

## Physico-Chemical and Sensory Characteristics of Defatted Roasted Peanuts During Storage<sup>1</sup>

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### ABSTRACT

Full-fat (53% oil) and defatted (22% oil) blanched, whole, roasted peanuts were stored at 4, 25, and 63°C for 12 wk. Defatted peanuts were lighter in color as indicated by a higher Hunter L and b values and a lower a value. The a value which indicated redness also decreased during storage until week 9. Defatting also resulted in roasted peanutty scores that were lower and decreased during storage and decreased pyrazine peak areas (Peaks 24 and 25). Rancidity-related attributes were generally more intense in defatted samples and increased during storage. PV and TBA values were higher in defatted peanuts and increased during storage. A higher moisture content in defatted peanuts may have contributed to its lower storage stability. TBA correlation with rancidity-related attributes indicated secondary oxidation in the samples during storage. The compounds 1-methylpyrrole, 2-methylpyrazine, 2,5-dimethylpyrazine, ethanol, hexanal, and pyridine were tentatively identified by gas chromatography.

Key Words: Gas chromatography (GC), oxidation.

Roasted peanuts (*Arachis hypogaea* L.) are widely consumed in the U.S. mainly as whole kernels and as peanut butter which account for a combined 62% of the market (USDA, 1993). Current trends toward low fat products once again focus attention on reducing oil in peanuts. Low fat peanut spread containing full-fat peanuts and soy protein isolate or carbohydrate replacers was explored by Rudolph *et al.* (1991). Similar products can already be found in the market.

Defatting of peanuts was first explored in 1965 by Vix *et al.* at the Southern Utilization Research and Development Division, where a laboratory and pilot plant scale process was developed (Vix *et al.*, 1966, 1967). To date, only a few studies have been carried out on defatted roasted peanuts. Pominski *et al.* (1964) extracted the oil

in whole kernels using hexane resulting in an oil loss of 81% with best appearance after 120 hr of extraction. The more recent study by Santerre *et al.* (1994) focused on the effects of extracting oil with supercritical carbon dioxide. Divino (1995), on the other hand, studied the flavor attributes and volatile compounds of ground, defatted, roasted peanuts. To date, only Santerre *et al.* (1994) and Divino (1995) quantified the sensory characteristics of defatted roasted peanuts.

A related study on the lipid stability of stored reconstituted partially defatted raw peanuts was conducted by Adnan *et al.* (1981). Reconstitution was done by immersing pressed peanuts (25% oil) in 2.5× by weight of boiling water for 6 min and then drying at 50°C for 18 hr to attain the original moisture content. Results indicated effective inactivation of the enzyme lipoxygenase although tocopherols were destroyed.

Divino *et al.* (1996) recently studied the enzymatic and autoxidation of defatted peanuts using ground, blanched, raw, and roasted peanuts with varying oil contents, respectively. Results supported the hypothesis of higher potential for autoxidation at higher oil contents (Rozen *et al.*, 1994). A slower autoxidation was noted with the raw peanuts.

Defatted peanuts have high protein and low calorie content as a consequence of removal of oil (Woodroof, 1983). The low oil content is believed to give the product a longer shelf-life and potential for utilization in low calorie products (Woodroof, 1983). A peanut spread made with defatted raw peanut flour, toasted and untoasted, has been developed (Lasdon *et al.*, 1989, 1991). The application of defatted, roasted peanuts to this and some other related products has great potential for expanding peanut markets. The extracted roasted oil also can be explored as a raw material for extraction of concentrated flavors.

Before a food material can be applied to an end product, characteristics must first be established. The objective of this study was to determine and compare the storage stability of defatted roasted peanuts to full-fat roasted peanuts. Specifically, it determined the oxidative stability of stored defatted peanuts based on peroxide value (PV), the Thiobarbituric Acid Test (TBA), and the gas chromatographic (GC) and sensory profiles of defatted peanuts during storage.

## Materials and Methods

### Peanut Sample Preparation

Six-month-old Florunner peanuts (Georgia Peanut Co.,

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Ashburn, GA) stored at 7 C were used. The stored peanuts were equilibrated at ambient temperature (*ca.* 22 C) for 1 hr prior to processing.

Shelled, whole, raw peanut kernels (4.1 kg) were roasted at 163 C for 20 min in a 13.6-kg capacity electric roaster (Model 37, Preedit Electric Roaster Co., Erie, PA) to Hunter color Lightness (L) average value of  $50.0 \pm 1.0$ . The roasted peanuts were cooled using forced air for 10 min to prevent further roasting. Upon cooling, the roasted whole peanuts were dry blanched for 15 min using a peanut blancher (Model EX, Ashton Food Machinery Co., Inc., Newark, NJ).

Three replicate batches of roasted, blanched, whole peanuts were made. Each replicate was divided into two batches. One batch represented the control, which is the full-fat or undefatted sample; and the other, the defatted sample. Defatting was carried out using a hydraulic press (Carver Laboratory Press Model M, Fred S. Carver Inc., WI). A pressure-time combination of  $2.76 \times 10^8$  Pa and 30 min was used in a batch lot of 330 g during defatting. Peanut samples had mean oil contents of 53% for full-fat samples and 22% for defatted.

Each batch of samples was divided into lots of 160 g and placed in tightly covered Mason jars. All three replicates of jars of full-fat and defatted samples were distributed in three storage chambers representing 4, 25, and 63 C. One jar of sample per replicate, oil level, and temperature was drawn at designated time intervals and stored at -85 C until evaluation.

### Experimental Design

A split-split plot design was used in the storage study. The whole plot effect compared three temperature levels (4, 25, and 63 C); the subplot effect compared two oil levels (53 and 22%); and, for the sub-subplot effect, sampling time of weeks 0, 1, 4, 9, and 12 were employed for each temperature level.

### Physical and Chemical Measurements

**Color Measurements.** Color was measured on whole kernels of full-fat and defatted roasted peanuts to determine the roasting endpoint set at  $50 \pm 1.0$  and at designated sampling times. Color was measured using a HunterLab color difference meter (Model D25-2, Hunter Associates Laboratory Inc., Fairfax, VA) with Standard Illuminant C and a 20 viewing angle. It was set against a white reference tile ( $L = 95.47$ ,  $a_L = -0.5$ ,  $b_L = 1.0$ ).

