INFRARED RADIANT WALL TECHNOLOGY FOR BLANCHING AND ROASTING OF SMALL PEANUTS AND THE ASSOCIATE SENSORY AND SHELF LIFE EFFECTS

by

CATHERINE FRANCESCA VANESSA SMITH

(Under the Direction of Rakesh Singh,)

ABSTRACT

A radiant wall oven was used for infrared blanching. Infrared treatments included 343˚C for 60 s and 288 for 90 s. High and low moisture groups with approximate moisture content of 9% and 6% were used. An impingement oven set at 100˚C for 20 min was used as the control treatment. No treatment differed from control in terms of blanchability. A descriptive sensory shelf life study found the greatest variability in fracturability. Roasting of infrared blanched peanuts was done using an impingement oven set to 177˚C for 10 min. Conventionally blanched peanuts roasted under the same parameter were used as a control. A consumer panel found the peanuts blanched by infrared radiation at 343˚C for 60 s to be the most likeable roasted IR sample and did not differ from control. IR heating is a viable alternative for small peanut blanching and has minimal effects on sensory qualities after roasting.

INDEX WORDS: Infrared Radiation; Peanuts; Blanching; Radiant Wall Oven; Sensory; Shelf-Life; Roasting

INFRARED RADIANT WALL TECHNOLOGY FOR BLANCHING AND ROASTING SMALL PEANUTS AND THE ASSOCIATE SENSORY AND SHELF LIFE EFFECTS

by

CATHERINE FRANCESCA VANESSA SMITH

B.S. in Agriculture, The University of Georgia, 2015

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2017

INFRARED RADIANT WALL TECHNOLOGY FOR BLANCHING AND ROASTING

SMALL PEANUTS OF VARIOUS MOISTURE CONTENTS AND THE ASSOCIATED

SENSORY AND SHELF LIFE EFFECTS

by

CATHERINE FRANCESCA VANESSA SMITH

Major Professor: Rakesh Singh
Committee: Koushik Adhikari
Fanbin Kong

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
August 2017

DEDICATION

This paper, as well as my entire educational career, is dedicated to Larry Hezekiah Teems. You taught me to how to read and encouraged me through all phases of life. I know you are with me now and always. This is for you.

ACKNOWLEDGEMENTS

I would like to acknowledge all my family, friends and professors that have helped me along the way to completing my thesis. First, thank you to my mother for supporting me in everything I have every wanted to do. Thank you to Cody Kruger for always holding down the fort. Thank you to Alex Maxwell and Carlyn Oswald for being along for the ride and understanding the trials and tribulations of graduate school. Thank you to Po-An Chi for always letting me in the FPL. Thank you to all my committee members, Dr. Rakesh Singh, Dr. Koushik Adikari and Dr. Fanbin Kong for your guidance during this process. A special thank you to Carl Ruiz and Paula Scott for their help along the way.

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS v

LIST OF TABLES viii

LIST OF FIGURES ix

CHAPTER

1 INTRODUCTION 1

2 LITERATURE REVIEW 4

3 MATERIALS AND METHODS 13

4 RESULTS AND DISCUSSION 20

5 CONCLUSIONS 39

REFERENCES 41

APPENDICES

A SAMPLE SENSORY BALLOTS 45

B IR RWO BELT SPEED CURVE 51

LIST OF TABLES

Page

Table 2.1: Absorption of Different Chemical Groups from Kathiravan, et al. 2008 11

Table 2.2: Peanut Composition. Data from USDA National Nutrient Database for Standard Reference, Release 27, Basic Report 16087 11

Table 2.3: Lexicon of Peanut Flavor Descriptors from Johnsen, Civille, Vercellotti, Sanders and Dus, 1988 11

Table 4.1: Blanching protocol treatments 26

Table 4.2: Terms used in descriptive analysis of peanut treatments during the shelf life study ...27

Table 4.3: Moisture content and lightness values of peanuts for various treatments post blanching 28

Table 4.4: Blanchability results for various treatments 28

Table 4.5: Shelf-life descriptive sensory study results for three time points 29

Table 4.6: Peroxide values of blanched peanuts over six weeks 30

Table 4.7: Moisture content and lightness values of peanuts for various treatments post roasting30

Table 4.8: Results for consumer demographic questionnaire for roasted peanut study 31

Table 4.9: Consumer study results for roasted peanuts 32

Table 4.10: Peroxide values of roasted peanuts for various treatments....................33

LIST OF FIGURES

Page

Figure 2.1: Schematic for the conventional hot air heating method 12

Figure 2.2: Schematic for the infrared radiant wall oven 12

Figure 4.1: Blanchability outcomes 34

Figure 4.2: Peroxide values of blanched peanuts over six weeks 35

Figure 4.3: Blanched peanut photos..36

Figure 4.4: Internal preference map for consumer study of roasted peanuts 37

Figure 4.5: Roasting – Roasted peanut photos..38

CHAPTER 1

INTORDUCTION

Currently, the removal of the red skin of the peanut, a process known as blanching, is achieved by passing batches of peanuts through a conventional hot air convection oven with several different heating zones followed by mechanically removing the loose skin. Previous studies of the conventional peanut blanching method have used a hot air oven at 100ºC for 30-60 min (Adelsberg & Sanders, 1997). Hot air convection blanching allows for peak blanchability of 71-75% of batches to be blanched (Adelsberg & Sanders, 1997). Peanut roasting is a common further processing step for blanched peanuts. Roasting has been defined as a non-enzymatic process in which reactions occur to form pigments with yellow-brown color (Harris, 2013). Conventional blanching and roasting methods require long periods of heating at high energy costs. There are two objectives of this study. The first is to blanch small peanuts using infrared (IR) technology in the radiant wall oven (RWO) and the second is to determine the effects of IR blanching on small peanuts after roasting.

In the first phase of the study, blanching was applied to peanuts of both high and low moisture levels using infrared (IR) technology in the radiant wall oven (RWO). A high moisture level of approximately 9% moisture and a low moisture level of approximately 6% moisture were selected to imitate peanuts at both the beginning and end of one year of storage after harvesting.

The second phase of the study, focused on roasting small peanuts that were blanched using the same heating parameters as the first phase. All peanuts (Both IR and conventionally blanched) were roasted using a hot air impingement oven set at 177˚ C for approximately 10 minutes. An added factor in this portion of the study is a holding period after blanching. One group of peanuts was roasted directly after blanching and another was roasted 30 days after blanching. This is done in order to imitate the time peanut processors generally hold blanched peanuts before sale to further processors.

Infrared technology increases the efficiency of small peanut blanching and roasting using radiative heat transfer from the RWO that utilizes IR technology. Infrared radiation for food processing has been increasing in popularity in the last decade (Kathiravan, Khurana, Soojin, Irudayaraj & Demirci, 2008). This increase is mainly due to its energy efficiency, retention of food quality, process speed and the simplicity of the equipment (Rastogi, 2012). Further research into IR heating for peanut blanching will open more opportunities for increased efficiency and shorter processing times in the peanut industry and ultimately reduce costs and increase profits.

Because IR radiation is a more direct method of heat transfer than the hot air convection method currently used in the industry. The IR RWO can be used for blanching small peanuts with comparable blanching percentages, with shorter processing times and less degradation to the food. IR blanched peanuts will have better sensory qualities and shelf life with lower peroxide values than their conventionally processed counterparts.

The second phase of this study was to determine the effects of IR blanching on small peanuts after roasting. Based on the same principles of the blanching phase, increased energy efficiency, retention of food quality, process speed and the simplicity of the equipment, small IR blanched peanuts should have comparable consumer likability and acceptance as those blanched using the convectional method.

This study will reveal the effectiveness of IR technology for blanching and the effect IR blanching has after small peanuts are roasted. Small IR blanched peanuts will have comparable if not better, instrumental and sensory quality measure when compared to large runner type peanuts studied by Kettler at al. (2017). Small IR blanched peanuts that are conventionally roasted will have comparable likability and acceptability when compared to small peanuts that were conventionally blanched and conventionally roasted.

CHAPTER 2

LITERATURE REVIEW

Currently there are three major peanut growing areas in the United States – the southeast region, the southwest region and the Virginia-Carolinas region. There are nine states that account for 99% of all peanuts produced in the U.S. with Georgia contributing 45% of the US production (Stalker & Wilson, 2016). The peanut industry contributes more than 50,000 jobs in Georgia and 23% of the state's new row and forage crop income (Georgia Peanut commission, 2016). The crop is lucrative and essential to the economy so innovating new technology is important for the state.

Peanuts are planted in April through May when the soil temperature reaches 15.5-21.1 ˚C (National Peanut Board, 2016). Peanuts grow for 120-140 days before they are harvested (National Peanut Board, 2016). Once harvested they are dried to moisture content of 10% or less for storage (National Peanut Board, 2016). Shelled and skinned peanuts are required for further processing into most peanut products. The process to remove skin from peanuts is called blanching.

Peanut blanching is the application of heat followed by the abrasive removal of the peanut skin (Schirack, Sanders, & Sandeep, 2007). A study based on multiple heating and cooling cycles of Spanish peanut kernels (initial moisture of 0.5 to 15.7%) found cubical thermal expansion coeffecient of $50.0 \times 10^{-5}/^{\circ}C$ to $60.5 \times 10^{-5}/^{\circ}C$ for peanut kernels and a rate of $26.5 \times 10^{-5}/^{\circ}C$ to $55.0 \times 10^{-5}/^{\circ}C$ for peanut skins as moisture content increased (Paulsen & Brusewits, 1976). The relativly high oil content of the peanut kernels is believed to cause a higher expansion rate for the kernels (Paulsen & Brusewits, 1976). The high rate of expansion for the peanut kernel compared with the expansion rate of the peanut skin causes more stress on the peanut skin which helps to loosen the skin from the kernel. Additionally, mositure loss and crispying of peanut skins will also aid fracturability and seed coat removal. Because IR heating is a more surface level treatment, the skins from these peanuts may be more crisp and easier to remove. Today, there are several methods used for peanut blanching including microwave, dry, alkali, spin, water and peroxide (Schirack, Sanders, & Sandeep, 2007).

Roasting is another common processing method applied to peanuts. Roasting is defined by Harris (2013) as a heat treatment at 125˚C, at which non-enzymatic reactions occur to form pigments with specific yellow brown color. Hunter L-values of 53.0 ± 1.0, 48.5 ± 1.0, and 43.0 ± 1.0, correspond to light, medium and dark roasting, respectivly (Xiaolei, et al. 2017). Dry roasting is a common method of peanut roasting that utilizes a hot air oven with air controlled air flow. In order to compare roasting methods it is best to compare nuts that are roasted to a standard L-value rather than using a common set point (Xiaolei, et al., 2017).

