AN ASSESSMENT OF THE PROCESSING, FERMENTATION, AND VOLATILE
CHARACTERISTICS OF JUICE FROM 'UFSUN' PEACHES GROWN ON THINNED
AND UNTHINNED TREES

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2019
To my Sister: Never be afraid of your potential. I love you and I know you will become the best version of yourself every single day.
ACKNOWLEDGMENTS

I would like to thank my wonderful parents, Sue and Kevin, as well as my sister, Lauren, for their continued support of my dreams – both personal and professional.

I am especially grateful for all of the faculty and staff in the Food Science and Human Nutrition department for helping meet tight deadlines, laughing at my quips as I run in and out of offices, and being always willing to help – no matter the request. Thank you to Marianne Mangone, Mindy Edwards, Herschel Johnson, Jenna Grogan, Janna Underhill, Julie Barber, Sheila Parker Hall, Tracie Halbrook, Annette Hodges, Mary Ann Spitzer, Roderick Tatum, Kenneth Gankofskie, and Timothy Jones for making up an incredible staff that I am thankful for each passing day. Thank you to Chris Nieves who always managed to make things a little simpler, a lot more efficient, and a great deal more hilarious. A huge thank you also needs to be given to my Master committee members Dr. Ali Sarkhosh, Dr. Charles Sims, and Dr. Paul Sarnoski for providing incredible advice, pointing my research in the right direction, reading my ridiculously long and thorough documents, and ensuring that my education has been well-rounded and top-notch. Finally, thank you to Dr. Renee Goodrich-Schneider for all of your kindness, mentorship, accountability, and serving as an outstanding graduate coordinator.

Additionally, I thank my lab mates Ryan Mitchell, Devanshu Mehta; Peter Chiarelli, Xuwei Song, Victor Cedeno, Melissa Perez, and Vicnie Leandre; my departmental friends Maria Espinosa, Kelley Ainsworth, Stephen Koltun, Caitlin McDermott, Rachel Gordon, Jasmine Ricke, Jessica Lee; and all of the other lives that have influenced my experience at the University of Florida. Thank you all for the days and night spent laughing and for sharing your friendship with me. I would especially like
to express my gratitude to Mario Guadalupe for being with me since day one – always pushing me, breaking out into song and dance with me, and serving as an incredible friend and sidekick.

Outside of academia, I owe my sanity to my theatre family at the Gainesville Community Playhouse. Thank you to Suzanne and Will Richardson, Mallory Rubek, Bob Ruggles, Kayla Zobel, Anna Cappelli, Olivia Turpening, Diana Truman, Dan and Susan Christophy, Bridget Siegel-fultz, Renna TenBroek, Kaylene Sattano, Wilfredo Gonzalez, Jacob Goldberger, Anne Rupp-Polo, and the rest of my theatre family for the backrubs and encouragement as I feverishly finished work and thesis drafts in the wings.

I would also like to acknowledge Dr. Susan Percival and Dr. Gloria Cagampang. Both of these incredibly strong willed, bright, exceptional women have served as sunshine and sources of motivation in my daily work life. Stopping in for cups of coffee, attending all of my presentations and demonstrations, offering a word of encouragement or advice, keeping me on track, and providing endless laughter and joy when I needed it. Their support and mentorship have not been taken for granted and I appreciate everything they have done to ensure my success.

More than anything, I would like to extend an enormous thank you to Dr. Andrew MacIntosh for his mentorship, kindness, and understanding. I am eternally thankful and grateful to have been given the opportunity to work under his supervision and guidance. I would not have had the fruitful experience I did without him challenging me, never allowing me to fall short, holding me accountable, refining my passion for food in all of its technical aspects, and allowing (forcing) me to develop an extremely
small threshold for terrible science jokes. I will never forget the laughter, Frisbee games, potlucks, high fives after a job well done, professional development sessions, giant spiders, and the friendships you allowed us all to cultivate within our laboratory family. I am more than proud to call you both a friend and a mentor. Thank you.
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Low-chill peaches are a promising fruit crop option for the Florida agricultural industry. However, achieving a satisfactory fruit size in Florida's subtropical climate is a major marketing limitation. When grown for fresh sale, peach trees are thinned to increase fruit size and quality - a high labor expense to growers. Potential revenue streams for unsold peaches exist in the fermentation industry as a substrate, natural flavoring, or brewing adjunct. This study assessed the impact of tree-thinning on peach juice characteristics in terms of processing (percent juice yield by weight, color, °Brix, volatile profile) and fermentation (yeast fermentable extract or YFE, kinetics, color).

‘UFSun’ juice was also trialed as a brewing adjunct in the manufacture of a peach Gose beer at First Magnitude Brewing Company. All juice was pressed from University of Florida-developed cultivar ‘UFSun’ grown on thinned and unthinned trees. Thinned had ~1% more sugar (p<0.05) and a higher juice yield than unthinned juice. YFE for thinned (75.0 ±1.6%w/w) and unthinned (73.5 ±2.6%w/w) were not significantly different (p>0.05). The rates of fermentation for both juices were not significantly different in terms of density attenuation (p>0.05). The red color of peach juice prior to fermentation
had dissipated by the end of fermentation, yielding a pale-yellow product. Analysis of volatile profiles in unflavored “Gose” style beer and peach juice indicated no unique differences. Chemically, the fruity profiles of the peach juice were also present in the “Gose” beer providing difficulty in discerning peach characteristics when peach juice was added to the beer.
CHAPTER 1
INTRODUCTION

The University of Florida has worked for years to develop peach cultivars that will grow in subtropical climates. With the citrus greening and canker diseases plaguing citrus crops (FDACS, 2018), Florida farmers are in need of novel revenue streams as income from citrus crop declines. Peaches have been explored as an alternative crop, especially due to their early harvest window (Olmstead et al., 2007) which is two months earlier than California, Georgia, and South Carolina. However, after the two-month window passes Florida peaches are typically less competitive due to their small size. The current challenge is to identify other ways in which the unsold and unmarketable Florida peaches can be used to generate income for Florida farmers. The research project aimed was to assess the processing and fermentation characteristics of ‘UFSun’, ultimately highlighting fermentation as a viable option for these peaches. It was hypothesized that the juice from Florida peaches is fermentable and will serve as an economically viable adjunct for beer, cider, wine, and other fermentable products.
1.1 The Peach

The peach (*Prunus persica*) grows on a deciduous tree that is native to the Northwest China region and has a global production of around 22 million tons of fruit per year (Maulión, Arroyo, Daorden, Valentini, & Domingo Lucio Cervignii, 2016). The genus “*Prunus*” denotes the peach’s classification in the rose family along with cherries, apricots, plums, and almonds. It belongs to the almond subgenus “*amygdalus*” due to the corrugated or wrinkled appearance of the seed, or stone, shell. The epithet “*persica*” comes from the longstanding belief that the peach originated in Persia, now known as modern-day Iran, and was then brought and transplanted to Europe. The peach was believed to have been brought to North America on the ships of Spanish explorers (Layne and Bassi, 2008). After their introduction, native North American peoples later propagated the seeds, thus cultivating the peach and integrating it into North American agriculture (Layne and Bassi, 2008).

1.2 Growth and Development

Peach growth is highly dependent on temperature. Some geographical locations cannot satisfy these growing requirements, leading breeders to work on combining traits of specific kinds of peaches in order to develop fruit with the desired qualities of traditional peach varieties. These newly developed types of peaches are known as “cultivars”.

1.2.1 Chilling Hours

Cultivars can be divided into three broad categories: low-, medium-, and high-chill. These classifications allow growers to distinguish how many chill hours each
specific type of peach needs. Chill hours are the number of hours under approximately 7°C required by a specific cultivar for its leaf and flower buds to break dormancy and transition to growth. The number of chill hours accumulated is combined with chill negation requirements to provide chill units (CU), a metric for how long a peach cultivar needs to spend in low temperatures. Low-chill cultivars grow best in subtropical climates, while high-chill growing well in temperate climates. Medium-chill peaches thrive in intermediate adaptations between subtropical and temperate climates. (Ferguson et al., 2008) Florida’s low-chill peach cultivar crop requires between 100 - 525 CUs and have short Fruit Development Periods (FDP) between 58 and 120 days (Ferguson et al, 2008). As noted by the University of Florida Horticulture department, the chilling times for low-chill peaches in central Florida are between November 1st and January 15th. North Florida cultivars receive maximum chilling between November 1st and February 10th annually.

Once the leaf and flower buds of the peach tree break dormancy, the peach enters the FDP. The FDP is the amount of time it takes for the peach to fully mature after breaking dormancy. FDP is highly dependent on the amount of warmth and sunshine (heat unit) each peach receives and therefore has a direct correlation to the size of the peach. A low-chill peach will break dormancy sooner than a high-chill peach since it requires less CUs. However, even though subtropical climates receive more sunshine and heat than a medium or high chill peach on a given day, the size of a low-chill peach is smaller because of the short amounts of daylight during a spring day in comparison to summer days in temperate regions. High-chill peaches, as mentioned, are bred for temperate climates, which have a lower amount of heat and sunshine to
provide the peaches with but have longer daylight hours where the sun is out. This slow growth and long day period allow for more cell growth and production which forms a larger peach.

### 1.2.2 Tree Care

**Pruning.** Peach trees need to be pruned to form trees that are strong, well-shaped, and able to produce the maximum amount of high-quality fruit (Olmstead *et al.*, 2007). Even with pruning, fruit growth is typically controlled by thinning. Without thinning, peaches would not be able to grow to a marketable size or quality.

**Thinning.** Thinning is a process in which fruit is removed from the branches to leave on fruit per 6-10 inches from each other per branch (Olmstead *et al.*, 2007). Thinning reduces overall yield; however, profitability and quality depend on size as a primary factor.

### 1.3 Peach Characteristics

#### 1.3.1 Nutritional Content

The primary nutrients studied in the peach are nitrogen, calcium, potassium, and iron. Nitrogen has been noted to have “the single greatest effect on peach quality” due to the important relationship between high amounts of leaf nitrogen and higher percents of the fruit surface that is red, higher yield, and larger size of the fruit (Layne and Bassi, 2008; Daane *et al.*, 1995). Calcium, involved in many biochemical and morphological events in plants, is important to production and post-harvest quality due to its accumulation throughout the growth of the peach. Its primary task is to aid the peach in maintaining significant rates of transpiration (Tagliavini *et al.*, 2000). Potassium is the major nutrient in the peach. At optimum levels (2-2.5kg/t on a fresh weight basis) leads
to high photosynthesis rates, reallocate sugars and organic acids to improve peach quality (Layne and Bassi, 2008; Tagliavini et al., 2000). Iron is a micronutrient in peaches that aids in optimization of fruit size and its deficiencies lead to low yield, non-optimum fruit size, and decreases in fruit color (Álvarez-Fernández et al., 2003).

1.3.2 Volatile Compounds

Aroma is made up of volatile components produced by peaches in concentrations perceivable by the human nose (Layne and Bassi, 2008). The “green aroma” in peaches is recognized as (E)-2-hexanol and (E)-2-hexanal while the fruity, ripe aroma is represented by gamma-decalactone and gamma-dodecalactone (Bavcon Kralj et al., 2014). A study performed by Do et al. (1969) studied the volatiles of peach fruit relating to harvest maturity from tree-ripened and artificially ripened fruit. This study identified several other main volatile components outside of gamma-lactones: delta-lactones, esters, aldehydes, benzyl alcohol, and d-limonene. However, the primary lactone noted was gamma-decalactone.

1.3.3 Sensory Characteristics

Sweetness is the primary factor that affects consumer acceptance of the peach (Bavcon Kralj et al., 2014, Layne and Bassi, 2008; Kralj et al., 2014). Sucrose, glucose, fructose, and sorbitol are reported to be the main sugars or sugar alcohols in peaches with fructose>sucrose>glucose>sorbitol as the sweetness hierarchy. (Génard and Souty, 1996). High-quality peaches tend to contain large amounts of fructose and low quantities of glucose and sorbitol (Génard et al., 2003; Layne and Bassi, 2008). According to Layne and Bassi (2008), sugars comprise over 60% of the soluble solids concentration (SSC) in peaches and an SSC reading of at least 12% typically ensures acceptability.
1.3.4 Fruit Flesh and Juice Color

There are three primary groups of pigments in fruits that influence flesh color: chlorophylls, anthocyanins, and carotenoids (Lewallen and Marini, 2003).

Anthocyanins provide a variety of colors including red, orange, maroon, and blue, the stability of which is affected by pigment concentration, pH, temperature, light intensity, oxygen, ascorbic acid, and sugar. (Laleh et al., 2006). A study of the stability of anthocyanin pigments in Berberis species by Laleh et al. discovered that increasing pH, temperature, or light exposure will spoil anthocyanin molecules. This study also reports the results of several other studies completed that have reported that high pH in grapes harvested in warm agricultural areas could cause fading in the color of juice made from the grapes.

Carotenoids provide a deep red, yellow or orange color (Rehrig, 2015). Carotene, a carotenoid and a precursor for vitamin A, can be stabilized, not oxidizing rapidly when exposed to light and oxygen, by brief branching treatments (Klein, 1987). All carotenoids in peaches are beta configured (Layne and Bassi, 2008). Carotenoids are unstable when exposed to low pH levels (Layne and Bassi, 2008; Klein 1987).

1.4 Characterization

Peach cultivars are morphologically and commercially classified under several criteria: tree use, commercial fruit type, fruit shape, flesh color, flesh texture (also known as flesh melting), and flesh acidity. However, the classifications focused on in this study and by the University of Florida Horticulture department are stone type, flesh color, and flesh texture or melting (Layne and Bassi, 2008).
**Stone characterization.** Stone characterization includes three different types of peach stones and how those stones interact with the surrounding peach flesh. These categories are freestone, clingstone, and semifree stone. Freestone peaches have pits that don’t attach to the flesh or are “free” from the flesh. Clingstone peaches have stones that are attached to the flesh of the peach, or “cling”. Semifree stones aren’t free from the flesh but are easier to remove from the flesh than clingstones (Ferguson et al. 2008; Layne and Bassi, 2008).

