Sensory and Chemical Evaluation of Stored Oil-Roasted, High Oleic Nonoil Sunflower Kernels

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High oleic acid (HOA) and high linoleic acid (HLA) nonoil (confectionery) sunflower kernels were oil-roasted at 180 C and then stored at 27 C for up to 26 weeks (wk). At two- and/or four-wk intervals, samples were removed for chemical and sensory analyses. Fatty acid composition of the oils extracted from the roasted kernels were as follows: HOA - 16:0, 3.6%; 18:0, 3.3%; 18:1, 68.3%, and 18:2, 23.7%; regular HLA - 16:0, 5.0%; 18:0, 3.5%; 18:1, 29.0%, and 18:2, 62.6%. Hunter L and a values and hue angle for HOA and HLA kernels changed significantly ($P<0.01$) during 26 wk storage. Hunter a values for HLA did not change significantly but Hunter a values for HOA decreased significantly ($P<0.01$) during storage. Free fatty acids (FFA) of both the HLA and the HOA kernels increased significantly ($P<0.01$) beginning at 16 wk storage. In addition, the FFA from HLA kernels were significantly higher ($P<0.01$) than those from HOA kernels. Both types of stored, roasted kernels showed significant differences in sensory scores from the control samples (regular HLA type held at -35 C) beginning at four wk but rate of change throughout storage was similar for both kernel types. Sensory data were combined with objective parameters to analyze the multivariate data set by VARCLUS. Four clusters of attributes were extracted that explained 71.9% of the variation in the data. The data show there was a significant increase in off-flavor for both HLA and HOA kernels but no significant difference between the two types of kernels. Changes in the color of the sunflower kernels during storage evidently were not related to flavor quality.

Nonoil (confectionery) sunflowerseed production for the U.S. in 1986 was about 330 million lb or 15% of total sunflowerseed production (1). This production is used primarily for human consumption and is marketed in two forms. The largest seeds are roasted, packaged whole and sold the same way as roasted peanuts in the shell. The remainder are dehulled and the kernels are roasted, salted or unsalted, and sold as a snack in competition with other packaged shelled nuts. The smaller seeds from the nonoilseed crop (approximately 15% of total nonoil production) are used mainly as bird food (Lofgren, J.R., personal communication, and 2).

Sunflower kernels sell below most nuts and usually compete with peanuts. However, the oil in sunflower kernels is highly unsaturated and tends to turn rancid faster than the oil from peanuts, which contain more saturated oils and are higher in oleic acid (3,4). As a result, shelf life is shorter than for peanuts, and low temperature storage is desirable.

The fatty acid composition of sunflower oil is known to vary, depending upon the temperature during seed development (5,6). Linoleic acid content of oil from commercial varieties has been found to range from 31.4% for plantings in Texas (5) to 75.5% for plantings in Canada (6); oleic acid content ranged from 15.4% for plantings in Minnesota to 59.3% for plantings in Florida (7). Studies have shown that sunflower oils produced in the South with high oleic acid contents are more stable to heat than oils produced in the North with low oleic acid and high linoleic acid contents (8,9).

Using chemical mutagenesis in sunflower breeding, Soldatov (10) developed a sunflower variety with high oleic acid content in the oil ranging from 64% to 79% which was genetically stable to climatic conditions. Studies in the U.S. with progenies from the Pervenets variety demonstrated their environmental stability and their suitability for commercial production (11 - 13). In 1984, oil-type high oleic acid seed was grown commercially for the first time in the U.S. The oleic acid content of oil extracted from high oleic seed grown in North Dakota, California and Texas was approximately the same, ranging from 80.5% to 86.7% (14). The oxidative stability of the oil extracted from the high oleic acid seed was directly related to the oleic and linoleic acid contents of the oil with an AOM value of 100 hr obtained for a sample with 89% oleic and 1% linoleic acids (15).

