REPORT OF PROGRESS:

Peanut Tarts

Research on the shelf life of peanut butter/strawberry tarts has been completed. Data are being analyzed so that a final report can be prepared.

Peanut Pasta

A peanut-based pasta product using 25% peanut flour [light (LR), medium (MR), and dark (DR) roasted peanut flour and flour made from peanut cake], 10% masa flour, and 65% semolina flour was produced and compared to 100% semolina flour. The pasta was either cooked directly or dried in an oven to produce a shelf-stable product. Dried pasta was stored at room temperature for 5 months before further evaluation. Moisture content and color of fresh, dried, fresh-cooked, dried-cooked pasta were evaluated. Stored-dried pasta after 5 months of storage was cooked and moisture content, color, and texture were compared with another set of fresh-cooked and dried-cooked pasta samples.

Fresh pasta all had similar moisture content (29 to 32%) which increased after cooking (63 to 67%). Fresh pasta also had similar color attributes as fresh-cooked pasta from the same formulation. However, pasta made with addition of peanut flour was darker than the pasta made with 100% semolina. Drying did not affect the color of dried pasta when compared with the fresh pasta. However, dried-cooked pasta had lower moisture content and was darker than fresh-cooked pasta from the same formulation. Storage at room temperature for 5 months did not affect the moisture content of cooked pasta when compared with the fresh-cooked pasta prepared 5 months ago. However, stored-dried-cooked pasta was darker than the dried-cooked pasta from the same formulation.

Another set of fresh and dried peanut pasta [light (LR), medium (MR), and dark (DR) roasted peanut flour] and pasta made from 100% semolina flour (control) were prepared at the time when stored-dried pasta was evaluated. In general, dried-cooked pasta had lower moisture content than the fresh-cooked pasta. Among the three peanut pasta formulations, pasta made with DR peanut flour had the lowest moisture content whereas pasta made with LR peanut flour had the highest moisture content. Stored-dried-cooked pasta also had similar moisture content to the fresh-cooked pasta from the same formulation. Cooked pasta from different stages of processing (fresh-cooked, dried-cooked, and stored-dried-cooked) had no significant difference in the degree of lightness. However, among the three peanut pasta formulations, pasta made with DR peanut flour was the darkest whereas pasta made with LR peanut flour was the lightest. Fresh-cooked pasta required the least amount of force (1.69 to 2.23 N) to cut followed by dried-cooked pasta (2.39 to 4.6 N). The stored-dried-cooked pasta required the highest cutting force (4.5 to 8.0 N) and was the firmest.
Final Report

Improving Shelf Stability of Peanut Butter Tarts and Optimizing Process Development of Peanut-based Pasta

Research Agreement Number 25-21-RD317-074

Submitted to Southeastern Peanut Research Initiative
National Peanut Board/Georgia Peanut Commission
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Executive Summary

Peanut Butter/Strawberry Jam Tarts

A study to determine the shelf life of baked tarts made with two types of filling—peanut butter alone and peanut butter with strawberry jam—was conducted. The tarts were baked by a commercial bakery on April 25, 2006 and packaged in (a) cardboard box, (b) high barrier film and flushed with nitrogen and (c) high barrier film without nitrogen flushing on April 26, 2006. Samples were stored at 22°C/50% RH and 32°C/70% RH and evaluated at 3-week intervals using physicochemical (moisture, water activity, color, pH, and texture), microbiological (total plate counts, yeast/mold counts), and sensory evaluation analyses. Sufficient samples were processed and packaged for a 24-week storage period.

At day 0, the total bacterial counts of the crust and filling were 1.47 and 2.48 log_{10} CFU/g, respectively; yeast and mold counts of the crust and filling were 1.76 and 3.12 log_{10} CFU/g, respectively. These data indicate that proper sanitary conditions were maintained during processing and handling. The total bacterial counts and yeast/mold counts after 9 weeks of storage were not more than 3.12 log_{10} CFU/g, which means that the tarts were safe for human consumption. However, results of sensory evaluation by a 4-member, in-house trained panel indicated that the hedonic (liking) ratings for several of the attributes, particularly texture and flavor, had declined to levels of ≤ 5 (neither like nor dislike); products with ratings of 5 or lower were no longer considered acceptable. The initial moisture content of the peanut butter tart crust was 6.7% while that of the peanut butter/strawberry tart crust was 7.3%. The initial moisture content of the peanut butter filling was 4.5% compared to 14.9% in the peanut butter/strawberry tart filling. One of the most notable quality changes which occurred during the storage test was the gradual and considerable loss of moisture from the strawberry jam, from 14.6% initially to 5.9-7.2% after 9 weeks. This storage study was terminated after 12 weeks due to a significant loss of overall product quality, regardless of package type or storage condition.

A follow-up study was conducted, using a foil laminate film to individually package the tarts, as is done in commercial packaging of Pop-tarts®. Nitrogen flushing was not employed in the follow-up storage study, since it demonstrated no added benefit in preventing product degradation. Tarts were baked in an impingement oven in the pilot plant of the Department of Food Science and Technology—Griffin Campus on September 19, 2006. They were cooled for 1 hr after baking, held overnight in moisture-vapor-proof containers, individually packaged in air the following day, using foil-like film (metallized oriented opaque polypropylene). Packages were stored at 22°C/50% RH and at 32°C/70% RH for evaluations to be conducted at 0, 6, 12, 18, and 24 weeks. Measurements of color, texture, water activity, moisture content, total bacterial counts, and yeast/mold counts were made as reported in the first study. For sensory evaluation, a 10-member panel of untrained consumers was recruited from the Griffin community.

The microbiological data (total bacterial counts, yeast and mold counts) at 6 weeks indicated that the tarts were still acceptable, i.e., the number of colony-forming units (CFU/gram) for both crust and filling were below 3.0. At 12 weeks, however, CFU for some of the samples were greater than 3.0, and there was visible mold on both the surface as well as the interior of the tarts. Therefore, the tarts were considered unsafe for human consumption and were not served to panelists for sensory evaluation. The storage study was terminated at this point due to degradation of the product. It is unfortunate that the air pack/metallized film package employed in this phase of the study did not prevent mold spoilage of the product. A
more robust regimen employing the use of mold inhibitors in the crust and filling as well as a modified atmosphere within each individual pouch is warranted to protect the product. A continuous process, such as that employed by commercial bakeries for processing/packaging of Pop-tarts® or other toaster pastries, rather than the batch process/package regimen employed in our pilot plant, may have extended the shelf life of the tarts for more than 12 weeks.

Peanut Pasta

Georgia is the leading producer of peanuts in the United States, and current research efforts are focused on utilizing peanut flour as a food ingredient. This project was to develop a peanut-based pasta product using roasted peanut flour and determine its stability. With the addition of peanut butter or peanut flour to the noodles, a potentially protein- and vitamin-fortified noodle can be formed. We found all dried samples were stable over the 5-month storage period. Moisture content of cooked pasta from dried pasta was generally lower than from fresh pasta. However, storage at room temperature for 5 months did not affect the moisture content of cooked pasta when compared with the fresh-cooked pasta prepared 5 months earlier. Pasta made with 100% semolina flour had a yellow color (hue angle of 87 to 90°) whereas peanut pasta was browner (hue angle of 63 to 73°) regardless of formulation. With regard to textural quality, fresh-cooked pasta required the least amount of force (1.69 to 2.23 N) to cut followed by dried-cooked pasta (2.39 to 4.6 N). The stored-dried-cooked pasta required the highest cutting force (4.5 to 8.0 N) and was the firmest. Within the same treatment, texture quality of peanut pasta was similar.
Study 1. Shelf Stability of Peanut Butter Tarts

Introduction

Breakfast is considered the most important meal of the day for many people, especially the young. Health studies have shown that eating breakfast can increase energy and concentration levels, and reduce the risk of diabetes and obesity (Anon., 2003). The increasing popularity of breakfast has led to an increase in the development of new products which primarily center on convenience (Covino, 2005). Convenience was one of the major drivers of the global food industry in 2004 (Sloan, 2005). Consumer demand for convenient breakfast products is increasing and will continue doing so as newer and better quality products are introduced to the consumer (Covino, 2005; Sloan, 2005).

Bakery products have been an important part of a balanced diet for thousands of years. They are convenient, nutritious, easy to package and shelf stable (Smith et al., 2004). Peanut butter and peanut butter/strawberry jam-filled breakfast tarts are one such product developed with the idea of providing a convenient and nutritious food (McWatters et al., 2006). These tarts contain peanut butter which is a good source of protein.

The development of a peanut butter-filled breakfast tart and its consumer acceptance has been documented (McWatters et al., 2006). Studies on bread and cake suggest that packaging in mixtures of CO₂ and N₂ and in 100% N₂ leads to a substantial increase in their shelf life (Bogadkte, 1979). Therefore, one of the test packaging conditions was chosen to be high barrier bags flushed with N₂.

However, the shelf life and packaging (type of package and atmosphere) which would deliver maximum shelf life while maintaining consumer acceptability of this product have not been determined.

Objectives

The objectives of this study were to determine:

1. The shelf life of peanut butter and peanut butter/strawberry jam-filled tarts packaged in three types of packages and stored at two conditions of temperature and relative humidity (%RH).
2. Moisture content, water activity, and pH of the crust and the filling.
3. Consumer acceptability of the stored tarts.

Materials and Methods

Tart formulation, preparation and fillings

Tarts were formulated using the procedure outlined by McWatters et al. (2006) with certain modifications. Table 1 shows the ingredient composition used to make the tart dough as well as the fillings. The tarts were formulated and baked in a conventional oven at 177°C for 10 min at a commercial bakery in Fayetteville, GA. Tarts were cooled on racks for 45 min, packaged individually in paper sleeves, and then placed in cardboard pizza boxes (7 tarts/box).

Packaging and storage of tarts

Tarts (n = 792) made with two types of filling, peanut butter alone and peanut butter with strawberry jam, were stored at two temperature and humidity conditions in three types of packages. The three types of packages were cardboard boxes, cardboard boxes sealed in high barrier bags, and cardboard boxes scaled in high barrier bags flushed with nitrogen. The storage
conditions were 22°C/50% RH, termed as room temperature storage, and 32°C/70% RH, termed as elevated storage condition. For storage at elevated conditions, the samples were stored in environmental chambers fitted with temperature and humidity controls. The samples were coded according to the coding scheme given in Table 2.

**Sampling**
Sample tarts were collected every 3 weeks from the time of their manufacture (day 0) up to a maximum time of 6 months (24 weeks), the date coinciding with the maximum expected shelf life of the tarts. Microbiological, sensory, and physicochemical analyses were performed initially and at each 3-week sampling period.