**Flesh color characterization.** Flesh color is split into two categories, ground color and overcolor. Ground color, also known as background color, changes from green to yellow as the fruit ripens. Overcolor is the amount of red color covering the surface of the peach. Overcolor is affected by the position of individual fruit in the canopy of the peach tree, which in turn, impacts the amount of sunlight each peach receives (Layne and Bassi, 2008). According to Lewallen and Marini (2003), the overall relationship between the ground color and the firmness of the tree-ripening fruit is affected by the light environment of the developing fruit.

**Flesh texture characterization.** Flesh texture is characterized by flesh melting. Flesh melting is how the flesh of the peach acts after it has been subjected to high temperatures and pressures during the canning process. Melting flesh peaches bruise easily during harvest, become soft when canned, can be clingstone or freestone, and have a short shelf life. Peaches with non-melting flesh are difficult to bruise, have firm flesh after canning, and have a longer shelf life than melting varieties (Layne and Bassi, 2008). Peaches with non-melting flesh do not contain the enzyme
endopolygalacturonase which is responsible for flesh softening in melting-flesh peaches (Layne and Bassi, 2008).

1.5 Grading and Harvesting

Grading refers to the peach selection process when deciding which peaches will be sold on the fresh market. According to an extension article from the University of Florida (Ferguson et al., 2008) fruit is graded by size, color, shape, sensory attributes, and the degree of flesh browning. This article goes on to explain how, while fruit size and color are more highly considered in grading, “fruit with high aroma, moderate acidity, and sweet taste are the most desirable.”

Harvesting time is important for peaches being that they are a climacteric fruit that does not produce more sugars after it has been removed from the tree but does soften throughout aging (Crisosto & Costa, 2008; Sarkhosh, Olmstead, Chaparro, Anderson, & Williamson, 2018). Climacteric fruits contain the same amount of sugar from the moment they are picked from the tree and throughout senescence (Ferguson, Anderson, Chaparro, & Williamson, 2009; Sarkhosh et al., 2018). If the fruit has been harvested too early, it will have poor flavor due to low sugar and a higher concentration of organic acids, polyphenolics, and aldehydes (Layne and Bassi, 2008). However, flesh tends to be stiffer and is better for handling and withstanding mechanical post-harvest treatments. The later fruit is harvested, the more sugar it will contain and the larger it will be in size, but the softer the flesh will be if it is past the peak of its maturity on the tree. Melting flesh peaches soften more rapidly after harvest, resulting in a shorter shelf life and therefore are harvested at an early ripening stage, never reaching their sensory potential (Layne and Bassi, 2008).
As explained in section 2.4, peach fruit color refers to the ground color and overcolor. It is typical for high percentages of red overcolor (over 50%) coupled with a bright yellow ground color to sell more efficiently in the US fresh market (Ferguson et al., 2008).

Fruit shape is measured subjectively by visually noting the degree of protruding tips and sutures the harvested fruit has. Shape ranges from round to oblong, with round being the ideal shape and oblong being non-ideal (Ferguson et al., 2008). High rated fruit is close to a perfect sphere and will be selected for market. Low rated fruit has a large degree of protruding tips and sutures which are not acceptable features for the fresh market.

Fruit shape is directly correlated to damage (Layne and Bassi, 2008):
“Symmetrical and rounded fruit are desirable because they result in less damage during harvest and handling.”

Flesh browning is caused by any kind of dent, cut, or bruise that befouls the surface of a ripened peach. A large degree of flesh browning will not appeal to consumers in the fresh market due to a disruption in the natural color which affects the overall aesthetics and health of the fruit (Olmstead et al., 2017).

Flesh browning is a common problem with melting flesh peaches that are harvested when fully ripened, as processing and transport are vigorous and damaging to the fruit if precautions are not taken. A solution to this problem is to harvest melting flesh peaches before they are fully ripened, ensuring that the flesh is not as soft as with fully ripened melting flesh peaches. Having a stiffer flesh will make bruising and damaging the outer skin of the fruit more difficult.
1.5.1 Culls

Layne and Bassi (2008) discuss that the main usage for peach culls is for cattle feed due to the fact that these peaches are still considered a good, palatable source of energy for cattle. However, they go on to explain that the high water content of peaches (about 85%), diminishes the feed value when factoring in costs of transporting large volumes and quickness of spoilage and degradation. Also, according to this excerpt, fuel alcohol production from peach culls has been discussed, but production is limited due to the low sugar concentration of the peach. A good use of peach culls outside of frozen, canned, and juiced varieties is still being explored.

1.5.2 Fruit Storage Conditions

Peaches are known to quickly ripen and deteriorate at ambient temperature (Crisosto & Costa, 2008; Lurie & Crisosto, 2005). Cold storage aids to combat senescence especially for long-distance market use and longer-term storage situations (Crisosto & Costa, 2008; Lurie & Crisosto, 2005). Peaches should ideally be stored in a relative humidity between 90-95% (Thompson et al., 1998) and around 0ºC (32ºF) (Layne and Bassi, 2008).

1.6 Significance of Low Chill Cultivars

Low-chill peach cultivar development is important for a multitude of reasons. However, only three will be focused on in this report: economic importance, globalization and trade barrier reduction, and global warming projections.

Due to the fact that low-chill peaches break dormancy and ripen before medium and high-chill peaches in other parts of the country, they are able to enter the fresh market before all other cultivars. This provides low-chill peaches with a market
advantage as they are able to be harvested and distributed to local markets and, potentially, distant markets that are not producing peaches at that time. Subtropical climates can produce peaches up to two months earlier than temperate cultivar climates that grow high-chill peaches (Bassi and Layne, 2008).

Another point that proves the importance of low-chill peach development is the seasonal demand for locations around the globe that are south of the equator. As low-chill peaches are the first to ripen and make it to market, they also have the opportunity to develop new market pathways around the world. Globalizing the peach industry will result in reduced barriers when it comes to trade between the northern and southern hemispheres, further stimulating the national economy through the development of new markets.

Global warming has been at the scientific forefront in regard to weather and temperature, but its effect on the food industry is not widely discussed. According to an IPCC projection analyzed by Bassi and Layne (2008), there is a projected increase of 0.8 to 2.6 °C (33.1 to 36.7 °F) by the year 2050. If global warming trends continue at the projected rates, this means that winter chilling requirements for medium and high-chill peach cultivars would not be met, causing a huge drive up in the price of peaches due to scarcity and an overall shortage of the crop in general. This problem could be solved with the continued development of low-chill peach cultivars whose demand and need would increase dramatically. A study lead by Hennessy and Clayton-Green in 1995 was designed to test the global warming theory on peaches in Australia. Their experiment modeled a temperature change of 1.5 to 2.0 °C (34.7 to 35.6 °F) at several locations in
Australia. Their results found that the rise in temperature increased the risk of prolonged dormancy for temperate locations in Australia that grew stone fruits.

1.7 Peach Processing

1.7.1 Traditional Peach Processing

Peaches are a highly perishable fruit in that they are subject to rapid softening once they are harvested (Ciacciulli, Cirilli, Chiozzotto, Attanasio, & Da Silva Linge, 2018; Ighbareyeh et al., 2019; Laslo, Teusdea, Socaci, Mierlita, & Vicas, 2017; Oliveira, Pintado, & Almeida, 2012). Fresh market peaches accounted for 45% of total peach production in 2017 while the remaining 55% was used for processing (USDA, 2019). It is important to note that not only low grade and damaged fruits are used for processing. A large portion of peaches for processing are specifically being bred and grown specifically for processing (Falguera et al., 2012). Peaches that are utilized in processing are used to create value-added products with a longer shelf life. Peaches can be canned; frozen; dried in pieces, halves, or slices; pureed or juiced for baking and cooking applications; and more (Bates, Morris, & Crandall, 2001; Kingsly, Valasubramaniam, & Rastogi, 2009; Laslo et al., 2017). The National Agricultural Statistics Service (NASS) of the USDA (2019) reported that, of the 55% of peaches used for processing, 83% were canned, 17% frozen, and the remainder used for drying and miscellaneous unit operations. However, processing peaches into a juice, pulp, nectar, or puree also can lead to the development of other value-added products like beverages, sauces, and more.
1.7.2 Pulp, Puree, Nectar, and Juice

Stone fruits like peaches and mangoes are all processed in similar ways due to the high pectin nature of their flesh and physical characteristics of their stones. Pulp, puree, nectar, and juice follow a processing hierarchy or sorts: first a stone fruit is processed into a pulp or puree, then refined into a nectar, which could then be diluted into a juice. This section details the definitions and main characteristics of the aforementioned types of liquid processed fruits.

**Pulp and puree.** According to Reyes-De-Corcuera et al. (2014), pulp is in reference to burst juice vesicles. When fruit is pulped its flesh is essentially “disintegrated” or liquified and separated from the peel and seeds, stones, or pits.

**Nectar.** Some beverages are created by diluting fruit paste, concentrate, or puree with or without adding exogeneous sweeteners. These beverages are known as “nectars” and can come either from a single fruit or a blend of fruits (Ignacio Reyes-De-Corcuera, Goodrich-Schneider, Barringer, & Landeros-Urbina, 2014). After stone fruits have been pulped or pureed, they are refined into nectar. The same companies that pulp and puree fruits are typically not the same ones that refine the pulps and purees into nectar or juice.

**Juice.** Juice can be defined as a mechanically processed juice and extracted from fruits and vegetables that does not contain any added substances or ingredients (Ignacio Reyes-De-Corcuera et al., 2014). Due to the large amount of waste produced by pectin-high fruits like peaches, juicing is not a common operation unlike pulping and puree processing. Little to no industrial scale peach juicing operations are documented, but stone fruits are processed so similarly that methods of processing for other fruits like
mangoes will generally apply to peach processing (Ignacio Reyes-De-Corcuera et al., 2014).

1.7.3 Stone Fruit Processing

Peaches are more often processed into a pulp or puree instead of a juice (Bates et al., 2001) and even more commonly as nectar (Ignacio Reyes-De-Corcuera et al., 2014). As all stone fruits have such similar properties that they are all processed in similar ways. The following Figure 2-1 displays a flow diagram of mango nectar production. Please note that the figure uses “ºBx” in place of “ºBrix.” Primary unit operations of stone fruit processing into puree and nectar, include washing and sorting, peeling, and pulping.

Figure 2-1. Mango puree and nectar flow diagram (Ignacio Reyes-De-Corcuera et al., 2014)
**Washing and sorting.** After harvesting and cooling, fruits are placed on a conveyor for water rinsing and brush washing.

**Peeling.** Skin can be removed by hand with knives, by blanching fruit in steam or boiling water to facilitate peel detachment, using lye for thinner skinned varieties (Bates et al., 2001), or, if the fruit has thin skin and a low polyphenol content, skin can remain attached and does not require peeling.

**Pulping.** Mangoes and peaches are typically peeled with a paddle pulper or destoner. This pulper separates the stones from the rest of the flesh. Bates *et al.* (2001) describe the use of thermo-screws heated by steam to separate stones from flesh as well, but this method could cause pits to be crushed and expel shards into the final product if not careful.

**Nectar production.** As mentioned previously, it is typical for producers of purees and nectars to be different. Typically frozen purees are mixed with additives and processed into nectars by a copacker or other large processing plant (Ignacio Reyes-De-Corcuera *et al.*, 2014).

### 1.7.4 Processing Considerations

Processing conditions are designed to produce a safe and efficient product. In the case of juices, the most pressing objectives of processing are enzyme inactivation and microbial load reduction to extend the shelf life and keep the product properties consistent throughout its shelf life (Oliveira *et al.*, 2012; Petruzzi *et al.*, 2017). Quality parameters like color and texture are often monitored throughout processing to ensure that each processing step is being performed correctly (Laslo *et al.*, 2017). Being that appearance is of extreme importance to quality in the eyes of the consumer, clarifying agents like pectin can also be used during processing. This is particularly true for peach
nectar and juices. This section will discuss the presence and activity of oxidation enzymes and microbial content of processed peach products as well as standard methods of treatment. Additionally, a brief overview of pectic enzymes for juice clarification will be reviewed.

**Oxidation enzymes.** Peaches, fresh and processed, exhibit enzymatic browning or oxidation due to the presence of polyphenoloxidase (PPO) enzymes (Kingsly et al., 2009). PPO is a copper-containing enzyme that can influence the color and flavor of peaches before, during, and after processing (Kingsly et al., 2009). The mechanism of color change facilitated by PPO includes the degradation of natural pigments and other polyphenols that then leads to discoloration and antioxidant activity loss (Petruzzi et al., 2017). It is important that PPO activity is controlled to preserve the quality of peach products over time. To denature PPO in stone fruits, ascorbic acid or Sulphur dioxide can be added (Kingsly et al., 2009), but the most effective method of control is with heat treatment (Ignacio Reyes-De-Corcuera et al., 2014; Kingsly et al., 2009). Peroxidase is another type of browning enzyme found in stone fruits, but is more thermally stable enzyme with activity that does not typically affect the quality of a stone fruit beverage or product (Ignacio Reyes-De-Corcuera et al., 2014).

