Sensory Stability of Canola Oil: Present Status of Shelf Life Studies[1]

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Sensory studies on autoxidation of canola oil, stored under several variations of Schaal Oven test conditions, suggest an induction period of 2–4 d at 60–65°C. Similar induction periods have been observed between canola and sunflower oils, whereas a longer induction period has been found for soybean oil. Canola oil seems to be more stable to storage in light than cottonseed and soybean oils but is less stable than sunflower oil. Storage stability of products fried in canola oil is similar to products fried in soybean oil. Storage stability of canola and cottonseed oils that had been used in the frying of potato chips showed that canola oil was more prone to autoxidation during storage at 40°C. The presence of light aggravated the oxidative effects and was similar for both oils. Advances in our knowledge about the shelf life of canola oil would be strengthened by standardization of Schaal Oven testing conditions and by specifying the testing protocol for photooxidation studies. Methods for training of panelists and for handling and evaluating oils and fried foods require definition. Rating scales used in the evaluation of oils need to be evaluated to ensure that reliable and valid measurements are achieved. Further progress is needed in the identification of chemical indicators that can be used to predict sensory quality of oils.

KEY WORDS: **Autoxidation, canola oil, photooxidation, sensory, shelf life, stability.**

Canola oil enjoys a nutritional advantage in health-conscious North American markets because of its low level of saturated fatty acids and its high level of the monounsaturated fatty acid, oleic acid. Currently, canola oil accounts for over 60% of the annual production of all vegetable oils in Canada where it is used widely in salad oils, tablespreads and shortenings. Since 1985, when the U.S. Food and Drug Administration granted generally recognized as safe status to canola oil, the demand has broadened for knowledge of its functional properties.

The odor or flavor of fully refined, deodorized canola oil is described as bland, slightly nutty and buttery when it is fresh, but during storage, grassy, painty or rancid off-flavors develop (1). Flavor deterioration has been attributed mainly to secondary oxidation products of the polyunsaturated fatty acid, linolenic acid, a fatty acid that normally makes up nine to fifteen percent of the fatty acids in canola oil (2,3). To compare the stability of canola with that of other edible oils, a full picture is needed of its resistance to autoxidation and photooxidation. The purpose of this paper is to summarize the present understanding of canola oil stability and to identify gaps in knowledge and experimental practice that limit this description, with particular emphasis on sensory evaluation studies. Sensory stability still remains the ultimate criterion of edible oil shelf life and serves as the basis for the validation of chemical and physical measurements (4). The thorough review of canola oil stability by Hawrysh (5) serves as a starting point for this discussion.

Schaal Oven studies. Edible oil stability to autoxidation is often determined by a modification of the Schaal Oven test, which accelerates oxidation by holding oil samples at 60–65°C in the dark. Samples may be examined at 24-h intervals or less frequently. The test was originally designed to monitor the stability of shortenings for inclusion in baked goods and stated a preference for the use of a convection oven (6). Variations in Schaal Oven test conditions for the testing of oils have been introduced on an *ad hoc* basis and include differences in the quantity of sample stored, the size of sample containers used, and whether or not the containers are covered during storage. Each of these factors could affect the headspace microenvironment. The definition of a standard protocol for Schaal Oven test conditions, by a body such as the American Oil Chemists' Society (AOCS), would appear timely.

Flavor stability. The AOCS has two recommended scoring systems for evaluating liquid vegetable oils (7). Panelists rate either the overall intensity of the oil on a scale from 10 = bland to 1 = extreme or the overall quality of the oil on a scale from 10 = excellent to 1 = bad. Panelists are then instructed to evaluate the oil for individual flavor characteritics by using a checklist of possible flavor attributes. Panelists assign an intensity value to each flavor characteristic on a scale from 1 = weak to 3 = strong. Although both scoring systems require the use of trained panelists, this is especially true for the flavor quality scale. Without intensive training and agreement among the panelists about quality criteria, panelists' scores will reflect affective judgments of quality rather than analytical judgments of quality. The practice of having panelists rate the overall intensity or quality, followed by rating of individual attributes, suggests that a single measurement is not always adequate to profile the flavor characteristics of an oil. In such instances, it may be more practical and informative to have panelists rate the intensity of specified flavor attributes by using scales that are less restrictive than the 3-point intensity scales used in the AOCS scoring system.

