

## Physicochemical Properties and Stability of Oil Extracted from Three Canola Cultivars Grown in Golestan Province of Iran

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### ABSTRACT

The oil extracted from three major canola cultivars (Hyolla401, Hyolla420 and RGS003) grown in Golestan Province was analyzed for physico-chemical properties, fatty acid composition, minerals content, and stability during 16 weeks of storage. According to the results, the highest iodine value and refractive index belonged to *Hyolla401*. The highest saponification value was observed in *Hyolla420*. There was no significant difference ( $P < 0.05$ ) between the relative densities of the three cultivars. Study on the mineral content showed the highest level of iron and phosphorus in *Hyolla420* and the maximum sulfur content in *RGS003* cultivar. Oleic acid ( $\omega$ -9) was the major fatty acid in all cultivars and the highest level was found in *RGS003* (include % of oleic acid here). The highest level of essential fatty acids, linoleic acid ( $\omega$ -6) was found in *Hyolla420* and linolenic acid ( $\omega$ -3) in *Hyolla401*. In all three cultivars, erucic acid content was low and within the permitted level (include % of oleic acid here). The *Hyolla420* had the highest content of free fatty acid, acid value, peroxide value, anisidine value and Totox value compared to the other cultivars, during storage. However, result of oil stability based on Rancimat test showed that the *Hyolla420* cultivar had the highest induction time during storage, which was in agreement with its low polyene index (PI).

**Keywords:** Canola oil, Fatty acid composition, Oil stability, Physico-chemical properties.

### INTRODUCTION

In the past two decades, production of *Brassica* oilseeds has become second only to soybeans as a source of vegetable oil. Canola oil is now claimed to be one of the best nutritious edible oils available. This oil was developed after significant improvement and modification of the original high-erucic acid rapeseed oil (HEAR). Canola (*Brassica napus* L.), an annual oilseeds, has been grown agriculturally for many centuries for its oil and meal. Canola cultivars, low in erucic acid and glucosinolates, are very different from high erucic acid rapeseed oil in chemical, physical and nutritional properties. Canola oil contains

a low content of saturated fatty acids (5–7%) and high content of polyunsaturated fatty acids with about 7–10% alpha-linolenic and 17–21% linoleic acids. It is therefore considered as a healthy edible oil (Baux *et al.*, 2008).

The rate of oxidation of fats and oils is affected by the oxygen partial pressure, access of oxygen, the degree of unsaturation of fatty acids, and the presence of light, heat, antioxidants and pro-oxidants such as iron and pigments. Lipid autoxidation is a free radical chain reaction and free radicals generated from lipids are a major cause for quality loss in color, flavor, texture, and nutritive values during food processing and storage (Nawar, 1998).

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The degradation of oils and fats due to light exposure is primarily a photocatalyzed oxidation. During photo-oxidation, singlet oxygen is generated by transformation of light energy to a sensitizer that activates oxygen. Singlet oxygen is an extremely reactive species of oxygen-1500 times more reactive than normal oxygen- and reacts with double bonds of unsaturated fatty acids. Typical photosensitizers are chlorophylls and their decomposition products formed during maturation of seed and processing, heme compounds, and polycyclic aromatic hydrocarbons (Smouse, 1994).

Chlorophyll is retained in mature canola seed as the result of an early frost or other environmental factors. Chlorophyll in seeds is extracted with the oil when it is processed. Also, at maturity, only chlorophyll a and b are present while all possible isomers/derivatives have been observed at other stages of maturation. These changes in the composition and content of chlorophylls can have a direct impact on the processing and quality of canola oil. During processing, chlorophyll completely decomposes to derivatives that are more difficult to remove during bleaching. This necessitates the use of higher amounts of activated bleaching earth to achieve complete removal of all chlorophyll derivatives (Suzuki and Nishioka, 1993). Sulfur in canola oil is in the form of organic compounds as the decomposition products of glucosinolates. Although these sulfur components occur in trace quantities, they poison catalysts used for hydrogenation as well as giving a characteristic odor to the oil. Sulfur components may also improve the stability of the oil. Some of these components can act as antioxidants and protect the oil from autoxidation by complexing hydroperoxyl radicals with the sulfur to form stable compounds. These compounds can also inactivate catalysts involved in oxidative processes, such as metals (Barnard *et al.*, 1958). The stability of canola oil is limited mostly by the presence of linolenic acid, chlorophyll, and its decomposition products and other minor components with high chemical reactivity, such as trace amounts of

fatty acids with more than three double bonds. The objective of the present study was to study the fatty acid composition, physicochemical properties, and stability of the extracted oil from three major canola cultivars grown in Golestan Province, Iran.