**Physicochemical analyses**

**Water activity (a_w)**
For a_w determination, the samples (crust and filling material) were allowed to reach a temperature of 25°C, homogenized and dispensed in sample cups. The cups were then placed in an Aqua Lab water activity meter (Decagon Devices, Inc., Pullman, WA) which had an accuracy of ±0.003 units for measuring the a_w.

**Moisture content**
The moisture content of tart crust and filling was determined by following the AOAC Official Method 925.09 (AOAC, 1998). Briefly, a weighed quantity (ca. 4-6 g) of sample was placed in a pre-dried moisture vessel which was placed in a vacuum oven at 98-100°C with partial vacuum having pressure equivalent to ≤ 25 mm Hg for ca. 5 h. The loss in weight of the sample was reported as moisture content.

**pH**
The pH of the strawberry jam portion of the filling was measured. For this, the strawberry jam was scraped out of the sample using a scalpel and homogenized with 20 volumes of deionized water for 1 min (Rosa et al. 2005). The pH of the resulting solution was then measured with a bench top portable pH meter (Model IQ240, IQ Scientific Instruments, Inc., San Diego, CA, USA) equipped with an ISFET sensor.

**Instrumental color**
For color determination, the top surface of the tart was placed on the reader of the MiniScan XE Plus colorimeter (Hunter Associates Laboratory, Inc., Reston, VA, USA) standardized with a black and a white reference tile. Three attributes of color, L*, a*, and b* indicating the lightness, redness and yellowness of the sample, respectively, were recorded.

**Texture analysis**
The texture analysis of the tart was carried out using an Instron 5542 texture analyzer (Instron, Canton, MA, USA). A blunt probe having a diameter of 0.3 mm and moving at a speed of 20 mm/min was used to puncture the top of the sample at three different points. The maximum force encountered to puncture the top and the bottom of the crust and the total force to puncture through the filling were recorded for two samples from each set.

**Bacteriological analyses**
Bacteriological and fungal analysis of the tarts was done by enumerating the bacteria and fungus on Tryptic soy agar (TSA) and potato dextrose agar (PDA), respectively. The tarts were removed from the storage containers and transferred to sterile sampling bags. They were then cut into half using a sterile knife; the crust and filling were separated and placed in two different Petri plates. The dilutions of the samples were prepared in sterile 0.1% peptone by mixing the crust in 100 ml and the filling in 20 ml of peptone, respectively. Appropriate dilutions of the samples were plated in duplicate; the plates were incubated at 37°C for 24-48 h for total plate counts and at room temperature for 3-5 days for yeast and mold counts.

Sensory analysis

Sensory evaluation was conducted after the samples were deemed safe for human consumption by the microbiological analyses. At each sampling time, the tart samples were presented to an in-house trained panel consisting of four members. Panelists signed consent forms and then evaluated the overall appearance, color, aroma, flavor, texture, and overall liking of peanut butter alone and peanut butter/strawberry jam tarts using a nine-point hedonic scale (1 = dislike extremely, 9 = like extremely). Panelists were also asked to comment freely about the samples. Individually packaged samples were coded with three-digit random numbers and presented to panelists monadically using a randomized serving order. The panelists evaluated the samples in partitioned, climate-controlled booths illuminated with white incandescent lights. Water and unsalted crackers were provided for panelists to cleanse their palate between samples.

Results and Discussion

Moisture content

The mean moisture content of the freshly baked and stored tarts is given in Tables 3 and 4. The initial moisture content of peanut butter tart crust was 6.70% while that of peanut/strawberry tart crust was 7.27%. Likewise the moisture content of peanut butter tart filling was 4.45% compared to 14.60% moisture in peanut/strawberry tart. Tarts filled with peanut butter/strawberry jam had a higher initial moisture content compared to the peanut butter tarts which seems logical because strawberry jam had higher moisture content than peanut butter. Moisture from strawberry jam might have migrated to the surrounding crust increasing its moisture content.

The crust and the filling of peanut butter tarts stored at room temperature lost moisture with the increase in the length of storage. Moisture loss may result in textural changes and may promote chemical and microbiological spoilage in low and intermediate moisture foods (Brody, 1989). The highest moisture gain was seen in the tarts packed in cardboard and stored at elevated conditions at the 9th week of storage (Table 3). The moisture content of the filling of these tarts was also the highest among tarts stored at all the other conditions (Table 3). The moisture content of the crust and the filling during the test period was always associated with the tarts stored at elevated conditions irrespective of the type of package (Table 3). However, among groups (room temperature vs. elevated conditions), the highest moisture content was always associated with tarts stored in cardboard boxes. The tarts stored at room temperature conditions lost moisture at a faster rate than the ones stored at elevated conditions in the same packaging.

Among the tarts having peanut butter/strawberry jam filling, the tarts stored at room temperature lost more moisture than the ones stored at elevated temperature (Table 4). At room temperature, the tarts stored in cardboard lost moisture rapidly compared to the ones stored in
high barrier bags (air or nitrogen flushed). The loss of moisture from the filling was also considerable. The filling of the tarts stored in cardboard at room temperature lost moisture at a faster rate than the tarts stored in high barrier bags (air or nitrogen flushed) (Table 4). The peanut butter/strawberry jam filling had become very dry by the 9th week of storage and had a rubbery consistency. The variation in the moisture content of tarts packaged in different materials and stored under different conditions over the storage period is shown graphically in Fig. 5.

Water activity

Water activity is a physical property that has a direct implication for microbiological safety of foods (Jay, 2000). It also influences the storage stability of foods as some deteriorative processes in food are mediated by water. The initial $a_w$ for peanut butter tart and filling was 0.478 and 0.488, respectively. These tarts fall under the category of low moisture bakery products with $a_w < 0.6$ (Smith and Simpson, 1995). The water activity of peanut butter tarts stored under elevated conditions increased with the advancement of the storage period, whereas the $a_w$ for tarts stored at room temperature diminished (Table 3). Strangely, after 9 weeks of storage, the $a_w$ of tarts stored at room temperature increased. The highest increase in $a_w$ was in the crust and filling of the tarts stored at elevated conditions in cardboard boxes and reached 0.676 and 0.661 for crust and filling, respectively, at the 9th week of storage (Table 3 and Fig. 6).

The initial water activity of peanut butter/strawberry tart crust and the filling was 0.543 and 0.725, respectively. These tarts fall under the category of intermediate moisture bakery products with $a_w$ between 0.6 and 0.85 (Smith and Simpson, 1995). The $a_w$ values for tarts stored at elevated conditions increased with the advancement of storage period, while it diminished for those stored at room temperature (Table 4). The highest increase was observed in the crust of the tarts packaged in cardboard boxes and stored at elevated conditions which increased from 0.543 and 0.725 (Table 4 and Fig. 6). The increase in water activity is a result of water migration from high moisture filling to low moisture crust and due to the uptake of moisture from the environment which had 70% relative humidity. The change in $a_w$ levels for tarts packaged in high barrier bags flushed with nitrogen and stored at room temperature was lower compared to that at other storage conditions (Table 4).

The moisture content and water activity of the tarts were related to each other. An increase in $a_w$ was seen when the moisture content of the product increased and the $a_w$ levels diminished if the moisture content went down. The moisture content of the product and $a_w$ are the two critical factors determining the shelf life of a food product (Jay, 2000).

pH

The pH of strawberry jam portion of peanut butter/strawberry jam filling was measured at each sampling time. The initial pH of the strawberry jam used as a filling was 5.15. As the storage time increased, an increase was observed in the pH. Each tart was filled with 3 g of strawberry jam along with 3 g of peanut butter. The jam lost some moisture during baking and subsequent storage. Even at the 3rd week of storage it was very difficult to get the jam portion of the filling separated from the peanut butter.

An increase in the pH of the jam was observed with the advancement of the storage time (Table 4). The increase in pH of the jam might not be a real increase but could be due to the mixing of crust ingredients (Table 1) in deionized water during pH measurement. Also most of the moisture of the strawberry jam portion of the filling is lost during baking and subsequent
storage, thereby making the growth of microorganisms in this portion of filling very difficult. Measurement of pH of strawberry jam filling in tarts is therefore deemed to be not necessary for further studies.

**Texture analysis**

The maximum force (N) required for penetrating the top and bottom crust and the total force required to penetrate the filling of the tart was measured; the values for peanut butter tarts and peanut butter/strawberry jam tarts are represented graphically in Fig 3 and 4, respectively. The force required to penetrate the top of peanut butter tart on day 0 was 5.510 N while the same to penetrate the bottom crust was 6.771 N (Fig. 3a and 3b). For peanut butter/strawberry jam filled tarts the penetration force values for top and bottom crust were 2.138 N and 1.723 N, respectively (Fig. 4a and 4b). At this time the values of total penetration force for peanut butter filling was 1.664 N while the same for peanut butter/strawberry jam filled tarts was 0.483 N (Fig. 3c and 4c). The data shows that at Day 0, the crust (top and bottom) of peanut butter/strawberry jam filled tart was softer than the ones filled with peanut butter only. The peanut butter/strawberry jam filling was also softer than only peanut butter filling. The variations in the penetration force for tarts stored under different storage conditions at various sampling times are shown in Fig. 3 and 4.

Moisture loss or gain in bakery products can result in textural changes (Smith et al. 2004). In most of the cases in this study it was observed that the top and bottom crust penetration force at 0, 3 and 6 weeks increased with the advancement of storage time during which there was a loss of moisture from the product (Fig. 3 and 4, Table 3 and 4). However, in some cases the penetration force at week 9 decreased, the reasons for which are not known.

**Color**

The color of the food is one of the most important criteria by which consumers judge the quality of a product at the time of purchase and at the time of consumption (Brimelow, 1987). The color values for peanut butter and peanut butter/strawberry jam tarts at 3, 6, and 9 weeks are shown in Tables 5 and 6. On the day of baking, the dough used for peanut butter/strawberry jam tarts, which were baked during the afternoon, contained more “rework” dough that the dough used for peanut butter tarts, which were baked during the morning. This difference led to non-uniform color in the tarts. Therefore, it is not possible to compare the color of peanut butter tarts with peanut butter/strawberry jam tarts. The color of day 0 tarts was not measured; therefore, we do not have the initial reading of color values. In order to have color values for day 0 we will again bake the requisite number of tarts in the conventional oven at the commercial bakery and record the readings.