**Microbial load.** Microbial inactivation is of utmost importance in the manufacture of any food product. “Hurdle Technology” is a technology employed specifically to improve the microbial stability and safety of a product (Petruzzi et al., 2017). As denoted by Petruzzi et al. (2017), examples of hurdle technology in thermal processing of juices include pH, dissolved solids (ºBrix), and combinations of preservation methods like antimicrobials.
**Pectic enzymes.** Pectinases, or pectinolytic enzymes, hydrolyze pectin and pectic substances (Jayani, Saxena, & Gupta, 2005). Pectins are known to increase the viscosity and turbidity of juices. Therefore, pectic enzymes are most widely used in fruit juice extraction and clarification (Jayani *et al.*, 2005). Typically, juices require a mixture of pectinases and amylases to clarify juices, but oftentimes pectinase alone yields satisfactory results. A study by Kaur, Kumar, and Satyanarayana (2004) discusses their success in fruit juice volume increase by treating fruit pulp from bananas, apples, and grapes with pectinase.

**1.7.5 Heat Treatment**

Blanching and pasteurization are two popular industrial heat treatment processes. Many methods of heat treatment exist to accomplish these operations, even in the manufacture of peach pulp, puree, nectar, and juice. This section will provide a broad overview on the goals of blanching and pasteurization as well as drawbacks to thermal treatment.

**Blanching.** Blanching is most commonly completed by using boiling water or steam and is typically employed prior to freezing, canning, or drying (Ignacio Reyes-De-Corcuera *et al.*, 2014). Kingsly *et al.* (2009) experimented with the effects of high-pressure blanching on PPO activity. As previously described, blanching stone fruit prior to processing allows for easy removal of skin if desired. Blanching also facilitates the texture modification and softening of flesh (Ignacio Reyes-De-Corcuera *et al.*, 2014) to aid in the pulping process (Bates *et al.*, 2001). Along with PPO denaturation and flesh softening, blanching also assists in color and flavor preservation typically caused by PPO and other lesser enzymes responsible for off-flavors (Ignacio Reyes-De-Corcuera *et al.*, 2014).
**Pasteurization.** Pasteurization is the most common heat treatment technique employed in the inactivation of spoilage organisms and pathogenic organisms (Oliveira et al., 2012). Stone fruits like peaches are recommended to undergo High Temperature Low Time (HTLT) pasteurization – holding at 90 °C (194°F) for 5 minutes (Petruzzi et al., 2017).

**Drawbacks of thermal treatment.** Although the benefits of thermal processing, safety and extended shelf life, far outweigh the drawbacks, it is still important that consequences are discussed. During thermal processing of any kind, unwanted changes exist. Laslo et al. (2017) report that can include losses in antioxidant compounds and non-enzymatic roasting reactions. An additional study by Oliveira et al. (2012) describes the reduction of total carotenoids, protocatechuic acid, zeaxanthin, and β-cryptoxanthin in peaches during pasteurization. These concerns are echoed by Petruzzi et al. (2017). In their overview of thermal treatments for fruits and vegetables, Petruzzi and colleagues discuss the HTLT processing of peaches and touches on the effects such vigorous heat treatment have on antioxidant compounds and their health benefit loss due to lost total anthocyanin and vitamin C content.

**1.7.6 Quality**

Quality is paramount in the sale of any consumer good. This is no difference between fresh market peaches and nectar produced from non-fresh market peaches. For fresh market peaches, main aspects of quality lie in flavor, aroma, and appearance (Bates et al., 2001; Ciacciulli et al., 2018; Cirilli, Bassi, & Ciacciulli, 2016; Falguera et al., 2012; Laslo et al., 2017; Maulión et al., 2016). As for processed peaches, no work has been found that analyzes consumer perception of peach juice and nectar. However, Falguera et al. (2012) discuss puree quality in a study on the influence of fresh and
processed peaches on the consistency of peach puree. They state that the only property of peach puree measured for quality is its consistency, using Bostwicks consistency methods, since the minimum sugar content of 10 °Brix is always reached industrially.

Flavor perception is a combination of taste, aroma, and mouthfeel of a substance (Spencer, Pangborn, & Jennings, 2002; Stillman, 1993). The “peach” specific flavor is made up of a balance of its basic organic components, soluble solids and acid (Cirilli et al., 2016; Laslo et al., 2017; Maulión et al., 2016), and the volatile aroma compounds (Laslo et al., 2017). Sugar content is often estimated using soluble solids concentration (SSC) and other measurements like °Brix, the latter which is used extensively through the research documented in this thesis. A previous study documented that peaches associated with “low-quality” had low levels of fructose and higher levels of sorbitol and glucose when compared to “high-quality” peaches (Robertson & Meredith, 1988). These flavor aspects are no different for nectar or juice of peaches as acidity levels influence a consumer’s sweetness perception as noted by (Cirilli et al., 2016). They also stated that standard juice quality assurance focuses on appearance and sugar content, which they argue is the most important characteristic perceived by consumers.

1.8 Fermentation

1.8.1 Alcoholic Fermentation

Alcoholic fermentation is known as the process by which microbial populations metabolize sugars into ethanol and carbon dioxide (Steinkraus, 1997). The predominant organism utilized in the alcoholic fermentation of products like beer and wine is the yeast *Saccharomyces cerevisiae* (Beltran et al., 2002; Walker & Stewart, 2016).
S. cerevisiae anaerobically metabolizes short chain sugars into pyruvic acid which is then catalyzed into ethanol and carbon dioxide. This process is demonstrated in Equations 4-1 and 4-2 (Walker & Stewart, 2016):

\[
\text{Glucose} + 2\text{ADP} + 2\text{Pi} + 2\text{NAD}^+ \rightarrow 2\text{Pyruvate} + 2\text{ATP} + 2\text{NADH}^+ + 2\text{H}^+ \quad (4-1)
\]

\[
2\text{Pyruvate} + 2\text{NADH} + 2\text{H}^+ \rightarrow 2\text{NAD}^+ + 2\text{Ethanol} + 2\text{CO}_2 \quad (4-2)
\]

Equal moles of ethanol and carbon dioxide are produced from one sugar molecule (Steinkraus, 1997; Walker & Stewart, 2016), that sugar being glucose in Equations 4-1 and 4-2. Carbon dioxide that is produced will flush any residual oxygen from the fermenting beverage to maintain an anaerobic fermentation (Steinkraus, 1997). The rate of sugar consumption and alcohol formation is linear, as shown in Figure 2-2 by Holzberg et al. (1967).

![Figure 2-2. The linear relationship between the rate of sugar consumption and the rate of alcohol fermentation by yeast (Holzberg et al., 1967)](image-url)
1.8.2 Fermentation Kinetics

**Yeast.** Yeasts are unicellular fungi with features similar to eukaryotes that have an ellipsoid shape and typically are around 5-10 μm in diameter (Walker & Stewart, 2016). Yeast cells require a balance of macronutrients (carbon, free amino nitrogen, oxygen, Sulphur, phosphorus, etc.) and micronutrients (calcium, copper, iron, manganese, zinc) to properly carry out their metabolic processes (Walker & Stewart, 2016). Yeasts will only metabolize short chain sugars, particularly glucose, fructose, mannose, and galactose (Harden, 1914). Mixtures of glucose and fructose have been seen to ferment at the same rate as fermentation broths containing either sugar type exclusively (Harden, 1914). In the presence of oxygen and appropriate nutrient content, yeasts will exponentially reproduce asexually. In anaerobic environments sans oxygen and supplemented with appropriate carbon sources, yeast will not reproduce, but will metabolize sugar into ethanol as previously discussed. Walker *et al.* (2016) claims that fruit juices are excellent natural sources of both free glucose and fructose and make for good fermentation media. In optimum conditions, *S. cerevisiae* will result in a growth curve that consists of four phases: the lag phase (no growth due to yeast adapting to their environment), exponential phase (cell doubling and growth), stationary phase (no growth rate, but consistent fermentation rate), and cell death or flocculation (cells no longer metabolizing sugars and either settling or falling out of solution) (Walker & Stewart, 2016). In large scale brewing and wine making, when a consistent product is required, active dry yeast cultures are utilized to metabolize sugars and outcompete any naturally occurring microbiota in the fermentation broth (Walker & Stewart, 2016).

**Density.** Density is an important fermentation trait as it allows a brewer or oenologist to discern what stage the fermentation is at. As sugar content decreases
throughout fermentation and ethanol concentration increases, the status of the fermentation can be determined over time. The sugar concentration at the start of fermentation is important in that if the sugar content is too high, as in some High Gravity and Very High Gravity fermentations for operations like rum making, yeast can undergo osmotic shock which affects cell physiology and ability to survive in the media (Walker & Stewart, 2016).

**pH.** Different yeast strains operate most efficiently at different pH values. Optimum pH, typically between 4.5 and 6.5 pH, is of paramount importance for yeast growth and metabolism (Reddy & Reddy, 2011; Walker & Stewart, 2016). Manufacturers of active dry yeast and liquid yeast cultures state the optimum growth and fermentation conditions of their yeast cultures.

**Temperature.** The influence of temperature on fermentation is high. It has been reported that the speed of enzyme action in a fermentation doubles with each 10 °C (50 °F) increase in temperature (Reddy & Reddy, 2011). Yeast cells become increasingly more sensitive to higher alcohol levels at higher fermentation temperatures due to membrane fluidity as well (Reddy & Reddy, 2011). Different types of yeast, however, are more efficient at different temperatures. For example, lager yeasts (*Saccharomyces pastorianus*) ferment best at lower temperatures while ale yeast (*Saccharomyces cerevisiae*) ferment best at higher temperatures (Walker & Stewart, 2016). Secondary metabolites are also affected by changes in temperature. For example, acetaldehyde and ester concentrations are known to decrease as temperature increases, as previously stated.
1.8.3 Color Stability

**Pigment.** The primary molecule that influences the color of peaches is known to be an anthocyanin, specifically identified as cyanidin 3-monoglucoside (Hsia, Luh, & Chichester, 1965). Anthocyanin molecules are known to be very sensitive to pH, displaying a variety of colors in even delicate changes of pH (Hsia *et al.*, 1965). Studies have also identified non-pH mechanisms of anthocyanin color change or degradation. Hsia *et al.* (1965) discuss several cases in which peaches that had higher red anthocyanin contents were subject to discoloration after processing and canning. A study by Rommel *et al.* (1990) found that most of the red color in wine made from thawed red raspberries mostly degraded during fermentation. Rommel *et al.* also discussed that color stability comes from a dominance of di- and triglycosides. A second study on blackberry wine also by Rommel *et al.* (1992) specifically identified that cyanidin-3-glucoside molecules were extremely unstable during fermentation. They deduced that the loss of cyanidin-3-glucoside was due to a combination of fermentation, depectinizing of juice, and storage. Although, they discovered that High Temperature Short Time (HTST) pasteurization of juice significantly retarded the degradation of this particular anthocyanin molecule.

**Importance.** A study by Stillman (1993) explored the importance of color on consumer perception of a fruit beverage. She found that color has a significant influence on consumer identification of flavored beverages. She also identified several other past studies by which color was seen to influence consumer judgment of basic taste like sweetness and saltiness. Stillman discusses that the influence of color on flavor is remarkable in that color does not activate any chemical or textural properties in a product, but consumers will associate particular colors with flavor through learned
experience throughout life. In regard to peach juice and products made from peach juice, consumers are hypothesized to be more likely to perceive a product as “natural” or more pleasing if the original color of the fruit product in the beverage is present.

**Color analysis.** HunterLabs Inc., a manufacturer of colorimeter and spectrophotometer technologies, goes in depth to describe the similarities and differences between the two types of color measurement (Ramanathan, 2016). Colorimeters are designed to perform psychophysical analyses on color samples to imitate human eye-to-brain perception in attempt to see color like humans do. Color is divided into “tristimulus” readings, otherwise known as giving color values in three colored lights: red, green and blue. Data is displayed as L* (lightness, 0 being black and 100 being white), a* (negative values being more green and positive values being more red), b* (negative values being more blue and positive values being more yellow), as seen in Figure 2-3. Colorimeters provide highly accurate, straightforward color measurements. However, their downfall is that they are not able to identify colorant strength and cannot provide accurate readings under variable outside light.

Spectrophotometers measure color via the full spectrum of wavelength, including above and below the visible color spectrum. Data is analyzed wavelength by wavelength in nanometers based on a sample’s reflectance, absorbance, or transmittance properties. Samples were analyzed in triplicate.
Throughout fermentation, yeast produce secondary metabolites that have high effects on the flavor and volatile profile of a beverage (Walker & Stewart, 2016; Yoshizawa, 2014). The kinetic properties of a fermentation, particularly temperature and pH; yeast type; osmotic stress; etc. of a fermentation batch all effect the end product. Yeast will emit different metabolites under stress and at different temperatures (Yoshizawa, 2014). Secondary metabolites of *S. cerevisiae* in particular include polyols, higher alcohols, esters, organic acids, diketones, and aldehydes (Yoshizawa, 2014). For example, acetaldehyde and ester concentrations are shown to decrease as fermentation temperature increases (Reddy & Reddy, 2011). Each secondary metabolite imparts particular flavor and aroma compounds into a beverage. Some positive sensory compounds like esters are known for their fruity aroma characteristics.
while other compounds, like diacetyl which is infamous for a rancid butty flavor in low thresholds, may be undesirable (Walker & Stewart, 2016). Yeast can be selected on the basis of what a brewer or oenologist desires the end notes of their product to contain, providing infinite possibilities for the fermented beverage world.

1.9 Overall Objectives and Hypothesis

1.9.1 Objective

The objective of this project is to assess the economic viability and characteristics of peach juice and fermented peach product made from ‘UFSun’ Florida peaches that have been tree-ripened on either thinned or unthinned peach trees. From this objective, one main hypothesis can be created, but divided into two categories: processing and fermentability. These hypotheses are described in detail in the next section.