The most commom method of blanching is through the use of a coventional hot air oven (Figure 2.1). In an extensive study carried out by Adelsberg and Sanders in 1997 medium, commercial size, runner peanuts were blanched using in a air flow direction controlled lab scale conventional hot air oven. The study took into account seed coat removed, mostiure content reduction and enzyme activity. Overall, it was found that the main factors affecting blanchability were intial moisture content, drying rate, thermal expansion. Reduction in mosture content to less than 4% from a initial content of 5.5% resulted in a maximum blanchability of approximatly 75%. These results were produced using a set point temperture of 87.7 ˚C with times of 45 and 60 min and a set point termperture of 98.9˚C with times of 40, 45 and 60 min.

Infrared blanching of large runner type peanuts showed comparable rates of blanchability when compared to the tradtional convection oven method (Kettler, et al., 2017). In that study, it was found that peanuts blanched using IR heating at 343 ˚C for 1.5 min, 316˚C for 1.5 min, 288 ˚C for 1.5 min, and 343 ˚C for 1 min did not differ significantly from the hot air controls. Figures 2.1 and 2.2 show schematics for the conventional hot air heating method and the IR heating method, respectivly. Additionally, a sensory evluation of shelf life done with one control and 3 IR treated sampled and indications of possible initiation of oxidation for the conventionally blanched peanuts at 18 weeks of storage with no indication of oxidation in the IR treated samples (Kettler et al., 2017).

Other electromagnetic heating techniques have also been studied. A process that was explored as an alternative to the conventional hot air process was microwave blanching. In a study by Schirack and others (2006), a continuous belt process was explored. All peanuts with internal tempertures exceeding 110 ˚C with a final mositure content of 5.5% or below produced blanchability greater than 85%. It was found that high blanchability was related to higher process tempertures coupled with lower final moisture contents. The study showed that microwave processing was a faster and more cost efficient process for peanut blanching. Microwave technology is another example of radiative technology applied to food.

The process to be covered in this experiment is the application of Infrared (IR) technology to blanch peanuts. IR heating is a form of radiative heating where the wavelength is determined by the temperature of the emitting body (Rastogi 2012). This relationship is described by the basic laws of black body radiation (Kathiravan, Khurana, Soojin, Irudayaraj & Demirci, 2008). Black body radiation depends on the emitting body's temperature. IR radiation is a form of electromagnetic radiation that has a wavelength of 0.38 to 1000 µm. Generally, IR wavelengths that can be absorbed by food components are in the far-IR region of the spectrum from 3.0 to 1000 μm (Sandu, 1986). Different food components absorb different wavelengths of radiation (Table 2.1) (Kathiravan, Kaur, Soojin, Irudayaraj & Demirci, 2008). Peanuts are mainly composed of protein and lipids (Table 2.2) (USDA National Nutrient Database, 2016). Due to their composition, peanuts will absorb wavelengths most between 2.83 μm and 5.76 μm.

Exposure of foods to these wavelengths causes changes in vibrational state of the atoms and molecules composing the food (Kathiravan, Kaur, Soojin, Irudayaraj & Demirci, 2008). This movement of molecules causes radiative heating. This creates a temperature gradient close to the surface of the food that will dissipate quickly pulling moisture from its core (Rastogi 2012). Sakai & Hanzawa (1994) stated that most FIR would be absorbed at the food surface and then transported by conduction in the food due to the energy absorption of water. Further study showed measured temperature distributions to be in agreement with their model. IR heating has many advantages over conventional heating such as reduced heating time, uniform heating, reduction in quality loss, versatility, simple equipment and significant energy savings (Rastogi, 2012). Additionally, because IR heating converts energy to heat directly at the surface, peanut skins may be better dried making them brittle and easier to remove.

Currently, IR heating is being used for drying, baking, roasting, blanching, pasteurization and thawing of food products (Rastogi, 2012). In addition, conventional processes are being improved with the addition of IR elements. In a study conducted on welsh onions, IR and convection heating were used in combination resulting in 48% less processing time and 63% less energy consumption when compared to the convection drying along (Kumar et al., 2005). Peanuts have also been roasted with a combination infrared-hot air method. In a study by Hadi and others, it was found that the combined hot-air and IR method was able to produce roasted peanuts with acceptable hardness, color difference, total phenolic compounds and total acceptance of peanut kernels. The combined method had values of specific energy consumed between 5.06 kWh/kg and 23.20 kWh/kg and showed considerable energy savings for the combined method.

French fries have been studied in order to compare their traditional water blanching process with a IR blanching process. In a study by Bingol et al. (2014) the two different pre-treatments were explored in order to produce a lower calorie French fry. Effectiveness of the treatments was measured by tracking the activity of polyphenol oxidase. Complete enzyme deactivation was achieved in 200 s with IR blanching as opposed to 16 min required for water blanching. The study also included an analysis of energy savings between treatment types. It was found that costs were similar for both processes. Finally, the study compared color of finished French fires for both treatments and found IR treated samples developed color faster. It was thought that this was due to water blanching leaching soluble solids out of the potatoes that are involved in the Maillard browning reaction.

Sensory Analysis of Peanuts

Peanuts contain approximately 50 to 55% oil and 25 to 28% protein. Oil in peanuts is composed of 30% linoleic acid which is the main oil responsible for the formation of off-flavors that occur vis lipid oxidation reactions (St. Angelo, 1996). Due to their high oil content and unsaturated fatty acid concentration peanuts are susceptible to lipid oxidation (Riveros et al., 2010).

A peanut lexicon was developed by Johnsen, Civille, Vercellotti, Sanders and Dus (1988) in order to give the peanut industry a standardized way to communicate about sensory. This lexicon includes aromatics, tastes and chemical feeling factors. Table 2.3 shows peanut descriptors that were decided on and accepted in this study.

A study on the sensory qualities of microwave blanched peanuts showed moisture content also played a significant role in determining the formation of off flavors. The study points to water contents affecting the concentrations of precursors available for flavor formation (Schirack, 2006). In previous studies it was shown that a lower final moisture content for peanuts was related to higher rates of blanching, however, this loss of moisture may also aid in the creation of off flavors (Schirack, 2006). In the same study it was found that peanuts that did not reach 110 ˚C had acceptable skin removal and prevented off flavors associated with microwave blanched peanuts.

Sensory analysis of roasted peanuts stored for 12 weeks found that products of lipid oxidation such as hexanal, octanal and 2-octanone increased during storage and are predictors of off-flavors (Bett and Boylston, 1992). Additionally, it was found in the same study that as storage time increased roasted peanutty flavor was dramatically decreased. Off-flavors associated with the products of oxidation are indicators of rancidity (St. Angelo, 1996). In a study that linked oxidation end products, specifically hexanal, as an indicator of acceptability ranting on a –point hedonic scale it was found that as hexanal content increased consumer acceptability was decreased (Grosso & Resurreccion, 2002). Also, as roasted peanutty flavor intensity decreased so did consumer acceptance (Grosso & Resurreccion, 2002). An earlier study had found a compound responsible for roasted panutty flavor, 2-ethyl-6-methyl pyrazine, was also positively correlated with sensory preference (Buckholz & Daun, 1981). A hexanal content between 5.39 μg/g and 5.54 μg/g was found to correlate to an acceptance rating of 5 on a 9-point scale (Grosso & Resurreccion, 2002). A rating of 5 indicates neither like nor dislike and can be considered the end point for consumer acceptability. Scores below 5 indicate some dislike of the product.

The same study by Grosso and Resurreccion found that certain descriptive ratings to be more highly correlated with consumer acceptance. These factors of descriptive studies found to be the best indicators of consumer acceptance ($R^2 \geq 0.70$) are overall oxidation, peanutty flavor, painty flavor, cardboard and astringency (Grosso & Resurreccion, 2002).

Table 2.1: Absorption of different chemical groups. (adapted from Kathiravan, et al. 2008)

Chemical Group	**Wavelength (µm)**
Lipids, ester	5.71 – 5.76
Proteins, amide	5.92
Proteins, NH	2.83 – 3.33
Unsaturated Lipids	4.44 – 4.76

Table 2.2: Peanut composition. (USDA National Nutrient Database, 2016)

Compositional Trait	**(%)**
Moisture	6.5
Protein	25.8
Total Lipid	49.2
Ash	2.3
Carbohydrate, by difference	16.1
Fiber, total dietary	8.5
Sugar, total	4.7

Table 2.3: Lexicon of peanut flavor descriptors (adapted from Johnsen, Civille, Vercellotti, Sanders and Dus, 1988).

Aromatics	**Aromatics**	**Tastes**	**Feeling Factors**
Roasted Peanutty	Painty	Sweet	Astringent
Raw Bean/Peanutty	Burnt	Sour	Metallic
Dark Roasted Peanut	Green	Salty	Crunchy
Sweet Aromatic	Earthy	Bitter	
Woody/Hulls/Skins	Grainy		
Cardboard	Fishy		
Chemical/Plastic	Skunky/Mercaptan		

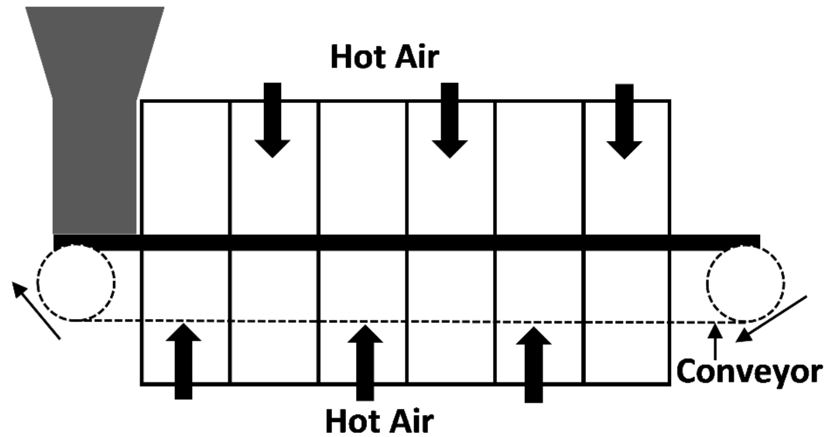


Figure 2.1: Schematic for the conventional hot air heating method (adapted from Kettler, et al., 2017).

