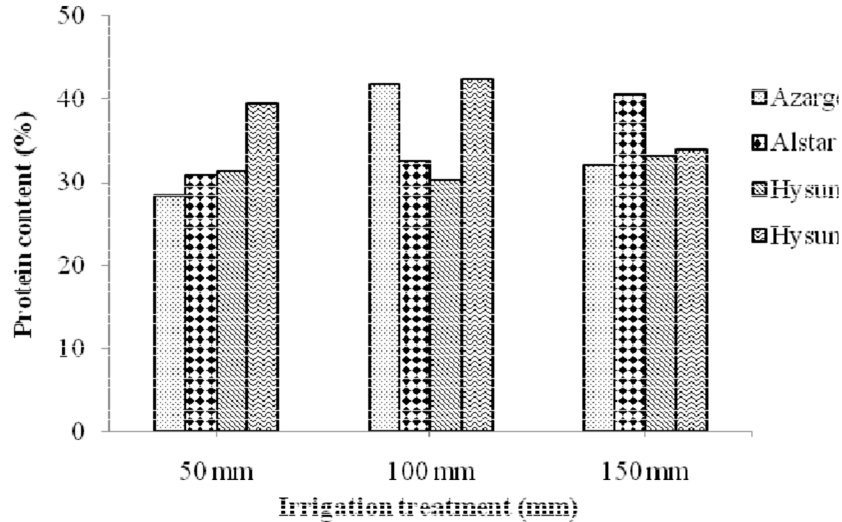

Figure 1. Effect of irrigation treatment on the protein contents of sunflower seeds.

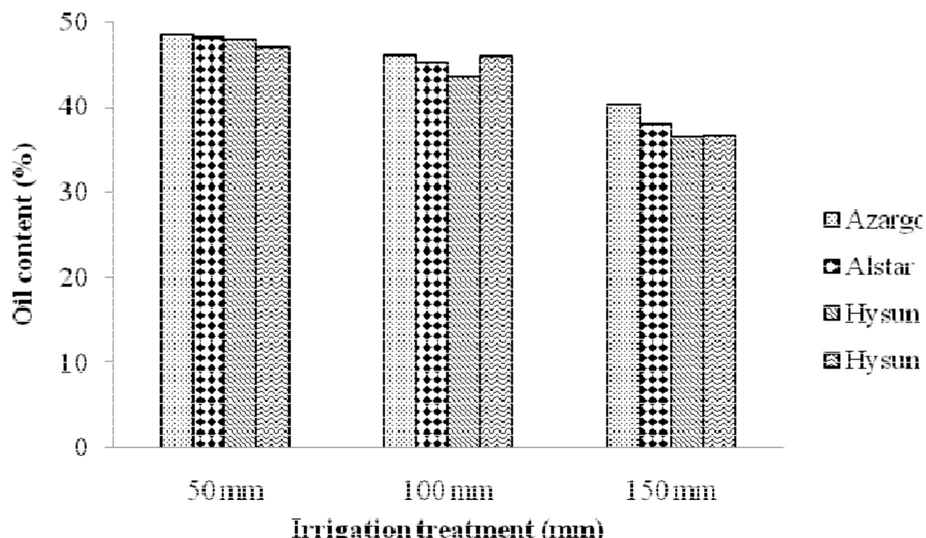

Figure 2. Effect of irrigation treatment on the oil contents of sunflower seeds.

studied especially in sunflower dwarf cultivars, such as Alstar and Hysun 25. The result of this work suggests that, variety and water supply significantly influences the protein content of the sunflower seed. Therefore, find useful applications in food fortification or supplementation to yield foods rich in protein content and thus, providing a cheap source of protein to low income earners.