Breeding research also has resulted genetically in stable, nonoil (confectionery) high oleic acid varieties, but there have been no reports in the literature on the chemical composition or stabilities of these varieties. Nonoil, high oleic sunflower germplasm lines have been released by the U.S. Department of Agriculture (Miller, J.F., personal communication, 1987). The purpose of this study was to determine the effect of storage on the stability of oil-roasted, nonoil kernels from a regular high linoleic acid hybrid compared with a new high oleic acid hybrid.

MATERIALS AND METHODS

High linoleic acid (HLA) and high oleic acid (HOA) nonoil (confectionery) sunflowerseed were provided by J.F. Miller. The two nonoil sunflower hybrid seed samples were produced on the NDSU agronomy farm and then dehulled in an experimental mill at a local processing plant in Fargo, ND. Both types of kernels were oil-roasted in a commercial high oleic acid sunflower oil in a household deep fat fryer at 180 C for one min. Then, 50-g aliquots for chemical analyses and 150-g aliquots for sensory evaluation were placed in cellophane bags, sealed and placed in storage at 27 C and 60% ± 10% RH for up to six mo. Samples were removed at 2-wk intervals and stored at -35 C until analyzed. The high oleic acid frying oil contained 0.1% free fatty acids and had the following fatty acid composition: 16:0, 3.1%; 18:0, 5.7%; 18:1, 83.3% and 18:2, 8.0%.

Chemical and physical evaluation of kernels. Kernels were analyzed for oil content by the wide-line NMR method (16). Hunter color values were determined with a Hunterlab Model D25-2 colorimeter using a 5.08-cm viewing port on the optical head. Hunter L, a and b values were determined on ca. 35- 40-g aliquots. The

Hunter a and b values obtained from kernel samples before and during storage were used to compute values for hue angle ($\Theta = \tan^{-1} b/a$), saturation index [S.I. = $(a^2 + b^2)$ 1/2] and total color difference [$\Delta E = (\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2$]1/2. Free fatty acid content of oil extracted from kernels was determined by the AOCS method (17). Fatty acid composition was determined by GLC (18). All samples were analyzed in duplicate except Hunter color values which were in triplicate. The data were analyzed using the general linear models procedure from SAS (19).

Sensory evaluation. A nine-member panel, trained in the detection of oxidative off-flavors, was selected to participate in further training to develop the sensory ballot and attribute descriptors for evaluation of sunflower kernels. Reference materials were selected or prepared to provide a range of the potential flavor character notes expected to be encountered in the storage study. These materials included a variety of nuts and oils subjected to accelerated storage conditions. The descriptive attributes selected by the panel were buttery; beany/grassy; green; nutty; roasted/toasted; burnt; musty/stale/cardboard; rancid/painty; sweet, and bitter. Panelists evaluated intensity of these attributes on a four-point scale (not detected, weak, moderate, strong) by checking the appropriate term. An overall quality scale was used to represent degree of overall off-flavor in comparison to a marked control sample. The scale for overall quality was a semi-structured 10-cm horizontal line anchored on the left side with the phrase no off-flavor, and on the right side, strong off-flavor. Panelists evaluated this category by making a vertical line across the horizontal line scale to represent his/her response. The vertical lines were converted to scores by measuring the distance in mm (1-100) from the left side of the scale.

At each session, panelists were presented a sample of fresh roasted HLA kernels, marked "Reference." Test samples at each session included Control HLA kernels (roasted and maintained at -35 C throughout the storage study), and HLA and HOA stored samples from a designated storage period. Storage times evaluated by the panel were 0, 4, 8, 12, 16, 20 and 24 weeks. Each storage time treatment was evaluated three times. Test samples were served in capped cups coded with three-digit numbers and randomly ordered for each panelist in individual stations. Green lighting was used to mask color. Sensory data were analyzed using the General Linear Models (GLM) procedure from SAS (19). Sensory and selected objective data of the test samples were combined and analyzed by the VARCLUS (Variable Cluster Analysis) procedure of SAS.