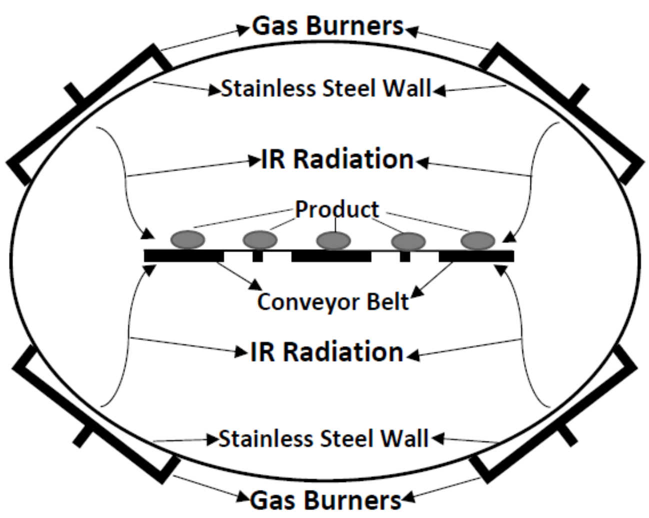


Figure 2.2: Schematic for the infrared radiant wall oven (adapted from Kettler, et al., 2017).

CHAPTER 3

MATERIALS AND METHODS

Peanut Sourcing and Conditioning

Small size commercial grade peanuts were obtained from Lewis M. Carter Manufacturing (LMC, Donaldsville, GA). The peanuts were an aggregate of different peanut varieties that were sorted based on size (Woodall, 2015). Once sorted, peanuts were stored at 4 ˚C until conditioned to two different moistures levels of approximately 6% and 9%. These two moisture levels were chosen in order to simulate moisture levels consistent with freshly harvested peanuts (9%) and peanuts that have been stored for a period of one year (6%). Conditioning was done using a Hotpack Humidity Chamber (Model 155314) set at 90% relative humidity (RH) and 40 ˚C in approximately 14 h or until moisture analysis showed the peanuts had reached appropriate moisture level.

Blanching

Peanut blanching was achieved by a conventional method using a conventional hot air impingement oven (Model 1450, Fort Wayne, IN 46804, USA) as a control and an IR Radiant Wall Oven (Model RWO-12-26, 152 Lorum Street Tweksbury, MA 01876, USA) for the new method to be tested. Control samples processed in the impingement oven were blanched at 100˚C for 1200 s (20 min) and samples processing in the IR RWO were blanched using two different time/temperature combinations, either 343.33˚C for 60 s or 287.7˚C or 90 s (Table 3.1).

These two time/temperature combinations previously had positive results for blanching when applied to large peanuts. When applied to large peanuts, these two settings were able to produce blanchability of 84% and 86%, respectively (Kettler et al., 2017). Small peanuts were removed from cold storage and allowed to come to room temperature (approximately 25˚C). Peanuts that were split and peanuts without seed coat were removed from the supply before blanching. One kilogram of whole, unblanched peanuts were placed in custom made 86.4 cm x 28.6 cm perforated wire mesh trays in a single layer. Two trays were placed backed to back per trial in order to process two kilograms of peanuts at once. After processing, peanuts were immediately force cooled with compressed air at ambient temperatures (23 ˚C) for four min. The peanuts were then fed into a laboratory scale blancher consisting of gritted horizontal rollers that were approximately 10.795 cm in diameter with variable roller speed and angle. The blancher was run for 45 s at 60 rpm, on a 2˚ decline. Peanuts were run through the blancher twice to achieve maximum peeling. A 20-gram sample was retained for moisture content determination before and after blanching. A 100-gram sample was retained for color determination and oil extraction for peroxide value determination.

Roasting

Roasting of IR blanched peanuts were completed using a conventional hot air impingement oven (Model 1450, Fort Wayne, IN 46804, USA). The control groups for this part of the study were small peanuts blanched and roasted in the conventional hot air impingement oven.

The two IR time/temperature combinations from the blanching study that resulted in the highest blanchability, 287.78˚C for 90 s and 343.33 for 60 s, were used for blanching in the roasting study (Table 3.2). In order to investigate how storage time may change quality of roasted peanuts, once blanched, two different hold times were explored, a period of 1 day and a period of 30 days (Table 10). Peanuts were held in sealed plastic bags at ambient temperature (approximately 25 ˚C). After the holding period, 750 grams of blanched peanuts were placed in a custom made 86.4 cm x 28.6 cm perforated wire mesh tray in a single layer and roasted in the conventional hot air impingement oven heated to 176.97±1.04˚C for 600 s (10 min). The same roasting time and temperature were used for all protocols. After roasting, the peanuts were immediately force cooled with compressed air at ambient temperature (23 ˚C) for 4 min. A 100-gram sample was retained for color determination and moisture contented determination. A 250-gram sample was retained from each trial for oil extraction for peroxide value determination. All other nuts blanched by the same protocol were combined and used for testing of consumer preference and acceptability.

Quality Testing

After blanching several physical and chemical tests were completed to determine quality of blanched and roasted peanuts. Blanched peanuts were tested for blanchability, color to ensure they remained raw, moisture content change, peroxide value and evaluated by a trained descriptive peanut panel. Roasted peanuts were tested for color to ensure they were roasted to the appropriate level, moisture content change, peroxide value as well as being tested for acceptability and preference by a consumer panel.

Blanchability

A 100-gram sample was separated by hand based on visual inspection to determine blanchability. Peanuts were separated into whole blanched, split blanched and unblanched nuts. Peanuts were considered unblanched if seed coat was still visible on the peanut.

Color Determination

After determination of blanchability, the same 100-gram sample was placed in a small petri dish on a black background for color determination using a HunterLab MiniScan EZ Colorimeter (Hunter Associates Laboratory, Inc., Reston, VA USA). This allowed the port of the device to be completely covered by peanuts while ensuring that no outside light interfered with measurements. Before use, the colorimeter was calibrated using black and white standardization tiles that were included with the device. Color is reported using CEI L* Values. Three measurements were taken per sample and averaged. Peanuts with L* values greater than 61 are considered to be raw.

Moisture Measurements

Twenty gram samples were taken from each trial and ground using a small coffee grinder and analyzed in a HR73 Mettler-Toledo Halogen Moisture Analyzer (Mettler-Toledo, LLC, Columbus, OH, USA). Three to four grams of coarsely ground peanuts were weighed in the aluminum tray of the moisture analyzer and dried at 110 ˚C for approximately six to ten minutes or until consistent sample weight was achieved.

Peroxide Value

In order to measure the extent of oxidation as an indicator of off flavor formation, oil was pressed from the peanuts using a hydraulic Carver press (Carver Inc., Wabash, IN, USA). After pressing, peanut oil samples were transferred to small glass bottles wrapped in tin foil and kept frozen until further analysis.

Peroxide value measurements were determined using AOCS Official Method Cd 8-53. This method determines all substances, in terms of milliequivalents of peroxide per kg of sample, that oxidized potassium iodide (KI) under the conditions of the test. The substances are generally assumed to be peroxides or other similar products of fat oxidation. A 5.00 ± 0.05 g sample of oil was measured and placed in a 250 mL glass stopped Erlenmeyer flask. About 30 mL of acetic acid – chloroform solution was added to the flask and swirled until the sample was dissolved. Then, 0.5 mL of saturated KI solution was used to the flask using a volumetric pipet. After 1 min, 30 mL of distilled water was added immediately to stop the reaction. This solution was then titrated with 0.1 N sodium thiosulfate under constant agitation and 2.0 mL of starch indicator. Peroxide value is expressing mM peroxide/kg oil sample.

$$\text{Peroxide Value} = \frac{(S-B) \times N \text{ Thiosulfate} \times 1000}{\text{Weight of Sample}} \qquad (1)$$

S = titration of sample (mL), B = titration of blank (mL)

Shelf Life Sensory Evaluation of Blanched Peanuts

A trained panel consisting of 7 trained (>100 h of training and 1,200 h of testing) panelists was used to evaluate blanched nuts at the UGA Griffin campus. Approval from the university's IRB (Project ID MOD00002419) was obtained. Samples for the shelf life study was stored in plastic containers at ambient temperature (23 ˚C) for 6 weeks. Peanuts were evaluated at 0, 3 and 6 weeks of storage.

Testing was conducted over a period of eight days. Seven panelists participated in a 2 h orientation prior to sensory evaluation where they evaluated all samples and determined the descriptors based on the peanut lexicon established by Johsen et all. (1988). Descriptors and their definitions are shown in Table 3.3. Each descriptor was anchored with multiple references on a 31 point scale using 0-15-point scale with 0.5 increments. At the beginning of each evaluation session panelist were calibrated using a warm up sample. Next, samples were randomly coded with 3 digit code and given to the panelist in random order for evaluation in booths using Compusense (Compusense Inc., Guelph, Ontario, Canada) software loaded onto computers. Samples were approximately 10 g in size. Room conditions were under incandescent lighting at 21 ˚C.

Consumer Study of Roasted Peanuts

Roasted peanuts were consumer tested for acceptability and preference with approximately 80 participants that are screened based on product usage levels. The screener form has been included in appendix C. Consumers were asked to rate their level of acceptance as well as participate in preference testing. The difference testing will compare conventionally blanched and roasted small peanuts to infrared blanched and conventionally roasted small peanuts. The preference testing was done through with a simple paired preference design employing forced choice as outline by Lawless (2010). A sample score card has been included in appendix C. The acceptability test with used a simple 9-point hedonic scale as outlined by Lawless (2010). A sample ballot has been included in appendix A

Statistical Analysis

One-way and two-way Analysis of Variance (ANOVA) were used to analyze the data in this experiment using the GLM Procedure in the SAS software (Version 9.4, SAS Institute, Cary, NC). Principle Component Analysis (PCA) was performed using XLSTAT (Version 2016, Addinsoft, New York, NY). Means comparison completed using Tukey's HSD procedure.

CHAPTER 4

RESULTS AND DISCUSSION

Blanching

High moisture loss should correlate to higher rates of blanchability for peanuts that lost more moisture because moisture loss is the most important factor impacting rate of blanchability (Schirack, 2007). Moisture change for control treatments was significantly different ($P < 0.05$) from all other samples in their same moisture category (Table 3.3). Because these samples were blanched using the conventional hot air blanching method, which required much longer time and thus the moisture change was greater. IR samples did not experience significant amounts of moisture loss because IR heating is largely a surface only treatment which took much less time and thus did not remove much water from the peanuts.

Although control treatments experienced a greater amount of moisture reduction, this did not lead to a greater rate of blanchability. There was no statistical difference between any protocol in factors that were used to determine blanchability (Table 3.5). These factors include whole blanched, split blanched and unblanched peanut categories. Additionally, total amount of blanched peanuts (the combination and whole and split nuts) did not vary among protocols. While there were not statistical significant differences between protocols, there are some trends in the data that are worth mentioning. Table 3.5 shows overall blanchability was marginally improved when initial moisture was lower. The 6% initial moisture category had somewhat greater overall blanchability without any increase in split nuts.

For all samples, L* values were greater than 61 indicating that all samples were still considered to be raw after blanching (Table 3.4). Figures 3.3 shows photos of peanuts after blanching under different protocols. Although no significant difference was found in blanchability, some groups appeared to have looser red skin than others. Figure 3.3 f. shows the best rate of overall blanchability.