**Moisture and Oil Analysis.** Ground samples of raw and roasted peanuts were analyzed for moisture and oil content. Moisture was determined on approximately 5.0 g of peanut sample by drying in a vacuum oven (Scientific Products, Evanston, IL) preheated to 70 C and set at  $1.72 \times 10^8$  Pa for 8 hr. Moisture was calculated as a percentage of weight of moisture of sample relative to weight of original sample (wet basis). Oil was extracted with hexane using Soxhlet apparatus. Oil extraction was carried out for 8 hr on moisture-free samples. Oil content was reported as percentage of weight of oil relative to weight of original sample (dry basis).

**PV.** Peroxide value was determined on oil extracted from fresh and rancid peanut samples using the Soxhlet apparatus. The A.O.C.S. Official Method Cd 8-53 for peroxide value was used (A.O.C.S., 1988).

**TBA.** The TBA procedure by Tarladgis *et al.* (1960, 1964) was adapted into the extraction system. Ten g of whole kernel sample and 50 mL distilled water were weighed into

a glass mixing vessel and blended using a Virtis blender (Virtis "45" Homogenizer, The Virtis Co., Gardiner, NY) for 2 min. The mixture was transferred into a Kjeldahl flask by washing with 47.5 mL distilled water. The solution was brought to pH 1.5 with the addition of 2.5 mL of 4N HCl. Antifoam and boiling chips were added to prevent bumping. Five to six drops of the following antioxidant mixture were added: 0.2 g BHT (Fisher Scientific Co., Fairlawn, NJ), 0.2 g *n*-propyl-gallate (Sigma Chemical Co., St. Louis, MO) and 15 mL of propylene glycol (J.T. Backer Inc., Philipsburg, NJ). The antioxidant mixture, brought to solution by heating in a water bath was added to prevent further oxidation during blending (Yu, 1967; Moerck, 1974; Rhee, 1978; Lee, 1993).

The flask was attached to a distillation apparatus and heated. Fifty mL of distillate was collected. Five mL of the distillate was pipetted into a 50-mL tube into which 5 mL of 0.02 M TBA reagent was added. The tubes were stoppered with a glass marble and immersed in boiling water bath for exactly 35 min. A distilled water-TBA reagent blank was prepared and treated the same way. The tubes were cooled immediately in running tap water for 10 min. A portion of the solution was transferred to a cuvette and the absorbance read against the blank at a wavelength of 538 nm.

**GC.** The gas chromatography procedures of Brown *et al.* (1971) and Fore *et al.* (1979) were adapted to this analysis system. A Varian Model 3700 gas chromatograph (Varian Associates, Inc., Palo Alto, CA) equipped with a flame ionization detector was used and attached to a Shimadzu Integrator (CR601 Chromatopac, Kyoto, Japan).

The sample was prepared by twisting a 100-mm long and 6.34-mm (O.D.) glass tube in a dish of ground, roasted peanuts until 0.3-g sample adhered inside. The tube was plugged on both ends with glass wool. The rod was attached to one end of a 1.83-M  $\times$  6.34-mm (OD) glass gas chromatography column packed with Porapak P (Supelco, Inc., Bellefonte, PA). This end was inserted into the injection port maintained at 100 C and held in place with a septum nut.

Volatile compounds were purged for 20 min with nitrogen gas onto the GC column cooled with an ice bath. Nitrogen gas flow rate was standardized by injecting 0.3 mL hexanal headspace and maintaining the retention time (min) within  $\pm 0.05$ .

After purging the volatile compounds, the rod with spent sample was removed from the inlet and the GC column and replaced with an empty tube plugged with glass wool. The column oven temperature was programmed from 40 to 200 C at 10 C/min. Detector temperature was set at 220 C. The program was allowed to run for 35 min. Gas chromatographic peaks were tentatively identified by comparison of retention times with those of commercially available standard references analyzed using the same system.

### Sensory Evaluation

Quantitative descriptive analysis was performed. A panel of 11 judges, composed of three males and eight females within the age range of 23-45, was recruited from the Dept. of Food Science and Technology, Univ. of Georgia. They were trained in 1-hr daily sessions for 2 wk. During training, the panel was presented with samples made from defatted and undefatted peanut kernels with the aim of generating terminology to describe the

products. The peanut lexicon by Johnsen *et al.* (1988) as updated by Sanders *et al.* (1989) and the list of oxidation terms by Civile and Dus (1992) were used as a basis.

A total of 11 descriptors were found to be representative of the sample attributes. For odor, roasted peanutty (RPO), dark roast (DRO), rancid/oxidized (ROO), and cardboardy (CO) were evaluated. Flavor attributes included roasted peanutty (RPF), raw beany/peanutty (RBP), woody/skins/hulls (WSH), cardboardy (CF), dark roast DRF), and rancid/oxidized (ROF). Bitter (BIT) was the only basic taste analyzed.

Spectrum™ intensity (Meilgaard *et al.*, 1991) standards were anchored at different points of the 150-mm unstructured line scale. The intensity standards used and the corresponding scores were grape in Welch's grape juice (100), orange in Minute Maid orange concentrate (65), soda in saltine crackers (50), and apple in Mott's applesauce (20). Full-fat reference samples A and B, fresh and rancid, and defatted samples C and D, fresh and rancid, respectively, were assigned scores by the panel and were anchored on the line scale. Reference samples were presented at every session during the actual analysis.

Evaluation procedures were established during training. Odor was first evaluated then flavor. Odor of the sample was evaluated by slightly lifting the container lid and sniffing the contents. Flavor was evaluated by placing a small amount of the sample in the mouth, allowing it to settle in, and then letting the volatile compounds pass from the mouth to the olfactory area. Samples were then expectorated. Panelists were asked to taste or smell the standard first for a given descriptor before evaluating the experimental samples.

A sensory laboratory equipped with partitioned booths and illuminated by red light was used during actual evaluation. Approximately 5.0 g of sample was placed in plastic cups labelled with random numbers and presented to panelists in random order. Water and crackers were made available for panelists to clear palate between samples. Sensory evaluation was conducted in two sessions, one in the morning and one in the afternoon.

