

# SENSORY AND GC PROFILES OF ROASTED PEANUTS: THEIR RELATIONSHIPS TO CONSUMER ACCEPTABILITY AND CHANGES DURING SHORT STORAGE

by

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(Under the Direction of Koushik Adhikari)

## ABSTRACT

The objectives of this study were to determine the drivers of consumer acceptability for freshly roasted peanuts as well as the effects of short storage on sensory and GC profiles.

Normal-oleic Georgia 06G kernels, high-oleic Georgia 13M kernels, Runner (mixed) in-shell & kernels, and Virginia (mixed) in-shell & kernels were medium-roasted and stored for 0, 4 and 8 weeks at 21 °C. Consumer overall liking was positively correlated with crispiness, crunchiness, roasted peanutty flavor and sweet taste while had a negative correlation with overall oxidized flavor. After 8 weeks, an apparent decrease in consumer overall liking was only found in in-shell Virginia. 13M was significantly preferred over 06G during this period. GC results indicated a significant increase in total aldehyde and alcohol content with a decreasing trend in the levels of total pyrazine. But these changes did not cause significant difference in most of related attributes in descriptive results.

INDEX WORDS:     Roasted peanuts, High-oleic V.S normal oleic, In-shell Runner V.S  
                         Virginia, Sensory, GC

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## CHAPTER 1

### INTRODUCTION

Peanuts (*Arachis hypogaea*) are widely grown worldwide. As a major crop in the United States, peanuts grow in 15 states. Among them, Georgia has the largest proportion.

Roasted peanuts are important peanut products in the United States. Roasting processing provides peanuts with pleasant sensory attributes through mainly Maillard reaction. This complicated reaction produces a lot of volatile compounds. Pyrazines are heterocyclic nitrogen-containing compounds formed from the Strecker degradation in Maillard reaction. This group of volatiles are mostly studied and have been considered to be responsible for roasted flavors (Baker and others 2003; Buckholz and others 1981; Maga and others 1973; Warner and others 1996; Williams and others 2006; Liu and others 2011).. Mason and Johnson (1966) firstly suggested the possible roles of pyrazines in roasted peanut flavor. Buckholz and others (1981) found that 2-ethyl-6-methyl pyrazine and 2-ethyl-3-methyl pyrazine were strongly correlated with consumer acceptability of roasted peanuts. Baker and others (2003) revealed that 2,5-dimethylpyrazine was the best predictor for the measurement of roasted peanut flavor.

Aldehydes are another key compounds affecting the flavor of roasted peanuts. They are mainly the lipid oxidation products developed with storage. Peanuts have a high lipid content, which make their products get oxidized easily. These oxidation products will further cause the loss of pleasant sensory attributes. Flavor fade is a major problem in roasted peanuts. During storage, the positive attributes (especially roasted peanutty flavor) associated with freshly roasted peanuts gradually diminishes accompanied by the development of off-flavors (Hui and others

2010). Warner and others (1996) indicated that the flavor fade was caused by masking of pyrazines and other roasted peanut flavor compounds by aldehydes. However, Bett and Boylson (1992) concluded that the loss of roasted flavor was more possibly caused by degradation of pyrazines. Their results were in agreement with others work ( Reed and others 2002; Williams and others 2006).

High-oleic peanuts are developed to extend the shelf life of roasted peanuts.

Researchers have indicated that high-oleic varieties were able to persist roasted peanutty flavor longer during storage. (Braddock and others 1995; Nepote and others 2006; Pattee and others 2002; Reed and others 2002; Talcott and others 2005). This advantage was also found in large-seed in-shell Virginia peanuts (Mozingo and others 2004). Moreover, Reeds and others (2002) indicated that high oleic trait offered roasted peanuts more resistance to the effects of storage humidity conditions. However, no significant difference in consumer acceptability was found between high-oleic and normal-oleic roasted peanuts (Nepote and others 2006; Riveros and others 2009)

Therefore, this study involved six roasted peanut samples including high-oleic roasted peanuts and in-shell roasted peanuts to:

- 1) determine the drivers of consumer acceptability for freshly roasted peanuts and their sensory and GC profiles;
- 2) identify and compare the effects of storage on consumer acceptability, sensory attributes and GC volatiles.

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## CHAPTER 2

### LITERATURE REVIEW

#### **Peanuts**

Peanuts (*Arachis hypogaea*) are self-pollinating plants. They are also called as groundnuts, because after pollination the flower stalk elongates rapidly towards the ground, which pushes the ovary into the ground to develop legume pods. Peanuts are thought to have originated in South America and were spread worldwide by European traders. In the United States, peanuts were mainly used as animal feed until the 1930s. Because of two World Wars and the research of Dr. George Washington Carver, the production of peanuts increased significantly (McArthur and others 1982) .

Now peanuts become a major crop worldwide with total production of 29 million metric tons per year. The United States is the world's third largest producer, having a share of 8% of overall production. Peanut grows in 15 states in the United States: Georgia, Texas, Alabama, North Carolina, Florida, Virginia, Oklahoma, New Mexico, South Carolina, Louisiana, Arizona, Arkansas, Mississippi, California, and Tennessee. Among them, Georgia grows the largest proportion with approximately 49 percent of the total national production (Figure.2.1).

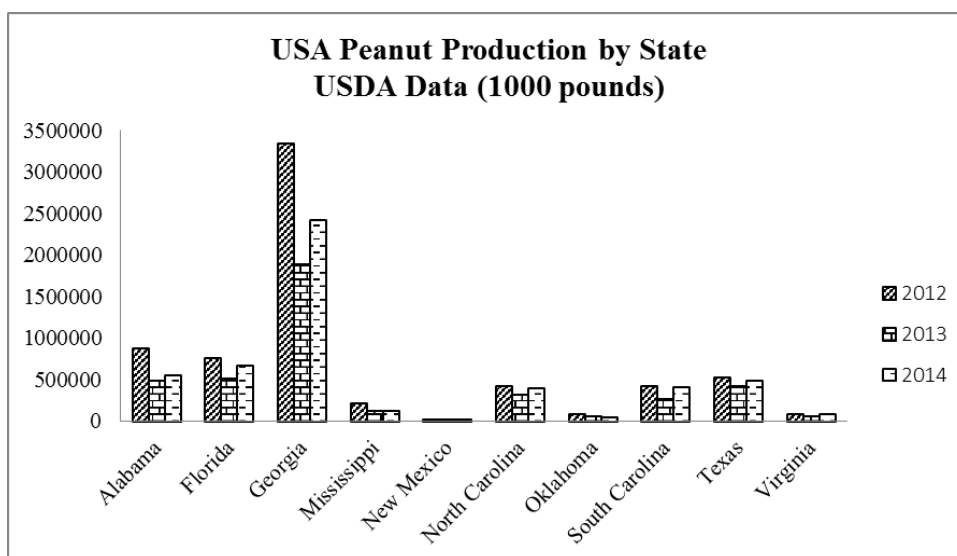


Figure 2.1: The U.S. peanut production by state (USDA 2015)

There are four main types of peanuts grown in the United States: Runner, Virginia, Spanish and Valencia.

Runner peanuts are preliminarily grown in Georgia, Alabama and Florida. Runner group has uniform kernel size and is majorly used for processing, especially for peanut butter. They have been the dominant type since 1979 and now account for 80 percent of the peanuts grown in the United States (National Peanut Board 2014; McArthur and others 1982). The popularity of Runner type is due to its good flavor and roasting characteristics as well as the introduction of Florunner which dramatically increases the peanut yields (McArthur and others 1982).

Virginia peanuts are preliminarily produced in Virginia and South Carolina. They have the largest kernels covered with red skin. Virginias are commonly used for in-shell roasted peanuts. Some larger kernels are also sold as salted peanuts.

Spanish peanuts are used to be the largest-grown type in the United States. They are typically produced in Texas and Oklahoma. Spanish peanuts have small kernels with red-brown

skin. They are predominantly processed into peanut butter, salted peanuts and peanut candy. Also, this group contains higher amount of oil compared to other types (McArthur and others 1982).

Valencia peanuts are mainly grown in New Mexico. They have three or more kernels in one pod and bright red skin. This group has a very sweet flavor and is usually used for in-shell roasted peanuts, peanut butter as well as boiled peanuts.

### **Peanut products**

Peanut butter is the most important peanut product in the United States which is consumed in 94 percent of the U.S. households (National Peanut Board 2015). Peanut snack is another major use in domestic market. According to a survey conducted by He and others (2005), snack peanuts were most frequently consumed at home and at work, usually with soft drinks or beer.

In-shell roasted peanut is a major kind of peanut snack preferred by consumers especially during sports activities. Many attributes influence consumers' attitudes towards it, including healthiness, fat, taste, pod appearance and kernel color. However, only taste affects the actual consumption (Moon 1999; Rimal and Fletcher 2000; Rimal and Fletcher 2002; Sanders 2003). After roasting of in-shell peanuts, it often takes 6 to 8 weeks to handle and ship products to the market (Mozingo and others 2004). Therefore, shelf life can be a very important factor to the quality of in-shell peanuts.

### **Roasted peanut processing**

#### **Harvesting**

Peanut harvesting consists of six steps: field preparation, vine clipping, digging, shaking, windrowing, and combining. All these operations are highly mechanized in all

producing areas of the United States (Pattee and Young 1982).

The optimum digging time can be predicted based on the change in the inside color of the hull. As pods mature the inside of the hull darkens. When 75% of the pods are dark, the peanuts can be dug (Pattee and Young 1982).

### Curing

Curing is very important in peanut processing. In this step, the moisture content of peanuts is reduced to prevent the formation of mold and aflatoxin.

Curing usually has two stages -field drying and artificial drying. After digging, peanuts are left in the inverted windrows to 18 to 24% moisture content. Then, peanuts are combined and put into mechanical dryers to 8%-10% moisture content (Woodroof 1983). The temperature and humidity of the air flow should be carefully controlled. High temperature can cause off-flavor of peanuts and low humidity can result in over-dry of the bottom-layer peanuts (Wilkin 2013). Usually, the temperature of drying air should not exceed 35 °C with a moisture reduction rate of 0.5% per hour until the average moisture content down to about 8.5% (Wilkin 2013).

### Cleaning and storage

Peanut pods are cleaned by separating foreign materials and then washing in wet, coarse sand to remove stains and discoloration. After cleaning, peanuts are stored as shelled or unshelled nuts at 2 °C - 6 °C with 60% - 70% relative humidity (Table 2.1).

Shelled peanuts are more susceptible to deterioration than unshelled peanuts due to the removal of protective hull, possible damage to the seed coat, broken and bruised kernels etc. Studies have verified in-shell seeds deteriorated more slowly than the shelled seeds under different storage conditions by germination trials, but the extent of differences varied between cultivars (Navarro and others 1989; Rao and others 2002). But in terms of seed longevity, there

is no advantage in in-shell stored peanut seeds (Mathur and others 1956; Navarro and others 1989).

Table 2.1: Recommended storage condition for peanut seeds (Woodroof 1983)

Treatment	Temperature	Humidity	Shelf life
In-shell	0 – 10 °C	65-75% RH	9-24 months
Shelled	0 – 10 °C	60-70% RH	9-18 months
Vacuum or gas packed	0 – 10 °C	As packed	1-2 years
Frozen	-17.2 °C	Not controlled	3-4 years

### Roasting

Roasting can improve sensory quality by developing aroma and increasing crispness and crunchiness. Peanuts are dry-roasted by either continuous or batch process. Continuous roaster can reduce labor work by using a conveyor belt or gravity feed to push peanuts into a stream of countercurrent hot steam. Compare to it, roasting in batch have the advantage of adjusting the roasting condition for peanuts with different moisture content and varieties (Woodroof 1983). The batch procedure involves a gas-fired revolving oven which is set to 426 °C. A 400 lb batch of peanuts are heated to 160 °C and held at this temperature for 40-60 min. (Woodroof 1983).

At the first 5-10 min of roasting, peanuts rapidly lose water. As the rate of moisture removal begins to decrease, the products begin to darken rapidly. When peanuts are heated to temperatures in excess of 150 °C, chemical reactions are initiated to produce roasted flavor and color change (Davidson and others 1999). Saklar and others (2001) found that roasting at 125 °C

or below always produced unacceptable products. They also pointed out that at low air velocity (0.3 m/s), acceptable hazelnuts were roasted at about 165 °C – 179 °C for 20 – 25 min.

A number of physiochemical changes are involved in this step, including heat exchange, chemical reactions and drying (Saklar and others 2001). Among them Maillard reaction is the main reaction. This reaction is a whole network of various reactions and the chemistry behind is very complicated, thus its mechanism is still a controversial issue.

In general, the mechanism can be described in three main phases (Hodge 1953; Martins and others 2000; van Boekel 2006). In the initial phase, free amino acid reacts with a reducing sugar to form an N-substituted glycosylamine which undergoes either Amadori rearrangement/Heyns rearrangement to form ketosamines/ aldosamine. In intermediary phase, three types of reactions can take place: 1,2-enolization, 2,3-enolization and fragmentation. The direction depends on PH, temperature and heating time. Strecker degradation is an important reaction in this stage which can form many aroma compounds and their precursors. The final stage leads to a wide range of reactions including dehydration, fragmentation, cyclization and polymerization. Consequently high molecular weight brown-colored substances (melanoidins) are formed. Figure 2.2 indicates how the flavor compounds formed in the Maillard Reaction.

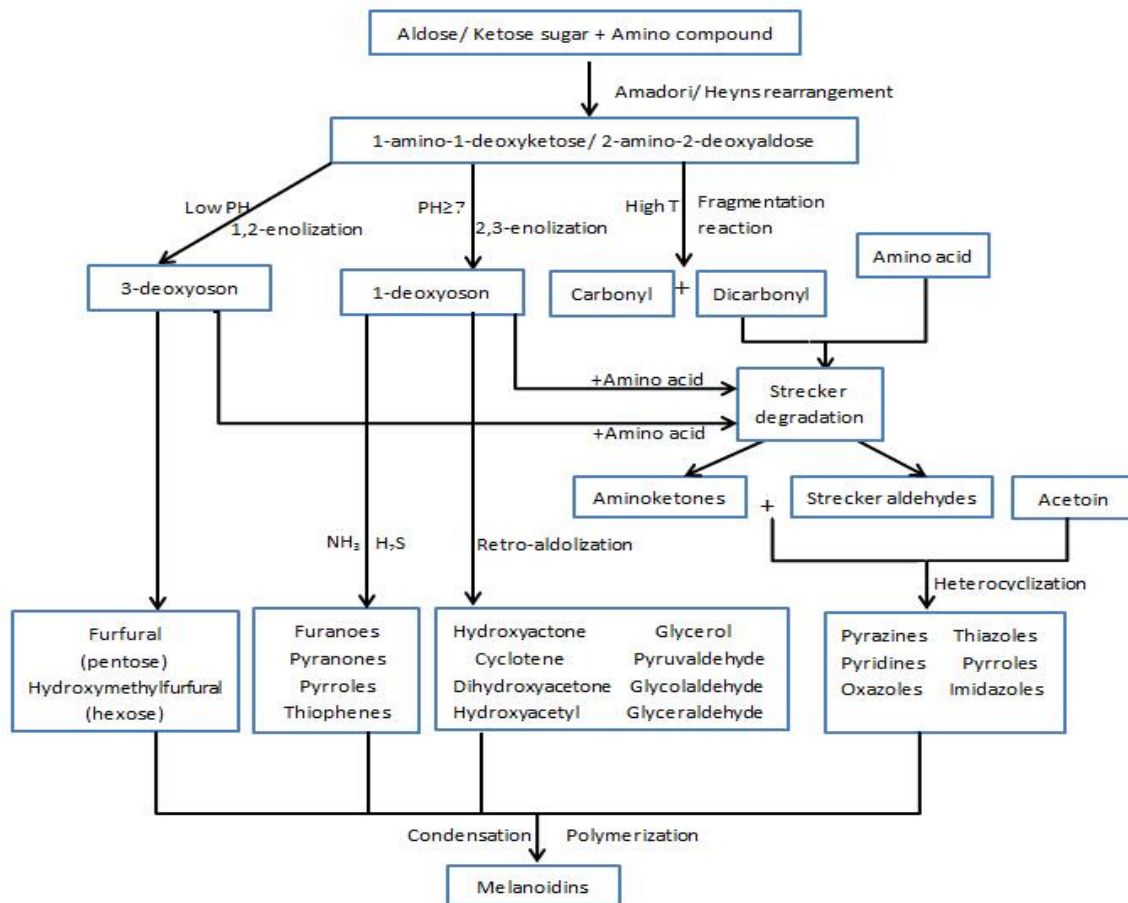


Figure 2.2: General overview of Maillard reaction showing flavor compounds in major steps (Hodge 1953; Martins and others 2000; Soee and others 2004; van Boekel 2006)

### Formation of pyrazines

During roasting process, a lot of volatile compounds are formed via mainly Maillard reaction. Among them, pyrazines are mostly studied. Pyrazines are volatile heterocyclic nitrogen-containing compounds which are thought to be the major flavor compounds responsible for roasted peanut flavor (Baker and others 2003; Buckholz and others 1981; Maga and others 1973; Warner and others 1996; Williams and others 2006; Liu and others 2011). Figure 2.3 shows a basic structure of pyrazine.

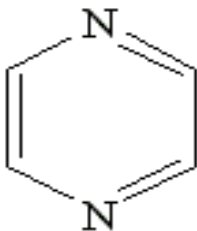


Figure 2.3: Basic structure of pyrazine

Theories for the formation of pyrazines are different based on their types. 2,5-Dimethylpyrazines are important pyrazines in roasted peanuts. Newell and others (1967) proposed a hypothetical mechanism for its formation. This mechanism involves the addition of an amino acid to the anomeric carbon atom of an aldose followed by 1,2-enolization and yield of Sciff base cation. The Sciff base cation decarboxylates to the imine which can hydrolyze to a dieneamine. Then an unsaturated ketoamine is yielded by 1,2-enolization and undergoes retro-aldol condensation to form amino acetone. At last, two molecules of amino acetone condense to yield 2,5-dimethylpyrazines.

In the case of alkenyl-substituted pyrazines, a more complex route is involved and its formation is possibly through dehydration of corresponding hydroxypyrazines. As for acetyl and methyl, the mechanism involves the condensation of a browning reaction product *cis*-methyl reductone with glyoxal or pyruvaldehyde and amno acids (Maga and others 1973).

Although there are different theories exist, amino acids and sugars are considered to be the major precursors of pyrazines and react in a 2-to-1 stoichiometric ratio during roasting (Newell and others 1967). Among the amino acids, aspartic acid, glutamic acid, glutamine, histidine, asparagine, and phenylalanine are the precursors of typical peanut flavor while threonine, tyrosine and lysine are precursors of atypical peanut flavor (Newell and others 1967).



Monosaccharides are of extreme importance in the formation of pyrazine compounds in roasted peanuts. Compared to glucose, fructose has higher rates of yielding pyrazines. The reason may be both that fructose forms carbon fragmentation units more readily than glucose and that fructose react more readily with primary amines than glucose (Koehler and Odell 1970; Newell and others 1967). Sucrose is the predominant sugar in peanuts and can be hydrolyzed to glucose and fructose in roasting process. A high level of sucrose can lead to a darker roast color due to caramelization reaction (Pattee and others 1982).

Koehler and Odell (1970) studied the factors for the yields of pyrazines in a sugar-amine model system. They found that pyrazine formation started at 100 °C and the production rapidly increased as temperature increased up to 150 °C. Above this temperature, the yields varied a lot due to destruction of pyrazines after formation. When the reaction was carried at 120 °C, the production of pyrazines increased rapidly as the heating time increased up to 24 h and then leveled off until 72 h. They also pointed out that addition of base can catalyzed the reaction because both of the increased reactivity of amino groups towards carbonyl group and of the increased rearrangement and fragmentation of sugars. Reineccius and others (1972) found that in roasted cocoa beans pyrazines rapidly and linearly formed at 150 °C during the first 30min of processing. Recently, Liu and other (2011) used roasted peanut oil and reported that pyrazine compounds became the predominant volatiles that contributed to nutty and roasty aroma after 30min.

### **Factors affecting the quality of roasted peanuts**

#### Maturity

Peanut maturity has significant effects on yield and overall quality of peanuts. Very immature peanuts always contain more precursors of atypical flavor which will form a high level

of off-flavor during processing and storage (Newell and others 1967). As peanuts mature, the intensity of the roasted peanutty flavor and sweet aromatic flavor increase, while the intensity of painty attribute decreases. Also the lots with a higher percent of mature peanuts have more potentiality of long shelf life (McNeill and Sanders 1999). Also, immaturity has been associated with the fruity fermented flavor which is a main off-flavor detected by consumers (Greene and others 2007). Sanders and others (1989) studied the interaction of maturity and curing temperature on the descriptive flavor of peanuts and found that immature peanuts cured at higher temperatures had the lowest intensity of roasted peanutty and sweet aromatic with the highest intensity of fruity fermented, painty, sour, and bitter.

### Color

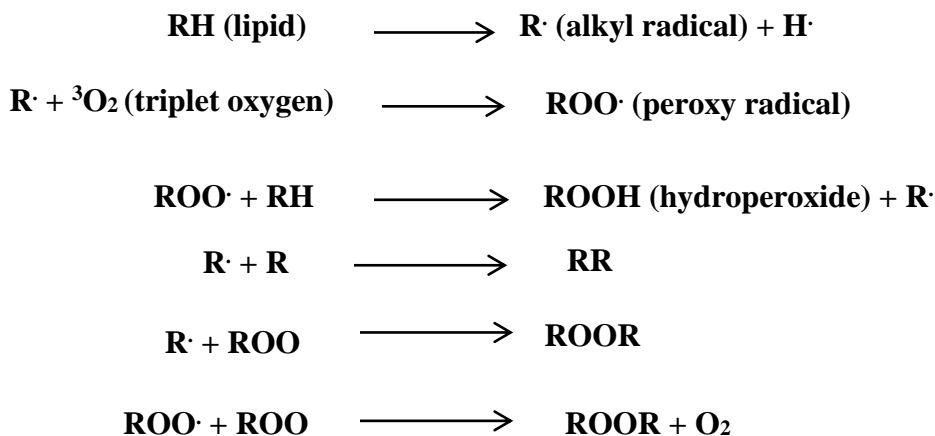
Color of the peanuts has been associated with its maturity and its roasting degree. Tannins and carotenoids are the dominant contributors to the raw peanuts color (Ahmed and Young 1982). Researchers found that the concentration of carotenoid pigment are highest in mature seeds and decreases with increasing maturity (Pattee and others 1969a). During roasting, brown pigments increase as the progress of sugar-amino acid reactions. The major changes in color development occur after about 6 - 8 min of roasting. At this time, the value of lightness scale decreases (Moss and Otten 1989). Increased roasting time and temperature offer an additional brown color caused by sugar caramelization. Also, a desirable brown color can be associated to the good quality of roasted peanuts by the consumers and the darker color will give them the impression of burnt. Therefore, it is important to determine the optimum degree of roasting. Color measurement is a simple and nondestructive method for this purpose. Pattee and others (1991) suggested that peanuts should be roasted to CIELAB  $L^*$  values of 58-59 or Hunter color  $L$  values of 51-52 when optimum roasted peanut attribute is of primary interest.

### Moisture

Moisture content plays an important role in color and flavor development during roasting. Under the same roasting conditions, products with higher initial moisture contents have more soluble carbohydrates than those with lower initial moisture contents, which tend to form darker color during roasting (Chiou and others 1991; Chiou and Tsai 1989). Immediate cooling after roasting is necessary to prevent further moisture loss due to the residual heat in nuts (Moss and Otten 1989).

### Storage

Lipid oxidation. Lipid oxidation is a major concern in food industry. Even with very low lipid (<1%), food products are still susceptible to oxidation (Wąsowicz and others 2004). This problem is especially true in peanuts because of their high lipid contents which vary from 44% to 56% in the four major market types (Runner, Virginia, Valencia and Spanish) (Pattee and others 1995). The process of autoxidation is free-radical reactions with three stages: initiation, propagation and termination.



In the initiation step, free alkyl radical is formed by the abstraction of  $\alpha$ -hydrogen from a methylene group in an unsaturated lipid molecule. Free alkyl radicals couple with triplet

oxygen in the propagation step to form peroxy radicals which further react with unsaturated fatty acids to form the unstable initial products – hydroperoxides. At last, the alkyl radicals and peroxy radicals interact together to form non-radical products.

Hydroperoxides is a primary non-volatile oxidation products during the oxidation process. They will decompose to various volatile aromatic secondary products including alcohols, aldehydes, ketones, furans, organic acids, and hydrocarbons. Most of these compounds are always associated with off-flavors. However, the threshold of hydrocarbons is very high (90-2150 ppm), which makes this group have least possibility to be responsible for off-flavors (Akoh and Min 2002). Table 2.2 shows the flavor perceptions for some lipid oxidation products.

Table 2.2 Flavor perception of volatile compounds formed by lipid oxidation (Min.D.B. and Bradley 1992)

Flavor perception	Responsible compounds
Cardboard	<i>trans,trans</i> - 2,6-Nonadienal
Oily	Aldehydes
Painty	Pent-2-enal, aldehydes
Fishy	<i>Trans,cis,trans</i> -2,4,7-Decatrienol, oct-1-en-3-one
Grassy	<i>Trans</i> -2-Hexenal, nona-2,6-dienal
Deep-fried	<i>Trans,trans</i> -2,3-Decandienal

*Peanut Flavor Fade*. Flavor fade is defined as loss of positive attributes associated with fresh-roasted peanuts accompanied by the development of off-flavors during storage (Hui and others 2010). There are two mechanisms about flavor fade. Warner and others (1996) considered

the flavor changes resulted from masking of pyrazines and other roasted peanut flavor compounds by large quantities of low-molecular weight aldehydes because the concentration of pyrazines (2-methyl pyrazine, 2,6-dimethyl pyrazine, 2,3,5-trimethyl pyrazine, 2-ethyl-5-methyl and 6-methyl pyrazine) that represents for roasted flavor did not reduce during storage while hexanal, heptanal, octanal and nonal increased. However, Bett and Boylson (1992) reported the content of alkylpyrazines decreased significantly during storage especially in the early storage time. Therefore, they concluded that the loss of peanut flavor was more possibly caused by the degradation of pyrazine. This mechanism is also supported by the work of other scientists (Reed and others 2002; Williams and others 2006). The lower pyrazine level may be the results of flavor entrapment or degradation by free radicals and hydroperoxides from lipid oxidation (Williams and others 2006).

#### High-oleic peanuts

Given the oxidation problem in peanuts, high-oleic varieties have been developed to increase the shelf life. Oleic acid is a monounsaturated fatty acid. As its amount increases, the lipid will have less double bonds. Therefore high-oleic peanuts will oxidize at a slower rate compared to normal-oleic peanuts. The shelf life of high-oleic roasted peanuts can be 2 to 25 times longer than normal-oleic peanuts depended on the cultivars, processing and storage conditions and estimation models (Braddock and others 1995; Mozingo and others 2004; Nepote and others 2006; Reed and others 2002). Moreover, high-oleic acid peanuts were reported to have more roasted peanut flavor and persist longer during storage compared to normal-oleic acid peanuts (Braddock and others 1995; Nepote and others 2006; Pattee and others 2002; Reed and others 2002; Talcott and others 2005).