In industry the standard for blanchability has been determined to be >85% (Schirack, 2007). Previous studies on blanching using the conventional hot air oven for times from 30 to 60 minutes produced blanchabilities between 71% and 75% with 2.94% being the lowest final moisture contents (Adelsberg & Sanders, 1997). Studies covering the use of IR heating for blanching large peanuts found peak blanchabilities to be between 76% and 86% (Kettler et al., 2017). In reflection of these studies, total blanchability for IR treatments in this study are comparable to the industry standard and previous work on IR heating of large peanuts. As previously mentioned, the largest driving force in determining blanchability is moisture loss (Schirack, 2007). However, the peanuts in this study did not reach levels as low as those seen in the study by Adelsberg, but still managed to have comparable rates of blanchability. The lower amount of moisture loss is most likely due to the surface level heating of the IR treatments and the much lower processing times. Processing times for IR treatments were either 60 or 90 s compared to the 20 minutes of the control treatments or the 30 to 60 min for the industry standard. On the same note, high MC samples had slightly lower blanched whole and total blanched percentages because they didn't reach a low enough ending moisture content.

The shelf life descriptive study displays several general trends (Table 3.5). The most variable factor out of all aspects of the peanuts tested was fracturability. The higher moisture groups had lower scores in fracturability and were perceived to be somewhat softer than the lower moisture group. Over time, all groups experienced hardening to some extent with low moisture groups ending with the highest levels of fracturability at the six-week period. No differences were found in the oiliness or raw/beany character of any group at any time. These two attributes are normal positive attributes associated with raw peanuts. Low levels of overall oxidation were found in the peanuts but were at levels that are too low to be perceived by the majority of people. These low levels may correlate with presence of octanal, nonanal, hexanal or 2-pentyl pyridine (Shangci, et al., 2017). The bitterness category has scores that are worth mentioning because they are somewhat higher and may be able to be tasted. However, the raw/beany attribute can sometimes be confused with a bitter flavor. This may contribute to the ratings produced from the panel. Peanuts were also perceived to be somewhat astringent with some reduction over time.

This descriptive study also asked panelist to rate the amount of overall oxidation perceived in various samples. The high moisture samples had higher scores in the overall oxidized category. The best scores were observed in IR samples with lower moisture content which had the lowest score of 0.02 at the end of the six weeks. These finding are also supported with peroxide value data (Table 3.7). IR 2 samples for both low and high moisture level experienced less change in PV over time. Throughout the storage, low moisture IR 2 had the same or lower PV than control samples.

International food standards state that fats and oils that are free from foreign and rancid odors and tastes should not exceed peroxide value of 10 mM/kg oil (Codex Alimentarius Commission, 1999). Additionally, it had been found that oils that are very poor in quality with significant off flavors have peroxide values ≥ 20 mM/kg oil (Nelson, 2010). In this study, lowest peroxide values were produced by low temperature long time treatments (IR 2). Over the six-week time period peroxide values for IR 2 samples ranged from a low of 3.98 mM/kg oil (week 0) to 4.68 mM/kg oil (week 6). Highest peroxide values were found in the high temperature short time treatments with values ranging from 3.99 mM/kg oil (week 0) to 7.35 mM/kg oil (week 6). While the values did increase over the course of the study, all values in IR treatments were below the limits set forth by the international standards for oils free of rancidity.

These findings indicate that the best treatment for blanching peanuts while limiting off flavor formation in IR 2 was 287.7˚C for 90 s and it belonged to peanuts with lower starting moisture of around 6%.

Roasting

Peanuts were roasted to lightness values that correspond to a medium roast. The lightness values achieved were within 0.9 of the target value of 48.5 (Table 3.7). The breakdown of consumer demographics are displayed in Table 3.8. Most consumers who participated were males, 35-44 years old who typically consume shelled, roasted peanuts 2-3 times per week. This descriptive study had consumers evaluate roasted peanut samples on 8 aspects of liking and 5 aspects of intensity using a nine-point hedonic scale (Table 3.9).

Scores for overall liking show that Control and IR 1 without any holding were the most liked samples with very similar score (Figure 3.9). However, IR 2 without any holding was the least liked sample. All samples that were held for 30 days before roasting were in between the most and least liked samples while the control for 30 days of holding had a slightly worse score of less than 5. Some specific aspects that are of concern, and may contribute to the variations in liking score, were detected as bitter and stale flavors. IR 1 samples, higher temperature with shorter blanching times, had the lowest bitterness scores. The single sample with the lowest bitterness score was IR 1 with 0 holding days. This sample also scored in the middle for sweetness intensity and was the most liked by panelists. IR 2 with 0 holding days had the most bitter flavor and was one of the least sweet samples. This relationship between sweetness and bitterness relates to how much a sample is liked. More sweet and less bitter samples are generally most liked by consumers. For IR blanching of the peanuts that were processed at higher temperatures and shorter times produced these likable qualities. This may be due to the shorter processing time that did not allow the production of bitter end products in the peanuts. The other concerning off flavor tasted by panelists was staleness. Overall scores were low with the highest staleness rating being 2.4 found in the IR 2 with 0 holding day sample. IR 1 with 0 holding days and control with 0 holding days were the least stale samples. IR 1 at 0 holding was the least stale sample and also the most liked sample.

Scores that were less than 5 indicate that consumers had a degree of disliking for samples and indicate a presence of hexanal levels ≥ 5.39 µg/g (Grosso & Resurrecion, 2002). Photos of roasted peanuts are displayed in Figure 3.6. Many consumers commented that peanuts appeared to be over roasted. While L* values were within the levels for medium roasting, peanuts appeared darker than what the consumers expected. If the peanuts were somewhat over roasted, this may have created more oxidized flavors due to heat exposure. Oxidized flavors like cardboard and painty are the most important factors in consumer disliking of a product (Shangci et al., 2017). These oxidized flavors have been correlated with the presence of ocantanal, nonanal, hexanal and 2-pentyl pyridine (Shangci et al., 2017). Because score for roasted peanuts were close to 5 for overall liking and many participants detected staleness. It is highly likely that some levels of these chemicals are present in the samples.

Peroxide values were not found to be significantly different however there are some general trends (Table 3.10, Figure 3.5). Control samples for both holding times had lower PV than any of the IR samples. Out of all the IR heat treatments, IR 1 with 0 holding days had the lowest score and is consistent with findings of the consumer study. A low PV score indicates a lower presence of end products associated with oxidation and flavors such as cardboard, fishy or painty. The Codex of Alimentarius Commission says the international food standard for fresh oils free of off-flavors is a PV of < 10 mM/kg (Codex Alimentarius Commission, 1999). While the roasting PV are high than that of the blanched peanuts they still are not above the standard for fresh oils.

Due to these findings IR 1 with 0 holding days is the best treatment for blanching peanuts with the intent of later roasting. Although this treatment produced a high peroxide value this was not picked up by consumers in the sensory study. This treatment had similar liking to the control sample with 0 holding days and will result in a more efficient use of energy and so money for the peanut industry. Pictures of samples for all treatments are show in Figure 3.6.

Table 4.1: Blanching treatments.

Treatment	Moisture Content (%)	Oven Type	Temperature (˚C)	Time (s)
Control	9.39±0.50	Impingement	100	1200
IR 1	9.27±0.90	RWO	343	60
IR 2	9.32±0.58	RWO	288	90
Control	5.99±0.96	Impingement	100	1200
IR 1	5.96±0.58	RWO	343	60
IR 2	5.84±0.86	RWO	288	90

Table 4.2: Terms used in descriptive analysis of peanut treatments during the shelf life study.

Descriptor	Modality	Definition	References
Fracturability	Texture	The force with which you first bite through the sample	Reference Sample: 6.5 Saltine Cracker: 4.5
Oiliness	Texture	Degree to which free oil is perceived in the mouth after 5 chews	Reference Sample: 1.0 Corn Chip: 3.0
Raw/beany	Flavor	The flavor associated with raw peanuts	Reference Sample: 3.5 Raw Peanut: 4.0
Overall oxidized	Flavor	The old/stale flavor associated with rancid fats and oils	Reference Sample: 0.0 Oxidized Oil: 6.0
Cardboard	Flavor	The flavor associated with somewhat oxidized fats and oils and reminiscent of wet cardboard	Reference Sample: 0.0 Wet Cardboard: 4.0
Fishy	Flavor	The flavor associated with trimethylamine, cod liver oil or old fish	Reference Sample: 0.0 Cod Liver Oil: 8.0
Painty	Flavor	The aromatic associated with linseed oil, or oil based paint	Reference Sample: 0.0 Boiled Linseed Oil: 11.5
Bitter	Basic taste	The taste on the tongue associated with bitter agents such as caffeine solution	Reference Sample: 1.0 Bitter Solution: 10.0 Bitter Solution: 5.0 Bitter Solution: 2.0
Sour	Basic taste	The taste on the tongue associated with acid solutions	Reference Sample: 0.0 Sour Solution: 10.0 Sour Solution: 5.0 Sour Solution 2.0
Salty	Basic taste	The taste on the tongue associated with sodium chloride solution	Reference Sample: 1.0 Salt Solution: 8.5 Salty Solution: 5.0 Salty Solution: 2.5
Sweet	Basic taste	The taste on the tongue associated with sucrose solution	Reference Sample: 2.0 Sweet Solution: 15.0 Sweet Solution: 10.0 Sweet Solution: 5.0 Sweet Solution: 2.0
Astringent	Feeling factor	The puckering or drying sensation on the mouth or tongue surface	Reference Sample: 1.5 Astringent Solution: 2.0 Astringent Solution: 5.0

Table 4.3: Moisture content and lightness values of peanuts for various treatments post blanching.

Treatment	**Initial Moisture Content (%wb)**	**Final Moisture Content (%wb)**	**Moisture Content Change (%)**	**L***
Low MC Control	5.93±0.71	4.52±0.87	1.48±0.39[a]	67.31±2.70
Low MC IR 1	5.93±0.71	5.39±0.58	0.57±0.11[b]	67.99±0.26
Low MC IR 2	5.93±0.71	5.47±0.53	0.37±0.40[b]	68.25±0.80
High MC Control	9.33±0.59	5.52±0.68	3.87±0.31[a]	66.41±1.30
High MC IR 1	9.33±0.59	7.60±0.19	1.41±0.93[b]	65.04±1.76
High MC IR 2	9.33±0.59	7.86±0.52	1.46±0.43[b]	64.00±1.69

Means with different letters in a section column are statistically significant at $P < 0.05$.

Table 4.4: Blanchability results for various treatments.

