

Sensory and Physical Properties of Peanut Butter Treated with Palm Oil and Hydrogenated Vegetable Oil to Prevent Oil Separation

L.A. GILLS AND A.V.A. RESURRECCION

ABSTRACT: Sensory properties of peanut butters stabilized with 0%, 1.5%, 2.0%, and 2.5% palm oil (PO) and hydrogenated vegetable oil (HVO) and stored for 153 d at 0, 21, 30, and 45 °C were determined. Oxidized flavor in unstabilized peanut butter (UPB) and PO was compared with HVO to determine shelf-life. Shelf-life of UPB stored at 21, 30, and 45 °C was 75 d. Peanut butter with 2.5% palm oil had a shelf-life of 113 d. Regression analysis indicated a linear association for the attributes graininess, hardness, oiliness, mouthdryness, and spreadability with day, treatment, and temperature. No linear relationships existed between stickiness, adhesiveness, and gumminess and day, temperature, and levels of PO.

Key Words: peanut butter, palm oil, shelf-life, sensory properties

Introduction

PEANUT BUTTER IS A SEMIPERISHABLE food, not readily susceptible to spoilage because of its low moisture content. The shelf life of peanut butter depends on the quality of peanuts used, method of curing and storage of the raw kernels, and the methods used in manufacturing and storing of the peanut butter (Woodroof 1983). According to Woodroof and others (1945), oil separation is a concern in the stability of peanut butter because it usually indicates that the peanut butter may be rancid due to the exposure of the free oil to air and light. Many stabilizers for preventing oil separation have been developed (Lenth 1939; Wait 1949; Anonymous 1987). Lenth (1939) studied the incorporation of between 1.5% to 2.0% glycerin into peanut butter after grinding to prevent oil separation by forming an emulsion between the oil and solids in the peanut butter. However, the author did not state how long the peanut butter would avoid oil separation. A product composed of hydrogenated vegetable oil (HVO) and salt that stabilizes peanut butter by reducing oil separation was developed (Wait 1949). Also reported is a similar product made from HVO and monoglycerides derived from vegetable oils (Anonymous 1987). The recommended level of usage of the stabilizer is between 1.5% to 2.0% by weight, and it can be added into the grinder with other ingredients such as sugar and salt.

Hydrogenated peanut oil is the stabilizer usually favored by the U.S. peanut butter industry for the prevention of oil separation (Woodroof 1983). More recently, unhydrogenated palm oil was

studied as a stabilizer for peanut butter (Hinds and others 1994). The authors predicted that between 2.0% to 2.5% by weight of unhydrogenated, refined, bleached, and deodorized palm oil would prevent oil separation for more than a year at temperatures between 21 to 24 °C. However, a verification of their prediction was not included in the study. Their indicator of stability was a maximum of 0.5% oil separation after 2 wk of storage at 30 to 35 °C. Their criteria used to establish stability was based on: (1) the U.S. Department of Agriculture (USDA) product specifications of a maximum of 0.5 mL free oil/jar of freshly manufactured peanut butter stored for 24 h at 30 °C, and (2) observations of commercial peanut butter, which should have remained stable for 1 y at 21 to 24 °C, that showed 1% oil separation after 2 weeks of storage at 35 °C (Hinds and others 1994).

Expected shelf-life of a product is influenced by the environmental conditions under which the product will be stored and the amount of the initial quality that can be lost before the product can no longer be purchased by consumers (Labuza and Schmidl 1985). To determine shelf-life of a product, without waiting months or years, accelerated self life testing is used. In accelerated shelf-life testing, the product is held under abuse conditions, including high temperatures or humidities to speed up the rate of quality loss (Labuza and Schmidl 1988). The most often used acceleration method is a combination of a higher humidity and temperature than the food would normally be subjected to (Labuza 1982).

The objective of this study was to determine sensory characteristics and oil separation of peanut butter stabilized with palm oil and hydrogenated vegetable oil to prevent oil separation, and increase stability to oxidized flavors, during storage at ambient and accelerated temperatures.

Results and Discussion

Oil separation

None of the peanut butters had oil separation after 24 h storage at ambient temperature (Fig. 1). USDA product regulations for peanut butter specify a maximum of 0.5 mL free oil of freshly manufactured product after 24 h storage at 30 °C (Hinds and others 1994). Oil separation did not occur at any time during storage of peanut butters stored at 0 °C regardless of amount of stabilizer added. Similarly, hydrogenated vegetable oil (HVO, control) did not exhibit any oil separation during storage for 153 d at any of the temperatures studied. These results agreed with those of Woodroof (1983), who conducted tests on peanut butter at different storage temperatures for one year and found no oil separation in peanut butter stored at 10 °C or lower irrespective of storage period. However, Woodroof (1983) did not mention if peanut butters were stabilized or not. Regardless of the amount of palm oil added, from 0% to 2.5%, less oil separation was found in peanut butters stored at 21 °C compared to peanut butter stored at the higher temperatures of 30 and 45 °C over time. There were no differences between oil separated in peanut butters stored at

30 and 45 °C. The amount of oil separated in unstabilized peanut butter (UPB, Fig. 1a) stored at 21 °C increased until the end of the storage study. UPB stored at 30 and 45 °C increased over time from 0 to 113 d and did not change thereafter for up to 153 d. The amount of oil separated in peanut butter stored at 21 °C for 153 d increased to between 14.3% to 14.8%, regardless of amount of palm oil added, from 0% to 2.5%. The amount of oil separated in peanut butter stored at 30 and 45 °C increased from day 0 to 113 then remained constant for up to 153 d, regardless of amount of stabilizer added.

Parameter estimates and intercepts used to predict oil separation, shown in Table 3, had a R^2 value of 0.95, indicating

a good linear fit. Treatment did not have a role in the prediction of oil separation, only the factors of day and temperature did. As the number of days and temperature increased, so did the amount of oil separated from the peanut butters. As expected, temperature had a greater influence on the amount of oil separated, compared to time of storage.

The amount of oil separated for a given day and temperature can be predicted from the reduced regression equation (Table 3) as follows:

$$Y = -3.9600 + 0.1000x_1 + 0.4300x_2 - 0.0005x_1^2 - 0.0071x_2^2 + 0.0022x_1x_2$$

where Y is the percent oil separated; x_1 is

the number of days of storage; x_2 is the storage temperature; x_1^2 and x_2^2 are their squared terms; and x_1x_2 is their cross product.

Oil separation in peanut butter is due to the differences in specific gravity of solid particles and oil comprising the product, which results in the gravitational separation of these 2 components (Freeman and Singleton 1952).

Sensory properties

Among the 11 variables used to develop prediction models, raw, stickiness, adhesiveness, and gumminess had a coefficient of determination, R^2 , of less than 0.50. These were not considered among the variables for which reduced models were developed. Reduced models were developed for the attributes, oxidized, graininess, hardness, oiliness, mouthdryness, and spreadability. All of these equations (Table 3) had $p < 0.0001$.