Figure 1 illustrates flavor scores for canola oils stored under modified Schaal Oven test conditions in four studies (1,2,8,9). In each of these experiments, seven to twelve trained panelists tasted stored oil samples, expectorated samples within 10–30 s and then rated their flavor intensity on the AOCS Flavor Intensity Scale (7). Although the scores for fresh canola oils varied, all were reasonably bland at day 0. Distinct departures from blandness in flavor intensity were evident at two days in two studies that used laboratory-processed oils (1,2), and at four days in another study that used commercially processed oil (8). In the fourth study (9) samples were not evaluated until the fourth day of storage, by which time there was a noticeable increase in flavor intensity. Failure to measure flavor intensity prior to 48 h of storage precluded the identification in all experiments of an induction period, defined by Warner and Frankel (10) as the time at which the slope changes sharply. Based on these studies, it would appear that there is an off-flavor induction

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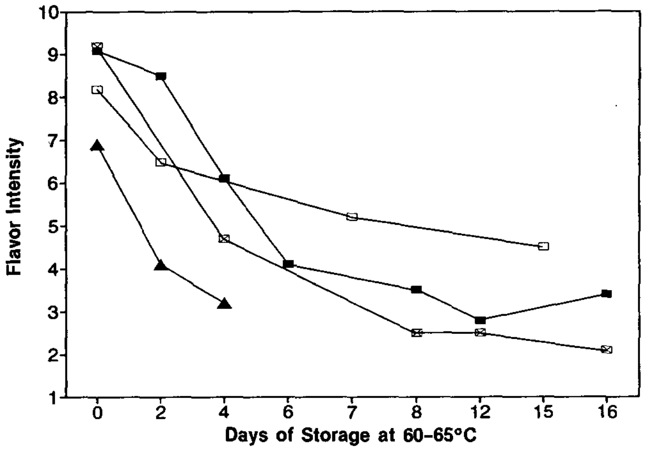

FIG. 1. Flavor stability of canola oil to autoxidation [fully-refined, deodorized oils with no additives; ■—■ (Ref. 8), 1988; ▲—▲ (Ref. 1); □—□ (Ref. 2); ⊠—⊠ (Ref. 9); scores of 10 = bland, 1 = extremely intense].

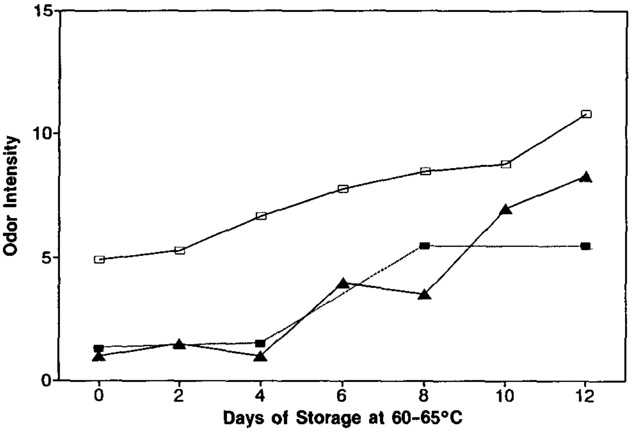

FIG. 2. Odor stability of canola oil to autoxidation [fully-refined, deodorized oils; ■—■ (Ref. 15); ▲—▲ (Ref. 16); □—□ (Ref. 17); scores of 0 = bland, 15 = strong/extremely intense].

period of two days at 60–65°C for canola oil of good initial quality.

