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QUALITY CHARACTERISTICS OF HIGH-OLEIC SUNFLOWER OIL EXTRACTED FROM SOME HYBRIDS CULTIVATED UNDER EGYPTIAN CONDITIONS

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ABSTRACT

This work was conducted to study the oil content, quality criteria of different seven sunflower hybrids growing under local environmental condition. Three high-oleic hybrids (2031, 2033 and Olivico), two mid-oleic hybrids (A12 AND A15) and two traditional hybrids (120 and 53) were studied to determine the oil content, physico-chemical properties, total tocopherol, oxidative stability by Rancimat method at 100ºC and fatty acid composition by GC during2012-2013.According to the results, the hybrids 2033, 2031 and A15 produced higher oil content (44.00%, 43.30% and 38.79% respectively, than other hybrids under study. Hybrids 2033, Olivico and 2031 had higher tocopherol content (445, 423, 419ppm) than other hybrids. In contrast, significant differences were noticed in oxidative stability and fatty acid composition. The hybrids 2033, Olivico and 2031 showed the higher oxidative stability (19.00, 17.50 and 17.00 hr) and oleic acid (82.87%, 82.11% and 81.40%) respectively. In conclusion, results indicated that the high-oleic and mid-oleic sunflower hybrids cultivated under Egyptian conditions gave higher quality oil.

Keywords: High-oleic sunflower, Oxidative stability, Tocopherol, Fatty acids, Oil content, Quality criteria.

Contribution/ Originality

Production of sunflower oil contained high oil content and also, high oleic acid level. Also, high content of tocopherols which lead to increased oxidative stability. The oil production was used in many food purposes such as cooking, frying and etc. Oils contained high level of oleic acid had characterized that nutritional and benefits health.

1. INTRODUCTION

Sunflower (*Helianthus annuus L.*) is the one of the main crops used for edible oil production in many countries of the world, including Egypt. The major problem facing oil production in Egypt is the wide gap between production and consumption. Egypt's production covers less than 10% of the national consumption. Although the main oil crop cultivated in Egypt is sunflower, both the area and the average yield per unit area decreased gradually. Consequently, great effort should by give to improve sunflower cultivars in Egypt (Taher *et al.*, 2008).

Cultivation of sunflower (*Helianthus annuus L.*) has significantly increased in recent years, mainly due to quality of its oil, which is useful for the human consumption and for production of biodiesel. In addition, due to its large capacity of adaptation to different edaphic and climatic conditions, sunflower is an excellent option for crop rotation for several production regions (Carvalho, 2003).

Sunflower is an important edible vegetable oil source as it is one of the most widely cultivated oil crops in the world due to its ability to grow in large semi-arid regions without irrigation (Osorio *et al.*, 1995; Piva *et al.*, 2000).

In the commercial hybrids, the oleic acid values ranged between 10 and 50%, depending on the climatic conditions of the field and the temperature of seed growth. A strong negative correlation between oleic and linoleic acids was reported (Fernandez-Martinez *et al.*, 1986; Vranceanu *et al.*, 1995).

The first genotype with a high oleic content is Pervenetz variety obtained in the former Soviet Union after treating the seeds with dimethyl-sulphonate (Soldatov, 1976)**.** The oleic acid content of this variety is of about 75% on an average, although with individual plants this content ranges between 50 and 80% (Miller and Zimmerman, 1983) and with individual seeds, the variation is often greater, between 19 and 94% (Urie, 1985). The off springs of this variety with a high oleic content were very stable even under various conditions of temperature, recording values of over 83% (Urie, 1985; Fernandez-Martinez *et al.*, 1989)**.** A few studies succeeded in elucidating the mechanisms of transmitting the oleic acid content of the germplasms derived from Pervenetz variety**.**

The oil containing a high level of oleic acid is preferred in nutritional use whereas that having higher linoleic content is preferred by paint or fuel industry. Standard sunflower cultivars contain high linoleic acid, moderate oleic acid and low linolenic acid (Sabrino *et al.*, 2003). Previously, both oil quality and rate in sunflower have been well documented by several researchers (Burton *et al.*, 2004; Nolasco *et al.*, 2004)**.** The fatty acid composition changes depending on genotypes and some other factors such as environmental conditions, planting and harvesting time (Gupta *et al.*, 1994; Baydar and Erbas, 2005; Roche *et al.*, 2006).