Oxidized flavor. The intensities of oxidized flavor from 0 to 153 d at 0, 21, 30, and 45 °C are shown in Fig. 2. No differences were found between PO1.5, PO2.0, and PO2.5 and UPB. Therefore, among the peanut butter samples stabilized with palm oil, only the results for oxidized flavor in PO2.5 (Fig. 2b) are presented. The regression equation for oxidized flavor is shown in Table 3. The coefficient of determination, R^2 , was low thereby indicating that no linear relation existed between the oxidized flavor intensity and the factors, day, and temperature. All samples appeared to decrease slightly in oxidized flavor intensity from 24 through 27 to 20 through 24 on day zero to day 20 followed by an increase from day 20 to 75 for all storage temperatures except 0 °C in PO2.5. After day 75, UPB stored at 30 and 45 °C remained constant for up to 113 d, then decreased. Peanut butter stabilized with HVO (Fig. 2c) decreased in oxidized flavor intensity after 75 d storage except for samples stored at 21 °C. Autoxidation proceeds in peanut butter rapidly for about 3 mo or until available oxygen is depleted, then the rate of autoxidation remains almost constant for more than 2 y (Freeman and others 1954). For this reason, a cut-off point equivalent to the highest intensity rating, 34.8, for oxidized flavor in HVO was used to determine oxidized samples. The intensity of oxidized flavor in HVO did not exceed 34.8 at the end of 153 d (5 mo) storage. UPB (Fig. 2a), stored at 21, 30, and 45 °C at day 75 and 30 and 45 °C at 113 d, had oxidized flavor intensities above 34.8. Oil separated in UPB and as a result became oxidized more readily than in stabilized peanut butters. Therefore, oxidized flavor is an important indicator

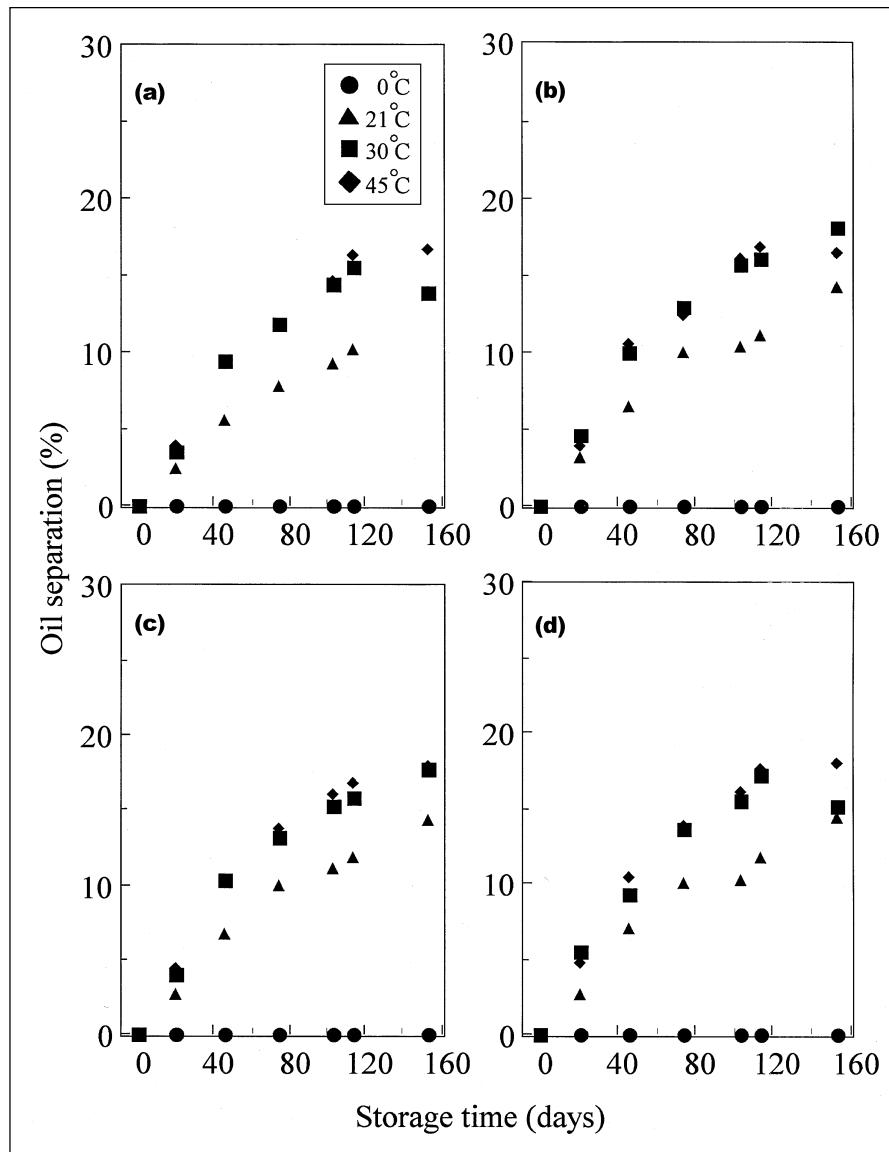


Fig. 1—Means for oil separation (%) of unstabilized peanut butter (a) and peanut butter stabilized with palm oil 1.5% (b), 2.0% (c) and 2.5% (d), and stored for 153 d at 0, 21, 30 and 45 °C. Each point represents a mean of 2 replications. At time zero, symbols overlap at the starting point for all storage temperatures.

attribute in peanut butter and ultimately determines shelf-life. PO2.5 at 113 d had oxidized flavor intensities above 34.8, 39 d after it developed in the UPB. This suggested that PO2.5 had a protective effect against oxidized flavor. Freeman and others (1954) found no decrease in stability of oil in freshly prepared peanut butter when stored for as long as 2 y.

Graininess. The intensities of graininess from 0 to 153 d at 0, 21, 30, and 45 °C are shown in Fig. 3. After day zero, there was a decrease in graininess for all treatments of peanut butter. Graininess in peanut butters then leveled off at 100 d. Parameter estimates and intercept for the prediction model of graininess are shown in Table 3. Only the factor, day, was significant in the determination of graininess. The coefficient of determination, R^2 , was 0.79. Graininess decreased as the number of days of storage increased. Graininess was defined by the panelists as the amount of particles or granules present or perceived in the sample. Graininess in peanut butter is not only due to the fineness of the grind but may also be due to the salt and sugar added. The moisture content of peanut butter is usually between 0.5% to 2.0% (Woodroof 1983). Therefore, the available moisture is insufficient to maintain the salt and sugar in solution. As a result, peanut butter manufacturers have used pulverized salt but found that the graininess still remains. Therefore, manufacturers have recognized that salt creates a minor degree of graininess, and they no longer persist in using an expensive pulverized salt (Woodroof 1983). Initially, there is enough moisture to dissolve the salt and sugar resulting in a slight decrease in graininess in peanut butter.

