Chemical and Physical Analyses and Sensory Evaluation of Six Deep-Frying Oils

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ABSTRACT: The performance of three high-oleic canola oils with different levels of linolenic acid [low-linolenic canola (LLC), medium-linolenic canola (MLC), and high-linolenic canola (HLC)], a medium-high-oleic sunflower oil, a commercial palm olein and a commercial, partially hydrogenated canola oil, was monitored by chemical and physical analyses and sensory evaluation during two 80-h deep-frying trials with potato chips. Linolenic acid content was a critical factor in the deep-frying performance of the high-oleic canola oils and was inversely related to both the sensory ranking of the food fried in the oils and the oxidative stability of the oils (as measured by color index, free fatty acid content, and total polar compounds). LLC and sunflower oil were ranked the best of the six oils in sensory evaluation, although LLC performed significantly better than sunflower oil in color index, free fatty acid content, and total polar compounds. MLC was as good as palm olein in sensory evaluation, but was better than palm olein in oxidative stability. Partially hydrogenated canola oil received the lowest scores in sensory evaluation. High-oleic canola oil (Monola) with 2.5% linolenic acid was found to be very well suited for deep frying.

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KEY WORDS: Canola oil, color index, deep frying, dielectric constant, fatty acid profile, free fatty acids, palm olein, sensory evaluation, sunflower oil, total polar compounds.

Canola is grown extensively in Australia and, due in part to its low saturate content and high monounsaturate content, has nutritional properties superior to those of most traditional frying oils (1,2). However, although standard canola oil with high linolenic acid content (HLC) performs very well in table spread and salad oil applications, these thermally unstable polyunsaturated fatty acids are less desirable in frying oils and have thus limited the commercial adoption of canola oil. Several studies have indicated that reducing the contents of linolenic and linoleic acid in frying oil increases its oxidative stability and reduces the acidic and fishy off-flavors of fried food when heated above 150°C (3,4). However, the oils used in these studies commonly differed from each other in several aspects of their fatty acid composition, rather than just in linolenic and linoleic contents.

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Although a general reduction in linolenic acid content is commonly accepted as necessary in the development of canola varieties of frying oil, there is very little information available to assist plant breeders in setting more precise compositional targets for the oil. The recent availability of new varieties of canola, with very similar oil compositions (except for linolenic and linoleic contents), now enables more rigorous comparisons to be made. The objective of this study was to use both chemical and physical analyses and sensory evaluation to compare the frying performance of three recently developed high-oleic canola oils (Monola) which differed principally only in linoleic and linolenic acid contents, and to further compare the performance of these oils with that of partially hydrogenated canola oil (PHC), medium-high-oleic sunflower oil (SO), and palm olein (PO).

EXPERIMENTAL PROCEDURES

Oils and chips. Royal Chef PO and Vegetol PHC were obtained from EOI Foods (Sydney, Australia). The SO and oils from three new lines of high-oleic canola oils (Monola) with different linolenic acid levels (LLC, MLC, and HLC) were developed and supplied by Ag-Seed Research (Victoria, Australia). The major fatty acid composition of the oils is given in Table 1. Neither the SO nor the Monola contained antioxidants, antifoaming agents, or any other additives. Both commercial oils (PO and PHC) contained 200 ppm tertiary butylhydroquinone antioxidant and 4 ppm antifoaming agent. Edgell (Grade A, Melbourne, Australia) 13-mm quick frozen straight cut chips were used in this study. They had been prefried in refined tallow by the manufacturer for 1 min prior to freezing and were stored at −18°C.

Frying procedure and oil sampling. Two replications of 80-h deep-frying trials were conducted, using six oil types per trial. Oils (7.5 L) were placed in each of the six temperature-regulated fryers (Roband type, Woodson Australia Pty. Ltd., Melbourne). The oils were heated to 190 ± 2°C and kept at this temperature for 8 h each day. Chips were fried for 5 min in each oil at a rate of 100 g every 20 min during non-taste panel time and for 3.5 min at a rate of 200 g every 10 min at taste panel time. Oil samples were taken at the end of the day and kept at −14°C for further chemical and physical analysis. Oils were not topped up during frying.