Treatment	**Blanched whole (%)**	**Blanched split (%)**	**Non-blanched (%)**	**Total blanched (%)**
Low MC Control	62.91±6.51	21.62±3.3	15.47±5.46	84.53±5.46
Low MC IR 1	63.91±3.01	23.99±2.57	12.09±2.59	87.91±2.59
Low MC IR 2	65.22±3.52	22.20±6.16	12.59±3.10	87.41±3.10
High MC Control	58.79±14.35	20.84±3.56	20.37±13.02	79.63±13.02
High MC IR 1	55.69±12.44	19.08±4.40	25.24±9.96	74.76±9.96
High MC IR 2	57.87±13.46	22.93±3.70	19.20±10.80	80.80±10.80

No significant difference found at $P < 0.05$

Table 4.5: Descriptive sensory study results for the three time points.

	Treatment	Fracturability	Oiliness	Raw/Beany	Overall Oxidized	Cardboard	Fishy	Painty	Bitter	Sour	Salty	Sweet	Astringent
Week 0	**Low MC Control**	4.29^{cde}	1.17	4.90	0.21^{ab}	0.12	0.10	0.17	1.00	0.05	0.86	1.69	1.26
	Low MC IR 1	4.88^{abcd}	1.10	5.26	0.00^{b}	0.00	0.00	0.00	0.95	0.05	1.00	1.74	1.31
	Low MC IR 2	4.81^{abcd}	1.10	5.21	0.00^{b}	0.00	0.00	0.00	0.88	0.05	1.02	1.81	1.12
	High MC Control	4.33^{cde}	1.14	5.43	0.10^{ab}	0.07	0.00	0.00	1.02	0.07	0.93	1.74	1.19
	High MC IR 1	3.19^{f}	1.24	5.31	0.62^{a}	0.38	0.10	0.14	1.17	0.14	0.90	1.48	1.24
	High MC IR 2	3.43^{ef}	1.29	5.24	0.40^{ab}	0.07	0.14	0.33	1.05	0.12	1.00	1.50	1.31
Week 3	**Low MC Control**	5.31^{abc}	1.14	4.62	0.05^{b}	0.00	0.00	0.00	0.81	0.00	1.00	1.67	1.21
	Low MC IR 1	5.14^{abc}	1.05	4.95	0.00^{b}	0.00	0.00	0.00	0.76	0.00	0.93	1.74	1.24
	Low MC IR 2	4.86^{abcd}	1.26	5.31	0.05^{b}	0.05	0.00	0.00	0.83	0.00	0.95	1.67	1.14
	High MC Control	4.57^{bcd}	1.19	4.83	0.12^{ab}	0.05	0.00	0.07	0.88	0.00	0.93	1.62	1.19
	High MC IR 1	4.05^{def}	1.07	5.00	0.40^{ab}	0.33	0.00	0.07	0.74	0.05	0.81	1.43	1.31
	High MC IR 2	3.88^{def}	1.21	5.17	0.19^{ab}	0.05	0.00	0.12	0.93	0.00	0.76	1.43	1.26
Week 6	**Low MC Control**	5.69^{a}	1.02	4.48	0.14^{ab}	0.14	0.00	0.00	0.81	0.00	0.90	1.74	1.19
	Low MC IR 1	5.52^{ab}	1.02	4.88	0.02^{b}	0.02	0.00	0.00	0.88	0.00	1.00	1.67	1.14
	Low MC IR 2	5.29^{abc}	1.05	5.12	0.02^{b}	0.02	0.00	0.00	1.14	0.00	1.02	1.67	1.26
	High MC Control	5.21^{abc}	1.08	4.67	0.02^{b}	0.02	0.00	0.00	0.86	0.00	0.90	1.52	1.17
	High MC IR 1	4.50^{bcd}	1.08	4.86	0.31^{ab}	0.24	0.00	0.07	0.86	0.00	0.90	1.48	1.17
	High MC IR 2	4.50^{b}	1.10	5.10	0.33^{ab}	0.33	0.00	0.00	0.93	0.00	0.88	1.40	1.19

Means with different letters in a section column are statistically significant at $P < 0.05$.

Table 4.6: Peroxide values of blanched peanuts over six weeks.

	Peroxide Value (millimol/kg)		
Treatment	**Week 0**	**Week 3**	**Week 6**
Low MC Control	4.65±1.15	5.33±2.32	5.98±5.26
Low MC IR 1	3.99±2.02	6.68±3.06	7.34±3.05
Low MC IR 2	3.98±1.98	4.66±1.16	4.68±1.16
High MC Control	3.99±3.45	5.31±1.13	5.98±3.43
High MC IR 1	4.64±1.15	5.99±3.47	6.62±3.02
High MC IR 2	4.00±0.01	3.99±0.00	3.99±1.98

No significant difference found at $P < 0.05$

Table 4.7: Moisture content and lightness values of peanuts for various treatments post roasting.

Treatment	**Holding Period (day)**	**Initial Moisture Content (%wb)**	**Final Moisture Content (%wb)**	**Moisture Content Change (%)**	**L***
Control	0	4.67±0.00	0.48±0.00	$4.19±0.00^{c}$	49.12±0.55
IR 1	0	7.26±0.30	0.43±0.09	$6.82±0.34^{a}$	47.77±0.45
IR 2	0	7.14±1.18	0.48±0.10	$6.66±1.25^{ab}$	47.60±0.45
Control	30	4.87±0.00	0.65±0.00	$4.22±0.00^{bc}$	47.74±0.78
IR 1	30	7.29±0.17	0.71±0.18	$6.58±0.18^{ab}$	48.53±0.45
IR 2	30	6.80±0.17	0.65±0.17	$6.14±0.31^{abc}$	48.30±0.45

Means with different letters in a section column are statistically significant at $P < 0.05$.

Table 4.8: Results for consumer demographic questionnaire for roasted peanut study. (n = 79)

Age Group	
18-24 y	6
25-34 y	17
35-44 y	18
45-54 y	16
55 y or older	22
Gender	
Male	43
Female	36
Frequency of eating peanuts	
Daily	18
2-3/week	40
1/week	12
3/month	3
2/month	4
1/month	2
Types of peanut products consumed	
Roasted peanuts	71
Boiled peanuts	41
Peanut Butter	68
Peanut Bars	37
Candy	3
Shelled compared with In-shell preference	
In-shell	18
Shelled	40
No preference	21

Table 4.9: Consumer study results for roasted peanuts.

		Liking								Intensity				
Treatment	Holding Period (day)	Appearance	Color	Aroma	Flavor	Roasted Peanut	Sweet	Texture	Overall	Roasted Peanut	Sweetness	Bitterness	Stale	% consumers who detected staleness
Control	0	5.10^{ab}	5.38^{ab}	5.53	5.62^{ab}	5.84^{a}	5.44^{a}	6.35^{a}	5.49^{a}	6.14	3.85^{a}	4.73^{ab}	1.13^{b}	24.05%
IR 1	0	5.32^{a}	5.61^{a}	5.80	5.80^{a}	5.94^{a}	5.19^{ab}	6.37^{a}	5.53^{a}	6.28	3.44^{abc}	4.29^{b}	1.00^{b}	21.52%
IR 2	0	4.59^{b}	4.81^{bc}	5.29	4.71^{c}	4.80^{b}	4.46^{c}	5.70^{b}	4.42^{c}	6.13	3.16^{bc}	5.25^{a}	2.43^{a}	46.84%
Control	30	4.62^{b}	4.62^{c}	5.49	4.94^{bc}	5.25^{ab}	4.63^{bc}	5.96^{ab}	4.70^{c}	6.09	3.04^{c}	5.14^{ab}	1.75^{ab}	36.71%
IR 1	30	5.48^{a}	5.63^{a}	5.56	5.15^{abc}	5.34^{ab}	5.00^{abc}	6.29^{a}	5.13^{abc}	6.05	3.78^{ab}	4.59^{ab}	1.49^{ab}	30.38%
IR 2	30	5.51^{a}	5.56^{a}	5.72	5.56^{ab}	5.66^{a}	4.96^{abc}	6.16^{ab}	5.20^{ab}	5.77	3.52^{abc}	4.61^{ab}	1.65^{ab}	29.11%

Means with different letters in a section column are statistically significant at $P < 0.05$.

Table 4.10: Peroxide values of roasted peanuts for various treatments.

Treatment	**Holding Period (Days)**	**Peroxide Value (mM/kg)**
Control	0	3.00±1.43
IR 1	0	6.00±5.32
IR 2	0	9.99±5.28
Control	30	3.98±0.00
IR 1	30	8.63±1.14
IR 2	30	8.69±2.43