TABLE 1

Characteristics of Nonoil Sunflower Kernels Before and After Oil-Roasting

	High linoleic acid		High oleic acid	
	Before roasting	After roasting	Before roasting	After roasting
Total oil, % dry basis	60.0	63.3	60.2	62.0
FFA, % as oleic	0.19	0.24	0.15	0.21
Hunter color values:				
L	50.6	42.8	55.8	42.4
a	1.3	4.5	1.4	6.2
b	12.4	16.3	12.1	16.5

RESULTS AND DISCUSSION

The characteristics of the nonoil sunflower kernels before and after oil-roasting are shown in Table 1. The oil content of the roasted kernels was slightly increased due to a portion of the moisture in the kernels being replaced by the frying oil. The color of the kernels as expected was slightly darker after roasting (lower L values); however, the increase in Hunter a and b values reflected the desirable golden brown appearance of the roasted kernels.

The oil extracted from HLA kernels was higher in polyunsaturated fatty acids than the oil extracted from the HOA kernels (Table 2). Raw HLA kernels contained 18.5% oleic and 71.6% linoleic acids; HOA kernels had 67.2% oleic and 26% linoleic acids. Thus, one would expect the HOA kernels to be more stable to oxidative rancidity (8). The commercial frying oil was an oil type, high oleic acid sunflower oil which contained 83% oleic and 8% linoleic acids. Because the kernels absorbed some of the frying oil during roasting (about 10% by the HOA kernels and 15% by the HLA kernels), the fatty acid compositions of the kernels after roasting were different from those of the raw, unroasted kernels (Table 2). After oil-roasting, the HLA kernels were much higher in oleic acid and much lower in linoleic

TABLE 2

Fatty Acid Composition of Oil Extracted from Kernels Before and After Roasting

Sample	Treatment	Fatty acid composition (wt %)			
		16:0	18:0	18:1	18:2
High linoleic acid kernels	Raw	6.0	3.7	18.5	71.6
	Roasted	5.0	3.5	29.0	62.6
High oleic acid kernels	Raw	3.2	3.1	67.2	26.0
	Roasted	3.6	3.3	68.3	23.7
Commercial sunflower frying oil	-	3.1	5.7	83.3	8.0

TABLE 3

Effect of Storage of Oil-Roasted Nonoil Sunflower Kernels on Hunter Color Values

Storage (wks)	High linoleic acid						High oleic acid					
	L	a	b	Hue θ^a	S.I.^{b}	ΔE^c	L	a	b	Hue θ^a	S.I.^{b}	ΔE^c
0	42.8	4.5	16.3	74.7	16.9		42.4	6.2	16.5	69.5	17.6	
4	45.2	4.4	15.5	74.0	16.1	2.5	43.3	5.8	15.3	69.4	16.4	1.6
8	45.7	4.5	16.8	75.1	17.4	2.9	44.4	5.9	15.9	69.7	17.0	2.1
12	44.9	4.3	16.3	75.3	16.9	2.1	45.0	6.4	16.0	68.3	17.2	2.7
16	45.4	4.0	15.9	75.9	16.4	2.8	44.7	5.0	16.4	73.1	17.1	2.6
20	45.1	4.4	16.3	74.8	16.9	2.3	43.9	5.2	16.1	72.0	16.9	1.9
24	45.3	4.3	16.4	75.3	17.0	2.5	43.8	5.2	16.2	72.1	17.0	1.8
26	45.4	4.3	16.2	75.3	16.8	2.6	44.5	4.9	16.0	73.0	16.7	2.5

[a]Hue angle.
[b]Saturation index.
[c]Total color difference.