Comparing measurements from different experiments of the end-products of lipid oxidation may have little meaning if storage studies are carried out at different oxygen levels. Narrow jars with high levels of fill are prone to different mechanisms of oxidation as a result of oxygen deficiency (11). Karel (12) measured the relation between the surface available for oxygen absorption and oil sample volume. When the ratio of volume to surface increased, oxidation rate decreased. This negative change in oxidation rate was directly related to oxygen partial pressure. Furthermore, Marcuse and Fredricksson (13) pointed out that reaction pathways are oxygen-dependent. Recent studies on factors affecting the gravimetric determination of the oxidative stability of olive oil have shown a strong influence of the oil–air surface area on the extent and rate of oxidation and some influence of the amount (14). Among the three groups whose research is reported in Figure 1, storage sample sizes were reported as follows: 75 mL (68 g) in a 100-mL beaker (8,9), 150 mL in a 240-mL jar (1) and 250 mL in a 500-mL beaker (2). Thus, headspace varied from one-fourth to one-half of the sample volume; in all cases, the samples were covered or stoppered loosely during storage. It seems that specifications for the surface area/volume ratios would be useful in standardizing the protocol for the Schaal Oven test.

Comparisons of the stability of canola oils across experiments may be compromised further by the effects of differences in additives, processing conditions or starting quality. In each of the studies summarized in Figure 1, the oil was free from either added antioxidant or a citrate chelator and had a peroxide value of less than one at the outset. But, although all canola oils had been fully refined and deodorized, their processing was carried out under different conditions. In the studies by Hawrysh *et al.* (8,9), oils were obtained from a Canadian commercial processor accustomed to handling canola oil, while those used by Warner *et al.* (1) and Liu and White (2) were laboratory-processed. The latter group noted that the dark green color and strong fish-like flavor of their laboratory-refined canola oil prompted them to bleach and deodorize it twice, after which it had an acceptable flavor quality score.

Odor stability. Figure 2 shows the increase in odor intensity of canola oils during oxidation under modified Schaal Oven test conditions in three different studies (15–17). In two of the experiments (15,16), an antioxidant mixture was added to the oil prior to storage. No additives were added to the oil used in the third study (17). In these experiments, eight to ten trained panelists rated the odor intensity of the oils on an unstructured 15-cm line scale with endpoints labelled bland (0 cm) and extremely intense/strong (15 cm). A midpoint labelled moderate was included in the study by Przybylski *et al.* (17). Panelists marked the point on the line that best described their opinion of the oil odor intensity. Numerical scores were assigned by measuring the distance in centimeters from the bland endpoint to the panelist's rating on the line scale. The rationale in using a scale in which the numerical order is reversed from the AOCS method (7) is that a larger value logically describes greater intensity.

The odor intensity patterns obtained in the three experiments presented in Figure 2 suggested an off-odor induction period of two to four days, which is in keeping with the flavor induction period shown in Figure 1.

Measuring odor rather than flavor is viewed as a sensory task less likely to fatigue panelists considering that oil samples are difficult to clear from the mouth. Hawrysh *et al.* (5,8,9,18) have consistently measured both odor and flavor on the same canola oil samples. Although the results have not been compared directly, examination of the studies suggests that odor and flavor intensity scores are equally effective in depicting differences in canola oil stability.

The translation of the results of Schaal Oven tests to canola oil shelf life has been aided by the "practical storage" studies by Hawrysh *et al.* (19) at ambient temperatures. Canola oil stored in glass bottles in the absence of light at approximately 24°C, remained unchanged in flavor for up to 16 wk. From this observation, it may be extrapolated that canola oil with a sensory induction period of 2–4 d at 60–65°C may be expected to retain good flavor quality for at least 16 wk under comparable storage conditions. Such speculation is consistent with a report by Evans *et al.* (20)

that flavor scores for soybean oil aged four days at 60°C were equivalent to scores for oils aged four months at ambient temperatures.