Hardness. The parameter estimates and intercept of hardness are shown in Table 3. The coefficient of determination, R^2 , for hardness was 0.67, indicating that a linear relation existed between hardness and the factors of day, temperature, and increasing levels of palm oil. As day, temperature, and treatment increased, hardness decreased. The hardness of the peanut butter samples is shown in Table 4. No differences were found in PO1.5, PO2.0, and PO2.5; therefore, only the results of UPB, PO2.5, and HVO are shown. After day 20, the hardness in UPB and PO2.5 decreased until day 113. HVO remained constant until day 45 and decreased after 74 days storage. After day 153, all peanut butters increased in hardness. HVO ranged in hardness from 15 to 30, whereas UPB and PO2.5 ranged from 7 to 23 in hardness. The panelists used cream cheese as a reference for hardness. The intensity of hardness of the cream

Table 1—Terms used in the descriptive analysis of peanut butter and their definitions

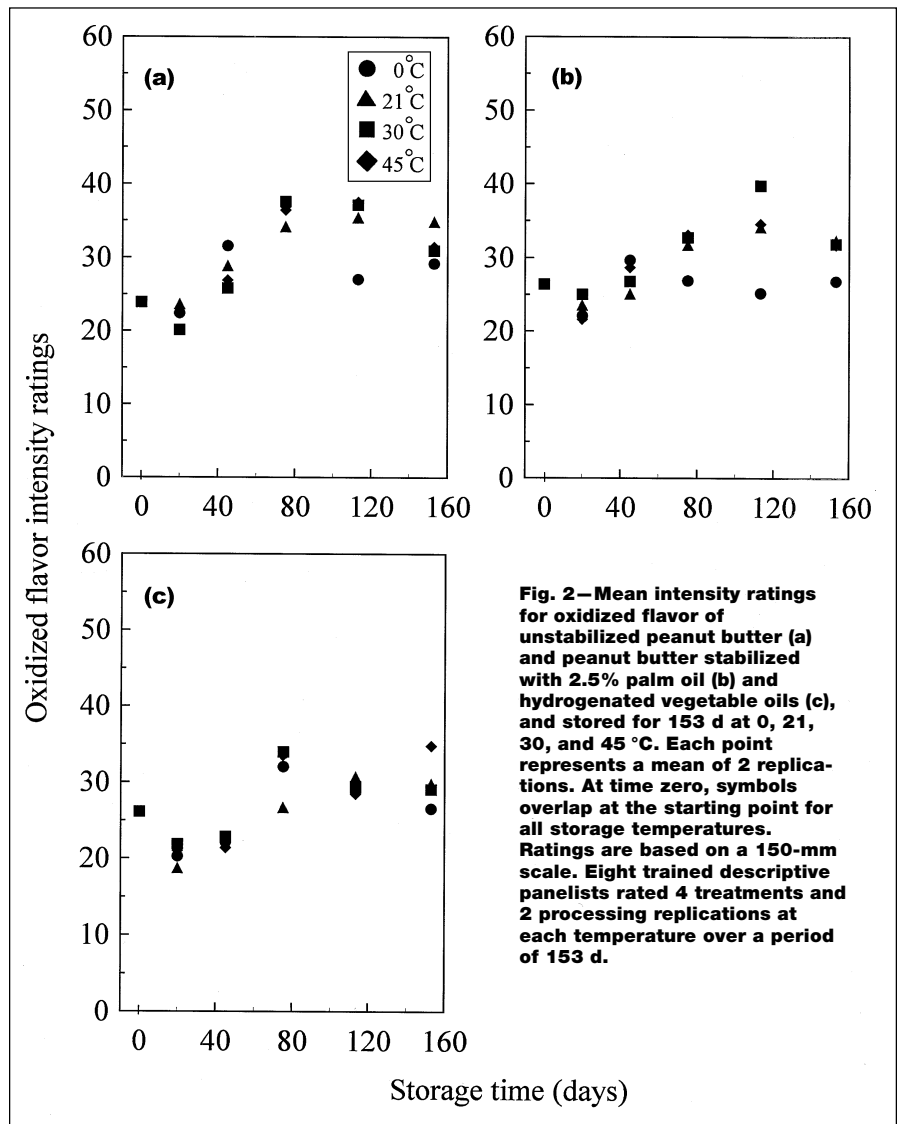
Attribute ^a	Definition
Appearance	
Brown color	The intensity or strength of brown color from light to dark brown
Aromatics	
Raw ^c	The aromatic associated with raw peanuts
Roasted peanutty ^b	The aromatic associated with medium-roasted peanuts
Oxidized ^c	The aroma associated with stale peanuts
Tastes	
Sweet	The taste associated with sucrose solutions
Bitter	The taste associated with caffeine solutions
Salty ^d	Degree of the taste sensation associated with sodium chloride solutions
Texture	
<i>Prior to mastication</i>	
Stickiness	The degree to which sample adheres to lips
Graininess ^c	The amount of particles or granules present or perceived in sample
<i>First bite</i>	
Hardness	The force required to compress the sample between the tongue and palate
<i>Masticatory</i>	
Adhesiveness ^c	The force required to remove the sample from the palate
Gumminess ^c	Energy required to disintegrate the sample to a state ready for swallowing
<i>Residual</i>	
Oiliness	Amount of oil perceived in mouth after the sample is expectorated
Mouthcoating	Amount of residual peanut butter perceived in mouth after sample is expectorated
Mouthdryness	Drying sensation on palate
Spreadability	Ease of spread of sample on a cracker

^aAttribute listed in order perceived by panelists.

^bJohnsen et al. (1988).

^cMuego and Resurreccion (1992).

^dResurreccion (1988).



cheese was 20. In most cases, UPB was always lower in hardness than the cream cheese, whereas HVO was always harder than the cream cheese.

Oiliness. The intensity of oiliness over 153 d and stored at 0, 21, 30, and 45 °C is shown in Fig. 4. No differences were found in the oiliness of peanut butters stabilized with palm oil. Therefore, only the results of UPB, PO2.5, and HVO are shown. Initially, there was no difference in the oiliness of UPB, PO2.5, and HVO. From day 20 to 74, UPB (Fig. 4a) and PO2.5 (Fig. 4b) increased in oiliness. HVO (Fig. 4c) decreased in oiliness after day 20 and remained constant in oiliness until day 45. Panelists were not able to detect differences in oiliness as the standard deviations were high at day 20. After day 74, oiliness in HVO held at 0, 30, and 45 °C increased. However, this increase may not have been a true increase, as the standard deviations were higher for HVO held at 0, 30, and 45 °C than for those peanut butters held at 21 °C. This suggests that there may have been variations in the samples stored at those temperatures. After 113 days, UPB and HVO remained constant in oiliness, and PO2.5 increased in oiliness. PO2.5 was higher in oiliness than UPB due to the addition of PO2.5. PO2.5 did not effectively stabilize the peanut butter. After day 153, oiliness remained constant in UPB, PO2.5, and HVO. The panelists used a cheese sauce and mayonnaise as references for oiliness, with intensities of 20 and 50, respectively. Although panelists rated all peanut butters oilier than the cheese sauce, they did not perceive that the peanut butter was as oily as the mayonnaise at any point during the storage study regardless of temperature.

