Storage Studies on Confectionery Sunflower Kernels[1]

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ABSTRACT

Two studies were conducted to examine the physical and chemical characteristics of dehulled confectionery sunflower kernels during storage. The first study dealt with recently harvested, unroasted and roasted kernels packaged in cellophane bags. The bagged samples were stored at 75 and 35° F for 27 weeks. Under these storage conditions, one portion of the samples was exposed to regular fluorescent lighting found in a typical commercial building, and the other portion was kept in the dark. At three-week intervals, portions of the samples were removed for analysis. Moisture content, test weight, color, firmness, oil content, free fatty acid, and peroxide value (PV) were analyzed. The second study utilized the same lot of sunflower kernels packaged in metallized, laminated material under a nitrogen atmosphere. The bagged samples were stored at 75° F for 18 weeks. In the first study, the values for the parameters analyzed were similar for storage under light or dark conditions, whereas temperature had a marked effect. PV in oil from roasted kernels and free fatty acid in unroasted kernels increased with storage time. The effect was most pronounced at the storage temperature of 75° F. An unpleasant aroma was evident with the roasted kernels having a PV of 135 meq/kg. In the second study the physical and chemical characteristics, with the exception of PV, were similar to those found for the first study (75° F). PV for the roasted kernels did not show any significant increase with storage. After storage for 18 weeks, the roasted kernels still possessed good quality characteristics.

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Studies have demonstrated that confectionery sunflower kernels have a relatively short shelf life because of their high oil content and high proportion of polyunsaturated fatty acids (Cobia 1978, Robertson and Thomas 1976). Because refrigeration is costly and profit margin is small, dehulled kernels are normally stored at ambient temperature. Such conditions lead to oxidative deterioration (Robertson and Thomas 1976).

According to Robertson and Thomas (1976), unroasted confectionery sunflower kernels should be stored at low temperature (35° F) and moisture (5.2%) to minimize chemical and microbiological changes. Different results were obtained by Poisson et al (1972), who found that high-oil sunflower seeds with a moisture content below 6% could be satisfactorily stored several months at 75° F. They also found that free fatty acid (FFA) increased as initial moisture decreased.

In general, sunflower oil contains enzymes and antioxidant compounds that act as natural protection against deterioration caused by moisture, light, temperature, atmospheric oxygen, and exoenzymes. After a certain storage period, however, a great part of the natural stability is lost, and the oil undergoes changes such as hydrolysis and autoxidation (Lea 1962). Baumann (1959) reported that the oil may deteriorate during storage, producing off-flavors and odors without oxygen (deterioration to rancidity is generally assumed to be an oxidative reaction). During storage sunflower oil can react with water (free moisture) and lipase enzymes. Consequently, the triaclyglycerols are hydrolyzed to FFA and glycerol. Moreover, high temperature and high pressure accelerate aqueous hydrolysis (Sonntag 1979). Robertson and Thomas (1976) reported that an increase in acid value is caused primarily by high storage temperature.

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The present study was undertaken to follow several physical and chemical properties of sunflower kernels during storage using two methods of packaging.

MATERIALS AND METHODS

Samples and Conditions

A single variety (no. 942) of freshly dehulled unroasted confectionery sunflower kernels (1983 crop) was obtained from Interstate Sunflower Inc., West Fargo, ND. One portion of the kernels was roasted by Prairie Products Inc., West Fargo, ND, by immersion in soybean oil (360° F) for 2 min or until the kernels were a light golden color. In experiment 1, approximately 300 g of kernels was packaged under atmospheric conditions in cellophane bags; in experiment 2 the same weight of kernels was placed into metallized laminated Aleure LD bags with nitrogen as atmosphere. According to the manufacturer, the lamination in this packaging offers an oxygen permeability of 0.05–0.06 $cm^3/100\ in.^2$ over 24 hr. The samples used for experiment 1 were stored at 35° F in a cold room and at room temperature (approximately 75° F), either under fluorescent light for 8 hr each day or in darkness for 27 weeks. Bags stored under dark conditions were kept in cardboard boxes, and bags subjected to light conditions were placed in open trays approximately 60 in. from the light source. At three-week intervals, a portion of the samples was removed for physical and chemical analyses. The samples used in experiment 2 were stored at 75° F for 18 weeks. Evaluations in this experiment were similar to those in experiment 1 but were made at six-week intervals.