## MATERIALS AND METHODS

### Materials

Three major Canola cultivars grown in Golestan Province of Iran, namely, *Hyolla401*, *Hyolla420*, and *RGS003*, were obtained from the Cultivation, Research and Development Center of Oil Seeds of Golestan (three samples for each cultivar). The seed samples were dried to 8% moisture at 30-35°C and kept in a cool place (10°C) until use. All chemicals used were of analytical grade and were obtained from Sigma (St. Louis, MO, USA) and Merck chemicals (Darmstadt, Germany).

### Oil Extractions

Oil from the three canola cultivars were extracted using laboratory press (OEKOTECH, DD85-Germany) at temperature range of 35-40°C, kept in aluminum covered flask and stored in dark at room temperature for four months.

### Physicochemical Properties

Oil samples were analyzed by standard methods Cd 1d -92, Cd 3 -25, Cc 10 - 95, and Cc 7- 25 for iodine value, saponification number, relative density, and refractive index, respectively (AOCS, 1998).

### Determination of Fatty Acids Composition

Fatty acid methyl esters (FAMES) were prepared according to the AOCS (1998)

recommended method Ce 1b-89. Fatty acid methyl esters (FAME) were prepared by vigorous shaking of a solution of each canola oil sample in n-hexane (0.2 g in 8 ml) with 2 ml 2M methanolic potassium hydroxide solution. The fatty acid composition of oils was determined by using a capillary gas chromatograph (Agilent, 6890N Plus, Palo Alto, CA, USA) with a flame ionization detector and a BPX70 column (120 m×0.25 mm i.d, 0.25 µm film thickness, Austin, TX, USA). Temperature program was from 140 to 220°C for 15 minutes with a 4°C min<sup>-1</sup> gradient. The injector temperature was 230°C and detector temperature was 260°C. Determination of fatty acid content was verified by comparison of retention times of the test samples with those of the reference standards.

#### Polyene Index (PI)

The ratio between polyunsaturated fatty acids (PUFA) and saturated fatty acids (SFA), known as polyene index (PI), was measured according to Mendez *et al.* (1996).

#### Hydrolytic and Oxidative Stability

Different methods were used to evaluate the stability for the oils fraction including determination of free fatty acids (FFA), acid value (AV) for Hydrolytic stability, peroxide value (PV), anisidine value (AnV), totox value (TV) and Rancimat method for the oxidative stability, according to the procedure described by the AOCS (1998).

##### Free Fatty Acids (FFA) and Acid Value (AV)

The FA and AV were estimated according to AOCS (1998) recommended method Ca 5a-40. The percentage of free fatty acids in oil samples was calculated as oleic acid.

##### Peroxide Value (PV)

Hydro peroxides, primary oxidation products, were measured and represented as

the PV according to AOCS (1998) method Cd 8-53.

##### Anisidine Value (AnV)

AnV of oxidized oils was determined according to AOCS (1998) recommended method Cd 18-90.

##### Totox Value (TV)

The Totox value was obtained from the potentiometric readings of PV and AV according to AOCS method (AOCS, 1998) using the following equation:

$$\text{Totox value} = 2\text{PV} + \text{AnV} \quad (1)$$

##### Rancimat Test

Oxidative stability was evaluated by the Rancimat method. Stability was expressed as the oxidation induction period (h), measured with the Rancimat (Metrohm, Model 679, Herisau, Switzerland) using an oil sample of 2 g, heated up to 110°C and a purified air flow rate of 20 ml h<sup>-1</sup>. In the rancimat method, the volatile degradation products were trapped in distilled water and measured conductmetrically. The induction period (IP) was defined as the necessary time to reach the inflection point of the conductivity curve (AOCS, 1998).