TABLE 1
Major Fatty Acid Profiles of the Palm Olein, Sunflower Oil, and the Four Canola Oils Before Deep-Frying[a]

Fatty acid	LLC	MLC	HLC	PHC	SO	PO
16:0	4.1	3.9	4.1	5.1	5.3	40.1
18:0	1.9	1.6	2.2	10.0	4.8	4.5
18:1*trans*	0.0	0.0	0.0	26.7	0.0	0.0
18:1n-9	65.4	67.7	66.5	41.2	54.4	40.1
18:1n-7	3.3	3.3	2.8	3.2	1.0	1.0
18:2n-6	20.1	16.5	13.8	2.8	32.4	10.5
18:3n-6	0.3	0.4	1.1	0.0	0.0	0.0
18:3n-3	2.2	4.0	5.7	0.5	0.0	0.1
20:1n-9	1.1	1.1	1.2	0.2	0.2	0.1
SAFA	6.6	6.0	6.9	17.2	10.8	46.7
MUFA	70.0	72.1	70.8	74.9	55.5	42.0
PUFA	22.9	21.1	21.2	4.1	33.5	10.8
n-3 PUFA	2.4	4.2	6.0	0.8	0.0	0.1

[a]The values shown are the average of two replications, in percentage. LLC, low-linolenic canola oil; MLC, medium-linolenic canola oil; HLC, high linolenic canola oil; SO, sunflower oil; PO, palm olein; PHC, partially hydrogenated canola oil; SAFA, total saturated fatty acids; MUFA, total monounsaturated fatty acids; PUFA, total polyunsaturated fatty acids.

Fatty acid analysis. Fatty acids were converted to their methyl esters prior to analysis by gas chromatography (GC). Oil samples (50 μL) were methylated in 4 mL of 1 M methanolic KOH for 1 h at room temperature. The resultant fatty acid methyl esters (FAME) were extracted with high-performance liquid chromatographic-grade hexane and analyzed by GC immediately, using a fused-silica capillary column (SGE BPX70, 0.25 μm film thickness, 30 m × 0.25 mm i.d.), a flame-ionization detector (FID), and helium as the carrier gas (2 mL min^{-1}). GC split ratio was 50:1. Initial column temperature was 100°C, raised to 160°C at 10°C min^{-1}, then programmed to 220°C at 2.5°C min^{-1}, and finally heated to 240°C at 10°C min^{-1}. Injector and FID temperatures were 250 and 280°C, respectively. FAME samples (1 μL) were injected by autosampler. Fatty acids were identified by chromatographic retention time by comparison with authentic standards (Sigma, Sydney, Australia).

Iodine value. Iodine value (IV) was calculated from fatty acid data according to AOCS Recommended Practice Cd 1c-85. Additional fatty acid numbers for the calculation were cited from *Bailey's Industrial Oil and Fat Products* (5).

Color index (CI). Minolta Chroma Meter CR 300 was used to measure oil color. Oil samples were placed in 1-cm optical path disposable cuvettes, and a chromametric calibration plate was used as background. The cuvettes were warmed in a 60°C oven for 15 min before measuring. The measurement was displayed in L* a* b* (International Commission on Illumination 1976). L* value represents lightness-darkness dimension, a* value represents red-green dimension, and b* value represents yellow-blue dimension. Only L* value was used as the CI in this study. The lower the value, the darker the oil. The results shown here were the average value of three measurements.

Dielectric constant. A Foodoil Sensor (Oil Quality Analyzer, Northern Instruments Corp., Lino Lakes, MN) was used to measure the dielectric constant (DEC) of frying oils. The "zero test" solution that came with the sensor was used to zero the instrumental reading.

Free fatty acid (FFA) content. FFA content as percentage oleic acid was determined using AOCS Official Method Ca 5a-40. Acid value was calculated by multiplying the percentage of FFA by 1.99 and was defined as the amount (mg) of KOH required to neutralize 1 g of oil sample.

Total polar compounds. Total polar compounds (TPC) were analyzed using the TPM VERI-FRY® PRO quick test (Test Kit Technologies Inc., USA) by measuring the absorbance at 490 nm. For calibration, TPC in a set of 11 oil samples taken from day 0 to day 10 were analyzed using AOCS Official Method Cd 20-91. There was a high correlation between these two methods ($r = 0.98$, $P < 0.001$). The equation for converting the readings to TPC content was:

$$y = -2.5887x^2 + 23.147x + 1.8839 \ (r^2 = 0.97) \qquad [1]$$

Sensory evaluation. Taste panels were conducted between 11:00 A.M. and 1:00 P.M. on days 1, 3, 6, 8, and 10 of each trial. Each taste panel was composed of 36 panelists, 10 of whom were trained oil panelists. The order of sample presentation to individual panelists was randomized by computer. Samples were presented in two sets of three samples each. Each panelist first received hot chips from three of the six oils, evaluated those, and then received hot chips from the other three oils after a 2-min break. Panelists were asked to cleanse their palates with warm water after each tasting.

Fried chips were evaluated by rating on a 9-point hedonic scale, where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely, according to acceptability of color, taste, and overall quality. For the level of unpleasant or off-flavor, 1 = absent and 9 = extremely strong. For the degree of greasiness, 1 = not extremely greasy and 9 = extremely greasy or fatty. For the degree of crispiness, 1 = extremely soft or soggy and 9 = extremely crisp.