Amount of oil separation increased in UPB with storage time to a maximum of 15%. Likewise, perceived intensity increased with storage time also. Surprisingly, at the highest perceived intensity of oiliness, 45, the amount of oil separated was only 12% in UPB. When the amount of oil separation increased to a maximum of 15%, the perceived oiliness remained at 45. The amount of oil separation in PO2.5 increased with storage time to a maximum of 17%, perceived intensity of oiliness also increased with storage time. At the highest perceived intensity of oiliness, 53, the amount of oil separated was 16%. As oil separation increased to a maximum of 17%, the perceived oiliness remained the same. The perception of oiliness was the same in UPB and PO2.5 up to 12% oil separated. After 12% oil separation, the perceived oiliness remained the same in UPB, but continued to increase in PO2.5. Panelists could no

Table 2—Standard references and intensities used in descriptive analysis of peanut butter

Attribute	Reference	Intensity ^a (mm)
Brown color	Cardboard	65
Raw	Raw, medium Florunner peanuts ^b	85
Roasted peanutty	Roasted peanuts ^b	65
Oxidized	Shortening ^c (Hunt-Wesson Inc., Fullerton, Calif.)	60
Sweet	2.0% sucrose in double deionized water	20
	5.0% sucrose in double deionized water	50
	10.0% sucrose in double deionized water	100
Bitter	(ICN Biomedicals Inc., Cleveland, Ohio)	
	0.05% caffeine in double deionized water	20
Salty	0.08% caffeine in double deionized water	50
	(Fisher Scientific, Fair Lawn, N.J.)	
Stickiness	0.2% sodium chloride in double deionized water	25
	0.35% sodium chloride in double deionized water	50
Graininess	(Fisher Scientific, Fair Lawn, N.J.)	
	Cheese sauce, cheddar flavor	20
Hardness	(Kroger Co., Cincinnati, Ohio)	
	Cream of wheat	120
Adhesiveness	(Nabisco Inc., East Hanover, N.J.)	
	Philadelphia cream cheese ^d	20
Gumminess	(Kraft Foods, Inc., Glenview, Ill.)	
	Philadelphia cream cheese ^e	45
Oiliness	(Kraft Foods, Inc., Glenview, Ill.)	
	Jif peanut butter	45
Mouthcoating	(Procter & Gamble, Cincinnati, Ohio)	
	Cheese sauce, cheddar flavor	20
Mouthdryness	(Kroger Co., Cincinnati, Ohio)	
	Mayonnaise	50
Spreadability	(Kraft Foods, Inc., Glenview, Ill.)	
	Phillips' milk of magnesia	65
Spreadability	(Bayer Corporation, Morristown, N.J.)	
	Phillips' milk of magnesia	55
Spreadability	(Bayer Corporation, Morristown, N.J.)	
	Philadelphia cream cheese	95
Spreadability	(Kraft Foods, Inc., Glenview, Ill.)	
	Mayonnaise	145
Spreadability	(Kraft Foods, Inc., Glenview, Ill.)	

^aRated on a 150-mm unstructured line scale with anchors at 12.5 mm and 137.5 mm.

^bMuego and Resurreccion (1992).

^cStored for 2 y and 9 mo at 5 °C and 1 y and 2 mo at 23 °C

^dMeilgaard et al. (1991).

^eSzczesniak et al. (1963).

longer detect the oiliness in the UPB as oil separation continued to increase.

Regression analysis (Table 3) indicated that treatment did not have an effect on the oiliness of the peanut butter samples. The coefficient of determination, R^2 , was 0.61, indicating a linear association of oiliness with day and temperature. As the storage time and temperature increased, so did the oiliness of the peanut butter.

Mouthdryness. There was not much of a change in mouthdryness, regardless of time, temperature, or treatment, therefore the results are not shown. The intensity of mouthdryness remained around 40, regardless of day, temperature, or treatment. Mouthdryness was defined by the panelists as the drying sensation on the palate after the sample was expectorated. Although the panel thought it was necessary to include mouthdryness as an attribute, it has never been used to describe the texture of peanut butter. As indicated by regression analysis (Table 3), only the factor, treatment, had a significant effect on the perceived intensity of mouthdryness. As the amount of palm oil added to the peanut butter increased, the intensity of mouthdryness decreased.

The coefficient of determination, $R^2 = 0.50$, was low, indicating that no linear relationships existed.

Spreadability. Spreadability of peanut butter is shown in Fig. 5. There were no differences in spreadability of the peanut butter stabilized with palm oil, and, therefore, only the results of UPB, PO2.5, and HVO are shown. Initially, UPB (Fig. 5a) appeared to be less spreadable than PO2.5 (Fig. 5b) and HVO (Fig. 5c). However, there was no significant difference between the treatments in spreadability on day 0. All peanut butters appeared to remain constant in spreadability throughout the 153-d storage, except at day 74 when HVO increased in spreadability. This increase was due to variability among panelists, as the standard deviations were high. HVO ranged in spreadability from 85 to 120, whereas UPB and PO2.5 ranged in spreadability from 110 to 135. Cream cheese and mayonnaise were used as standard references for the attribute spreadability. In general, panelists believe that all treatments of peanut butters were less spreadable than mayonnaise. However, only UPB and HVO were more spreadable than cream cheese. Peanut butter stabilized with HVO was simi-

lar in hardness to cream cheese.

Spreadability of peanut butter was best explained by all 3 factors, day, temperature, and treatment (Table 3). The coefficient of determination, R^2 , was 0.58, indicating lack of good linear fit of the data. Other textural attributes including stickiness, adhesiveness, and gumminess ratings did not change very much throughout the storage study and, therefore, were not discussed. Their coefficients of determination (R^2) were less than 0.50.

Conclusions

STABILIZATION OF PEANUT BUTTER WITH different levels of palm oil did not have an effect in the prediction of shelf-life from oil separation. Palm oil could not effectively stabilize peanut butter for 1 y at ambient temperature. The amount of oil separation increased over time in peanut butter regardless of level of palm oil added, whereas HVO showed no oil separation during the entire study. Oxidized flavor, used as an indicator of shelf-life, was prevalent in UPB at 74 d of storage and was evident in PO2.5 after another 39 d (113 d of storage), indicating that palm oil may suppress the oxidized flavor in peanut butter.