**Bacteriological analyses**

Microbiological spoilage is often the major factor limiting the shelf life of high and intermediate moisture bakery products (Smith et al. 2004). Water activity is the most important factor influencing the spoilage of bakery products. For low moisture baked products (a_w < 0.6) such as peanut butter tarts (Table 3), microbiological spoilage is not a problem. However, in intermediate moisture products (a_w 0.6-0.85), osmophilic yeasts and molds are the predominant spoilage microorganisms (Smith et al. 2004). In this study the stored tarts were to be evaluated by a sensory panel for assessing their consumer acceptability; therefore, bacteriological analyses
of the peanut butter/strawberry jam tarts was done at each sampling period to determine their suitability for human consumption.

The total bacterial counts of the crust and filling at day 0 were $1.47 \log_{10}$ CFU/g and 2.48 $\log_{10}$ CFU/g, respectively, while the yeast and mold counts of the crust and the filling at this time were 1.76 $\log_{10}$ CFU/g and 3.12 $\log_{10}$ CFU/g (Fig. 1 and 2). The total bacterial counts and yeast and mold counts of the tarts at subsequent sampling periods are shown in Fig. 1 and 2. At certain points in the graph the log of total bacterial counts or yeast and mold counts is zero, because the counts in the test material might be below the detection limit of the microbial plating procedure used. A zero total bacterial or yeast and mold count does not mean that the microorganisms have been inhibited.

Mold problems in bakery products are more troublesome during the summer months, due to warmer and more humid storage conditions (Smith et al. 2004). The results of this study also show higher mold counts in tarts stored at high moisture and relative humidity conditions (32C/70% RH). The SEC filling had higher mold counts than SRC at weeks 3 and 9 (Fig. 1 and 2). The yeast and mold counts for SEA crust at week 3, SEA crust and filling at week 6 and 9 were higher than their corresponding samples stored at room temperature (Fig. 1 and 2).

Commercially produced and properly handled bakery products generally lack sufficient amounts of moisture to allow for the growth of any organisms except molds (Jay, 2000). In accordance with this, the total bacterial counts of the tart crust as well as the filling were in the low to very low range (Fig. 1 and 2). During baking, the products are submitted to a temperature and time heat treatment, which practically eliminates the bacterial load present (Rosa et al. 2005). Post processing contamination may be responsible for higher bacterial counts. In our study the bacterial counts in the crust and filling were low which means that proper sanitary conditions were maintained during formulation and handling of the tarts. Low yeast and mold counts indicate that tarts were handled in a safe and hygienic manner after baking since contamination of products by osmophilic yeasts results from unclean utensils and equipment (Legan and Voysey, 1991). The total bacterial counts and yeast and mold counts at the end of 9 weeks of storage were not more than 3.12 $\log_{10}$ CFU/g in all the batches studied which means that the tarts were safe for human consumption, however, sensory analysis will give information about the consumer acceptability of the products.

**Sensory analysis**

The results of the sensory analysis of the fresh and stored tarts are shown in Fig. 7 and 8. Tarts rated 5 or higher on the hedonic scale (1 = dislike extremely, 9 = like extremely) are considered to be of acceptable quality. The appearance of the peanut butter and peanut butter/strawberry jam tarts at day 0 was in the range of “like very much” to “like extremely” (Fig. 7a and 8a). With increasing storage time, the appearance ratings for peanut butter/strawberry jam became lower than the ratings for peanut butter tarts. Similarly, the color rating for peanut butter/strawberry jam tarts was lower than that for peanut butter tarts at the 9th week of storage. Both varieties of tarts had aroma in the range of “like very much” to “like extremely” at day 0. These ratings however dropped as the length of storage increased (Fig. 7c and 8c). The flavor of peanut butter/strawberry jam tarts was slightly better than that of peanut butter tarts at day 0. Flavor ratings followed a diminishing trend and became unacceptable at the 9th week of storage for most of the tarts. The texture ratings for the tarts decreased as the length of storage increased. Moisture loss from the tart crust and filling led to the very low ratings. Peanut butter and peanut butter/strawberry jam tarts had an overall acceptability ratings of “like
very much” at the start of the study. Some tarts began to lose their overall acceptability as early as the 3rd week of storage. By the 9th week of storage, all tarts with the exception of peanut tart stored at room temperature and packaged in high barrier bag flushed with N₂ (PRN 9) had overall acceptability ratings of less than 5. The PRN 9 tart had a score of 5.5 which is very close to the rejection limit.

Conclusions

Based on the results of study 1, a follow-up study was designed utilizing individual foil packages for packaging the tarts, rather than the high barrier film and bulk packaging employed in the present study.
Table 1. Recipe for the tart dough and fillings

<table>
<thead>
<tr>
<th>Dough ingredients</th>
<th>Amount (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat flour (White Lily® plain, all purpose)(^a)</td>
<td>52.5</td>
</tr>
<tr>
<td>Sugar (Kroger, granulated, cane)(^b)</td>
<td>12.7</td>
</tr>
<tr>
<td>Milk (Kroger, whole)(^b)</td>
<td>11.4</td>
</tr>
<tr>
<td>Shortening (Crisco® partially hydrogenated vegetable)(^c)</td>
<td>11.3</td>
</tr>
<tr>
<td>Egg (Kroger, large, whole, fresh)(^b)</td>
<td>11.3</td>
</tr>
<tr>
<td>Baking powder (Calumet)(^d)</td>
<td>0.4</td>
</tr>
<tr>
<td>Salt (iodized)(^e)</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Filling ingredients (ca. 6 g per tart)

Peanut butter (smooth)\(^f\) sweetened with 5% confectioner’s sugar
Layer (3 g) of peanut butter (smooth) sweetened with 5% confectioner’s sugar\(^b\) and layer (3 g) of strawberry filling\(^g\)

\(^a\) The White Lily Foods Co., Knoxville, TN 37917.
\(^b\) The Kroger Co., Cincinnati, OH 45202.
\(^c\) The J. M. Smucker Co., Orrville, OH 44667.
\(^d\) Kraft Foods, Inc., Rye Brook, NY 10573.
\(^e\) Morton International Inc., Morton Salt, Chicago, IL 60606.
\(^f\) Unilever Bestfoods, Englewood, Cliffs, NJ 07632.
\(^g\) Dawn® Baker’s Select \(\text{TM}\) Chopped Strawberry Filling 12/2#, Dawn Food Products of Atlanta, Douglasville, GA 30134.
Table 2. Codes used to label the tarts

<table>
<thead>
<tr>
<th>Filling</th>
<th>Storage condition</th>
<th>Packaging</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-Peanut butter</td>
<td>R-room (22°C/50% RH)</td>
<td>C- Cardboard box</td>
<td>PRC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A- Cardboard box in barrier bag/ air flushed</td>
<td>PRA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N- Cardboard box in barrier bag/ N₂ flushed</td>
<td>PRN</td>
</tr>
<tr>
<td></td>
<td>E-Elevated (32°C/70% RH)</td>
<td>C- Cardboard box</td>
<td>PEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A- Cardboard box in barrier bag/ air flushed</td>
<td>PEA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N- Cardboard box in barrier bag/ N₂ flushed</td>
<td>PEN</td>
</tr>
<tr>
<td>S-Peanut butter/strawberry jam</td>
<td>R-room (22°C/50% RH)</td>
<td>C- Cardboard box</td>
<td>SRC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A- Cardboard box in barrier bag/ air flushed</td>
<td>SRA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N- Cardboard box in barrier bag/ N₂ flushed</td>
<td>SRN</td>
</tr>
<tr>
<td></td>
<td>E-Elevated (32°C/70% RH)</td>
<td>C- Cardboard box</td>
<td>SEC</td>
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<tr>
<td></td>
<td></td>
<td>A- Cardboard box in barrier bag/ air flushed</td>
<td>SEA</td>
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<td></td>
<td></td>
<td>N- Cardboard box in barrier bag/ N₂ flushed</td>
<td>SEN</td>
</tr>
</tbody>
</table>
Table 3. Moisture content and water activity of peanut butter filled tarts stored at different temperature and relative humidity conditions\(^a\)

<table>
<thead>
<tr>
<th>Weeks of storage</th>
<th>Parameter</th>
<th>Room temperature</th>
<th>Elevated temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PRC</td>
<td>PRA</td>
</tr>
<tr>
<td>0</td>
<td>Moisture (%)</td>
<td>6.70</td>
<td>4.45</td>
</tr>
<tr>
<td></td>
<td>a(_w)</td>
<td>0.478</td>
<td>0.488</td>
</tr>
<tr>
<td>3</td>
<td>Moisture (%)</td>
<td>5.55</td>
<td>3.52</td>
</tr>
<tr>
<td></td>
<td>a(_w)</td>
<td>0.457</td>
<td>0.452</td>
</tr>
<tr>
<td>6</td>
<td>Moisture (%)</td>
<td>5.96</td>
<td>4.04</td>
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<tr>
<td></td>
<td>a(_w)</td>
<td>0.448</td>
<td>0.451</td>
</tr>
<tr>
<td></td>
<td>a(_w)</td>
<td>0.571</td>
<td>0.573</td>
</tr>
</tbody>
</table>

\(^a\)Sample codes refer to: P, Peanut butter filling; R, room temperature conditions (22°C/50% RH); C, cardboard box, A, cardboard box sealed in high barrier film, N, cardboard box sealed in high barrier film and flushed with N\(_2\); F, elevated storage conditions (32°C/70% RH). The sample codes are also explained in Table 2.
Table 4. Moisture content, water activity and pH of peanut butter/strawberry jam filled tarts stored at different temperature and relative humidity conditions \(^a\)

<table>
<thead>
<tr>
<th>Weeks of storage</th>
<th>Parameter</th>
<th>Room temperature</th>
<th>Elevated temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SRC</td>
<td>SRA</td>
</tr>
<tr>
<td>0</td>
<td>Moisture (%)</td>
<td>7.27</td>
<td>14.60</td>
</tr>
<tr>
<td></td>
<td>(a_w)</td>
<td>0.543</td>
<td>0.725</td>
</tr>
<tr>
<td></td>
<td>pH</td>
<td>n.d. (^b)</td>
<td>5.15</td>
</tr>
<tr>
<td></td>
<td>(a_w)</td>
<td>0.465</td>
<td>0.496</td>
</tr>
<tr>
<td></td>
<td>pH</td>
<td>n.d.</td>
<td>5.23</td>
</tr>
<tr>
<td>6</td>
<td>Moisture (%)</td>
<td>5.90</td>
<td>7.61</td>
</tr>
<tr>
<td></td>
<td>(a_w)</td>
<td>0.436</td>
<td>0.495</td>
</tr>
<tr>
<td></td>
<td>pH</td>
<td>n.d.</td>
<td>5.28</td>
</tr>
<tr>
<td>9</td>
<td>Moisture (%)</td>
<td>8.01</td>
<td>6.44</td>
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<tr>
<td></td>
<td>(a_w)</td>
<td>0.580</td>
<td>0.584</td>
</tr>
<tr>
<td></td>
<td>pH</td>
<td>n.d.</td>
<td>5.24</td>
</tr>
</tbody>
</table>

\(^a\) Sample codes refer to: S, Peanut butter/strawberry jam filling; R, room temperature conditions (22°C/50% RH); C, cardboard box, A, cardboard box sealed in high barrier film, N, cardboard box sealed in high barrier film and flushed with \(N_2\); E, elevated storage conditions (32°C/70% RH). The sample codes are also explained in Table 2.