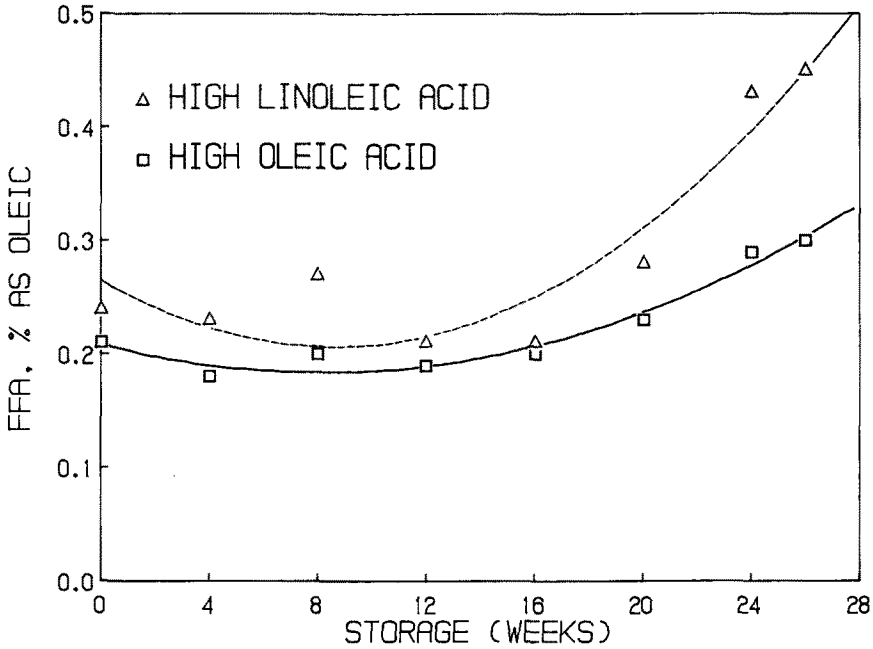

FIG. 1. Effect of storage of oil-roasted nonoil sunflower kernels on free fatty acid content.

acid, thus improving the stability of the HLA kernels. No significant change was obtained in the fatty acid composition of the HOA kernels. Six-month storage of the kernels at 27 C had no significant effect on the fatty acid composition of either type kernel.

The effects of storage of the oil-roasted kernels on Hunter color values are shown in Table 3. Analysis of the data by GLM procedures showed that Hunter L and a color values and hue angle of the HLA kernels differed significantly ($P<0.01$) from the color values of HOA kernels. No significant difference was found for the Hunter b values and S.I. Hunter L values and hue angle were higher and Hunter a values were lower for the HLA than for the HOA kernels. Thus, the HLA kernels appeared to be slightly more golden brown or yellow than the HOA kernels.

Hunter L and a values and hue angle for HLA and HOA kernels changed significantly ($P<0.01$) during 26 wk storage. Hunter L color values for both type kernels slightly increased during the first four wk storage, then leveled off. Hunter a values for HLA did not change significantly during storage, but Hunter a values for HOA decreased significantly ($P<0.01$) during 26 wk storage. Changes in the color of the sunflower kernels during storage evidently were not related to quality deterioration. Quality deterioration of some nutmeats is associated with darkening of their testa color (20) and with significant decreases in Hunter L values, hue angle and S.I. (21), which was not the case in this study (Table 3). These data seem to support conclusions drawn from a pecan kernel study that color alone is not a reliable index to kernel quality (20).

The effect of storage of oil-roasted kernels on free fatty acid (FFA) content is shown in Figure 1. FFA of both the HLA and the HOA kernels increased significantly ($P<0.01$) beginning at 16 wk storage. In addition, the FFA from HLA kernels were significantly higher ($P<0.01$) than those from HOA kernels. Unfortunately, because of a limited quantity of HOA kernels, storage had to be terminated after six mo and before a high level of FFA had been attained. However, the slopes of the curves indicate that serious deterioration was beginning to occur.