No significant difference found at P < 0.05

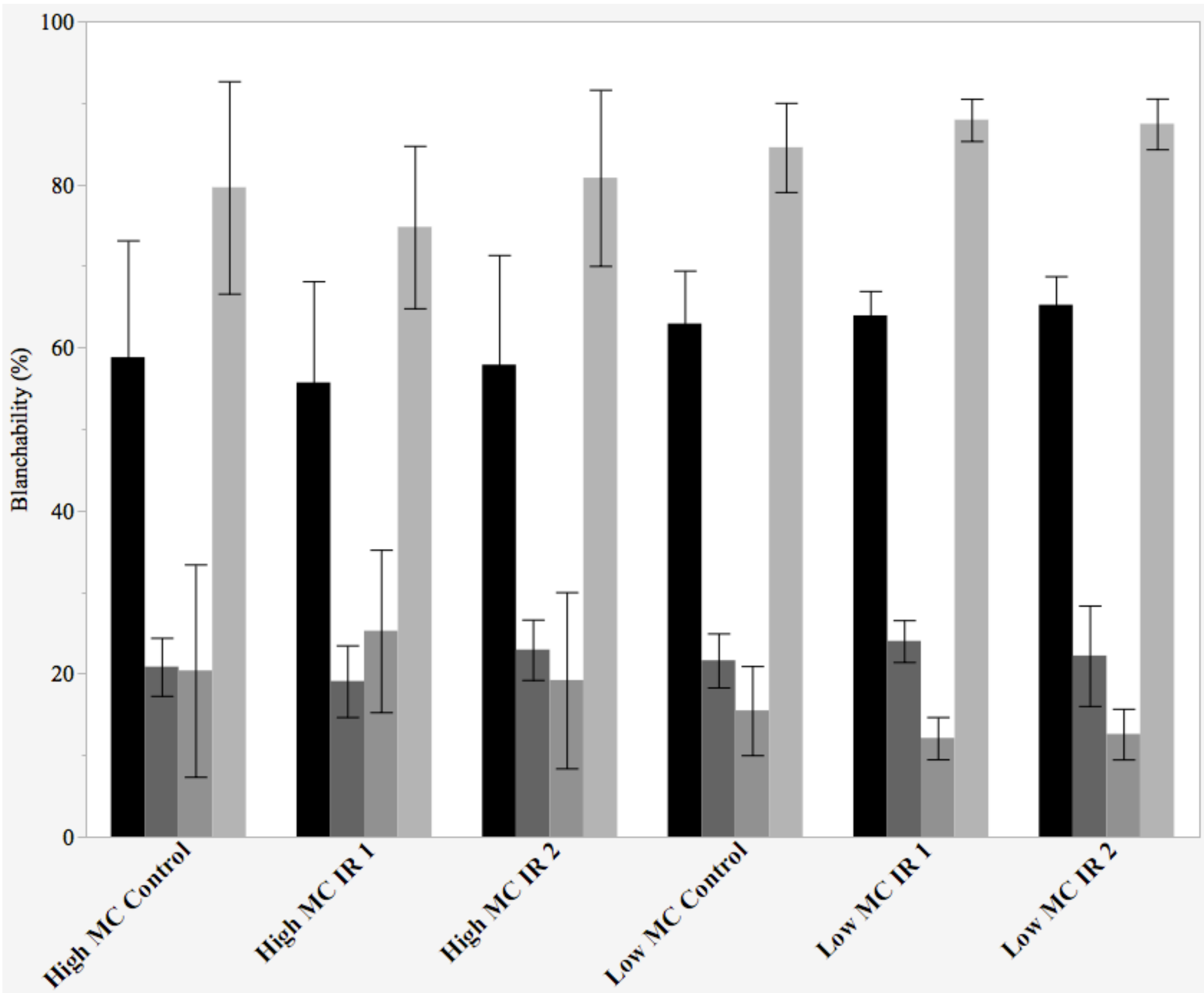


Figure 4.1: Blanchability outcomes. ■ whole blanched, ■ split blanched, ■ unblanched, ■ blanched

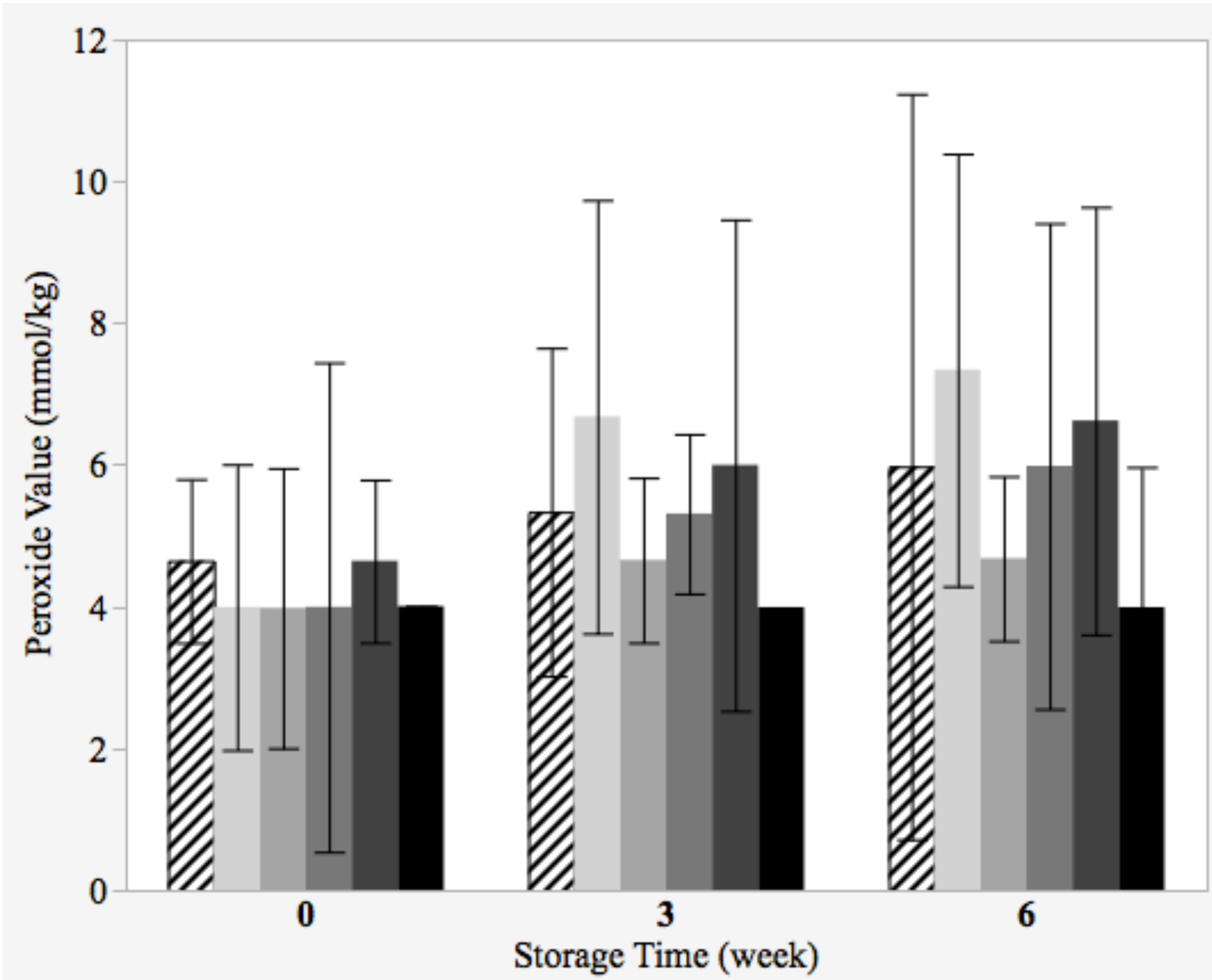


Figure 4.2: Peroxide values of blanched peanuts over six weeks of storage. ▨ Low MC Control ■ Low MC IR 1 ■ Low MC IR 2 ■ High MC control ■ High MC IR 1 ■ High MC IR 2

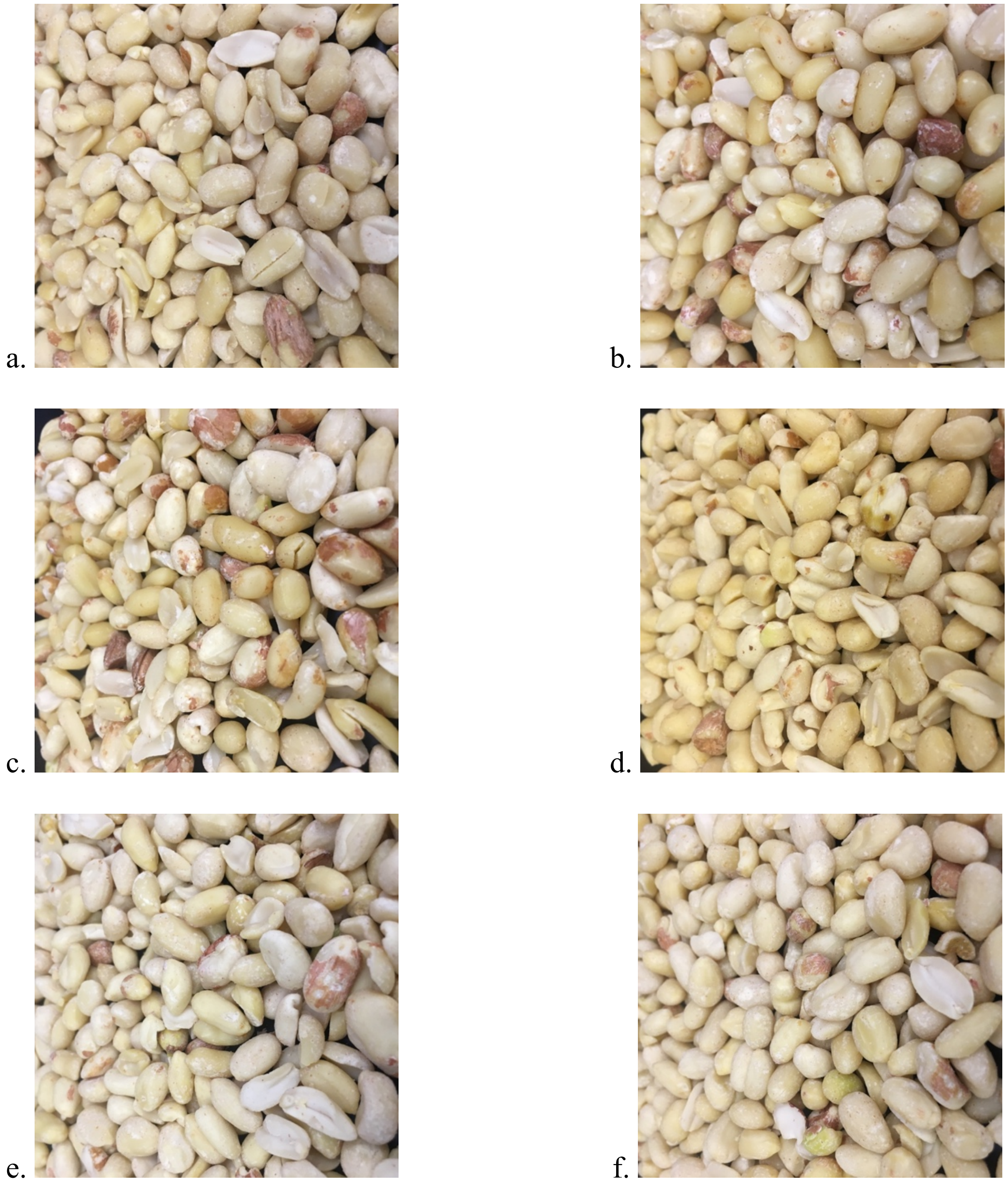


Figure 4.3: a. High MC Control b. High MC IR 1 c. High MC IR 2 d. Low MC Control e. Low MC IR 1 f. Low MC IR 2