#### Statistical Analysis

Data was analyzed using the Statistical Analysis System (SAS, 1990) program package. Cluster analysis (VARCLUS) of the weekly sampling data was utilized to determine panel outliers. Data for any outliers was deleted from subsequent analysis. Analysis of variance (ANOVA) of results at the statistical significance level of  $P \leq 0.05$  was performed using the general linear model (GLM) procedure. The model consisted of the dependent variables moisture, Hunter L, a, and b values, PV, TBA, GC peak areas, and sensory scores. The independent variables consisted of the main, and two- and three-way interaction effects of storage time (WEEK), oil content (OIL), temperature (TEMP), and replication (REP). Means were compared using Fisher's protected least square difference. Correlation of sensory data with data of statistically significant GC peaks, PV, and TBA was determined using the proc corr method (SAS, 1990).

## Results and Discussion

### Moisture Content (%)

Figure 1 shows the effect of temperature and oil content on moisture content of full-fat and defatted peanuts during storage. Significant WEEK ( $P = 0.0001$ ), TEMP ( $P = 0.002$ ), and OIL ( $P = 0.0001$ ) main effects;

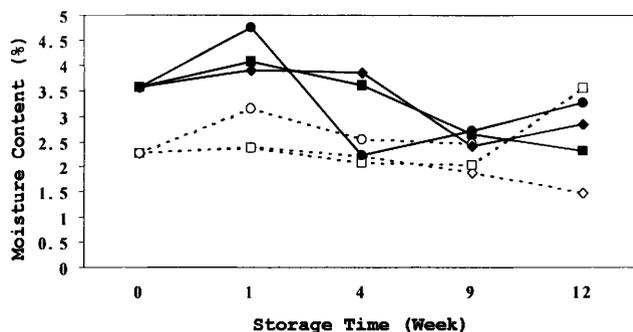


Fig. 1. Moisture content of full-fat (53%) and defatted (22%) whole peanuts at different storage times and temperatures. Missing data for 53%-63 C at week 12. Legend for oil-temperature: (◇) 53%-4 C, (□) 53%-25 C, (○) 53%-63 C, (◆) 22%-4 C, (■) 22%-25 C, (●) 22%-63 C.

OIL\*WEEK ( $P = 0.004$ ) and TEMP\*OIL ( $P = 0.319$ ) two-way interaction effects; and three-way interaction effects (WEEK\*TEMP\*OIL) ( $P = 0.02$ ) were found for moisture. The initial mean moisture content was 2.3% for full-fat and 3.6% for defatted samples. A generally higher moisture content was observed for defatted peanuts than for full-fat peanuts. Moisture content increased during the first week then generally declined until week 9.

The significant interactions were indicated by a lower moisture content for defatted peanuts stored at 63 C than peanuts stored at 4 or 25 C at week 4. In fact, its moisture content at week 4 was similar to moisture content of full-fat peanuts stored at 4, 25, and 63 C. Another cause for a significant interaction was the increase in moisture content of some samples at week 9. Roasted peanuts are hygroscopic in nature and are apt to absorb moisture depending on the nature of the packaging and storage conditions (Shewfelt and Young, 1977).

### Color

The Hunter L (lightness or darkness), a (redness or greenness), and b (yellowness and blueness) values of roasted peanuts indicated significant differences due to OIL ( $P = 0.03$ ) (Table 1). An increase in both lightness and yellowness of samples was noted with decreased oil content. A similar relationship has been established in an earlier study by Divino (1995). The amount of the pigment melanin, which is responsible for the color of oil, decreases when oil is removed, thereby resulting to a product with a lighter color.

Defatting reduced the redness of the samples. The a value of defatted and full-fat samples also indicated a significant WEEK ( $P = 0.03$ ) main effect. Redness of

Table 1. Hunter L, a, and b values for data pooled for full-fat (53%) and defatted (22%) peanuts.

Oil	Hunter color parameter <sup>a</sup>		
	L	a	b
%			
53	51.8 b	7.5 a	19.0 b
22	61.1 a	6.7 b	19.7 a

<sup>a</sup>Means within a color parameter followed by the same letter are not significantly different from each other at  $P \leq 0.05$ .

samples decreased to 6.8 on the 9<sup>th</sup> week then increased to 7.3 on the 12<sup>th</sup> week.

An OIL\*TEMP interaction ( $P \leq 0.0111$ ) for b value can be explained by a higher value for the defatted peanuts at each temperature level except at 63 C where b values were similar. Hunter b values at 4, 25, and 63 C for full-fat were 18.81, 18.61, and 19.57, and 19.45, 20.26, and 19.58 for defatted, respectively.

### PV and TBA

A significant WEEK ( $P = 0.0001$ ), TEMP\*WEEK ( $P = 0.006$ ), and TEMP\*WEEK\*OIL ( $P = 0.02$ ) main and interaction effects were noted for PV. Shown in Fig. 2 are the PV of full-fat and defatted whole peanuts stored for 12 wk at different temperatures. PV of defatted and full-fat peanuts stored at 25 and 63 C increased until week 4 then generally declined thereafter. Interestingly, defatted peanuts stored at 25 C had the highest PV at week 4. Thus, at higher temperatures of 25 and 63 C, stability of samples may depend on the oil contents. Full-fat and defatted peanuts stored at 4 C were still increasing at week 12, indicating greater stability of samples at lower storage temperatures. A higher PV was noted for defatted than full-fat peanuts stored at 4 C. PV measures the amount of hydroperoxides which are the primary degradation products formed (Gray, 1978). These are highly reactive compounds, thus the higher temperatures of 25 and 63 C facilitated their conversion into the more stable secondary form as indicated by sharp increases followed by a fast decline at week 4.

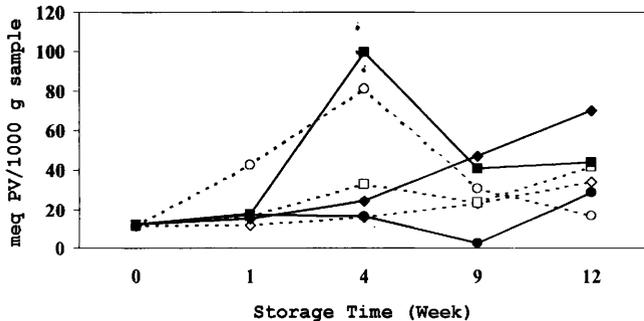


Fig. 2 Peroxide value (PV) of full-fat (53%) and defatted (22%) whole peanuts at different times and temperatures. Legend for oil-temperature: (○) 53%-4 C, (□) 53%-25 C, (○) 53%-63 C, (◆) 22%-4 C, (■) 22%-25 C, (●) 22%-63 C.