\(^b\) n.d. Not determined.
Table 5. Mean values for instrumental color measurements\(^a\) of top surface of peanut butter tarts

<table>
<thead>
<tr>
<th>Weeks of storage</th>
<th>Sample(^b)</th>
<th>L(^*)</th>
<th>a(^*)</th>
<th>b(^*)</th>
</tr>
</thead>
<tbody>
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<td>0</td>
<td>P</td>
<td>76.4</td>
<td>3.3</td>
<td>27.8</td>
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<td>3</td>
<td>PRC</td>
<td>76.73</td>
<td>3.54</td>
<td>28.88</td>
</tr>
<tr>
<td></td>
<td>PRA</td>
<td>76.61</td>
<td>3.57</td>
<td>28.67</td>
</tr>
<tr>
<td></td>
<td>PRN</td>
<td>74.11</td>
<td>4.02</td>
<td>29.04</td>
</tr>
<tr>
<td></td>
<td>PEC</td>
<td>73.30</td>
<td>4.40</td>
<td>30.67</td>
</tr>
<tr>
<td></td>
<td>PEA</td>
<td>72.02</td>
<td>4.45</td>
<td>31.33</td>
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<td></td>
<td>PEN</td>
<td>73.06</td>
<td>5.29</td>
<td>32.04</td>
</tr>
<tr>
<td>6</td>
<td>PRC</td>
<td>76.43</td>
<td>3.73</td>
<td>28.16</td>
</tr>
<tr>
<td></td>
<td>PRA</td>
<td>76.89</td>
<td>3.90</td>
<td>29.17</td>
</tr>
<tr>
<td></td>
<td>PRN</td>
<td>75.34</td>
<td>4.02</td>
<td>28.40</td>
</tr>
<tr>
<td></td>
<td>PEC</td>
<td>73.25</td>
<td>4.14</td>
<td>30.09</td>
</tr>
<tr>
<td></td>
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<td>72.80</td>
<td>4.99</td>
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<td></td>
<td>PEN</td>
<td>72.80</td>
<td>4.90</td>
<td>30.20</td>
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<tr>
<td>9</td>
<td>PRC</td>
<td>94.76</td>
<td>3.98</td>
<td>32.88</td>
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<tr>
<td></td>
<td>PRA</td>
<td>94.52</td>
<td>3.84</td>
<td>32.92</td>
</tr>
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<td></td>
<td>PRN</td>
<td>92.82</td>
<td>4.72</td>
<td>33.74</td>
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<td></td>
<td>PEC</td>
<td>90.12</td>
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<td></td>
<td>PEA</td>
<td>88.85</td>
<td>5.09</td>
<td>36.70</td>
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<tr>
<td></td>
<td>PEN</td>
<td>89.79</td>
<td>5.52</td>
<td>35.51</td>
</tr>
</tbody>
</table>

\(^a\) L\(^*\) = lightness (0 = black, 100 = white); +a\(^*\) = redness, -a\(^*\) = greenness; +b\(^*\) = yellowness, -b\(^*\) = blueness.

\(^b\) Sample codes refer to: P, Peanut butter filling; R, room temperature conditions (22\(^\circ\)C/50\% RH); C, cardboard box, A, cardboard box sealed in high barrier film, N, cardboard box sealed in high barrier film and flushed with N\(_2\); E, elevated storage conditions (32\(^\circ\)C/70\% RH). The sample codes are also explained in Table 2.
Table 6. Mean values for instrumental color measurements\(^{a}\) of top surface of peanut butter/strawberry jam tarts

<table>
<thead>
<tr>
<th>Weeks of storage</th>
<th>Sample(^{b})</th>
<th>(L^{*})</th>
<th>(a^{*})</th>
<th>(b^{*})</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
<td>77.7</td>
<td>2.3</td>
<td>25.5</td>
</tr>
<tr>
<td>3</td>
<td>SRC</td>
<td>74.31</td>
<td>5.03</td>
<td>32.14</td>
</tr>
<tr>
<td></td>
<td>SRA</td>
<td>76.29</td>
<td>3.85</td>
<td>28.81</td>
</tr>
<tr>
<td></td>
<td>SRN</td>
<td>74.16</td>
<td>5.02</td>
<td>30.61</td>
</tr>
<tr>
<td></td>
<td>SEC</td>
<td>74.67</td>
<td>5.51</td>
<td>32.39</td>
</tr>
<tr>
<td></td>
<td>SEA</td>
<td>76.10</td>
<td>4.30</td>
<td>28.95</td>
</tr>
<tr>
<td></td>
<td>SEN</td>
<td>73.18</td>
<td>5.68</td>
<td>32.19</td>
</tr>
<tr>
<td>6</td>
<td>SRC</td>
<td>73.81</td>
<td>4.99</td>
<td>30.83</td>
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<tr>
<td></td>
<td>SRA</td>
<td>76.04</td>
<td>4.23</td>
<td>28.37</td>
</tr>
<tr>
<td></td>
<td>SRN</td>
<td>74.50</td>
<td>5.00</td>
<td>29.65</td>
</tr>
<tr>
<td></td>
<td>SEC</td>
<td>74.70</td>
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<td>75.99</td>
<td>4.53</td>
<td>29.32</td>
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<td>SEN</td>
<td>74.07</td>
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<td>31.53</td>
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<tr>
<td>9</td>
<td>SRC</td>
<td>92.00</td>
<td>5.39</td>
<td>36.25</td>
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<tr>
<td></td>
<td>SRA</td>
<td>92.86</td>
<td>4.20</td>
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<td></td>
<td>SRN</td>
<td>92.16</td>
<td>5.54</td>
<td>34.46</td>
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<td></td>
<td>SEC</td>
<td>91.07</td>
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<td>SEA</td>
<td>91.76</td>
<td>4.75</td>
<td>33.53</td>
</tr>
<tr>
<td></td>
<td>SEN</td>
<td>89.79</td>
<td>5.52</td>
<td>35.51</td>
</tr>
</tbody>
</table>

\(^{a}\) \(L^{*}\) = lightness (0 = black, 100 = white); \(^{c}\) \(+a^{*}\) = redness, \(-a^{*}\) = greenness; \(^{d}\) \(+b^{*}\) = yellowness, \(-b^{*}\) = blueness.

\(^{b}\) Sample codes refer to: S, Peanut butter/strawberry jam filling; R, room temperature conditions (22°C/50% RH); C, cardboard box, A, cardboard box sealed in high barrier film, N, cardboard box sealed in high barrier film and flushed with N\(_2\); E, elevated storage conditions (32°C/70% RH). The sample codes are also explained in Table 2.
Fig. 1. Total bacterial counts of crust (CTC, ◆), yeast and mold count of the crust (CYM, ▲), total count of the filling (FTC, ▲) and yeast and mold count of filling (FYM, X). (a) SEC (b) SEA and (c) SEN. S, Peanut butter/strawberry jam filling; R, room temperature conditions (22°C/50% RH); C, cardboard box, A, cardboard box sealed in high barrier film, N, cardboard box sealed in high barrier film and flushed with N₂; E, elevated storage conditions (32°C/70% RH). The sample codes are also explained in Table 2.
Fig. 2. Total bacterial counts of crust (CTC, ◆), yeast and mold count of the crust (CYM, *) total count of the filling (FTC, ▲) and yeast and mold count of the filling (FYM, X) (a) SRC (b) SRA and (c) SRN. S, Peanut butter/strawberry jam filling; R, room temperature conditions (22°C/50% RH); C, cardboard box, A, cardboard box sealed in high barrier film, N, cardboard box sealed in high barrier film and flushed with N₂; E, elevated storage conditions (32°C/70% RH). The sample codes are also explained in Table 2.
Fig. 3. Force needed to penetrate the (a) top crust (b) bottom crust, and (c) filling of the peanut butter tarts. P, Peanut butter filling; R, room temperature conditions (22°C/50% RH); C, cardboard box, A, cardboard box sealed in high barrier film, N, cardboard box sealed in high barrier film and flushed with N₂; E, elevated storage conditions (32°C/70% RH). The sample codes are also explained in Table 2.
Fig. 4. Force needed to penetrate the (a) top crust (b) bottom crust, and (c) filling of the peanut butter tarts. S, Peanut butter/strawberry filling; R, room temperature conditions (22°C/50% RH); C, cardboard box, A, cardboard box sealed in high barrier film, N, cardboard box sealed in high barrier film and flushed with N₂; E, elevated storage conditions (32°C/70% RH). The sample codes are also explained in Table 2.
Fig. 5. Variation in moisture content of peanut butter filled tarts stored at room temperature (a), and at elevated temperature (b). Variation in moisture content of peanut butter/strawberry jam filled tarts stored at room temperature (c), and at elevated temperature (d). The sample codes are also explained in Table 2.
Fig. 6. Variation in water activity of peanut butter filled tarts stored at room temperature (a), and at elevated temperature (b). Variation in water activity of peanut butter/strawberry jam filled tarts stored at room temperature (c), and at elevated temperature (d). The sample codes are also explained in Table 2.
Fig. 7(e) and Fig. 7(f)

Fig. 7. Mean ratings for sensory quality of peanut butter tarts stored at different temperature and relative humidity conditions. The sample codes are explained in Table 2.
Fig. 8(e) and Fig. 8(f)

Fig. 8. Mean ratings for sensory quality of peanut butter/strawberry jam tarts stored at different temperature and relative humidity conditions. The sample codes are explained in Table 2.
Study 2. Shelf Stability of Peanut Butter Tarts

Introduction
A storage study to determine the shelf life of baked tarts with two types of filling — peanut butter alone and peanut butter with strawberry jam — was initiated on April 26, 2006 but was terminated after 12 weeks due to significant quality degradation of the tarts. The type of packaging employed in the study was (a) cardboard box, (b) high barrier film flushed with nitrogen and (c) high barrier film without nitrogen flushing. This type of packaging did not prevent moisture loss from the product; therefore, the tarts became unacceptably dry and crumbly during storage. Nitrogen flushing was concluded to be of no benefit with the high barrier film and was, therefore, not employed in the design of a follow-up storage study initiated on September 19, 2006.