Physical Tests

Kernels were analyzed for moisture content and test weight (lb/bu and kg/hl) on whole kernels according to AACC methods 44-15A and 55-10 (AACC 1983). Color data were obtained from the ground samples with a Hunter Lab color difference meter, model D25H9. A standard yellow plate was used. The total color difference (ΔE) and chromaticity (ΔC) were calculated by the equations:

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}, \text{ and}$$

$$\Delta C = [(\Delta a)^2 + (\Delta b)^2]^{1/2},$$

respectively, ΔL, Δa, and Δb values were calculated as the

difference between the initial ground sample as reference and the sample after each storage period. Also, the tristimulus X, Y, and Z values were recorded directly from the color difference meter at the same time. Firmness was assessed by an Instron universal testing instrument model 1000, which was fitted with an extrusion cell. The extrusion test was performed with 75 g of kernels boiled in 400 ml of water for 30 min. A compression pressure of 50 kg/cm^2 was used with the Instron, and the crosshead and chart speed were both set at 50 mm/min. The results were reported in terms of Instron peak height (cm) and area under the curve (cm^2).

Chemical Tests

Oil content was recorded by a Newport nuclear magnetic resonance (NMR) analyzer, which contains a radio frequency (R-F) coil located in a permanent magnet with a steady field value of 655 gauss. The R-F level for the analysis was set at 399 μA, and the R-F signal set for both 32 and 138 seconds. The extraction of oil was performed according to D'Appolonia and MacArthur (1979). PV and FFA as percent linoleic acid were determined by AOCS method Cd 8-53 (AOCS 1980) and AACC method 58-16 (AACC 1983), respectively.

Statistical Analysis

A factorial [2 (roasted/unroasted), 2 (light/no light), 2 (35/75° F), 9 (time)] experimental design was used in experiment 1. The analysis of variance was performed in a completely randomized manner. All the variables were analyzed by a correlation coefficient matrix. Experiment 2 was analyzed by the factorial design [2 (roasted/unroasted), 3 (time)].

TABLE I
Average Initial Values for Physical and Chemical Properties of Fresh, Dehulled Confectionery Sunflower Kernels

Characteristic	Kernels	
	Unroasted	Roasted
Physical		
Moisture (%)	6.4	0.5
Test weight (lb/bu)	42.4	41.9
(kg/hl)	54.6	54.0
Firmness		
Peak height (cm)	10.2	9.2
Area (cm^2)	26.1	27.0
Color[a]		
Hunter L	48.3	44.8
a	1.5	3.7
b	11.0	16.6
Chemical		
Oil content %, 128 sec	57.3	58.6
Oil content %, 32 sec	57.5	58.5
Peroxide value (meq/kg)	3.1	14.9
Free fatty acid % (as linoleic acid)	0.2	0.3

[a] L (100 white, 0 black), a (− green, + red), b (− blue, + yellow).

TABLE II
Area (cm^2)[a] as Obtained with the Instron of Dehulled, Unroasted and Roasted Confectionery Sunflower Kernels Stored Under Different Conditions

Storage (weeks)	Unroasted				Roasted			
	35° F		75° F		35° F		75° F	
	L[b]	D[c]	L	D	L	D	L	D
3	26.4	21.2	22.2	27.7	24.8	28.4	25.4	25.7
6	21.4	21.5	23.1	21.1	19.5	20.1	21.4	20.8
9	28.2	25.7	29.5	30.3	25.9	26.2	26.5	26.0
12	35.6	36.2	38.8	39.8	36.7	34.3	35.8	37.9
15	34.1	36.8	36.3	37.2	37.0	34.5	33.5	33.5
18	36.8	39.4	42.5	42.8	41.0	40.4	38.1	40.1
21	31.9	31.3	33.6	37.0	38.6	38.3	37.5	38.4
24	31.6	34.0	37.7	37.0	35.9	32.0	37.6	33.8
27	32.5	33.4	36.8	38.1	33.9	32.5	31.5	30.4

[a] Area under the curve measured with a planimeter.
[b] Storage of samples under fluorescent light 8 hr each day.
[c] Storage in the dark.

RESULTS AND DISCUSSION

Experiment 1

Table I shows average initial values for physical and chemical properties of the fresh, dehulled confectionery sunflower kernels. These results were used as reference values throughout this experiment. With exception of Hunter a and b, the physical characteristics of roasted kernels had similar or lower values than for unroasted kernels. For the chemical characteristics, the oil content and the FFA values were similar for both types of kernels but PV of the roasted kernels was approximately five times higher than for the unroasted kernels. For the subsequent evaluations, unroasted kernels stored at 35° F under either light or dark conditions did not show any change in moisture, test weight, color, oil content, or PV, whereas firmness and FFA increased. The unroasted kernels at 75° F showed a decrease in moisture. Such results were caused by the chemical reaction between triacylglycerols and water to yield FFA. These results agree with the sharp increase in FFA found in the unroasted kernels stored at 75° F (Fig. 1). Unroasted kernels stored at 75° F under both light and dark conditions became lighter in color than unroasted kernels stored at 35° F.