#### Chlorophyll Quantitation

The content of chlorophyll pigments was estimated according to AOCS (1998) recommended method Cc 13i-96 using the following equation:

$$C = 345.3[A_{670} - (A_{630} + A_{710})/2]/L$$

Where, *C* is the Pheophytin *a* (mg kg<sup>-1</sup> of oil), *A* is the absorbance of the oil at the corresponding wavelength, and *L* is the cell thickness (mm).

#### Phosphorus and Phosphatide Content

Phosphorous and Phosphatide content were determined by ashing the sample in the presence of zinc oxide, followed by the spectrophotometric measurement of phosphorus as a blue phosphomolybdic acid complex according to AOCS (1998) recommended method Ca 12- 55.



## Iron Content

Iron content was determined according to AOAC recommended method 990-05 (AOAC, 2005).

### 2.10. Sulfur Content

Sulfur content was determined according to the method described by Abraham and deMan (1987).

## Statistical Analysis

Statistical analyses were conducted with the SAS software package (SAS, 2001). Analysis of variance was performed by ANOVA procedures. Significant differences ( $P < 0.05$ ) were determined by the least square means comparisons. All experiments were performed on duplicate samples.

## RESULTS AND DISCUSSION

### Fatty Acids Composition

The fatty acids profile of the oil extracted from three canola cultivars is presented in Table 1. The main constituents of canola oil are saturated fatty acids (C14:0, C16:0, C18:0 and C20:0), mono-unsaturated fatty acids (C16:1, C18:1, C20:1 and C22:1) and poly unsaturated fatty acids (C18:2 and C18:3). The result showed that palmitic acid was the major saturated fatty acid in all three cultivars and the highest level was found in *Hyolla420* cultivar. The *Hyolla420* showed the highest level of total saturated fatty acids compared to the other cultivars ( $P < 0.05$ ). The unsaturated fatty acids were predominant in all cultivars. However, oleic acid ( $\omega$ -9) was the major fatty acid in all three cultivars and its content ranged from 61.4 to 64.0%. The highest level of oleic acid was found in *RGS003* cultivar. The range

**Table 1.** Fatty acid composition (w/w %) of oil from different canola oil cultivars <sup>a</sup>.

Fatty acids	<i>Hyolla401</i>	<i>Hyolla420</i>	<i>RGS003</i>
C14:0	<sup>c</sup> 0.50 ± 0.10	<sup>a</sup> 0.15 ± 0.12	<sup>b</sup> 0.06 ± 0.11
C16:0	<sup>c</sup> 0.16 ± 4.0	<sup>a</sup> 0.29 ± 4.4	<sup>b</sup> 0.05 ± 4.0
C18:0	<sup>c</sup> 0.07 ± 2.27	<sup>a</sup> 0.07 ± 2.86	<sup>b</sup> 0.07 ± 2.35
C20:0	<sup>a</sup> 0.06 ± 1.51	<sup>b</sup> 0.09 ± 1.26	<sup>b</sup> 0.06 ± 1.26
SFAΣ	<sup>b</sup> 0.10 ± 8.11	<sup>a</sup> 0.17 ± 8.68	<sup>b</sup> 0.13 ± 8.09
C16:1	<sup>b</sup> 0.06 ± 0.52	<sup>a</sup> 0.11 ± 0.52	<sup>c</sup> 0.31 ± 0.51
C18:1( $\omega$ -9)	<sup>b</sup> 0.14 ± 63.3	<sup>c</sup> 0.34 ± 61.4	<sup>a</sup> 0.12 ± 64.0
C20:1	<sup>b</sup> 0.08 ± 1.00	<sup>a</sup> 0.10 ± 1.11	<sup>a</sup> 0.08 ± 1.11
C22:1	<sup>c</sup> 0.34 ± 0.34	<sup>a</sup> 0.13 ± 0.61	<sup>b</sup> 0.12 ± 0.56
MUFAΣ	<sup>b</sup> 0.16 ± 65.27	<sup>c</sup> 0.12 ± 63.30	<sup>a</sup> 0.23 ± 66.19
C18:2( $\omega$ -6)	<sup>c</sup> 0.20 ± 17.28	<sup>a</sup> 0.32 ± 18.21	<sup>b</sup> 0.09 ± 18.09
C18:3( $\omega$ -3)	<sup>a</sup> 0.10 ± 10.34	<sup>b</sup> 0.18 ± 8.48	<sup>b</sup> 0.14 ± 8.44
PUFAΣ	<sup>a</sup> 0.16 ± 27.62	<sup>b</sup> 0.13 ± 26.69	<sup>b</sup> 0.10 ± 26.54
USFAΣ	<sup>a</sup> 0.39 ± 92.9	<sup>b</sup> 0.22 ± 90.3	<sup>a</sup> 0.33 ± 92.7
PI	<sup>a</sup> 0.0001 ± 3.40	<sup>c</sup> 0.0001 ± 3.07	<sup>b</sup> 0.0001 ± 3.28

SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids; USFA: Unsaturated Fatty Acids, PI: Polyene Index.