Manzingo and others (2004) pointed out high-oleic trait can also extended shelf-life of large-seed Virginia in-shell peanuts. They also found salted processing had few effects on the high-oleic in-shell peanuts, while it made normal-oleic in-shell peanuts oxidized much more rapidly.

Reeds and others (2002) found water activity had more influence on normal (Florunner) oleic acid peanuts compared to high (SunOleic 97R) oleic acid peanuts because of the low levels of oxidation in high-oleic peanuts during first 7 weeks. They pointed out roasted peanut flavor lost less at higher storage water activity ( $a_w = 0.6$  VS  $a_w = 0.19$ ). The GC results also showed that normal-oleic peanuts at low  $a_w$  treatment had higher levels of aldehydes and decreased content of pyrazines. However, Bakers and others (2002) stored high-oleic roasted peanuts at 25 °C for 14 weeks and concluded the roasted-flavor intensity of high-oleic peanuts maintained best at lowest water activity ( $a_w = 0.12$ ) and worst at highest water activity ( $a_w = 0.64$ ).

## **Sensory**

### **Sensory testing**

Sensory evaluation plays a very important role in food industry, providing insight to food development and market strategy. It is defined as a scientific method used to evoke, measure, analyze, and interpret reactions to those characteristics of foods and materials as they are perceived by human senses (Anonymous 1975). Human senses involves different sensory systems- vision, gustation, olfaction, touch, audition and multimodal perception-all of which work together to perceive the outside stimuli. Given the sophistication of the whole system, human judgments are very difficult to be interpreted and can be affected by psychological or physiological factors. For example, in a set of products, the first product is always scored higher

than expected regardless of its attribute. Although human senses are more susceptible than instruments, reliable sensory measurement can still be achieved via careful design.

There are two categories of testing in sensory evaluation (Kemp and others 2009). The first one is subjective tests which are also called as consumer tests. This type of test is very important in product development because it is a straightforward method to help producer understand the consumers' attitude and preference towards their products. Completely randomized design is commonly used in this type of test, especially in central location consumer tests with small number of samples (Lawless and Heymann 2010). In this design, products are assigned randomly, monadically to assessors who will evaluate all products in a single session. In order to analyze the consumer's acceptability, their perception should be quantified. Hedonic scale is one of the most popular scales used. It is a very simple scale which assumes consumer preferences exist on a continuum. A series of successive integer values are anchored on this scale with equal interval. These values represent the consumer's preference to a food product ranged from dislike to like. Among all the hedonic scale, 9-point hedonic scale is most widely used. In this scale, 1 is for dislike extremely and 9 is for like extremely.

The second type is objective tests which are carry out by a group of trained panelists. Descriptive analysis belongs to this category. In descriptive tests, a small group of trained panelists are involved to identify both qualitative and quantitative aspects of food products. Both consumer ratings and GC data can be used to correlate with descriptive ratings in sensory science.

In general, descriptive analysis can be carried out in three steps: panel selection and training, performance evaluation and sample evaluation.

Before starting descriptive analysis, 6 to 18 assessors should be selected based on the criterion which includes suitable personality, good sensory ability and be in good health. All assessors must be able to recognize and describe stimuli as well as to discriminate different stimuli. A taste and aroma recognition test can be applied for selection. Only panelists who can correctly identify the all four basic tastes (bitter, sour salty and sweet) and more than half of the aromas used in the test will be recruited.

During the training session, all samples should be presented to the panelists for generation of a preliminary lexicon. Sometime, given the limitation of time and cost, only a subset of samples is chosen to present the major attributes. After discuss, a final list of attributes are decided by panel consensus. Then agreement should be reached on the evaluation methods, definition and reference(s) for each descriptor. Also, the intensity of warm-up (WUP) sample should be decided in the training sessions. Using WUP sample is a method to reduce first-order bias. Also study has shown that a WUP sample combined with basic tastes and references can improve the reliability of responses in descriptive tests (Plemmons and Resurreccion 1998).

The panel performance should be checked during both training and test sessions. A WUP sample can be added to the test samples for accuracy checking; replicated samples can be used to evaluate reproducibility. In either way, standard deviation can be applied. Normally, variation within 10% of scale unit (e.g. 15 mm on a 0-150 mm scale) from the expected value is considered acceptable (Kemp and other 2009).

In descriptive tests, randomized complete block design is very commonly used. All products are completely randomized within each session (block). Panelists assess all products in a single session and replication can be made for each product over several sessions. When the number of samples is too large for panelists to evaluate in one session, incomplete black design



should be applied (Lawless and Heymann 2010). In this situation, panelists only see a subset of randomized samples in one session and at the conclusion of all sessions all products are presented at least once to each panelist.

#### Sensory profile of roasted peanuts

Sensory profile is applied to qualify and quantify different roasted peanuts and their changes during storage in sensory tests. In 1988, Johnson and others involved 17 peanut samples prepared under different roasting conditions to develop a comprehensive lexicon for both desirable and undesirable flavors (Table 2.3). After that, the lexicon has been expanded by the work of other researchers with the addition of the following descriptors: fermented/fruity, rancid/oxidized, brown, even color, fracturability, crispiness, crunchiness, chewy and toothpack (Braddock and others 1995; Brannan and others 1999; Grosso and Resurreccion 2002; Sanders and others 1989).

Table 2.3. Lexicon of peanut flavor descriptors (Johnsen and others 1988)

<i>AROMATICS</i>	
Roasted Peanutty	The aromatic associated with medium-roast peanuts (about 3-4 on USDA color chips) and having fragrant character such as methyl pyrazine.
Raw bean/peanutty	The aromatic associated with light-roast peanuts (about 1-2 on USDA) and having legume-like character (specify beans or pea if possible).
Dark roasted peanut	The aromatic associated with dark-roasted peanuts (4 + on USDA color chips) having very browned or toasted character.
Sweet aromatic	The aromatics associated with sweet material such as caramel, vanilla, molasses, fruits (specify fruit).
Woody/Hulls/Skins	The aromatics associated with base peanut character (absence of fragrant top notes) and related to dry wood, peanut hulls, and skins.
Cardboard	The aromatic associated with some-what oxidized fats and oils and reminiscent of cardboard.
Painty	The aromatic associated with linseed oil, oil based paint.
Burnt	The aromatic associated with very dark roast, burnt starches, and carbohydrates, (burnt roast or espresso coffee).
Green	The aromatic associated with uncooked vegetables/grasstwigs, <i>cis-3-hexanal</i>
Earthy	The aromatic associated with wet dirt and mulch
Grainy	The aromatic associated with raw grain (bran, starch, corn, sorghum).
Fishy	The aromatic associated with trimethylamine, cod liver oil or old fish.
Chemical/plastic	The aromatic associated with plastic and burnt plastics.
Skunky/mercaptan	The aromatic associated with sulfur compounds, such as mercaptan, which exhibit skunk-like character.
TASTES	
Sweet	The taste on the tongue associated with sugars.
Sour	The taste on the tongue associated with acids.
Salty	The taste on the tongue associated with sodium ions.
Bitter	The taste on the tongue associated with bitter agents such as caffeine or quinine.
CHEMICAL FEELING FACTORS	
Astringent	The chemical feeling factor on the tongue described as puckering/dry and associated with tannins or alum.
Metallic	The chemical feeling fact on the tongue described a flat, metallic an associated with iron copper.

### **Gas chromatography profile of roasted peanuts**

Gas chromatography (GC) is a popular method for the detection of the volatile flavor compounds in food system. Walradt and other (Walradt and others 1971) used GC method to detect 187 compounds from Spanish roasted peanuts. Among them 142 compounds were firstly detected, including 17 pyrazines, 10 aldehydes, 16 alcohols and 17 ketones. Buckholz and others (Buckholz and others 1981) correlated GC compounds with sensory acceptability of roasted peanuts. They found that 2-ethyl-6-methyl pyrazine and 2-ethyl-3-methyl pyrazine were strongly correlated with acceptability. Other compounds that also correlated with acceptability involved 2-ethyl 3,6-dimethyl pyrazine, 2-vinyl-3,6(5)-dimethyl pyrazine, isovaleraldehyde, phenyl acetaldehyde, hexanal, and an unidentified compound. Also, GC results can be used to explain descriptive results. Hexanal has been associated with beany flavor in raw peanuts (Pattee and others 1969b); methylbutanal and methylpropanal are found to correlate with dark roast flavor, N-methylpyrrole is considered to contribute to woody/hulls/skins flavor (Crippen and others 1992).

### **SPME**

Solid-phase microextraction (SPME) is a relatively new technique invented by Pawliszyn in 1989. Compared to traditional sample preparation procedures which are labor-intensive, time and money consuming, this new development combines sample extraction and pre-concentration in one single step. Also, SPME produces relatively clean extracts and is ideal for MS applications (György and Károly 2004).

SPME syringe consists of a fiber holder and a fiber assembly where contains a 1 or 2cm-long retractable fused-silica fiber coated with polymers. Although 2cm fiber is also provided, 1cm fiber is more widely used. Compare to 1 cm fiber, 2 cm one is more fragile.

Before the first time of using, the SPME fiber should be appropriately conditioned to reduce the background noise in the GC-MS results. The conditioning time and temperature depend on fiber coating materials. During extraction process, the syringe needle is inserted into a suitable position where the protecting needle will be retracted to expose the fiber either above or in the samples. Then the fiber adsorbs the analytes until it gets saturated. After adsorption, the needle retracts the fiber and transfers it to the GC injection port for desorption.

As mentioned above, there are two common types of extraction methods: headspace-SPME (HS-SPME) extraction and direct-immersion-SPME (DI-SPME) extraction. HS-SPME extraction is used to study volatiles, while DI-SPME extraction is mainly applied for non-volatile and polar samples. Compare to DI-SPME sampling, HS-SPME sampling is suitable for very complex matrices like food products because it protects the fiber from the possible harms caused by non-volatile substances; also, modifications like adding salt and pH adjustment are allowed in HS-SPME extraction (György and Károly 2004).

There are two states of equilibrium in HS-SPME extraction: one is between the sample and its headspace; the other is between headspace and the coating on the fiber (Balasubramanian and Panigrahi 2011). The amount of compounds absorbed by the fiber is determined by the following equations when the stirring is not considered (Frank 2010).

$$n = \frac{K_{fs} V_f V_s C_o}{K_{fs} V_f + V_s} \quad (1)$$

$$n = K_{fs} V_f C_o \quad (2)$$

Where:  $n$  = analyte moles extracted by the fiber coating

$K_{fs}$  = distribution constant of fiber/ sample

$V_f$  = fiber coating volume

$V_s$  = sample volume

$C_o$  = concentration of the analyte in the sample

Eq.1 is used for small sample volumes (2-5 mL), while Eq.2 is applied when the volume is large ( $V_s \gg V_f$ ). The distribution constant is compound specific. It depends on fiber material and sample matrix. Normally, compound with higher K value requires longer time to reach equilibrium (Frank 2010). During adsorption the sample can be agitated under a relatively higher temperature (compared to room temperature) to accelerate equilibrium. Other methods like sample agitation, sample modification, increasing extraction temperature and changing the type and thickness of the coating material can all improve the extraction efficiency.

This study involved sensory and GC methods to compare between high-oleic and normal oleic roasted peanut peanuts, in-shell Runner and Virginia as well as between in-shell and shelled samples from the aspects of drivers of consumer acceptability and of the storage effects.

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## CHAPTER 3

### METHODS

#### **Peanut samples**

High (GA 13M) and normal (GA 06G) oleic peanut pods were obtained from the University of Georgia Department of Crop & Soil Science (Tifton Campus). Runner (mixed) and Virginia peanut pods were provided by Golden Peanuts.

Before processing, defective pods and foreign materials were separated. Sorted pods were brushed under warm water, drained in a colander ( 0.2 cm holes, 5 kg capacity) and dried at 40 °C overnight in a mechanical convection oven (Model 645 Freas, Precision Scientific, Winchester, VA). The moisture content after drying was detected in duplicated for four varieties (Table 3.1). Because the potentiality of mold problem, the samples were heated in Lincoln impingement oven (Lincoln Impinger, Fort Wayne, IN) at 163 °C for 5 min and cooled down to room temperature (21 °C  $\pm$  1). All the samples were flushed with nitrogen, vacuum sealed and kept at 4 °C before roasting.

Table 3.1: Moisture content (wet weight basis) for peanut samples before heating

Variety	Kernel (%)	Shell (%)
GA 06G	4.43	6.99
GA 13M	5.79	8.84
Virginia	5.62	10.34
Runner	5.99	11.15

### Sample preparation

All the samples were equilibrated to room temperature at least 12h before processing. GA 06G and GA 13M were used only for shelled roasted peanuts, while Runner and Virginia were used for both in-shell and shelled roasted samples. Trials were carried out to determine the optimum roasting conditions based on  $L$  value of  $50 \pm 1$ . Lincoln impingement oven (Lincoln Impinger, Fort Wayne, IN) was firstly set at 171 °C. Samples were roasted on perforated trays (50 cm\*25 cm\*2.5 cm) and were obtained every 3 min from 15 - 30 min. The color lightness values were obtained in duplicated after the samples were cooled down to room temperature in metal trays with a cooling fan. Roasting conditions were further changed if required  $L$  value was not detected. After the first round of trial, the roasting conditions were only found for Runner type. For GA 06G and GA 13M, the second round of trials were carried out at 171 °C with obtaining samples every 2.5 min. The results were still not ideal. Given that a lower roasting temperature with longer time can produce a better roasting result (Moss and Otten 1989), the roasting temperature was reduced to 168 °C. For Virginia, it was difficult to achieve an even roast at 171 °C due to its larger size. The roasting temperature was reduced to 168 °C for in-shell samples and 165 °C for shelled samples. The final conditions for roasting are shown in Table 3.2. After roasting, the roasted kernels were cooled to room temperature, blanched in an Ashton peanut blancher (Model EX, Ashton Food Machinery Co., Newark, NJ) and split into two halves. After resorting, all the samples were vacuum packaged, flushed with nitrogen in plastic bags and stored at 4 °C until 2 d earlier than the first sensory test day when samples were equilibrated to room temperature overnight and stored in Ziploc® bags at 21 °C. The lipid profiles after roasting were analyzed by Daniel L. Jackson at University of Georgia, Pesticide & Hazardous Waste Laboratory, 2300 College Station Rd., Athens, GA. The results were shown in Table 3.3. .

Moisture, color and both descriptive and consumer analysis were performed at week 0, 4 and 8.

Runner roasted in-shell peanuts at week 0 were also used as warm-up (WUP) samples in descriptive analysis. Both WUP samples and samples for GC tests at each time point were vacuum packaged with nitrogen and frozen in plastic bags at -20 °C.

Table 3.2: Roasting conditions for peanut samples

Variety	Temperature ( °C)	Time (min)
Runner (in-shell)	171	21
Runner (kernel)	171	18
Virginia (in-shell)	168	25
Virginia (kernel)	165	30
GA 06G (kernel)	168	22.5
GA 13M (kernel)	168	20

Table 3.3: Fatty acid composition (area %) of four roasted peanut varieties

Fatty acids	GA 06G	GA 13M	Runner	Virginia
<i>Saturated fatty acids</i>				
Palmitic Acid (C16:0)	9.35	5.38	9.69	9.01
Stearic Acid (C18:0)	2.00	2.21	2.28	1.90
Arachidic Acid (C20:0)	1.00	1.59	0.98	1.02
Behenic Acid (C22:0)	2.97	3.55	2.94	2.50
Lignoceric Acid (C24:0)	1.36	1.87	1.34	1.30
<b>Total</b>	16.68	14.61	17.22	15.73
<i>Monounsaturated fatty acids</i>				
Oleic Acid (C18:1)	56.08	81.58	56.11	54.68
Eicosenic Acid (C20:1)	1.07	1.31	1.12	1.02
<b>Total</b>	57.15	82.89	57.23	55.70
<i>Polyunsaturated fatty acids</i>				
Linoleic Acid (C18:2)	26.17	2.50	25.55	28.57
<b>Total</b>	26.17	2.50	25.55	28.57
Oleic to linoleic acid ratio	2.14	32.63	2.20	1.91

### **Moisture measurement**

Method used in this thesis was modified based on standard method AOAC 925.40. Samples were grinded into small particles in a coffee grinder (Hamilton Beach Co., Southern Pines, NC). About 2 g kernel or 1 g shell samples were placed in aluminum pans, weighed and dried in a vacuum oven (285A, Fisher Scientific, Pittsburgh, PA) at 100 °C under pressure 51 cm Hg for 6 h to constant weight. Moisture contents (wet weight basis) were reported as weight loss in duplicate.

### **Color measurement**

A benchtop ColorFlex Spectrophotometer (HunterLab, Reston, VA) was standardized by black glass and white tile ( $L=93.24$ ,  $a^*=-1.30$ ,  $b^*=0.84$ ). Surface color of roasted peanuts was measured in duplicate by placing samples evenly on the bottom of the sample cup and 4 readings per sample were obtained with rotation of the cup a quarter of turn each time (Yeh and others 2002).

### **Consumer analysis**

One hundred consumers and ten alternates (for no-show cases) were recruited through facebook, flyers and an existing consumer database established and maintained at Sensory Evaluation and Consumer Lab, Department of Food Science and Technology, University of Georgia, Griffin Campus. All the consumers were screened based on the following criteria (Appendix A): 1) 18-65 years old, 2) 60% female and 40% male, 3) no allergic to peanuts or any kind of nuts, 4) must eat peanut products at least once a month and 5) must be willing and available for the tests. All the consumers were required to sign two copies of consent forms (Appendix B) before they entered the test areas.

Peanut kernels (~5 g) were served in a 1 oz. sample cup and in-shell peanuts (~5 g) were served in a 2 oz. sample cup. The tests were conducted in partitioned booths under incandescent light at room temperature. Samples were presented with corresponding ballot (Appendix C) to panelists in a balanced sequential monadic order. Demographic questionnaire (Appendix D) was presented with the last sample. The evaluation sequence was based on a completely randomized design (Appendix E). Unsalted crackers (Kroger Co., Cincinnati, OH) and water were used as palate cleansers between samples.

### **Descriptive analysis**

Samples were evaluated by a descriptive panel trained using generic descriptive analysis.

Eight panelists with more than 10-year-experience were recruited on the basis of the following criteria: 1) nonsmokers; 2) no food allergy; 3) eat peanuts; 4) available to attend all training and testing sessions; 5) interest in participating; and 6) able to verbally communicate about the product.

### **Training**

The training sessions included two 2 h training sessions and another 1 h special training session which was only for flavors. All 8 panelists participated in the first two training sessions and 6 panelists were chosen from the panel to participate in the special training session.

On the first training session, panelists read and signed 2 consent forms at first (Appendix F). After calibration with basic solutions (bitter 20, 50, 100; sour 20, 50, 100; salty 25, 50, 85; sweet 20, 50 100, 150; astringent 20, 50, 100), panelists were introduced to 4 samples of roasted peanuts (fresh pods, oxidized pods, fresh kernels, oxidized kernels) to develop preliminary lexicon for both in-shell and shelled roasted peanuts. After discussion, a final list of



descriptors with evaluation methods, definitions and references were decided by panel consensus (Appendix G). The panelists rated intensity of the suggested references in a range between 0 and 150 using flash cards. The panelists whose answer varied beyond 10 units (mm) from the mean were asked to re-evaluate the samples.

On the second training session, panelists finalized the ballots for both in-shell and shelled roasted peanuts after calibration. Also, the WUP samples were rated using flash cards. The intensity for each descriptor (except for flavor descriptors) were decided when agreement was reached.

On the special training session, panelists were asked to calibrate themselves with basic solutions at first. The intensity of each flavor descriptors for WUP sample was decided. Then panelists rated 4 samples of roasted peanuts (2 oxidized samples, 1 fresh sample, 1 WUP) individually on paper ballots and the intensity ratings were discussed as a group. After discussion, they were asked to compare oxidized samples with the fresh sample and WUP sample to feel the change of flavors during the storage.

### Testing

Panelists were calibrated with basic solutions and a WUP sample at the beginning of each test session before entering the booths. All the samples were served in partitioned booths under incandescent light at room temperature according to a randomized complete block design with two replications (Appendix H). A 5 min break was inserted between the sixth and seventh samples to prevent panelists from fatigue. . The flavors of roasted peanuts were done separately on another day by the 6 panelists who participated in the special training sessions. Paper ballots with 150-mm line scales (Appendix I) were used to record responses. Unsalted crackers (Kroger Co., Cincinnati, OH) and water were used to clean palate.

## GC analysis

1,2,3-Trichloropropane (Fisher Scientific, Pittsburgh, PA) was firstly used as internal standard (IS). 1 mg/mL IS stock solution was made by dissolving 144  $\mu$ L 1,2,3-trichloropropane in 200 mL methanol (Fisher Scientific, Pittsburgh, PA). In order to make the IS solution evenly distribute in the sample, 500  $\mu$ L of IS stock solution was further diluted in 200 mL distilled water to make 'add-in' IS solution. This IS worked fine at first, but the retention time of a compound named oxime-, methoxy-phenyl started to shift, which overlapped the peak of IS. Little information was found for this compound and it might come from the column according to the results of running IS solution and blank samples. This problem still remained after conditioning the oven, so IS was changed to 1,3-dichlorobenzene (Sigma-Aldrich, St. Louis, MO). 0.045 mg/mL IS solution was made by diluting 1,3-dichlorobenzene twice in 200 mL methanol. The concentration of stock solution was 12 mg/mL. After several trials, 20  $\mu$ L IS solution was applied in formal tests.

All the samples were de-frozen at room temperature for at least 24 h before any analysis. Peanut kernels were grinded into small particles in a coffee grinder (Hamilton Beach Co., Southern Pines, NC) and 1.5 g samples were transferred to a 20 mL screw-cap vial equipped with a polytetrafluoroethylene/silicone septum in duplicate. 2 mL distilled water was added with 20  $\mu$ L of 0.045 mg/mL IS solution to the vial and the final concentration of IS in the sample was 60  $\mu$ g/kg. The extraction procedure and GC program was modified based on published papers (Koppel and others 2013; Lee and others 2011; Liu and others 2011).

Headspace-solid phase microextraction (HS-SPME) technique was applied. The vials were equilibrated for 15 min at 50  $^{\circ}$ C in the autosampler (Model GC Sampler 80, Agilent

Technologies, Santa Clara, CA) and agitated at 250 rpm. After the equilibration, a 50/30  $\mu\text{m}$  divinylbenzene/carboxen/polydimethylsiloxane fiber was exposed to the sample headspace for 40 min at 50  $^{\circ}\text{C}$ . Then the analytes were desorbed to the injection port of gas chromatography-mass spectrometry (GC-MS) at 250  $^{\circ}\text{C}$  for 5 min in splitless mode (Table 3.4)

Table 3.4: Parameters of autosampler

Parameter	Value
Pre-incubation time (s)	900
Incubation Temperature ( $^{\circ}\text{C}$ )	50
Pre-incubation Agitator Speed (rpm)	250
Agitator on time (s)	5
Agitator off time (s)	2
Vial penetration in mm ( $\mu\text{L}$ )	30
Extraction time (s)	2400
Desorb to	GC Inj1
Injection penetration in mm ( $\mu\text{L}$ )	54
Desorption time (s)	300
Post fiber condition time (s)	1500
GC run time (s)	3420

GC-MS analysis was performed on a GC system (Model 7890A, Agilent Technologies, Santa Clara, CA) equipped with a HP-5MS column (30 m\*250 $\mu\text{m}$ \*0.25 $\mu\text{m}$ ) and with a MS detector (Model 5977A, Agilent Technologies, Santa Clara, CA). Volatile compounds were carried by helium with flow rate 1 mL/min and the solvent delay was set at 3 min. The column

was maintained at 40 °C for 5 min, programmed at 2 °C /min to 116 °C and at 6 °C /min to the final temperature 200 °C. MS detector scanned a mass range (m/z) from 30 – 400 with scan speed 1.562 u/s. The temperature of MS source and MS quadrupole was 230 °C and 150 °C respectively.

Identification of compounds was based on both mass spectra database (NIST/EPA/NIH mass spectral library, Version 2.2, 2014) and Kovats indices (NIST spectra library collection). Kovats indices (KI) were calculated based on the retention time of a series of n-alkanes (C7-C30).

The C7-C30 standard solution was obtained commercially (SUPELCO, Bellefonte, PA) with initial concentration of 1000 µg/mL in hexane. The diluted solution was made according to the following steps: 1) add 100 µL of 1000 ug/mL standard solution to 1 mL methanol; 2) transfer 250 µL solution made in step 1 to 500 µL distilled water. The diluted solutions was run in duplicate under the same GC-MS program with the exception that the solvent delay was changed to 2.75 min in order to collect heptane.

The relative concentration of investigated compounds was semi-quantified according to the peak area of IS

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## CHAPTER 4

### ACCEPTABILITY AND PREFERENCE DRIVERS OF FRESHLY ROASTED PEANUTS

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## Abstract

The objectives of this study were to determine and compare the sensory perception and GC volatiles of six freshly roasted peanuts as well as to explore the drivers of consumer acceptability based on sensory and GC profiles. Normal-oleic Georgia 06G kernels (06G), high-oleic Georgia 13M kernels (13M), Runner in-shell (InR) & kernels (R), and Virginia in-shell (InVA) & kernels (VA) were roasted to medium doneness for consumer, descriptive and GC tests. In-shell samples were liked the most in consumer tests. High-oleic 13M was significantly preferred over normal-oleic 06G in overall liking, aroma liking, flavor liking, sweet liking and roasted peanut flavor liking. Descriptive tests showed that 06G had the highest oxidized flavor and bitter taste, which may explain its lowest overall liking. Cluster analysis divided consumers into 3 segments. Consumer overall liking was positively correlated with crispiness, crunchiness, roasted peanutty flavor and sweet taste while had a negative correlation with overall oxidized flavor. Consumers in cluster 1 and 2 had more drivers of liking associated with textural aspects of roasted peanuts; while sweet taste was the key driver for the third cluster. GC analysis identified 30 volatile compounds from roasted peanuts with benzene derivatives and pyrazines as the principal volatiles. 06G was revealed to have a significantly higher concentration of alcohols, aldehydes, and ketones with lowest concentration of total pyrazines. As the major pyrazine, 2,5-dimethyl-pyrazine was found to have a strong correlation with roasted peanutty flavor; while octanal, nonanal and 2-pentyl pyridine showed more association with overall oxidized flavor. Similar patterns were found for the drivers of flavor liking in three clusters. The flavor liking was positively correlated with pyrazines, benzaldehyde and benzeneacetaldehyde but was negatively correlated with alcohols, aldehydes, ketones, pyrroles etc.

## Introduction

Peanuts (*Arachis hypogaea*) are a major crop worldwide with total production of 29 million metric tons per year. As the world's third largest producer, the United States has a share of 8% of overall production. Peanuts are widely grown in 15 states in the United States. Among them, Georgia has the largest proportion with about 49% of the total national production.

Runner and Virginia are two main types of peanuts grown in the United States. Runner peanuts have uniform kernel size and are majorly used for processing, especially for peanut butter. Georgia 06G and Georgia 13M are Runner varieties developed at the University of Georgia, Coastal Plain Experiment Station in Tifton, GA. They both have high yields and resistance to tomato spotted wilt virus (TSWV). Compared to Georgia 06G, Georgia 13M has high-oleic and low-linoleic fatty acid profiles with smaller seed size. Virginia peanuts have the large kernels covered with red skin and are commonly used for in-shell roasted peanuts. Some larger kernels are also sold as salted peanuts.