The Hunter L value measures the degree of lightness or brightness of an object (Wyszecki and Stiles 1967). Most of the color differences throughout storage period were differences in L values. Therefore, the L value is recommended for measurement of color in confectionery sunflower kernels.

The firmness of unroasted and roasted kernels changed during storage regardless of temperature or presence or absence of light (Table II). Because no previous studies using Instron measurements on sunflower kernels have been reported, it is not possible to compare the results obtained in this study. It is possible that the increase in the firmness during storage was caused by some change in the sunflower kernel's biochemical components. Roasted kernels stored at 35° F did not show any change in physical characteristics except firmness. Among the chemical characteristics, the oil content was constant throughout storage (Table III).

The effect of storage on PV (meq/kg) of the oil extracted from dehulled unroasted and roasted confectionery sunflower kernels stored under different conditions is shown in Figure 2. The PV of roasted kernels sharply increased after the third week of storage, which indicates that oxidation took place even at 35° F. These results confirm the data presented by List et al (1972), who found that peroxide value increased appreciably during storage and that rate of oxidation was especially accelerated at high temperatures. The roasted kernels stored at 75° F gave a higher PV than those

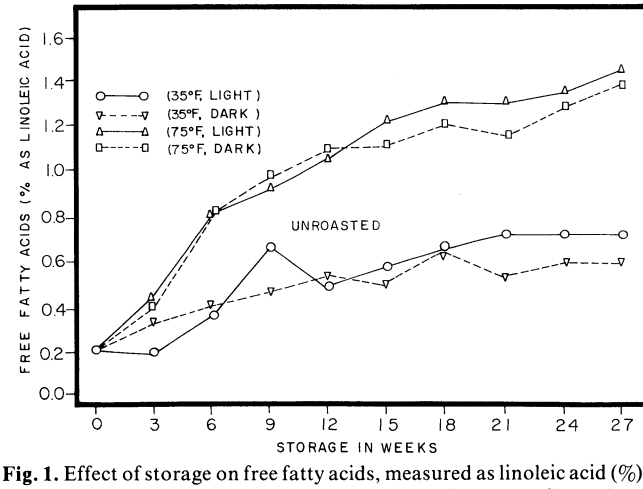

Fig. 1. Effect of storage on free fatty acids, measured as linoleic acid (%), in the oil extracted from dehulled, unroasted confectionery sunflower kernels stored at 35° F and 75° F, under light or dark conditions.

stored at 35° F, whereas the unroasted kernels stored at both temperatures in either light or dark conditions showed no increase in PV. Similar results were obtained by Robertson and Thomas (1976), who found that PV decreased in unroasted dehulled confectionery kernels stored 12 weeks at different moisture levels and temperatures.

The rapid increase in PV of the roasted kernels was perhaps caused by a loss of cell integrity of the entire kernel together with destruction of antioxidant compounds during the roasting process. These physical and chemical changes could have permitted greater contact between oxygen and the unsaturated bonds present. At a PV of 135 meq/kg, the roasted kernels exhibited bad odor and flavor; thus, kernels subjected to 75° F with or without light developed rancidity after 12 weeks of storage. After an additional six weeks, the roasted kernels stored at 35° F with or without light also exhibited rancidity.

Figure 3 illustrates the amount of FFA present in roasted kernels stored under different conditions. Roasted kernels did not show any appreciable increase in FFA during the first 18 weeks of storage. Heat destruction of lipase enzymes may have been the reason. After this period of storage, temperature appeared to be the important factor contributing to the increase in FFA for roasted kernels stored at 75° F. The roasted kernels stored at 35° F remained relatively constant in amount of FFA. Light or dark conditions did not play a role in the increase or decrease of FFA during storage of sunflower kernels.

Results of statistical analyses of physical and chemical characteristics with a factorial design indicated that unroasted and roasted kernels stored at both temperatures showed highly significant alterations in their physical and chemical characteristics. However, the presence or absence of light did not show any effect on either the unroasted or roasted confectionery sunflower kernels during storage.