1.9.2 Hypothesis

The overall hypothesis of this Master’s project is that ‘UFSun’ Florida peaches, compared on the basis of their growth on either thinned or unthinned trees, can be processed for juice, are fermentable, and are a viable option for use as a commercial brewing adjunct. In terms of processing, it is hypothesized that there will be a higher juice yield from blanched peach flesh than unblanched peach flesh, that blanching peach flesh prior to processing will prevent peach juice from browning and retain its pink-red color, and that peach juice will be physically different between thinned and unthinned trees in terms of color and sugar content. After determining the processing and physical characteristics from peach flesh to juice, fermentation can be discussed. It is hypothesized that thinned peaches will have a higher amount of fermentable sugars,
that the color of the peach juice will change in both juice types during fermentation, that peach juice will serve as an appropriate beer flavoring agent, and have more fruity volatile characteristics than beer.
CHAPTER 3
PROCESSING THINNED AND UNTHINNED UFSUN PEACHES

1.1 Summary

The University of Florida has worked for years to breed peach cultivars that will grow well in subtropical climates like Florida’s. Amongst the most successful is ‘UFSun’ – a high yield cultivar that is harvest-ready two months prior to the rest of the United States peach crop. Although the yield is high, ‘UFSun’ fruit is much smaller than is typically accepted in the fresh market due to longer days with higher heat during their growth and development period. Thinning is one method used by growers to encourage larger fruit size, although it incurs an additional cost per acre. Fruit thinning involves the reduction of the number of fruit on a branch which in turn decreases competition for sugar and other key nutrients to grow larger fruit, but in lower quantities. Although other revenue streams like U-pick operations and farmer’s markets exist, they are not reliable in terms of revenue for growers. This research aimed to use processing characteristics to identify the physical differences between UFSun peach fruit that has been tree-ripened on thinned and unthinned trees. Thinned and unthinned fruits were pressed for juice and compared by sugar content, yield from flesh, effect of heat treatment of flesh, juice color, and possible total revenue.

After analyzing fruit harvested in Citra, FL in May 2018, it was found that the sugar content of thinned and unthinned peaches is significantly different (p < 0.05) with thinned peaches being heavier, larger, and having a higher ºBrix than unthinned peaches. When pressed under the same conditions (using the same bladder press at the same pressure), non-heat-treated thinned peaches yielded more juice (42% w/w) than non-heat treated unthinned peaches (39% w/w). Economically, with assumptions,
not thinning peach trees could potentially lead to greater profit than thinning them, providing revenue options for Florida farmers and growers looking to expand their business.

1.2 Objectives and Hypothesis

The following objectives and hypothesis identify the focuses of this study:

1. Assess the processing characteristics of non-melting flesh ‘UFSun’ Florida peaches from thinned and unthinned trees

2. Analyze the physical characteristics of juice processed from ‘UFSun’ peach from thinned and unthinned trees

3. Highlight economic considerations of using ‘UFSun’ peaches tree-ripened on thinned versus unthinned trees for pressed juice

**Processing hypothesis 1.** There will be a higher yield of juice from blanched flesh than from unblanched flesh. This is an important processing step because it allows for the assessment of the quality and quantity of the juice pressed from whole (un-pressed) peach flesh. To satisfy this hypothesis, juice yielded from peaches that were blanched prior to pressing and not blanched prior to pressing will be compared by weight in kilograms. Several trials of this will help to determine which processing method is superior for yielding juice from peach flesh.

**Processing hypothesis 2.** Blanching peach flesh prior to processing will denature oxidation enzymes so that juice retains its pink-red color. Oxidation reactions will cause unblanched juice to brown, losing any red or orange color previously present when pressing the juice from the whole peach flesh. Once the juice is pressed, it will be sterilized in a steam jacketed vessel and subjected to heat treatment. The degree of browning between pre and post sterilization samples were be analyzed with a
spectrophotometer utilizing the fixed wavelength requirements of the American Society of Brewing Chemists (ASBC).

**Processing hypothesis 3.** *Peach juice from thinned and unthinned trees will have the following different physical characteristics: juice yield from flesh, color, and sugar content.*

### 1.3 Experimental Materials and Methods

#### 1.3.1 Harvesting and Storage

In May 2018 one metric ton of ripe ‘UFSun’ peaches were harvested from a research orchard located at the University of Florida (UF) Plant Science and Research Education Unit in Citra, Florida. Approximately half of these peaches were hand-picked from thinned trees and the other half from unthinned trees. After transportation back to the UF main campus in Gainesville, FL, peaches were stored in plastic harvesting bins in a cooling room at 40 °F and relative humidity between 80% and 90% until processed.

#### 1.3.2 Processing Peach Flesh

A full diagram of processing methods for May 2018 UFSun peaches can be seen in Figure 3-1.

**Rinsing, sorting, and de-stoning.** Peaches from both thinned trees and unthinned trees was rinsed with tap water to remove field debris, dirt, and insects remaining from harvest. Throughout this section, peaches before being cut or processed will be referred to as “whole peaches”, peach flesh removed or cut from the pit/stone will be referred to as “whole flesh”, and peach flesh remaining after juicing will be referred to as “pressed flesh”. After rinsing, peach flesh was cut from pits in quarters by hand with kitchen knives (whole flesh). Brown rot, mold, insect burroughs, etc. were
cut from peach flesh and discarded along with removed pits, leaves, and stems. Once cut, whole flesh was either subjected to a blanching heat treatment or was not blanched.

**Heat treatment.** Heat-treated whole flesh was steam blanched 25 kg (55 lb) at a time in a hooded steel steam blanching unit with 10 lb steam for eight minutes then rinsed with 20 °C (68 °F) water for three minutes. Heat treated whole flesh is referred to as “blanched” while non-heat-treated whole flesh is referred to as “unblanched” in this document.

**Pressing.** Blanched and unblanched whole flesh were pressed either in a Mori hydraulic basket press at 200 bar or in an Enrossi bladder basket press at 3 bar depending on the amount of peaches being processed at the time. The pressing method is denoted on recorded data in the results section. After juice was pressed from whole flesh, it was sterilized in a jacketed steam kettle in batches immediately after pressing.

**Sterilizing and storage.** Sterilization methods followed thermal treatment guidelines for peach juice set by Petruzzi *et al.* (2017). Peach juice was heated to 90 °C (194 °F), held for 5 minutes at 90 °C (194 °F), and then rapidly cooled below 37 °C (98.6 °F) by flushing cooling water through the steam jacket of the boiling kettle. Sterilized juice was collected in food-grade 11.4 L (3-gallon) buckets. Pectic enzyme (BSG HandCraft, Shakopee, MN) was added to each bucket of sterilized juice to aid in clarification and the breakdown of residual pectic fibers (0.5 teaspoons or 1.52 g per gallon of juice, per label instruction). Buckets of juice were stored at -40 °C (-40 °F) until use.
1.3.3 Physical Property Analysis

The three fruit and juice properties that will be focused on in this section are the overall yield of juice from whole flesh by weight, sugar content of the juice, and the color of the juice.

**Juice yield.** In order to calculate juice yield by weight, whole flesh cut from whole peaches was weighed in tared buckets before pressing. If whole flesh was blanched,
fruit was weighed after blanching and before pressing. Juice was measured after whole flesh was pressed. Percent yield by weight was calculated via Equation 3-1:

\[
\% \text{ Juice} = \frac{\text{Total Weight of Juice}}{\text{Total Weight of Whole Flesh}} \cdot 100
\]  

(3-1)

**Sugar content.** Sugar content by weight, also known as °Brix, was assessed in all juice types. Approximately 25 mL (0.85 fl oz) of each juice sample was filtered with Double Rings 201 – 125 cm ashless filter paper into a clean beaker. After filtering, °Brix was measured using an Anton Paar Densitometer that had first been washed twice with deionized water prior to sampling. To analyze one sample, the densitometer was first washed with deionized water, then washed with the juice sample twice. After rinsing with the juice sample, the juice sample is then expelled and taken until the same °Brix measurement is read three times in a row. This method was use in triplicate for individual juice samples.

**Blanched versus unblanched juice color.** Samples were taken in triplicate before juice was sterilized, after juice was sterilized, and again after pectinase was added to sterilized juice. Absorbance was measured using a Beckman Coulter DU®730 Life Science UV/VIS spectrophotometer and plastic cuvettes. Peach juice was filtered through Double Rings 201 – 125 cm ashless filter paper, poured into 10 mm (0.4 in) plastic cuvettes, wiped clean with a Kim Wipe, and inserted into the chamber of the machine. Absorbance at wavelengths 430 nm and 700 nm were measured per methodology the American Society of Brewing Chemists (ASBC Beer-10). Absorbance units were converted to reference units by the following equation:

\[
°\text{SRM} = 10 \cdot 1.27 \cdot A_{10} \cdot F
\]  

(3-2)
Where °SRM is standard reference method units, \( A_{10} \) is the absorbance units at a specific wavelength through a 10 mm cuvette, and \( F \) is the dilution factor of the media analyzed. According to the Beer-10 method, the absorbance recorded at 430 nm is meant to assess beer color, typically brown or yellow. The relationship between 430 nm and 700 nm is used to determine the turbidity of the sample. If the absorbance at 700 is less than or equal to 0.039 times the absorbance at 430 nm, the sample is free of turbidity.

### 1.3.4 Volatile Compound Analysis

**Sample preparation.** Frozen 11.4 L (3-gallon) buckets of juice were thawed on the day of experimentation in steam kettles. Once thawed, juice was collected in 200 mL (6.8 fl oz) glass pyrex bottles and sealed. Samples were vacuum filtered through 70 mm (2.8 in) glass microfiber Whatman filter paper (GE Healthcare Life Sciences, CAT No. 1822-070) into a clean Büchner flask. Filtered samples were poured into 40 mL (1.4 fl oz) amber sample vials with duplicate samples for each juice type. Then 3 µL of antifoam reagent (Trans-400, Bristol, WI, USA) was added to each vial and vortexed on a Fisher digital vortex mixer at an instrument speed of 2225 for 20 seconds. An internal standard (carvone, 125 ppb v/v) was added in 2 µL amounts to each sample vial during sample runs.

**Gas Chromatography/Mass Spectroscopy conditions.** An autosampler drew 5 mL (0.2 fl oz) of sample from each amber vial and purged them internally with a nitrogen flow rate of 200 mL/min (6.8 fl oz/min) for 30 minutes. Volatile compounds were adsorbed by a Tenax® trap, desorbed at 180 °C (365 °F). These compounds were transferred in-line to the unit injection port of an Agilent gas chromatograph (Santa
Clara, CA, USA) with a quadruple mass spectrometer detector (5975C MSD). Separation was completed using a ZB-WAX plus column (30 m x 250 μm x 0.25 μm) (Phenomenex, Torrance, CA, USA). GC oven conditions included a split mode run with a 20:1 ratio, oven temperature of 45 °C (113 °F) held for 7 minutes then increased first to 150 °C (302 °F) at a rate of 3 °C/min (37 °F/min), second to 210 °C (410 °F) at a rate of 10 °C/min (50 °F), and third to 240 °C (464 °F) at a rate of 30 °C/min (86 °F) holding at 240 °C (464 °F) for 4 minutes. The flow rate of helium gas was 1 mL/min (0.03 fl oz/min). Volatile peaks were identified using the 2011 NIST mass spectral library, comparing mass spectral and retention index data.

**Calculating volatile compound concentration.** In order to understand the intensity of a volatile compound identified in the headspace of each sample, the area under the peak of an identified compound must be directly compared to the area under the peak of an internal standard of a known concentration. In the case of this research, all identified volatile compounds were compared to carvone at 125 ppb v/v as previously described. Equation 3-3 will be used to determine the concentrations in ppb of each identified volatile compound per individual sample:

\[
\frac{\text{Volatile Compound Concentration (ppb)}}{\text{Total Area of Volatile Compound}} = \frac{\text{Internal Standard Concentration (ppb)}}{\text{Total Area of Internal Standard}} \tag{3-3}
\]

1.3.5 Statistical analysis

**Juice sugar content.** The sugar content in °Brix for all juice samples were analyzed using a single-factor Analysis of Variance (ANOVA) test on Microsoft Excel (α = 0.05) to compare all data between thinned blanched and unthinned blanched juice.

**Color analysis: spectrophotometry.** Raw data was analyzed using average and standard deviation functions on Microsoft Excel.
**Color analysis: colorimetry.** Raw data was analyzed using single-factor ANOVA on Microsoft Excel to distinguish significant differences at $\alpha = 0.05$ between color parameters $L^*$, $a^*$, and $b^*$.

**Volatile analysis.** Each sample was run in duplicate. Volatiles were analyzed with average and standard deviation functions on Microsoft Excel to combine duplicates for comparison. Volatile concentrations were calculated via Equation 3-3 in relation to their parts per billion (ppb) levels as compared to an internal standard, carvone. Concentrations were compared between juice types using the Microsoft Excel single-factor ANOVA function ($\alpha = 0.05$).

### 1.4 Economic Considerations of Juicing Florida Peaches

In order to determine the economic feasibility of processing 'UFSun' peaches, a theoretical cost analysis was prepared based on a list of assumptions. The analysis was designed to fit the standard projected yields of North and Central Florida peach growers. Highly based on assumptions, the analysis includes a simple breakdown of what kinds of costs these growers can expect from processing their own tree-ripened peach crop. The analysis is based on a one-acre basis, does not include labor costs outside of hand-thinning trees (pruning, harvesting, pest control, general field care, etc.), grading is based solely on fruit size, does not include capital costs and utilities for processing, and that growers have the necessary equipment to process large quantities of peaches into juice. It is known that not all have access to such equipment, but outside costs for equipment purchases have not been taken into account in this analysis.