<sup>a</sup> Values Followed by different letters in each row are significantly different ( $P < 0.05$ ).

of oleic acid in canola cultivars has been reported to be between 51 and 70% (Codex Alimentarius Commission, 2001). Among these cultivars, *RGS003* showed the highest level of total monounsaturated fatty acids (66.2%), whereas the highest level of total polyunsaturated fatty acids was observed in *Hyolla401* cultivar (27.6%). The highest level of essential fatty acids, including linoleic acid (18.2 %) and linolenic acid (10.3 %) were found in *Hyolla420* and *Hyolla401* cultivars, respectively. The content of linoleic acid in canola ranges between 15.0 and 30.0% (Codex Alimentarius Commission, 2001). In all three cultivars, erucic acid content was low and within the permitted level (maximum 2%) and the lowest level (0.34%) was found in *Hyolla401* cultivar. Based on our study, the seeds of all three cultivars had similar (but not identical) fatty acid compositions and contained low amounts of saturated fatty acids.

### Physicochemical Properties

Physicochemical properties of the oil extracted from the three different canola cultivars are presented in Table 2. The measured iodine value (IV) of the extracted oils ranged from 109.34 to 116.06 g iodine 100 g<sup>-1</sup> oil. It can be expected that *Hyolla401* cultivar, with the highest levels of polyunsaturated and unsaturated fatty acids, show the highest iodine value compared to the other cultivars. The IV of canola oil has been reported in the range of 110–126 g iodine 100 g<sup>-1</sup> oil (Gunstone, 2004), thus, our results are in close agreement with the previously reported

values. There was significant difference between saponification number of oil extracted from the three canola cultivars and the amount ranged from 181 to 187 (mg KOH per g of sample). This parameter is inversely proportional to the molecular weight of the fat. In other words, the higher the molecular weight, the lower is the saponification value. The saponification number for canola cultivars has been reported between 188 and 192 mg KOH per g of sample (Gunstone, 2004), which is in close agreement with our data.

There was no significant difference between the relative density of the oil extracted from the three canola cultivars. The density of canola oil has been reported to be 0.906 to 0.914 g cm<sup>-3</sup> (Appelqvist and Ohlson, 1972).

There was significant difference ( $P < 0.05$ ) between the refractive index of oil extracted from different canola cultivars. The refractive index (RI) differs based on the fatty acid chain length, degree of unsaturation, and degree of conjugation. The refractive index of the oil shows strong correlation with the degree of unsaturation (Gunstone, 2004). Cultivar *Hyolla 401*, with a high level of polyunsaturated fatty acids, showed the maximum refractive index. It has been reported that refractive indices of high erucic acid rapeseed oil range between 1.465 and 1.469 and, in canola cultivars, between 1.465 and 1.467 (Gunstone, 2004).