Roasted peanuts are an important peanut product consumed in the United States. Raw peanuts can be roasted either in in-shell or shelled form. Normally, the shelling process is carried out before roasting, followed by shell separation and seed-size screening. During roasting, a series of reactions, mainly Maillard reaction, contribute to improve the sensory quality of peanuts. Maillard reaction is a complicated reaction between reducing sugars and basic amino acids, producing a lot of volatile compounds. Among them, pyrazines are the mostly studied because of their contributions to roasted flavor. These heterocyclic nitrogen-containing compounds are normally formed from the condensation of two aminocarbonyls produced by Strecker degradation. They have been related with roasted flavors for a long time. Mason and Johnson (1966) were first to identify five pyrazines (methyl pyrazine, 2,5-dimethyl pyrazine,



trimethyl pyrazine, methyl-ethyl pyrazine and dimethyl-ethyl pyrazine) from roasted peanuts and suggested their possible roles in roasted peanut flavor. Buckholz and others (1981) correlated volatile compounds with acceptability of roasted peanuts and found that 2-ethyl-6-methyl pyrazine and 2-ethyl-3-methyl pyrazine were strongly correlated with consumer acceptability. Siegmund and Murkovic (2004) found that all alkylated pyrazines were responsible for the roasted aroma in pumpkin seed. Baker and others (2003) correlated several pyrazines with roasted peanut flavor and revealed that 2,5-dimethylpyrazine was the best predictor of this flavor.

Lipid oxidation is a main problem in peanut industry due to the high fat content of peanuts. During oxidation process, fatty acids decompose to volatile aromatic secondary products like alcohols, aldehydes, ketones, furans, organic acids, and hydrocarbons, causing off-flavors. High-oleic peanut varieties were therefore developed to increase the shelf life of peanuts by increasing the oleic acid content. High-oleic peanuts have shown more roasted peanut flavor in descriptive tests and were able to retain the flavor longer during storage compared to normal-oleic acid peanuts (Braddock and others 1995; Nepote and others 2006; Pattee and others 2002; Reed and others 2002; Talcott and others 2005). But this difference in chemical composition did not shown any significant difference in consumer acceptability (Nepote and others 2006; Riveros and others 2009).

The study involved six freshly roasted peanuts samples including high-oleic roasted peanuts and in-shell roasted peanuts to 1) determine and compare the sensory perception and GC volatiles of six roasted peanuts; 2) explore the drivers of consumer acceptability based on sensory and GC profiles.

## **Material and methods**

### Samples preparation

High (GA 13M) and normal oleic (GA 06G) peanut pods were obtained from the University of Georgia Department of Crop & Soil Science (Tifton Campus). Runner (mixed) and Virginia (mixed) peanut pods were provided by Golden Peanuts. Before processing, peanut pods were sorted, cleaned and dried at 40 °C overnight in a mechanical convection oven (Model 645 Freas, Precision Scientific, Winchester, VA). Then all the pods were heated at 163 °C for 5 min in Lincoln impingement oven (Lincoln Impinger, Fort Wayne, IN) to reduce the potentiality of mold problem. After cooling down to room temperature ( $21 \pm 1$  °C), sample were flushed with nitrogen, vacuum sealed and kept at 4 °C.

Before roasting, the samples were firstly equilibrated at room temperature for at least 12h. GA 06G (06G) and GA 13M (13M) were used for shelled roasted peanut samples, while Runner and Virginia were used for both in-shell (InR, InVA, respectively) and shelled (R, VA, respectively) roasted samples. All samples were roasted in a Lincoln impingement oven (Lincoln Impinger, Fort Wayne, IN) to a medium doneness based on the surface color Lightness ( $L$ ) value of  $50 \pm 1$ . A benchtop ColorFlex Spectrophotometer (HunterLab, Reston, VA) was standardized by black glass and white tile ( $L=93.24$ ,  $a^*=-1.30$ ,  $b^*=0.84$ ) and the color of roasted peanuts was measured in duplicate by placing samples evenly on the bottom of the sample cup. Four readings per sample were obtained for each sample (Yeh and others 2002). After roasting, peanuts were cooled to almost room temperature by a cooling fan and the roasted kernels were then blanched in an Ashton peanut blancher (Model EX, Ashton Food Machinery Co., Newark, NJ). The blanched kernels were further manually split into two halves and resorted before packaging. All the samples were flushed with nitrogen, vacuum packaged, properly labeled, and stored at 4 °C

till further used. The fatty acid profiles of four varieties (GA 06G, GA 13M, Runner, Virginia) were analyzed after roasting by Daniel L. Jackson at University of Georgia, Pesticide & Hazardous Waste Laboratory, 2300 College Station Rd., Athens, GA. The results were shown in Table 4.1.

#### Sampling procedure

Samples were moved from the fridge 2 d before the first sensory test day, equilibrated to room temperature overnight and stored in Ziploc® bags at 21 °C. Runner freshly roasted in-shell peanuts were also used as the warm-up (WUP) sample in descriptive analysis. Both WUP samples and samples for gas chromatography (GC) tests were vacuum packaged with nitrogen and frozen in plastic bags at -20 °C.

#### Moisture measurement

Moisture contents (wet weight basis) were measured based on a method modified from AOAC 925.40 (AOAC. 2000). Samples were grinded into small particles in a coffee grinder (Hamilton Beach Co., Southern Pines, NC). About 2 g kernel or 1 g shell samples were dried in duplicate in a vacuum oven (285A, Fisher Scientific, Pittsburgh, PA) at 100 °C under pressure 51 cm Hg for 6 h to constant weight. The weight loss of shell and kernel was separately reported as their moisture content.

Approval from UGA's IRB was taken before collecting the sensory data.

#### Descriptive analysis

Samples were evaluated by a descriptive panel trained using generic descriptive analysis. Eight panelists with more than 10-year experience in descriptive analysis participated in the panel, especially with peanut and peanut products. All of them participated in two 2 h orientation sessions to decide a lexicon for both in-shell and shelled roasted peanuts. The final

list of descriptors with evaluation methods, definitions and references were decided by panel consensus. Six of them were further chosen for another 2 h-special training session where they focused on the flavor of roasted peanuts. Paper ballots with 150 mm unstructured line scale anchored at 12.5 and 137.5 mm were used for scaling during the training and test sessions. Water and unsalted crackers (Kroger Co., Cincinnati, OH) were used to clean palate.

At the beginning of each test session, the panelists were calibrated with basic taste solutions (bitter 20, 50, 100; sour 20, 50, 100; salty 25, 50, 85; sweet 20, 50, 100, 150; astringent 20, 50, 100) and a WUP sample (equilibrated to room temperature) before entering the booths. They were asked to re-evaluate the WUP sample if their readings went beyond 10 mm from the means on the scale (Kemp and others 2009). All the samples were served in partitioned booths under incandescent light at room temperature according to a randomized complete block design with two replications. A 5 min break was inserted between the sixth and seventh samples to prevent panelists from fatigue. The flavors of roasted peanuts were done separately on another day by the 6 panelists who participated in the special training sessions.

### Consumer Response Evaluation

All the samples were evaluated by 99 consumers who were recruited through Facebook, flyers and an existing consumer database established and maintained at Sensory Evaluation and Consumer Lab, Department of Food Science and Technology, University of Georgia, Griffin Campus. All the consumers must age between 18-65 years old, having no allergic to peanuts or any kind of nuts, and eat peanut products at least once a month.

The consumer tests were carried out in partitioned booths under incandescent light at room temperature. About 5 g of each peanut sample were served with corresponding ballot in a sequential monadic order based on a completely randomized design. Demographic questionnaire

was presented with the last sample. Unsalted crackers (Kroger Co., Cincinnati, OH) and water were used as palate cleansers between samples.

#### GC analysis

Headspace-solid phase microextraction (HS-SPME) technique was applied for extraction of the volatiles. Samples (equilibrated to room temperature) were grinded into small particles in a coffee grinder (Hamilton Beach Co., Southern Pines, NC) and exactly 1.5 g were transferred to a 20 mL screw-cap vial equipped with a polytetrafluoroethylene/silicone septum in duplicate. Exactly 2 mL distilled water was added with 20  $\mu$ L of 0.045 mg/mL 1,3-dichlorobenzene (Sigma-Aldrich, St. Louis, MO) solution (methanol) to the vial. The vials were equilibrated for 15 min at 50  $^{\circ}$ C in the autosampler (Model GC Sampler 80, Agilent Technologies, Santa Clara, CA) and agitated at 250 rpm. After the equilibration, a 50/30  $\mu$ m divinylbenzene/carboxen/polydimethylsiloxane fiber was exposed to the sample headspace for 40 min at 50  $^{\circ}$ C. The analytes were desorbed to the injection port of gas chromatography-mass spectrometry (GC-MS) at 250  $^{\circ}$ C for 5 min in splitless mode.

GC-MS analysis were performed on a GC system (Model 7890A, Agilent Technologies, Santa Clara, CA) equipped with a HP-5MS column (30 m $\times$ 250 $\mu$ m $\times$ 0.25 $\mu$ m) and with a MS detector (Model 5977A, Agilent Technologies, Santa Clara, CA). Helium was used as the carrier gas with flow rate of 1 mL/min. The solvent delay was set at 3 min. The column was maintained at 40  $^{\circ}$ C for 5 min, programmed at 2  $^{\circ}$ C/min to 116  $^{\circ}$ C and at 6  $^{\circ}$ C/min to the final temperature 200  $^{\circ}$ C. MS detector scanned a mass range ( $m/z$ ) from 30 – 400  $m/z$  with scan speed 1.562  $\mu$ /s. The temperature of MS source and MS quadrupole was 230  $^{\circ}$ C and 150  $^{\circ}$ C, respectively.

Identification of compounds was based on both mass spectra database (NIST/EPA/NIH mass spectral library, Version 2.2, 2014) and Kovats indices (NIST spectra library collection).

Kovats indices (KI) were calculated based on the retention time of a series of n-alkanes (C7-C30). Semi-quantification was done for the identified compounds, and the relative concentration was reported based on the area of the IS.

### Statistical analysis

The data from consumer, descriptive and physicochemical analyses were analyzed by ANOVA in SAS® (version 9.4, SAS Institute, Cary, NC). Glimmix procedure (General Linear Mixed Models) was used for sensory test with consumer/panelist as a random factor. Least Square means were calculated. Post-hoc mean separation was done using Fisher's LSD (Least Significant Difference). The cluster analysis was conducted in SAS® based on the consumer liking data and demographic data using Ward's minimum variance method. The preference pattern of consumer groups were compared using correlation analysis by XLSTAT (version 2015.2.02, Addinsoft, New York, NY). In order to figure out the relationship of sensory flavor/taste attributes to the GC volatile compounds, Partial Least Squares Regression (PLSR) model was used in XLSTAT to correlate the descriptive and GC data. Finally, PLS-R was applied again to develop external preference mapping for overall liking and flavor liking of consumer clusters.

## **Results and discussion**

### Descriptive analysis

Eighteen sensory attributes were identified by the panelists for describing the roasted peanuts. Fracturability of the shell was only used for the two in-shell peanut samples, the rest of attributes were common to all samples, including 1 appearance (brown), 5 textural attributes (fracturability, crispiness, crunchiness, chewy and toothpacking), 5 flavors (roasted peanutty, overall oxidized, cardboard, fishy and painty), 4 basic tastes (bitter, sour, salty and sweet) and

two feeling factors (astringent and oily). Three-way ANOVA (sample, panelist and replication) with panelist as a random factor was applied. Results showed that both panelist and replication effects were not significant ( $p > 0.05$ ), which certified the acceptable performance of panelists. Among all these attributes, significant difference ( $p < 0.05$ ) was only found for crunchiness, overall oxidized and bitter (Table 4.2). InVA and VA had the highest crunchiness scores which were significantly higher ( $p < 0.05$ ) than 06G, 13M and R samples. Some studies have found that moisture content was negatively correlated with sensory crunchiness. (Vickers and others 2014). However, this relationship (correlation coefficient = 0.52) between moisture content (Table 4.3) and crunchiness was not found in this study. Sensory texture is very complicated. Except for moisture content, it can also be influenced by factors such as protein levels and types, processing parameters, product diameter, bulk density, microstructure as well as oral physiology (Alonzo-Mac ías and others 2014; Kreger and others 2012; Van Vliet and Primo-Mart ín 2011). Those factors might affect the crunchiness more in this study. The most bitter sample was 06G with significant difference ( $p < 0.05$ ) from InR and R. It also showed a significantly ( $p < 0.05$ ) higher oxidized flavor than all other samples.

#### Consumer acceptability

For this population (n=99), most consumer (57%) consumed roasted peanuts 1- 3 times per week, 33% consumed 1-3 times per month and only 10% consumed daily. Among all the peanut products surveyed, peanut butter (81%) and roasted peanuts (77%) were consumed largely by this group, followed by peanut bars and candies (51%). Boiled peanuts (35%) seemed to be the least popular peanut products to this group. As for roasted peanuts, shelled roasted peanuts were largely preferred with 50% preferred shelled types, 19% preferred in-shell types and 31% had no preference/preferred both. When buying peanuts, 'Flavor' was the most

important consideration (51% in shelled type, 49% in in-shell type). Other factors like 'Price' (39% in shelled type, 31% in in-shell type), 'Expiration date' (35% in shelled type, 40% in in-shell type), and 'Texture' (28% in shelled type, 32% in in-shell type) also affected consumer's buying choices. However, 'Health benefit', 'Packaging' and 'Brand' had minimal effects (< 20%) on this group. In general, the purchase decisions of the group was influenced by flavor related factors (flavor, expiration date), texture and price, which were consistent with previous studies (Rimal and Fletcher 2000; Young and others 2005).

The mean scores for consumer liking and intensity data are given in Table 4.4. The samples differed significantly ( $p < 0.05$ ) in most of the ratings, except for appearance liking, liking and ease of shelling as well as intensity of sweetness. In general, both in-shell samples were liked the most. VA and 06G were the least liked by consumers with significantly lower ( $p < 0.05$ ) overall liking scores than other four samples. Also, these two samples had lower liking scores for flavor and roasted peanut flavor. When comparing normal-oleic 06G and high-oleic 13M, the high-oleic sample had significantly higher scores ( $p < 0.05$ ) in most of the ratings (overall liking, aroma liking, flavor liking, roasted flavor liking, sweet liking and roasted peanut intensity). When cross-checked with descriptive analysis results, 06G had the highest oxidized flavor and bitter taste, which might be the cause of its low overall liking score.

Cluster analysis was also used to investigate specific consumer preferences. 99 consumers were segmented into 3 clusters containing 42, 24, 33 individuals, respectively (Table 4.5). Correlation analysis was done to explore the correlation between overall liking and other consumer ratings. Results were shown in Table 4.6. Overall liking scores of cluster 1 was significantly ( $p < 0.05$ ) and positively correlated with flavor liking, roasted peanut flavor liking, sweet liking, texture liking, roasted peanut intensity and sweetness intensity, while there was a



significantly ( $p < 0.05$ ) negative correlation with the percentage of consumers who tasted old/stale flavor in the samples. The correlation results for cluster 2 were similar to cluster 1 with the only exception that sweetness intensity became a less important factor. As for cluster 3, only flavor liking and roasted peanut flavor liking had a significant ( $p < 0.05$ ) correlation with overall liking as positive contributors. In sum, flavors of roasted peanuts were mostly important to consumers' overall liking. Appearance seems to be of less importance. This finding was also confirmed by other researchers (Moskowitz and Krieger 1995). Therefore, companies should put the most focus on the flavor aspects when developing roasted peanut products.

PLSR was used to further examine the drivers of liking for these three clusters (Figure 4.1 and Figure 4.2). Sensory descriptors were used as a set of explanatory variables in X-matrix and the averaged overall liking score of three clusters were used as dependent variables in Y-matrix. Sour taste, cardboard, fishy and painty flavor were not included in this model, because their intensities were almost zero in all six samples. In the first three factors, 83% variation in X explained 84% variation in Y.

Cluster 1 has highest percentage of older age (55y or older) males. It also has a slightly more portion that preferred shelled roasted peanuts in their daily life. It consisted of consumers who liked all samples with R as their favorite (Table 4.7). This group also showed a slight tendency of preferring shelled samples over the in-shell ones, which was consistent with the demographic results. Although this group slightly likes 06G, it was still given the lowest overall liking scores. The drivers of liking in this cluster were crispiness, crunchiness, roasted peanutty flavor, saltiness and chewiness. The drivers of dislike were overall oxidized, bitter and brown.

Cluster 2 has a highest proportion of female subjects and the least proportion of consumers who preferred in-shell roasted peanuts. However, our test results showed that this

group liked in-shell samples, especially in-shell Virginia sample which had significantly higher scores ( $p < 0.05$ ). Also, they significantly preferred ( $p < 0.05$ ) high-oleic peanuts over normal-oleic peanuts. Compared to other two clusters, this group had a higher percent of consumers who tasted oxidized flavor from shelled samples. This may explain why consumers in cluster 2 preferred in-shell roasted peanuts least in the survey while gave this type a higher scores in the test. The drivers of liking for this group were crispiness, roasted peanutty and salty. The drivers of disliking were overall oxidized, fracturability and oily.

Cluster 3 is characterized by consumers who disliked all the samples. They slightly preferred in-shell samples over their corresponding shelled types. More than half of the consumers (54.6%) in this cluster ate peanuts less than once per week, which was much lower compared to first two clusters. It also had the lowest proportion of consumers who ate roasted peanuts. These findings might confirm the results of studies that the frequency of consumption was a determinant of food liking (Wadhera and others 2015). PLS-R plots showed that sweet was its key driver of liking; overall oxidized, brown and bitter were the drivers of disliking. Compared to other two clusters, consumers in cluster 3 paid less attention to the texture aspects of roasted peanuts, because they had no drivers associated with texture. Also, this cluster had more light eaters based on demographic results. This might indicate that flavors and tastes are more important to light eaters than textures.

In general, most of the positive drivers for three clusters are normally related to fresh products such as crispiness, crunchiness, roasted peanutty flavor and sweet taste. Oxidized flavor was the most important contributor to consumers overall disliking, since it was the driver of disliking for all three clusters with a very large negative loading on the main factor (PLS1).

### GC analysis and its correlation with sensory profile and consumer acceptability

GC-MS system identified a total of 30 volatile compounds which were classified to 10 groups (Table 4.8): alcohols (1 compound), aldehydes (5 compounds), alkanes (3 compounds), terpene (1 compound), benzene derivatives (3 compounds), furan derivatives (3 compounds), ketones (1 compound), pyrroles (2 compounds), pyrazines (10 compounds) and pyridines (1 compound). Among them, 22 compounds were common to all roasted peanuts. 1-Octen-3-ol, hexanal, 2,4- Decadienal, 2-pentyl furan were only not found in 13M. All of them are the oxidation products of linoleic acids (Frankel 1983). 13M contained only 2.5% of linoleic acids and this may explain the absence of these oxidation products in it. D-limonene was not detected from R and InR. This compound does not originate from lipid oxidation and has not been associated with rancid off-flavor (Jacobsen and others 1999; Jacobsen and others 2000). 3-Nonen-2-one was only detected in 06G. This compound was also considered as oxidation product from linoleic acid (Schäfer and Aaslyng 2006). Researchers have found that the competition between fatty acids may affect the production of 2-ketones (Zhou and others 2013). This may to some extent explain why this compound was only detected in 06G. In general, normal-oleic and in-shell roasted peanuts had higher total concentration of volatile compounds than high-oleic and shelled ones. Significant differences ( $p < 0.05$ ) were found between the six samples in the total concentration of alcohol, aldehydes, alkanes, terpenes, benzene derivatives, ketones and pyridines. 06G had significantly higher ( $p < 0.05$ ) concentration of alcohols, aldehydes, and ketones than other samples, which explained its higher oxidized flavor in sensory tests. However, except for 13M, no obvious difference in fatty acid profile was found between 06G and other samples. It would be possible that 06G might undergo higher level of oxidation before roasting, which caused the significantly ( $p < 0.05$ ) more oxidation products in its freshly

roasted samples. Benzene derivatives and pyrazines were the two major groups in all six samples, accounting for 64% - 85% of total volatiles. The proportion of benzene derivatives were the largest in 06G, R and InR, while 13M, VA and InVA contained a higher percentage of pyrazines. 06G was found to have the lowest concentration of total pyrazines.

PLSR model was run to explore the relationship between 6 sensory attributes (roasted peanutty flavor, overall oxidized flavor, bitter, salty, sweet and astringent in Y-matrix) and 30 GC volatile compounds (X-matrix). The plots are shown in Figure 4.3 and Figure 4.4. In the first three factors, 92% variation in X explained 87% variation in Y. Pyrazines are heterocyclic nitrogen-containing compounds formed from Maillard reaction and have always been related with roasted flavor. The correlation was confirmed again in this study. Except for methyl pyrazine and 2-ethyl-5-methyl pyrazine, all other pyrazines were all located in the same area with roasted peanutty flavor on the plots. 2,5-Dimethyl pyrazine was the major pyrazine compound in roasted peanuts. Baker and others (2003) found that it can be used as the best pyrazine to predict the roasted peanut flavor and aroma. Their finding was supported by this study, because 2,5-dimethyl pyrazine was closest to roasted peanutty flavor among all pyrazines, which suggests a strong correlation between them. Astringent was also located in the upper right area and very close to the 6 pyrazine compounds, especially 2,5-diethyl pyrazine. Astringent defined as the puckering or drying sensation on the mouth or tongue surface and commonly exists in roasted products such as cocoa, coffee, roasted peanuts etc. Some studies have found that some pyrazines like 2-methyl pyrazine and 2,5-dimethyl-3,6-disopropyl pyrazine had some astringent taste (Burdock and Fenaroli 2010; Winter and others 1981). As a same class of compounds, it is likely that these pyrazines may have some correlations with astringency.

Benzaldehyde and benzeneacetaldehyde were relatively close to sweet in plots. These two benzene derivatives have been found to be associated with sweet, almond-like and floral odor/flavor in some food products (Serra Bonvehi 2005; Gualberto Sotelo and others 2015; Ng and others 2008; Weschenfelder and others 2015; Wu and others 2014; Xiao and others 2014). Benzeneacetaldehyde is a Strecker aldehyde formed from the reaction of phenylalanine with dicarbonyl groups (Huang and Ho 2012). It was also the predominant volatile in all six roasted samples. Benzaldehyde is also considered to originate from the Strecker degradation during roasting but with the reaction of tyrosine and dicarbonyl groups (Watanabe and others 2015). It may also form from the thermal degradation of 2,4-decadienal (Huang and Ho 2012).

Alcohols, aldehydes and ketones were all considered as the lipid oxidization products, all of which went to the opposite side of roasted peanutty flavor and were closer to overall oxidized flavor in the plots. Octanal and nonanal were two important oxidation products originating from linoleic acid and oleic acid respectively and showed stronger correlation with overall oxidized flavor. 2-Pentyl pyridine was another compound near overall oxidized flavor. This compound is produced by reaction of 2,4-decadienal with amino acid and is considered as a major contributor to undesirable flavor (grassy and throat catching) in soy protein (Boatright and Crum 1997; Zhou and Boatright 2000).

Ho and others (1982) described N-methyl pyrroles as a woody and sweet odor in roasted peanuts. Brannan and others (1999) found that 1-methyl pyrrole was positively correlated with woody/skin/hull and bitter. In our study, two pyrroles (1-methyl-1H-pyrrole, 3-methyl-1H-pyrrole) showed a stronger correlation with bitter taste but negatively correlated with sweet taste. This may be caused by its inherent woody/skin/hull aroma.

As stated earlier, flavor liking played an important role in consumer overall liking. Therefore, PLSR was further applied to determine the drivers for consumer flavor liking of three clusters (Y-matrix) for roasted peanuts based on both sensory and GC profile(X-matrix). The percentage explained by first three clusters was very high with 87% variation in X explained 93% of variation in Y (Figure 4.5 & Figure 4.6). Sweet, roasted peanutty and salty were positively correlated with flavor liking for all three clusters. Salty and roasted peanutty flavor had relatively less correlation with cluster 2 and 3 respectively. From the aspect of GC profile, flavor liking was positively correlated with pyrazines (mainly 2,5-dimethyl-pyrazine and 2-methyl-6-(trans-1-propenyl) pyrazine) and two benzene derivatives (benzaldehyde and benzeneacetaldehyde; majorly benzaldehyde). Drivers of flavor dislike involved bitter and oxidized flavor in sensory profile which were separately represented by pyrroles and alcohols, aldehydes, ketones, pyridines in GC profile.

### **Conclusion**

The results of this work showed that in-shell samples were liked the most by consumers, but they did not show any significant differences over shelled samples in either the descriptive or GC-MS analysis. High-oleic 13M was significantly preferred over normal-oleic 06G in overall liking, aroma liking, flavor liking, sweet liking and roasted peanut flavor liking. Roasted peanutty flavor was not different among the six samples as noted in descriptive tests. But 06G showed the highest oxidized flavor and bitter taste. From the aspect of GC profile, 06G had a significantly higher concentration of alcohols, aldehydes, and ketones with lower concentration (no significant difference) of total pyrazines. Cluster analysis divided the consumers into 3 segments. Oxidized flavor was found to be the most important driver for all three clusters. PLSR model revealed that 2,5-dimethyl-pyrazine had a strong correlation with roasted peanutty flavor;

while octanal, nonanal and 2-pentyl pyridine were strongly correlated with oxidized flavor. Similar patterns of flavor liking was found in three clusters. The flavor liking was positively correlated with volatiles that represent roasted, salty and sweet. These compounds includes pyrazines (majorly 2,5-dimethyl pyrazine and 2-methyl-6-(trans-1-propenyl) pyrazine) and two benzene derivatives (benzaldehyde and benzeneacetaldehyde; mainly benzaldehyde). The drivers of flavor dislike were bitter and oxidized flavor in sensory profile. From GC profile, these drivers corresponded to pyrroles (bitter), alcohols, aldehydes, ketones and pyridines (oxidized).

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Table 4.1: Fatty acid composition (area %) of four roasted peanut varieties <sup>1</sup>

Fatty acids	GA 06G	GA 13M	Runner	Virginia
<i>Saturated fatty acids</i>				
Palmitic Acid (C16:0)	9.35	5.38	9.69	9.01
Stearic Acid (C18:0)	2.00	2.21	2.28	1.90
Arachidic Acid (C20:0)	1.00	1.59	0.98	1.02
Behenic Acid (C22:0)	2.97	3.55	2.94	2.50
Lignoceric Acid (C24:0)	1.36	1.87	1.34	1.30
<b>Total</b>	16.68	14.61	17.22	15.73
<i>Monounsaturated fatty acids</i>				
Oleic Acid (C18:1)	56.08	81.58	56.11	54.68
Eicosenic Acid (C20:1)	1.07	1.31	1.12	1.02
<b>Total</b>	57.15	82.89	57.23	55.70
<i>Polyunsaturated fatty acids</i>				
Linoleic Acid (C18:2)	26.17	2.50	25.55	28.57
<b>Total</b>	26.17	2.50	25.55	28.57
Oleic to linoleic acid ratio	2.14	32.63	2.20	1.91

<sup>1</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, R = Runner (mixed) kernel, VA = Virginia kernel.