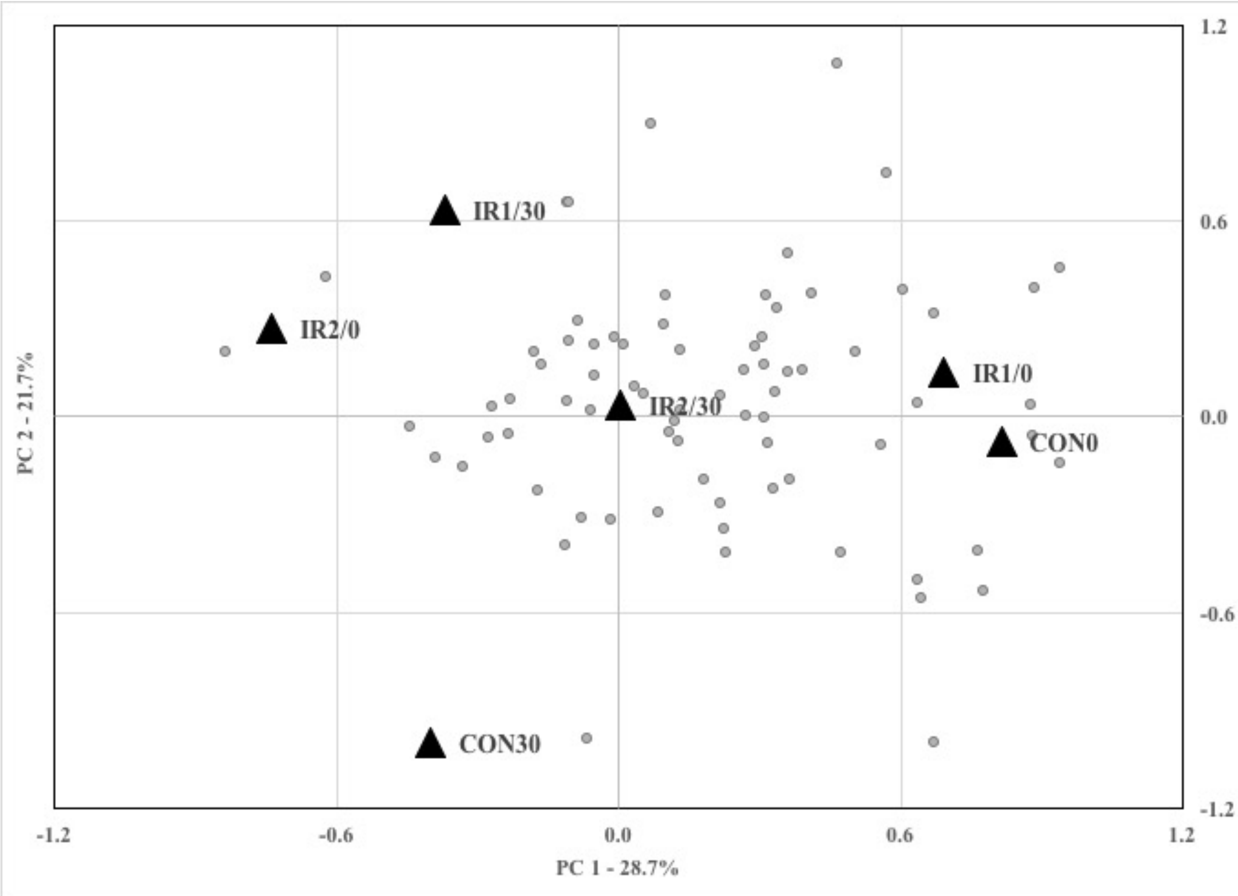


Figure 4.4: Internal preference map for consumer study of roasted peanuts.

Image 4.5: a. Control 0 holding days b. IR 1 0 holding days c. IR 2 0 holding days d. Control 30 holding days e. IR 1 30 holding days f. IR 2 30 holding days

CHAPTER 5

CONCLUSIONS

Infrared heating is a viable alternative to conventional blanching. Blanchability data and data from the descriptive shelf life study of blanched peanuts was consistent with results seen in other studies. One study found no significant differences in blanchability or sensory outcomes using large sized peanuts (Kettler, 2017). Applying the technology to small peanuts yielded similar effects. The best outcomes in blanching were a result at heating to 288˚C for 90 seconds. When applied to peanuts with lower initial moisture content of approximately 6% this treatment results in the best blanchability while limiting off flavor formation.

Results from this section of the study indicate that there is no difference in blanchability between the conventional method and the new IR heating method being tested when applied to small peanuts. Additionally, there is no difference in blanchability between the high moisture category and the low moisture category. Sensory shelf life evaluation indicates that only the fracturability category has difference that are notable in the sense that the high intial moisture category are somewhat softer overall than the low starting moisture groups. Over time the fracturability of the peanuts increased as storage time increased. These findings indicate that it would be possible to use the new hotter, faster infrared oven to blanch peanuts more quickly using a reduced amount of energy with similar quality parameters.

Peanuts blanched using IR technology that were subsequently roasted by conventional method were comparable to their counterparts. Combination methods of infrared and hot air technology for roasting peanuts have already been employed in peanuts with positive results

(Hadi, et al., 2016). Roasting applied to small IR blanched peanuts in this study are similarly favorable. The most liked IR blanched peanut groups were heated using the RWO set at 343˚C for 60 seconds and did not significantly differ from control samples. Ideally, peanuts should be roasted directly after blanching to achieve the highest likeability and acceptance however, a 30 day storage period did not change likeability significantly.

Results from the roasting portion of the study determined that while roasting in the IR RWO was not possible, peanuts that were blanched using the IR method and roasted using the conventional method were comparable in overall liking to the conventionally blanched peanuts. Although peroxide value data shows higher score for the IR processed nuts, the consumer study was not affected by this. Of the two IR treatments tested, IR 1, a higher temperature shorter time process used for blanching, had the best liking scores. Overall the amount of storage time did not affect liking.

For the reasons stated above the recommendation for applying IR heating to would be in a high temperature short time treatment. Although the sensory data from the shelf life study of the blanched peanuts had the best results with a low temperature for longer time, the high-temperature short-time method results had only minor differences. Additionally, the high-temperature short-time treatments (IR 1) were best for roasting peanuts, one of the most popular further processes for blanched peanuts.

In future studies, an all infrared roasting method could be explored. An oven with better temperature control and timing could make IR roasting a viable option for the industry.

REFERENCES

Adelsberg, G. D., & Sanders, J. H. (1997). Effect of peanut blanching protocols on bed and seed temperatures, seed moisture, and blanchability. *Peanut Science, 24*(1), 42-46. doi:10.3146/i0095-3679-24-1-10

Bett, K., & Boylston, T. (1992). Effect of storage on roasted peanut quality: Descriptive sensory analysis and gas chromatographic techniques. *ACS Symposium Series - American Chemical Society*, (500), 322-343.

Bingol, G., Wang, B., Zhang, A., Pan, Z., & McHugh, T. H. (2014). Comparison of water and infrared blanching methods for processing performance and final product quality of French fries. *Journal of Food Engineering, 121*, 135-142. doi:http://dx.doi.org/10.1016/j.jfoodeng.2013.08.001

Buckholz, L. J., Daun, H. (1981). Instrumental and sensory characteristics of roasted peanut flavor volatiles. *ACS Symposium Series*, *170*163-181.

Codex Alimentarius Commission. (1999). Codex standards for edible fats and oils not covered by individual standards. Rome: World Health Organization: Food and Agriculture Organization of the United Nations

Georgia Peanut Commission. (2016). About Us. Retrieved September 5, 2016 from http://www.gapeanuts.com/about_us.php

Grosso, N. R., & Resurreccion, A. A. (2002). Predicting consumer acceptance ratings of cracker coated and roasted peanuts from descriptive analysis and hexanal measurements. *Journal of Food Science,* 67(4), 1530-1537. Doi:10.1111/j.1365-2621.2002.tb10317.x

Hadi, B., Mahdi, K., Aman M., Z., & Mehran, A. (2016). Novel hybridized infrared-hot air method for roasting of peanut kernels. *Innovative Food Science And Emerging Technologies*, 37(Part A), 106-114. doi:10.1016/j.ifset.2016.08.014

Harris, L. (Ed.). (2013). *Improving the safety and quality of nuts*. Woodhead Publishing Limited.

Jiao S, Zhu D, Deng Y, Zhao Y. Effects of Hot Air-assisted Radio Frequency Heating on Quality and Shelf-life of Roasted Peanuts. Food & Bioprocess Technology [serial online]. February 2016;9(2):308-319. Available from: Academic Search Complete, Ipswich, MA. Accessed October 24, 2016.

Johnsen, P. B., Civille, G. V., Vercellotti, J. R., Sanders, T. H., & Dus, C. A. (1988). Development of a lexicon for the description of peanut flavor. *Journal of Sensory Studies, 3*(1), 9-17. doi:10.1111/j.1745-459X.1988.tb00426.x

Kathiravan, K., Kaur, K., Soojin, J., Irudayaraj, J., & Demirci, A. (2008). Infrared heating in food processing: an overview. *Comprehensive Reviews In Food Science and Food Safety*, 7(1), 2-13. doi:10.1111/j.1541-4337.2007.00024.x

Kettler, K., Adhikari, K., & Singh, R. K. (2017). Blanchability and sensory quality of large runner peanuts blanched in a radiant wall oven using infrared radiation. *Journal of the Science of Food and Agriculture*, doi:10.1002/jsfa.8332

Kirmaci, B., & Singh, R. K. (2016). Quality of the pre-cooked potato strips processed by Radiant Wall Oven. LWT - Food Science and Technology, 66, 565-571. doi:10.1016/j.lwt.2015.11.006

Kumar, D. G. P., Hebbar, H. U., Sukumar D., Ramesh, M. N. (2005) Infrared and hot-air drying of onions. *Journal of Food Processing and Preservation*, 29(2), 132-150. doi:10.1111/j.1745-4549.2005.00019.x

Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food: Principles and practices.* Springer.

National Peanut Board. (2016). How peanuts grow. Retrieved September 05, 2016 from <http://nationalpeanutboard.org/the-facts/how-peanuts-grow/>

Nelson, S. (2010). *Food Analysis*. (4th ed.). New York, NY: Springer.

Paulsen, M. R., & Brusewitz, G. H. (1976). Coefficient of cubical thermal expansion for Spanish peanut kernels and skins. *Transactions of the ASAE*, 19(3), 592.

Rastogi, N. (2012). Recent trends and developments in infrared heating in food processing. *Critical Reviews in Food Science and Nutrition, 52*(9), 737-760.

Riveros, C. G., Mestrallet, M. G., Gayol, M. F., Quiroga, P. R., Nepote, V., & Grosso, N. R. (2010). Effect of storage on chemical and sensory profiles of peanut pastes prepared with high-oleic and normal peanuts. *Journal of the Science of Food and Agriculture, 90*(15), 2694-2699. doi:10.1002/jsfa.4142

Sakai, N., & Hanzawa, T. (1994). Applications and advances in far-infrared heating in Japan. *Trends in Food Science & Technology*, 5(11), 357-362. doi:10.1016/0924-2244(94)90213-5

Sandu, C. (1986). Infrared radiative drying in food engineering: a process analysis. *Biotechnology Progress* 2(3), 109-119. doi: 10.1002/btpr.5420020305

Sanders, T. H., Adelsberg, G. D., Hendrix, K. W., & McMichael, R. W., Jr. (1999). Effect of blanching on peanut shelf-life. Peanut Science, 29(1), 8-13.