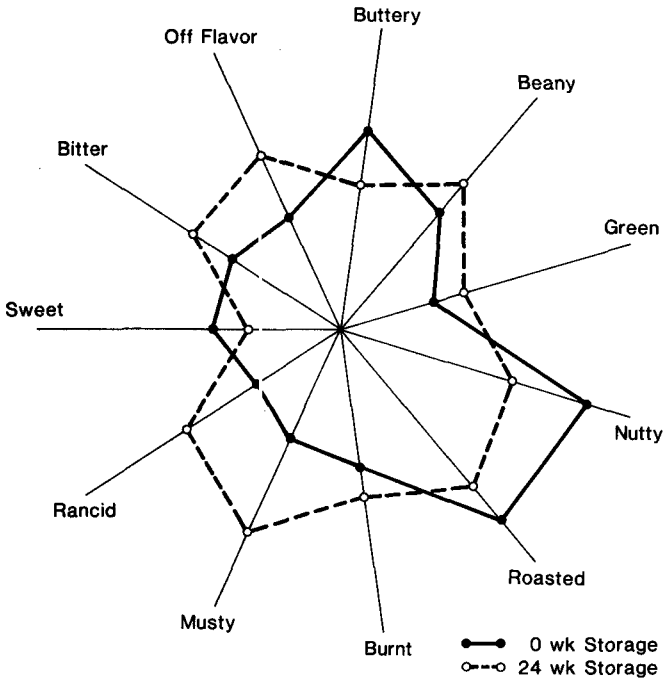

FIG. 2. Comparison of sensory attribute profiles of 0 and 24-wk stored HLA kernels.

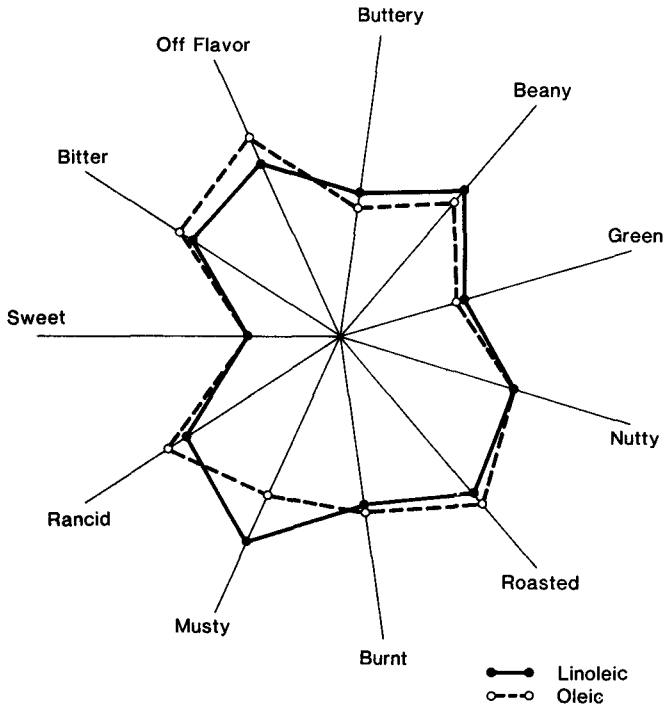

FIG. 3. Comparison of sensory attribute profiles of 24-wk stored HLA and HOA sunflower kernels.

Analysis of sensory scores from the coded control and stored HLA and HOA samples indicated that there were differences among samples for most attributes at the various storage levels. Green, beany and roasted did not show differences until about eight wk. Differences were primarily between stored kernels of both lines versus the control samples. The rate of change between the stored lines was similar.

A graphic presentation of sensory attribute profiles of 0 and 24-wk stored HLA sunflower kernels is shown in Figure 2. The profile shows that flavor attributes normally associated with fresh kernels (e.g. nutty, roasted, buttery and sweet) decreased during 24-wk storage, whereas flavor attributes associated with oxidative deterioration (e.g. rancid, musty, bitter and beany) and overall off-flavor attributes increased during 24-wk storage. The profile for HLO (0 vs 24-wk) was very similar to that of HLA. In addition, the sensory attribute profiles of 24-wk stored HLA and HOA sunflower kernels were very similar (Fig. 3).