Methods and Materials

Experimental design

Peanut butters were prepared using four levels by weight of palm oil (PO) as a stabilizer. A peanut butter using 1.5% hydrogenated vegetable oil (Fix-X, Procter & Gamble, Cincinnati, Ohio, U.S.A.) was used as a control (HVO). Treatments included peanut butter stabilized with 1.5%, 2.0%, and 2.5% palm oil (PO1.5, PO2.0, and PO2.5, respectively), HVO and peanut butter with no stabilizer (UPB) added. Five samples, including the control, were prepared in 2 processing replications and stored at 4 storage temperatures (0, 21, 30, and 45 °C). Samples at 0, 20, 45, 74, 113, and 153 d from processing of the peanut butter were obtained and analyzed.

Sample preparation

Shelled runner type medium peanut kernels were purchased (1997 crop, McCleskey Mills, Smithville, Ga., U.S.A.) and stored at 7 °C until the time of processing. Peanuts were roasted in 22 kg batches in a gas roaster (Model L5, Probat Inc., Memphis, Tenn., U.S.A.), preheated at

Table 3—Parameter estimates and intercepts used in prediction models of descriptive attributes

Variables	Parameter estimates						
	Oil separation	Oxidized	Graininess	Hardness	Oiliness	Mouth-dryness	Spreadability
Intercept	-3.9600	21.7400	33.5000	23.1500	30.0670	43.6200	111.8600
Day	0.1000	0.1600	-0.2700	-0.1900	0.1300	-0.0370	0.1600
Temperature	0.4300	0.0530	—	-0.0650	0.2400	-0.0900	0.3300
Treatment	—	—	—	-1.1400	—	-2.4400	2.3700
Day*day	-0.0005	-0.00	0.00	0.00	-0.00	—	-0.00
Temperature*temperature	-0.0071	—	—	—	-0.00	0.00	-0.0100
Treatment*treatment	—	—	—	—	—	0.4500	—
Day*temperature	0.0022	—	—	—	0.00	—	0.00
Day*treatment	—	—	—	0.0100	—	-0.00	-0.0180
Temperature*treatment	—	—	—	—	—	0.0100	—
Day*temperature*treatment	—	—	—	—	—	—	—
R^2	0.95	0.54	0.79	0.67	0.61	0.50	0.58

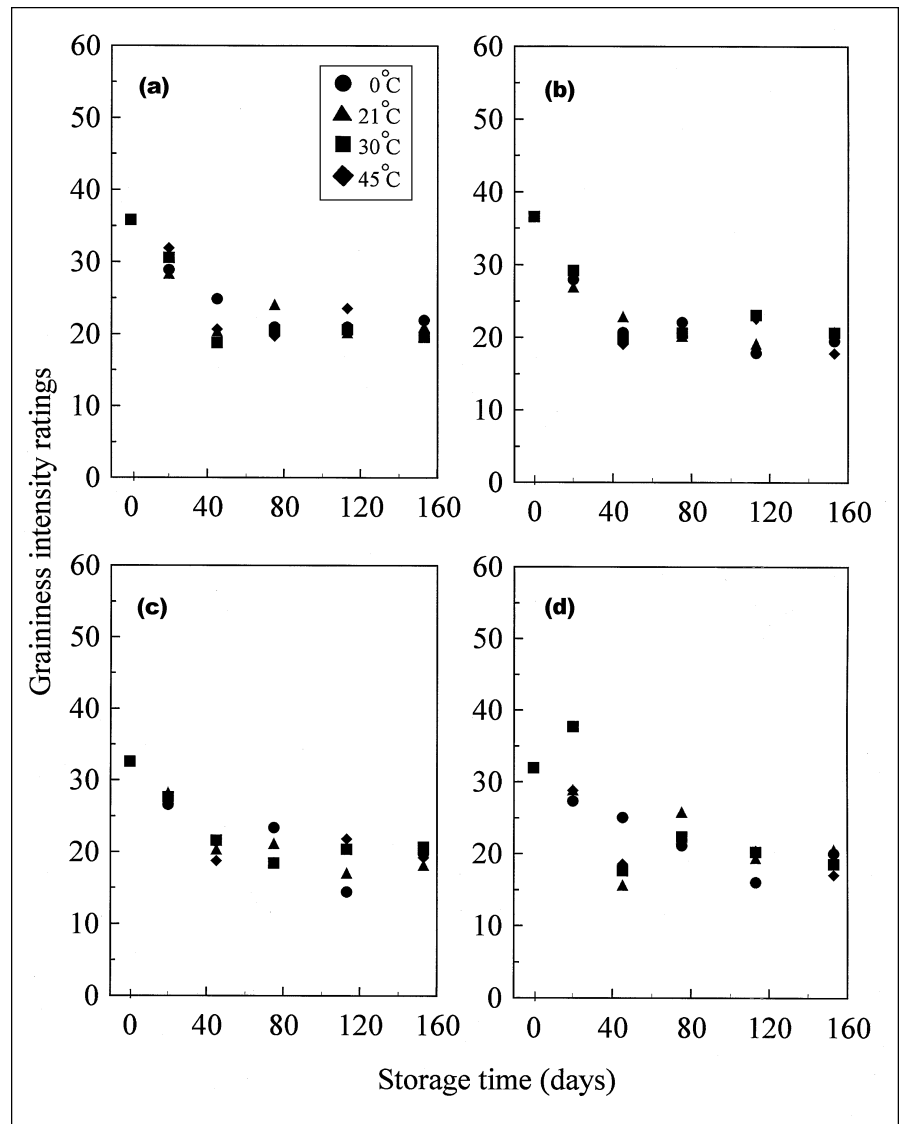


Fig. 3—Mean intensity ratings for graininess of unstabilized peanut butter (a) and peanut butter stabilized with palm oil 1.5% (b), 2.0% (c), and 2.5% (d), and stored for 153 d at 0, 21, 30 and 45 °C. Each point represents a mean of 2 replications. At time zero, symbols overlap at the starting point for all storage temperatures. Ratings are based on a 150-mm scale. Eight trained descriptive panelists rated 4 treatments and 2 processing replications at each temperature over a period of 153 d.

177 °C, and maintained at 138 °C for 10 min. Samples were collected from the roaster every 5 min, and the color lightness, L, value was measured until an L = 49.2, for a medium roast (Johnsen and others 1988), was attained. Peanuts were then cooled for 5 min in a perforated cooling tray (65 cm inside dia × 12 cm deep), then passed through a dry blancher (Model EX, Ashton Food Machinery Co. Inc., Newark, N.J., U.S.A.) to remove testa. Peanuts were visually inspected for damaged kernels, which were separated and removed. Kernels with any remaining testa were passed through the blancher an additional time. Blanched peanuts (40-kg batches) were then weighed (Toledo Scale Co., Toledo, Ohio, U.S.A.) and ground through a colloid mill (Morehouse Industries, Los Angeles, Calif., U.S.A.), set at a stone clearance of 0.25 mm (10 notches), and maintained at 77 °C with steam. The following ingredients, added by weight, were manually mixed into peanut butter and passed through the colloid mill an additional time: 1% salt (Astor Plain Salt, Jacksonville, Fla., U.S.A.); 6% corn syrup solids (Star-Dri® 42R, A.E. Staley Manufacturing, Decatur, Ill., U.S.A.); and stabilizer consisting of 0%, 1.5%, 2.0%, or 2.5% PO (Palm Oil Research Institute of Malaysia, Kuala Lumpur, Malaysia) or 1.5% HVO (Fix-X, Procter & Gamble, Cincinnati, Ohio, U.S.A.). Approximately 222 g cooled peanut butter was filled into glass jelly jars (Ball Corporation, Muncie, Ind., U.S.A.), except for one jar from each treatment and replication which was filled with exactly 210 g peanut butter for determination of amount of oil separated. Jars were placed at various temperatures (0, 21, 30 or 45 °C) after 24 h storage at ambient temperature.

