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# Quality Characteristics of High-Oleic Sunflower Oil Extracted from Some Hybrids Cultivated under Egyptian Conditions

**Abstract:** This work was conducted to study the oil content and some quality criteria of oil extracted from seven different sunflower hybrids growing under local environmental condition during seasonal 2012–2013. Three high-oleic hybrids (2031, 2033 and Olivko), two mid-oleic hybrids (A12 and A15) and two traditional hybrids (120 and 53) were studied to determine the oil content, some physicochemical properties, total tocopherol content, oxidative stability by Rancimat method at 100°C and fatty acid composition by GC. 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, Olivko and 2031 had higher tocopherol content (445, 423, 419 ppm, respectively) than other hybrids. In contrast, significant differences ($P \geq 0.05$) were noticed in oxidative stability and fatty acids composition. The hybrids 2033, Olivko and 2031 showed the higher oxidative stability (19.00, 17.50 and 17.00 h) 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, quality criteria

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## 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

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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 were decreased gradually. Consequently, great effort should be given 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 suitable 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 and succession systems for several production regions (Carvalho *et al.*, 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 the seeds growing in particular. A strong negative correlation between oleic and linoleic acids was reported (Fernández-Martinez *et al.*, 1986; Vrânceanu *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-sulfonate (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; Fernández-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 acid 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 (Nolasco *et al.*, 2004; Burton *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 (40–50%) 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-Martınez *et al.*, 2004). Recent research has led to the development of high-oleic acid sunflower varieties with oil that exceed 89% oleic acid content. The high amount of monounsaturation 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 β-sitosterol (60%) and to lesser extent campesterol (8%), stigmasterol (8%), Δ-5-avenasterol (4%), Δ-7-stigmastenol (15%), Δ-7-avenasterol (4%) and also minor amounts of other phytosterols such as Δ-campesterol, clerosterol and Δ-5,24-stigmastadienol (Padley *et al.*, 1994; Fernández-Martínez *et al.*, 2004).

From 1977 onward, 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 (LDL-C) and has no effect on the level of the triglycerides or on the cholesterol associated with (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 condition of Egypt and also to study the effect of climate conditions on seed oil content, quality criteria and fatty acid composition of oil extracted from hybrids under study.

# Material and Methods

## Source of sunflower hybrids seeds

Seven sunflower hybrid seeds (120, 53, A12, A15, 2031, 2033 and Olivko) were obtained from Oil Seeds Crops Dept., Field Crop Res. Inst., Agric. Res. Center, Giza, Egypt, during summer seasonal 2012 and 2013. A climatic condition in the region under study was temperature ranged between 28°C and 44°C, humidity ranged between 35 and 90% and the soil is clay loam according to Central Laboratories for Agriculture Climate, Dokki, Giza, Egypt. The origin of hybrids under study is showed in Table 1.

**Table 1:** Origin of seven sunflower hybrid seeds

| Genotype | Origin | Classification |
|---|---|---|
| Hybrid 120 | Egypt | Traditional oleic acid |
| Hybrid 53 | Egypt | Traditional oleic acid |
| Hybrid A12 | USA | Mid-oleic acid |
| Hybrid A15 | USA | High-oleic acid |
| Hybrid 2031 | Yugoslavia | High-oleic acid |
| Hybrid 2033 | Yugoslavia | High-oleic acid |
| Hybrid Olivko | Yugoslavia | High-oleic acid |

## Source of chemicals

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.

## Analysis of seeds

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

## Extraction of oil

Sunflower seed oil was extracted by Soxhlet method (A.O.A.C., 2005). A total of 50 g of seed sample was weighted and extracted with n-hexane in a Soxhlet

apparatus at a condensation rate of 5 or 6 drops per second for 4 h with 300 ml of n-hexane at a temperature of 70°C. The solvent was evaporated to dryness using a rotary vacuum evaporator at 40°C.

## Physicochemical properties of oil

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

## Oil stability

Oxidative stability of oil 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., Herisau, Switzerland), using an oil sample of 5.00 g heated to 100°C ± 2°C with an air flow of 20 l/h.