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 (Lopez *et al.*, 2000; Monotti, 2004). Oil quality is determined by the fatty acid composition and the levels of tocopherols, sterols, carotenoids, and other compounds. Sunflower is regarded as one of the most promising crops when it comes to the genetic alteration of oil quality (Scharp, 1986). Standard sunflower oil is predominantly composed of linoleic acid (C-18:2) and oleic acid (C-18:1). These two acids account for about 90% of the total fatty acid content of sunflower oil. The remaining 8-10% is comprised of palmitic and stearic acids (C-16:0 and C-18:0, respectively). Conventional sunflower oil also contains several other fatty acids, but these are usually found only in traces (C-14:0, C-16:1, C-14:1, C-20:0, C 22:0) (Friedt *et al.*, 1994).

In high oleic sunflower, several major and minor genes are involved in increased oleic acid concentration and its stability (Fernandez-Martynez *et al*., 2004). Recent research has lead to the development of high-oleic acid sunflower varieties with oil that exceed 89% oleic acid content. The high amount of monounsaturated fatty acid makes high-oleic sunflower oil much less susceptible to oxidative degradation than traditional sunflower oil with high polyunsaturation (Dorrell and Vick, 1997). As a result, high-oleic oil is naturally stable and does not need to be hydrogenated.

Sunflower oil is also a rich source of phytosterols (3,900 mg kg-1) largely made up of □-sitosterol (60%) and to lesser extent campesterol (8%), stigmasterol (8%), delta-5-avenasterol (4%), delta-7-stigmastenol (15%), delta-7-avenasterol (4%), and also minor amounts of other phytosterols such as delta-campesterol, clerosterol, and delta-5,24-stigmastadienol (Padley *et al*., 1994; Fernandez-Martynez *et al*., 2004).In particular, a diet rich in mono-unsaturated fatty acids reduces the cholesterol level associated with low-density lipoproteins "harmful cholesterol" and has no effect on the level of the triglycerides or on the cholesterol associated with high density lipoprotein, if compared to a diet rich in saturated fatty acids (Grundy, 1986).

From 1977 onwards, after the FAO published results on the possible negative effects of some fats and oils on human health, interest in polyunsaturated fatty acids of plant origin grew and there have been many studies conducted to determine the effect on health of the different fatty acids in the diet. In general a diet rich in vegetable oils prevents heart disease (Krajcova-Kudlackova *et al*., 1997). In particular, a diet rich in mono-unsaturated fatty acids reduces the cholesterol level associated with low-density lipoproteins(LDL-C) and has no effect on the level of the triglycerides or on the cholesterol associated with high density lipoprotein (HDL-C), when compared to a diet rich in saturated fatty acids (Grundy, 1986).Other more recent studies have reached the same conclusion: a diet intended to prevent cardiovascular disease must include a reduction in saturated fatty acids intake (Jing *et al*., 1997) and these should not provide more than 30% of the energy supplied by fats (Woo *et al*., 1997). The objective of the present study is to determine the suitability of high-oleic sunflower hybrids for growing under the climate conditions of Egypt, and also to study the effect of climate conditions on oil content, quality criteria and fatty acid composition of hybrids under study.

2. MATERIAL & METHODS

2.1. Source of Hybrid Sunflower Seeds

Seven hybrid sunflower seeds (120, 53, A12, A15, 2031, 2033 and Olivico) were obtained from Oil Seeds Crops Dept., Field Crop Res. Inst., Agric. Res. Center. Giza, Egypt., during summer seasonal 2012 and 2013. The origin of hybrids under study is shown in Table (1).

Table-1. Origin of seven hybrids sunflower seeds.

Genotype	Origin
Hybrid 120	Egypt
Hybrid 53	Egypt
Hybrid A12	USA
Hybrid A15	USA
Hybrid 2031	Yugoslavia
Hybrid 2033	Yugoslavia
Hybrid Olivico	Yugoslavia

2.2. Source of Solvents

N-hexane used in oil extraction and other solvents were of analytical grade. Solvents and chemicals used in physicochemical analysis were purchased from Merck and Sigma Co., respectively.

2.3. Analysis of Hybrids Sunflower Seeds

Sunflower hybrid seeds were analyzed for moisture and oil contents according to A. O. A. C. (2005).

2.4. Extraction of Oil

Hybrid sunflower seed oil was extracted by Soxhlet method (A. O. A. C., 2005). A total of 50 g hybrid sunflower seed sample was weighed and extracted with n-hexane in a Soxhlet Apparatus at a condensation rate of 5 or 6 points per second for 4 hours with 300ml of hexane at a temperature of 70°C. The solvent was evaporated to dryness using a rotary evaporator at 40°C.

2.5. Physico-Chemical Properties Determination

Refractive index, free fatty acids, peroxide value, and iodine number of the oil samples were determined according to (A. O. A. C., 2005).