The TBA test is based on the reaction of the lipid oxidation product malonaldehyde and 2-thiobarbituric acid (Hoyland and Taylor, 1991). Significant WEEK ( $P = 0.0001$ ), OIL ( $P = 0.001$ ), and TEMP ( $P = 0.004$ ) main effects and TEMP\*WEEK ( $P = 0.0002$ ) and OIL\*WEEK ( $P = 0.03$ ) interaction effects were found for TBA. Figure 3 shows the effect of oil content on TBA values of peanuts stored over 12 wk. Defatted peanuts exhibited a higher TBA content than the full-fat sample. The defatted peanuts showed an increase until the 4<sup>th</sup> wk then declined, while the TBA values of full-fat peanuts continued to increase even until the 12<sup>th</sup> wk. This indicates that defatted peanuts were less stable than full-fat peanuts. Higher temperatures generally

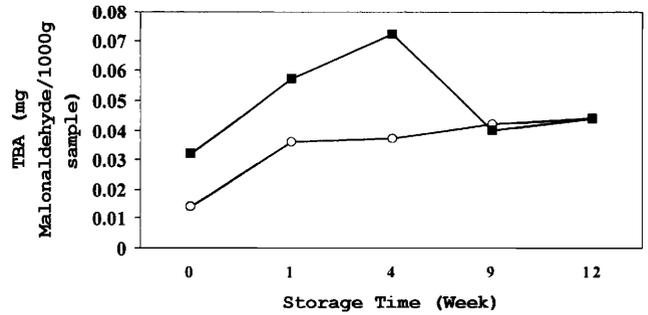


Fig. 3. Thiobarbituric acid (TBA) values of full-fat (53%) and defatted (22%) peanuts at different storage times. Legend: (○) 53% oil, (■) 22% oil.

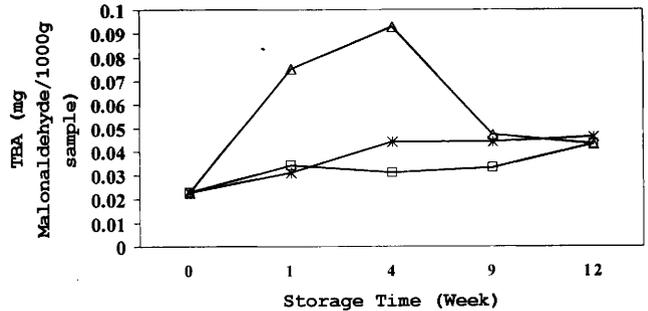


Fig. 4. Thiobarbituric acid (TBA) values pooled for full-fat and defatted whole peanuts at different storage times and temperatures. Legend: (□) 4 C, (★) 25 C, (Δ) 63 C.

Table 2. Gas chromatography (GC) peaks in 50 and 22% oil peanuts found to differ significantly on storage at 4, 25, and 63 C.\*

Peak number	Tentative identification
P12	Ethanol
P15	Unidentified
P18	Unidentified
P19	Hexanal
P20	1-Methylpyrrole
P22	Pyridine
P24	2-Methylpyrazine
P25	2,5 Dimethylpyrazine
P28	Unidentified
P33	Unidentified
P37	Unidentified

\*Peak number reflects order of appearance in chromatogram.

accounted for a higher TBA value at a relatively shorter period of time for peanut samples (Fig. 4).

### GC

A total of 37 GC peaks were present in the full-fat and defatted peanut samples. Among these, only 11 differed significantly ( $P < 0.05$ ) during storage (Table 2). GC peaks 12 (P12), 20 (P20), 22 (P22), 24 (P24), 25 (P25), and 19 (P19) were tentatively identified through comparison of retention times with those of authentic compounds. Peaks 15 (P15), 18 (P18), 28 (P28), 33 (P33), and 37 (P37) were not identified.

P12 was tentatively identified as ethanol. Ethanol has been associated with abusive drying in raw peanuts (Young and Hovis, 1990) and has been isolated and identified from high temperature-cured off-flavor raw peanuts (Pattee *et al.*, 1965). Its presence in roasted peanuts has likewise been documented (Ho *et al.*, 1981). P20 was tentatively identified as 1-methylpyrrole which is described as possessing a sweet, woody odor (Ho *et al.*, 1981). P22 or pyridine occurs in breakdown flavors of products such as baked potato, but its role in roasted peanut flavor is yet to be established (Coleman, 1981; Ho, 1981). P24 has been tentatively identified to be 2-methylpyrazine, and P25, 2,5 dimethylpyrazine. The role of pyrazine compounds in the flavor of roasted peanuts was first established when Mason *et al.* (1966) isolated five pyrazines from roasted peanuts and concluded that they are contributory to its "nutty" characteristics. P19 has been tentatively identified as hexanal, a carbonyl compound associated with "green or beany" flavor of raw peanuts (Pattee *et al.*, 1970). Hexanal also was isolated from roasted peanuts in concentrations 10× its flavor threshold (Brown *et al.*, 1971).

Shown in Table 3 are the area of GC peaks of peanuts significantly influenced by WEEK ( $P = 0.02$ ). All 11 peaks were significant and peak areas generally increased through storage. Four peaks identified as 1-methylpyrrole, 2-methylpyrazine, 2,5 dimethylpyrazine, hexanal, and an unidentified peak, P15, increased until week 4 and then declined. The unidentified P37 seemed to have developed only at week 9.

Shown in Table 4 are the GC peak areas of stored peanuts significantly influenced by OIL ( $P = 0.02$ ). Peaks identified as 2-methylpyrazine and 2,5 dimethylpyrazine and an unidentified peak, P37, decreased with decreased oil content.

Some of the GC peaks were significantly affected by TEMP ( $P = 0.02$ ) (Table 5). The peak areas of 1-methylpyrrole, P15, and P37 increased with increased storage temperature. Ethanol and P18 peak areas decreased with increased storage temperature. Ethanol concentration in raw peanuts previously was found to increase with increased curing temperature (Singleton

**Table 4. Gas chromatographic (GC) peak areas of stored peanuts significant for oil content (OIL).<sup>a</sup>**

Peak no.	Tentative identity	Oil (%)	
		53	22
P24	2-Methylpyrazine	39064 a	30577 b
P25	2,5 Dimethylpyrazine	94909 a	66177 b
P37	Unidentified	747 a	0 b

<sup>a</sup>Means within a peak followed by the same letter are not significantly different from each other at  $P \leq 0.05$ .