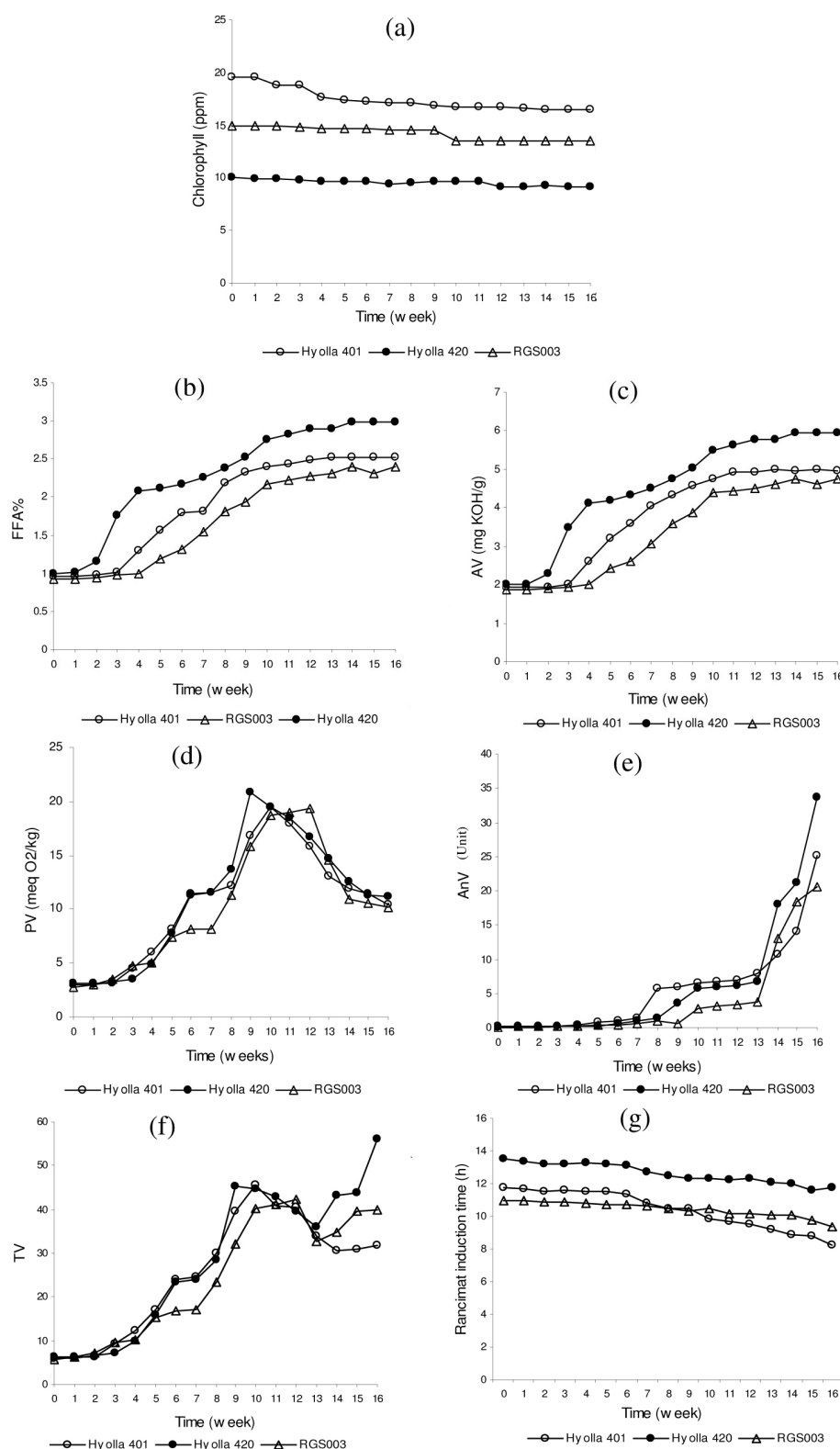
### Chlorophyll Content

Figure 1-a shows the changes in chlorophyll content of oils extracted from the three different cultivars during 16 weeks

**Table 2.** Some Physicochemical properties and mineral content (mg kg<sup>-1</sup>) of oil from different canola oil cultivars <sup>a</sup>.

Parameter	<i>Hyolla401</i>	<i>Hyolla420</i>	<i>RGS003</i>
Iodine Value (g iodine 100 g <sup>-1</sup> oil)	116.1 ± 0.50 <sup>a</sup>	110.7 ± 0.80 <sup>b</sup>	109.3 ± 0.70 <sup>b</sup>
Saponification Value (mg KOH per g of sample)	184.1 ± 0.61 <sup>b</sup>	187.3 ± 0.57 <sup>a</sup>	181.1 ± 0.5 <sup>c</sup>
Relative Density (gr cm <sup>-3</sup> at 20°C)	0.92 ± 0.0003 <sup>a</sup>	0.92 ± 0.0003 <sup>a</sup>	0.92 ± 0.0001 <sup>a</sup>
Refractive Index (40°C)	1.4675 ± 0.0001 <sup>a</sup>	1.4652 ± 0.0001 <sup>c</sup>	1.4655 ± 0.0001 <sup>b</sup>
Iron (mg kg <sup>-1</sup> )	1.19 ± 0.001 <sup>c</sup>	4.67 ± 0.001 <sup>a</sup>	2.37 ± 0.001 <sup>b</sup>
Sulfur (mg kg <sup>-1</sup> )	7.12 ± 0.338 <sup>a</sup>	4.85 ± 0.272 <sup>b</sup>	3.87 ± 0.260 <sup>c</sup>
Phosphorus (mg kg <sup>-1</sup> )	1441 ± 36.927 <sup>b</sup>	2085.6 ± 106.124 <sup>a</sup>	1238 ± 32.048 <sup>c</sup>