The following assumptions can be made to support the analysis in Figure 3-5:

1. The orchard is 15x20 with 145 trees
2. Thinning costs $1,500.00 per acre
3. Thinned trees produce 100 lb (43 kg) of fruit mass
4. Unthinned trees produce two times the mass of a thinned tree, 200 lb (91 kg) in this case
5. High-grade fruit (2 – 2.5 inches or 5 – 6.4 cm in diameter) can be sold for $1.50/lb to fresh markets
6. Low-grade fruit will not be sold (less than 2 inches or 5 cm in diameter)
7. For an acre of thinned trees, 70% of the harvested fruit will be an acceptable size, considered high grade, and be sold to the fresh market
8. For an acre of unthinned trees, 0% of the harvested fruit will be sold to the fresh market meaning 100% of the fruit will be unacceptable in size and therefore considered low grade
9. There is a 60% yield by weight when pressing the juice from flesh
10. Juice has 10% sugar by weight and is 10 °Brix in sugar content (10 °Brix = 1.038kg/L in density)
11. Juice will be sold for sold for $0.80/L (an estimate for this analysis)

1.5 Results

1.5.1 Juice Yield

Figure 3-2 shows juice yield data from May 2018. Unthinned blanched whole flesh (*) was pressed hydraulically at 200 bar while all other flesh was processed with a bladder basket press at 3 bar. For unblanched whole flesh, thinned produced ~3% more juice than unthinned whole flesh. Being that all blanched whole flesh was not pressed the same way, their yields cannot be compared directly as size and weight is statistically different between unthinned and thinned fruits (Sarkhosh et al. 2019). However, it can be hypothesized that blanched thinned peaches would produce more juice when pressed hydraulically than blanched unthinned peaches due to their significantly larger size. Blanching prior to pressing increased the yield of juice from 42% with no heat.
treatment to 50% with heat treatment. This supports the conclusion that blanching whole flesh before pressing will encourage higher yields of juice from fruit flesh as opposed to no heat treatment.

![Graph showing percent juice yield by weight for unblanched and blanched fruit flesh, with thinned and unthinned bars.](image)

Figure 3-2. UFSun pressed juice yields. All whole flesh was pressed with a bladder basket press at 3 bar except for unthinned blanched whole flesh, denoted with an asterisk (*), which was pressed using a hydraulic basket press at 200 bar.

1.5.2 Sugar Content

Independent of heat treatment, thinned juice had a significantly different (p < 0.05) higher sugar content (ºBrix) than unthinned juice. Unblanched juice for both thinned and unthinned had a higher ºBrix than juice from blanched whole fruit as seen in Figure 3-3. This is believed to be due to the blanching process. During blanching, quartered whole flesh was spread on to wire mesh trays in a hood that was flushed with steam. Excess juice was likely washed off of cut peaches throughout blanching and
throughout additional rinsing during the cooling process. Therefore, blanched juice has a slightly lower sugar content than unblanched juice. If peach fruit were blanched as whole fruit instead of blanching after cutting, juice would most likely have a higher sugar content. Overall, thinned and unthinned juices had significantly different amounts of sugar (p < 0.05) when blanched before being pressed.

![Graph showing the %Brix of heat-treated and non-heat treated thinned versus unthinned peach juice.](image)

**Figure 3-3.** °Brix of heat-treated and non-heat treated thinned versus unthinned peach juice. Different letters on each bar indicate significant difference (p < 0.05).

### 1.5.3 Juice Color

**Spectrophotometric analysis.** All juice that was pressed from blanched whole flesh kept its pink-red color, a positive trait in peach juice. Juice that was pressed from unblanched whole flesh turned brown, as expected. Figure 3-4 shows the color of blanched juice and unblanched juice. Spectrophotometric color analyses also supported this evidence, as seen tabulated in Table 3-1 and 3-2. Blanched juices showed little to no change when comparing values taken before sterilization, after sterilization, and after
the addition of pectinase to sterilized juice. This confirms that blanching is an effective way to retain the original color of the peach juice. For unblanched juices, °SRM at 430 nm decreased slightly after sterilization. After pectinase was added and long fibers were broken down enzymatically, readings decreased from 22.1 °SRM to 8.1 °SRM for thinned and from 27.3 °SRM to 4.8 °SRM for unthinned juice.

Figure 3-4. Comparison of blanched and unblanched peach juice color

| Table 3-1. Thinned spectrophotometric scan data at 430 and 700 nm |
|---------------------|---------------------|--------|
| Heat treatment      | Sample time         | 430    | 700    |
|                    |                     | °SRM   | °SRM   |
| Blanched            | Pre-Sterilization   | 6.6 ± 0.07 | 2.6 ± 0.03 |
|                     | Post-Sterilization  | 6.4 ± 0.90 | 2.4 ± 0.49 |
|                     | Post-Sterilization + Pectinase | 5.2 ± 0.01 | 1.7 ± 0.01 |
|                     | Pre-Sterilization + Pectinase | 26.5 ± 0.02 | 6.8 ± 0.03 |
| Unblanched          | Post-Sterilization  | 22.1 ± 0.01 | 9.2 ± 0.01 |
|                     | Post-Sterilization + Pectinase | 8.1 ± 0.01 | 2.2 ± 0.01 |

| Table 3-2. Unthinned spectrophotometric scan data at 430 and 700 nm |
|---------------------|---------------------|--------|
| Heat treatment      | Sample time         | 430    | 700    |
|                    |                     | °SRM   | °SRM   |
| Blanched            | Pre-Sterilization   | 6.6 ± 0.73 | 2.3 ± 0.51 |
|                     | Post-Sterilization  | 7.6 ± 1.20 | 2.7 ± 0.88 |
|                     | Post-Sterilization + Pectinase | 5.1 ± 1.79 | 1.4 ± 0.70 |
|                     | Pre-Sterilization + Pectinase |         |         |
| Unblanched          | Post-Sterilization  | 27.3 ± 0.95 | 11.3 ± 2.11 |
|                     | Post-Sterilization + Pectinase | 4.8 ± 0.66 | 1.2 ± 0.35 |

A hyphen “-” means no data was taken for the sample. Unthinned unblanched pre-sterilization samples were compromised and unable to be analyzed.
**Colorimetric analysis.** Raw colorimeter data in L*, a*, and b* values for blanched thinned and unthinned juice can be found in Tables 3-3. Lightness readings, L* where 0 is black and 100 is white, are very similar between thinned, 89.78, and unthinned, 88.27, juices. Thinned juice shows a higher L* reading, indicating a slightly lighter beverage. The a* readings, positive being more red and negative being more green, showed that unthinned juice, 6.89, was slightly more red than thinned juice, 5.76. It is hypothesized that this is due to a lesser amount of flesh in relation to the surface area of the peach compared to thinned peaches, which have more flesh that provides more juice, therefore diluting red color from the peach skin. For b* values, positive being more yellow and negative being more blue, unthinned juice also had a higher positive b* value, 10.44, than thinned juice, 8.29, indicating a slightly more yellow tint to the juice. Each color component for thinned and unthinned juice is significantly different (p < 0.05). Parameter a* has a larger difference between thinned and unthinned – unthinned juice samples were more red than thinned juice samples.

<table>
<thead>
<tr>
<th>Juice type</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thinned</td>
<td>89.78A</td>
<td>5.76A</td>
<td>8.29A</td>
</tr>
<tr>
<td>Unthinned</td>
<td>88.27B</td>
<td>6.89B</td>
<td>10.44B</td>
</tr>
</tbody>
</table>

N = 3 for each sample; different letters in the same column indicate a significant difference (p < 0.05)

**1.5.4 Volatile Analysis**

A total of 12 different volatile compounds were identified but thinned and unthinned juice each had one compound unique to that juice type. Only thinned juice samples contained 3-nonen-2-one and only unthinned samples contained acetophenone. The concentration of these compounds in ppb along with their odor attributes are listed in Table 3-4. Ethanol was identified in high amounts in both thinned
and unthinned juice likely due to fermentation products produced during storage via natural microflora on the fruits, but ethanol is not included in Table 3.3 or this discussion as it does not have a large bearing on the volatile profile of the fruits. The most highly concentrated compound in both juices was ethyl acetate, hexanal, and acetone. The top four identified volatiles account for the majority of “fruity” volatiles found in both types of peach juice (“The Good Scents Company Information System,” 2018). Five of the 12 identified volatile compounds for each type of juice have a “fruity” odor while five have a “green/fresh” “fatty/buttery” odor, one more with “almond”, and one with a “powerful, acrid, pungent” scent.

Past literature reports that other peach volatile experiments identified alcohols (Hadi, Zhang, Wu, Zhou, & Tao, 2013), ethyl acetate (Hadi et al., 2013; Mojca Bavcon Kralj, 2014) hexanal (Hadi et al., 2013; Horvat et al., 1990; Mojca Bavcon Kralj, 2014), benzaldehyde (Horvat et al., 1990; Mojca Bavcon Kralj, 2014), and 2-octenol (Mojca Bavcon Kralj, 2014) as major volatile compounds in their respective studies. Eduardo et al. (2010) identified C9 compounds, much like 3-nonen-2-one found in thinned peach juice, in their study as well. Overall, the volatile compounds identified in ‘UFSun’ peaches are similar to those found in peach cultivars of international studies.

Threshold ranges for ethyl acetate, acetone, benzaldehyde, and acetaldehyde have been identified based on compiled data from Ruth et al. (2010). These have all been identified in past research as described and seen as important peach volatile characteristics. Ethyl acetate and acetone have been identified at concentrations between the low and high thresholds for thinned and unthinned juices. The concentrations of benzaldehyde and acetaldehyde identified in both juice types are far
above the “high” odor thresholds found, likely indicating high volatility and a large impact on sensory profile of the peach juices.

Table 3-4. Volatile compounds identified in 2018 thinned and unthinned peach juice

<table>
<thead>
<tr>
<th>Compound</th>
<th>Concentration (ppb)</th>
<th>Odor thresholds (ppb)</th>
<th>Odor attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thin.</td>
<td>Unthin.</td>
<td>Low</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>2744A</td>
<td>946B</td>
<td>0.02</td>
</tr>
<tr>
<td>Hexanal</td>
<td>949A</td>
<td>1119A</td>
<td>4.1</td>
</tr>
<tr>
<td>Acetone</td>
<td>406A</td>
<td>708B</td>
<td>47.47</td>
</tr>
<tr>
<td>Benzaldehyde</td>
<td>131A</td>
<td>395B</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>2-octenol</td>
<td>106A</td>
<td>141A</td>
<td>-</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>138A</td>
<td>105B</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Pentanal</td>
<td>80A</td>
<td>96A</td>
<td>-</td>
</tr>
<tr>
<td>2-heptanal</td>
<td>40A</td>
<td>93A</td>
<td>-</td>
</tr>
<tr>
<td>2,3-butanedione</td>
<td>74A</td>
<td>45B</td>
<td>-</td>
</tr>
<tr>
<td>Acetoin</td>
<td>73A</td>
<td>36B</td>
<td>-</td>
</tr>
<tr>
<td>3-non-2-one</td>
<td>32</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Acetophenone</td>
<td>-</td>
<td>48</td>
<td>-</td>
</tr>
</tbody>
</table>

Volatile compounds in the table are listed loosely from highest to lowest average concentration. "Thinned Juice" and "Unthinned Juice" are abbreviated as "Thin.” And "Unthin.”, respectively. N = 2 for each sample; a hyphen “-” means not detected for that sample; n/a means no odor threshold for that compound; different letters in the same row indicated significant difference (p < 0.05). Odor threshold ranges are from (Ruth, 2010) except for hexanal which is from (Burdock, 2010). Odor attribute information is from (The National Library of Medicine, 2019)\(^1\) or (The Good Scents Company, 2018)\(^2\).

1.5.5 Economic Analysis

As described previously, the analysis in Figure 3-5 is highly dependent on assumptions made for North and Central Florida peach growers.

High-quality fruit will make a larger profit overall than low-quality fruit, but with double the fruit mass from an unthinned tree when compared to a thinned tree, fruit used for juice processing would most likely lead to higher profits in juice sale for an acre of unthinned trees. It is clear that juicing operations on their own will be able to provide alternative revenue options. Depending on the amount that a juicing operation is able to sell bulk juice for, unthinned peach juice would make much more in profit under these assumptions than thinned peach juice. Any peach juice could be sold to any local wine,
mead, beer, kombucha, or other fermented beverage operation as an adjunct or flavoring agent. There are also possibilities that peach juice could be sold at farmer’s markets, as long as they are properly treated and follow FDA regulation codes for pressed juice beverages per state and local government requirements.

While the theoretical cost analysis was created on the basis that a grower has access to or owns processing equipment, it is understood that this may not be true for many facilities.

<table>
<thead>
<tr>
<th>THINNED</th>
<th>ASSUMPTIONS</th>
<th>UNTINNED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HARVESTING</strong></td>
<td><strong>SELLING WHOLE FRUIT</strong></td>
<td><strong>JUICING UNSOLD WHOLE FRUIT</strong></td>
</tr>
<tr>
<td>14,500 lb/acre</td>
<td>29,000 lb/acre</td>
<td>$0</td>
</tr>
<tr>
<td>70% accepted for fresh market = 10,150 lb</td>
<td>0% accepted for fresh market = 0 lb</td>
<td>$6,554</td>
</tr>
<tr>
<td>$15,225</td>
<td>$0</td>
<td>$6,554</td>
</tr>
<tr>
<td>$13,725</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4,350 lb of rejected fruit used for juicing = 1229 L of juice</td>
<td>29,000 lb of rejected fruit used for juicing = 8193 L of juice</td>
<td></td>
</tr>
<tr>
<td>$983</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Figure 3-5](image)

Figure 3-5. Theoretical analysis of peach processing for fruit yield from thinned versus unthinned trees based on specific assumptions (0.454 kg = 1 lb, 1 L = 0.26 US gal)

### 1.6 Discussion

**Processing ‘UFSun’ peaches for juice.** Blanching whole peach flesh prior to pressing the flesh for juice resulted in a higher (p < 0.05) juice yield (~50%) than whole peach flesh that was not blanched (39-42%). Blanching also prevented flesh and juice from browning during pressing and sterilization, thus preserving the pink-red color of the
peach juice, a positive trait to consumers. This is believed to be due to the denaturation of present oxidation enzymes by heat. The overall yield pressed from peach flesh is also dependent on the pressing method. Pressing juice at a higher pressure, as in the hydraulic press used, provided a higher yield. Blanched flesh from thinned and unthinned whole peach flesh was pressed with two different presses: thinned with a bladder press at 3 bar and unthinned with a hydraulic press at 200 bar.