**Table 5. Gas chromatographic (GC) peak areas of peanuts significant for temperature (TEMP).<sup>a</sup>**

Peak no.	Tentative identity	Temperature (C)		
		4	25	63
P12	Ethanol	52849 a	30486 b	20489 c
P15	Unidentified	755402 b	827203 b	1432488 a
P18	Unidentified	58406 a	36219 b	19087 b
P20	1-Methylpyrrole	26395 b	26645 b	80360 a
P37	Unidentified	0 b	0 b	1120 a

<sup>a</sup>Means within a peak followed by the same letter are not significantly different from each other at  $P \leq 0.05$ .

*et al.*, 1971). Studies by Singleton *et al.* (1971) and Brown *et al.* (1977) found ethanol in raw peanuts to be negatively correlated with roasted flavor of the roasted peanuts. However, no similar literature was found relating ethanol with roasted flavor in roasted peanuts. It is possible that ethanol in roasted peanuts is affected differently by storage temperature.

Significant interactions were also noted. A WEEK\*OIL ( $P = 0.01$ ) and WEEK\*TEMP ( $P = 0.002$ ) were found for peaks identified as ethanol (Fig. 5) and 1-methylpyrrole (Fig. 6), respectively. The ethanol peak areas of full-fat peanuts were generally higher than for defatted peanuts except at week 4. Peak areas

**Table 3. Gas chromatographic (GC) peak area of peanuts significant for storage time (WEEK).<sup>a</sup>**

Peak no.	Tentative identity	Storage time (week)				
		0	1	4	9	12
P12	Ethanol	5330 c	25897 b	37876 b	42238	61699 a
P15	Unidentified	538792 b	1547996 a	1157414 ab	1359185 a	421770 ab
P18	Unidentified	14128 b	28218 b	46193 ab	35589	65392 a
P19	Hexanal	5632 b	7924	16122 a	23359 a	19423 a
P20	1-Methylpyrrole	11732 b	22726 b	51541 a	57824 a	78509 a
P22	Pyridine	4131 c	12464 c	44346 bc	158038 a	106552 b
P24	2-Methylpyrazine	16868 b	26365 b	38599 a	43177 a	49095 a
P25	2,5 Dimethylpyrazine	30587 c	23750 b	96928 a	103136 a	111254 a
P28	Unidentified	48162 b	66427 ab	95896 a	80654 a	101676 a
P33	Unidentified	98 c	9383 c	14329 bc	23750 a	28037 ab
P37	Unidentified	0 b	0 b	0 b	1867 a	0 b

<sup>a</sup>Means within a peak followed by the same letter are not significantly different from each other at  $P \leq 0.05$ .

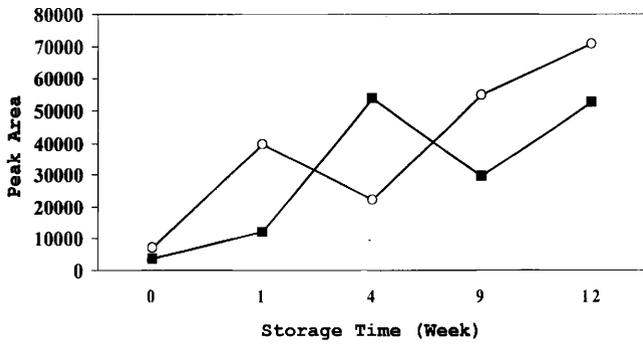


Fig. 5. Ethanol gas chromatographic (GC) peak indicating WEEK\*OIL interaction. Legend: (○) 53% oil, (■) 22% oil.

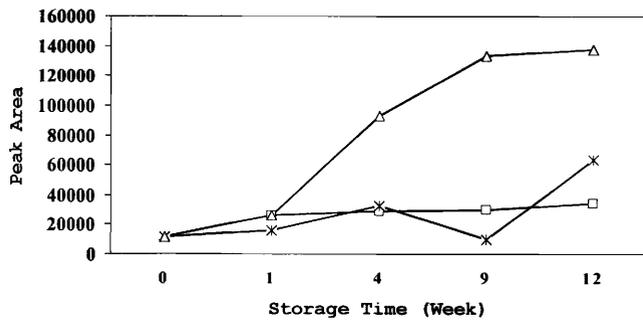


Fig. 6. Gas chromatographic (GC) peak area of 1-methylpyrrole indicating WEEK\*TEMP interaction. Legend: (□) 4 C, (\*) 25 C, (Δ) 63 C.

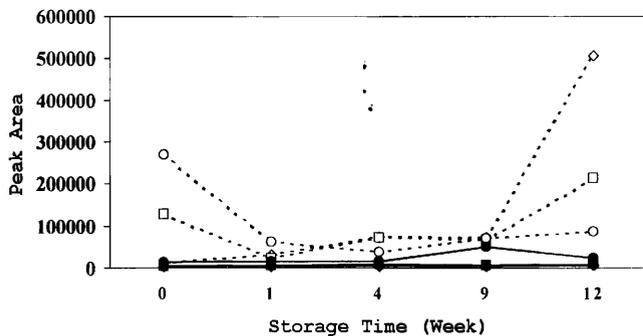


Fig. 7. Gas chromatographic (GC) peak area of pyridine indicating TEMP\*OIL\*WEEK interaction. Legend for oil-temperature: (○) 53%-4 C, (□) 53%-25 C, (○) 53%-63 C, (◆) 22%-4 C, (■) 22%-25 C, (●) 22%-63 C.

of 1-methylpyrrole were the same at 4 and 25 C except at weeks 9 and 12.

A significant TEMP\*OIL\*WEEK interaction ( $P = 0.003$ ) was observed for the peak identified as pyridine (Fig. 7) and P37. Different rates in change of pyridine concentration under different storage conditions for full-fat and defatted peanuts explained the interaction. The interaction for P37 was explained by its absence in peanuts during storage until week 12 where it attained a peak area of 3735 in full-fat peanuts stored at 25 C.

**Sensory Evaluation**

Two of the nine panelists were consistent outliers. Data of outliers were deleted from subsequent analysis.

Six attributes—namely RPO, DRO, ROO, CO, RPF,

and DRF—were influenced significantly by all three main effects of OIL ( $P = 0.05$ ), TEMP ( $P = 0.03$ ), and WEEK ( $P = 0.0001$ ). CF and ROF were influenced significantly by WEEK ( $P = 0.0005$ ) and TEMP ( $P = 0.0004$ ), while RBP and BIT were significantly influenced by OIL ( $P = 0.04$ ). WSH and BIT were influenced significantly by WEEK ( $P = 0.007$ ).