Materials and Methods
A foil-like film (metallized oriented opaque polypropylene) which is used to package commercial Pop-tarts® was obtained from Printpack Co., Atlanta, GA. Peanut butter/strawberry tarts were packaged in metallized film and stored at room (22°C/50% RH) and elevated (32°C/70% RH) temperature conditions. Tarts were prepared and baked for 8.5 min at 177°C in an impingement oven (model 1452, Lincoln® Foodservice Products, Inc., Fort Wayne, IN) in the pilot plant of the Department of Food Science and Technology on September 19, 2006, cooled for 1 hour after baking, held overnight in moisture-vapor-proof containers, individually packaged in air in metallized film on September 20th and placed into storage at 22°C/50% RH and at 32°C/70% RH for evaluations at 0, 6, 12, 18, and 24 weeks. Measurements of color, texture, water activity, moisture content, total bacterial counts, and yeast/mold counts were made as reported in the first study. For color measurements, 4 tarts from each treatment were measured at the initiation of storage and then individually packaged in metallized film. These samples were resealed and restored after color testing at each storage period. Nutrition analysis of tarts with peanut butter/strawberry jam filling was determined by Silliker, Inc., 1304 Halsted St., Chicago Heights, IL.

Sensory analysis
Sensory evaluation of tarts in study 2 was conducted as previously described in study 1, except that a 10-member panel of untrained consumers was recruited from the Griffin community. In addition to the consent form, panelists completed a demographic questionnaire and an honorarium form. Each panelist received $10/session for their participation.

Results and Discussion
Moisture content
The mean moisture content of freshly prepared and stored tarts is shown in Tables 7 and 8 and Fig. 9. The initial moisture content of the crust of peanut butter-filled tarts was 6.86% while the crust of the peanut butter/strawberry jam tart was 10.33%. Likewise, the initial moisture content of the peanut butter filling was 5.43% compared to 28.38% for the peanut butter/strawberry jam filling. The higher initial moisture content of the peanut butter/strawberry jam tarts is not surprising since strawberry jam contains considerably more moisture than peanut butter. At both room and elevated storage temperature, tarts filled with peanut butter only lost ~1.0% moisture or less during 12 weeks of storage. In contrast, tarts filled with peanut
butter/strawberry jam and stored at room temperature exhibited greater moisture loss than tarts made with peanut butter alone: 2.4% loss from the crust and 21% loss from the filling. Visual observation of the interior of these tarts confirmed that the strawberry jam had become dry, rubbery, and stringy after 12 weeks. For the peanut butter/strawberry jam tarts stored at elevated temperature, an increase of 7.8% moisture occurred in the crust after 12 weeks whereas a loss of 0.79% occurred in the filling.

Water activity

The initial water activity (a_w) for the crust and filling of peanut butter tarts was 0.527 and 0.57, respectively, which was notably lower than the initial a_w of tarts filled with peanut butter/strawberry jam – 0.692 and 0.895 for the crust and filling, respectively (Tables 7 and 8 and Fig. 10). Tarts with peanut butter alone retained a_w < 0.6 at both room and elevated storage temperature throughout the storage period and, therefore, would be classified as low moisture bakery products (Smith and Simpson, 1995). Tarts with peanut butter/strawberry jam had a_w ranging from 0.624 to 0.895 at both room and elevated temperatures throughout the 12-week storage period; products with a_w between 0.6 and 0.85 are classified as intermediate moisture bakery products (Smith and Simpson, 1995). The shelf life of intermediate moisture bakery products would be shorter than low moisture products. Greater variation in water activity occurred in the peanut butter/strawberry jam tarts during the 12-week storage period than in those made with peanut butter alone.

Bacteriological analysis

For tarts made with peanut butter alone, the crust had low total bacterial counts (1.76 log_{10} CFU/g) and yeast/mold counts (1.99 log_{10} CFU/g) initially; these counts remained low (below 3.0 log_{10} CFU/g) throughout the 12-week storage period, at both room and elevated temperatures (Tables 7 and 8 and Fig. 11). Likewise for the filling, total bacterial counts were 1.76 log_{10} CFU/g initially and remained below 3.0 throughout the 12-week storage period at both room and elevated storage temperatures. Yeast and mold counts for the filling were 2.02 log_{10} CFU/g initially but after 12 weeks had increased to 3.76 in tarts stored at room temperature and to 4.15 in those stored at elevated temperature.

For tarts filled with the peanut butter/strawberry jam combination, total bacterial counts and yeast/mold counts were the same initially: 2.24 log_{10} CFU/g for the crust and 1.61 log_{10} CFU/g for the filling. After 12 weeks of storage, both the crust and filling of this type of tart had yeast/mold counts that were either very close to or greater than 3.0 log_{10} CFU/g. Counts > 3.0 log_{10} CFU/g would indicate that the tarts would not be safe for human consumption. For this reason, this storage study was terminated due to product degradation.

Texture

The force required to penetrate the top crust of peanut butter tarts at the initiation of storage was 3.77 N and 10.42 N for the bottom crust (Table 7 and Fig. 10). For tarts filled with peanut butter/strawberry jam, the penetration force values for top and bottom crust at 0 week were 3.2 N and 1.46 N, respectively (Table 8 and Fig. 12). Also at the initiation of storage, penetration force values were 1.17 N for peanut butter filling and 0.14 N for peanut butter/strawberry jam filling. Tarts made with the combination of peanut butter/strawberry jam had softer (lower force values) top and bottom crusts and fillings than those made with peanut
butter only. In most cases, top and bottom crusts as well as fillings were firmer and required more force to penetrate after 12 weeks than at the initiation of storage.

Color

Instrumental color measurements of baked tarts packaged in metallized film and stored at room (22°C/50% RH) and elevated (32°C/70% RH) temperature for 0, 6, and 12 weeks are shown in Table 9 and Figure 13. Derived color parameters (chroma, hue angle, and total color difference) showed that all samples were similar in color initially and varied only slightly during storage. This indicates that the preparation and baking conditions produced tarts that were very uniform in color and that the metallized film was effective in preventing substantial change in product color during storage.

Chroma (color saturation or intensity) of the tarts ranged from 26.0 to 28.8 at week 0, 27.4 to 28.1 at week 6, and 26.9 to 29.2 at week 12. Hue angle values ranged from 83.0 to 85.2 initially, 82.9 to 84.3 at week 6, and 81.5 to 84.7 at week 12. Hue angles in this range represent yellow/brown colors. Total color difference values ranged from 7.6 to 10.1 at week 0, 7.6 to 8.8 at week 6, and 7.7 to 9.7 at week 12. Visual observation confirmed that color changes of the tarts during the 12-week storage period were minimal.

Sensory analysis

Panelists were primarily female (80%), white (80%) and married (80%). Most (70%) were in the 45-64 age range, 40% had completed vocational school or some college, and 50% were retired. Panelists had a wide distribution of household income ranging from $10,000 to $29,999 (30%), $30,000 to $39,999 (30%), $50,000 to $69,999 (20%) and ≥ $70,000 (20%).

Mean sensory ratings of freshly baked (reference) and stored tarts are shown in Table 10. A rating of 5 or higher on the hedonic scale (1 = like extremely, 9 = dislike extremely) was considered to be of acceptable quality. At week 0, all samples had acceptable ratings for appearance, color, aroma, and overall liking. Surprisingly, ratings for the flavor (= 5.0) and texture (= 4.6) of tarts filled with peanut butter alone at the initiation of storage were either at or below the acceptability level. Comments by panelists were that these tarts were bland and dry. At week 6, some of the tarts filled with peanut butter alone and stored at room temperature were found to have visible mold; therefore, this treatment was not served to the panelists for evaluation. This finding was not expected since the low total bacterial counts (log_{10} CFU/g = 1.74 for crust and 2.8 for filling) and low a_w (0.53) of these tarts indicated they should have been safe for human consumption. At week 6, all other treatments had acceptable ratings (≥ 5) for appearance, color, aroma, and flavor. Tarts filled with peanut butter alone and stored at room temperature, as well as its comparative reference sample, received texture and overall liking ratings below 5 at the 6-week evaluation, and therefore would no longer be considered to be acceptable.

No samples were served to sensory panelists at the 12-week evaluation since bacteriological analyses indicated that some of the tarts, notably those filled with peanut butter/strawberry jam combination and stored at elevated temperature, were unsafe for human consumption. These samples had total bacterial counts and yeast/mold counts greater than 3.0 log_{10} CFU/g as well as visible mold on both the surface and interior.

Nutrition analysis
Nutrition analysis of baked tarts with peanut butter/strawberry jam filling is shown in Table 11. The baked goods package for nutrition labeling included all mandatory nutrients except vitamin C, calories from fat, total fat by fatty acid analysis, saturated fat, trans fat, cholesterol, sodium, total carbohydrate, sugars, protein, vitamin A, calcium, and iron. Instead of serving size and servings per container as is customarily shown on a nutrition label, results were expressed on a 100-g basis.

**Conclusions**

Plans were to conduct quality measurements at 18 and 24 weeks. The microbiological data (total bacterial counts, yeast and mold counts) at 6 weeks indicated that the tarts were still acceptable, i.e., the number of colony-forming units (CFU/gram) for both crust and filling were below 3.0. At 12 weeks, however, CFU for some of the samples were greater than 3.0, and there was visible mold on both the surface as well as the interior of the tarts. Therefore, the tarts were considered unsafe for human consumption and were not served to panelists for sensory evaluation. The storage study was terminated at this point due to degradation of the product. It is unfortunate that the air pack/metallized film package employed in this phase of the study did not prevent mold spoilage of the product. A more robust regimen employing the use of mold inhibitors in the crust and filling as well as a modified atmosphere within each individual pouch is warranted to protect the product. A continuous process, such as that employed by commercial bakeries for processing/packaging of Pop-tarts® or other toaster pastries, rather than the batch process/package regimen employed in our pilot plant, may have extended the shelf life of the tarts for more than 12 weeks.
Table 7. Mean values for instrumental texture measurement, moisture content, water activity, total bacterial counts, and yeast and mold counts of baked peanut butter tarts packaged in metallized film and stored at room (22°C/50%RH) and elevated (32°C/70%RH) temperature for 0, 6, and 12 weeks.