Statistical analysis of data. Data from chemical and physical analyses and sensory evaluation were analyzed statistically using analysis of variance, *F*-test, *t*-test, correlation,

and/or regression analysis. Most of the data presented in the following figures were fitted into linear, exponential, or polynomial curves. Equations for the fitted curves are not shown, but their corresponding r^2 values are given in the appropriate place in the text.

RESULTS AND DISCUSSION

The major fatty acid profiles of the six fresh oils are shown in Table 1. The three high-oleic canola oils (Monola) had similar proportions of total saturated fatty acids (SAFA), total monounsaturated fatty acids (MUFA), and total polyunsaturated fatty acids (PUFA). The main differences were in 18:3n-3 and 18:2n-6 content. PHC contained 26.7% *trans* fatty acid (18:1), and had higher SAFA and lower PUFA than the three high-oleic canola oils. PO contained 40% 16:0 plus 40% 18:1n-9. SO was rich in 18:2n-6, contained a moderate amount of 18:1n-9, but no detectable 18:3n-3.

Profiles of all the major fatty acids, except 18:1n-9 in LLC, HLC, PHC, and SO oils, showed systematic changes during the course of deep frying. The proportions of palmitic (16:0), stearic (18:0), and SAFA in the oils all increased significantly ($P < 0.001$) and were strongly correlated with hours of deep frying ($r > 0.92$). Linoleic (18:2n-6), linolenic (18:3n-3), PUFA, and total n-3 PUFA all decreased significantly ($P < 0.001$) during frying and all were strongly correlated with hours of frying ($r < -0.85$). The data all fit well into linear curves with $r^2 \geq 0.9$, except 16:0 ($r^2 = 0.34$) in PO and PUFA ($r^2 = 0.73$) in PHC (Fig. 1). Significant changes in oleic (18:1n-9) content during frying were only evident in MLC and PO ($P < 0.01$). The content of 18:1 *trans* in PHC decreased significantly ($P < 0.001$) during deep frying and was also highly correlated with hours of frying ($r = -0.66$). The MUFA level only in PO and PHC changed significantly ($P < 0.05$) during frying.

The fatty acid composition of oil has marked effects on its frying performance as well as on its physical and chemical behavior. During the course of deep frying, fatty acid profiles of the frying oils all changed due to cyclization, polymerization, and pyrolytic, hydrolytic, oxidative, and other chemical reactions promoted by frying conditions. Monitoring fatty acid profiles during frying provides only limited information about these compositional changes that are associated with oil degradation. On the other hand, the fatty acid profile of the unused oil can be used to predict its subsequent performance and stability during frying.

Previous studies have shown that reducing the content of linolenic acid in vegetable oils increased oxidative stability of the oils (3,4). This study further demonstrates that the content of 18:3n-3 is critical to the frying performance and stability of canola oils and the flavor and overall quality of the fried food. LLC (2.5% 18:3) performed much better in terms of color darkening, FFA and TPC content, taste, and overall quality than MLC (4.4% 18:3). Similarly, MLC performed much better than HLC (6.8% 18:3).

Linoleic acid (18:2n-6) was the major PUFA in these oils, the relative amount of which decreased significantly during frying. Linoleic acid level in deep-frying oils appears not to be an obviously negative factor in oil stability and sensory ranking of the fried food. Indeed, previous studies indicate that a certain level of linoleic content, balanced with oleic and palmitic acids, may improve the taste and overall quality of a frying oil (6,7). In this study, LLC had a higher linoleic level (20.1%) than MLC (16.5%) and HLC (13.8%). LLC was more stable chemically and physically and had a higher sensory ranking than MLC and HLC. Similarly, MLC was much better than HLC. The sunflower oil used in this study contained 54.4% 18:1n-9 and 32.4% 18:2n-6. Its sensory evaluation results, just the same as LLC, were ranked the best of the six oils.

SO had the highest initial IV (104.4) due to its higher PUFA content. LLC, MLC, and PHC had IV of 101.7, 102.1, and 103.1, respectively. PHC had an IV of 71.4, and PO had the lowest IV of 55.1 (Fig. 2A). IV in all the oils decreased significantly during the course of frying and were strongly correlated with hours of deep frying ($r \leq -0.916$, $P < 0.001$).

The color of the oils changed from clear and pale yellow to light and then dark brown during deep frying. Chroma Meter data showed the trend of coloring from light to dark. Oil CI were similar initially. They all decreased significantly during frying and strongly correlated with hours of frying ($r \leq -0.99$, $P < 0.001$). Color darkening patterns in the six oils were similar (Fig. 2B). Color darkening rates in all the oils except SO and PO were significantly different from each other ($P < 0.05$). PHC had the lightest and PO had the darkest final oil color. For the three high-oleic canola oils, the higher the linolenic content, the darker the final oil color. Oil color darkening was the most apparent change during deep frying and was significantly correlated with hours of deep frying, FFA, DEC, and TPC. For the three high-oleic canola oils, CI was a good indicator of oil degradation during frying. Using a Chroma Meter to measure CI was quick and convenient. Color darkening is a complicated process, involving interactions with fatty acids, dimers, polymers, and other minor compounds present in the oil and in the food being fried. CI could be used as a reference together with other parameters to monitor oil quality during deep frying.