Table 4.2: Mean intensity score for sensory attributes from descriptive analysis of freshly roasted peanuts <sup>1</sup>

Sensory attributes	Sample					
	06G	13M	InR	InVA	R	VA
Brown	41.63 <sup>2</sup>	41.88	41.06	41.13	40.44	44.75
Fracturability	30.31	32.81	29.38	30.19	30.63	33.13
Crispiness	21.81	23.75	23.13	25.06	24.00	23.94
Crunchiness	40.50 <sup>b</sup>	41.88 <sup>b</sup>	43.19 <sup>ab</sup>	44.69 <sup>a</sup>	41.50 <sup>b</sup>	44.63 <sup>a</sup>
Chewy	29.81	29.38	30.31	29.25	29.69	28.75
Toothpacking	22.94	22.00	22.31	23.25	22.38	22.50
Roasted peanutty	41.25	41.67	42.92	44.17	42.50	43.17
Overall oxidized	7.92 <sup>a</sup>	2.08 <sup>bc</sup>	0.00 <sup>c</sup>	1.25 <sup>bc</sup>	1.04 <sup>bc</sup>	3.58 <sup>b</sup>
Cardboard	0.00	0.00	0.00	0.00	0.00	0.00
Fishy	0.00	0.00	0.00	0.00	0.00	0.00
Painty	0.00	0.00	0.00	0.00	0.00	0.00
Bitter	16.53 <sup>a</sup>	15.94 <sup>ab</sup>	13.13 <sup>c</sup>	15.75 <sup>ab</sup>	13.63 <sup>bc</sup>	15.78 <sup>ab</sup>
Sour	1.38	1.38	2.13	2.50	0.75	0.00
Salty	14.63	17.19	15.94	15.50	16.88	15.31
Sweet	16.56	16.75	18.94	17.50	17.81	16.38
Astringent	20.00	20.13	20.63	20.13	20.00	21.44
Oily	15.13	15.00	15.94	13.69	15.00	18.25
Fracturability of shell	N/A	N/A	51.38	49.56	N/A	N/A

<sup>1</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel. <sup>2</sup> No letter or same letters within same row indicate no significant difference between means  $p > 0.05$ .

Table 4.3: Mean of moisture content (wet weight basis) in freshly roasted peanuts <sup>1</sup>

Sample	Moisture content (%)	
	Kernel	Shell
06G	0.58 <sup>d 2</sup>	N/A
13M	1.02 <sup>b</sup>	N/A
InR	1.01 <sup>b</sup>	2.94 <sup>b</sup>
InVA	1.19 <sup>a</sup>	3.02 <sup>a</sup>
R	1.13 <sup>a</sup>	N/A
VA	0.91 <sup>c</sup>	N/A

<sup>1</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel. <sup>2</sup>. Same letters within same column indicate no significant difference between means  $p > 0.05$ .

Table 4.4: Mean score for consumer liking and intensity from consumer analysis of freshly roasted peanuts <sup>1</sup>

Liking	Samples					
	06G	13M	InR	InVA	R	VA
Appearance	6.75	6.74	7.04	6.61	6.87	6.60
Color	6.88 <sup>ab</sup>	6.85 <sup>abc</sup>	7.10 <sup>a</sup>	6.56 <sup>bc</sup>	6.99 <sup>a</sup>	6.51 <sup>c</sup>
Aroma	5.53 <sup>d</sup>	6.53 <sup>ab</sup>	6.13 <sup>bc</sup>	5.88 <sup>cd</sup>	6.68 <sup>a</sup>	6.21 <sup>bc</sup>
Flavor	5.28 <sup>c</sup>	6.23 <sup>ab</sup>	6.58 <sup>a</sup>	6.52 <sup>a</sup>	6.45 <sup>a</sup>	5.77 <sup>b</sup>
Roasted Peanut	5.24 <sup>c</sup>	6.16 <sup>ab</sup>	6.53 <sup>a</sup>	6.32 <sup>ab</sup>	6.40 <sup>ab</sup>	6.03 <sup>b</sup>
Sweet	5.04 <sup>e</sup>	5.60 <sup>bcd</sup>	5.56 <sup>bcd</sup>	5.78 <sup>abc</sup>	5.81 <sup>abc</sup>	5.3 <sup>de</sup>
Texture	6.40 <sup>b</sup>	6.87 <sup>ab</sup>	7.01 <sup>a</sup>	6.96 <sup>a</sup>	7.04 <sup>a</sup>	6.58 <sup>bc</sup>
Like of shelling	N/A	N/A	6.25	6.17	N/A	N/A
Overall	5.39 <sup>b</sup>	6.28 <sup>a</sup>	6.42 <sup>a</sup>	6.65 <sup>a</sup>	6.38 <sup>a</sup>	5.82 <sup>b</sup>
Intensity						
	06G	13M	InR	InVA	R	VA
Roasted Peanut	4.93 <sup>c</sup>	6.15 <sup>a</sup>	5.87 <sup>ab</sup>	5.83 <sup>ab</sup>	5.82 <sup>ab</sup>	5.69 <sup>b</sup>
Sweetness	4.05	4.37	4.18	4.30	4.43	4.22
Bitterness	4.16 <sup>a</sup>	4.11 <sup>ab</sup>	4.40 <sup>a</sup>	4.02 <sup>ab</sup>	3.60 <sup>b</sup>	4.22 <sup>a</sup>
Ease of shelling	N/A	N/A	5.91	5.94	N/A	N/A
% of consumers tasted stale flavor	32.30%	18.20%	18.20%	17.20%	18.20%	33.30%

<sup>1</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel. <sup>2</sup>.No letter or same letters within same row indicate no significant difference between means  $p > 0.05$ .



Table 4.5: Results for consumer demographic questionnaire

	Cluster1 (%)	Cluster2 (%)	Cluster3 (%)
% Consumer surveyed	42.42% (n = 42)	24.24% (n = 24)	(33.33% n = 33)
Age group			
18-24 y	9.52%	20.83%	6.06%
25-34 y	21.43%	41.67%	27.27%
35-44 y	7.14%	25.00%	15.15%
45-54 y	30.95%	8.33%	27.27%
55y or older	30.95%	4.17%	21.21%
Gender			
Male	47.62%	29.17%	33.33%
Female	52.38%	70.83%	63.64%
Frequency of eating peanuts			
Daily	11.90%	8.33%	9.09%
2-3/week	50.00%	50.00%	15.15%
1/week	16.67%	16.67%	18.18%
3/month	9.52%	12.50%	21.21%
2/month	11.90%	12.50%	18.18%
1/month	0.00%	0.00%	15.15%
Types of peanut products			
Roasted peanuts	85.71%	87.50%	54.55%
Boiled peanuts	42.86%	41.67%	21.21%
Peanut butter	85.71%	87.50%	63.64%
Peanut bars	54.76%	33.33%	36.36%
Candy	7.14%	4.17%	6.06%
Shelled VS In-shell preference			
Inshell	26.19%	8.33%	21.21%
Shelled	33.33%	62.50%	57.58%
no preference	40.48%	29.17%	18.18%
Aspects that consumers care about for in-shell roasted peanuts			
Expiration date	52.38%	25.00%	21.21%
Texture	42.86%	25.00%	9.09%
Flavor	57.14%	33.33%	30.30%
Health benefits	23.81%	8.33%	9.09%
Packaging	19.05%	12.50%	3.03%
Brand	26.19%	8.33%	0.00%
Price	38.10%	20.83%	18.18%

Table 4.5: (continued)

	Cluster1 (%)	Cluster2 (%)	Cluster3 (%)
% Consumer surveyed	42.42% (n = 42)	24.24% (n = 24)	(33.33% n = 33)
Aspects that consumers care about for shelled roasted peanuts			
Expiration date	45.24%	54.17%	45.45%
Texture	33.33%	50.00%	33.33%
Flavor	61.90%	91.67%	57.58%
Health benefits	21.43%	20.83%	24.24%
Packaging	19.05%	29.17%	9.09%
Brand	19.05%	33.33%	18.18%
Price	47.62%	70.83%	45.45%

Table 4.6: Correlation coefficients among the consumer variables and overall liking of freshly roasted peanuts

Related variables	Correlation coefficient <sup>1</sup>		
	Cluster 1	Cluster 2	Cluster 3
Liking VS overall liking			
Appearance	0.34	0.80	0.48
Color	0.10	0.80	0.45
Aroma	0.78	0.72	0.09
Flavor	<b>0.90</b> <sup>2</sup>	<b>0.99</b>	<b>0.88</b>
Roasted Peanut	<b>0.96</b>	<b>0.96</b>	<b>0.89</b>
Sweet	<b>0.88</b>	<b>0.94</b>	0.50
Texture	<b>0.86</b>	<b>0.98</b>	0.61
Intensity VS overall liking			
Roasted Peanut	<b>0.89</b>	<b>0.91</b>	0.62
Sweetness	<b>0.87</b>	0.74	0.69
Bitterness	-0.37	-0.68	-0.19
% of consumers tasted stale flavor	<b>-0.96</b>	<b>-0.96</b>	-0.80

<sup>1</sup>.Pearson correlation coefficients.

<sup>2</sup> Values in bold indicate significant correlation between related variables with  $p < 0.05$ .

Table 4.7: Intensity score for consumer ratings from cluster analysis of freshly roasted peanuts <sup>1</sup>

Sample	Overall liking			% of consumers tasted old/ stale flavor		
	Cluster1	Cluster2	Cluster3	Cluster1	Cluster2	Cluster3
06G	6.59 <sup>cde 2</sup>	3.71 <sup>i</sup>	4.87 <sup>gh</sup>	21.43%	54.17%	30.30%
13M	7.21 <sup>abcd</sup>	5.80 <sup>ef</sup>	5.24 <sup>fg</sup>	11.90%	25.00%	21.21%
InR	6.93 <sup>bcd</sup>	6.46 <sup>de</sup>	5.54 <sup>fg</sup>	14.29%	20.83%	21.21%
InVA	7.07 <sup>abcd</sup>	7.46 <sup>ab</sup>	5.30 <sup>fg</sup>	11.90%	12.50%	30.30%
R	7.64 <sup>a</sup>	5.31 <sup>fg</sup>	5.33 <sup>fg</sup>	7.14%	37.50%	18.18%
VA	7.29 <sup>abc</sup>	4.38 <sup>hi</sup>	4.79 <sup>hg</sup>	11.90%	58.33%	42.42%

<sup>1</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel. <sup>2</sup>. Same letters in overall liking table indicate no significant difference between means  $p > 0.05$ .

Table 4.8: Mean concentration (µg/kg) of volatile compounds in freshly roasted peanuts <sup>1</sup>

Compound	KI (Exp)	KI (Lit)	06G		13M		InR		InVA		R		VA	
			Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Alcohols														
1-Octen-3-ol	978.34	976.00	16.02	1.87	n.d.		1.71	0.35	3.40	0.36	3.38	0.18	5.21	0.15
Total alcohols			16.02 <sup>a 2</sup>		0 <sup>d</sup>		1.71 <sup>cd</sup>		3.40 <sup>bc</sup>		3.38 <sup>bc</sup>		5.21 <sup>b</sup>	
Aldehydes														
Hexanal	800.83	800.00	32.77	1.33	n.d.		14.00	1.03	27.71	2.56	12.36	0.97	16.15	2.77
Heptanal	901.43	901.00	4.87	1.93	n.d.		1.20	0.19	2.37	0.49	1.56	0.12	1.98	0.30
Octanal	1000.91	1001.00	32.92	2.05	17.67	1.03	12.12	0.72	19.02	6.65	19.80	1.10	23.13	8.22
Nonanal	1100.94	1102.00	103.04	14.14	56.47	6.31	33.05	7.52	51.43	6.92	53.50	10.88	59.69	2.56
2,4-Decadienal	1306.65	1317.00	7.51	0.51	n.d.		0.89	0.05	2.18	0.57	1.38	0.35	1.79	0.43
Total aldehydes			181.12 <sup>a</sup>		74.14 <sup>cd</sup>		61.25 <sup>d</sup>		102.72 <sup>b</sup>		88.59 <sup>bc</sup>		102.72 <sup>b</sup>	
Alkanes														
Undecane	1097.24	N/A	54.08	5.88	42.59	3.08	54.08	7.92	79.62	19.03	44.32	3.84	36.57	3.81
Dodecane	1195.21	N/A	53.02	1.85	51.56	3.84	4.72	1.38	15.97	3.05	37.56	1.19	40.80	5.45
Tridecane	1293.33	N/A	65.81	1.92	54.19	0.87	3.18	0.11	22.48	5.36	36.20	4.96	53.02	7.50
Total alkanes			172.91 <sup>a</sup>		148.34 <sup>ab</sup>		61.98 <sup>d</sup>		118.07 <sup>c</sup>		118.09 <sup>c</sup>		130.39 <sup>bc</sup>	
Terpenes														
D-Limonene	1022.67	1028.00	6.76	4.15	7.77	0.72	n.d.		2.40	0.44	n.d.		6.57	0.16
Total terpenes			6.76 <sup>a</sup>		7.77 <sup>a</sup>		0 <sup>c</sup>		2.40 <sup>bc</sup>		0 <sup>c</sup>		6.57 <sup>ab</sup>	

Table 4.8: (continued)

Compound	KI	KI	06G		13M		InR		InVA		R		VA	
	(Exp)	(Lit)	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Benzene derivatives														
Benzaldehyde	953.23	961.00	100.6 6	13.23	68.11	2.02	136.8 6	37.8 7	95.79	15.7 3	118.7 6	0.92	86.47	6.62
Benzeneacetaldehyde	1037.5 8	1043.0 0	553.0 7	124.4 6	418.0 2	36.1 1	659.0 5	83.9 0	412.8 8	58.8 9	703.8 5	95.1 4	478.4 6	23.2 0
Acetophenone	1058.8 9	1065.0 0	17.76	0.02	19.74	2.62	15.41	4.86	15.76	2.39	19.54	2.38	23.62	3.29
Total benzene derivatives			671.4 <sup>ab</sup>		505.87 <sup>b</sup>		811.32 <sup>a</sup>		524.43 <sup>b</sup>		842.14 <sup>a</sup>		588.54 <sup>b</sup>	
Furan derivatives														
Furfural	827.45	835.00	84.39	0.68	47.44	0.21	37.94	2.30	38.86	2.04	67.11	4.16	75.88	9.62
Furan, 2-pentyl-	989.41	996.00	6.69	0.56	n.d.		2.94	1.49	4.33	0.22	2.76	0.74	5.06	2.31
Benzofuran, 2,3-dihydro-	1214.2 7	1219.0 0	25.18	0.32	93.01	11.4 9	77.50	25.0 0	59.74	27.9 5	83.46	20.5 8	43.73	24.3 6
Total furan derivatives			116.26		140.44		118.38		102.94		153.33		124.68	
Ketones														
3-Nonen-2-one	1135.3 7	1136.0 0	5.58	0.12	n.d.		n.d.		n.d.		n.d.		n.d.	
Total ketones			5.58 <sup>a</sup>		0.00 <sup>b</sup>		0.00 <sup>b</sup>		0.00 <sup>b</sup>		0.00 <sup>b</sup>		0.00 <sup>b</sup>	
Pyrroles														
1H-Pyrrole, 1-methyl-	739.33	750.00	40.55	7.36	33.57	2.49	20.84	14.9 2	33.32	23.3 4	29.54	18.7 1	37.14	22.8 7
1H-Pyrrole, 3-methyl-	847.46	841	9.50	0.24	7.93	0.70	5.44	1.95	6.35	0.47	6.46	0.34	9.66	0.23
Total pyrroles			50.05		41.50		26.28		39.67		36.00		46.80	

Table 4.8: (continued)

Compound	KI (Exp)	KI (Lit)	06G		13M		InR		InVA		R		VA	
			Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Pyrazines														
Pyrazine, methyl	817.99	826.00	15.42	1.94	20.29	4.10	14.15	6.70	16.49	3.06	14.79	0.48	25.76	1.60
Pyrazine, 2,5-	907.66	913.00	201.7 1	26.7 0	245.1 6	64.1 6	357.3 1	61.9 9	313.3 9	27.0 8	284.6 3	3.62	335.3 4	55.4 9
Pyrazine, 2-ethyl-5-	994.05	1001.0 0	23.99	0.66	35.15	1.14	23.66	10.6 4	36.43	0.28	25.34	3.52	47.80	5.33
Pyrazine, 3-ethyl-2,5-	1073.7 2	1078.0 0	74.04	1.06	143.7 7	2.72	129.8 5	67.1 6	129.2 2	8.39	101.4 9	21.6 3	176.5 2	16.4 2
Pyrazine, 2-ethyl-3,5-	1079.3 6	1088.0 0	8.01	0.03	11.97	0.44	12.20	4.90	13.50	0.16	9.75	1.28	17.51	1.70
2,3-Dimethyl-5-	1081.1 3	1089.0 0	9.10	0.32	14.90	0.51	16.35	7.58	16.68	1.00	13.06	2.32	22.48	1.89
Pyrazine, 2,5-diethyl-	1083.8 6	1091.0 0	6.05	1.08	7.36	0.50	7.05	3.39	8.96	0.82	7.41	0.11	10.28	0.64
Pyrazine, 2-methyl-6-	1092.5 0	1099.0 0	10.19	1.21	14.93	0.84	19.88	3.23	16.21	0.92	14.72	0.64	13.90	0.05
Pyrazine, 2,3-diethyl-	1149.8 2	1157.0 0	2.52	0.17	4.43	0.01	3.56	2.60	4.42	0.94	3.03	1.15	6.04	0.32
Pyrazine, 3,5-diethyl-	1151.4 8	1159.0 0	7.28	0.66	14.17	0.28	10.73	7.41	12.78	2.59	9.40	2.50	17.25	1.42
Total pyrazines			358.32		512.14		594.73		568.07		483.63		672.87	

Table 4.8: (continued)

Compound	KI (Exp)	KI (Lit)	06G		13M		InR		InVA		R		VA	
			Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Pyridines														
Pyridine, 2-pentyl-	1188.23	1192	21.59	1.37	n.d.		n.d.		2.01	0.00	1.62	0.38	6.02	0.05
Total pyridines			21.59 <sup>a</sup>		0.00 <sup>c</sup>		0.00 <sup>c</sup>		2.01 <sup>c</sup>		1.62 <sup>c</sup>		6.02 <sup>b</sup>	

<sup>1</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel; <sup>2</sup>.No letter or same letters within same row indicate no significant difference between means  $p > 0.05$



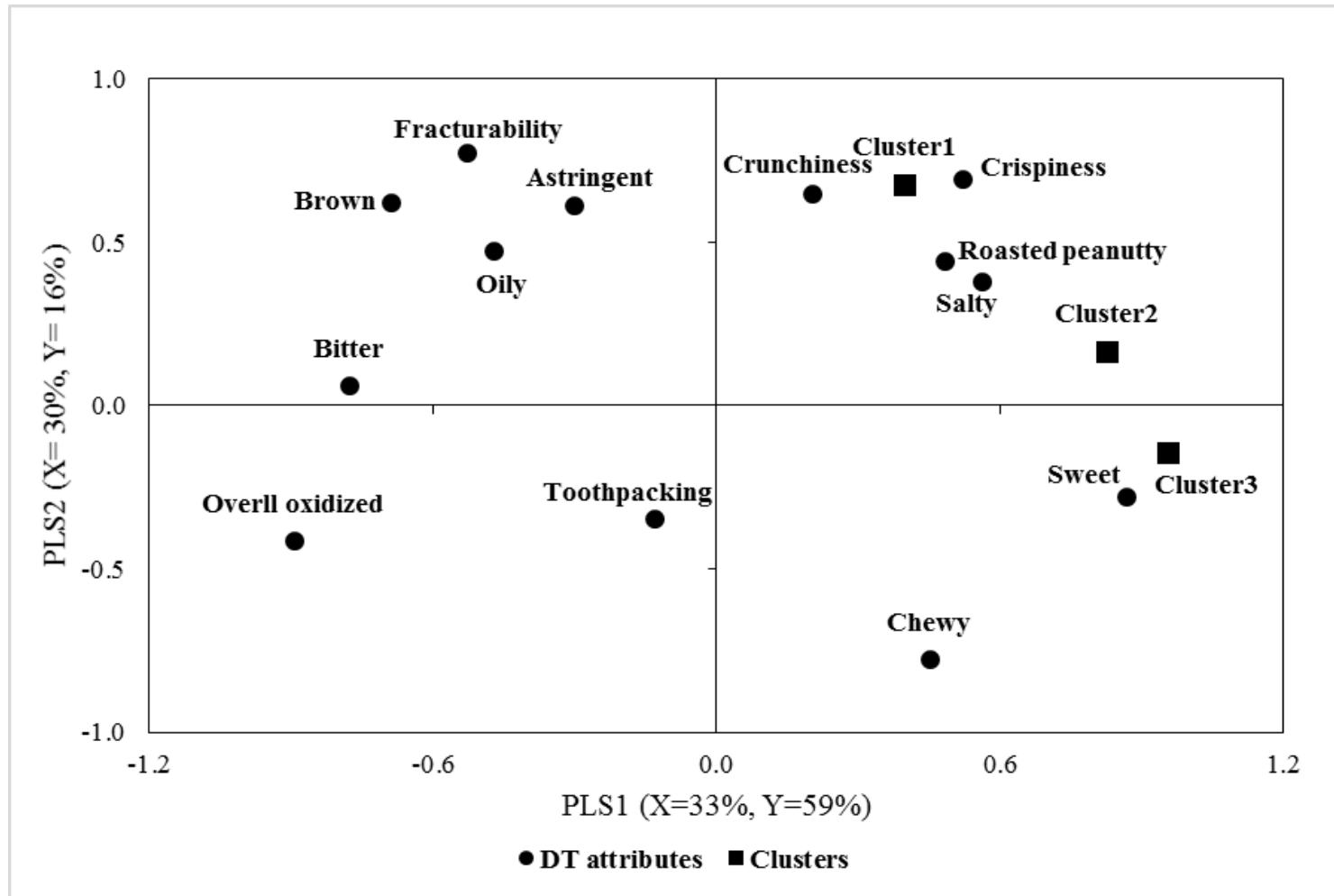


Figure 4.1: PLS-R plot of factor 1 and factor 2 for drivers of consumer overall liking  
(a) Descriptive data (X); (b) overall liking by 99 consumers devided into 3 clusters (cluser 1 =42 , cluster2 =24, cluster 3= 33)

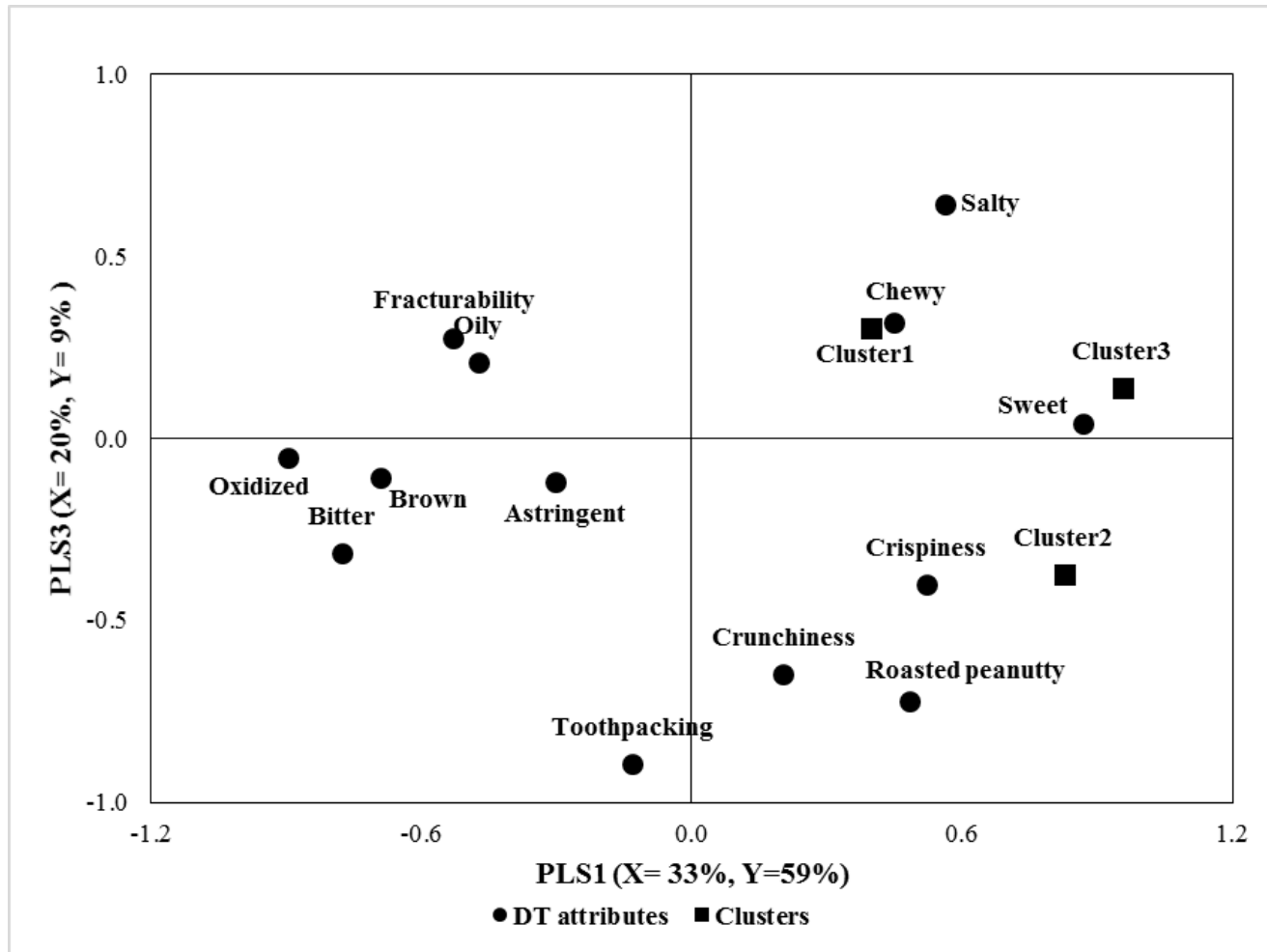


Figure 4.2: PLS-R plot of factor 1 and factor 3 for drivers of consumer overall liking  
(a) Descriptive data (X); (b) overall liking by 99 consumers divided into 3 clusters (cluster 1 =42 , cluster2 =24, cluster 3= 33)

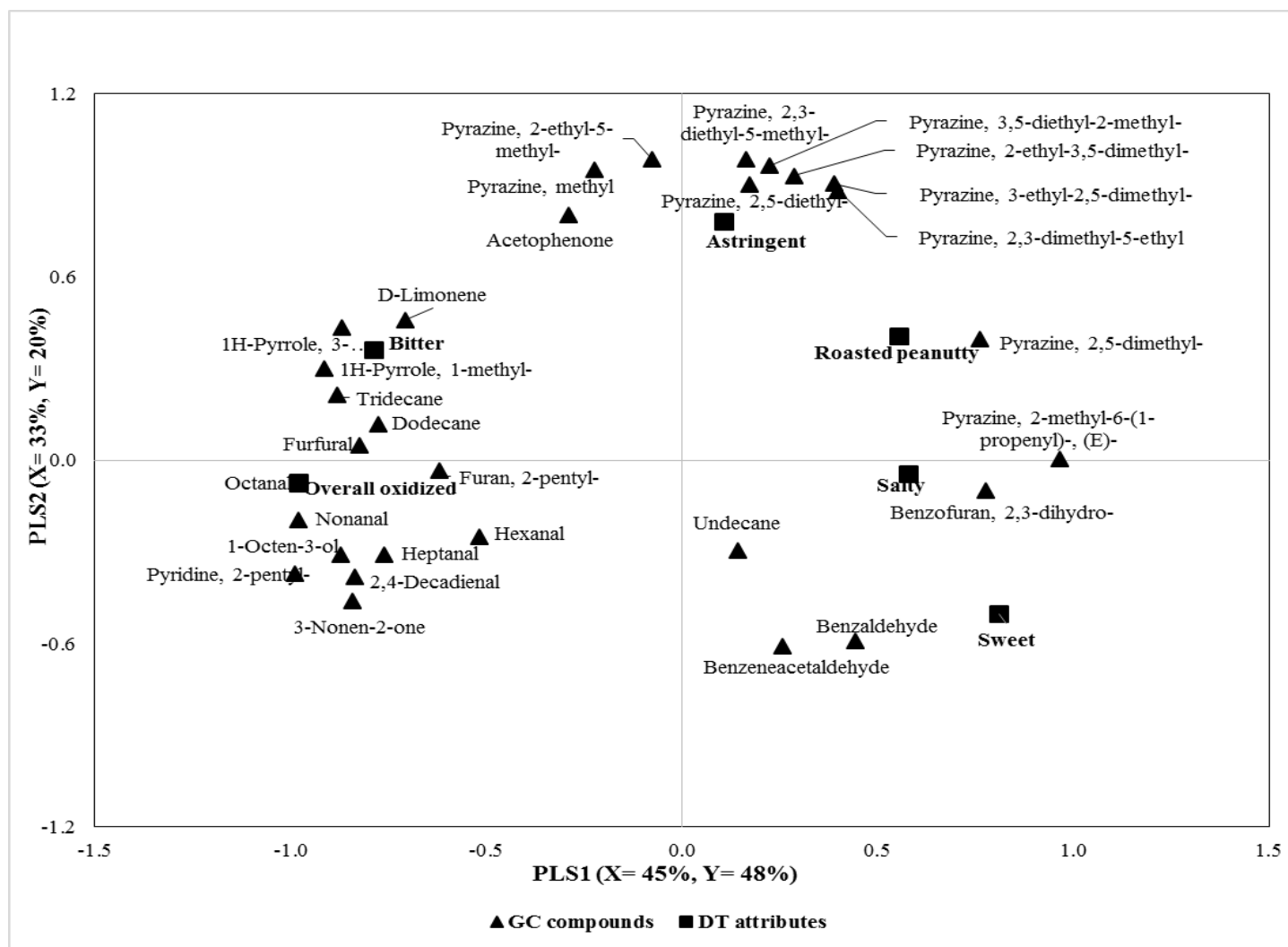


Figure 4.3: PLS-R plot of factor 1 and factor 2 for relationship between GC and sensory profile  
(a) Gas chromatography data (X); (b) descriptive data (Y).