Interspecies comparisons. When comparing the sensory stability of oils from different species, it may be necessary to take into account the diverse sensory properties that are characteristic of the fresh oils. This observation is suggested from work by Durance (16), who examined the odor stabilty of canola, cottonseed and sunflower oils to autoxidation under Schaal Oven test conditions with a trained panel. Canola and sunflower oils exhibited similar odor induction periods of four days (Fig. 3). Both oils became increasingly more intense in odor over the 12-d storage period, and this was particularly noticeable for canola oil. Cottonseed oil had a higher initial odor score than the other two oils. The odor score for cottonseed oil decreased over the first four days of storage. Between the fourth and eighth day of accelerated storage, cottonseed oil increased in odor intensity, in keeping with the effects of autoxidation. The high initial intensity scores observed with fresh cottonseed oil suggests that, when interspecies oils are evaluated, it is more appropriate to measure the intensities of specific odor/flavor attributes rather than total odor/flavor intensity.

Warner *et al.* (1) compared the flavor stability of canola, soybean and sunflower oils by using a trained panel. Both sunflower and canola oils were reported to be less stable than soybean oil to accelerated storage at 60°C. Peroxide values of oils without added citric acid showed oxidation induction periods of one day for sunflower and canola oils, compared to a five-day induction period for soybean oil. Liu and White (2) also reported that canola oil was less flavor-stable to accelerated oxidation than soybean oil. Deodorization temperatures used in the laboratory processing of canola oil by these researchers were 220°C for 3 h (1) and 230–240°C for 2 h (2), whereas higher deodorization temperatures are customarily used by commercial processors of canola oil in Canada (21). Results for canola oil might have been different if commercially processed oils had been studied.

Temperature effects in accelerated autoxidation. Abbreviating the time required for accelerated shelf life tests is of prime importance to oilseed processors. Ideally, they would like to predict the stability of an oil within hours of a processing run. Logical solutions include using smaller samples with higher storage temperatures and chemical or physical tests that relate well to sensory scores from Schaal Oven tests.

Such motivation probably accounts for the continued use of the active oxygen method (AOM) despite its reported lack of correlation with sensory tests of the onset of rancidity in salad oils held at room temperature (22). The AOM, also known as the Swift Stability Test, exposes a 10-g sample of oil in a test tube held in a water bath at a temperature of 97.8°C under constant aeration for the number of hours required to reach a defined peroxide value and/or a definite rancid odor. Weiss (23) has stated that the AOM is obsolete, apart from its use with unstabilized lard, for which it was initially adapted from use in the rubber industry.

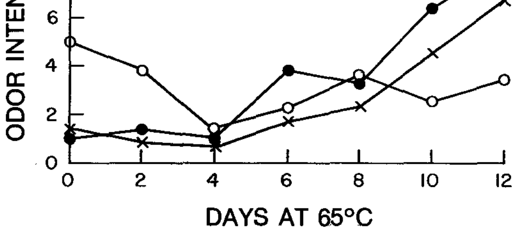

FIG. 3. Odor stability of canola oil in comparison to cottonseed and sunflower oils to autoxidation (fully-refined and deodorized with antioxidant mixture; scores of 0 = bland, 15 = strong); (Ref. 16).

Warner *et al.* (1) reported a promising method that was significantly faster than the Schaal Oven test. It involved heating 0.5 g of oil in a sealed 10-mL test tube for 24 h at 80°C and measuring the total volatiles in the headspace at four-hour intervals. The behavior of three oils, canola, soybean and sunflower, in response to these conditions, was examined and compared to results from Schaal Oven storage. Values for total volatiles showed that aging at 80°C for 24 h in headspace vials was equivalent to aging 150 g in 8-oz (237 mL) glass bottles for eight days at 60°C. Canola and soybean oils showed similar patterns of total volatile accumulation for the first 16 h at 80°C and for the first six days at 60°C. Following this, soybean oil exhibited superior stability to canola oil. For this method to be adopted widely, it will be necessary to be confident that measurements of total volatiles are accurate predictors of judgments of sensory quality. Sunflower oil showed higher levels of total volatiles throughout storage at both 60 and 80°C than either canola or soybean oil. However, the fact that sunflower oil in this experiment proved less stable than canola oil, as far as total volatiles are concerned, is contrary to the sensory results and to the findings of Durance (16) (Fig. 3).