**Juice sugar content of thinned versus unthinned fruits.** Juice pressed from blanched peaches was found to contain lower amounts of sugar by weight (ºBrix) than juice pressed from unblanched fruit. Thinned fruit juice contained 10.3 ºBrix when blanched and 11.9 ºBrix when unblanched. Unthinned fruit juice contained 9.7 ºBrix when blanched and 10.9 ºBrix when unblanched. Comparing the blanched juices only, thinned juice had a significantly higher (p < 0.05) sugar content by weight (10.3 ºBrix) in relation to unthinned juice (9.7 ºBrix). This confirms the hypothesis that thinned fruit is believed to contain a higher amount of sugar due to lowered competition for sugar, water, and nutrients during tree-ripening – in turn promoting larger fruit size. Unthinned peach trees have more fruit growing on each branch, resulting in more competition for growth resources and therefore containing less sugar overall in its juice when pressed.

**Cost analysis comparison of tree care methods.** As stated in the economic analysis, high-quality fruit will make a larger profit than low-quality fruit. However, it is clear that additional profits can be made from selling peach juice if processed and sold, but analysis is highly dependent on assumptions provided. With a competitive sale price on peach juice from unthinned trees or late-season thinned peaches, farmers and
growers can still make adequate profit if late-season peaches are unable to be sold at high-grade fresh market cost.

**Color analysis.** Spectrophotometric readings on blanched and unblanched juice for both thinned and unthinned juice types indicate that juice retains high amounts of red color when blanched prior to processing. Without blanching, the enzyme polyphenoloxidase will cause the juice to oxdize and turn brown – a negative trait. In comparing the thinned and unthinned juices that had been blanched, thus retaining their red color, the main differences were that unthinned juice was more red (a* value of 6.89) with a slightly more yellow tint (b* value of 10.44) than thinned juice (a* value of 5.76, b* value of 8.29). This is believed to be due to unthinned fruit being of smaller size, with less flesh to extract juice from, therefore having a more highly concentrated amount of pigment from the peach flesh which contains the same amount of red blush as thinned peaches. Thinned peaches, being larger with more flesh, likely contain a diluted amount of red pigment and appears less red than unthinned fruit juices.

**Volatile comparison of thinned and unthinned peach juice.** Thinned and unthinned ‘UFSun’ peach fruit juices had similar volatile profiles, but the largest differences between compounds found in both juices were that unthinned juice had a concentration of 2-heptenal (green, fatty) over two times higher, a concentration of almond-like compound benzaldehyde three times higher, and a concentration of fruity acetone volatiles nearly two times higher than those of thinned juice. Thinned juice had a concentration of benzaldehyde lower than the aroma threshold for the compound. Thinned juice had a concentration of benzaldehyde lower than the aroma threshold for benzaldehyde. Unthinned juice likely had a higher detectable concentration of
benzaldehyde’s characteristic “bitter almond” compound due to there being less flesh around the outside of the pit, which is known for an almond-like aroma profile, therefore a more concentrated amount of the compound. Thinned juice had nearly three times the concentration of ethyl acetate (fruity, pineapple) than was identified in unthinned juice. Overall, identified volatile compounds were aligned with what has been found in past peach volatile research including alcohols (Hadi et al., 2013), ethyl acetate (Hadi et al., 2013; Mojca Bavcon Kralj, 2014) hexanal (Hadi et al., 2013; Horvat et al., 1990; Mojca Bavcon Kralj, 2014), benzaldehyde (Horvat et al., 1990; Mojca Bavcon Kralj, 2014), and 2-octenol (Mojca Bavcon Kralj, 2014).

1.7 Conclusions

Although peaches are typically pureed and filtered for nectar, this research has proven that it is possible to press peaches for juice. When peach flesh was blanched before pressing, yields were higher than when peach flesh was not blanched (p < 0.05). Blanched juice also kept its red color throughout processing as suggested by past research. Therefore, it is recommended to heat treat peach flesh before pressing to increase juice yield by weight and preserve the natural juice color. Juice yield is also dependent upon pressing method. When blanched flesh was pressed with a bladder press at 3 bar, thinned fruits yielded 50% juice by weight, but blanched smaller unthinned fruit was pressed with a hydraulic press at 200 bar, yield was 62% juice by weight. When not blanched, thinned peach juice had a higher yield than unthinned peach fruits. In terms of sugar content, thinned fruit juice contained ~1 °Brix more sugar than unthinned peach juice (p < 0.05) when blanched and unblanched. GC/MS purge and trap analysis showed similar chemical aroma profiles for thinned and unthinned,
however thinned juice had generally higher concentrations of fruity compounds than unthinned juice. Economically, based on assumptions, it is possible to supplement fresh market sale profits by selling peach juice.
CHAPTER 4
CHARACTERIZING THE FERMENTATION OF THINNED AND UNTINNED ‘UFSUN’ PEACH JUICE

1.1 Summary

In the past, fermentation was utilized as a way to preserve perishable foods. Today it is recognized as not only a method of preservation, but a means to create value-added and nutritionally fortified foods and beverages. A growing trend exists in the incorporation of underutilized crops in fermented products, especially for unique flavors and other organoleptic properties. Prior to using any crop for fermentation, the following properties should be characterized: sugar content by weight (ºBrix), pH, Yeast Fermentable Extract (YFE), fermentation kinetics (changes over time), and fermented product organoleptics. Peaches, one of the most notably perishable stone fruits, have not been fully studied as a fermentation substrate. This chapter serves as a case study to characterize and model the usability of a fermentation adjunct – specifically Florida peach cultivar UFSun. In this study, juice from ‘UFSun’ peaches that were grown on two different types of trees (thinned and unthinned) was fermented compared in terms of their fermentation characteristics (YFE, kinetics, color). Juice from thinned ‘UFSun’ was also used in a commercial beer product and compared to beer without peach juice, beer with peach juice, and peach juice on its own for color and volatile content.

All ‘UFSun’ peaches were harvested from Citra, FL. For characterization, juice pressed from thinned and unthinned ‘UFSun’ peaches was fermented with Lalvin-1118 ale yeast from Lallemand for characterization. Results indicated that both thinned and unthinned ‘UFSun’ juices have the same amount of fermentable sugars (~74% of sugars being consumed during fermentation) even though previous research indicates that thinned juice has a significantly higher sugar content. Total alcohol content was
around 4.5%w/w for thinned juice and 4%w/w for unthinned juice. The rate of fermentation between thinned and unthinned juices was not significantly different \((p > 0.05)\). Both thinned and unthinned juices began the fermentation process with a red color and became a pale-yellow color by the end of fermentation, as analytically proven by spectrophotometer and colorimeter. When utilized as a brewing additive in a 15 BBL batch of Gose style sour beer, informal sensory analysis reported a difficulty in detecting organoleptic peach traits in the beer. Volatile testing indicated that this beer style without peach juice shared similar volatile compounds to the peach juice on its own – confirming that the detection of peach aromas is difficult in this particular beer style.

1.2 Objectives and Hypotheses

Objectives:

1. Identify the amount of fermentable sugars present in “UFSun” from thinned and unthinned trees.
2. Characterize the kinetics of the fermentation of thinned vs unthinned peach juice.
3. Test the viability of ‘UFSun’ Florida peach juice as an adjunct in a commercial beer product.
4. Assess the volatile characteristics of a commercial beer product containing peach juice and determine the appropriateness of peach juice as a beer additive.

Fermentation hypothesis 1. Thinned UFSun will have more fermentable sugars than unthinned UFSun. Due to the fact that thinned UFSun fruit is larger in size, it typically has a higher \(^\circ\)Brix than unthinned UFSun, which is smaller in size (Sarkhosh, 2018). With a higher amount of sugar overall, it is hypothesized that thinned UFSun will have a higher amount of fermentable sugars in comparison to unthinned UFSun.
Fermentation hypothesis 2. The color of the peach juice will change during fermentation. Previous research indicates that anthocyanin molecules, the major colorant in peach juice, is unstable during fermentation.

Fermentation hypothesis 3. Peach juice will serve as an appropriate beer flavoring agent.

Fermentation hypothesis 4. Peach juice will have more fruity characteristics than beer with peach juice.

1.3 Experimental Materials and Methods

1.3.1 Peach Juice

Peach juice (blanched thinned and blanched unthinned) from the 2018 pressing experiments outlined in Chapter 3 were used for all fermentation experiments.

Additional thinned tree-ripened peaches were harvested, heat-treated, and pressed in 2019 using the same processing guidelines developed in 2018. The juice from 2019 was used for a commercial peach Gose sour beer brewing trial with First Magnitude Brewing Company (Gainesville, FL). To prepare samples for non-commercial scale fermentation experiments, one bucket of frozen juice was thawed in a hot water bath during the day each experiment was to begin. Only peach juice pressed from blanched peaches were used for experimentation in this chapter.

1.3.2 Yeast

Yeast strain. All peach juice was fermented using Lallemand’s Lalvin-1118 champagne yeast.

Counting. Yeast was counted via the methodology by the American Society of Brewing Chemists (ASBC Yeast-3). This method calculates the number of cells
suspended per mL of liquid with a hemocytometer and cover slip through a microscope (AMSCOPE Model T610D, 400x magnification). Yeast slurry or fermentation samples was suspended in either distilled water or Ethylenediamine Tetraacetic Acid (EDTA) for counting. Five out of twenty-five blocks were counted, four corners and the center block. The top and right borders of each block were counted.

The number of yeast pitched is important for optimal fermentation. The volume of the yeast slurry mixed during rehydration is factored in along with the number of cells counted via microscope and hemocytometer as seen in Equation 4-3:

\[ C_1V_1 = C_2V_2 \]  
(4-3)

Where \( C_1 \) is the number of yeast cells counted in the slurry in cells/mL, \( V_1 \) is the amount of slurry needed in mL, \( C_2 \) is the desired number of yeast cells suspended in the fermentation broth after pitching in cells/mL, and \( V_2 \) is the volume of the substance that the yeast will be pitched into.

**Viability.** Yeast viability will be determined using similar methods to those discussed, however the yeast samples will be mixed with Methylene Blue (MB). Alive, or viable, cells will metabolize the MB and appear white while dead cells will be stained blue. The same five blocks were counted for viability, four corners and center. However, dead and alive cells were counted along with the overall total cells in the five blocks. The ratio of alive cells to total cells is taken to calculate viability as seen in Equation 4-4:

\[ \% \text{Viability} = \frac{\text{Number of Viable Yeast Cells}}{\text{Total Counted Yeast Cells}} \]  
(4-4)

1.3.3 Assessing the Fermentability and Fermentation Characteristics of Florida Peach Juice

When assessing any adjunct or sugar containing product for brewing or fermentation, it is important to know the amount of yeast fermentable sugars in the
product; the kinetics of its fermentation - including the changes in ethanol, sugar, yeast cells in suspension, and pH over time; and viability for use in a commercial beverage product. This section details methods used to assess these characteristics for thinned and unthinned peach juice as well as industrially trialed beer.

**Yeast fermentable extract.** The first set of fermentations conducted were carried out based on the ASBC Yeast Fermentable Extract (YFE) method (ASBC Wort-5). The purpose of the YFE method is to determine the amount of fermentable sugars in the product being fermented. Once the amount of fermentable sugars in the product is known on a small scale, it provides an idea for how that product will act when assessed on larger scales, including bench and pilot scale. This method requires 5 g of dry yeast to be added to 250 mL of wort (peach juice), swirling the flasks and allowing all consumable sugars to be metabolized by the yeast in the mixture over 48 hours or until the end of fermentation. The method states that fermentation is completed when the wort reaches its minimum specific gravity. Yeast Fermentable Extract (YFE) analyses were conducted in duplicate.

**Residual sugar content.** The residual sugar content, also known as the apparent sugar content or apparent °Brix, of the fermented peach product will be measured per the YFE method (ASBC Wort-5) of alcohol content determination via volumetric distillation. During distillation the ethanol in the fermented product, along with some water, will evaporate and condense into a distillate. The concentrate left behind contains all of the sugar that was present in the solution. The concentrate is brought back up to its original volume and sugar content is evaluated with a densitometer.
Calculating the amount of fermentable sugars. Per the ASBC Wort-5 method, Equation 4-5 is used to calculate the amount of fermentable sugars within the peach juice:

\[
\% \text{Fermentable Sugars} = \frac{\text{Initial } \text{Brix} - \text{Final } \text{Brix}}{\text{Initial } \text{Brix}} \times 100
\]

(4-5)

where Initial \(^\text{Brix}\) is the sugar content of the peach juice before fermentation and Final \(^\text{Brix}\) is the residual sugar content of the peach juice after fermentation and % Fermentable Sugars is the real degree of fermentation and amount of fermentable extract in the juice samples.