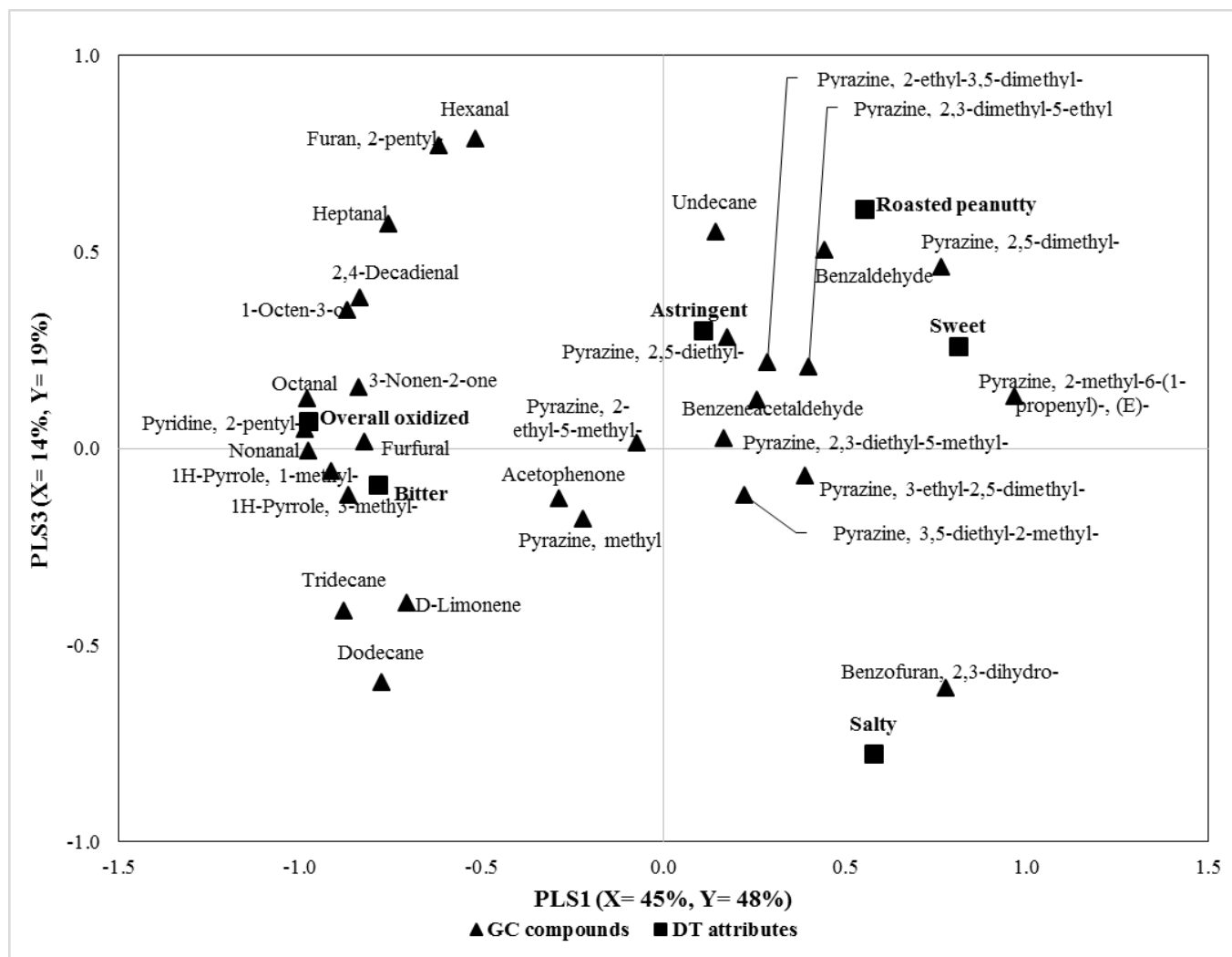


Figure 4.4: PLS-R plot of factor 1 and factor 3 for relationship between GC and sensory profile  
(a) Gas chromatography data (X); (b) descriptive data (Y).

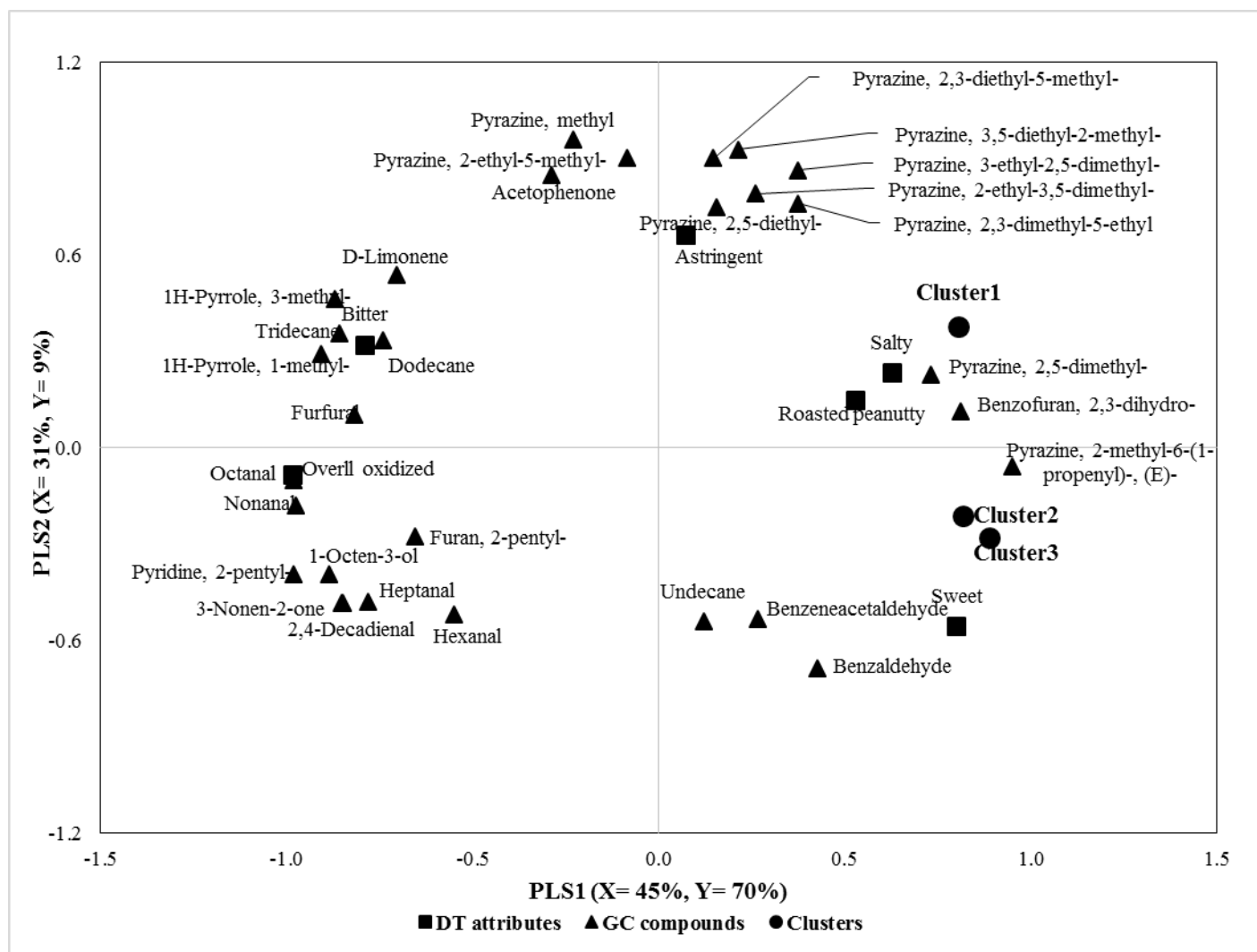


Figure 4.5: PLS-R plot of factor 1 and factor 2 for drivers of consumer flavor liking  
(a) Gas chromatography data and descriptive data (X); (b). flavor liking by 99 consumers divided into 3 clusters (cluster 1 =42 , cluster2 =24, cluster 3= 33)

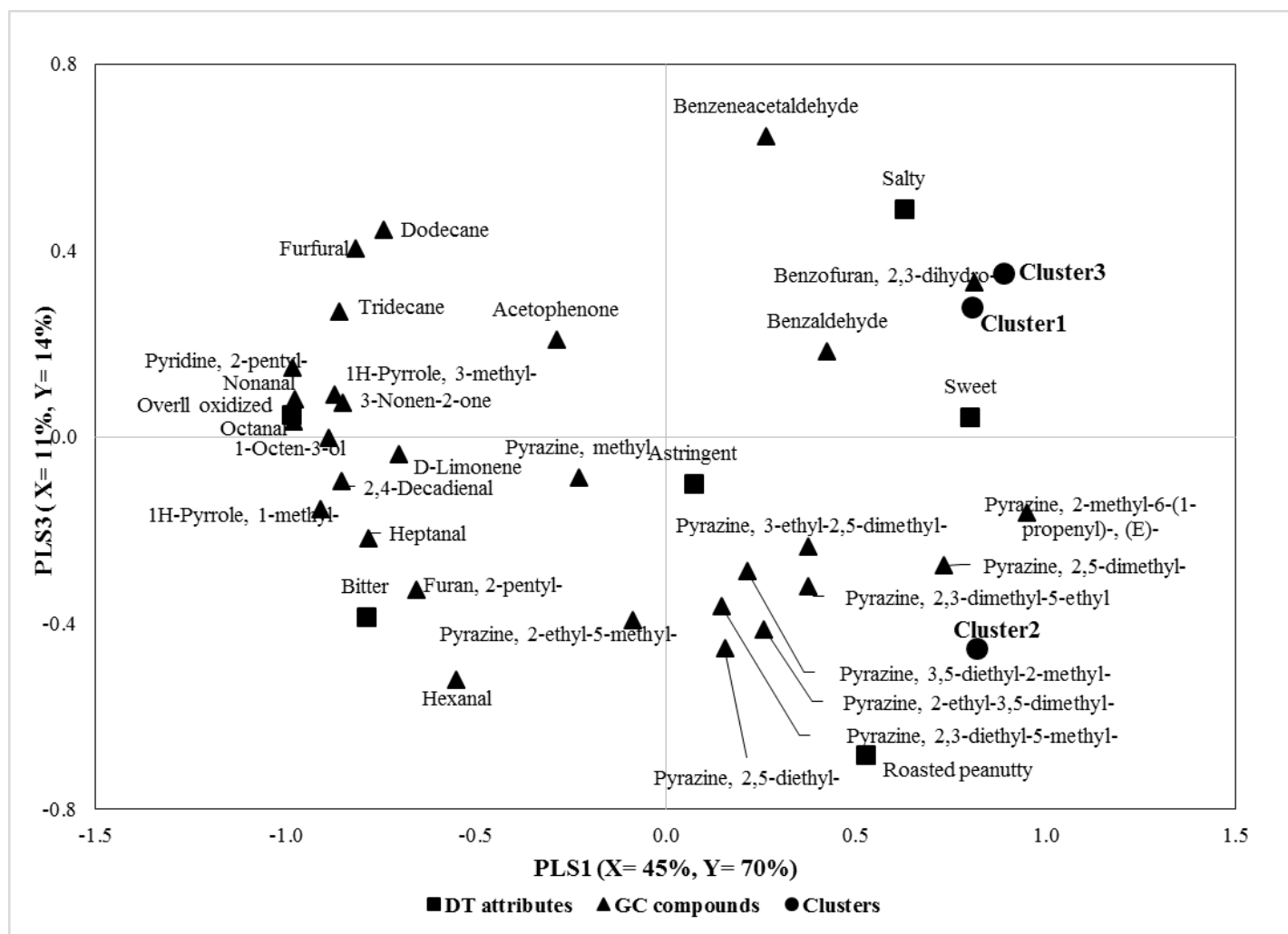


Figure 4.5: PLS-R plot of factor 1 and factor 3 for drivers of consumer flavor liking

(a) Gas chromatography data and descriptive data (X); (b). flavor liking by 99 consumers divided into 3 clusters (cluster 1 =42 , cluster2 =24, cluster 3= 33)

CHAPTER 5

EFFECTS OF SHORT STORAGE ON THE SENSORY AND GC PROFILES OF ROASTED

PEANUTS

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Wang, S., Adhikari, K., and Hung, Y.-C. To be submitted to *Journal of Food Science*

## **Abstract**

The major objective of this study was to determine the effects of short storage of eight weeks on the sensory flavor and GC profiles of roasted peanuts. Normal-oleic Georgia 06G kernels, high-oleic Georgia 13M kernels, Runner (mixed) in-shell & kernels, and Virginia (mixed) in-shell & kernels were roasted to medium doneness and stored for 0, 4 and 8 weeks at 21 °C. The concentrations of total aldehyde and alcohol content were significantly increased in 8 weeks. A decreasing content was observed in the level of total pyrazine. But these changes did not cause significantly difference in most of related attributes. InVA showed the greatest change in consumer acceptability, roasted peanutty flavor, total aldehyde and alcohol content. Compared with normal-oleic 06G, high-oleic 13M was significantly preferred by consumers at all three time points. Also, normal-oleic 06G was the most oxidized sample, while high-oleic 13M exhibited the best ability to retain pyrazines and developed less oxidation products. Given the decreased content of pyrazines, the loss of roasted peanutty flavor was more likely caused by the degradation of pyrazines rather than the masking effects of aldehydes.



## **.Introduction**

Peanuts (*Arachis hypogaea*) are known as a major crop in many countries. As a major peanut products, roasted peanuts are very popular in the United States because of its pleasant flavors formed during roasting. However, these positive attributes (especially roasted peanutty flavor) associated with freshly roasted peanuts gradually diminishes accompanied by the development of off-flavors during storage (Hui and others 2010). Pyrazines and aldehydes are considered as two key compounds that influence the flavor stability of roasted peanuts. Pyrazines are an important group of volatiles formed during roasting and are always associated with roasted flavor/aroma. (Baker and others 2003; Buckholz and others 1981; Maga and others 1973; Warner and others 1996; Williams and others 2006; Liu and others 2011). Aldehydes are mainly formed from lipid oxidation during storage. Given the high lipid content of peanuts, this product is very vulnerable to oxidation during storage. Although both of them will affect the flavors of roasted peanuts, their roles in the loss of roasted peanut flavor are still not clear. Warner and others (1996) pointed out that the concentration of pyrazines did not decrease with storage and they considered the flavor fade was caused by masking of pyrazines and other roasted peanut flavor compounds by aldehydes. However, Bett and Boylson (1992) noted a significantly decrease in alkylpyrazines in the early storage time. Therefore, they concluded that degradation of pyrazines might be the reason for loss of roasted flavor. Reeds and others (2002) further found that low water activities led to higher levels of oxidation compounds with more decline in pyrazines. The degradation of pyrazines possibly result from flavor entrapment or degradation by free radicals and hydroperoxides from lipid oxidation (Williams and others 2006).

In order to extend the shelf life of roasted peanuts, high-oleic varieties have been developed. Researchers have found that compared to normal-oleic peanuts high-oleic lines were

able to persist roasted peanutty flavor longer during storage. (Braddock and others 1995; Nepote and others 2006; Pattee and others 2002; Reed and others 2002; Talcott and others 2005). This advantage was also proved in large-seed in-shell Virginia peanuts (Mozingo and others 2004). Moreover, Reeds and others (2002) indicated that high-oleic trait offered roasted peanuts more resistance to the effects of storage humidity conditions.

The purposes of this study were: 1) to study the effect of storage on sensory attributes and GC volatile compounds; 2) to compare the difference between high oleic and normal oleic variety, in-shell and shelled type; 3) to explore the possible reasons for flavor fade.

## **Material and methods**

### **Sample preparation**

High (GA 13M) and normal (GA 06G) oleic peanut pods were obtained from the University of Georgia Department of Crop & Soil Science (Tifton Campus). Runner (mixed) and Virginia peanut pods were provided by Golden Peanuts. Before processing, sample pods were sorted, cleaned and dried at 40 °C overnight in a mechanical convection oven (Model 645 Freas, Precision Scientific, Winchester, VA). Then all the samples were heated at 163 °C for 5 min in Lincoln impingement oven (Lincoln Impinger, Fort Wayne, IN) to reduce the potential for mold growth. After cooling down to room temperature ( $21 \pm 1$  °C), samples were flushed with nitrogen, vacuum sealed and kept at 4 °C.

Before roasting, the samples were firstly equilibrated at room temperature for at least 12h. GA 06G (06G) and GA 13M (13M) were used for shelled roasted peanuts, while Runner and Virginia were used for both in-shell (InR, InVA) and shelled (R, VA) roasted samples. All samples were roasted in Lincoln impingement oven (Lincoln Impinger, Fort Wayne, IN) to a medium doneness based on the surface color Lightness ( $L$ ) value of  $50 \pm 1$ . After roasting,

peanuts were cooled to room temperature by a cooling fan and the roasted kernels were then blanched in an Ashton peanut blancher (Model EX, Ashton Food Machinery Co., Newark, NJ). The blanched kernels were further manually split into two halves and resorted before packaging. All the samples were flushed with nitrogen, vacuum packaged, and stored at 4 °C till further use. The fatty acid profiles of four varieties (GA 06G, GA 13M, Runner, Virginia) were analyzed after roasting by Daniel L. Jackson at University of Georgia, Pesticide & Hazardous Waste Laboratory, 2300 College Station Rd., Athens, GA. The results were shown in Table 5.1.

#### Sampling procedure

Samples were moved from the fridge 2 d before the first sensory test day, equilibrated to room temperature overnight and stored in Ziploc® bags at 21 °C. Moisture, color and both descriptive and consumer analysis were performed at week 0, 4 and 8. Runner roasted in-shell peanuts at week 0 were also used as warm-up (WUP) samples in descriptive analysis. Both WUP samples and samples for gas chromatography (GC) tests at each time point were vacuum packaged with nitrogen and frozen in plastic bags at -20 °C.

#### Color measurement

A benchtop ColorFlex Spectrophotometer (HunterLab, Reston, VA) was used to measure the surface color of roasted peanuts. It was standardized by black glass and white tile ( $L=93.24$ ,  $a^*=-1.30$ ,  $b^*=0.84$ ) and the  $L$  value was measured in duplicate by placing samples evenly on the bottom of the sample cup and 4 readings per sample were obtained for each sample (Yeh and others 2002).

#### Moisture measurement

Moisture contents (wet weight basis) were measured based on a method modified from AOAC 925.40 (AOAC. 2000). Samples were grinded into small particles in a coffee grinder

(Hamilton Beach Co., Southern Pines, NC). About 2 g kernel or 1 g shell samples were dried in duplicate in a vacuum oven (285A, Fisher Scientific, Pittsburgh, PA) at 100 °C under pressure 51 cm Hg for 6 h to constant weight. The weight loss of shell and kernel was separately reported as their moisture content.

Approval from UGA's IRB was taken before collecting the sensory data.

### Descriptive analysis

Samples were evaluated by a descriptive panel trained using generic descriptive analysis. 8 panelists with more than 10-year experience were recruited. All of them participated in two 2 h training sessions to develop a lexicon for both in-shell and shelled roasted peanuts. The final list of descriptors with evaluation methods, definitions and references were decided by panel consensus. Six of them were further chosen for another 2 h-special training session where they were majorly trained for the flavor of roasted peanuts. Paper ballots with 150 mm unstructured line scale anchored at 12.5 and 137.5 mm were applied during the training and test sessions. Water and unsalted crackers (Kroger Co., Cincinnati, OH) were used to clean palate.

At the beginning of each test session, the panelists were calibrated with basic solutions (bitter 20, 50, 100; sour 20, 50, 100; salty 25, 50, 85; sweet 20, 50 100, 150; astringent 20, 50, 100) and a WUP sample (equilibrated to room temperature) before entering the booths. They were asked to re-evaluate the WUP sample if their readings went beyond 10 mm from the means on the scale (Kemp and others 2009). All the samples were served in partitioned booths under incandescent light at room temperature according to a randomized complete block design with two replications. A 5 min break was inserted between the sixth and seventh samples to prevent panelists from fatigue. The flavors of roasted peanuts were done separately on another day by the 6 panelists who participated in the special training sessions.

### Consumer Analysis

All consumers were recruited through facebook, flyers and an existing consumer database established and maintained at Sensory Evaluation and Consumer Lab, Department of Food Science and Technology, University of Georgia, Griffin Campus. They must age between 18-65 years old, having no allergy to peanuts or any kind of nuts, and eat peanut products at least once a month. The number of consumers participated in three tests was 99, 92, 91 respectively.

The consumer tests were carried out in partitioned booths under incandescent light at room temperature. About 5 g of each peanut sample were served with corresponding ballot in a sequential monadic order based on a completely randomized design. Unsalted crackers (Kroger Co., Cincinnati, OH) and water were used as palate cleansers between samples.

### GC analysis

Headspace-solid phase microextraction (HS-SPME) technique was applied for extraction. Samples (equilibrated to room temperature) were grinded into small particles in a coffee grinder (Hamilton Beach Co., Southern Pines, NC) and exactly 1.5 g were transferred to a 20 mL screw-cap vial equipped with a polytetrafluoroethylene/silicone septum in duplicate. Exactly 2 mL distilled water was added with 20  $\mu$ L of 0.045 mg/mL 1,3-dichlorobenzene (Sigma-Aldrich, St. Louis, MO) solution (methanol) to the vial. The vials were equilibrated for 15 min at 50  $^{\circ}$ C in the autosampler (Model GC Sampler 80, Agilent Technologies, Santa Clara, CA) and agitated at 250 rpm. After the equilibration, a 50/30  $\mu$ m divinylbenzene/carboxen/polydimethylsiloxane fiber was exposed to the sample headspace for 40 min at 50  $^{\circ}$ C. Then the analytes were desorbed to the injection port of gas chromatography-mass spectrometry (GC-MS) at 250  $^{\circ}$ C for 5 min in splitless mode.

GC-MS analysis were performed on a GC system (Model 7890A, Agilent Technologies, Santa Clara, CA) equipped with a HP-5MS column (30 m\*250 $\mu$ m\*0.25 $\mu$ m) and with a MS detector (Model 5977A, Agilent Technologies, Santa Clara, CA). Volatile compounds were carried by helium with flow rate of 1 mL/min. The solvent delay was set at 3 min. The column was maintained at 40  $^{\circ}$ C for 5 min, programmed at 2  $^{\circ}$ C /min to 116  $^{\circ}$ C and at 6  $^{\circ}$ C /min to the final temperature 200  $^{\circ}$ C. MS detector scanned a mass range (m/z) from 30 – 400 with scan speed 1.562  $\mu$ /s. The temperature of MS source and MS quadrupole was 230  $^{\circ}$ C and 150  $^{\circ}$ C respectively.

Identification of compounds was based on both mass spectra database (NIST/EPA/NIH mass spectral library, Version 2.2, 2014) and Kovats indices (NIST spectra library collection). Kovats indices (KI) were calculated based on the retention time of a series of n-alkanes (C7-C30). Semi-quantification method was used to calculate the relative concentration of investigated compounds according to the peak area of IS.

#### Statistical analysis

The data from consumer, descriptive and physicochemical analyses were analyzed by ANOVA in SAS (version 9.4, SAS Institute, Cary, NC). Glimmix procedure (General Linear Mixed Models) procedure was used for sensory test with consumer/panelist as a random factor. Least Square means were calculated. Post-hoc mean separation was done using Fisher's LSD (Least Significant Difference). Correlation analysis was conducted in XLSTAT (version 2015.2.02, Addinsoft, New York, NY).

## Results and discussion

### Color lightness value and moisture content

Color lightness ( $L$ ) value was significantly ( $p<0.05$ ) increased during storage (Figure 5.1). The highest  $L$  value was found in 06G in week 8. Lipid oxidation has been known to cause the loss of fat soluble pigments (Kamal-Eldin and Appelqvist 1996). Researchers have found that roasted peanuts with decreased oil content exhibited a lighter color (Brannan and others 1999). Divino (1995) considered that decreased content of fat soluble pigment (melanin) was responsible the lighter color in defatted roasted peanuts. Therefore, it would be possible that this increase in  $L$  value resulted from the loss of fat soluble pigments through the degradation of fatty acids during oxidation process. Storage was also found to have significant ( $p<0.05$ ) effects on moisture content (Figure 5.2). The moisture content of the kernels increased gradually during storage. 06G had the lowest moisture content during the whole storage period. The largest rate of increase was detected in both InR and R from week 4 to week 8. The moisture content of the shell was found to firstly decrease during the first month and then increased (Figure 5.3). InR had a slightly lower shell-moisture content at the very beginning, but showed a larger rate of increase from week 4, ending with a significantly ( $p<0.05$ ) higher shell moisture content than InVA.