Sensory score attributes for oil decreased for the attributes RPO, DRO, RPF, DRF, and BIT with decreased oil content (Table 6). RBP and rancidity-related attributes ROO and CO intensified with decreased oil content.

Shown in Fig. 8 are the scores of sensory attributes found to be significant for TEMP. Scores for RPO, DRO, RPF, and DRF decreased with increased storage temperature. As expected, the rancidity-related attributes ROO, CO, CF, and ROF increased with increased storage temperature.

Shown in Fig. 9 are the scores of sensory attributes found to be significant for WEEK. WSH, RPO, DRO, RPF, and DRF decreased in intensity with increased storage time. Rancidity-related attributes ROO and ROF

Table 6. Sensory scores of attributes influenced significantly by oil content (OIL).<sup>a</sup>

Sensory attribute	Oil (no.)	
	53	22
RPO	38.4 a	23.3 b
DRO	18.3 a	2.7 b
ROO	16.4 b	19.2 a
CO	2.0 b	3.5 a
RPF	40.2 a	13.8 b
DRF	15.0 a	1.3 b
RBP	1.8 b	2.8 a
BIT	3.6 a	0.9 b

<sup>a</sup>Means within a sensory attribute followed by the same letter are not significantly different from each other at  $P \leq 0.05$ . Sensory attributes: RPO = roasted peanutty odor, DRO = dark roast odor, ROO = rancid/oxidized, CO = cardboardy odor, RPF = roasted peanutty flavor, DRF = dark roast flavor, RBP = raw beany/peanutty, and BIT = bitter taste.

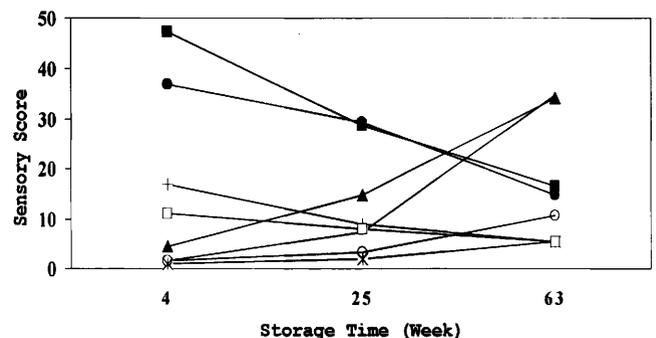


Fig. 8. Sensory attributes and scores of peanuts significantly influenced by storage temperature (TEMP). Legend: (■) RPO = roasted peanutty odor, (+) DRO = dark roast odor, (▲) ROO = rancid/oxidized, (\*) CO = cardboardy odor, (●) RPF = roasted peanutty flavor, (□) DRF = dark roast flavor, (○) CF = cardboardy flavor, ( ) ROF = rancid/oxidized flavor.

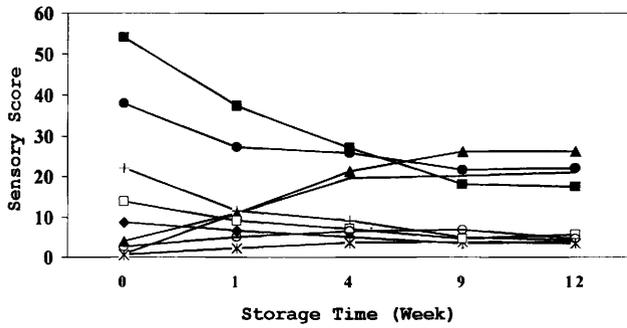


Fig. 9. Sensory attributes and scores of peanuts significantly influenced by storage time (WEEK). Legend: (♦) WSH = woody/skins/hulls, (■) RPO = roasted peanutty odor, (+) DRO = dark roast odor, (▲) ROO = rancid/oxidized, (\*) CO = cardboardy odor, (●) RPF = roasted peanutty flavor, (◊) DRF = dark roast flavor, (○) CF = cardboardy flavor, ( \_ ) ROF = rancid/oxidized flavor.

Table 7. Sensory scores of attributes with significant OIL\*WEEK interaction.<sup>a</sup>

Sensory attribute <sup>b</sup>	Oil	Storage time (week)				
		0	1	4	9	12
	%					
DRO	53	36.2 a	21.7 b	15.6 c	9.7 d	8.2 d
	22	8.0 d	1.5 e	2.8 e	0.8 e	0.6 e
ROO	53	5.5 ef	9.7 ef	19.4 d	24.6 d	22.6 d
	22	2.7 f	12.4 e	23.3 bcd	27.7 abc	30.1 ab
CO	53	0.6 d	1.6 cd	3.6 bc	2.5 bcd	1.9 cd
	22	0.8 d	2.7 bcd	3.8 abc	5.1 ab	5.0 ab
DRF	53	27.1 a	17.7 b	12.9 c	8.8 cde	8.6 de
	22	1.0 d	0.7 d	1.4 d	0.7 d	2.9 d
RPO	53	64.0 a	45.8 b	33.7 c	24.9 cde	23.7 de
	22	44.1 b	28.6 cd	20.4 d	11.7 f	11.6 f
RPF	53	59.2 a	39.1 b	38.5 b	31.2 c	32.9 c
	22	16.6 d	15.5 d	13.2 d	12.3 d	11.5 d

<sup>a</sup>Means within a sensory attribute followed by the same letter are not significantly different from each other at  $P \leq 0.05$ . Sensory attributes: DRO = dark roast odor, ROO = rancid/oxidized, CO = cardboardy odor, DRF = dark roast flavor, RPO = roasted peanutty odor, and RPF = roasted peanutty flavor.

increased with increased storage time. Two other rancidity-related attributes CO and CF, increased minimally until the 4<sup>th</sup> wk then leveled off.

An OIL\*WEEK interaction effect ( $P = 0.049$ ) was found for DRO, ROO, CO, DRF, RPO, AND RPF (Table 7). However, the significant interactions were of different natures. DRO of defatted peanuts decreased then leveled off from week 1, whereas DRO of full-fat peanuts did not level off until week 9. ROO scores for defatted and full-fat peanuts crossed over at week 1. CO scores decreased at week 4 for full-fat peanuts and at week 9 for defatted peanuts. DRF score was the same for defatted peanuts but decreased for full-fat peanuts throughout storage. RPO scores leveled off starting at week 9 for defatted peanuts and starting at week 4 for full-fat peanuts. RPF score of defatted peanuts remained the same but decreased for full-fat during storage.