The DEC of these oils all increased significantly during deep frying and were strongly correlated with hours of frying ($P < 0.001$, $r \geq 0.98$). LLC had the highest final DEC of 10.8. PHC had the lowest initial and final DEC values (0.3 and 6.1, respectively). The rates of DEC increase in the oils were all significantly different from each other ($P < 0.05$, Fig. 2C). The DEC values for each PO replicate were significantly different, even though the oil used for each was from the same container and the initial DEC readings were similar. However, there were no significant differences in any other parameter between the two replicates. The broken line in Figure 2C is the fitted curve for the two sets of data measured in the two replicates.

During frying, as oil breaks down, peroxides, acids, and other radicals are formed in the frying oil. These cause some

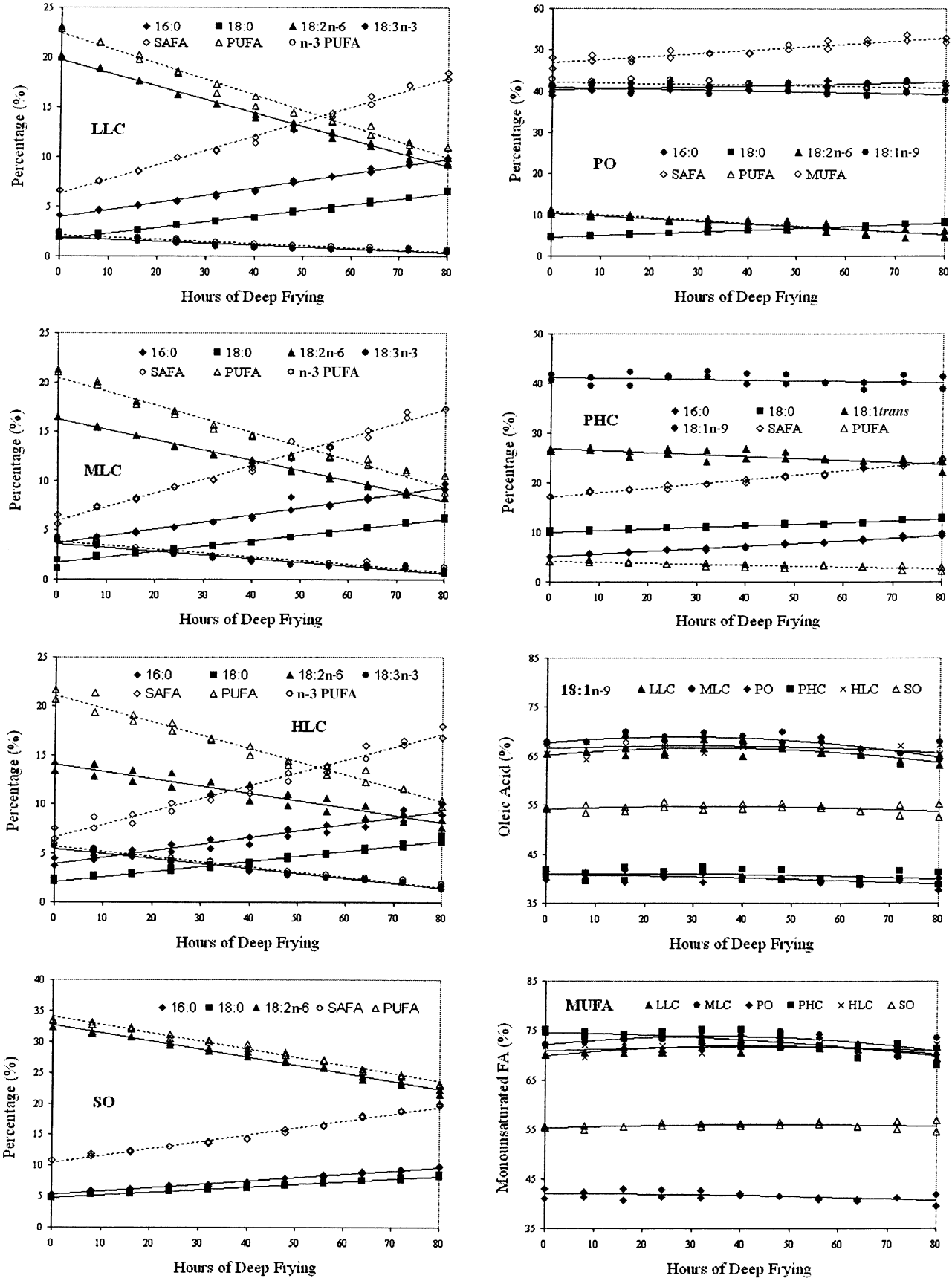

FIG. 1. Changes in the major fatty acids of the oils during deep frying. The two data points in the charts represent the two replicates. LLC, low-linolenic canola oil; MLC, medium-linolenic canola oil; HLC, high-linolenic canola oil; SO, sunflower oil; PO, palm olein; PHC, partially hydrogenated canola oil; PUFA, polyunsaturated fatty acid; SAFA, total saturated fatty acids; MUFA, monounsaturated fatty acid.