While the test of Warner *et al.* (1), for "smaller sample-higher temperature" seems attractive, storage temperatures above 60–65°C should be viewed with caution. Labuza (11) pointed out that both autoxidation and antioxidant behavior proceed by different mechanisms at higher temperatures and oxygen concentrations than at lower temperature and oxygen concentrations, thus decreasing the odds of predicting stability under normal shelf storage conditions with accuracy. Evidence to support this statement is found in a study by Prior *et al.* (24) on the antioxidant activity of nontriglyceride components of crude nondegummed canola press oils. The synergistic effect between tocopherols and phospholipids on oil oxidation seemed to be temperature-dependent, with greater antioxidant effects being evident at temperatures of 60°C or below.

The use of temperatures as high as 180°C in static headspace analyses of total volatiles calls into question the relevance of these measurements to sensory judgments, which are made on samples that are heated to 50°C for evaluation. Cooney *et al.* (25) showed that the peroxide content of soybean oil remained high in samples heated at 100°C, in contrast to those heated at 150 and 180°C. Therefore, total volatiles may be artificially inflated by peroxide degradation when excessively high temperatures are used in their analyses. Recent studies by Przybylski (26) have shown excellent recovery of volatiles from canola oil by purging at 110°C for 15 min, suggesting that the use of lower temperatures in gas chromatography (GC) volatile analysis may be feasible. More work is needed to lower temperatures further, so that they more closely match conditions used in sensory analyses. Pinpointing the volatile components that are most indicative of sensory changes in oxidizing oils may prove more achievable when the temperature differential between chemical and sensory methods of measurement is minimized.

Fluorescent light studies. Photosensitized oxidation in edible oils results from singlet oxygen produced by exposure to light in the presence of a photosensitizer, such as chlorophyll or polycyclic aromatic hydrocarbons (27–29). Direct photooxidation, which involves short wavelengths in the order of 200 nm and sufficient energy (30), is seldom the culprit. Light-induced oxidative changes in edible oils normally have been produced experimentally by using some adaptation of the test reported by Moser *et al.* (31), which involved surrounding an oil sample, at room temperature, with daylight fluorescent tubes. Daylight fluorescent bulbs are reported to have a color temperature of 6,500°K and a spectral energy distribution between 300 and 750 nm, properties that are similar to a combination of the sunlight and skylight of a north window (31). Protocols used by contemporary research groups vary in cabinet design, sample size, temperature control and light intensity, expressed in foot candles or lux (1 ft-c = 10.764 lux). Such variation in test conditions makes it difficult to compare results from one research group to another, suggesting a need for standardizing testing protocol.

Sattar *et al.* (32) first reported on the sensory stability of canola oil to light. They exposed commercially refined, bleached and deodorized oils (low-erucic acid rapeseed, corn, soybean and coconut) with no added antioxidants to fluorescent light with an intensity of 500 ft-c (5382 lux) at 25°C in a low-temperature incubator. Oil samples were stored in disposable petri dishes. A panel of eight members rated the oils at four storage intervals (3, 6, 9 and 12 h) on a 10-point category scale, where 9–10 = good, 7–8 = less desirable but acceptable, 5–6 = objectionable, 3–4 = unpleasant and 1–2 = repulsive. They found that corn oil was the most stable, canola oil was intermediate, and soybean and coconut oils were the most sensitive to light.

Durance (16) compared the stability of canola, sunflower and cottonseed oils containing an antioxidant mixture to fluorescent light with an intensity of 250 ft-c (2691 lux). Samples were exposed to light in a storage cabinet held at 40°C. Distinct differences in the odor intensities were observed among the oils over the four-day test period (Fig. 4). Cottonseed oil was particularly prone to off-odor formation under these conditions. Its susceptibility to the development of a "light-struck" odor has been attributed to the formation of 1-decyne as a result of the photodegradation of naturally occurring cycloprenoid fatty acids (33). While canola oil was less sensitive to light than cottonseed oil, sunflower oil proved to be the most stable of the three oils.