<table>
<thead>
<tr>
<th>Penetration Force (N)</th>
<th>Peanut butter - room temperature</th>
<th>Peanut butter - elevated temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 week</td>
<td>6 week</td>
</tr>
<tr>
<td>Top Crust</td>
<td>3.77</td>
<td>6.72</td>
</tr>
<tr>
<td>Filling</td>
<td>1.17</td>
<td>1.34</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Crust</td>
</tr>
<tr>
<td>Filling</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water activity (a_w)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Crust</td>
</tr>
<tr>
<td>Filling</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total bacterial counts (log_{10} CFU/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crust</td>
</tr>
<tr>
<td>Filling</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Yeast and mold counts (log_{10} CFU/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crust</td>
</tr>
<tr>
<td>Filling</td>
</tr>
</tbody>
</table>

¹n.d. = not determined (samples were inadvertently discarded).
Table 8. Mean values for instrumental texture measurement, moisture content, water activity, total bacterial counts, and yeast and mold counts of baked peanut butter/strawberry jam tarts packaged in metallized film and stored at room (22°C/50%RH) and elevated (32°C/70%RH) temperature for 0, 6, and 12 weeks.

<table>
<thead>
<tr>
<th>Penetration Force (N)</th>
<th>Peanut butter + strawberry jam – room temperature</th>
<th>Peanut butter + strawberry jam – elevated temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 week</td>
<td>6 week</td>
</tr>
<tr>
<td>Top Crust</td>
<td>3.20</td>
<td>2.42</td>
</tr>
<tr>
<td>Bottom Crust</td>
<td>1.46</td>
<td>3.23</td>
</tr>
<tr>
<td>Filling</td>
<td>0.14</td>
<td>0.57</td>
</tr>
</tbody>
</table>

| Moisture Content (%)   |                                                |                                                     |
|                       | 0 week | 6 week | 12 week | 0 week | 6 week | 12 week |
| Crust                 | 10.33  | 13.30  | 7.94     | 10.33  | 10.88  | 18.13   |
| Filling               | 28.38  | 17.19  | 7.38     | 28.38  | 12.39  | 27.59   |

| Water activity (a_w)  |                                                |                                                     |
|                       | 0 week | 6 week | 12 week | 0 week | 6 week | 12 week |
| Crust                 | 0.692  | 0.774  | 0.624    | 0.692  | 0.707  | 0.873   |
| Filling               | 0.895  | 0.784  | 0.636    | 0.895  | 0.721  | 0.881   |

| Total bacterial counts (Log_{10} CFU/g) |                                                |                                                     |
|                                       | 0 week | 6 week | 12 week | 0 week | 6 week | 12 week |
| Crust                                 | 2.24   | 1.83   | 4.25     | 2.24   | 1.82   | 3.36    |
| Filling                               | 1.61   | 0      | 1.17     | 1.61   | 1.09   | 3.15    |

| Yeast and mold counts (Log_{10} CFU/g) |                                                |                                                     |
|                                       | 0 week | 6 week | 12 week | 0 week | 6 week | 12 week |
| Crust                                 | 2.24   | n.d.¹  | 4.26     | 2.24   | n.d.   | 3.36    |
| Filling                               | 1.61   | n.d.   | 2.98     | 1.61   | n.d.   | 4.89    |

¹ n.d. = not determined (samples were inadvertently discarded).
Table 9. Instrumental color characteristics of baked tarts packaged in metallized film and stored at room (22°C/50%RH) and elevated (32°C/70%RH) temperature for 0, 6, and 12 weeks.

<table>
<thead>
<tr>
<th></th>
<th>L* (lightness)</th>
<th>0 week</th>
<th>6 week</th>
<th>12 week</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBR</td>
<td>75.2c</td>
<td>78.2a</td>
<td>77.7</td>
<td></td>
</tr>
<tr>
<td>PBE</td>
<td>77.5ab</td>
<td>77.4ab</td>
<td>78.2</td>
<td></td>
</tr>
<tr>
<td>SPR</td>
<td>76.8b</td>
<td>77.8ab</td>
<td>77.3</td>
<td></td>
</tr>
<tr>
<td>SPE</td>
<td>78.6a</td>
<td>76.9b</td>
<td>76.3</td>
<td></td>
</tr>
<tr>
<td>Pr &gt; 0.05</td>
<td>0.0001</td>
<td>0.0331</td>
<td>0.0724</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>a* (redness)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PBR</td>
<td>2.9ab</td>
<td>2.7b</td>
<td>2.5c</td>
<td></td>
</tr>
<tr>
<td>PBE</td>
<td>3.6a</td>
<td>3.1a</td>
<td>3.0bc</td>
<td></td>
</tr>
<tr>
<td>SPR</td>
<td>2.2c</td>
<td>3.1a</td>
<td>3.3b</td>
<td></td>
</tr>
<tr>
<td>SPE</td>
<td>2.3bc</td>
<td>3.5a</td>
<td>4.3a</td>
<td></td>
</tr>
<tr>
<td>Pr &gt; 0.05</td>
<td>0.0003</td>
<td>0.0032</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>b* (yellowness)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PBR</td>
<td>27.0ab</td>
<td>27.3</td>
<td>26.7b</td>
<td></td>
</tr>
<tr>
<td>PBE</td>
<td>28.6a</td>
<td>27.9</td>
<td>27.9ab</td>
<td></td>
</tr>
<tr>
<td>SPR</td>
<td>25.1c</td>
<td>27.3</td>
<td>27.5b</td>
<td></td>
</tr>
<tr>
<td>SPE</td>
<td>25.9bc</td>
<td>27.9</td>
<td>28.8a</td>
<td></td>
</tr>
<tr>
<td>Pr &gt; 0.05</td>
<td>0.0006</td>
<td>0.3109</td>
<td>0.0057</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Chroma^2</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>PBR</td>
<td>27.1ab</td>
<td>27.4</td>
<td>26.9b</td>
<td></td>
</tr>
<tr>
<td>PBE</td>
<td>28.8a</td>
<td>28.0</td>
<td>28.0ab</td>
<td></td>
</tr>
<tr>
<td>SPR</td>
<td>25.2c</td>
<td>27.5</td>
<td>27.7b</td>
<td></td>
</tr>
<tr>
<td>SPE</td>
<td>26.0bc</td>
<td>28.1</td>
<td>29.2a</td>
<td></td>
</tr>
<tr>
<td>Pr &gt; 0.05</td>
<td>0.0006</td>
<td>0.2812</td>
<td>0.0035</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Hue angle^3</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PBR</td>
<td>83.9bc</td>
<td>84.3a</td>
<td>84.7a</td>
<td></td>
</tr>
<tr>
<td>PBE</td>
<td>83.0c</td>
<td>83.7b</td>
<td>84.0ab</td>
<td></td>
</tr>
<tr>
<td>SPR</td>
<td>85.2a</td>
<td>83.5b</td>
<td>83.3b</td>
<td></td>
</tr>
<tr>
<td>SPE</td>
<td>84.9ab</td>
<td>82.9c</td>
<td>81.5c</td>
<td></td>
</tr>
<tr>
<td>Pr &gt; 0.05</td>
<td>0.0003</td>
<td>0.0003</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>ΔE^4</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>PBR</td>
<td>10.1a</td>
<td>7.6c</td>
<td>8.0bc</td>
<td></td>
</tr>
<tr>
<td>PBE</td>
<td>8.4bc</td>
<td>8.2ab</td>
<td>7.7c</td>
<td></td>
</tr>
<tr>
<td>SPR</td>
<td>9.4ab</td>
<td>8.2b</td>
<td>8.8ab</td>
<td></td>
</tr>
<tr>
<td>SPE</td>
<td>7.6c</td>
<td>8.8a</td>
<td>9.7a</td>
<td></td>
</tr>
<tr>
<td>Pr &gt; 0.05</td>
<td>0.0051</td>
<td>0.0022</td>
<td>0.0025</td>
<td></td>
</tr>
</tbody>
</table>

^1PBR = Peanut butter-filled tart stored at room temperature; PBE = Peanut butter-filled tart stored at elevated temperature; SPR = Peanut butter and strawberry jam-filled tart stored at room temperature; SPE = Peanut butter and strawberry jam-filled tart stored at elevated temperature.

^2Chroma = (a*^2 + b*^2)^1/2

^3Hue angle = [tan^(-1)(b*/a*)] was calculated from +a* (redness) and +b* (yellowness) values.

^4ΔE (total color difference) = [((L* - L* reference)^2 + (a* - a* reference)^2 + (b* - b* reference)^2)^1/2.

The mean of four tarts stored for color analysis for each treatment was taken on day 0 and used as the reference factor in the calculation.
Table 10. Mean sensory ratings of baked tarts packaged in metallized film and stored at room (22°C/50%RH) and elevated (32°C/70%RH) temperature for 0 and 6 weeks.¹

<table>
<thead>
<tr>
<th></th>
<th>Appearance</th>
<th>Color</th>
<th>Aroma</th>
<th>Flavor</th>
<th>Texture</th>
<th>Overall Liking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 wk</td>
<td>6 wk</td>
<td>0 wk</td>
<td>6 wk</td>
<td>0 wk</td>
<td>6 wk</td>
</tr>
<tr>
<td>Peanut Butter (PB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference²</td>
<td>6.6</td>
<td>6.8</td>
<td>7.2</td>
<td>6.8</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Stored: room temperature</td>
<td>6.2</td>
<td>mold</td>
<td>6.6</td>
<td>mold</td>
<td>5.3</td>
<td>mold</td>
</tr>
<tr>
<td>Stored: elevated temperature</td>
<td>6.2</td>
<td>6.9</td>
<td>6.6</td>
<td>7.1</td>
<td>5.3</td>
<td>6.0</td>
</tr>
<tr>
<td>PB &amp; Strawberry jam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference</td>
<td>6.9</td>
<td>6.4</td>
<td>7.0</td>
<td>6.3</td>
<td>5.5</td>
<td>5.9</td>
</tr>
<tr>
<td>Stored: room temperature</td>
<td>6.7</td>
<td>7.0</td>
<td>6.9</td>
<td>7.1</td>
<td>6.0</td>
<td>6.4</td>
</tr>
<tr>
<td>Stored: elevated temperature</td>
<td>6.7</td>
<td>7.0</td>
<td>6.9</td>
<td>7.0</td>
<td>6.0</td>
<td>6.1</td>
</tr>
<tr>
<td><strong>Pr &gt; F</strong></td>
<td>0.68</td>
<td>0.79</td>
<td>0.54</td>
<td>0.56</td>
<td>0.48</td>
<td>0.93</td>
</tr>
</tbody>
</table>

¹ Mean values in a column not followed by the same letter are significantly different at P ≤ 0.05. Sensory attributes were evaluated on a 9-point scale, 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.
² Tarts that were freshly baked and evaluated on each sensory test date were used as a reference sample.
Table 11. Nutrition analysis of baked tarts with peanut butter/strawberry jam filling.