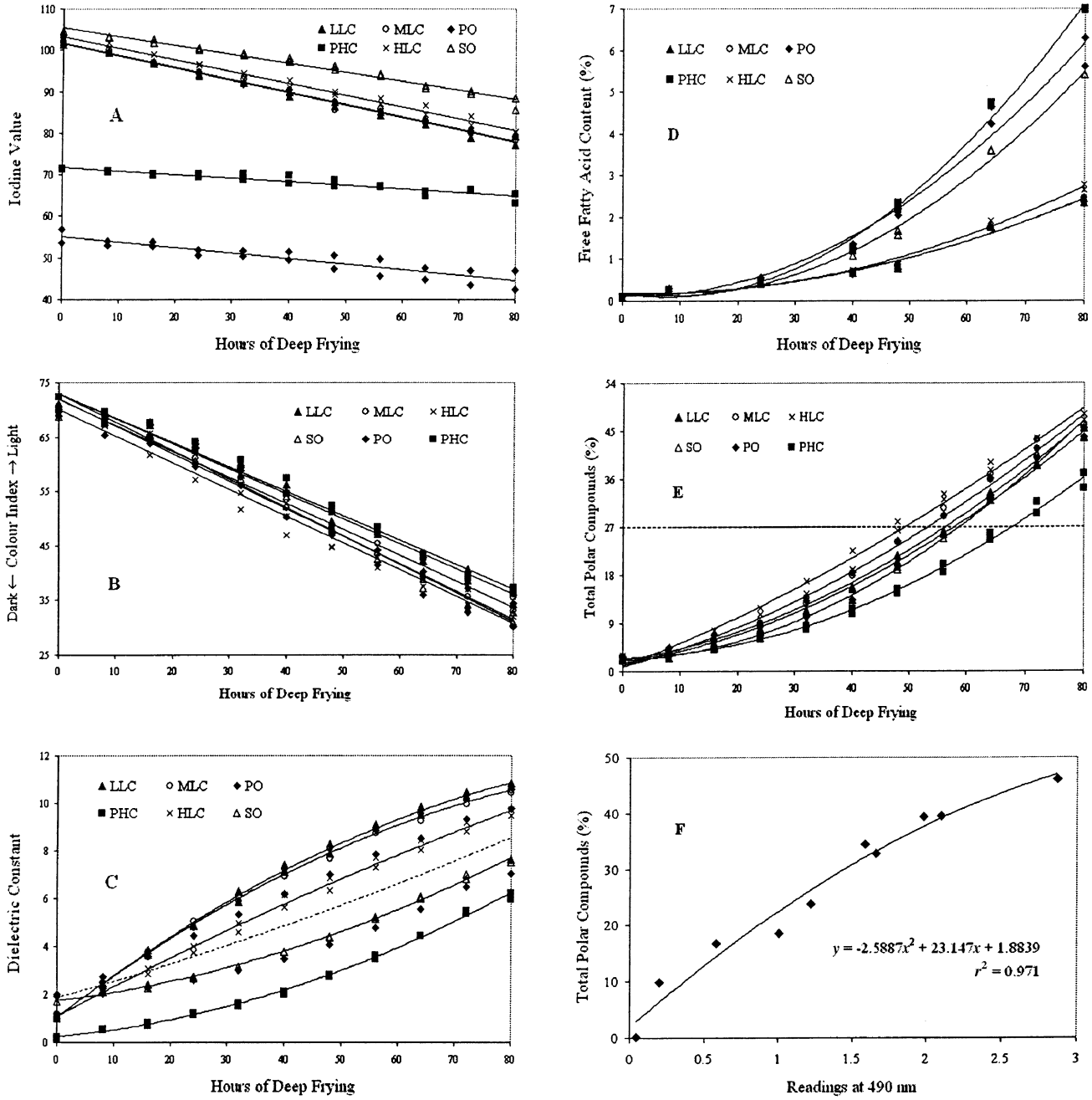

FIG. 2. Changes of iodine value (A), color index (B), dielectric constant (C), free fatty acids (D), and total polar compounds (TPC) (E) in the oils during deep frying (the two data points in the charts represent the two replicates). Figure 2F shows the correlation of VERI-FRY® PRO quick test readings and AOCS method for TPC and the equation for converting the quick readings to TPC contents. For abbreviations see Figure 1.