The superior light stability of sunflower oil noted by Durance (16) was confirmed by Warner *et al.* (1) in a study where canola, sunflower and soybean oils, with and without added citrate (100 ppm), were exposed to fluorescent light at 7535 lux (700 ft-c) at 30°C for 8 to 16 h. The oils were stored in 8-oz (237 mL) clear glass bottles. Sunflower oil proved to be the most flavor stable, whether or not citrate was present. In the presence of citrate, canola oil was more light-stable than soybean, whereas without this additive, flavor scores of both canola and soybean oils were significantly more intense than scores for sunflower oil.

Hawrysh *et al.* (19) have placed the consequences of the photosensitized oxidation of canola oil in practical terms. Their trained panel measured the flavor and odor intensities of commercially processed canola oil exposed to simulated supermarket conditions. This involved an intensity of 1400 lux (130 ft-c) from daylight fluorescent tubes over a period of 16 wk at ambient temperatures. Oil samples (100 mL) were held in clear and amber glass bottles. Amber glass filtered incident light below 500 nm (30). Canola oil stored in amber glass showed much less flavor deterioration than canola oil stored in clear glass. Measurements of total volatiles suggested that the oxidative changes for canola oil stored in light-resistant amber bottles for 16 wk were similar to those for canola oils stored only four weeks in clear glass.

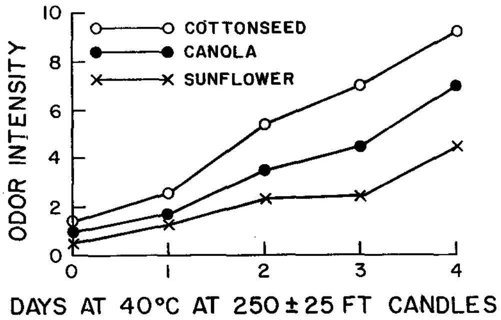

FIG. 4. Odor stability of canola, cottonseed and sunflower oils during photooxidation (fully-refined and deodorized with antioxidant mixture; scores of 0 = bland, 15 = strong); (Ref. 16).

Oxidation in fried foods. During frying of foods, oil is subjected to temperatures of 180–190°C in the presence of air and moisture, conditions that exacerbate oxidative and thermal degradation. Depending on their size and composition, foods absorb appreciable amounts of the frying medium, which then is susceptible to oxidative change on storage. While there have been some reports on the frying performance of canola fats and oils (34–37), less has been published on the stability of snack foods fried in them, suggesting a need for research in this area.

Liu and White (35) had a twelve-member trained sensory panel evaluate bread cubes that had been fried in laboratory-processed canola, soybean and low-linolenic acid soybean oils. Fried bread cubes were evaluated before and after seven days' storage under Schaal Oven test conditions (60°C). Panel scores for the freshly fried bread cubes showed no significant differences among oils in either flavor quality or flavor intensity. After storage, the bread cubes fried in canola and soybean oils were judged comparable, but had poor flavor quality ratings. Sensory scores were significantly better for stored bread cubes fried in low-linolenic acid soybean oil.

Hawrysh (36) examined the effect of four frying oils: canola, soybean, cottonseed and partially hydrogenated canola on the quality of potato chips after Schaal Oven storage at 60°C for 0, 6 and 12 d and after practical storage at 23°C for 18 wk. During Schaal Oven storage, no differences in potato chip odor/flavor or off-odors/flavors were observed between chips fried in canola, soybean or cottonseed oils. After 18 wk at 23°C, potato chips fried in canola oil had higher typical potato chip odor/flavor and lower off-odor/flavor than did chips fried in the other two oils.