The correlation coefficient matrix for physical and chemical

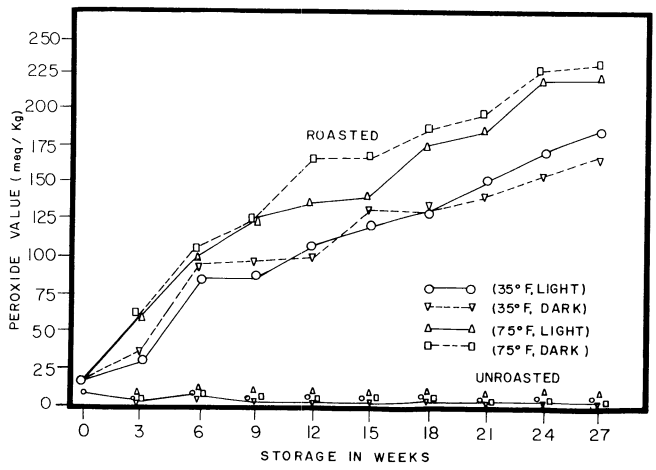

Fig. 2. Effect of storage on peroxide value (meq/kg) of the oil extracted from dehulled, unroasted and roasted confectionery sunflower kernels stored at 35° F and 75° F, under light or dark conditions.

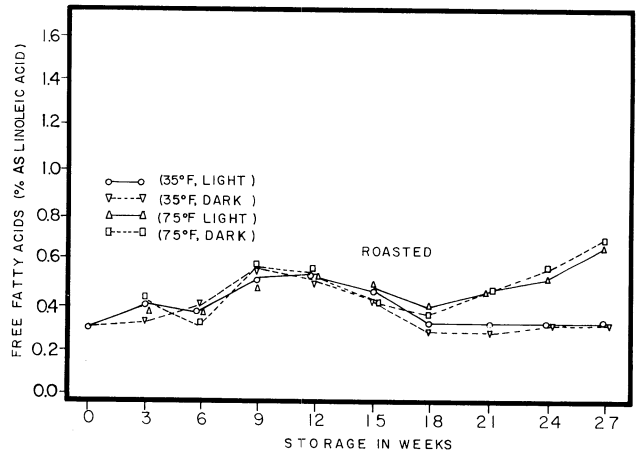

Fig. 3. Effect of storage on free fatty acids, measured as linoleic acid (%), in the oil extracted from dehulled, roasted confectionery sunflower kernels stored at 35° F and 75° F, under light and dark conditions.

TABLE III
Oil Content (%) Read at 128 Sec[a] of Dehulled, Unroasted and Roasted Confectionery Sunflower Kernels Stored Under Different Conditions

Storage (weeks)	Unroasted				Roasted			
	35° F		75° F		35° F		75° F	
	L[b]	D[c]	L	D	L	D	L	D
3	58.7	58.6	58.4	58.5	58.8	58.6	58.1	59.0
6	58.2	58.0	57.7	58.6	58.8	56.2	58.5	58.7
9	58.6	58.1	58.7	58.4	59.2	59.4	59.4	59.1
12	57.9	57.9	57.9	57.9	58.8	58.5	58.8	57.6
15	57.5	57.4	57.5	57.3	58.3	58.3	57.9	58.1
18	56.9	57.5	56.8	57.0	57.1	57.7	55.1	55.2
21	57.6	57.3	57.7	57.2	58.1	58.3	56.8	56.8
24	57.0	57.0	57.0	56.9	57.4	57.6	55.6	56.6
27	58.2	58.3	58.0	58.0	58.7	58.7	57.7	57.9

[a] Radio-frequency used in the nuclear magnetic resonance spectroscopy.
[b] Storage of samples under fluorescent light 8 hrs each day.
[c] Storage in the dark.

TABLE IV
Correlation Coefficient Matrix for Physical and Chemical Characteristics of Confectionery Sunflower Kernels Studied in Experiment 1

Characteristic	Test Weight		Firmness		Color						
					Color[b]			Oil		Peroxide Value	Free Fatty Acid
	lb/bu	kg/hl	Peak Height	Area	*L*	*a*	*b*	128 sec	32 sec		
Moisture	−0.082	0.008	−0.154	−0.029	0.841**[a]	−0.975**	−0.989**	−0.175**	−0.161**	−0.800**	0.389**
Test weight (lb/bu)		0.862**	0.095	0.083	0.048	0.002	0.004	−0.211**	−0.333**	0.133	−0.117
Test weight (kg/hl)			0.059	−0.006	−0.067	0.093	0.084	−0.127	−0.201*	0.153	−0.193*
Firmness											
Peak height				0.865*	0.013	0.167	0.102	−0.086	−0.355**	0.179*	0.268**
Area					0.172*	−0.037	−0.021	−0.210**	−0.528**	0.205**	0.426**
Color[b]											
Hunter *L*						−0.918**	−0.871**	−0.191*	−0.262**	−0.692**	0.677**
a							0.986**	0.179*	0.168*	0.796**	−0.539**
b								0.171*	0.157*	0.818**	−0.479**
Oil content (128 sec)									0.584**	−0.025	−0.613*
(32 sec)										−0.136	−0.218**
Peroxide value											−0.343**