### Descriptive analysis

Former researchers found that with increased storage time some off-flavors like oxidized, cardboard developed in roasted peanuts accompanied by a decrease in roasted peanutty flavor (Hui and others 2010). In this study, the highest level of oxidized flavor was observed in 06G in week 8 with the mean intensity of 13.71 (Figure 5.4). Except for the highest value, all other intensities were below threshold (12.5 mm on a 150 mm scale) during eight weeks. When

the intensity drops below threshold, the changes in that intensity will be difficult for human senses to identify. Thus, although a significant ( $p<0.05$ ) increase in overall oxidized flavor was found in 06G and InVA from statistical analysis, it's risky to conclude that panelists did observe this change in the descriptive tests given the threshold. Cardboard flavor is associated with oxidized products in their earlier stages of oxidation (Lee and Resurreccion 2004). As storage time further increases, other off-flavors like fishy and painty appears. Nepote and others (2006) found that the cardboard flavor intensity was about 10 mm on a 150mm scale on day 56 for both high-oleic and normal-oleic roasted peanuts stored at 23 °C. Braddock and others (1995) stored roasted peanuts at 25 °C and detected an apparent increase in both cardboard and painty flavor at day 45. However, the increase in these off-flavors were not found in this study. Cardboard and fishy flavor were only detected in InVA in week 8 with mean intensity of 0.83. Painty flavor was detected in 06G in week 4 and 8 with mean intensity of 1.33 and 0.83 respectively. Given these extremely low intensities, all these three off-flavors can be considered as negligible in the samples. Compared to others work, these very low intensities might be caused by factors like lower storage temperature, different environmental relative humidity, different varieties etc. In general, the off-flavors were very low after the storage of 8 weeks.

Roasted peanutty flavor was found to be significantly ( $p<0.05$ ) different among samples but not among the storage times. However, the trend of decrease in roasted peanutty flavor from week 0 to week 8 was still observed (Figure 5.5) for 06G, R and InVA, especially for InVA. InVA had the highest roasted peanutty flavor at the very beginning, but showed the greatest loss from week 4 to week 8, ending with a lower intensity than most of the samples except for 06G. Normal-oleic 06G had the lowest intensity at all three time points. Compare to it, high-oleic 13M had a relatively higher and more stable roasted peanutty flavor during 8 weeks.



This finding was in agreement with the work of other researchers (Braddock and others 1995; Nepote and others 2006; Pattee and others 2002; Reed and others 2002; Talcott and others 2005). VA was another sample that persisted roasted peanutty flavor longer. In week 8, it had the greatest roasted flavor that was significantly ( $p<0.05$ ) higher than InVA and 06G.

Sweet taste is also associated with freshly roasted peanuts, which was expected to decrease in the earlier stage of storage (Williams and others 2006). However, this change was not found in this study. During 8 weeks, significantly ( $p<0.05$ ) increase was observed in all the samples except for InR (Figure 5.6). But no significant difference was tested among samples.

#### Consumer acceptability

Although storage effect did not show significant differences in consumer overall liking, some samples like InVA still exhibited an obvious decrease in acceptability scores during storage (Figure 5.7). In this study, 6 on a 9-point hedonic scale was the cut-off point of the consumer liking to roasted peanuts. Both in-shell samples were relatively preferred than other samples at week 0, but their overall liking began to decrease at a higher rate after the first time point. This made R become the most liked sample followed by high-oleic 13M in week 4 and week 8. The largest decrease was found in InVA. Even if consumers lost their likings for InVA at the third time point, they still gave it a higher overall liking score than VA at all three time points. When normal-oleic 06G was compared with high-oleic 13M, 13M was significantly ( $p<0.05$ ) preferred during this period with significantly ( $p<0.05$ ) higher intensities in liking of aroma, flavor, sweet taste and roasted peanut flavor. In general, for Runner variety (except for 06G), consumers liked both of its shelled and in-shell roasted products in 56 days. As a widely grown Runner cultivar, 06G might oxidized at a higher level before processing in this study, which to some extent explained its higher oxidized flavor at week 0 and consumers' disliking.

In-shell Virginia-type roasted peanuts have a short shelf-life in the market (Mozingo and others 2004). In our study, the greatest decrease was found in InVA. This might result from the oxidation problem. Therefore, from the aspect of consumer acceptability, Runner might be a better variety for in-shell roasted peanuts.

#### Volatile changes

A total of 30 volatile compounds were identified by GC-MS system and classified to 10 groups: alcohols (1 compound), aldehydes (5 compounds), alkanes (3 compounds), terpenes (1 compound), benzene derivatives (3 compounds), furan derivatives (3 compounds), ketones (1 compound), pyrroles (2 compounds), pyrazines (10 compounds) and pyridines (1 compound). Details were include in former chapter (Table 4.8). Among them, 22 compounds were detected from all roasted peanuts.

Lipid oxidation is thought as a mechanism that raises the peanut volatiles during storage (Pattee and others 1971). As the major class of oxidation products, five aldehydes (hexanal, heptanal, octanal, nonanal and 2,4-decadienal) was detected. However, hexanal, heptanal, and 2,4-decadienal were not found in high oleic 13M during the storage. Both hexanal and 2,4-decadienal are normally regarded as the oxidation products of linoleic acid but from different hydroperoxide source. The precursor of hexanal is 13-hydroperoxides, while 2,4-decadienal is converted from 9-hydroperoxides (Frankel 1983). Given that 13M only had 2.5% of linoleic acids, this may explain why these two compounds were not detected in it. Heptanal is formed through the oxidation of both oleic and linoleic acids (Frankel 1983; Nawar 1996). 13M had the O/L ratio of 32.63 which was 15-17 times higher than other varieties (06G-2.14; Runner-2.20; Virginia-1.91). Thus, 13M should oxidize slower than other samples and the absence of heptanal in 13M might due to this reason.

The concentration of total aldehydes increased from week 0 to week 8 for all six samples (Figure 5.8). Among them, a significant ( $p<0.05$ ) increase was observed in 06G, InR, InVA, and VA. The largest percentage of increase was in InVA. The amount of aldehydes in 06G was significantly ( $p<0.05$ ) higher than all other samples at the start point. An apparent increase in this sample started from week 4. After another 4 weeks of storage, it reached the highest level of aldehydes with an averaged total concentration of 236.7  $\mu\text{g/kg}$ .

Nonanal was the major aldehydes in 06G, 13M, R and VA, accounting for more than 50% of total aldehyde concentration throughout the storage. Nonanal originates from the 9- and 10- hydroperoxides during the autoxidation of oleic acid (Frankel 1983). 13M had 81.58% of oleic acids and more than 75% of its total aldehyde was consisted of nonanal. After 8 weeks, its concentration increased by the largest percentage, ending with a concentration only lower than 06G. Nonanal was also the most important aldehyde in two in-shell samples during the first 4 weeks. However, hexanal played a more influential role from week 4 to week 8 with concentrations underwent three and four fold increase (week 0 to week 8) in InR and InVA respectively. This increase led to a boost of total aldehyde concentration in InVA and might have further caused the increase in overall oxidized flavor. Octanal was another important aldehyde produced from the oxidation of oleic and linoleic acids (Nawar 1996). Its initial concentration was the second largest in 06G, R and VA. But its rates of increase were relatively lower compare to that of nonanal and hexanal. As for heptanal and 2,4-decadienal, their concentrations also increased slightly during storage. But considering their extremely low content in this study, their contributions to oxidized flavor might be negligible.

As another type of oxidation products, only one alcohol, 1-octen-3-ol, was detected in this study. This volatile derives from linoleic acid and has been associated with the rancid odor

in mayonnaise (Jacobsen and others 1999). This compound was not detected in 13M. Except for it, an increase in its concentration was found for all other samples, especially for InVA and InR which had a significant ( $p<0.05$ ) increase from week 4 to week 8 (Figure 5.9). Although the increase in 06G was the least, it still had significantly ( $p<0.05$ ) higher levels than all other samples throughout the storage period.

In general, normal oleic 06G was the most oxidized sample followed by InVA. This was in agreement with descriptive analysis. Nonanal was the most important aldehyde in shelled roasted peanut samples, especially in 13M. While, hexanal had more influences in in-shell samples with a larger rate of increase during the storage. Besides storage and varieties, moisture content also plays a role in lipids oxidation. Considering its significant ( $p<0.05$ ) differences among samples during the storage, moisture content may also affect the formation of oxidation products in this study. On one hand, moisture can slow down oxygen molecules from getting access to unsaturated fatty acids and further impede the lipid oxidation reaction (Nawar 1996). On the other hand, it can form association colloids with oil, which provides both of their surfaces and interfaces as reaction sites for oxidation reaction (Nawar 1996). Furthermore, moisture can play a role in the formation of oxidation products including 2-propenal, hexanal, *trans*-2-heptenal, and 2,4-decadienal (Kim and others 2014). However, no significant ( $p > 0.05$ ) correlations were found for moisture content with either individual aldehydes/ alcohols or their total contents. Further work is required in order to determine the role of moisture in lipid oxidation of roasted peanuts.

Pyrazines were another group of key volatiles in the stability of roasted peanut flavor (Braddock and others 1995). Ten pyrazines were identified in all six samples. Among them, 2,5-dimethyl pyrazine and 3-ethyl-2,5-dimethyl pyrazine were presented in much higher levels

(Figure 5.10) than the rest. 2,5-Dimethyl pyrazine was considered as the best predictor to measure roasted peanutty flavor (Baker and others 2003). A slight decrease in its concentration was noted with storage in most of the samples. This change was more obvious in the aspect of total pyrazine concentration. R presented the largest decrease during the entire storage with the mean total concentration decreased from 483.63  $\mu\text{g/kg}$  to 348.59  $\mu\text{g/kg}$ . This decrease was obvious even in the earlier stages of storage. This decreasing pattern was similar in VA. This variety was also found to have the largest rate of pyrazine loss in 8 weeks. Compare to VA and R, their corresponding in-shell types showed a relatively better retention of pyrazines in the first 4 weeks and an apparent change started from week 4 to week 8. Difference between high-oleic 13M and normal-oleic 06G in total pyrazine content was also detected. 06G showed the lowest concentration throughout the storage, which was significantly ( $p<0.05$ ) lower than 13M at week 4 and week 8. The change in total pyrazine content was lowest in 13M with only 5.58% of decrease. This indicates that high oleic 13M had the best ability to maintain pyrazines in 8 weeks.

Warner and others (1996) indicated that the concentration of pyrazines did not reduce during storage and that the loss of roasted peanutty flavor was due to masking of pyrazines by aldehydes. However, Bett and Boylson (1992) considered that the loss of peanut flavor was more possibly caused by the degradation of pyrazine given the significantly decreased content of alkylpyrazines during storage. Their findings were also in agreement with the work of other scientists (Braddock and others 1995; Reed and others 2002; Williams and others 2006).

In order to explore the loss of roasted peanutty flavor in this study, Pearson's correlation was done. Our results showed that roasted peanutty flavor was positively correlated (0.74,  $p<0.05$ ) with total pyrazine content while negatively correlated (-0.52,  $p<0.05$ ) with total

aldehyde content. Normally, a high correlation will be noted with a correlation coefficient higher than 0.70. Therefore, our results indicate that both of the aldehydes and pyrazines were correlated with roasted peanutty flavor but its loss might have a closer relationship with the degradation of pyrazines. Although significant change in pyrazine content was not found with storage in this study, an obvious decreasing trend was still observed. It is reasonable to assume that a significant change would appear if the storage period was further extended. The decrease in pyrazine level may result from flavor entrapment or degradation by lipid radicals (Williams and others 2006). Therefore, the lower level of oxidation in 13M might be the reason for its better ability to maintain pyrazines during the storage.

As for other group of volatiles, alkanes was the only one showing significant ( $p<0.05$ ) decrease during storage (Figure 5.11). Lipid oxidation can produce short-chain hydrocarbons like, pentane, heptane and octane whose concentration normally increase during storage. But all the alkane detected in this study had longer chain length and the reason for their reduced content was unclear.

## CONCLUSION

The effects of storage were found for roasted peanuts with reduced pyrazines with development of oxidation products. Descriptive results showed a decreasing trend in roasted peanutty flavor, but the levels for off-flavors were very low. InVA exhibited an apparent decrease in consumer overall liking with storage. Differences between high-oleic 13M and normal-oleic 06G were also observed. 13M was significantly preferred by consumers at all three time points. It also had more stable pyrazine content and significantly less amount of oxidation products. Based on our results, the loss of roasted peanutty flavor was more likely caused by the degradation of pyrazines rather than the increase in oxidation products.

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Table 5.1: Fatty acid composition (area %) of four roasted peanut varieties.<sup>1</sup>

Fatty acids	GA 06G	GA 13M	Runner	Virginia
<i>Saturated fatty acids</i>				
Palmitic Acid (C16:0)	9.35	5.38	9.69	9.01
Stearic Acid (C18:0)	2.00	2.21	2.28	1.90
Arachidic Acid (C20:0)	1.00	1.59	0.98	1.02
Behenic Acid (C22:0)	2.97	3.55	2.94	2.50
Lignoceric Acid (C24:0)	1.36	1.87	1.34	1.30
<b>Total</b>	16.68	14.61	17.22	15.73
<i>Monounsaturated fatty acids</i>				
Oleic Acid (C18:1)	56.08	81.58	56.11	54.68
Eicosenic Acid (C20:1)	1.07	1.31	1.12	1.02
<b>Total</b>	57.15	82.89	57.23	55.70
<i>Polyunsaturated fatty acids</i>				
Linoleic Acid (C18:2)	26.17	2.50	25.55	28.57
<b>Total</b>	26.17	2.50	25.55	28.57
Oleic to linoleic acid ratio	2.14	32.63	2.20	1.91

<sup>1</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, R = Runner (mixed) kernel, VA = Virginia kernel.

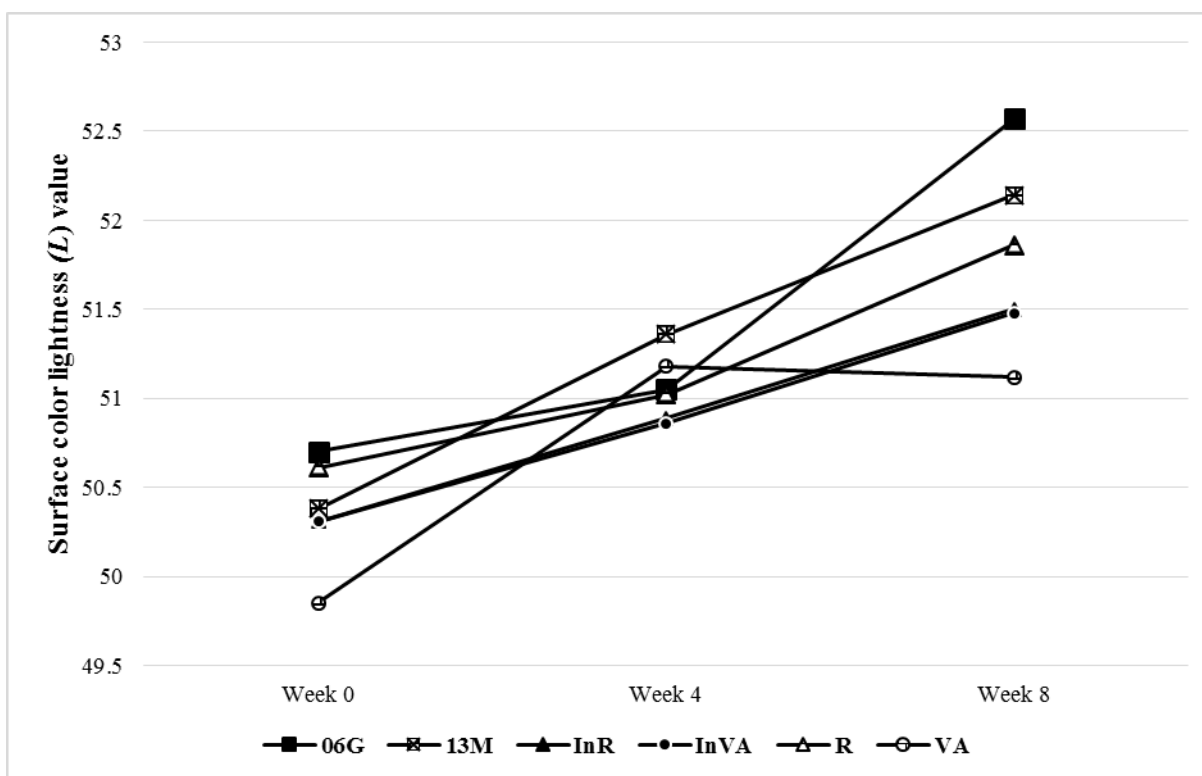


Figure 5.1: Surface color lightness (*L*) value of roasted peanuts at different storage time  
<sup>a</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel

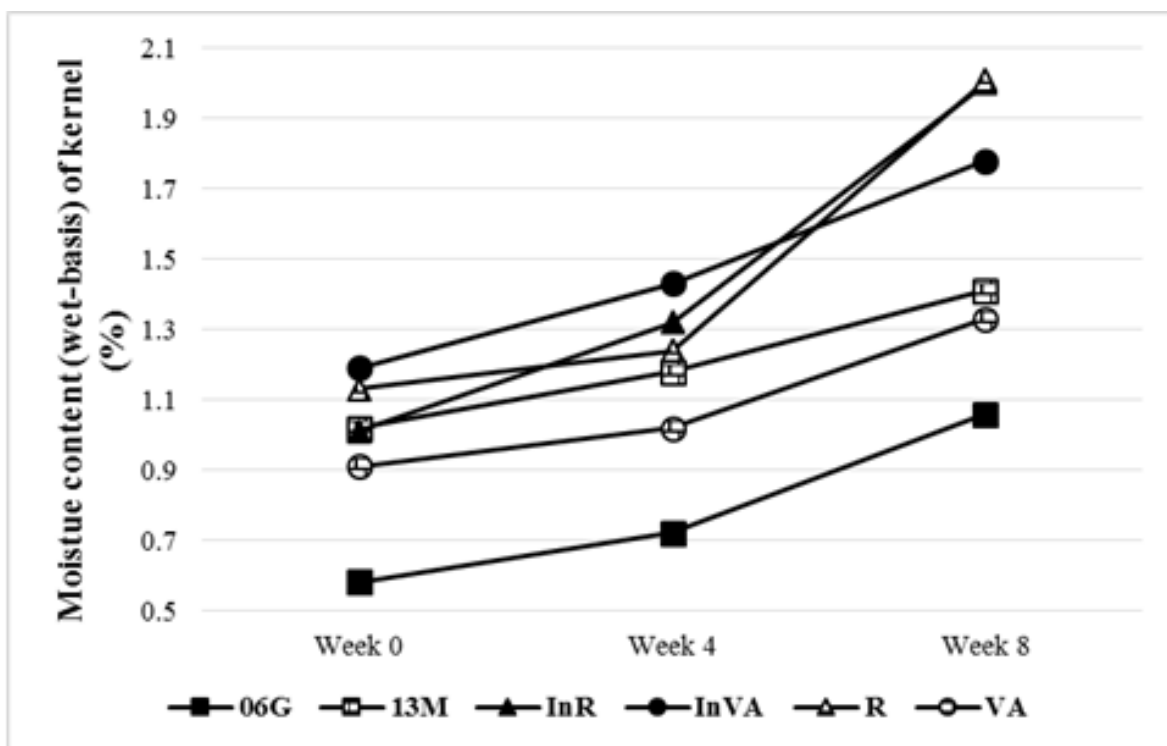


Figure 5.2: Kernel moisture content of roasted peanuts at different storage time

<sup>a</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel

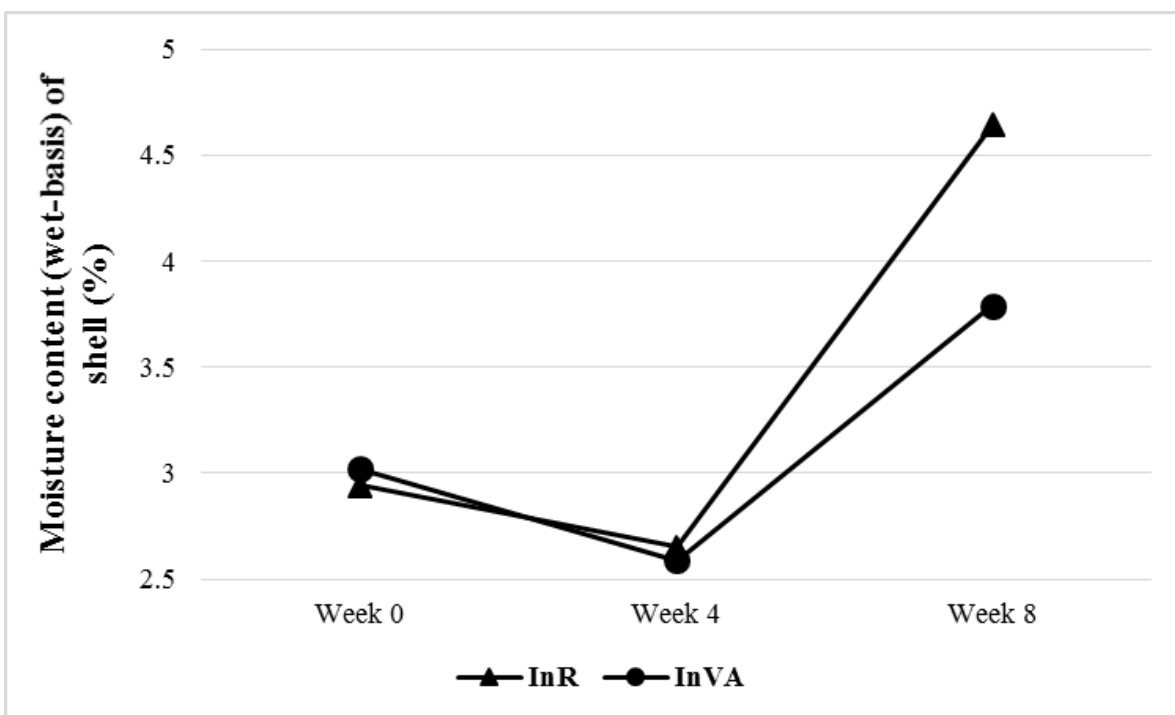


Figure 5.3: Shell moisture content of roasted peanuts at different storage time  
<sup>a</sup> cultivar type: InR = Runner (mixed) in-shell, InVA = Virginia in-shell

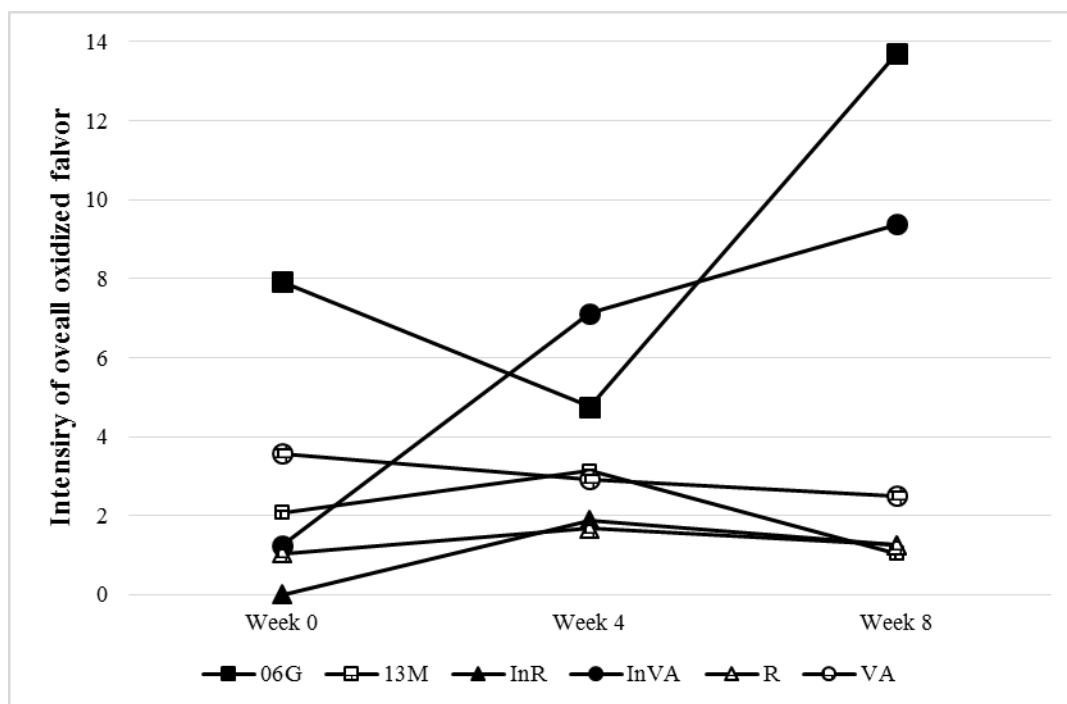


Figure 5.4: Overall oxidized flavor (150 mm scale) of roasted peanuts at different storage time  
<sup>a</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel

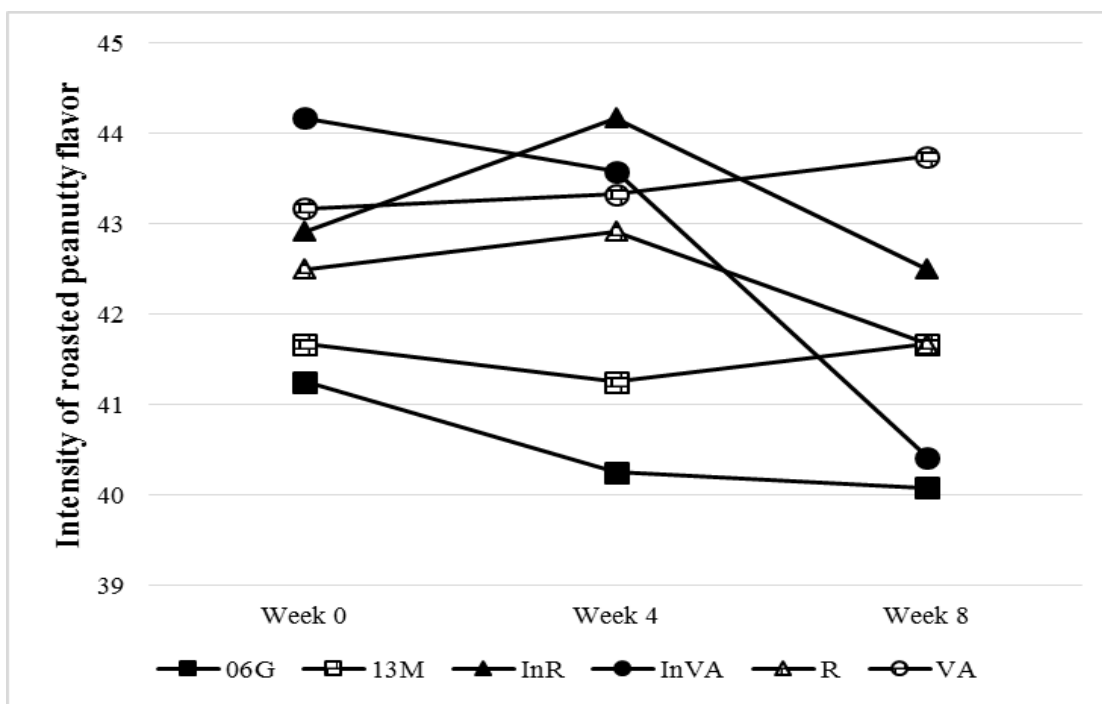


Figure 5.5: Roasted peanutty flavor (150 mm scale) of roasted peanuts at different storage time  
<sup>a</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel

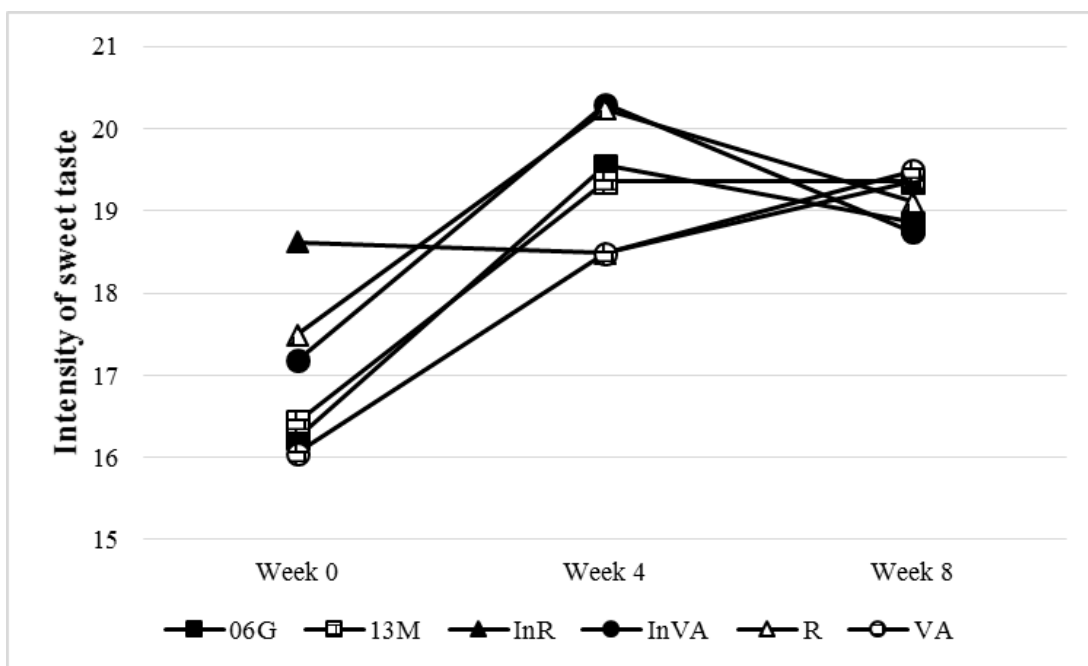


Figure 5.6: Sweet taste (150 mm scale) of roasted peanuts at different storage time  
<sup>a</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel; b) storage time



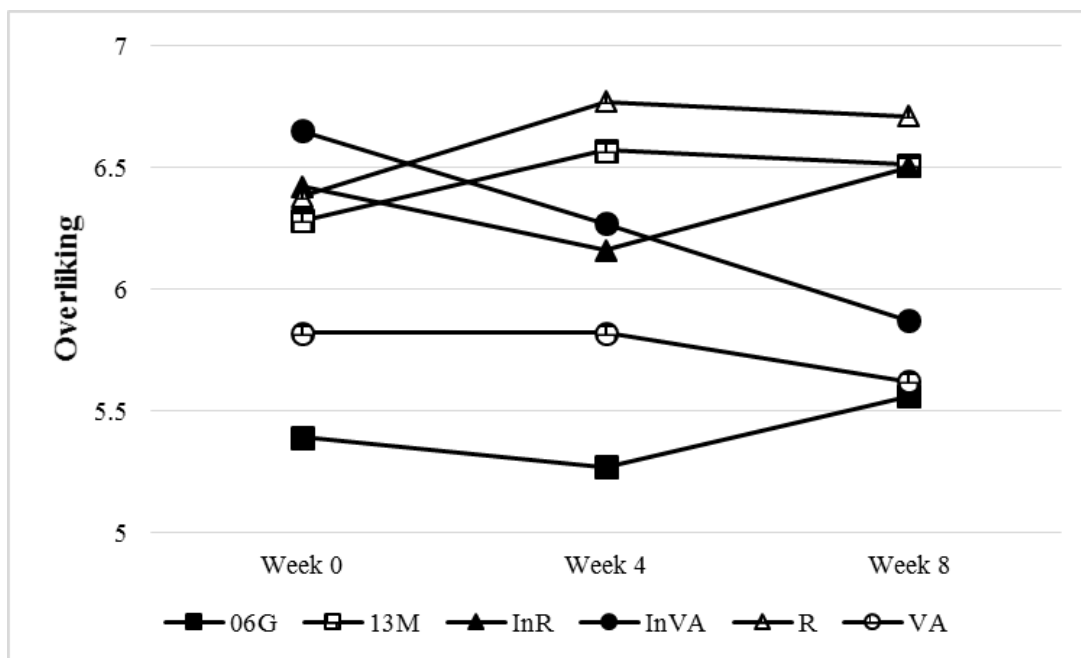


Figure 5.7: Consumer overall liking (9-point scale) of roasted peanuts at different storage time.

<sup>a</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel

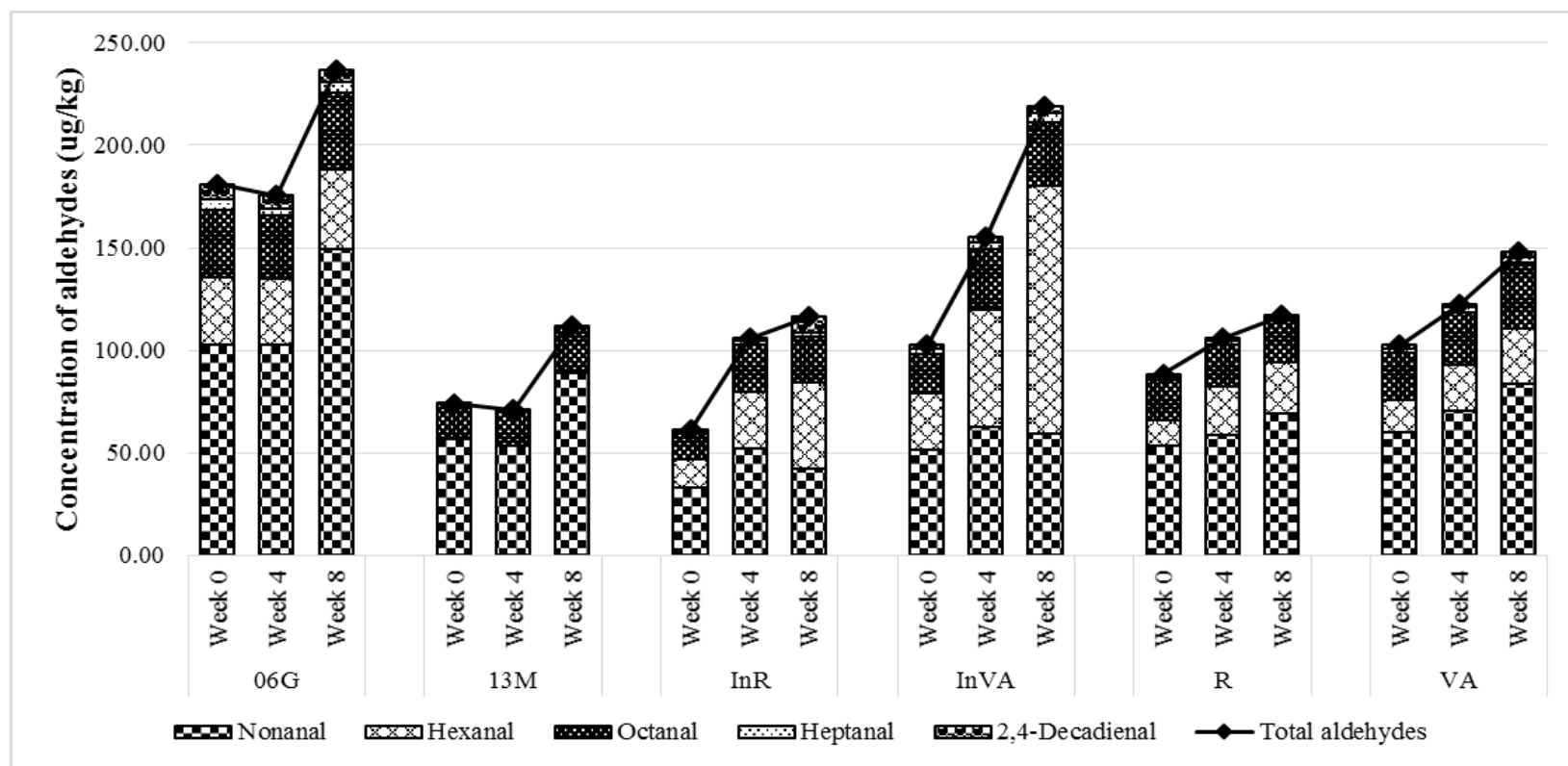


Figure 5.8: Aldehyde concentration of roasted peanuts at different storage time

<sup>a</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel

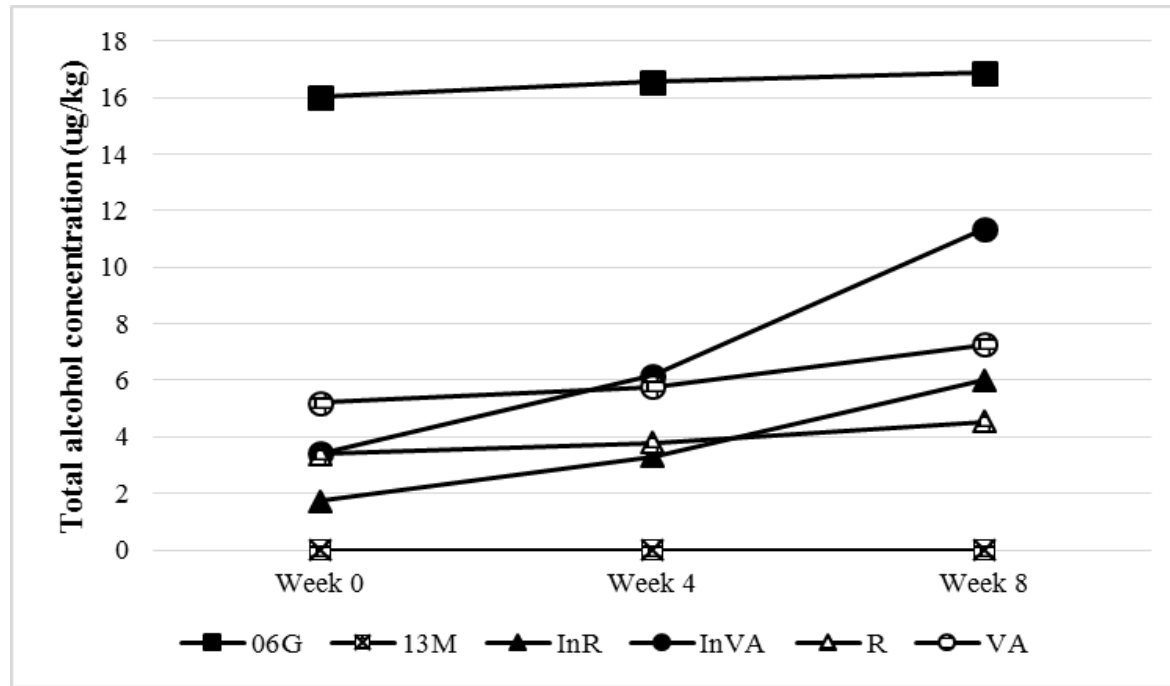


Figure 5.9: Alcohol concentration of roasted peanuts at different storage time

<sup>a</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel

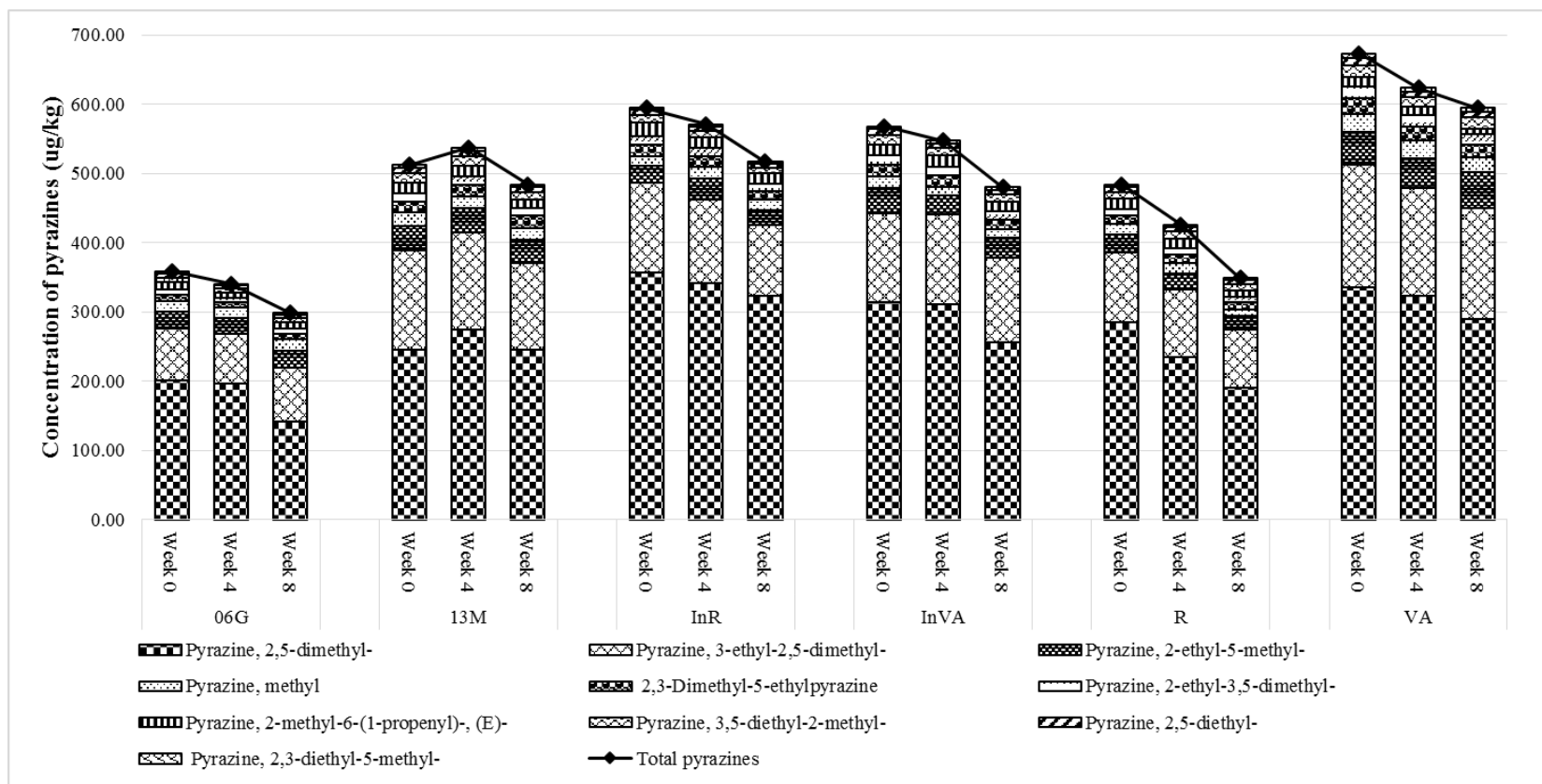


Figure 5.10: Pyrazine concentration of roasted peanuts at different storage time

<sup>a</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel

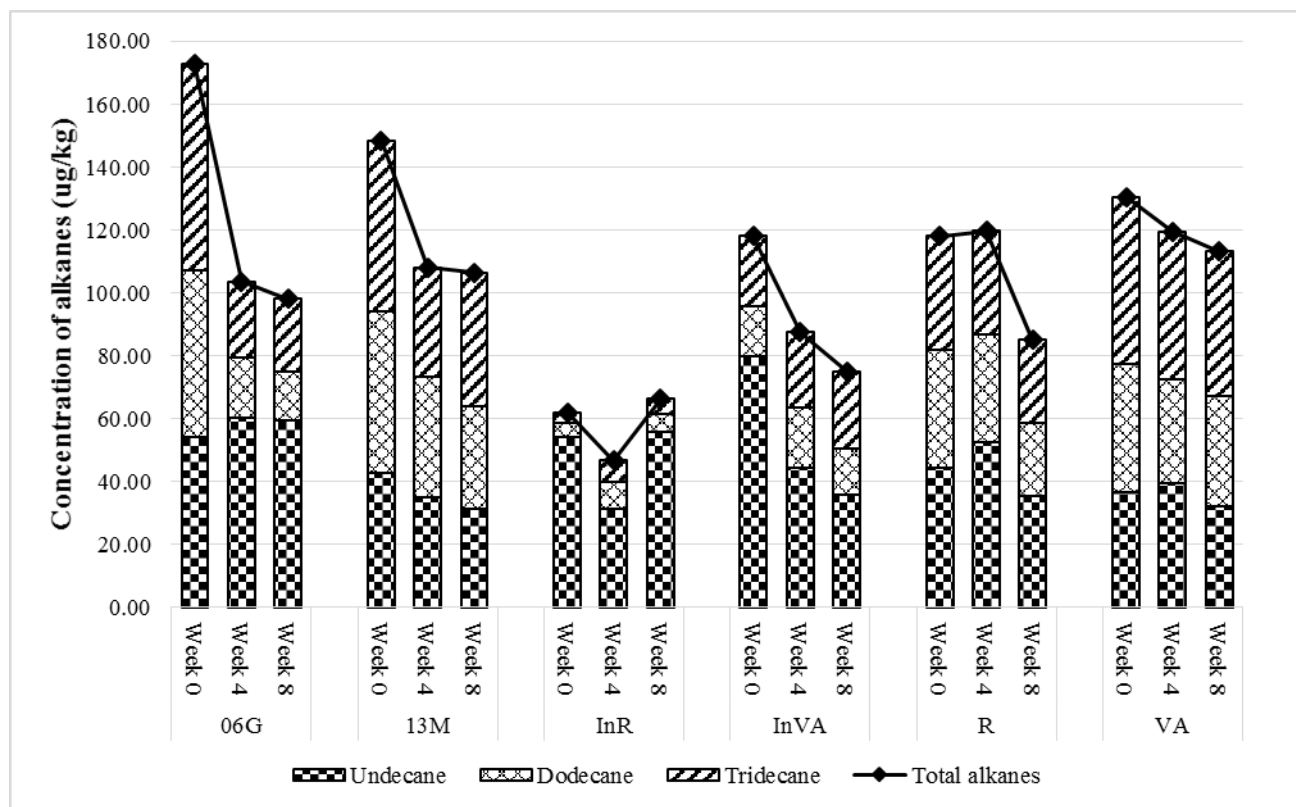


Figure 5.11: Alkane concentration of roasted peanuts at different storage time

<sup>a</sup> Cultivar type: 06G = GA 06G, 13M = GA 13M, InR = Runner (mixed) in-shell, InVA = Virginia in-shell, R = Runner (mixed) kernel, VA = Virginia kernel

## CHAPTER 6

### CONCLUSIONS

For freshly roasted peanuts, consumer overall-liking was majorly positively correlated with attributes that related to fresh products such as crispiness, crunchiness, roasted peanutty flavor and sweet taste. While overall oxidized flavor was the most important driver for consumer overall-disliking. Flavor was found to be the major factor to consumer acceptability. In order to further explore this aspect of roasted peanuts, GC profile was involved. 2,5-Dimethyl-pyrazine had a strong correlation with roasted peanutty flavor; octanal, nonanal and 2-pentyl pyridine were strongly correlated with overall oxidized flavor. The flavor liking was positively correlated with volatiles that represent roasted, salty and sweet. These compounds includes pyrazines (majorly 2,5-dimethyl pyrazine and 2-methyl-6-(trans-1-propenyl) pyrazine) and two benzene derivatives (benzaldehyde and benzeneacetaldehyde; mainly benzaldehyde). The drivers of flavor disliking were bitter and oxidized flavor from sensory profile and were pyrroles, alcohols, aldehydes, ketones and pyridines from GC profile.

With storage, a significantly increase in the concentrations of total aldehyde and alcohol was found while the content of total pyrazines was decreased. From sensory profile, after 8 weeks the levels of oxidized flavor were very low in all samples and a decreasing trend in roasted flavor was found in InVA.

Virginia type of peanuts were preferred by consumers as in-shell form over the shelled form during the storage of 56 days. InVA was the most liked sample by consumers in week 0. But as storage time increase, it was the only sample that exhibited an obvious decrease in overall

acceptability. InVA also showed the greatest change in roasted peanutty flavor, total aldehyde and alcohol content. 06G is a widely grown Runner cultivar in Georgia. But in this study, it was the least liked and the most oxidized sample even from week 0. It would be possible that this variety oxidized at a higher level before processing in this study. Compared normal-oleic 06G with high-oleic 13M, 13M was significantly preferred at all three time points. GC results showed that 13M exhibited the best ability to maintain pyrazines and developed less oxidation products.

In general, roasted peanut industries should put the most focus on the flavors when developing roasted peanut products. Compare to 06G, 13M would be able to increase companies' sales given its higher acceptability and better resistance to oxidation. InVA was very susceptible to oxidation. From the aspects of shelf life and changes of consumer acceptability in 8 weeks, Runner might be a better variety for in-shell roasted peanuts.

## APPENDICES



## Appendix A

### RECRUITMENT SCREENER FOR CONSUMER TEST OF ROASTED PEANUTS

(Please write down all information of each consumer on a separate sheet)

Consumer Name \_\_\_\_\_ Phone \_\_\_\_\_

Date of Calling:

Status of calling:


---

Hello, My name is \_\_\_\_\_, I am calling from the University of Georgia – Griffin Campus. We are calling to see if you would agree to participate in a research study entitled “Acceptance of in-shell peanuts, and comparison of acceptance of high-oleic acid to normal/regular-oleic acid peanuts” which is being conducted by Dr. Koushik Adhikari, Department of Food Science & Technology, UGA, Griffin, GA, telephone number (770) 412-4736. The purpose for the research is to gather sensory information on consumer opinions on roasted peanut samples and the benefits that I may expect from the research are a satisfaction that I have contributed to the solution and evaluation of problems relating to such examinations.

Do you think you might be interested in participating in that study?

{If No}: Thank you very much for your time.

{If Yes}: But before enrolling you in this study, we need to ask you some questions to determine if you are eligible for our main study. And so what I would now like to do is ask you a series of questions about yourself examples: gender, age etc. This should only take about \_\_\_\_\_ minutes of your time.

If there is any possibility that some of the questions I will be asking you, make you uncomfortable or distressed please let me know. You don’t have to answer those questions if you don’t want to.

All information that I receive from you during this phone interview, including your name and any other information that can possibly identify you {if applicable}, will be strictly confidential and will be kept under lock and key. Remember, your participation is voluntary; you can refuse to answer any questions, or stop this phone interview at any time without penalty or loss of benefits to which you are otherwise entitled.

Do I have your permission to ask you these questions?

We are scheduling appointments for a taste test on roasted peanuts. Whom am I speaking with, please? \_\_\_\_\_ (write name of person, if not person on data base ask for a person on data base. If person is not there, proceed with questions)

You are required to visit the facility 2 times total 4 weeks apart. Each session will last approximately 1 hour and you will be compensated \$40 after each session. Would you be interested?

If yes, please answer / verify the following questions:

1. Gender: Male    Female
2. Age:
  - 1) 18-25
  - 2) 26-35
  - 3) 36-45
  - 4) 46-55
  - 5) 56-65
  - 6) Older than 65 (Terminate)
3. Are you allergic to peanut or any kind of nut?
  - 1) Yes (Terminate)
  - 2) No
4. Do you eat peanuts?
  - 1) Yes
  - 2) No (Terminate)
5. How often on average do you consume peanuts and peanut products?
  - 1) Daily
  - 2) 2-3 times/ week
  - 3) 2-3 times/ month
  - 4) Once /month
  - 5) Less than once /month (Terminate)

You have qualified to take the study.

The test sessions are:

First Test		Second Test		Third Test	
Jan 21	Jan 22	Feb. 18	Feb.19	Mar. 18	Mar.19
12pm-1pm	12pm-1pm	12pm-1pm	12pm-1pm	12pm-1pm	12pm-1pm
3pm-4pm	3pm-4pm	3pm-4pm	3pm-4pm	3pm-4pm	3pm-4pm
6pm-7pm	6pm-7pm	6pm-7pm	6pm-7pm	6pm-7pm	6pm-7pm

Please choose your sessions to participate: \_\_\_\_\_.

(Check the response for the time closest to their preferred schedule if space is still available  
If not, offer closest time available)

**The testing site is Experiment Station in Griffin at Melton/Food Science building.**

**Do you know where it is?**

( If the consumer does not know the location, ask them if they would like for you to give them directions, and then give directions on how to get to the facility)

1109 Experiment St, Griffin 30223.

Directions

**From 19/41**

It is intersection of 92 highway and 19/41. Turn to the left (from north), to the right (from south) on Tower St and Tower St becomes Experiment St. Drive around 0.5 miles. The Experiment station is on your right. Turn to the right and pass the gates, drive until stop sign. Turn left and then turn to your first right. The FSD will be the last building on the left before the gates.

**From Taylor street (16 highway)**

If close to 19/41 turn to the right onto 19/41. On first traffic light turn to the right on Ellis rd then drive until you hit the Experiment St. Turn left and the main gates of the Experiment Station will be on your left.

Thank you. If you have any additional questions or problems regarding your rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 609 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address [IRB@uga.edu](mailto:IRB@uga.edu) or Dr. Koushik Adhikari Department of Food Science & Technology, UGA, Griffin, GA, telephone number (770) 412-4736; E-Mail Address [koushik7@uga.edu](mailto:koushik7@uga.edu).

## Appendix B

### CONSENT FORM OF CONSUMER TESTS

#### Researcher's Statement

I am asking you to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. This form is designed to give you the information about the study so you can decide whether to be in the study or not. Please take the time to read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, you can decide if you want to be in the study or not. This process is called "informed consent." A copy of this form will be given to you. Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time without penalty or loss of benefits to which you are otherwise entitled.

#### Principal Investigator/Researcher Information

Koushik Adhikari (770-412-4736, [koushik7@uga.edu](mailto:koushik7@uga.edu)), Department of Food Science and Technology, University of Georgia, 1109 Experiment St., Griffin, GA 30223.

#### Purpose and Benefits of the Study

The purpose of the study is to gather sensory information on consumer opinions of some roasted peanuts samples. Although there are no direct benefits for you, this information will help Georgia peanut farmers to market their produce more effectively to consumers. This will also add to the body of knowledge related to peanut research and food product development.

#### Study Procedures

This research study will be conducted from January 2015 thru March 2015. The test will last approximately one hour per session. If you agree to participate, you will be asked to evaluate 6 peanut samples. Coded samples and the score sheets (ballots) will be placed in front of you. You will evaluate samples by tasting, and indicate your evaluation/opinion on the score sheets. You might be asked some demographic questions associated with the study as well. All procedures used in the study are standard sensory analysis methods as published in books, research articles etc.

#### Risks and Discomforts

Although the researchers have tried to avoid risks, you may feel that some questions/procedures that are asked of you might be stressful or upsetting. You do not have to answer anything you do not want to.

No other risks except for *food allergies* are anticipated from participating in this research study. However, because the food to be tested is known beforehand, the situation can normally be avoided. Please do not participate in the tests if you have any allergies towards peanuts and products containing peanuts. It is your responsibility to inform the researchers about your food allergies.