molecules in the oil to become somewhat polar (8). As the number of polar molecules increases, the DEC of the oil increases. DEC of frying oils have been reported to increase linearly during deep frying (9) and have high correlations with TPC (10,11). These results are in agreement with those of the present study. For the same type of oils with similar fatty acid profiles, DEC is a good indicator for monitoring oil quality during frying, and the Foodoil Sensor system provides a quick and convenient way to monitor oil quality. However, it should be noted that different types of oils show different DEC variations during frying. For example, nonhydrogenated vegetable oils show greater changes in DEC than animal fats, and the DEC of animal fat is more variable than that of hydrogenated oils (9). Furthermore, oils of the same type, but differing fatty acid profiles, like the three high-oleic canola oils in this study, can also show different DEC variations during frying. The three oils had a similar DEC initially, but significant differences in the DEC of the oils developed during the course of frying. This may have been due to differences in linolenic and linoleic contents or possibly in some other

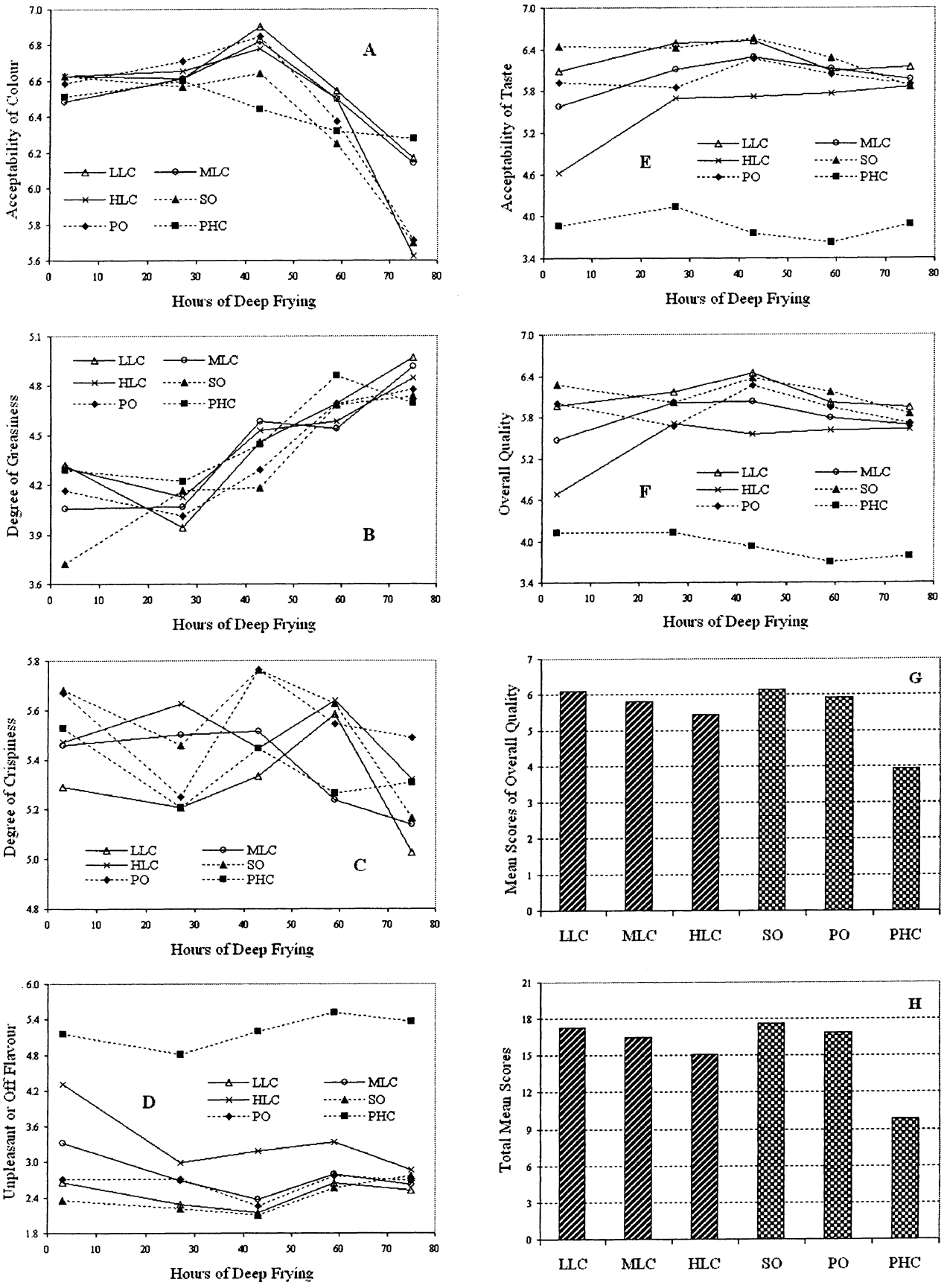

FIG. 3. Changes in the mean scores ($n = 36 \times 2$) of sensory evaluation for the chips fried in the six oils during deep frying (A–F). Figure 3G shows the mean scores of overall quality. Figure 3H shows the calculated total mean scores of sensory evaluation of the six oils.