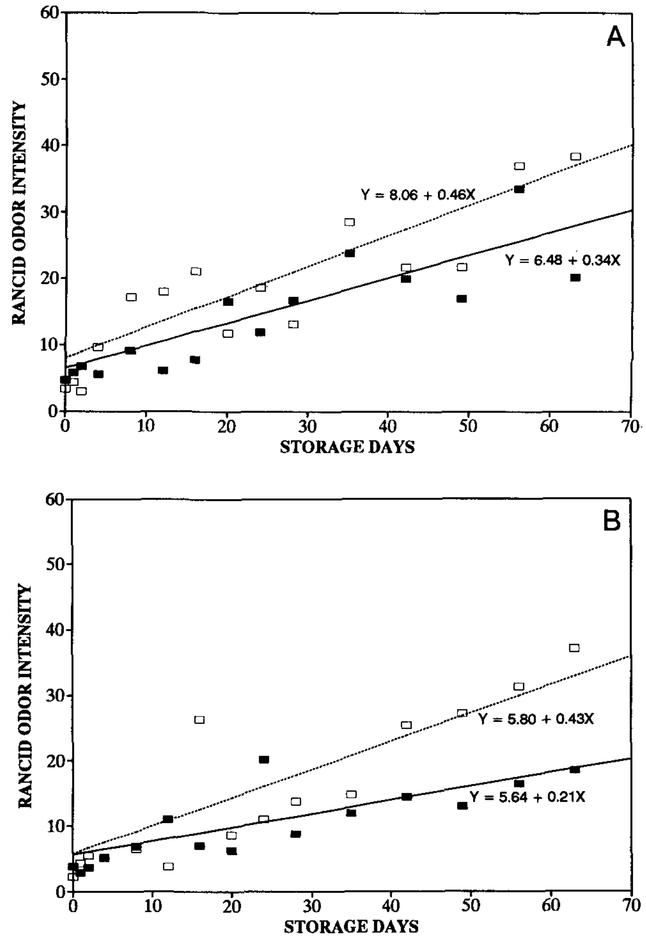

FIG. 5. Odor stability of oils used in frying during storage at 40°C (■—■) and during storage at 40°C + 250 ft-c (□· · · □) (scores of 0 = none, 60 = strong; A = canola B = cottonseed) (Malcolmson and Vaisey-Genser, unpublished data).

Malcolmson *et al.* (unpublished data, University of Manitoba, Canada) studied the susceptibility to autoxidation and photooxidation of oils that had been used in the commercial frying of potato chips. The researchers' rationale for studying the "used" oil was that the oil that had been used in frying a snack food may be considered a surrogate for testing the stability of the food fried in it. Canola and cottonseed oils, which had been pre-seasoned by heating for 8 h at 190°C, were used by a commercial manufacturer for frying one lot of potato chips. Samples of the used oils were then stored at 40°C in the presence or absence of fluorescent light (250 ft-c/2690 lux). Rancid odor scores for used canola oil increased over a 63-d period of storage at 40°C; these oxidative changes tended to be aggravated in the presence of light (Fig. 5A). The development of rancidity at 40°C was more gradual in used cottonseed oil than in canola oil ($P < 0.05$), while the deleterious effect of light was similar for the two oils (Fig. 5B). Storing used oil as an index of the stability of fried snack foods is attractive because oil is more homogeneous to store and test than fried foods. More work is needed to validate this approach as a method to predict the stability of fried foods.

Recommendations. Storage tests of canola oil show sensory changes after 2–4 d at 60–65°C in comparison to 16 wk at room temperature. Sensory stability is further compromised by exposure of canola oil to light. Knowledge of the shelf life of canola and other oils would be enhanced by further standardization of the methods used in accelerated storage. In particular, the storage container size in relation to sample size requires standardization in the Schaal Oven test because this affects oxygen accessibility through the ratio of surface area exposed to oxygen to oil volume. In testing the effects of photooxidation, standardization of testing methods is needed with respect to ratio of sample size to container size, distance of sample to light source and specification of the light source in terms of color temperature and intensity. Storage temperature for both Schaal Oven and photooxidation also requires standardization. Defining of procedures for scoring of oils needs to continue with an evaluation of the quality rating scale to determine its reliability as a measurement tool. Further progress is needed in identifying the most useful chemical indicators of sensory changes in oxidized oils. Measurement of volatiles at temperatures that more closely parallel those used in sensory testing holds the greatest promise for attaining this goal. More information is needed on the stability of foods fried in canola in comparison to other oils because more oil is consumed through fried foods than in salad oils.

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