Fermentation kinetics analysis of 15mL fermentation assays. In order to accurately characterize a fermentation, multiple trials need to be conducted to analyze the spread of the data. A method designed by Lake et al. (2008) and adapted by the ASBC (ASBC, Yeast-14) allows for small controlled fermentations at 21 °C (69.8 °F) isolated from one main batch of prepared fermentation broth. The only deviation from the method was that yeast nutrient was not added to peach juice samples prior to fermentation. The kinetics of fermentation parameters were modeled using the following equations (ASBC, Yeast-14). Density attenuation, pH, and ethanol content using a four-parameter logistic non-linear model:

\[
P_t = P_e + \frac{P_i - P_e}{1 + e^{-B(t-M)}}
\]

(4-6A)

Where \(P_i\) is the initial value of the measured parameter, \(B\) is the inflection point of the raw data at time \(M\), \(P_e\) is the final asymptote value of the measured parameter, and \(t\) is the time of the individual sample taken. Figure 4-1 (ASBC Yeast-14) shows the effect of each parameter on the modeled data as described, modeled using density attenuation in °Plato, a typical brewing soluble solids content measurement. To calculate the rate of
density attenuation, the first derivative of Equation 4-6A can be taken with respect to
time as shown in Equation 4-6B. The numerical values for each parameter described for
Equation 4-6A are the best fit parameters identified for each generated density
attenuation data plot.

\[
\frac{dP'_1}{dt} = -B(P_i - P'e) e^{(B't + B'mt)} \left( e^{-B't} + e^{B'mt} \right)^2
\]  
(4-6B)

Absorbance correlating to cells in suspension using a four-parameter tilted Gaussian
model:

\[
Abs_t = R \times t + A \times e^{-0.5 \left( \frac{t-\mu}{\sigma} \right)^2}
\]  
(4-7)

Where \(Abs_t\) is the absorbance in absorbance units (AU), \(\mu\) is the time of peak
absorbance or the mean time of the curve, \(\sigma\) controls the width of the bell curve as the
standard deviation of the mean time, \(t\) is the time of the sample, and \(R\) is the Gaussian
curve rotation. Figure 4-2 (ASBC Yeast-14) shows the effect of each parameter on the
modeled data as described.

**Color change during fermentation.** In order to analyze the change in color over
the fermentation process, an additional miniature fermentation assay was performed at
15 °C (59 °F) on thinned and unthinned juice simultaneously. Color was analyzed as is
detailed in Chapter 3.
1.3.4 15 BBL production scale fermentation

In order to test the behavior of Florida peach juice in a commercial product, a trial beer collaboration with First Magnitude Brewery was organized for 2019. The goal of this collaboration was to assess the viability of Florida peach juice as a brewing adjunct and flavor additive. Florida peach juice from thinned peaches were used to brew a Gose – a traditional German style of beer high in lactic acid similar to a sour beer, but unique in that it is brewed with saltwater and coriander.

Peach harvesting, processing, and storage. In April 2019, a metric ton of thinned peaches were harvested from Citra, FL with harvesting, storage, and processing techniques identical to those explained in detail in Chapter 3. These peaches were blanched prior to pressing in a hydraulic basket press. After pressing, juice was transferred into two food-grade plastic 50-gallon drums to yield approximately 90 gallons of juice. Before storage, pectic enzyme (BSG HandCraft, Shakopee, MN) was added to each drum of juice to aid in clarification and the breakdown of residual pectic fibers. The drums of juice were stored at -40 °C (104 °F) until use.

Peach juice preparation: thawing, pasteurization, and vessel sterilization. Before transferring juice to First Magnitude Brewing Co. for fermentation, the drums of frozen juice were thawed in hot water baths. After thawing, drums were fully scrubbed...
and sanitized with bleach (33NT68 Ultra Bleach – Cloro Ultrapotente, W.W. Grainger, Inc., Lake Forest, IL, USA), scrubbed with Dawn soap (Procter & Gamble, Cincinnati, OH, USA), rinsed with water, scrubbed with Powdered Brewery Wash (PBW) (Five Star Chemicals & Supply, Inc., Commerce City CO, USA) and sterilized with steam prior to opening. Once the outsides of the drums were thoroughly cleaned, juice was pasteurized using a shell and tube heat exchanger (Model 5024-F 25HV, Microthermics, Raleigh, NC, USA) and a typical low temperature low time (LTLT) pasteurization at 73 °C (163 °F) holding for 30 seconds. The pasteurized juice was stored in food-grade plastic drums that had been sanitized with iodine (Five Star Chemicals & Supply, Inc., Commerce City, CO, USA) per user instructions. Pasteurized peach juice was sealed in the sanitized drums and wrapped with cooling water hoses to cool juice prior to being shipped to First Magnitude Brewing Co. for brewing operations.

**Brewing.** Brewers performed a two-part fermentation with the Gose beer. The first stage of fermentation was a lactic acid fermentation performed with *Lactobacillus* cultures for souring purposes. Once the lactic acid fermentation was complete, wort was transferred to a cylindroconical vessel and fermented with yeast previously used in an American IPA style beer at a fermentation temperature of 20 °C (68 °F). Yeast was pitched at $1.57 \times 10^9$ cells/mL with a viability of approximately 86%. After the lactic fermentation, starting gravity for the wort was 9.1 °Plato (°P). Prior to adding peach juice into the wort, gravity was 1.8 °P. Approximately 85 gallons of peach juice was pumped into the fermentation vessel aseptically and circulated through the tank to mix with roughly 540 gallons of beer product. Terminal gravity after adding peach juice was 1.6 °P and terminal pH was 3.26. Once fermentation was completed, beer was cold
crashed by flooding 2 °C (36 °F) water through fermenter jackets to force yeast to fall out of suspension.

**Analysis: color.** Color was analyzed as is detailed in Chapter 3 on color analysis.

**Analysis: volatiles.** Volatile analysis for this chapter used the same conditions as those described in Chapter 3, including the use of Equation 3-3 to calculate the concentration of identified volatile compounds in ppb. The only difference being that beer brewed with peach juice and beer brewed without peach juice were used for samples along with plain peach juice harvested and processed in the 2019 season. To collect beer samples, kegs were de-pressurized and beer was poured from kegs into clean 200 mL (0.05 gal) Pyrex bottles. These samples were then filtered in identical conditions to the peach juice samples in Chapter 3. Sample handling and runs were completed with those same methods described.

1.3.5 Statistical Analysis

**Yeast Fermentable Extract.** YFE data was analyzed using a single factor Analysis of Variance (ANOVA) test on Microsoft Excel to compare all fermentable sugar data from the triplicate runs performed at \( \alpha = 0.05 \).

**Fermentation kinetics runs.** Miniature fermentation assays and 10 L (0.3 gal) fermentations were compared individually to their respective repeat runs and also compared to each other using an F-Test \( (\alpha = 0.05) \) (GraphPad Prism version 8.2.0 for Windows, GraphPad Software, La Jolla, CA USA) with the rate of sugar consumption and the cells in suspension over time.
**Color analysis: spectrophotometry.** An F-test ($\alpha = 0.05$) using the same software described in the kinetics runs analysis above was performed on data from pre- and post-fermentation samples of both juice types. The purpose of this test was to analyze the differences between the presence of red color before and after fermentation in the peach juice samples.

**Color analysis: colorimetry.** Data was analyzed using the same parameters described in Chapter 3 for colorimetry.

**Volatile analysis.** Data was analyzed using the same parameters described for volatiles in Chapter 3.

### 1.4 Results

#### 1.4.1 Yeast Fermentable Extract (YFE)

Triplicate YFE experiments were performed and analyzed. Figure 4-3 displays the initial $^\circ$Brix values before fermentation and final apparent $^\circ$Brix values after fermentation for blanched juice from 2018 thinned and unthinned peaches.

As discussed in Chapter 3 results, thinned peach juice has significantly higher amounts of sugar than unthinned peach juice. During the YFE trials, thinned juice had an average starting $^\circ$Brix of 10.25 while unthinned juice started at 9.55 $^\circ$Brix. At the end of fermentation, thinned and unthinned juice residual sugar contents of 2.57 $^\circ$Brix and 2.53 $^\circ$Brix, respectively. Using Equation 4-5, the amount of fermentable sugars for blanched thinned and unthinned peach juice were calculated to be 75.0 ± 1.6% and 73.5 ± 2.6%, respectively. A single factor ANOVA on the triplicate data from each calculated percent fermentable sugar concluded that the percent of fermentable sugars in thinned and unthinned peach juice are not significantly different ($p > 0.05$).
Brix values between thinned and unthinned juices, after being completely fermented, are also not significantly different (p > 0.05).

Figure 4-3. Apparent °Brix before and after fermentation using the Wort-5 method of Yeast Fermentable Extract analysis. Different letters for the same juice type indicate significant difference between starting and final apparent °Brix (p < 0.05).

1.4.2 Fermentation Kinetics

Figure 4-4 displays the fermentation kinetics of thinned and unthinned peach juices at 21 °C (70 °F) overlayed on top of each other for ease of comparison. The figure appears to show that thinned and unthinned juices ferment at similar rates even though they are shown reaching terminal gravity, a peak in yeast cells in suspension measured via absorbance at 600 nm, and a plateau in ethanol content approximately at slightly different times. This is likely due to the thinned juice beginning fermentation at a higher °Brix, due to its higher sugar content. Using Equation 4-6B, the rate of fermentation at the midpoint of the sigmoidal models of thinned juice (16.5 hours) and unthinned juice (21.7 hours) were calculated to be 0.38 apparent °Brix/hour and 0.52
apparent °Brix/hour, respectively. However, an F-test performed on the logistic density attenuation curve concluded that the fermentation rates of thinned and unthinned juices are not statistically different (p > 0.05).

Figure 4-4. Comparing fermentation kinetics of thinned and unthinned fruit juices at 21 °C (70 °F). Dotted lines with triangles represent unthinned juice data and solid lines with circles represent thinned juice data.

1.4.3 Color Change During Fermentation

L*, a*, and b* values for each sample can be found in Table 4.1. Results indicated that the amount of lightness, L*, after fermentation increased slightly in both thinned and unthinned samples. Thinned juice showed an L* value of 89.78 which increased to 93.83 after fermentation while unthinned juice showed an L* value of 88.27 and increased to 91.67. Both types of juice and fermented juice exhibit similar lightness. The largest visual difference between samples before and after fermentation was the presence of a pink-red color before fermentation that was degraded by the time fermentation was complete. Colorimeter data shows this phenomenon as a* readings,
positive being more red and negative being more green, decreased. Both thinned and unthinned juice start out with a relatively positive a* value, 5.76 and 6.89, respectively. Their fermented juices both read slightly negative a* values with fermented thinned juice reading -0.92 and unthinned reading -0.48. This denotes an absence of red color. For both juice types, b* values, positive being more yellow and negative being more blue, positive b* values increased slightly once fermented. Thinned samples were slightly lower (8.68) than unthinned samples (9.94) indicating that they were slightly less yellow than unthinned samples.

![Sample vials of thinned and unthinned juice before and after fermentation](image)

**Figure 4-5.** Sample vials of thinned and unthinned juice before and after fermentation

<table>
<thead>
<tr>
<th>Tree treatment</th>
<th>Juice sample type</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thinned</td>
<td>Unfermented</td>
<td>89.78&lt;sup&gt;A&lt;/sup&gt;</td>
<td>5.76&lt;sup&gt;A&lt;/sup&gt;</td>
<td>8.29&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Fermented</td>
<td>93.83&lt;sup&gt;B&lt;/sup&gt;</td>
<td>-0.92&lt;sup&gt;B&lt;/sup&gt;</td>
<td>8.68&lt;sup&gt;B&lt;/sup&gt;</td>
</tr>
<tr>
<td>Unthinned</td>
<td>Unfermented</td>
<td>88.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.89&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.44&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Fermented</td>
<td>91.67&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.48&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.94&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

N = 3 for each sample; different letters in each grouped column (thinned or unthinned) indicate significant difference (p < 0.05), uppercased and lowercased letters represent comparisons within thinned and unthinned groups, respectively, as thinned and unthinned data were not compared – only unfermented and fermented juice samples within thinned and unthinned groups

**1.4.4 First Magnitude Brewing Company Industrial Beer Case Study**

**Informal in-brewery taste assessments.** The final beer product was informally evaluated in-house by brewers at First Magnitude Brewing Company. The finished product was described as “clean (no phenolic, estery, or diacetyl aromatics) kettle-sour
ale with subtle coriander and fruity/peach aromatics…mid-palate and finish are very dry, thin, and puckeringly sour – lactic acid dominant.” It was also noted that casual taste panels in-house indicated that panelists had difficulty detecting any peach flavor. Lactose was added to the beer product (16 kg or 36 lbs of powdered lactose dissolved into 30 L or 8 gal of hot water, then mixed into 2044 L or 540 gal of beer) in an effort to enhance peach volatiles. After lactose addition, flavor was described as “clean…with a distinct fresh peach top note and retronasal flavor” and “lactic, moderately sour mid-palate with a more balanced finish…in terms of malty-sweet/lactic-sour…slightly fuller body” by a head brewer. All comments were gathered by personal communication with First Magnitude head brewer Eric Dreyer, M.S.

**Colorimetric analysis.** Raw colorimeter data in L*, a*, and b* readings can be found in Table 4.2. Lightness, L* where 0 is black and 100 is white, is highest in peach beer, 89.03, with non-peach beer being slightly less light, 88.47, and peach juice being much less light than both beer samples, 85.47. All samples analyzed for L* were significantly different (p < 0.05). The largest visual difference between samples pink-red color in peach juice, a* of 11.79, compared to both beer samples, -0.47 for non-peach beer and 0.38 for peach beer. Colorimeter data shows this phenomenon as a* readings, positive being more red and negative being more green, was low in peach beer, 0.38, where non-peach beer was completely devoid of red color, - 0.47. All samples analyzed for a* were significantly different (p < 0.05). For b* values, positive being more yellow and negative being more blue, all samples had positive b* values. Non-peach beer had the highest amount of yellow, 18.73, peach beer having the second highest amount,
16.88, and peach juice being significantly less yellow than both beer samples, 9.03. All samples analyzed for b* were significantly different (p < 0.05).