minor components in the oils. Even the same oil from the same container, like PO in this trial (a 25-L drum), had significant DEC variations in the two replications, perhaps due to inadequate mixing. It is also likely that DEC may change quite differently during the course of deep frying in the same type of oil with different levels and types of antioxidants and antifoaming agents. Therefore, caution should be taken when using DEC to compare different types of oils or the same type of oils with different fatty acid profiles, since only slight differences in initial fatty acid profile will significantly affect DEC during frying.

The DEC and TPC of the oils in this study were significantly correlated ($r \geq 0.855$, $P < 0.001$), as reported previously (9,10). In this case, the highest TPC content was detected in HLC and the lowest one in PHC, while the highest final DEC was measured in LLC and the lowest in PHC. HLC had a lower final DEC than LLC. This suggests that polar compounds contribute significantly to the DEC value, but are not the only factor affecting DEC.

FFA of the oils all increased significantly during frying and were strongly correlated with hours of frying ($P < 0.001$, $r \geq 0.93$). Initially, all the oils had the same FFA level of 0.1%. There were no significant differences in FFA contents during the first 24 h of deep frying, although the contents were slightly higher in PO and PHC oils. After 24 h of frying, FFA in PHC, PO, and SO increased much faster than in the three canola oils (Fig. 2D). The FFA contents of LLC and MLC were significantly lower than those of the other oils during frying, and FFA in HLC were also lower than in SO, PO, and PHC ($P < 0.001$). After 80 h of frying, the final FFA contents were 2.4% in LLC and MLC, 2.7% in HLC, 5.4% in SO, 6% in PO, and 7% in PHC.

FFA are formed during oxidation, hydrolysis (12,13), and pyrolysis as a result of the cleavage of triglyceride. Previous studies of frying oils have shown that FFA content increases during deep frying (10,14). Similar results were obtained in this study with a rapid increase in FFA levels occurring after 40 h of deep frying, especially in PHC, PO, and SO. The final FFA contents of PHC, PO, and SO were two- to threefold higher than that of the high-oleic canola oils. The low FFA contents of LLC, MLC, and HLC oils after 80 h of deep frying at 190°C, without any additives, suggest that these new high-oleic canola oils have high inherent oxidative stability.

The standard method for FFA determination measures acid value, rather than actual FFA content in oil. Acid value will be affected by the type of frying oil and the type of food being fried. Using FFA content as an indicator of frying oil degradation and of fried food quality is still controversial. Both high correlations (10,11) and poor correlations (15,16) between FFA (or acid value) and TPC in frying oil are found in the literature. Although the changes of FFA were highly correlated with the changes in TPC, CI, and DEC during frying in this study, it is not recommended to use FFA as the sole indicator for determining the life of a frying oil. In practice, FFA levels may not affect frying performance or have significant adverse effects on health or sensory evaluation. For example, in this study PO and SO had twofold higher FFA levels, but similar or even better sensory evaluation scores than MLC and HLC.

TPC in the oils all increased significantly during frying and were strongly correlated with frying time ($P < 0.001$, $r \geq 0.964$). TPC contents of the unused oils were similar initially, at 2.2 to 2.8%. After 80 h of deep frying, the final TPC levels were: 47.5% in HLC, 45.8% in MLC, 44.6% in SO and PO, 43.7% in LLC, and 35.6% in PHC (Fig. 2E). The rates of TPC increase in the oils were significantly different from each other ($P < 0.01$) except with LLC and SO. The standard method for measurement of TPC by silica gel column chromatography can be accurate, but time-consuming and relatively expensive. The VERI-FRY® quick test for TPC was employed in this study and, by measuring spectrophotometric asorbance at 490 nm, was found to be relatively fast and inexpensive and to give a high correlation ($r = 0.98$, $P < 0.001$) with the AOCS Official Method Cd 20-91 for TPC. When comparing TPC contents calculated by the equation in Figure 2F with those determined by the AOCS method, the TPC contents of the 11 oil samples used for calibration were similar ($r = 0.985$, $P < 0.001$ and SE = 2.63).