Table 8. Sensory attributes of peanuts influenced by temperature and storage time (TEMP\*WEEK) interaction.<sup>a</sup>

Sensory attribute <sup>b</sup>	TEMP	Storage time (week)				
		0	1	4	9	12
C						
DRO	4	21.6 a	18.3 abc	21.0 ab	13.2 bcd	10.7 cde
	25	23.2 ab	12.1 cd	5.7 de	2.2 ef	1.9 ef
	63	21.5 ab	4.4 ef	0.8 ef	0.3 f	0.6 ef
ROO	4	3.8 d	2.5 d	3.2 d	5.8 d	6.6 d
	25	4.0 d	5.5 d	13.8 c	25.5 b	25.1 b
	63	4.4 d	25.0 b	47.1 a	47.2 a	47.4 a
CO	4	0.6 d	0.8 d	0.9 d	0.6 d	2.2 cd
	25	0.8 d	0.6 d	1.1 d	4.0 c	2.9 c
	63	0.7 d	5.2 b	9.1 a	6.8 b	5.2 b
RPO	4	57.5 a	49.3 bc	51.7 b	40.1 cd	37.6 d
	25	52.7 ab	44.4 c	23.1 e	12.9 g	11.1 g
	63	51.9 b	17.9 f	6.4 gh	1.8 h	4.3 h
RPF	4	39.7 ab	33.7 b	40.9 ab	34.5 b	35.8 ab
	25	38.4 ab	32.2 b	29.8 b	23.1 c	23.0 c
	63	35.5 ab	16.0 d	6.9 e	7.6 e	7.9 e
CF	4	2.7 cd	1.3 d	1.5 d	1.2 d	1.2 d
	25	2.9 cd	3.4 cd	2.2 cd	5.3 c	3.2 cd
	63	2.3 cd	10.9 b	15.6 a	14.6 a	9.9 b
ROF	4	0.8 f	1.0 f	0.9 f	3.4 ef	1.6 ef
	25	1.0 f	2.4 ef	6.7 e	12.5 d	14.1 d
	63	0.9 f	29.8 c	51.4 a	44.6 b	47.4 ab

<sup>a</sup>Means within a sensory attribute followed by the same letter are not significantly different from each other at  $P \leq 0.05$ . Sensory attributes: DRO = dark roast odor, ROO = rancid/oxidized, CO = cardboardy odor, RPO = roasted peanutty odor, RPF = roasted peanutty flavor, CF = cardboardy flavor, and ROF = rancid/oxidized flavor.

A significant TEMP\*WEEK interaction effect ( $P = 0.0003$ ) was found for DRO, ROO, CO, CF, ROF, RPO, RPF (Table 8). Again, interactions were due to unequal rates of change in parameters of a given variable. DRO and RPO showed the fastest decrease in score at 63 C. Peanuts stored at 4 C did not show a significant change in ROO, CO, RPF, CF, and ROF scores during the storage period. However, storage of peanuts at 25 and 63 C resulted in varying rates of increase or decrease depending on the specific attribute.

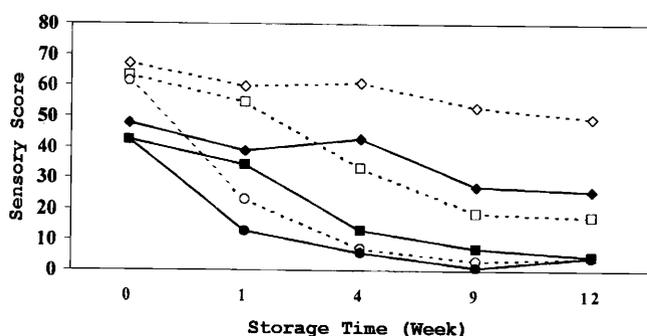
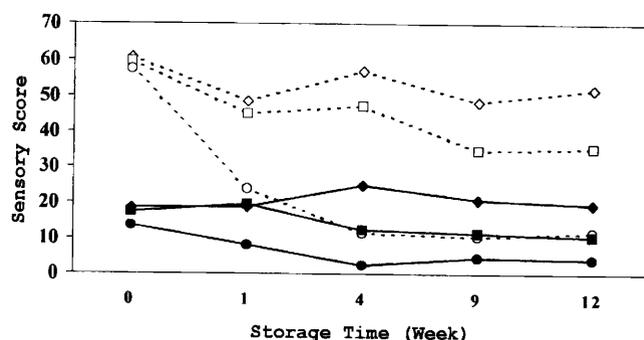
A TEMP\*OIL interaction effect ( $P = 0.003$ ) was observed in RPO, DRO, RPF (Table 9). DRO score of defatted peanuts stored at three temperature levels did not vary significantly during the storage period, but full-fat peanuts decreased with increased storage temperature. RPO and RPF declined at different rates with increased storage temperature.

A TEMP\*OIL\*WEEK interaction effect ( $P = 0.04$ ) was noted for RPO (Fig. 10) and RPF (Fig. 11). Storing full-fat peanuts at 63 C resulted in an RPO score that was not significantly different from defatted peanuts stored at the same temperature or at 25 C. Full-fat peanuts stored at 25 C had the same RPO scores as defatted peanuts stored at 4 C. Similar to RPO, full-fat peanuts stored at 63 C had the same RPF scores as defatted peanuts stored at 25 C.

**Table 9. Sensory attributes significantly influenced by temperature and oil (TEMP\*OIL) interaction.<sup>a</sup>**

Sensory attribute	Oil %	Storage temperature (C)		
		4	25	63
DRO	53	36.2 a	21.7 b	15.6 c
	22	8.0 d	1.5 d	2.8 d
RPO	53	58.1 a	37.5 b	19.7 c
	22	36.4 b	20.2 c	13.2 d
RPF	53	53.2 a	44.3 b	23.0 c
	22	20.6 c	14.3 d	6.6 e

<sup>a</sup>Means within a sensory attribute followed by the same letter are not significantly different from each other at  $P \leq 0.05$ . Sensory attributes: DRO = dark roast odor, RPO = roasted peanutty odor, and RPF = roasted peanutty flavor.