Sensory data were combined with objective parameters to analyze the multivariate data set by VARCLUS (21). The purpose of VARCLUS, using the principal component analysis option, is to group similar attributes into a smaller number of dimensions. The first cluster (Table 4) accounts for the most variation explained in the data, with subsequently extracted groups accounting for the remaining variation in descending order of magnitude.

Four clusters of attributes were extracted that explained 71.9% of the variation in the data (Table 4). The first cluster, explaining 41.7% of the variation, included seven sensory parameters. Sweet and buttery had negative loadings on this cluster, while overall quality, burnt, musty, rancid and bitter had positive loadings. This dimension might represent off-flavor, taking into account that sweet and buttery would represent fresh character notes. Fresh character notes would be the opposite of musty and rancid, which represent oxidized off-flavor notes. Overall quality, musty and rancid contributed most to Cluster 1 according to their loadings (correlations to the new grouping).

The second cluster explained an additional 13.9% of the variation in the data. This cluster included FFA, Hunter L values, Hunter a values, and hue angle. The third cluster included Hunter b values and S.I., both of which had not shown significnat sample differences by GLM analysis. The fourth cluster included the sensory attributes beany, green, nutty and roasted, which had not shown sample differences consistently throughout the storage period. This dimension may represent inherent character notes relating to basic description of and distinction between kernel varieties. Therefore, the differences that did exist in the data were best explained by parameters included in Clusters 1 and 2. Sensory attributes representing the description of off-flavor notes and included in Cluster 1 explained the most variation in the data. Objective tests which added to the total variance explained included FFA, Hunter L, Hunter a, and hue angle.

TABLE 4

Cluster Structure of Sensory and Objective Measures of the Quality of Stored Oil-Roasted Sunflower Kernels

Cluster	Variable	Cluster loadings[a] I	II	III	IV	$(R)^2$
I	Overall quality	97	26	-15	67	93
	Buttery	-78	-15	18	-54	61
	Burnt	67	-19	11	31	45
	Musty	91	26	-15	68	82
	Rancid	92	38	1	63	84
	Sweet	-81	-19	15	-40	66
	Bitter	86	11	9	47	74
II	Free fatty acid	36	66	22	29	43
	Hunter L	33	68	-5	56	47
	Hunter a	-3	-94	14	-29	88
	Hue θ	2	95	1	27	90
III	Hunter b	-7	29	92	-4	85
	Saturation index	-8	-30	92	-21	85
IV	Beany	44	36	2	84	71
	Green	57	51	-3	86	74
	Nutty	-68	-15	34	-81	66
	Roasted	-43	-35	10	-83	69
Variation explained		41.7	13.9	8.9	7.4	
Cumulative variation explained		41.7	55.6	64.5	71.9	

[a]Cluster loadings are multiplied by 100 and rounded. Loadings represent correlation coefficients of the variable to the new cluster group.

The VARCLUS procedure also creates weights (scoring coefficients) which can be applied to standardized raw data to obtain new values relating to the clusters. These cluster scores were subjected to GLM procedures to test sample, storage time and sample × storage time interaction. The GLM procedure indicated that cluster 1 variable showed differences among samples based on storage time, while Cluster 2 (objective measurements) distinguished between color of the two lines of kernels. The data show there was a significant increase in off-flavor for both HLA and HOA kernels compared to control but no significant differences in off-flavor between the two types of kernels. Based on the fatty acid composition of the kernels, the increase in off-flavors would have been expected to have been less for the HOA kernels. Further research is needed on the flavor stability of sunflower kernels from other nonoil sunflower hybrids with oleic acid contents similar to that of the oil-type high oleic hybrids (greater than 80%).

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