TPC in frying oil are composed of breakdown products, nonvolatile oxidized derivatives, polymeric and cyclic substances produced in the course of deep frying, and those oil-soluble components from the food fried in that oil. The TPC of frying oil has been proposed as a good indicator of frying oil quality, with the suggestion that oil with 25–27% TPC should be discarded (13,17). This has even been adopted as a regulatory parameter for frying oils in some countries (18). If the maximal content for TPC in frying oil is accepted as 27%, the TPC-based stability ranking of these oils would be: PHC > LLC > SO > PO > MLC > HLC. For the nonhydrogenated oils (excluding PHC), TPC was also a good indicator of sensory ranking, with lower TPC contents giving higher sensory scores. TPC was significantly correlated to CI, DEC, and FFA ($P < 0.001$). For these reasons, it is suggested that, among the chemical and physical parameters examined, TPC is the best indicator for monitoring oil quality during the deep frying of potato chips.

Sensory evaluation results are shown in Figure 3A to 3F. The mean scores for acceptability of color for the fried chips changed significantly during frying ($P < 0.01$), as shown in Figure 3A. The pattern of color variation was broadly similar for each oil except PHC. Color acceptability of PHC chips decreased markedly from the beginning of frying. The color scores for the chips were highly correlated with TPC and FFA in the oils ($r = -0.665$ and -0.661, $P < 0.001$).

For all samples, the mean scores for degree of greasiness increased significantly during deep frying ($P < 0.01$) and were negatively correlated with degree of crispiness ($r = -0.504$) of the fried chips. There were no significant differences in greasiness scores between the oils, which all showed similar effects (Fig. 3B). The scores for greasiness of the chips were highly correlated with the TPC contents of the oils ($r = 0.753$, $P < 0.001$). The degree of chip crispiness appeared to de-

crease slightly during frying although there were large within-sample variations (Fig. 3C). Crispiness scores for LLC were significantly lower than those of SO and PO ($P < 0.05$).

The scores of unpleasant or off-flavors represent the levels of unpleasant or off-flavor in the oils. The higher the score for the fried chips in the oil, the higher the level of unpleasant or off-flavor in that oil. For most of the oils, only slight changes in the mean scores for unpleasant or off-flavors of the chips were observed after 80 h of frying. PHC had significantly higher levels of unpleasant or off-flavors than any other oil ($P < 0.001$), whereas SO and LLC were significant lower ($P < 0.05$) than the rest (Fig. 3D). For the three high-oleic canola oils, higher levels of unpleasant or off-flavors were associated with oils containing higher levels of linolenic acid. Unpleasant or off-flavor scores were also negatively correlated with taste scores ($r = -0.885$) and overall acceptability scores ($r = -0.945$).

The mean scores for acceptability of taste and overall quality varied over 80 h of frying in a similar manner within each oil, but some significant differences were evident between oils (Figs. 3E and 3F). Scores for acceptability of taste were significantly correlated with those for overall quality ($r = 0.966$, $P < 0.001$). The scores of taste and overall quality did not change significantly during frying, indicating that all the oils maintained high taste stability and flavor stability over 80 h of deep frying. PHC had significantly lower scores for taste and overall quality than all the other oils ($P < 0.001$). The scores of MLC and PO were similar and significantly higher than HLC scores ($P < 0.05$). LLC and SO had similar scores, which were significantly higher than the other oils ($P < 0.05$). The ground mean scores for the overall quality of the six oils are shown in Figure 3G. A similar result is evident in Figure 3F, which presents the sum mean scores for acceptability of color, acceptability of taste, degree of crispiness, and overall quality, after subtraction of the sum mean scores for degree of greasiness and unpleasant or off-flavor.

PO is a popular deep-frying oil in fast food outlets (15,16) due to its oxidative stability (47% saturates, 40% oleic, 11% polyunsaturates) and good flavor stability. In this study, the sensory evaluation results for PO were similar to MLC and significantly inferior to LLC and SO. That is, a high-oleic canola oil with 4.4% or less linolenic (MLC) was as good as PO, and a high-oleic canola oil with 2.5% linolenic (LLC) was much better than PO in sensory evaluation and in most of the chemical and physical properties after two 80-h deep-frying trials. These high-oleic canola oils also have better nutritional values than PO due to their high-oleic acid and low SAFA contents.

It is known that hydrogenation can destroy the natural flavor and odor of oil or fat, producing in its stead a distinctive, rather unpleasant "hydrogenation odor" that must then be removed by steam deodorization (19). Sensory evaluation results indicated that this undesirable hydrogenation flavor was evident in the PHC used in this study, leading to very poor flavor and acceptability scores. Furthermore, PHC had a two-fold higher final FFA or acid value than the three high-oleic canola oils. The high level of FFA in PHC might be attributed to a trace amount of metal catalysts left in the processing of hydrogenation. A recent survey of take-out food outlets in northeastern Australia (20) also showed that hydrogenated frying oils, as well as some animal fats and palm oils, develop high acid values. With regards to performance and nutritional values, the use of high-oleic canola oils (Monola) with low linolenic acid to replace hydrogenated canola oils is recommended.

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