2.6. Oil Stability

Oxidative stability was evaluated by the Rancimat method Gutierrez (1989). Stability was expressed as the oxidation induction time (h), measured with the Rancimat 679 apparatus (Metrohm Co., Herisou, Switzerland), using an oil sample of 5.0 g heated to 100°C ± 2°C with an air flow of 20 l/hr-1.

2.7. Total Tocopherol Content

The total tocopherol content in oils was determined according to the method of Wong *et al.* (1988).

2.8. Fatty Acid Composition

The fatty acid methyl esters were prepared as described in the International Olive Council (IOOC, 2009) and fatty acid profile was analyzed by GC according to the method described by (IOOC, 2009).

2.9. Statistical Analysis

The results are reported as the mean values ± standard deviation. In addition, Duncan's significant differences among data were also calculated. Statistical analysis was performed using the statistical 5.00 package (Stat Soft 97 editions).

3. RESUTS AND DISCUSIION

3.1. Moisture and Oil Contents

Data for sunflower seed samples collected from seven hybrids (120, 53, A12, A15, 2031, 2033 and Olivico) growing under Egyptian climatic conditions were analyzed to determine moisture and oilcontents, and the results are presented in (Table 2). Data showed no significant differences between all hybrids in moisture content.

Table-2. Moisture and oil contents (%) of sunflower hybrid seeds.

Genotype	Moisture content (%)			Oil content (%)		
	2012	2013	Mean	2012	2013	Mean
Hybrid 120	6.76±0.95	6.58±0.84	6.67±0.93	40.56±3.51	41.24±3.42	40.90±3.09
Hybrid 53	6.98±1.00	7.14±1.15	7.06±1.12	38.00±2.80	37.52±2.57	37.76±2.77
Hybrid A12	6.80±0.98	7.00±1.02	6.90±1.00	40.75±3.71	39.87±2.93	40.31±3.39
Hybrid A15	7.10±1.10	7.14±1.06	7.12±1.20	39.44±2.92	38.13±2.81	38.79±2.25
Hybrid 2031	6.22±0.83	6.46±0.75	6.34±0.88	42.90±3.90	43.70±3.69	43.30±3.91
Hybrid 2033	6.19±0.80	6.21±0.81	6.20±0.81	44.20±4.01	43.80±3.83	44.00±4.12
Hybrid Olivico	6.59±0.85	6.79±0.98	6.69±0.90	38.90±2.83	40.60±3.00	40.25±3.15

Results are the means of three replicates ± SD.

The mean seed oil content varied between 37.76 – 44.00 % among the traditional, mid- and high-oleic oil types (Table 2). The high-oleic hybrids 2033, 2031 and A15 contained the highest percentage of oil (44.00, 43.30 and 38.79% respectively) and these values are significantly higher than the oil contents for the other hybrids under study. Traditional hybrid 53 recorded a lower percentage in oil content. The mean seed oil content of approximately 41.25% for the seven oils under study was similar when compared to oil contents reported previously (Radic *et al.*, 2008). Oil content in sunflower seed ranged between 25-48%, but can reach 65% depending on the genotype and environmental factors (Weiss, 2000; De Souza Abreu *et al.*, 2013).

3.2. Quality Criteria

The seven oil types differed significantly in their refractive index and iodine values due to the significant variation in their fatty acid composition (Table 3). Refractive index and iodine values showed significant and positive correlations with linoleic acid and other polyunsaturated content.

Data indicated that the hybrids 120, 53 and A12 had the highest in refractive index and iodine values, followed by the hybrids A15 and Olivico (Table 3). For refractive index significant differences were observed among some hybrids within each oil type that could be attributed to the significant differences in their linoleic acid contents. The refractive index and iodine values were in the ranges recommended by the (Codex Standard, 2003). The PUFA/SFA ratios as well as refractive index and iodine values were indicative of unsaturation levels and as a result, the oil has a tendencyto undergo autoxidation (Farhoosh *et al.*, 2008). Decreased levels of unsaturation (linoleic acid) will result in increased levels of oxidative stability. Therefore the high oleic sunflower oil with their lower levels of unsaturation should be more resistant to oxidation than the mid-oleic and traditional sunflower oil.

Free fatty acids ranged between 0.21-0.36% for all seven oil types (Table 3). When considering the oxidative stability, the seven oil types differed significantly for mean peroxide value (Table 3).Free fatty acid content is an important oil quality parameter (Moschner and Biskupek-Korell, 2006). The free fatty acid values obtained were below the limit of 2% and indicated that the oil of all seven hybrids was having good oxidative quality.