<sup>a</sup> Values Followed by different letters in each row are significantly different ( $P < 0.05$ ).



**Figure 1.** Changes in chlorophyll content (a), free fatty acid (b), acid value (c), peroxide value (d), anisidine value (e), Totox value (f), and oxidative stability (g) of oil extracted from different canola cultivars during 16 weeks of storage at room temperature.

of storage. The chlorophyll content of these cultivars ranged between 10 and 20 ppm, however, it decreased in all oil samples during storage. Oxidative distinguish was the main factor to decrease chlorophyll content in vegetable oils during storage. Cultivar *Hyolla 401* contained the maximum level of chlorophyll while the lowest level of chlorophyll was determined in *Hyolla 420* cultivar; in accordance with its low stability. Chlorophyll is one of the most important factors in oil stability and acts as antioxidant in the dark (Geier, 2004).

### Mineral Content

The mineral contents in the oils of the three canola cultivars are presented in Table 2. The results showed varietal differences with Fe ranging from 1.19 mg kg<sup>-1</sup> in *Hyolla401* to 4.67 mg kg<sup>-1</sup> in *Hyolla420*. Transition metals such as iron play an important role in initiation and propagation steps of lipid oxidation. The initiation step of oil oxidation requires removal of a hydrogen atom. The presence of metals can accelerate the initiation step of lipid oxidation. Metals can decompose hydroperoxides to form peroxy and alkoxy radicals, and accelerate lipid oxidation at an exponential rate. It has been reported that the best stability of oils is achieved when the iron content is below 0.1 ppm (Appelqvist and Ohlson, 1972). The lowest levels of phosphorus (1238 mg kg<sup>-1</sup>) and sulfur (3.86 mg kg<sup>-1</sup>) were detected in *RGS003* cultivar and the highest level of phosphorus (2085 mg kg<sup>-1</sup>) was observed in *Hyolla420* cultivar and the highest levels of sulfur (7.12 mg kg<sup>-1</sup>) detected in *Hyolla401* cultivar. Sulfur in canola oil is in the organic form and is the product of glucosinolates decomposition. Only Brassica oils contain significant quantities of divalent sulfur components. These components may improve the stability of the oil because they can act as antioxidants and protect the oil from autoxidation by complexing with hydroperoxy radicals to form stable

compounds. These compounds can also inactivate catalysts, such as metals, involved in oxidative processes (Barnard *et al.*, 1958). Among the studied cultivars, *Hyolla420* contained the highest phosphorus level of 2085 mg kg<sup>-1</sup>. Phosphorus in oils is mostly present in the form of phospholipids and is removed mostly through degumming procedures and also other refining steps. The conditions used during crushing of the seed have a dramatic effect on the sulfur and phosphorus content. Levels of sulfur in excess of 100 ppm can cause downstream processing problems associated with high contents of phosphorus and sulfur in the oil and of high glucosinolate in the meal (Gunstone, 2002).

### Hydrolytic and Oxidative Stability

Free fatty acid and acid value are parameters indicating the extent of hydrolytic stability. Figure 1-b shows the changes in free fatty acids (FFAs) contents of oil extracted from the three canola cultivars during 16 weeks of storage. In all cultivars, the FFA content increased during storage. The rate of increase in *Hyolla 420* was noticeable after three weeks and in the other two cultivars after four weeks of storage. *Hyolla420* cultivar showed the highest content of FFA and the amount increased from 1% immediately after oil extraction to 3% after 16 weeks of storage. The FFA content of crude canola oil has been reported to be between 0.3 and 1.2 percent (Gunstone, 2002). FFAs are products of triacylglycerols (TAG) formed either through chemical or enzyme mediated hydrolysis. FFA's are usually associated with undesirable flavor and textural changes when they are present in fats and oils. Figure 1-c shows the results of Acid value (AV) of oil extracted from the canola cultivars during 16 weeks of storage. An AV of two is equivalent to approximately 1% FFA when the AV is expressed as a percent of oleic acid. The results showed that, in all cultivars, the AV increased during 16 weeks