Oil separation

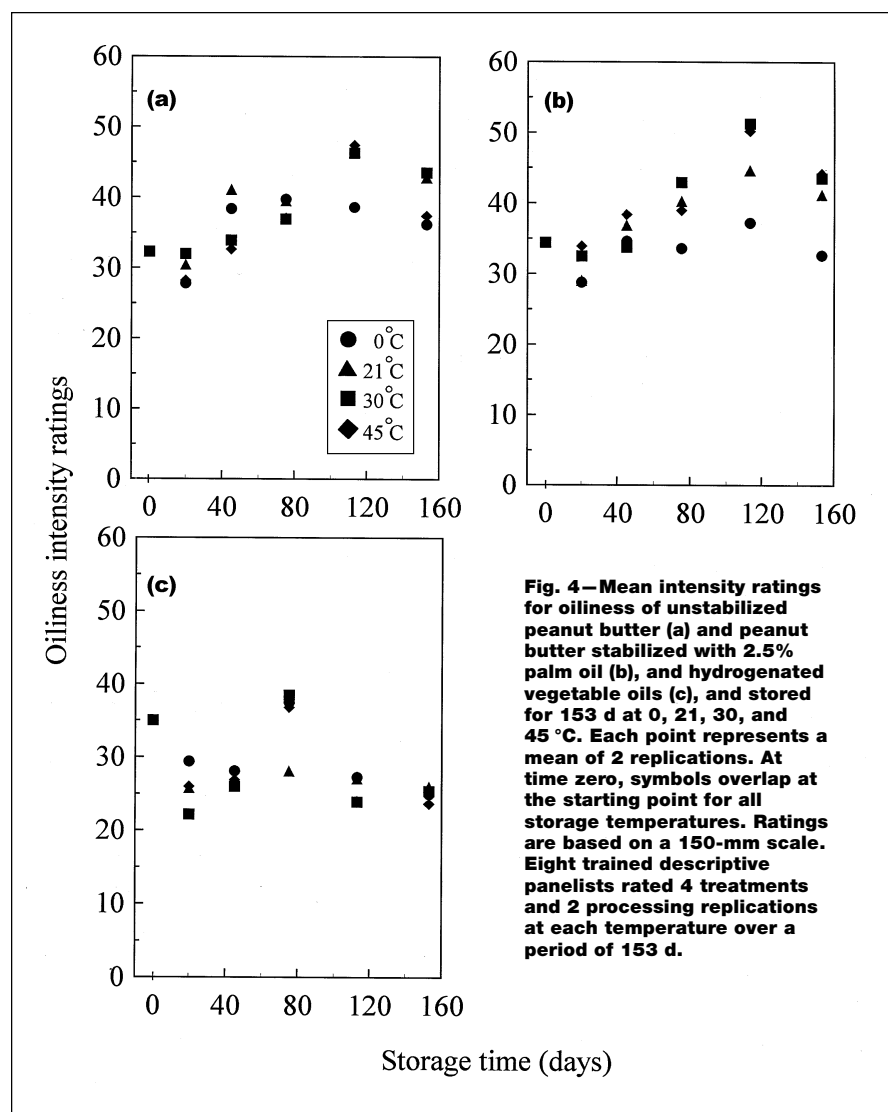
Peanut butter samples were observed daily for oil separation, but measurements were made the day before each sensory test. Oil was collected using a Pasteur pipette, transferred to a 50 mL graduated cylinder and measured. Oil separated was calculated as follows:

$$\text{Oil separation (\%)} = (\text{Volume of oil separated}) / (\text{Volume of peanut butter before oil separated}) \times 100$$

Table 4. Mean intensity ratings^a for hardness of unstabilized peanut butter (UPB), peanut butter stabilized with 2.5% palm oil (PO2.5), and hydrogenated vegetable oil (HVO), and stored for 153 d at 0, 21, 30, and 45 °C

Storage temperature (°C)	Storage time (day)	UPB	PO2.5	HVO
0	0	22.8	17.2	21.2
0	20	19.0	13.9	22.7
	45	12.8	12.7	21.3
	75	13.8	13.4	15.9
	113	14.9	13.4	21.3
	153	15.9	16.4	23.8
21	20	15.7	14.8	22.6
	45	15.0	12.4	20.2
	75	12.5	11.9	22.5
	113	8.9	10.7	20.0
	153	12.6	13.0	28.7
30	20	14.3	14.0	25.2
	45	10.8	9.5	17.2
	75	8.3	16.5	17.1
	113	9.4	9.3	21.6
	153	12.3	13.5	27.9
40	20	16.0	12.2	23.3
	45	11.4	10.2	16.6
	75	16.9	11.3	18.1
	113	10.5	8.8	26.5
	153	14.7	12.7	27.6

^a Intensity ratings are based on a 1502-mm line scale with anchors at 12.5 mm and 137.5 mm.



Oil was then mixed into the peanut butter manually with a spoon 30 times before preparation for sensory panel to insure that each panelist obtained a good representation of the peanut butter and consumed a sample handled similarly to one used by consumers. The HVO sample was not stirred as it did not exhibit oil separation.