## Total tocopherol content

Two hundred ± 10 mg of the oil samples are weighed accurately into a 10-ml volumetric flask. Five ml of toluene is added by pipette and the oil taken into solution. Three and one-half ml of 2,2-bipyridine (0.07% w/v in 95% aqueous ethanol) and 0.5 ml of $FeCl_3 \bullet 6H_2O$ (0.2% w/v in 95% aqueous ethanol) are added in that order. The solution is made up to 10 ml with 95% aqueous ethanol. After standing for one min, the adsorption at 520 nm is determined using as a reference a blank solution, prepared as above but omitting the oil. Solution should be protected from strong light during color development. The method was calibrated by preparing standards containing 0.240 μg of pure α-tocopherol in 10 ml of toluene and then analyzing as above. The concentration of tocopherol in the samples was calculated according to the method of Wong *et al.* (1988).

## Fatty acid composition

Methylation of fatty acids: About 10 mg samples were dissolved in 2 ml hexane and then 0.4 ml 2N KOH in anhydrous methanol was added (Cossignani *et al.*, 2005), after 3 min, 3 ml water was added. The organic layer, separated by centrifugation, was dried over anhydrous sodium sulfate, then concentrated

with a $N_2$ stream to around 0.5 ml for GC analysis of fatty acids methyl esters (FAME) as described below.

GC analysis of fatty acids: Agilent 6890 series GC apparatus provided with a DB-23 column (60 m × 0.32 mm × 0.25 μm) was used. Fatty acids results after the previous procedure steps were transformed into methyl esters and directly injected into the GC.

### Statistical analysis

Statistical analysis for all values is expressed as mean ± standard deviation for seven independent samples of sunflower oil (H-120, H-53, H-A12, HA15, H-2031, H-2033 and H-Olivko). Analysis of variance (ANOVA) and the least significant difference (LSD) test at $P < 0.05$ were calculated to allow comparison between the mean values of the studied parameters using the COSTAT software package (Cohort Software, CA, USA). Differences between studied parameters were considered significant if $P < 0.05$.

## Results and discussion

### Moisture and oil contents

The moisture and oil contents of sunflower seed samples 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 seed samples.

| 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 ± 3.25 |
| 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 Olivko | 6.59 ± 0.85 | 6.79 ± 0.98 | 6.69 ± 0.90 | 38.90 ± 2.83 | 40.60 ± 3.00 | 40.25 ± 3.15 |

Notes: Results are the means of three replicates ± SD ($P \geq 0.05$). Means within each column followed by the same letter are not significantly different at $P < 0.05$.

The mean seed oil content varied between 37.76 and 44.00% among the traditional, mid-oleic 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 hybrids under study was similar compared to oil contents reported previously (Radić *et al.*, 2008). Oil content in sunflower seed ranged between 25 and 48%, but can reach 65% depending on the genotype and environmental factors (Weiss, 2000; de Souza Albrea *et al.*, 2013).

## Quality criteria of oil

The seven oil types differ significantly in their refractive index and iodine values (Table 3) due to the significant variation in their fatty acid composition (Table 4). Refractive index and iodine values showed significant and positive correlations ($P \geq 0.05$) with linoleic acid and other polyunsaturated content. Data indicated that the hybrids H-120, H-53 and H-A12 had the highest in refractive index and iodine values, followed by the hybrids H-A15 and Olivko (Table 3). For refractive index, significant differences ($P \geq 0.05$) were observed among 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 polyunsaturated fatty acids/saturated fatty acids (PUFA/SFA) ratios as well as refractive index and iodine values were indicative of unsaturation levels and as a result, the oil has a tendency to 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 for all oil samples ranged between 0.21 and 0.36% (Table 3). When considering the oxidative stability, the seven oil types differed significantly ($P \geq 0.05$) 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 H-2033, H-2031 and H-A15 had significantly lower peroxide values than the other hybrids. No significant differences were observed between the hybrids H-2033, H-2031 and H-A15 for peroxide values, but among the

**Table 3:** Some physicochemical properties of oil extracted from sunflower hybrid seeds

| Properties | H-120 | H-53 | H-A12 | H-A15 | H-2031 | H-2033 | Olivko |
|---|---|---|---|---|---|---|---|
| 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 ($meqO_2/kg$) | 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 (g/100 g) | 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 content (mg/kg) | 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 |
| Induction period (h) | 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 |

Notes: Results are the means of three replicates ± SD ($P \geq 0.05$). Means within each column followed by the same letter are not significantly different at $P < 0.05$.