**Food Safety & Quality Solutions**
**SILLIKER, Inc.**
**Illinois Laboratory**
1304 Halsted Street, Chicago, IL 60610
708/756 3210 Fax 708/756 0049

TO:  Ms. Susan K. McWatters
    Agricultural Research Scientist
    Univ. of GA-Dept. of Food Sci.
    1109 Experiment Street-Melton Bld.
    Griffin, GA 30223

CERTIFICATE OF ANALYSIS

<table>
<thead>
<tr>
<th>COA No.</th>
<th>CHG-31786650-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supersedes:</td>
<td>None</td>
</tr>
<tr>
<td>COA Date</td>
<td>6/6/07</td>
</tr>
<tr>
<td>Page 1 of 4</td>
<td></td>
</tr>
</tbody>
</table>

Received From: Griffin, GA
Received Date: 5/24/07

Location of Test: (except where noted) Chicago Heights, IL

---

### Analytical Results

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Analytical Data Per 100 g</th>
<th>Analytical Data Per 100 grams</th>
<th>Rounded Data Per 100 grams</th>
<th>% Daily Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>455.8</td>
<td>455.8</td>
<td>460</td>
<td></td>
</tr>
<tr>
<td>Calories from Fat</td>
<td>225.8</td>
<td>225.8</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>Total Fat</td>
<td>26.08</td>
<td>26.08</td>
<td>25</td>
<td>38</td>
</tr>
<tr>
<td>Saturated Fat</td>
<td>5.91</td>
<td>5.91</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>Trans Fat</td>
<td>0.45</td>
<td>0.45</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cholesterol</td>
<td>34.1</td>
<td>34.1</td>
<td>35</td>
<td>12</td>
</tr>
<tr>
<td>Sodium</td>
<td>271</td>
<td>271</td>
<td>270</td>
<td>11</td>
</tr>
<tr>
<td>Total Carbohydrate</td>
<td>49.4</td>
<td>49.4</td>
<td>49</td>
<td>16</td>
</tr>
<tr>
<td>Dietary Fiber</td>
<td>2.05</td>
<td>2.05</td>
<td>2</td>
<td>6</td>
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<tr>
<td>Sugars</td>
<td>16.93</td>
<td>16.93</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Protein (F+L,25)</td>
<td>8.11</td>
<td>8.11</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Vitamin A</td>
<td>IU</td>
<td>76</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>Vitamin C</td>
<td>mg</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>mg</td>
<td>42.7</td>
<td>42.7</td>
<td>4</td>
</tr>
<tr>
<td>Iron</td>
<td>mg</td>
<td>2.1</td>
<td>2.1</td>
<td>10</td>
</tr>
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</table>

### Contributing Nutrients

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Analytical Data Per 100 g</th>
<th>Analytical Data Per 100 grams</th>
<th>Rounded Data Per 100 grams</th>
<th>% Daily Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>16.25</td>
<td>16.25</td>
<td>16.25</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>1.17</td>
<td>1.17</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td>Beta Carotene</td>
<td>IU</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td></td>
</tr>
<tr>
<td>Vitamin A % Beta Carotene</td>
<td>IU</td>
<td>78</td>
<td>78</td>
<td></td>
</tr>
</tbody>
</table>

*Contains less than 2% of the Daily Value of this nutrient.

N/A Not analyzed, as product is generally not considered a source of this nutrient.

The results of these tests relate only to the samples tested. This report shall not be reproduced except in full, without the written approval of the laboratory.
Table 11. (cont.)

![SILLIKER logo]

CERTIFICATE OF ANALYSIS

<table>
<thead>
<tr>
<th>COA No.</th>
<th>CHG-31786950-0</th>
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</thead>
<tbody>
<tr>
<td>Superseded</td>
<td>None</td>
</tr>
<tr>
<td>COA Date</td>
<td>6/8/07</td>
</tr>
<tr>
<td>Page</td>
<td>2 of 4</td>
</tr>
</tbody>
</table>

TO:
Ms. Susan K. McWatters
Agricultural Research Scientist
Univ. of GA-Dept. of Food Sci.
1109 Experiment Street-Mellon Bldg.
Griffin, GA 30223

| Location of Test: (except where noted) |
| Griffin, GA |
| 6/24/07 |

<table>
<thead>
<tr>
<th>Analytical Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUGAR PROFILE</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Fructose</td>
</tr>
<tr>
<td>Lactose</td>
</tr>
<tr>
<td>Sucrose</td>
</tr>
<tr>
<td>Glucose</td>
</tr>
<tr>
<td>Maltose</td>
</tr>
</tbody>
</table>

The results of these tests relate only to the samples tested. This report shall not be reproduced except in full, without the written approval of the laboratory.
### Analytical Results

<table>
<thead>
<tr>
<th>Fatty Acids</th>
<th>% Fatty Acid in Product (Weight/Weight Basis)</th>
<th>Laboratory ID: 308869364</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%Saturation</td>
<td>%MUFA</td>
</tr>
<tr>
<td>4:0 Butanoic (Butyric)</td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td>5:0 Pentanoic (Valeric)</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>6:0 Hexanoic (Caproic)</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>7:0 Heptanoic (Caprioic)</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>8:0 Octanoic (Caprylic)</td>
<td>0.008</td>
<td></td>
</tr>
<tr>
<td>9:0 Nonanoic (Petargonic)</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>10:0 Decanoic (Capric)</td>
<td>0.013</td>
<td></td>
</tr>
<tr>
<td>11:0 Undecanoic</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td>12:0 Dodecanoic (Lauroic)</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td>13:0 Tridecanoic</td>
<td>0.000</td>
<td></td>
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<tr>
<td>14:0 Tetradecanoic (Myristic)</td>
<td>0.076</td>
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</tr>
<tr>
<td>14:1 trans-Tetradecanoic</td>
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<td></td>
</tr>
<tr>
<td>14:1 Tetradecanoic (Myristoleic)</td>
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</tr>
<tr>
<td>15:0 Pentadecanoic</td>
<td>0.010</td>
<td></td>
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<tr>
<td>15:1 Pentadecenoic</td>
<td>0.000</td>
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<tr>
<td>16:0 Hexadecanoic (Palmitic)</td>
<td>3.340</td>
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<td>16:1 trans-Hexadecenoic</td>
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</tr>
<tr>
<td>16:1 Hexadecenoic (Palmitoleic)</td>
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<td>18:3 Octadecatrienoic (Miroctic)</td>
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<td>22:4 Docosatetraenoic (Beringoic)</td>
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<tr>
<td>22:5 8,11,14-Eicosatetraenoic (gamma)</td>
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<tr>
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<tr>
<td>20:1 11,14,17-Eicosatrienoic</td>
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The results of these tests relate only to the samples tested. This report shall not be reproduced except in full, without the written approval of the laboratory.
### Analytical Results

**FAT ANALYSIS BY GC**

<table>
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<th>Fatty Acids</th>
<th>% Fatty Acid in Product (Wt/Weight Basis)</th>
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<td>24:1 Tetracosanoic (Nervonic)</td>
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<td>22:3 Docosatrienoic</td>
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</tr>
<tr>
<td>22:5 Docosapentaenoic</td>
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<td>22:6 Docosahexaenoic</td>
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<td>% of Total Fatty Acid Concentration</td>
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<td>34.55</td>
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**FAT ANALYSIS BY GC - SUMMARY**

- Fat by Fatty Acid Profile: 25.08 (g/100g) Total Polysaturated Fatty Acids: 9.33 (g/100g)
- Total Saturated Fatty Acids: 0.81 (g/100g) Total Trans Fatty Acids: 0.45 (g/100g)
- Total Monounsaturated Fatty Acids: 6.28 (g/100g) Total Conjugated Fatty Acids: 0.01 (g/100g)

---

*The results of these tests remain the property of the suppliers issued. This report shall not be reproduced except in full, without written approval of the laboratory.*
Fig. 9. Moisture Content

Crust

Average MC

0.0  5.0  10.0  15.0  20.0

0 day  6 week  12 week

Time

PBR

SPR

PBE

SPE

Filling

Average MC

0.0  5.0  10.0  15.0  20.0  25.0  30.0

0 day  6 week  12 week

Time

PBR

SPR

PBE

SPE

Fig. 9. Average moisture contents for the crust and filling of baked tarts packaged in metallized film and stored at room (22°C/50%RH) and elevated (32°C/70%RH) temperature for 0, 6, and 12 weeks. PBR = Peanut butter-filled tart stored at room temperature; PBE = Peanut butter-filled tart stored at elevated temperature; SPR = Peanut butter/strawberry jam-filled tart stored at room temperature; SPE = Peanut butter/strawberry jam-filled tart stored at elevated temperature.
Fig. 10. Water Activity ($a_w$)

Fig. 10. Water activity ($a_w$) for the crust and filling of baked tarts packaged in metallized film and stored at room (22°C/50%RH) and elevated (32°C/70%RH) temperature for 0, 6, and 12 weeks. PBR = Peanut butter-filled tart stored at room temperature; PBE = Peanut butter-filled tart stored at elevated temperature; SPR = Peanut butter/strawberry jam-filled tart stored at room temperature; SPE = Peanut butter/strawberry jam-filled tart stored at elevated temperature.
Fig. 11. Total Bacterial Counts \( (\log_{10} \text{CFU/g}) \)

Crust

<table>
<thead>
<tr>
<th>Time</th>
<th>Log 10 CFU/g</th>
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<tbody>
<tr>
<td>Day 0</td>
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<tr>
<td>Week 6</td>
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<tr>
<td>Week 12</td>
<td>3.0</td>
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</table>

- PBR
- SPR
- PBE
- SPE

Filling

<table>
<thead>
<tr>
<th>Time</th>
<th>Log 10 CFU/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 0</td>
<td>0.0</td>
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<tr>
<td>Week 6</td>
<td>4.0</td>
</tr>
<tr>
<td>Week 12</td>
<td>5.0</td>
</tr>
</tbody>
</table>

- PBR
- SPR
- PBE
- SPE

Fig. 11. Total bacterial counts \( (\log_{10} \text{CFU/g}) \) for the crust and filling of baked tarts packaged in metallized film and stored at room (22\(^\circ\)C/50\%RH) and elevated 32\(^\circ\)C/70\%RH) temperature for 0, 6, and 12 weeks. PBR = Peanut butter-filled tart stored at room temperature; PBE = Peanut butter-filled tart stored at elevated temperature; SPR = Peanut butter/strawberry jam-filled tart stored at room temperature; SPE = Peanut butter/strawberry jam-filled tart stored at elevated temperature.
Fig. 12. Texture

**Top Crust**

![Graph showing penetration force (N) over time for top crust samples.]