**Fig. 10. Roasted peanutty odor (RPO) scores of full-fat and defatted peanuts as influenced by a significant storage temperature, oil content and storage time (TEMP\*OIL\*WEEK) interaction. Legend for oil-temperature: (◇) 53%-4 C, (□) 53%-25 C, (○) 53%-63 C, (◆) 22%-4 C, (■) 22%-25 C, (●) 22%-63 C.****Fig. 11. Roasted peanutty flavor (RPF) scores of full-fat and defatted peanuts as influenced by a significant storage temperature, oil content and storage time (TEMP\*OIL\*WEEK) interaction. Legend for oil-temperature: (◇) 53%-4 C, (□) 53%-25 C, (○) 53%-63 C, (◆) 22%-4 C, (■) 22%-25 C, (●) 22%-63 C.**

The results of this study seem to be contradictory to the results of the oxidation study by Divino *et al.* (1996). This could be attributed to the effect of particle size and cell disruption. In the present study, defatted, whole peanuts were less stable than whole, full-fat peanuts due to disruption of the cell by hydraulic pressing. In the oxidation study by Divino *et al.* (1996), defatted peanuts were more stable, even though there also was cell disruption due to hydraulic pressing and grinding. The higher level of oil in ground, full-fat peanuts translates to exposure of greater amount of substrate rendering it more susceptible to oxidation.

#### Correlation of Sensory with GC Peaks, TBA, and PV

Shown in Table 10 are the correlation results of sensory data with GC peak, TBA, and PV data. Ethanol concentration was positively correlated with intensity of rancidity-related sensory attributes ROO, CO, CF, and ROF. DRO, RPF, WSH, DRF, and BIT correlated positively with 1-methylpyrrole. This compound probably correlated with RPF and WSH because of its inherent

**Table 10. Correlation values of GC peaks, PV and TBA with sensory attributes of stored full-fat and defatted peanuts at  $P \leq 0.05$  and  $P \leq 0.0001$ .**

Parameter <sup>a</sup>	Sensory attributes <sup>b</sup>										
	RPO	DRO	ROO	CO	RPF	RBP	WSH	CF	DRF	ROF	BIT
P1	0.28	0.42	ns	ns	0.46 a	ns	0.34	ns	0.42 a	ns	0.33
P2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
P3 (ethanol)	ns	ns	0.36	0.32	ns	ns	ns	0.33	ns	0.36	ns
P4	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
P5	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
P6 (1-methylpyrrole)	ns	0.30	ns	ns	0.26	ns	0.23	ns	0.32	ns	0.41
P7 (Pyridine)	ns	0.32	ns	ns	0.40	ns	ns	ns	0.34	ns	0.28
P8 (2-methylpyrazine)	ns	0.39	ns	ns	0.31	-0.27	ns	ns	0.41	ns	0.44 a
P9 (2,5 dimethylpyrazine)	ns	0.48 a	ns	ns	0.43 a	-0.47 a	ns	ns	0.50 a	ns	0.55 a
P10	0.23	0.27	ns	ns	0.27	-0.27	ns	ns	0.30	ns	0.32
P11 (hexanal)	ns	0.32	ns	ns	0.30	ns	0.23	ns	0.37	ns	0.24
PV	-0.30	-0.30	ns	ns	ns	ns	-0.24	ns	ns	ns	ns
TBA	-0.60 a	-0.54 a	0.52 a	0.55 a	-0.55 a	ns	-0.30	0.43	-0.43 a	0.53 a	-0.34

<sup>a</sup>Identities of confirmed peaks shown in parentheses.

<sup>b</sup>RPO = roasted peanutty odor, DRO = dark roast odor, ROO = rancid/oxidized, CO = cardboardy odor, RPF = roasted peanutty flavor, RBP = raw bean/peanutty, WSH = woody/skins/hulls, CF = cardboardy flavor, DRF = dark roast flavor, ROF = rancid/oxidized flavor, and BIT = bitter taste. Means ( $P \leq 0.001$ ) marked with letter; otherwise  $P \leq 0.05$ .

sweet and woody aroma. It also was possible that ethanol possesses a bitter characteristic which also was the underlying taste in DRF. Similarly, pyridine may be responsible for the bitter-sweet underlying notes of roasted peanuts common among the attributes DRO, RPF, DRF, and BIT which correlated positively with it. As expected, the two pyrazine compounds 2-methylpyrazine and 2,5-dimethylpyrazine, which are characteristic of roasted peanutty flavor, correlated positively with DRO, DRF and RPF. Their absence in raw peanuts explains the negative correlation with RBP. The positive correlation of the two pyrazines with BIT may be due to its close association with the attributes DRF and DRO. Hexanal's positive correlation with RPF was not unexpected because it is a normal constituent of roasted peanuts. Its positive correlation with other sensory attributes normally associated with roasted peanuts, DRO, DRF, BIT, and WSH also was expected. DRF and WSH particularly are normally present in fresh, roasted full-fat peanuts but only in slightly above threshold levels (Johnsen *et al.*, 1986).

PV was negatively correlated with RPO, DRO, and WSH which were considered normal attributes of roasted peanuts. TBA had the same expected results with RPO, DRO, DRF, BIT, and WSH. In addition, it correlated positively with the rancidity-related attributes ROO, CO, CF, and ROF, indicating a secondary oxidation may have taken place in the samples during storage.

## Summary and Conclusions

Defatted (22% oil) roasted whole peanuts upon storage at 4, 25, and 63 C for 12 wk exhibited a higher Hunter L and b values and a lower Hunter a value than the full-fat (53% oil) samples. The a value, which indicated redness, also decreased during storage until week 9. Therefore, any product into which the defatted peanuts will be incorporated would have a naturally lighter color than if full-fat peanuts were used. Defatting also resulted in a less intense roasted peanutty character as indicated by lower RPF and RPO scores and pyrazine peak areas (Peaks 24 and 25). These sensory attributes also decreased during storage. The rancidity-related attributes ROO and CO of defatted samples were higher indicating a faster rate of rancidity than full-fat peanuts. ROO and another rancidity-related attribute (ROF) also increased during storage. PV and TBA values both indicated defatted peanuts to have less oxidative stability than full-fat peanuts. A higher moisture content in defatted peanuts may have contributed to its lower storage stability. TBA also correlated with rancidity-related attributes, indicating secondary oxidation in the samples during storage.

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