Sensory methods

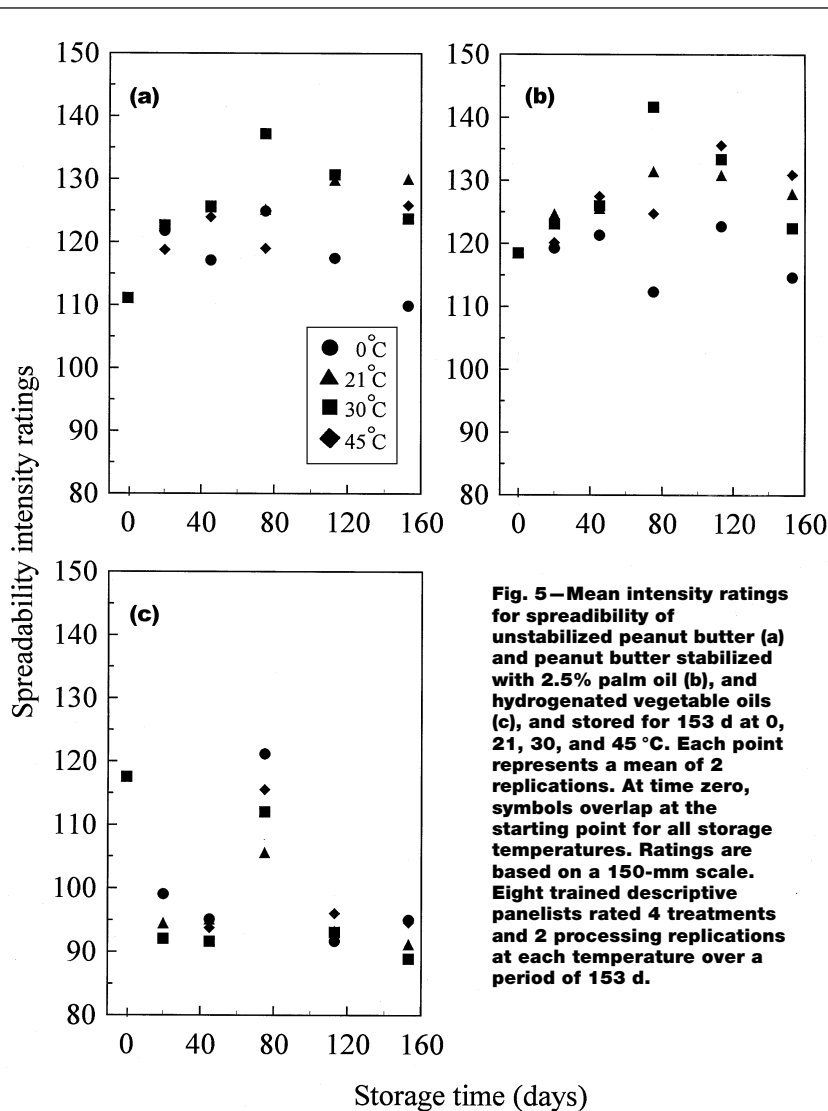
A hybrid (Einstein 1991) of the Spectrum, Quantitative Descriptive Analysis (QDA) and Texture Profile Analysis techniques were used. Panelists evaluated 10 samples, in each of 4 test sessions in one day.

Panel. Prospective members of the descriptive panel were recruited from a pool of previously trained and untrained consumers, who had participated in sensory tests at the Center

for Food Safety and Quality Enhancement as well as students from the center. Screening was conducted to insure that panelists had no dentures (Civille and Szczesniak 1973) or food allergies, did not smoke, were available for all sessions (ASTM 1981) and ate peanut butter at least once a month. To qualify potential panelists were screened on their ability to rank 4 food items from a hardness scale (Meilgaard and others 1991) in order of hardness. The items included frankfurters (Hebrew National Kosher Foods, Bronx, N.Y., U.S.A.), peanuts (Planters, Nabisco Foods Inc., Winston-Salem, N.C., U.S.A.), almonds (Blue Diamond, Sacramento, Calif., U.S.A.) and hard candy (LifeSavers, Nabisco Foods Inc., Winston-Salem, N.C., U.S.A.). Eight panelists were recruited (Civille and Szczesniak 1973), 7 females and one male, all between the ages of 18 and 64. The

panelists indicated they ate peanut butter, on average, twice a month. Panelists were required to complete and sign a consent form approved by the University of Georgia Institutional Review Board that oversees the use of human subjects in research.

Training. Each panelist was trained for a total of 10 h. There were 5 training sessions for 2 h each day. During the first day of training, panelists were given an overview of sensory evaluation and an introduction to the use of the computers to be used for data collection. On the second day, panelists developed and defined textural descriptive terms (Table 1) that they felt described two samples of peanut butter, a commercial sample of peanut butter (Jif, Procter & Gamble, Cincinnati, Ohio, U.S.A.) and freshly prepared UPB, purchased at a local farmers market (DeKalb, Ga., U.S.A.). In addition, panelists were given a list of color, flavor, and texture terms and definitions (Table 1) from published papers containing descriptors of peanuts (Johnsen and others 1988), peanut butter (Resurreccion 1988) and peanut paste (Muego and Resurreccion 1992). To minimize training time, the papers were presented to panelists to provide a list of attributes, previously used to describe the attributes of peanut butter. Panelists then decided on a final list of flavor and texture terms that was comprehensive with definitions understood by all panelists. Panelists did not necessarily define an attribute as indicated in an existing literature. During the second day, panelists also determined references (Table 2) that would best help them to explain the descriptive terms developed. Each panelist rated the attribute intensity of each reference by first evaluating the reference for a particular attribute and then giving it an intensity rating between 0 and 150 using flashcards. Calibration of the panel was conducted by first obtaining an average rating and those panelists not rating within 10 points of the average were asked to re-evaluate the sample and adjust their rating until consensus was reached. Consensus scores were obtained on a sample of peanut butter (Jif, Procter & Gamble, Ohio, U.S.A.), used as a warm-up sample and presented to each panelist as the initial sample during training and testing sessions (Plemmons and Resurreccion 1998). During the remaining 3 days of training, panelists practiced evaluating samples of peanut butter using a computerized ballot (Compusense, Version 2.4, Compusense Inc., Guelph, Ontario, Canada), with 16



attributes listed vertically in their order of appearance. Using a light pen, panelists pointed at each attribute on a 150-mm unstructured line scale, with anchors at 12.5 and 137.5 mm that appeared on the computer video display with a heading consisting of that particular attribute and definition. Panelists made a vertical mark on the line scale indicating the intensity of that attribute. The numerical rating for that attribute would then appear next to it indicating that the attribute had been rated and panelists could proceed to rate the next attribute. All attributes of one sample were rated for intensity before a panelist could proceed to the next sample.

Individual panelist's ratings were analyzed after each session. These and mean ratings and standard deviations from the entire panel were distributed to each panelist before the next session. Panelist ratings within 10 points of the mean were considered to be calibrated (Meilgaard and others 1991). The panel as a whole was considered to be calibrated if the group's standard deviations were within 10 points from the mean attribute rating. Panelists continually evaluated and calibrated themselves on the warm-up sample (Jif, Proctor & Gamble, Cincinnati, Ohio, U.S.A.) during the remaining 3 d of training.

Test procedures

All tests were performed at the Center for Food Safety and Quality Enhancement, University of Georgia in Griffin, Ga. Samples were evaluated in environmentally controlled partitioned booths illuminated with two 50-watt indoor reflector flood lamps, which provided 33 watts/square meter of light at

the surface of the peanut butter.