Schirack, A. V., Drake, M., Sanders, T. H., & Sandeep, K. P. (2006). Impact of microwave blanching on the flavor of roasted peanuts. *Journal of Sensory Studies*, 21(4), 428-440. doi:10.1111/j.1745-459X.2006.00075.x

Schirack, A. V., Sanders, T. H., & Sandeep, K. P. (2007). Effect of processing parameters on the temperature and moisture content of microwave-blanched peanuts. *Journal of Food Process Engineering*, 30(2), 225-240. doi:10.1111/j.1745-4530.2007.00110.x

Shangci, W., Koushik, A., Yen-Con, H. (2017). Acceptability and preference drivers of freshly roasted peanuts. *Journal of Food Science, 82*(1), 174-184. Doi:10.1111/1750-3841.13561

Smith, A., Perry, J.J., Marshall, J.A.,Yousef, A.E., Barringer, S.A. (2014). Oven, microwave, and combination roasting of peanuts: companion of inactivation of Salmonella surrogate Enterococcus faecium, color, volatiles, flavor and lipid oxidation. *Journal of Food Science,* 79(8), S154-S1594

St. Angelo, A.J. (1996). Lipid oxidation in food. *Critical Reviews in Food Science and Nutrition*. 36(3):175-224.

Stalker, H. T., & Wilson, R. F. (2016). *Peanuts genetics, processing, and utilization*. Amsterdam: Academic Press is an imprint of Elsevier.

USDA National Nutrient Database. (2016). *National Nutrient Database for Standard Reference*. Release 27, Basic Report 16087.

Woodall, M., personal communication, phone, December 14, 2015

Xiaolei, S., Davis, J. P., Zhoutong, X., Sandeep, K. P., Sanders, T. H., & Dean, L. O. (2017). Characterization of peanuts after dry roasting, oil roasting, and blister frying. *LWT -- Food Science and Technology*, 75520-528. doi:10.1016/j.lwt.2016.09.030

APPENDIX A

Sample Sensory Forms

Shelf Life Descriptive Analysis of Blanched Peanuts

Descriptive Analysis of Infrared Peanut Blanching Study

Panelist Code: __________ **Date: Feb 2017**

Texture: Please take 1 whole kernel and evaluate for the following TEXTURE.

Fracturability – the force with which first bite through the sample. Reference: cracker = 4.5; Control = 6.5
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

Oiliness – Degree to which free oil is perceived in the mouth after 5 chews. Reference: corn chips = 3.0; Control = 1.0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

Flavors: Please take 2 whole kernel's and evaluate for the following FLAVORS.

Raw/beany - the flavor associated with raw peanuts. Reference: raw peanuts = 7.5; Control = 3.5
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

Overall oxidized– the old / stale flavor associated with rancid fats and oils. Reference: Oxidized oil = 6.0; Control = 0.0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

Cardboard - the flavor associated with somewhat oxidized fats and oils and reminiscent of wet cardboard. Reference: wet cardboard = 4.0; Control = 0.0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

Fishy – the flavor associated with trimethylamine, cod liver oil or old fish. Reference: cod liver oil = 8.0; Control = 0.0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

Painty – the aromatic associated with linseed oil, oil based paint. Reference: boiled linseed oil = 11.5; Control = 0.0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

Bitter - the taste on the tongue associated with bitter agents such as caffeine solution Reference: bitter 2.0; bitter 5.0; bitter 10.0; Control = 1.0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

Sour- the taste on the tongue associated with acid solutions. Reference: sour 2.0; sour 5.0; sour 10.0; Control = 0.0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

Salty - the taste on the tongue associated with sodium chloride solutions. Reference: salty 2.5; salty 5.0; salty 8.5; Control = 1.0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

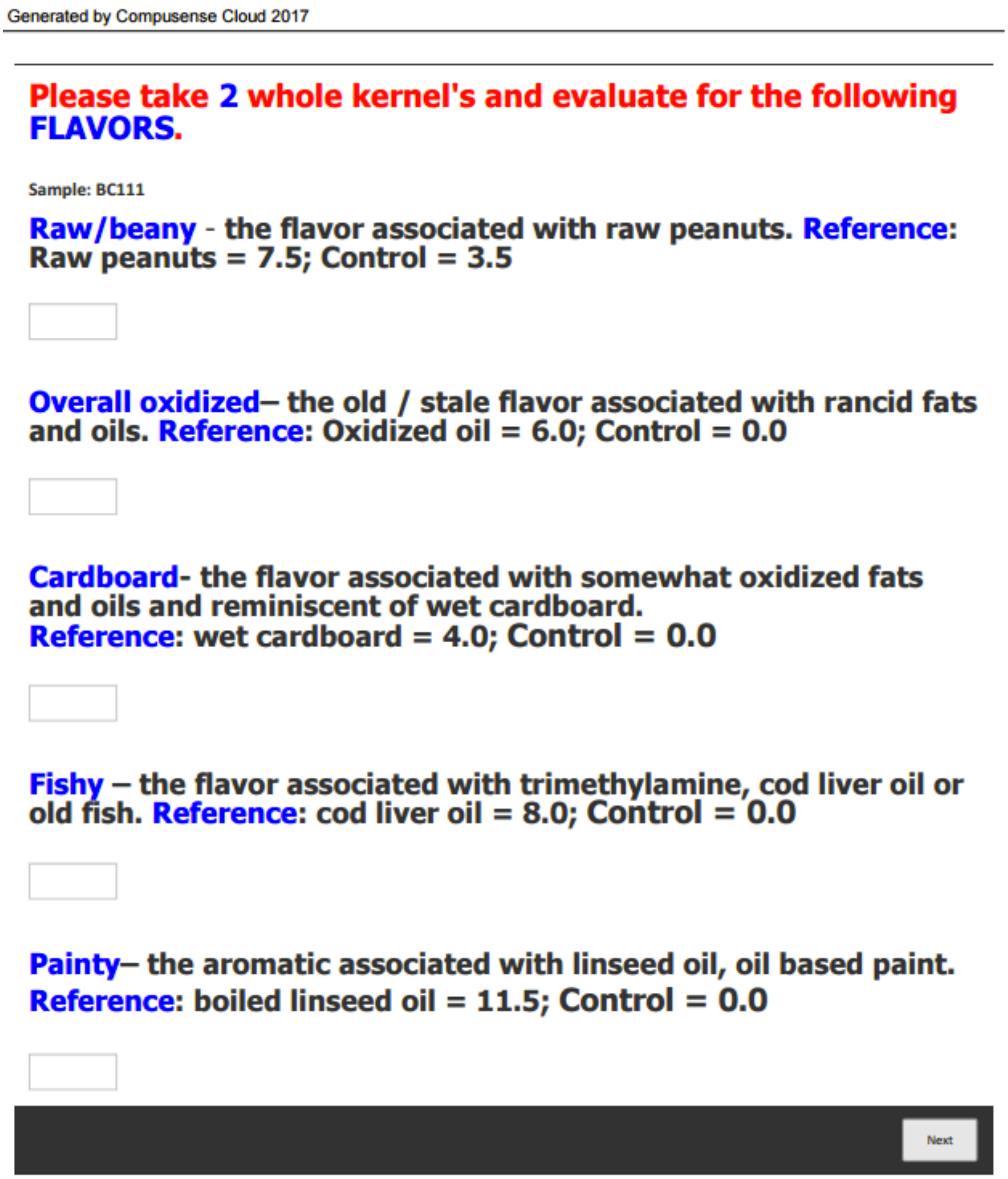
Sweet – the taste on the tongue associated with sucrose solution. Reference: sweet 2.0; sweet 5.0; sweet 10.0; sweet 15.0; Control = 2.0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

Please take 2 whole kernels and evaluate for the following FEELING FACTORS.

Astringent - the puckering or drying sensation on the mouth or tongue surface. Reference: astringent 2.0; astringent 5.0; Control = 1.5
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15
Day 1 WUP Day 2 WUP Day 3 WUP

1

1: Sample descriptive analysis warm up ballot.



Generated by Compusense Cloud 2017

Please take 2 whole kernel's and evaluate for the following FLAVORS.

Sample: BC111

Raw/beany - the flavor associated with raw peanuts. **Reference**: Raw peanuts = 7.5; Control = 3.5

Overall oxidized– the old / stale flavor associated with rancid fats and oils. **Reference**: Oxidized oil = 6.0; Control = 0.0

Cardboard- the flavor associated with somewhat oxidized fats and oils and reminiscent of wet cardboard.
Reference: wet cardboard = 4.0; Control = 0.0

Fishy – the flavor associated with trimethylamine, cod liver oil or old fish. **Reference**: cod liver oil = 8.0; Control = 0.0

Painty– the aromatic associated with linseed oil, oil based paint.
Reference: boiled linseed oil = 11.5; Control = 0.0

Next

2: Sample Compusense screen from descriptive analysis.

Consumer Study of Roasted Peanuts

Recruitment Screener for Consumer Test on Roasted Peanuts

Consumer Name:______________________________

Phone number: (H) _________________________ (C)____________________________

Email address: ____

The sensory lab at University of Georgia Griffin campus is conducting a research on roasted peanuts. For this project, we have 1 test on April 20. The test will last approximately 1 hour and you will be compensated $20 after the test. Would you be interested?

If yes, please answer / verify the following questions:

1. Gender: Male Female

2. Age: _________ DOB:___________ Address: ____
   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 are qualified to take this test. We have the following time sessions; please choose one time to take the test. Your test sessions are: (**Circle only one.**)

Thursday April 20th, 2017
10am-11am
11am-12pm
12pm-1pm
1pm-2pm

Please arrive at our center 10 minutes earlier than your scheduled session for check-in purposes. The tests will be held in Melton/ Food Science Building, 1109 Experiment St., Griffin, GA.

3: Recruitment screener for consumer test of roasted nuts.

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 ☐
25-34 years ☐
35-44 years ☐
45-54 years ☐
55 years or older ☐

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

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

Roasted peanuts ☐
Boiled peanuts ☐
Peanut butter ☐
Peanut bars ☐
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

4: Demographic questionnaire for consumer study of roasted peanuts.

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.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

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

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like 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.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like 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.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

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

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

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

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

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

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

5a: Ballot for consumer study of roasted peanuts.

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

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Now please evaluate the taste intensity of samples 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.

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

☐	☐	☐	☐	☐	☐	☐	☐	☐
1 Low	2	3	4	5 Moderate	6	7	8	9 High

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

☐	☐	☐	☐	☐	☐	☐	☐	☐
1 Low	2	3	4	5 Moderate	6	7	8	9 High

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

☐	☐	☐	☐	☐	☐	☐	☐	☐
1 Low	2	3	4	5 Moderate	6	7	8	9 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.

☐	☐	☐	☐	☐	☐	☐	☐	☐
1 Low	2	3	4	5 Moderate	6	7	8	9 High

5b: Ballot for consumer study of roasted peanuts.

APPENDIX B

IR RWO Belt Speed Curve