The hybrids 3033, 2031 and A15 had significantly lower peroxide values than the other hybrids. No Significant differences were observed between the hybrids 2033, 2031 and A15 for peroxide values, but among the hybrids, 120, 53 and A12 had significantly higher peroxide values than other hybrids under study. This observation was a consequence of the significantly higher linoleic acid content observed for hybrids 120, 53 and A12. Only hybrids with peroxide values of 10meq/1000g and less (Table 3) were used for oxidative stability analysis and therefore all hybrids were included for oxidative stability determination. A low peroxide value of 10 meq/1000g indicates that oil oxidation has not occurred yet and therefore the oil is of good oxidative quality.

The initial oxidation status of the seven hybrids oil samples was evaluated by peroxide values. The significantly lower peroxide values observed for the high oleic sunflower oil confirmed that this oil samples was more stable to oxidation than the mid oleic sunflower oil. The all samples under study differed in their oxidative stability (Table 3). This observation was a result of the different unsaturation levels of the oils. The hybrid 120 and 53 showed the lowest in oxidative stability values (7.60 and 7.50hr) and was followed by the hybrids A12 and A15 that showed a slightly higher values (10.90 and 12.10/hr). The hybrids, Olivico and 2031 had the highest oxidative stability values with means (17.50 and 17.00hr). Among these, hybrid 2033 performed the best of all hybrids with the highest oxidative stability values (19.00hr). The high oleic sunflower oil was the most stable oil with the highest oxidative stability value, while the mid-oleic sunflower oil showed better oxidative stability. The considerably better oxidative stability of the high and mid oleic sunflower oil was attributed to its low level of polyunsaturation. Márquez-Ruiz *et al.* (2008); and Merrill *et al.* (2008) reported lower oxidative stability values for traditional sunflower oil compared to high-oleic oil. The hybrids 2033, 2031 and A15 should be considered for release in commercial production as high-oleic acid hybrid with excellent oil oxidative stability.

Results in (Table 3) show the total tocopherol content in hybrid samples under study. Hybrid 2033 hasrecorded a tocopherol value that is significantly higher (445.00ppm) followed by hybrid 2031 (423.00ppm) and Olivico (419.00ppm), respectively. But the hybrid 53 recorded a significantly lower (360.00ppm) tocopherol content. The tocopherol content of oil is important in order to protect lipids against autoxidation and therapy increases its storage life and value as a wholesome food. Tocopherol has a polar chromanol ring with a lipophilic prenyl side chain and comprises of four homologous forms, α, β, γ and δ-tocopherol, differing only in the number and position of methyl substituent on the chromanol head group (Traber and Sies, 1996).These different tocopherol forms have different antioxidative abilities, with α-tocopherol being the most biological active form. They function as lipid-soluble antioxidants that are able to scavenge oxygen radicals and to quench singlet oxygen (Ricciarelli *et al.*, 2001).

Table-3. Some physicochemical properties of oil extracted from some sunflower hybrids seeds.

Properties	H-120	H-53	H-USA-A12	H-USA-A15	H-2031	H-2033	Olivico
Refractive index at 25°C	1.4640±0.0.001	1.4630±0.001	1.4668±0.001	1.4675±0.001	1.4685±0.001	1.4696±0.001	1.4679±0.001
Acid value (% as oleic acid)	0.33±0.01	0.36±0.01	0.31±0.01	0.29±0.01	0.22±0.01	0.21±0.01	0.25±0.01
Peroxide value ($meq.O_2/kg$ oil)	2.17±0.21	1.95±0.13	2.01±0.19	2.00±0.17	1.71±0.11	1.66±0.10	1.81±0.12
Iodine number $gI_2/100g$ oil)	105.50±5.20	103.90±4.91	94.50±3.88	90.60±3.64	88.30±3.25	86.10±3.11	87.40±3.20
Total tocopherol ppm	380.00±15.19	360.60±14.55	390.00±16.30	415.00±18.05	423.00±19.01	445.00±19.55	419.00±18.83
Oxidative stability (hr)	7.60±1.00	7.50±0.95	10.90±2.01	12.10±2.61	17.00±3.11	19.00±3.71	17.50±3.42

Results are the means of three replicates ± SD.