Sample presentation. On the test day, 20 g peanut butter was placed into 28.57-g capacity plastic cups with lids, coded with a three digit random number, 1 h before tests. Samples were served at ambient temperature (25 °C). Ten samples representing replicates of 5 treatments stored at one of 4 temperatures were evaluated by each panelist at each session in 4 test sessions in 1 d. A total of 40 samples included 2 processing replications of each of the 5 treatments stored at each of the 4 storage temperatures. Panelists were instructed to use one teaspoon of sample when evaluating flavor attributes and one teaspoon when evaluating each of the stages of textural evaluation — prior to mastication, first bite, masticatory, and residual (Civille and Szczesniak 1973) — for a total of 4 teaspoons. Panelists were also instructed to expectorate and rinse with water after each sample. Crackers were also provided to use in rating the intensity of spreadability. Panelists used a computer ballot, light pen, and the scales used during the training sessions. A scoresheet identifying panelists' consensus scores for the attribute intensity (Table 2) was posted in each booth. A 15-min compulsory break requiring panelists to leave the booth area and rest in the training room was taken between sessions to minimize fatigue.

Statistical analysis

Statistical software (SAS Institute Inc. 1987) was used to analyze all data results. Analysis of Variance (PROC GLM) was used to determine significant effects of treatment, replication, storage time, and temperature on all attributes

(Table 1). Significant effects were found for the attributes, oxidized, graininess, stickiness, oiliness, gumminess, adhesiveness, mouthdryness, and spreadability. The coefficient of determination, R^2 , was determined using regression (PROC RSQUARE) analysis. Prediction models for these attributes were determined. Reduced models with a coefficient of determination, R^2 , greater than or equal to 0.50, with the least number of terms and showing no significant difference between it and its full model ($\alpha = 0.05$) were used in prediction equations. The partial F-statistic was used to determine significance and was calculated as follows:

$$F = [(SSE_{(\text{reduced})} - SSE_{(\text{full})}) / (df_{(\text{reduced})} - df_{(\text{full})})] / MSE_{(\text{full})}$$

where SSE is the sum of squares of error, MSE is the mean square error and df is the degrees of freedom. A second order polynomial regression model with 3 linear terms was used as the full model. Terms in the full model included all linear terms; day, temperature, and treatment; their squared terms; and all possible cross products as follows:

$$Y = \beta_0 + \beta_1x_1 + \beta_2x_2 + \beta_3x_3 + \beta_{11}x_1^2 + \beta_{22}x_2^2 + \beta_{33}x_3^2 + \beta_{12}x_1x_2 + \beta_{13}x_1x_3 + \beta_{23}x_2x_3 + \beta_{123}x_1x_2x_3 + \epsilon$$

where Y is the response variable; β_0 is the intercept when x_1 , x_2 and x_3 equal 0; β_1 , β_2 and β_3 are parameter estimates of x_1 , x_2 and x_3 , which are day, temperature, and treatment or level of PO, respectively, and x_1^2 , x_2^2 and x_3^2 are their squared terms; and x_1x_2 , x_1x_3 , x_2x_3 are the cross product terms.

References

- Anonymous. 1987. Peanut butter requires versatile stabilizer. *Food Eng.* 59:68.
- ASTM. 1981. Guidelines for the selection and training of sensory panel members. Philadelphia, Pa.: American Society for Testing and Materials. ASTM Special Technical Publication 758. p 3-32.
- Civille GV, Szczesniak AS. 1973. Guidelines to training a texture profile panel. *J. Texture Stud.* 4:204-223.
- Einstein MA. 1991. Descriptive techniques and their hybridization. In: Lawless HT and Klein BP, editors. *Sensory Science Theory and Applications in Foods*. New York: Marcel Dekker Inc. p 317-338.
- Freeman AF, Morris NJ, Willich RK. 1954. Peanut butter. USDA Southern Regional Research Laboratory, New Orleans, LA. p 1-61.
- Freeman AF, Singleton WS. 1952. Prevention of oil separation in peanut butter—A review. *Peanut Journal and Nut World.* 31(4):23, 30, 45-46.
- Hinds MJ, Chinnan MS, Beuchat LR. 1994. Unhydrogenated palm oil as a stabilizer for peanut butter. *J. Food Sci.* 59:816-820, 832.
- Johnsen PB, Civille GV, Vercellotti JR, Sanders TH, Dus CA. 1988. Development of a lexicon for the description of peanut flavor. *J. Sensory Stud.* 3:9-17.
- Labuza TP. 1982. *Shelf-Life Dating of Foods*. Westport, Conn.: Food and Nutrition Press. p 41-87.
- Labuza TP, Schmidl MK. 1985. Accelerated shelf-life testing of foods. *Food Technol.* 39(9):57-64, 134.
- Labuza TP, Schmidl MK. 1988. Use of sensory data in the shelf life testing of foods: principles and graphical methods for evaluation. *Cereal Foods World* 3(2):193-206.
- Lenth CW. 1939. New method for preventing oil separation. *Food Industries.* 2:678-679.
- Meilgaard M, Civille GV, Carr BT. 1991. *Sensory Evaluation Techniques*. 2nd ed. Boca Raton, Fla.: CRC Press Inc. p 173-185.
- Muego-Gnanasekharan KF, Resurreccion AVA. 1992. Physicochemical and sensory characteristics of peanut paste stored at different temperatures. *J. Food Sci.* 57:1385-1389.
- Plemmons L and Resurreccion AVA. 1998. Warm-up sample improves reliability of responses in descriptive analysis. *J. Sensory Stud.* 13:359-376.
- Resurreccion AVA. 1988. Comparison of flavor quality of peanut based pastes and peanut butter by sensory methods. *J. Food Sci.* 53:1827-1830.
- SAS Institute Inc. 1987. *SAS/STAT Guide for Personal Computers*. 6th ed. Cary, N.C.: SAS Institute Inc. p 773-876.
- Szczesniak AS, Brandt MA, Friedman HH. 1963. Development of standard rating scales for mechanical parameters of texture and correlation between the objective and the sensory methods of texture evaluation. *J. Food Sci.* 28:397-403.
- Wait, R.A. 1949. Production of stabilized peanut butter. *Peanut J. Nut World.* 28(3):26,48.
- Woodroof JG. 1983. Peanut butter. In: *Peanuts: Production, Processing, Products*. 3rd ed. Westport, Conn.: VI Publishing Company Inc. p 181-227.
- Woodroof JG, Thompson HH, Cecil SR. 1945. Improving the quality of peanut butter. Griffin, Ga.: Georgia Experiment Station. Bulletin 243. p 5-20.
- MS 1999-0329 received 3/22/99; revised 10/6/99; accepted 12/2/99.

This study was part of the masters thesis of Lebecca A. Gills and was supported in part by grants from the U.S. Agency for International Development, Peanut Collaborative Research Support Program (Grant number LAG-4048-G-00-6013-00). Recommendations do not represent an official position or policy of USAID.

Authors are affiliated with the Center for Food Safety and Quality and Enhancement, Dept. of Food Science and Technology, University of Georgia, 1109 Experiment Street, Griffin, GA 30223-1797. Direct inquiries to Resurreccion (E-mail: aresurr@cfsqe.griffin.peachnet.edu).