[a] ** = Significant at $P = 0.01$, * = significant at $P = 0.05$.
[b] *L* (100 white, 0 black), *a* (+ red, − green), *b* (+ yellow, − blue).

TABLE V
Physical and Chemical Values for Dehulled, Unroasted and Roasted Confectionery Sunflower Kernels Packaged in Aleure LD[a] and Nitrogen Flush Stored at 75° F Under Light Conditions

	Storage Period in Weeks							
	Unroasted				Roasted			
Characteristic	0[b]	6	12	18	0[b]	6	12	18
Physical								
Moisture (%)	6.4	6.0	5.5	5.3	0.5	0.4	0.5	0.5
Test weight (lb/bu)	42.4	42.4	42.2	42.6	41.9	42.4	42.6	42.8
(kg/hl)	54.6	54.6	54.4	54.8	54.0	55.1	54.8	55.3
Firmness								
Peak height (cm)	10.2	10.3	11.2	12.2	9.2	10.2	10.7	10.9
Area (cm^2)	26.1	28.3	35.6	38.7	27.0	34.3	34.3	34.8
Color[c]								
Hunter *L*	48.3	50.1	50.9	49.4	44.8	44.7	45.0	45.1
a	1.5	1.4	1.1	0.7	3.7	3.9	3.5	3.8
b	11.0	11.0	11.5	11.1	16.6	16.6	17.7	16.9
ΔE	...	1.2	2.3	2.2	...	0.3	0.7	0.5
ΔC	...	0.3	0.7	0.3	...	0.3	0.3	0.3
Chemical								
Oil % (128 sec)	57.3	56.9	57.2	58.4	58.6	58.4	57.3	58.3
Oil % (32 sec)	57.5	56.9	57.2	58.3	58.5	58.3	57.4	58.2
Peroxide value (meq/kg)	3.1	0.9	0.9	1.0	14.9	30.1	29.6	29.8
Free fatty acid (as linoleic acid)	0.2	1.3	1.4	1.6	0.3	0.3	0.3	0.3

[a] Metallized polyester polyethylene film.
[b] Data obtained in initial evaluation.
[c] *L* (100 white, 0 black), *a* (− green, + red), *b* (− blue, + yellow).

characteristics of confectionery sunflower kernels is shown in Table IV. At the 1% level of probability, no significant correlations were found between moisture and test weight or firmness. However, moisture content and the different color values, oil content, PV, and FFA were significantly correlated. The positive correlation found between moisture and FFA agrees with the findings of Robertson and Thomas (1976) who reported that lipase enzymes and water react with triacylglycerols to form FFA. The negative correlation found between moisture and PV agrees with the low moisture content of the roasted kernels and the increase in PV value during the storage period. No significant correlation coefficients were found between test weight and the remaining physical and chemical characteristics. The correlation matrix indicated that if firmness increased, *L* value, PV, and FFA also increased. Most of the color values showed a highly significant correlation with the chemical characteristics. In general, *L* value showed similar results to the tristimulus *X*, *Y*, and *Z* values measured, indicating that the determination of the *L* value should be sufficient to predict any of the tristimulus values.

Experiment 2

Table V shows the average values obtained in experiment 2 for the physical and chemical characteristics of unroasted and roasted kernels stored for 0, 6, 12, and 18 weeks. In general, unroasted kernels showed similar physical and chemical changes to those obtained for unroasted kernels stored at the same temperature in experiment 1. The increase in firmness indicates that confectionery sunflower kernels become tougher regardless of the packaging conditions. When the results from experiments 1 and 2 were compared, a considerable decrease in the PV for roasted kernels was observed in experiment 2. The oxidation reaction in roasted kernels packaged under nitrogen conditions in laminated metallized polyester bags was retarded by 85% and did not increase after six weeks. Moreover, the development of objectionable tastes and odors was overcome. Thus, to retain the high quality of the roasted kernels, the kernels should be packaged under nitrogen atmosphere and in metallized polyester bags.

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