#### Peanut Allergy Symptoms

<http://www.mayoclinic.org/diseases-conditions/peanut-allergy/basics/symptoms/con-20027898>

An allergic response to peanuts usually occurs within minutes after exposure, and symptoms range from mild to severe. Peanut allergy signs and symptoms can include:

- Skin reactions, such as hives, redness or swelling
- Itching or tingling in or around the mouth and throat
- Digestive problems, such as diarrhea, stomach cramps, nausea or vomiting

- Tightening of the throat
- Shortness of breath or wheezing
- Runny nose

#### **Anaphylaxis: A life-threatening reaction**

Peanut allergy is the most common cause of food-induced anaphylaxis, a medical emergency that requires treatment with an epinephrine (adrenaline) injector (EpiPen, Twinject) and a trip to the emergency room.

Anaphylaxis signs and symptoms can include all of the above, plus:

- Constriction of airways
- Swelling of your throat that makes it difficult to breathe
- A severe drop in blood pressure (shock)
- Rapid pulse
- Dizziness, lightheadedness or loss of consciousness

**Seek immediate medical attention if you display symptoms of peanut allergy**

#### **Incentives for participation**

On completion of each session (45 minutes; 4 weeks apart), you will be paid a monetary incentive of \$20. You will have to provide your name and mailing address on a separate payment sheet for audit purposes before receiving the money.

#### **Privacy/Confidentiality**

The results of this participation will be confidential and will not be released in any individually identifiable form without my prior consent unless required by law. Your confidentiality will be maintained in that a participant's name will not appear on the ballot or in the published study itself, and the researcher will not know who said what and cannot connect comments back to the participant. The data will be reported in aggregate form. Score sheets and the signed informed consents will be stored with principal investigator for period of three years and then destroyed. Researchers will not release identifiable results of the study to anyone other than individuals working on the project without your written consent unless required by law.

#### **Research Subject's Consent to Participate in Research**

To voluntarily agree to take part in this study, you must sign on the line below. Your signature below indicates that you have read or had read to you this entire consent form, and have had all of your questions answered.

<b>Name of Researcher</b>	<b>Signature</b>	<b>Date</b>
<b>Name of Participant</b>	<b>Signature</b>	<b>Date</b>

Please sign both copies, keep one and return one to the researcher.

Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 629 Boyd GSRC, Athens, Georgia 30602; telephone (706) 542-3199; email address [irb@uga.edu](mailto:irb@uga.edu).

## Appendix C

### BALLOTS OF CONSUMER TESTS

Sample \_\_\_\_\_

Panelist Code \_\_\_\_\_

#### Roasted In-shell Peanuts Consumer Acceptance

**Please clean your palate with crackers and rinse your mouth with water before starting.  
You can rinse at any time during the test if you need to. Thank you!**

**Please shell this sample, then answer the following question.**

**1. Mark the box that best describes your liking of the ease of shelling for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

**Please remove the skins and look at the kernels (without skins ), then answer the following questions:**

**2. Mark the box that best describes your liking of the appearance for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

**3. Mark the box that best describes your liking of the color for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

**Please sniff the sample for at least 3 times, then answer the following question:**

**4. Mark the box that best describes your liking of the aroma for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

**Please taste this sample and answer the following questions:**

**5. Mark the box that best describes your liking of the overall flavor for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

**6. Mark the box that best describes your liking of the roasted peanut flavor for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

**7. Mark the box that best describes your liking of the sweet-taste for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

**8. Mark the box that best describes your liking of the texture for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

**9. Mark the box that best describes your OVERALL liking for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

**Now please evaluate the intensity of this sample using scale ranges from 1-low to 9-high. Note that the choices are different from the previous liking scale. Please DO NOT evaluate liking.**

**10. Mark the box that best represents the ease of shelling for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9
Low				Moderate				High

**11. Mark the box that best represents the intensity of roasted peanut flavor for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9
Low				Moderate				High

**12. Mark the box that best represents the intensity of sweetness for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9
Low				Moderate				High

**13. Mark the box that best represents the intensity of bitterness for this sample.**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9
Low				Moderate				High

**14. Do you taste any stale/old flavor in this sample? Yes\_\_\_\_\_ No**

**If Yes, please answer the following question**

**Mark the box that best represents the intensity of stale/old flavor for this sample.**

☐

1

Low

☐

2

☐

3

☐

4

☐

5

Moderate

☐

6

☐

7

☐

8

☐

9

High



Sample \_\_\_\_\_

Panelist Code \_\_\_\_\_

### Roasted Shelled Peanuts Consumer Acceptance

Please clean your palate with crackers and rinse your mouth with water before starting.  
You can rinse at any time during the test if you need to. Thank you!

Please look at this sample, then answer the following questions:

1. Mark the box that best describes your liking of the appearance for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

2. Mark the box that best describes your liking of the color for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

Please sniff this sample for at least 3 times, then answer the following question:

3. Mark the box that best describes your liking of the aroma for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

Please taste this sample and answer the following questions:

4. Mark the box that best describes your liking of the overall flavor for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

5. Mark the box that best describes your liking of the roasted peanut flavor for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

6. Mark the box that best describes your liking of the sweet-taste for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

7. Mark the box that best describes your liking of the texture for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

8. Mark the box that best describes your OVERALL liking for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dis like	Dis like	Dis like	Dis like	Neither Like	Like	Like	Like	Like
Extremely	Very Much	Moderately	Slightly	nor Dislike	Slightly	Moderately	Very Much	Extremely

Now please evaluate the taste intensity of samples using a different scale ranges from 1-low to 9-high.

Note that the choices are different from the previous liking scale. Please DO NOT evaluate liking.

9. Mark the box that best represents the intensity of roasted peanut flavor for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9
Low				Moderate				High

10. Mark the box that best represents the intensity of sweetness for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9
Low				Moderate				High

11. Mark the box that best represents the intensity of bitterness for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9
Low				Moderate				High

12. Do you taste any stale/ old flavor in this sample? Yes \_\_\_\_\_ No

If Yes, please answer the following question

Mark the box that best represents the intensity of stale/old flavor for this sample.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9
Low				Moderate				High

Appendix D

DEMOGRAPHIC QUESTIONNAIRE OF CONSUMER TESTS

**PEANUT CONSUMER TEST – DEMOGRAPHIC QUESTIONNAIRE**

Date: \_\_\_\_\_

Panelist #: \_\_\_\_\_

**Please answer the following questions. All your answers will be kept confidential.**

**1. Which of the following describes your age group?**

- |                   |                          |
|-------------------|--------------------------|
| 18-24 years       | <input type="checkbox"/> |
| 25-34 years       | <input type="checkbox"/> |
| 35-44 years       | <input type="checkbox"/> |
| 45-54 years       | <input type="checkbox"/> |
| 55 years or older | <input type="checkbox"/> |

**2. What is your gender?**

- Male ☐
- Female ☐

**3. How often do you eat peanut products, for example roasted peanuts, peanut butter etc.?  
(Check one)**

- |                  |                          |
|------------------|--------------------------|
| Daily            | <input type="checkbox"/> |
| 2-3 times / week | <input type="checkbox"/> |
| Once a week      | <input type="checkbox"/> |
| Thrice a month   | <input type="checkbox"/> |
| Twice a month    | <input type="checkbox"/> |
| Once a month     | <input type="checkbox"/> |

**4. What types of peanut products do you consume? (Check all that apply)**

- |                              |                          |
|------------------------------|--------------------------|
| Roasted peanuts              | <input type="checkbox"/> |
| Boiled peanuts               | <input type="checkbox"/> |
| Peanut butter                | <input type="checkbox"/> |
| Peanut bars                  | <input type="checkbox"/> |
| Other (Please specify) _____ |                          |

**5. In roasted peanuts, do you prefer in-shell peanuts or shelled peanuts?**

In-shell peanuts ☐

**If you prefer in-shell peanuts, please answer QUESTIONS 6-10**

Shelled peanuts ☐

**If you prefer shelled peanuts, please answer QUESTIONS 11-15**

Like them equally ☐

**If you have no preference, please answer QUESTIONS 6-15**

**6. How often do you eat in-shell roasted peanuts? (Check one)**

Daily ☐

- 2-3 times / week ☐
- Once a week ☐
- Thrice a month ☐
- Twice a month ☐
- Once a month ☐
- Less than once a month ☐

**7. For what occasion(s) do you eat in-shell roasted peanuts? (Check all that apply)**

- Studying/working ☐
- Attending sporting events ☐
- At sport bars ☐
- Watching TV/movies at home ☐
- Watching movies in theater ☐
- Casual socializing like potlucks, picnics ☐
- Other (Please specify) \_\_\_\_\_

**8. Which aspects do you care about when buying in-shell roasted peanuts? (Check all that apply)**

- Expiration date ☐
- Texture ☐
- Flavor ☐
- Health benefits ☐
- Packaging ☐
- Brand ☐
- Price ☐
- Other (Please specify) \_\_\_\_\_

**9. Which aspect do you care about most when buying in-shell roasted peanuts? (Check one)**

- Expiration date ☐
- Texture ☐
- Flavor ☐
- Health benefits ☐
- Packaging ☐
- Brand ☐
- Price ☐
- Other (Please specify) \_\_\_\_\_

**10. Which flavored in-shell roasted peanuts do you eat most often? (Check one)**

- Unsalted ☐ | Salted ☐ | Hot & Spicy ☐ | Smoked ☐  
 Cajun Hot ☐ | Other (Please specify) \_\_\_\_\_

**11. How often do you eat shelled roasted peanuts? (Check one)**

- Daily ☐
- 2-3 times / week ☐
- Once a week ☐

Thrice a month	<input type="checkbox"/>
Twice a month	<input type="checkbox"/>
Once a month	<input type="checkbox"/>
Less than once a month	<input type="checkbox"/>

**12. For what occasion(s) do you eat shelled roasted peanuts? (Check all that apply)**

Studying/working	<input type="checkbox"/>
Attending sporting events	<input type="checkbox"/>
At sport bars	<input type="checkbox"/>
Watching TV/movies at home	<input type="checkbox"/>
Watching movies in theater	<input type="checkbox"/>
Casual socializing like potlucks, picnics	<input type="checkbox"/>
Other (Please specify) _____	

**13. Which aspects do you care about when buying shelled roasted peanuts? (Check all that apply)**

Expiration date	<input type="checkbox"/>
Texture	<input type="checkbox"/>
Flavor	<input type="checkbox"/>
Health benefits	<input type="checkbox"/>
Packaging	<input type="checkbox"/>
Brand	<input type="checkbox"/>
Price	<input type="checkbox"/>
Other (Please specify) _____	

**14. Which aspect do you care about most when buying shelled roasted peanuts? (Check one)**

Expiration date	<input type="checkbox"/>
Texture	<input type="checkbox"/>
Flavor	<input type="checkbox"/>
Health benefits	<input type="checkbox"/>
Packaging	<input type="checkbox"/>
Brand	<input type="checkbox"/>
Price	<input type="checkbox"/>
Other (Please specify) _____	

**15. Which flavored shelled roasted peanuts do you eat most often? (Check one)**

Unsalted ☐ | Salted ☐ | Hot & Spicy ☐ | Smoked ☐  
 Lightly Salted ☐ | Honey Roasted ☐ | Cajun Hot ☐  
 Other (Please specify) \_\_\_\_\_

## Appendix E

### AN EXAMPLE OF SERVING SEQUENCE FOR CONSUMER TESTS

Kernels: 453- 06G; 221- 13M; 926- Virginia; 371- Runner  
Inshell: 104- Virginia; 715- Runner

```
dm'log;clear;output;clear;';
ods rtf;
proc plan seed=324785;
proc format;
value Sample 1='453'
              2='221'
              3='926'
              4='371'
              5='104'
              6='715';
run;
proc plan seed=324785;
factors r=1 Panelists= 100 ordered Sample=6;
format Sample Sample.;
output out=ctl1;
run;
proc sort data=ctl1;
by Panelists;
run;
proc transpose data=ctl1 out=ctl1(drop=_Name_);
by notsorted Panelists;
var Sample;
data ctl1; set ctl1;
rename COL1-COL6 = Sample_1-Sample_6;
proc print data=ctl1 noobs;
title 'serving order for peanuts consumer test';
run;
ods rtf close; quit;
```

## Appendix F

### CONSENT FORM OF DESCRIPTIVE TESTS

#### Researcher's Statement

I am asking you to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. This form is designed to give you the information about the study so you can decide whether to be in the study or not. Please take the time to read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, you can decide if you want to be in the study or not. This process is called "informed consent." A copy of this form will be given to you. Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time without penalty or loss of benefits to which you are otherwise entitled.

#### Principal Investigator/Researcher Information

Koushik Adhikari (770-412-4736, [koushik7@uga.edu](mailto:koushik7@uga.edu)), Department of Food Science and Technology, University of Georgia, 1109 Experiment St., Griffin, GA 30223.

#### Purpose and Benefits of the Study

The purpose of the study is to gather descriptive sensory information on four varieties of peanut samples. Although there are no direct benefits for you, this study will add to the body of knowledge related to peanut research and food product development efforts.

#### Study Procedures

This research study will be conducted over a period of two weeks or 10 business days by trained panel of ~8 panelists. Each day the panel will spend ~2 hours. The panelists will be trained to on descriptive analysis method which is an analytic sensory method. The panel would define descriptors based on the characteristics of the peanut samples based on consensus. Blind evaluations of the 6 samples will be then carried out by panelists for the agreed upon descriptors in triplicate.

#### Risks and Discomforts

No other risks except for *food allergies* are anticipated from participating in this research study. However, because the food to be tested is known beforehand, the situation can normally be avoided. Please do not participate in the tests if you have any allergies towards peanuts and products containing peanuts. It is your responsibility to inform the researchers about your food allergies.

#### Peanut Allergy Symptoms

<http://www.mayoclinic.org/diseases-conditions/peanut-allergy/basics/symptoms/con-20027898>

An allergic response to peanuts usually occurs within minutes after exposure, and symptoms range from mild to severe. Peanut allergy signs and symptoms can include:

- Skin reactions, such as hives, redness or swelling
- Itching or tingling in or around the mouth and throat
- Digestive problems, such as diarrhea, stomach cramps, nausea or vomiting
- Tightening of the throat
- Shortness of breath or wheezing
- Runny nose

#### Anaphylaxis: A life-threatening reaction

Peanut allergy is the most common cause of food-induced anaphylaxis, a medical emergency that requires treatment with an epinephrine (adrenaline) injector (EpiPen, Twinject) and a trip to the emergency room.

Anaphylaxis signs and symptoms can include all of the above, plus:

- Constriction of airways
- Swelling of your throat that makes it difficult to breathe
- A severe drop in blood pressure (shock)
- Rapid pulse
- Dizziness, lightheadedness or loss of consciousness

**Seek immediate medical attention if you display symptoms of peanut allergy**

#### Incentives for participation

An honorarium will be paid based on the number of hours (~20 hours) required for completing the study. The hourly rate will be \$9 for experienced panelists and \$7.50 for new panelists.

**Privacy/Confidentiality**

The results of this participation will be confidential and will not be released in any individually identifiable form without my prior consent unless required by law. Your confidentiality will be maintained in that a participant's name will not appear on the ballot or in the published study itself, and the researcher will not know who said what and cannot connect comments back to the participant. The data will be reported in aggregate form. Score sheets and the signed informed consents will be stored with principal investigator for period of three years and then destroyed. Researchers will not release identifiable results of the study to anyone other than individuals working on the project without your written consent unless required by law.

**Research Subject's Consent to Participate in Research**

To voluntarily agree to take part in this study, you must sign on the line below. Your signature below indicates that you have read or had read to you this entire consent form, and have had all of your questions answered.

_____ <b>Name of Researcher</b>	_____ <b>Signature</b>	_____ <b>Date</b>
_____ <b>Name of Participant</b>	_____ <b>Signature</b>	_____ <b>Date</b>

Please sign both copies, keep one and return one to the researcher.

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Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 629 Boyd GSRC, Athens, Georgia 30602; telephone (706) 542-3199; email address [irb@uga.edu](mailto:irb@uga.edu).



Appendix G  
LEXICON FOR ROASTED PEANUTS

Attributes	Definition	References	Intensity	WUP <sup>b</sup>
<i>Texture of the shell<sup>a</sup></i>				
Fracturability of the shell	The force needed to open the shell and get kernels	Corn chips (Frito Lay, Plano, TX)	30	53
<i>Appearance</i>				
Brown color	The intensity of strength of brown color from light to dark brown	White paper (L = 91.42, a = -0.22, b = 0.04) Dry cardboard (L=47.3, a=7.13, b=3.79 )	0 60	42
<i>Texture</i>				
Fracturability	The force with which the sample breaks	Corn chips (Frito Lay, Plano, TX)	55	30
Crispiness	Amount of force needed and intensity of sound (high pitch) generated from chewing a sample with incisors	Corn chips (Frito Lay, Plano, TX)	70	23
Crunchiness	The force needed and intensity of sound (low pitch) generated from chewing a sample with molar teeth	Corn chipsh (Frito Lay, Plano, TX)	75	43
Chewy	The length of time in seconds required to masticate a sample at the rate of one chew per second in order to reduce it to a consistency satisfactory for swallowing	Raw peanuts (John B. Sanfilippo & Son Inc., Elgin, IL)	35	30
Tooth packing	The degree to which product sticks on the surface of molars	Raw peanuts (John B. Sanfilippo & Son Inc., Elgin, IL)	40	23
<i>Flavors</i>				
Roasted peanutty	The aromatic associated with medium-roast peanuts	Roasted peanut butter (Kroger Co., Cincinnati, OH)	55	45
Oxidized	The flavor associated with rancid fats and oils	Rancid oil <sup>c</sup>	60	0

Cardboard	The aromatic associated with somewhat oxidized fats and oils and reminiscent of wet cardboard	Wet cardboard	40	0
Fishy	The aromatic associated with trimethylamine, cod liver oil or old fish	Cod liver oil (Walgreen Co., Deerfield, IL)	80	0
Painty	The aromatic associated with linseed oil, oil based paint	Boiled linseed oil (W. M. Barr & Co., Inc., Memphis, TN)	115	0
<i>Basic tastes</i>				
Bitter	The taste on the tongue associated with caffeine	0.05% caffeine solution 0.08% caffeine solution 0.15% caffeine solution	20 50 100	15
Sour	The taste on the tongue associated with citric acids	0.05% citric acid solution 0.08% citric acid solution 0.15% citric acid solution	20 50 100	0
Salty	The taste on the tongue associated with sodium chloride	0.2% sodium chloride solution 0.35% sodium chloride solution 0.5% sodium chloride solution	25 50 85	20
Sweet	The taste on the tongue associated with sugars	2.0% sucrose solution 5.0% sucrose solution 10.0% sucrose solution 15.0% sucrose solution	20 50 100 150	21
<i>Feeling factors</i>				
Astringent	The puckering of drying sensation of the mouth or tongue surface	0.05% alum solution 0.08% alum	20 50 100	20

		solution 0.15% alum solution		
Oily	The amount of oil left on tongue after expectoration	Virgin peanut oil (Bell Plantation Inc., Tifton, GA)	30	15

<sup>a</sup>Only evaluated for in-shell samples

<sup>b</sup>In-shell roasted Runner peanuts at week 0

<sup>c</sup>Prepared by microwaving 250 mL vegetable oil (Kroger Co., Cincinnati, OH) at high heat for 3 min and then cooling to room temperature.

## Appendix H

### AN EXAMPLE OF SERVING SEQUENCE FOR DESCRIPTIVE TESTS

Kernels: 817, 148- 06G; 209, 240 - 13M; 429, 739- Virginia; 710, 829- Runner  
In-shell: 317, 354- Virginia; 107, 601- Runner

```
dm'log;clear;output;clear;';
ods rtf;
proc plan seed=324785;
factors Session=2 ordered Panelist=8 ordered sample=6 random;
output out=dt1;
run;
data dt2;
set dt1;
if session=1 then do; if sample=1 then sample= 817;end;
if session=1 then do; if sample=2 then sample= 209;end;
if session=1 then do; if sample=3 then sample= 429;end;
if session=1 then do; if sample=4 then sample= 710;end;
if session=1 then do; if sample=5 then sample= 317;end;
if session=1 then do; if sample=6 then sample= 107;end;
if session=2 then do; if sample=1 then sample= 148;end;
if session=2 then do; if sample=2 then sample= 240;end;
if session=2 then do; if sample=3 then sample= 739;end;
if session=2 then do; if sample=4 then sample= 829;end;
if session=2 then do; if sample=5 then sample= 354;end;
if session=2 then do; if sample=6 then sample= 601;end;
proc sort data=dt2;
by Session Panelist;
run;
proc transpose data=dt2 out=dt3(drop=_Name_);
by notsorted Session Panelist;
var Sample;
run;
data dt4;
set dt3;
rename COL1-COL6 = Sample1-Sample6;
run;
proc print data=dt4 noobs;
title 'serving order for peanut descriptive tests';
run;
ods rtf close; quit;
```

## Appendix I

### BALLOTS OF DESCRIPTIVE TESTS

#### Descriptive Analysis of Roasted In-shell Peanuts

**Sample Code:** \_\_\_\_\_ **Panelist:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Texture of the shell:** Please use the peanut pod which has 2 kernels to evaluate the FRACTURABILITY OF THE SHELL. Squeeze the pod with your fingers. Do this step for at least two times before your evaluation and take the average of force needed as your reading.

**Fracturability of the shell** – the force needed to open the shell and get kernels.

Reference: corn chips = 30      WUP: 53

\_\_\_\_\_  
**Appearance:** Please remove the skin and look at the kernels as a whole to evaluate its **COLOR**.

**Brown** – the intensity of brown color from light to dark brown

Reference: white paper = 0; dry cardboard (L=47.3, a=7.13, b=3.79 ) = 60;      WUP: 42

\_\_\_\_\_  
**Texture:** Please take 2 halves/ 1 whole kernel and evaluate for the following **TEXTURE**.

**Fracturability** – the force with which the sample breaks.

Reference: corn chips = 55      WUP: 30

\_\_\_\_\_  
**Crispness** – amount of force needed and intensity of sound (high pith) generated from chewing a sample with incisors.

Reference: corn chips = 70      WUP: 23

\_\_\_\_\_  
**Crunchiness** – the force needed and amount of sound (lower pitch) generated from chewing a sample with molars.

Reference: corn chips = 75      WUP: 43

\_\_\_\_\_  
**Chewy** – the length of time in seconds required to masticate a sample at the rate of one chew per second in order to reduce it to a consistency satisfactory for swallowing.

Reference: raw peanuts= 35      WUP: 30

\_\_\_\_\_  
**Tooth packing** - the degree to which product sticks on the surface of molars.

Reference: raw peanuts= 40

WUP: 23

\_\_\_\_\_  
**Basic Tastes:** Please take 2 halves/ 1 whole kernel and evaluate for the following **TASTES**.

**Bitter** - the taste on the tongue associated with bitter agents such as caffeine solution

Reference: bitter 20; bitter 50; bitter 100;      WUP: 15

\_\_\_\_\_  
**Sour**- the taste on the tongue associated with acid solutions

Reference: sour 20; sour 50; sour 100;

WUP: 0

\_\_\_\_\_  
**Salty** - the taste on the tongue associated with sodium chloride solutions

Reference: salty 25; salty 50; salty 85;

WUP: 20

\_\_\_\_\_

**Sweet** – the taste on the tongue associated with sucrose solution

Reference: sweet 20; sweet 50; sweet 100; sweet 150; WUP: 21

\_\_\_\_\_

**Feeling factors:** Please take 2 halves/ 1 whole kernel and evaluate for the following **FEELING FACTORS**.

**Astringent** - the puckering or drying sensation on the mouth or tongue surface.

Reference: astringent 20; astringent 50; astringent 100 WUP: 20

\_\_\_\_\_

**Oily** - the amount of oil left on tongue after expectoration.

Reference: virgin peanut oil = 30 WUP: 15

## Descriptive Analysis of Roasted Shelled Peanuts

**Sample Code:** \_\_\_\_\_ **Panelist:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Appearance:** Please remove the skin and look at the kernels as a whole to evaluate its **COLOR**.

**Brown** – the intensity of brown color from light to dark brown

Reference: white paper = 0; dry cardboard (L=47.3, a=7.13, b=3.79 ) = 60; WUP: 42

\_\_\_\_\_

**Texture:** Please take 2 halves/ 1 whole kernel and evaluate for the following **TEXTURE**.

**Fracturability** – the force with which the sample breaks.

Reference: corn chips = 55 WUP: 30

\_\_\_\_\_

**Crispness** – amount of force needed and intensity of sound (high pith) generated from chewing a sample with incisors.

Reference: corn chips = 70 WUP: 23

\_\_\_\_\_

**Crunchiness** – the force needed and amount of sound (lower pitch) generated from chewing a sample with molars.

Reference: corn chips = 75 WUP: 43

\_\_\_\_\_

**Chewy** – the length of time in seconds required to masticate a sample at the rate of one chew per second in order to reduce it to a consistency satisfactory for swallowing.

Reference: raw peanuts= 35 WUP: 30

\_\_\_\_\_

**Tooth packing** - the degree to which product sticks on the surface of molars.

Reference: raw peanuts= 40 WUP: 23

\_\_\_\_\_

**Basic Tastes:** Please take 2 halves/ 1 whole kernel and evaluate for the following **TASTES**.

**Bitter** - the taste on the tongue associated with bitter agents such as caffeine solution

Reference: bitter 20; bitter 50; bitter 100; WUP: 15

\_\_\_\_\_

**Sour**- the taste on the tongue associated with acid solutions

Reference: sour 20; sour 50; sour 100; WUP: 0

\_\_\_\_\_

**Salty** - the taste on the tongue associated with sodium chloride solutions

Reference: salty 25; salty 50; salty 85; WUP: 20

\_\_\_\_\_

**Sweet** – the taste on the tongue associated with sucrose solution

Reference: sweet 20; sweet 50; sweet 100; sweet 150; WUP: 21

\_\_\_\_\_

**Feeling factors:** Please take 2 halves/ 1 whole kernel and evaluate for the following **FEELING FACTORS**.

**Astringent** - the puckering or drying sensation on the mouth or tongue surface.

Reference: astringent 20; astringent 50; astringent 100    WUP: 20

\_\_\_\_\_

**Oily** - the amount of oil left on tongue after expectoration.

Reference: virgin peanut oil = 30                      WUP: 15

\_\_\_\_\_



## Descriptive Analysis of Roasted Peanuts

Sample Code: \_\_\_\_\_ Panelist: \_\_\_\_\_ Date: \_\_\_\_\_

**Flavors:** Please take 4 halves/ 2 whole kernels and evaluate for the following **FLAVORS**.

**Roasted peanutty**- the aromatic associated with medium roasted peanuts.

Reference: roasted peanut butter = 55      WUP: 45

\_\_\_\_\_

**Overall oxidized**- the flavor associated with rancid fats and oils.

Reference: oxidized oil =60      WUP: 0

\_\_\_\_\_

**Cardboard**- the aromatic associated with somewhat oxidized fats and oils and reminiscent of wet cardboard..

Reference: wet cardboard= 40      WUP: 0

\_\_\_\_\_

**Fishy** – the aromatic associated with trimethylamine, cod liver oil or old fish.

Reference: cod liver oil= 80      WUP: 0

\_\_\_\_\_

**Painty**- the aromatic associated with linseed oil, oil based paint.

Reference: boiled linseed oil= 115      WUP: 0

\_\_\_\_\_

\_\_\_\_\_