of storage, in accordance with FFA content of these cultivars. The AV is an indicator of hydrolytic rancidity, which may occur enzymatically or non-enzymatically at high temperatures, producing free fatty acids. Fatty acids oxidize at a slightly greater rate when free than when esterified to glycerol, and may impart undesirable flavors and aromas, especially in the oils with large quantities of low molecular weight fatty acids.

Figure 1-d shows the changes in Peroxide value (PV) of different canola oils during 16 weeks of storage. The results showed that, in all cultivars, the PV increased initially and then decreased. Compared to other cultivars, the *Hyolla420* was less stable to oxidation and its PV attained a maximum level after 9 weeks storage, whereas the PV of *Hyolla401* and *RGS003* cultivars reached the maximum after 10 and 12 weeks of storage, respectively. The high rate of oxidation in *Hyolla420* cultivar can be attributed to the higher AV of this cultivar because, as mentioned earlier, fatty acids oxidize at a slightly greater rate when they are in free state. The PV for canola crude oil has been reported to be between 0.5 and 3 meq O<sub>2</sub> kg<sup>-1</sup> (Fennema, 1996). In our study, the PV in crude oil was less than 3 meq O<sub>2</sub> kg<sup>-1</sup> in *Hyolla420* and *RGS003* cultivars, but in *Hyolla401*, it was 3.1 meq O<sub>2</sub> kg<sup>-1</sup>, indicating that canola oils had no similar initial quality. It has been reported that, during prolonged oxidation, PV reaches a maximum and then begins to decrease due to peroxide degradation. This maximum value occurs early for soybean and rapeseed oil, due to the more rapid decomposition of the hydroperoxides of the polyunsaturated fatty acids (Gunstone, 2002). Figure 1-e shows the changes in Anisidine Value (AnV) of different canola oils during 16 weeks of storage. The results showed that the AnV increased during storage. The rate of increase was slow in all three cultivars up to 13 weeks of storage and increased rapidly thereafter. The rate of increase was higher in *Hyolla420* and the amount ranged from 0.05 units immediately after oil extraction to 33.6

unit after 16 weeks of storage. The range of AnV in canola crude oil has been reported between 1 and 3 units (Gunstone, 2002). In our study, the AnV in crude oil of all three cultivars was less than 0.15. The AnV is a measure of carbonyl compounds that have medium molecular weight and are less volatile. Carbonyl compounds in oxidized lipids are the secondary oxidation products resulting from decomposition of the hydroperoxides (Gunstone, 2002).

Results of Totox Value (TV) for different canola oils during 16 weeks of storage are presented in Figure 1-f. Compared to the other cultivars, *Hyolla420* showed a higher Totox value at the end of storage period, which is in agreement with higher AnV and PV in this cultivar after the storage. The result is also in agreement with a higher iron and a lower chlorophyll content of this cultivar. In the absence of light, chlorophylls may act as a weak antioxidants. Transition metals, especially iron and copper, are known as pro-oxidant factors, because they generate free radicals (Gunstone, 2002). Among different cultivars, the *Hyolla420* contained the highest amount of iron and, therefore, the lowest stability against oxidation, which is in accordance with its high rate of oxidation (Figure 1-d).

The primary oxidation products are normally measured with peroxide value (PV) test and the secondary products with Anisidine test. Anisidine value (AnV) represents the level of non-volatile aldehydes, primarily 2-alkene present in the fat. Study of the oxidative stability of vegetable oils is required to measure the content of the primary and secondary oxidation products as a function of time. Figure 1-g shows results of Rancimat induction time in the three canola cultivars during 16 weeks of storage. The Rancimat measures the increase in the conductivity of deionized water resulting from the trapped volatile oxidation products produced when the oil product is heated under a flow of air. Compared to the other cultivars, *Hyolla420* showed the highest induction time during storage that means this cultivar has more