Generally, the oil contents are higher than the protein contents in all the cultivars studied. Highly significant (P > 0.001) differences with respect to oil content of seeds were observed in the all water supply treatment. The result of this study indicated water deficit stress treatments decreased oil content in all sunflower hybrids. The decrease in oil content was more pronounced when water supplied after 150 mm evaporation (20%) than that at the mean water stress deficit (6%) . The oil content for all irrigation treatments in the seeds ranged from 38 to 48% with cultivar Azargol having the highest value (45%) while cultivar Hysun 33 had the least value (43%) (Figure 2). The oil content in the seed of the different cultivars in the well watered treatment ranged from 47 to 48% with cultivar Azargol having the highest and Hysun 25 having the least value. However, in the irrigation after 100 and 150 mm evaporation (mean water deficit stress and maximum water deficit stress) the oil contents ranged from 44 to 46% and 36 to 40% respectively with cultivar Azargol having the highest value (46 and 40% respectively) and Hysun 33 had the lowest value (44 and 36% respectively) (Figure 2). The findings of this work are consistent with other previous studies, that sunflower

Table 1. Some selected physical properties of sunflower seeds.

Water deficit stress (mm)	Physical properties	Number of observation	Mean value				Range of values				Standard deviation			
			A	B	C	D	A	B	C	D	A	B	C	D
	Length- mm	120	12.73	12.16	10.47	9.68	11.9-13.4	11.5-13.3	10-10.9	9-10	0.7	1.0	0.4	0.5
	Width- mm	120	5.76	6.59	6.27	6.52	5.3-5.9	6.2-6.8	4.8-6.9	5-7.2	0.33	0.31	1.2	1.3
	Thickness- mm	120	3.33	4.82	3.11	4.08	3-3.8	4.6-4.9	3-3.1	3.7-4.6	0.4	0.15	0.05	0.51
50	Volume- mm^3	120	137.69	208.17	122.21	142.7	129.7-140.9	179.9-238.7	85.4-147.1	123.3-160.4	6.8	29.4	32.5	18.6
	Surface area- mm^2	120	105.4	140.4	92	105.7	99.8-110.2	127.8-154.7	77.2-102.6	100.5-111.7	5.2	13.5	13.1	5.6
	Mass- g	30	53	60	49.6	55.7	51-54.6	59.5-60.6	49-50	55-57.2	1.8	0.5	0.5	1.2
	Moisture content- %	3	9.9	10.2	9.2	11.4	----	----	----	----	----	----	----	----
	Length- mm	120	10.16	10.82	8.68	8.38	9-11.1	10-10.6	8.2-9	8-9	1.0	0.5	0.3	0.5
	Width- mm	120	4.48	5.91	4.42	5.73	4.1-4.7	5.8-5.9	4.3-4.4	4.8-6.2	0.31	0.08	0.06	0.8
	Thickness- mm	120	2.88	3.59	2.59	3.62	2.8-2.9	3.3-3.9	2.2-2.9	3.6-3.6	0.05	0.2	0.3	0.005
100	Volume- mm^3	120	72.16	128.24	56.16	95.99	67.5-76.5	114.5-140.2	51.2-64.0	83.9-103.7	4.5	12.8	6.9	10.5
	Surface area- mm^2	120	69.7	99.5	57.3	82.3	65.6-71.9	91.3-107.3	53.6-64	76.9-85.9	3.5	7.9	5.8	4.7
	Mass- g	30	32.8	39.9	30.3	35.96	34-33.4	39-41	30-31	34.9-36.5	1.5	1	0.5	0.9
	Moisture content- %	3	9.6	9.9	8.9	10.7	----	----	----	----	----	----	----	----
	Length- mm	120	9.37	10.22	6.9	7.44	9-9.7	10-10.6	7-7.2	7-8.2	0.3	0.3	0.3	0.6
	Width- mm	120	2.98	5.66	3.32	4.21	2.9-3	5.5-5.7	2.6-3.6	3.7-4.5	0.02	0.07	0.6	0.4
	Thickness- mm	120	2.06	3.37	2.12	3.11	2-2.1	3.2-3.5	2-2.3	3-3.1	0.05	0.15	0.17	0.004
150	Volume- mm^3	120	31.35	109.21	26.82	52.11	29.8-32.9	104.7-112.2	22.8-29.8	50.8-54.2	1.5	3.95	3.6	1.8
	Surface area- mm^2	120	42.1	89.2	35.3	55.9	40.4-44	86-91.2	33.4-37.2	54.8-56.8	1.7	2.8	1.9	1
	Mass- g	30	25.3	33.9	26.1	28.4	25-25.5	33-34.6	26-26.5	27.3-29.9	0.2	0.8	0.2	1.3
	Moisture content- %	3	9	9.5	8.6	9.8	----	----	----	----	----	----	----	----