3.3. Fatty Acids Composition

Data in (Table 3) illustrates the fatty acid composition of seven hybrid sunflower oil grown under Egyptian conditions. Only major fatty acids were palmitic, stearic, oleic and linoleic presented in Table 3.Mean palmitic acid percentages ranged between 4.29-6.91% among the seven oil samples. Significant differences were observed between oil samples for palmitic acid percentages. The hybrids A15 and 120 contained (6.91% and 6.63%) more palmitic acid than other samples. Stearic acid percentage ranged between 2.90-5.32%, showing significant differences between all samples under study. Oleic acid percentages ranged between 51.24- 82.87% with significant differences between all hybrid oil samples. The highest oleic acid value was found in hybrids 2033 (82.87%) followed by hybrid 2031 (81.40%), while the lowest oleic acid value was recorded in hybrid 53 (51.24%) followed by hybrid 120 (52.83%).Highest linoleic acid value (C18:2) was recorded in hybrid 53 (37.57%) followed by hybrid 120 (33.15%), and lowest linoleic acid values were recorded in hybrids A15 (5.48%) followed by hybrid 2031(6.15%). The increase in oleic acid percentages and corresponding decrease in linoleic acid percentages was due to the significant and negative correlation between oleic and linoleic acid (Table 3). Significant differences were observed between the high-oleic hybrids, mid- oleic and low-oleic for oleic and linoleic acids percentages.

The seven oil samples differed significantly in their refractive index and iodine values due to the significant variation in their fatty acid composition (Table 2). The polyunsaturated fatty acid/saturated fatty acid (PUAF/SFA) ratios as well as refractive index and iodine values were indicative of unsaturation levels and as a result oils have a tendency to undergo autoxidation (Farhoosh *et al.*, 2008). Decreased levels of unsaturation will result in increased levels of oxidative stability. Therefore, the high-oleic and mid-oleic hybrids sunflower oil with their lower levels of unsaturation should be more resistant to oxidation than lower oleic hybrids sunflower oil. This conjecture was verified by determining the oxidative quality and stability of the all samples under study. These results are in agreement with those obtained by Merrill *et al.* (2008).

Table-4. Fatty acid composition (%) of oil extracted from seven hybrids of high-oleic sunflower seeds.

Fatty acids	H-120	H-53	H-USA-A12	H-USA-A15	H-2031	H-2033	Olivico
C16:0	6.63±0.56	5.25±0.42	4.29±0.39	6.91±0.51	5.37±0.52	4.60±0.36	4.44±0.32
C16:1	0.32±0.01	0.23±0.01	0.16±0.01	0.20±0.01	0.27±0.01	0.24±0.01	0.22±0.01
C18:0	4.97±0.39	4.15±0.31	4.08±0.30	5.32±0.41	4.49±0.39	2.94±0.21	2.90±0.28
C18:1	52.83±4.23	51.24±4.12	64.74±5.70	79.30±6.91	81.40±7.04	82.87±7.80	82.11±7.20
C18:2	33.15±2.29	37.57±2.91	24.89±1.95	5.48±0.43	6.15±0.59	7.21±0.65	8.82±0.73
C18:3	0.51±0.02	0.16±0.001	0.22±0.01	0.24±0.01	0.03±0.001	0.29±0.01	0.08±0.001
C20:0	0.93±0.03	0.34±0.01	0.43±0.01	0.85±0.01	0.54±0.01	0.53±0.01	0.33±0.01
C20:1	0.12±0.001	0.20±0.001	0.30±0.02	0.85±0.09	0.23±0.001	0.39±0.001	0.28±0.001
C22:0	0.86±0.06	0.86±0.06	0.89±0.07	0.75±0.05	0.52±0.04	0.86±0.06	0.82±0.04
T.S	13.39±1.19	10.60±0.95	9.69±0.83	13.83±1.43	10.92±1.00	8.93±0.73	8.49±0.70
T.US	86.61±7.52	89.40±8.14	90.31±8.33	86.17±7.11	89.08±7.91	91.07±8.20	91.51±8.33

Results are the means of three replicates ± SD.

4. CONCLUSION

With regarded to the results obtained, it is suggested the oil content and fatty acid composition of sunflower hybrids is dependent on the variety and its interaction with the environment. Environmental factors contributed most to variability in oil content, while, a variety of factors contributed the most to variability in fatty acid content. The high-oleic and mid-oleic sunflower gave higher oil content compared to traditional varieties. Hybrids 2033, Olivico and 2031 gave higher levels in oil content, oleic acid, tocopherol and higher stability compared to other varieties.

The high-oleic sunflower variety suitable for planting under Egyptian conditions, had a high percentage of oil and also a high percentage of oleic acid, and therefore we can rely on this varietyto increase oil production thereby contributing to narrowing the gap between production and consumption of edible oils in Egypt.

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