stability under accelerated condition of Rancimat test. The di- and triunsaturated fatty acid chains contain the most reactive sites for initiation of the autoxidation chain reaction sequence. Oxidative stability does not correlate with the total number of double bonds, but with the total number of bis-allylic sites (the methylene CH directly adjacent to the two double bonds). These sites react with oxygen via the autoxidation mechanism with the classical radical chain reaction steps of initiation, propagation, chain branching, and termination (Gunstone, 2002). The ratio between polyunsaturated fatty acids (PUFA) and saturated fatty acids (SFA), also known as polyene index (PI), is usually taken as a measure of the extent of polyunsaturation of an oil and, obviously, of its tendency to undergo autoxidation (Mendez *et al.*, 1996). The polyene index for *Hyolla401*, *Hyolla420* and *RGS003* cultivars were 3.40, 3.07, and 3.28, respectively. Therefore, it can be expected that *Hyolla401* with higher PI shows a lower stability.

It has been reported that oxidizability is the primary factor explaining differences in induction time for biodiesel derived from soy and canola oil samples. Oxidizability (McCormick *et al.*, 2007), is defined as follows:

$$\text{Oxidizability} = [0.02(\% \text{Oleic}) + \% \text{linoleic} + 2(\% \text{linolenic})] / 100$$

The coefficients for oleic (C18:1), linoleic (C18:2), and linolenic (C18:3) fatty esters are proportional to the relative rates of oxidation of these compounds (Cosgrove *et al.*, 1987). The polyunsaturated content (or oxidizability) has the largest impact on reducing induction time (McCormick *et al.*, 2007). Therefore, the higher stability of oil extracted from *Hyolla420* cultivar compared to *Hyolla401* (Figure 1-g) can be attributed to lower amount of polyunsaturated fatty acids in this cultivar.

#### ACKNOWLEDGEMENTS

The authors are grateful to research section, Gorgan University of Agricultural

Science and Natural Resources for their valuable supports. Authors are also grateful to Dr. Ghorbani for his valuable helps.

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### خصوصیات فیزیکی شیمیایی و پایداری روغن سه رقم کلزا کاشته شده در استان گلستان

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#### چکیده

در این پژوهش، روغن سه رقم عمده کلزای استان گلستان (هایولا ۴۰۱، هایولا ۴۲۰ و RGS003) به منظور بررسی ترکیب اسیدهای چرب، خصوصیات فیزیکی شیمیایی، عناصر معدنی و پایداری اکسیداتیو، استخراج و سپس نمونه‌ها در شرایط دور از نور و در دمای محیط، به مدت ۱۶ هفته نگهداری شدند. بررسی خصوصیات فیزیکی شیمیایی نمونه‌های روغن نشان داد که رقم هایولا ۴۰۱ دارای بیشترین میزان اندیس یدی و ضریب شکست، و رقم هایولا ۴۲۰ دارای بیشترین میزان اندیس صابونی در روغن بودند. میزان دانسته نسبی در هیچیک از واریته‌ها معنی‌دار ( $P < 0.05$ ) مشاهده نگردید. با بررسی ترکیب روغن بیشترین میزان آهن و فسفر در رقم هایولا ۴۲۰، و بیشترین میزان سولفور در رقم هایولا ۴۰۱ تعیین گردیدند. اسید چرب عمده در روغن هر سه رقم کلزا، اسید اولئیک (۹-ω) بود. بیشترین میزان اسیدهای چرب ضروری شامل اسید لینولئیک (۶-ω) در رقم هایولا ۴۲۰ و بیشترین میزان اسید لینولئیک (۳-ω) در رقم هایولا ۴۰۱ تعیین گردید. میزان اسید اروسیک نیز در تمامی واریته‌ها کمتر از حد مجاز آن (۲ درصد) اندازه‌گیری شد. نتایج حاصل از بررسی پایداری اکسیداتیو نشان داد که رقم هایولا ۴۲۰، دارای بیشترین میزان اسیدیته، عدد اسیدی، اندیس پراکسید، اندیس آنیزیدین و عدد توتکس و همچنین بیشترین میزان پایداری اکسیداتیو بر اساس آزمون رنسیمت در طی دوره نگهداری بود که به دلیل داشتن میزان کمتر اندیس پلی‌ان در آن می‌باشد.