[a] A group of four seeds implies an observation: A-Azargol; B-Alstar; C-Hysun 33; D-Hysun 25.

seed could serve as a rich source of oil and protein to both temperate regions and the tropics. Monoti (2004) reported that, sunflower seed oil was rich in unsaturated fatty acids such as linoleic acid which is an essential fatty acid in human nutrition.

Physical characteristics

Mean results, range and standard deviation of the physical parameters of sunflower seeds are presented in Table 1. The moisture content recorded for the samples of the different varieties in the well watered treatment, mean water deficit stress and maximum water deficit stress ranged from 9.2 to 11.4%, 8.9 to 10.7% and 8.6 to 9.8% (d.b) respectively (Table 1). Water stress treatments decreased moisture content in all sunflower hybrids (Table 1). The moisture content may suggest the storage stability of the seed, thus supplying information in designing appropriate storage conditions for the seeds. The relatively high moisture contents observed might indicate ease of dehulling, since in several instances, the higher the moisture content the harder it suggests without adverse effects to the crop, in the dehulling technology. The mean length, width, thickness and their dependence on irrigation treatments are shown in Table 1. There were significant differences among the entire cultivars and water supply treatments. Sunflower seed dimension decreased with water stress deficit increase. The highest physical properties value of all sunflower hybrids studied were found in well watered treatment. Thus, the average seed length, width and thickness in well watered treatment were 12.73-5.76-3.33 mm, 12.16-6.59-4.82mm, 10.47-6.27-3.11 and 9.68-6.52-4.08 mm for Azargol, Alstar, Hysun 33 and Hysun 25 respectively; while the average seed length, width and thickness in intense water deficit stress were 9.37-2.98-2.06 mm, 10.22-5.66-3.37mm, 6.9-3.32-2.12 and 7.44-4.21-3.11 mm for Azargol, Alstar, Hysun 33 and Hysun 25 respectively. The importance of these and other characteristic axial dimensions in determining aperture sizes and other parameters in machine design have been discussed by Mohsenin (1978) and highlighted lately by Omobuwajo et al. (2000).

The range of volume, surface area and mass of 1000 seeds in the well watered condition were found to be 122.21 to 208.17 mm ^{3}, 92 to 140.4 mm^2 and 53 to 60 g respectively, while in the mean water deficit stress, the range of these parameters were 56.16 to 128.24 mm^3, 57.3 to 99.5 mm^2 and 30.3 to 39.9 g respectively. However, in the irrigation after 150 mm evaporation (maximum water deficit stress) the range of volume, surface area and mass of 1000 seeds were 26.82 to 109.21 mm^3, 35.3 to 89.2 mm^2 and 26.1 to 33.9 g respectively. The surface area is a relevant tool in determining the shape of the seeds. This could be an indication of the way the seeds would behave on oscillating surfaces during processing as reported by Alonge and Adigun (1999) . Thus, the average masses of the seeds as indicated in Table 1 could be pertinent in cleaning with aerodynamic forces.

Conclusion

The result of this study suggested that, proximate compositions and certain physical properties of sunflower seeds are dependent on cultivars and irrigation treatments. Generally, in all water supply treatments the protein contents of the seeds obtained from the various cultivars studied ranged from 33 to 37%; while oil content varied from 38 to 48%, confirming the potential of sunflower seeds as a rich source of oil and protein in the world. The information supplied on the physical characteristics of the sunflower seed under different water supply conditions could serve as a useful tool in designing processing equipment such as planters, sorters, separators, dehulling and cleaning equipment.

In conclusion, this report studied the effect of water deficit stress on the engineering properties of some sunflower hybrids, providing useful data to improve the performance of oil and protein extraction processes from the selection of suitable strategies for handling hybrids with different structural characteristics.

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