**Bottom Crust**

![Graph showing penetration force (N) over time for bottom crust samples.]

**Filling**

![Graph showing penetration force (N) over time for filling samples.]

Fig. 12. Penetration force (N) for the top crust, bottom crust and filling of baked tarts packaged in metallized film and stored at room (22°C/50%RH) and elevated 32°C/70%RH) temperature for 0, 6, and 12 weeks. PBR = Peanut butter-filled tart stored at room temperature; PBE = Peanut butter-filled tart stored at elevated temperature; SPR = Peanut butter/strawberry jam-filled tart stored at room temperature; SPE = Peanut butter/strawberry jam-filled tart stored at elevated temperature.
Fig. 13. Instrumental Color

Fig. 13. Instrumental color characteristics of baked tarts packaged in metallized film and stored at room (22°C/50%RH) and elevated 32°C/70%RH) temperature for 0, 6, and 12 weeks. PBR = Peanut butter-filled tart stored at room temperature; PBE = Peanut butter-filled tart stored at elevated temperature; SPR = Peanut butter/strawberry jam-filled tart stored at room temperature; SPE = Peanut butter/strawberry jam-filled tart stored at elevated temperature.
References


Study 3. Optimizing Process Development of Peanut-based Pasta

Introduction

Georgia is the leading producer of peanuts in the United States, and current research efforts are focused on developing new food products utilizing this abundant commodity. One such area of focus is the use of peanut flour as a food ingredient. Many Asian and Caribbean-based cuisines use peanut flavor for a staple or important part of the flavor profile. With the addition of peanut butter or peanut flour to the noodles, a potentially protein- and vitamin-fortified noodle can be formed. This will allow for a healthier alternative noodle when compared with many of the current commercial types of wheat-based noodles.

Objectives

The overall objective of this project was to develop a peanut-based pasta product using light (LR), medium (MR), and dark (DR) roasted peanut flour and dark roasted peanut cake (PC). Specific objectives were to: (1) evaluate the quality attributes of peanut pasta formulations and (2) evaluate the stability of dried peanut pasta stored at room temperature.

Materials and Methods

Light, medium, and dark roasted partially defatted peanut flours and dark roasted peanut cake (12%) were obtained from Golden Peanut Company, 100 North Point Center East, Suite 400, Alpharetta, GA, 30022. The pasta formulation was based on last year’s research findings and contained a mixture of peanut flour (25%), corn flour (10% Masa.), and semolina flour (65%, Bobs Red Mill Natural Foods, 5209 S. E. International Way, Milwaukie, OR, 97222). Peanut pasta dough was made by adding salt and an appropriate amount of water into the flour mixture manually and then passing through an extruder (Hobart Model N-50, Commercial Food Preparing Machine, Troy, OH) for final mixing. Peanut pasta dough was covered with plastic film and allowed to rest for 20 min. Pasta was then made by passing the dough through the same extruder with a Kitchen Aid pasta maker attachment (SNPA & FGA, Kitchen Aid, Shelton, CT). The pasta was either cooked directly or dried in an oven to produce a shelf-stable product. Fresh pasta was cooked in boiling water for three min before color, texture, and moisture content were measured. To make dried pasta, fresh pasta was dried in a convection oven at 200°F (93°C) for 15 to 30 min. Dried pasta was stored in brown paper bags at room temperature before further evaluation. After 5 months of storage, stored-dried pasta was cooked and the moisture content, color, and texture were compared with a set of fresh-cooked and dried-cooked pasta samples.

Moisture content was measured on a 5 g sample using method 925.05, Official Methods of Analysis of AOAC International, 17th Ed., Association of Official Analytical Chemists, Arlington, VA.

Textural quality was measured using an Instron universal testing machine (model 1122, Instron Corp., Canton, MA) as described by Oh et al. (1983) at a crosshead speed of 20 mm/min and a chart speed of 50 mm/min. Five strands of noodles suspended on a sample holder were cut crosswise using a blade (1 mm thick) attached to the crosshead. Maximum cutting force (N) and energy to cut (mJ) were interpreted as peak height and peak area from the force-deformation curves, respectively.

Hunter color values (L*, a*, b*) were determined with a MiniScan XE Plus colorimeter (Hunter Associates Laboratory, Inc., Reston, VA, USA). Psychometric color terms involving
chroma, saturation index ($\Delta E$), hue angle ($\tan^{-1} b/a$) were calculated from $L^*$, $a^*$ and $b^*$ values (Anon., 1979).

**Results and Discussion**

Fresh pasta all had similar moisture content (29 to 32%) which increased after cooking (63 to 67%, Table 1). Fresh pasta also had similar color attributes as fresh-cooked pasta from the same formulation. Dried peanut pasta all had moisture content around 8% regardless of degree of roasting. Dried pasta made from peanut cake and 100% semolina flour had a moisture content of 13.9% and 15.6%, respectively. All dried samples were also stable over the 5-month storage period. Moisture content of cooked pasta from dried pasta was generally lower than from fresh pasta. Storage at room temperature for 5 months did not affect the moisture content of cooked pasta when compared with the fresh-cooked pasta prepared 5 months earlier.

Pasta made with addition of peanut flour was darker (lower $L^*$ values) than the pasta made with 100% semolina (Table 2). Drying did not affect the color of dried pasta when compared with the fresh pasta. However, dried-cooked pasta was darker than fresh-cooked pasta from the same formulation. Dried-stored-cooked pasta was darker than the dried-cooked pasta from the same formulation. Pasta made with 100% semolina flour was yellow in color (hue angle of 87 to 90°) where as peanut pasta was browner in color (hue angle of 63 to 73°) regardless of formulation. Psychometric color terms of peanut pasta were also not affected by the treatment.

Another set of fresh and dried peanut pasta [light (LR), medium (MR), and dark (DR) roasted peanut flour] and pasta made from 100% semolina flour (control) were prepared at the time when stored-dried pasta was evaluated (experiment 2). In general, dried-cooked pasta had lower moisture content than the fresh-cooked pasta (Table 1). Among the three peanut pasta formulations, pasta made with DR peanut flour had the lowest moisture content whereas pasta made with LR peanut flour had the highest moisture content. Stored-dried-cooked pasta also had similar moisture content to the fresh-cooked pasta from the same formulation. Cooked pasta from different stages of processing (fresh-cooked, dried-cooked, and stored-dried-cooked) had no significant difference in the degree of lightness (Table 2). However, among the three peanut pasta formulations, pasta made with DR peanut flour was the darkest whereas pasta made with LR peanut flour was the lightest.

Cutting force (N) and cutting energy (mJ) of cooked pasta are reported in Table 3. Fresh-cooked pasta required the least amount of force (1.69 to 2.23 N) to cut followed by dried-cooked pasta (2.39 to 4.6 N). The stored-dried-cooked pasta required the highest cutting force (4.5 to 8.0 N) and was the firmest. Within each treatment, pasta made with 100% semolina flour required the highest force and energy to cut. Within the same treatment, texture quality of peanut pasta was similar.
Table 1. Moisture content of cooked pasta from various treatments.

<table>
<thead>
<tr>
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<th>Experiment Two</th>
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<td>Formula</td>
<td>Moisture content (%)</td>
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<tr>
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¹Treatments (100% semolina or peanut mixtures): Fresh pasta = uncooked raw noodle; Dried pasta = fresh pasta dried at 200°F for 15 to 30 min in convection oven; Fresh-cooked pasta = raw noodle cooked in boiling water for 3 min and drained; Dried-cooked pasta = Dried pasta cooked in boiling water for 3 min and drained; Dried-stored-cooked pasta = Dried pasta stored at room temperature in paper bag for ~5 months, cooked in boiling water for 3 min and drained; Commercial control = Mueller’s spaghetti cooked according to package directions and drained.

²Formulas contained 65% semolina flour, 10% masa flour and 25% partially defatted peanut flour (12% fat): LR (light roast), MR (medium roast), DR (dark roast), PC (dark roast peanut cake, milled).

³Experimental control = 100% semolina flour (SEM).

⁴Commercial control = Mueller’s spaghetti.
Table 2. Color measurements of cooked pasta from various treatments.

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¹Treatments (100% semolina or peanut mixtures): Fresh pasta = uncooked raw noodle; Dried pasta = fresh pasta dried at 200°F for 15 to 30 min in convection oven; Fresh-cooked pasta = raw noodle cooked in boiling water for 3 min and drained; Dried-cooked pasta = Dried pasta cooked in boiling water for 3 min and drained; Dried-stored-cooked pasta = Dried pasta stored at room temperature in paper bag for ~5 months, cooked in boiling water for 3 min and drained; Commercial control = Mueller’s spaghetti cooked according to package directions and drained.

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³Experimental control = 100% semolina flour (SEM).

⁴Commercial control = Mueller’s spaghetti.
Table 3. Texture measurements of cooked pasta from various treatments.

<table>
<thead>
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<th>Treatment</th>
<th>Experiment One</th>
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<th>Experiment Two</th>
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<tbody>
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<td>Formula</td>
<td>Cutting force (N)</td>
<td>Cutting energy (mJ)</td>
<td>Modulus (mpa)</td>
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1Treatments (100% semolina or peanut mixtures): Fresh pasta = uncooked raw noodle; Dried pasta = fresh pasta dried at 200°F for 15 to 30 min in convection oven; Fresh-cooked pasta = raw noodle cooked in boiling water for 3 min and drained; Dried-cooked pasta = Dried pasta cooked in boiling water for 3 min and drained; Dried-stored-cooked pasta = Dried pasta stored at room temperature in paper bag for ~5 months, cooked in boiling water for 3 min and drained; Commercial control = Mueller’s spaghetti cooked according to package directions and drained.

2Formulas contained 65% semolina flour, 10% masa flour and 25% partially defatted peanut flour (12% fat): LR (light roast), MR (medium roast), DR (dark roast), PC (dark roast peanut cake, milled).

3Experimental control = 100% semolina flour (SEM).

4Commercial control = Mueller’s spaghetti.
References