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

| Fatty acids | H-120 | H-53 | H-A12 | H-A15 | H-2031 | H-2033 | Olivko |
|---|---|---|---|---|---|---|---|
| C-16:0 | 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 |
| C-16:1 | 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 |
| C-18:0 | 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 |
| C-18:1 | 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 |
| C-18:2 | 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 |
| C-18:3 | 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 |
| C-20:0 | 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 |
| C-20:1 | 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 |
| C-22:0 | 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 |
| *SFA | 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 |
| **PUFA | 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 |
| PUFA/SFA | 6.36 ± 0.54 | 8.43 ± 0.71 | 9.31 ± 0.82 | 6.23 ± 0.45 | 8.15 ± 0.68 | 10.19 ± 0.87 | 10.77 ± 1.01 |

Notes: Results are the means of three replicates ± SD ($P \geq 0.05$). Means within each column followed by the same letter are not significantly different at $P < 0.05$. *Total of saturated fatty acids. **Total of unsaturated fatty acid.

hybrids H-120, H-53 and H-A12 had a significant higher ($P \geq 0.05$) in peroxide values than other hybrids under study. This observation was a consequence of the significantly higher linoleic acid content observed for hybrids H-120, H-53 and H-A12. Only hybrids with peroxide values of 10 meq/kg 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/kg indicates that oil oxidation has not occurred yet and therefore that 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 sample was more stable to oxidation than the mid-oleic sunflower oil. All the 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 7.50 h) and was followed by the hybrids A12 and A15 that showed a slightly higher values (10.90 and 12.10 h). The hybrids Olivko and 2031 had the highest oxidative stability values with means (17.50 and 17.00 h). Among these, hybrid 2033 performed the best of all hybrids with the highest oxidative stability values (19.00 h). 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 has recorded a tocopherol value that is significantly higher (445.00 mg/kg) followed by hybrid 2031 (423.00 ppm) and Olivko (419.00 ppm), respectively. But the hybrid 53 recorded a value that is significantly lower ($P \geq 0.05$) (360.00 ppm) in tocopherol content. The tocopherol content of oil is important in order to protect lipids against autoxidation and therapy to increase its storage life and value as a wholesome food. Tocopherol has a polar chromanol ring with a lipophilic prenyl side chain and comprise of four homologous forms, α, β, $\gamma$ and δ-tocopherol, differing only in the number and position of methyl substituent on the chromanol head group (Traber *et al.*, 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).

## Fatty acid composition

Data presented in Table 4, illustrate the fatty acid composition of seven sunflower hybrids growing under Egyptian conditions, wherein only major fatty acids, such as palmitic, stearic, oleic and linoleic acid, were presented. Averages for palmitic acid percentages ranged between 4.29 and 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 and 5.32%, this result showed a significant difference between all samples under study in stearic acid percentages. Oleic acid percentage ranged between 51.24 and 82.87%, found a significant differences ($P \geq 0.05$) clearly between all hybrids of oil samples. The highest value in oleic acid found in hybrids 2033 was (82.87%) followed by hybrid 2031 was (81.40%), while the lowest value in oleic acid recorded in hybrids 53 was (51.24%) followed by hybrid 120 was (52.83%). The higher value in linoleic acid (C-18:2) was recorded in hybrids 53 was (37.57%) followed by hybrid 120 was (33.15%), but the lower value in linoleic acid recorded in hybrids A15 was (5.48%) followed by hybrid 2031 was (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 4). Significant differences ($P \geq 0.05$) were observed between the high-oleic hybrids, mid-oleic and low-oleic for oleic and linoleic acids percentages.

The PUFA/SFA ratios as well as refractive index and iodine values were indicative of unsaturation levels and as a result, oil has 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 all the samples under study. These results are in agreement with those obtained by Merrill *et al.* (2008).

# Conclusion

The results obtained from this study suggest that hybrids sunflower oil content and fatty acid composition are dependent on the variety of sunflower and its interaction with the environment. The environmental factors contribute to the variability in oil content, and the varieties contribute to fatty acid content. The

high-oleic and mid-oleic sunflower gave high oil content when compared to the traditional varieties. Hybrids 2033, Olivko and 2031 gave high oil content, oleic acid tocopherol and high stability compared to other varieties. In Egypt, there is a sharp decline in the production of edible oils, and the success in producing sunflower oil high in oleic acid contributes to reducing the gap between production and consumption.

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