<table>
<thead>
<tr>
<th>Sample</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-peach beer</td>
<td>88.47</td>
<td>-0.47</td>
<td>18.73</td>
</tr>
<tr>
<td>Peach beer</td>
<td>89.03</td>
<td>0.38</td>
<td>16.88</td>
</tr>
<tr>
<td>Peach juice</td>
<td>85.47</td>
<td>11.79</td>
<td>9.03</td>
</tr>
</tbody>
</table>

N = 3 for each sample; different letters in each column indicate significant difference (p < 0.05)

**Volatile analysis.** Volatile concentrations can be found in Table 4.3 for peach beer, non-peach beer, and peach juice. The three highest volatiles in the beer samples, ethyl acetate, isoamyl alcohol, and ethanol.

Overall, 15 volatile compounds were identified in peach juice, 24 in peach beer, and 25 in non-peach beer. However, four of these compounds do not have identifiable odor thresholds (acetoin, butyl-vinyl-ether, ethylhexanol, 4-penten-1-ol).

Non-peach beer and peach juice exclusively had 2-octenol (fresh, green) and hexanal (fruity, green grass) while peach beer interestingly did not have either of these compounds. Peach beer, non-peach beer, and peach juice all contained acetone (fruity, sweet, mint-like), acetaldehyde (fruity), ethyl acetate (fruity, pineapple), and ethanol. Of the 15 volatile compounds found in peach juice, the four compounds with the highest concentration detected in peach juice were also found in either one or both beer samples (not including ethanol). The highest concentrated compounds above their reported odor thresholds were ethyl acetate (fruity) which was found in both beer samples, acetaldehyde (fruity) which was found in both beer samples, acetone (fruity) which was found in both beer samples, hexanal (green, fatty) which was found in only non-peach beer. This provides evidence to the inability for recognizable peach volatiles to be detected in the peach Gose beer during the First Magnitude brewing trial.
However, it is unclear why hexanal was found in both the peach juice and the non-peach beer, but not detected at all in the beer that contained peach juice.

Table 4-3. Volatile compounds identified in Gose beer with peach juice, Gose beer with no peach juice added, and in peach juice alone

<table>
<thead>
<tr>
<th>Compound</th>
<th>Concentration (ppb)</th>
<th>Odor attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isoamyl alcohol</td>
<td>128675</td>
<td>146896</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>47803</td>
<td>44975[^A] 5099[^B]</td>
</tr>
<tr>
<td>Isobutyl alcohol</td>
<td>19758</td>
<td>23455</td>
</tr>
<tr>
<td>1-butanol, 3-methyl, acetate</td>
<td>6855</td>
<td>5709</td>
</tr>
<tr>
<td>1-propanol</td>
<td>4008</td>
<td>3971</td>
</tr>
<tr>
<td>Linalool</td>
<td>3951</td>
<td>4733</td>
</tr>
<tr>
<td>Ethyl octanoate</td>
<td>3946</td>
<td>3363</td>
</tr>
<tr>
<td>Ethyl hexanoate</td>
<td>2475</td>
<td>1419</td>
</tr>
<tr>
<td>Phenylethyl alcohol</td>
<td>2116</td>
<td>2659</td>
</tr>
<tr>
<td>Ethyl lactate</td>
<td>1850</td>
<td>2839</td>
</tr>
<tr>
<td>2-Phenylethyl acetate</td>
<td>754</td>
<td>673</td>
</tr>
<tr>
<td>1-butanol</td>
<td>513</td>
<td>433</td>
</tr>
<tr>
<td>Ethyl decanoate</td>
<td>428</td>
<td>406</td>
</tr>
<tr>
<td>4-penten-1-ol</td>
<td>330</td>
<td>408</td>
</tr>
<tr>
<td>Ethyl butyrate</td>
<td>282</td>
<td>187</td>
</tr>
<tr>
<td>Ethyl-9-decenoate</td>
<td>248</td>
<td>-</td>
</tr>
<tr>
<td>Camphor</td>
<td>200</td>
<td>242</td>
</tr>
<tr>
<td>1-hexanol</td>
<td>187</td>
<td>260</td>
</tr>
<tr>
<td>Acetone</td>
<td>165</td>
<td>186[^A] 397[^B]</td>
</tr>
<tr>
<td>1-ocatol</td>
<td>88</td>
<td>2508</td>
</tr>
<tr>
<td>1-pentanol</td>
<td>70</td>
<td>88</td>
</tr>
<tr>
<td>Furfuryl alcohol</td>
<td>56</td>
<td>61</td>
</tr>
<tr>
<td>2-propanol, 2-methyl</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Acetoin</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2-heptanal</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Butane, 1-(ethenyloxy)-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Acetic acid, methyl ester</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2,3-butandiedione</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2-octenol</td>
<td>-</td>
<td>188[^A] 105[^A]</td>
</tr>
<tr>
<td>Pentanal</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1-hexanol, 2-ethyl</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Benzaldehydedehyde</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hexanal</td>
<td>-</td>
<td>992[^A] 1246[^A]</td>
</tr>
</tbody>
</table>

Volatile compounds in the table are listed loosely from highest to lowest average concentration. N = 2 for each sample; a hyphen “-“ means not detected for that sample; n/a means no odor threshold for that compound; different letters in the same row indicated significant difference (p < 0.05) between bolded compounds. Only Non-Peach Beer and Peach Juice were analyzed for significant differences. Odor attribute information is from (The National Library of Medicine, 2019)^1, (The Good Scents Company, 2018)^2, or (Burdock, 2010)^3
1.5 Discussion

1.5.1 Comparing Thinned and Unthinned ‘UFSun’

Fermentable sugar content and fermentation kinetics. Although thinned and unthinned ‘UFSun’ peaches have different amounts of sugar in their respective juices per findings in Chapter 3, their fermentable sugar content is not significantly different (p > 0.05). Thinned juice had a fermentable sugar content, or yeast fermentable extract (YFE) of 75.0 ±1.6% while unthinned juice fermented 73.5 ±2.6% of sugars present. This negates the hypothesis that thinned peach juice would have a higher amount of fermentable sugars. Both types of juice ferment the same way in terms of sugar reduction and alcohol content. The fermentation rates of thinned and unthinned peach juice are not significantly different (p > 0.05). The rate of fermentation at the midpoint of sigmoidal models for thinned juice (16.5 hours) and unthinned juice (21.7 hours) apparent ºBrix attenuation model were calculated to be 0.38 apparent ºBrix/hour and 0.52 apparent ºBrix/hour, respectively.

Color change during fermentation. Spectrophotometric and colorimetric readings both showed the decrease and absence of red color by the end of fermentation. It was also clear that unthinned peach juice had a higher amount of red color than thinned peach juice. Spectrophotometric readings do not denote the value of this red color in relation to what the human eye sees, but colorimetric measurements reported that thinned and unthinned peach juice had an a* value of 5.76 and 6.89, respectively. Their fermented juices both read slightly negative a* values with fermented thinned juice reading -0.92 and unthinned reading -0.48, denoting a complete absence of red color by the end of fermentation.
1.5.2 Industrial Beer Case Study

The creation of a beer product with peach juice was successful and reported to be well received by beer patrons at First Magnitude.

Color analysis. When analyzed for color, peach beer had a miniscule amount of red color, but not enough for the naked eye to detect while non-peach beer was devoid of red color. Peach juice had a significantly high amount of red color, a* of 11.79, compared to a low a* in peach beer, 0.38, while non-peach beer was completely devoid of red color, - 0.47. It is likely that red color was both diluted in the peach beer and also degraded by the end of the beer fermentation, even though it was added into the fermentation broth late in the fermentation process.

Volatile analysis. On the nose, brewers reported difficulty in sensing any recognizable peach volatiles in the peach Gose beer. Volatile analysis via GC-MS concluded that the Gose style beer has similar volatile compounds to peach juice from ‘UFSun’ peaches (processed in 2019) with the four most highly concentrated volatile compounds identified in the peach juice (not including ethanol) also being detected in the plain Gose beer, but at much higher levels than found in peach juice. These volatile compounds included ethyl acetate (fruity) which was found in both beer samples, acetaldehyde (fruity) which was found in both beer samples, acetone (fruity) which was found in both beer samples, hexanal (green, fatty) which was found in only non-peach beer. This allows for the conclusion that the Gose sour style beer is not appropriate for showcasing peach flavor and volatile compounds, but other beer types that do not have the same volatile characteristics as peach juice may be a better fit for a peach beer.
1.6 Conclusions

Fermentation is recognized as a means of preservation and creation of value-added and nutritionally fortified foods and beverages. A growing trend exists in the incorporation of underutilized crops in fermented products, especially for unique flavors and other organoleptic properties. Florida peaches served as a promising option to serve as a novel fermented product or adjunct for fermented products. Looking at the fermentation of juice from thinned and unthinned peaches, the fermentable sugar content was not significantly different (p > 0.05) even though thinned juice had a higher °Brix. There were also no kinetic differences in the fermentation rates of thinned and unthinned juice in respect to density attenuation (p > 0.05). Throughout the fermentation of blanched juice, red color dissipated and was not present by the end of fermentation – finishing as a pale-yellow beverage. It is believed that the red color of the juice is attributed to suspended fiber particles that are broken down and destroyed by yeast during fermentation, although more research needs to be done to conclude this point.

When ‘UFSun’ peach juice was used as a brewing adjunct in a commercial ‘Gose’ style sour, ‘peach’ aroma and flavor was difficult to detect by brewers. GC/MS purge and trap volatile analysis compared between Gose beer with no added peach juice and fresh peach juice showed similar chemical profiles with many overlapping fruity compounds, specifically ethyl acetate (fruity). Gose beer with no added peach juice had a concentration of ethyl acetate nearly nine times higher than fresh peach juice. The similarities prevented standard peach characteristics from being detectable, showing that this particular style of beer, a Gose sour, is not an appropriate style to highlight peach juice specifically. However, in the commercial beer trial peach juice was
successfully utilized as a brewing adjunct and able to create a product that appeared to be successfully sold and enjoyed by patrons.
CHAPTER 5
FINAL DISCUSSION

1.1 Conclusions

The primary hypothesis of this study, that thinned and unthinned ‘UFSun’ peaches have the same processing, juice, and fermentation characteristics, has been proven false.

In terms of processing, thinned peaches yielded more juice overall than unthinned peaches under the same pressing and processing conditions ($p > 0.05$), possibly due to thinned peaches being significantly larger in size than unthinned peaches (Sarkhosh, 2018). The yield of juice from whole peach flesh is highly dependent on the processing conditions which include degree of heat treatment, the type of press used (ie. hydraulic press, bladder press), and the amount of total pressure applied to the peaches.

When analyzing sugar content of juice between heat-treated thinned and unthinned peaches, thinned juice had a significantly higher ($p < 0.05$) sugar content by weight (10.3 ºBrix) in relation to unthinned juice (9.7 ºBrix). However, thinned and unthinned peach juice were not significantly different ($p > 0.05$) when comparing percent of fermentable sugars, 75.0 ±1.6% w/w and 73.5 ±2.6% w/w, and in their rates of fermentation with respect to density attenuation ($p < 0.05$).

During fermentation, the pink-red color of peach juice ($a^*_{\text{thinned}}$ being 5.76 and $a^*_{\text{unthinned}}$ being 6.89) degraded completely by the end of fermentation ($a^*_{\text{fermented thinned}}$ being -0.92 and $a^*_{\text{fermented unthinned}}$ being -0.48). Fermented thinned and unthinned peach juice ended fermentation with a pale-yellow color, having $b^*$ values of 8.68 and 9.94, respectively.
Thinned and unthinned ‘UFSun’ peach fruit juices had similar volatile profiles overall, aside from acetophenone (sweet, almond) being unique to unthinned juice. However, the largest differences between compounds found in both juices were that unthinned juice had a concentration of 2-heptenal (green, fatty) over two times higher, a concentration of almond-like compound benzaldehyde three times higher, and a concentration of fruity acetone volatiles nearly two times higher than those of thinned juice. The volatile profile of thinned juice showed concentrations of ethyl acetate (fruity) nearly three times higher than that of unthinned juice. Thinned juice had a concentration of benzaldehyde lower than the aroma threshold for the compound. The higher concentration of fruity ethyl acetate in thinned fruit is possibly due to a larger amount of flesh, providing a higher ratio of pit-to-flesh, and therefore diluting the aroma characteristics of the peach pit.

High-quality fruit will yield a larger profit than low-quality fruit when sold at the fresh market price. However, it is economically clear that additional profits can be made from processing low-quality peach fruit (ie. small in size, cannot be sold at fresh market value) into juice, but analysis is highly dependent on assumptions provided. With a competitive sale price on peach juice from unthinned trees or late-season thinned peaches, farmers and growers can still make additional profit if late-season peaches are unable to be sold at high-grade fresh market price.

The hypothesis that Florida peach juice would perform well as a fermentation adjunct was tested in a trial brew at First Magnitude Brewing Company in Gainesville, FL where a traditional Gose beer was flavored with peach juice from thinned-tree, tree-ripened fruit that was processed in May 2019. The peach Gose beer was antidotally well
received and completely sold out, proving that juice from ‘UFSun’ can be utilized in brewing applications in a commercial setting. Color analysis via colorimetry testing results reported a lack of red color in the resulting peach beer. The peach juice utilized in the peach beer had a higher amount of red color, $a^*$ of 11.79, compared to a low $a^*$ in peach beer, 0.38, while non-peach beer was completely devoid of red color, -0.47. It is likely that red color was both diluted in the peach beer and degraded by the end of the beer fermentation, even though it was added into the fermentation broth late in the fermentation process. An observation by head brewers reported difficulty in detecting recognizable peach flavor and volatiles in the final product. When comparing the peach juice, peach beer, and non-peach beer, results indicated that the four most highly concentrated compounds identified in peach juice, not including ethanol, (ethyl acetate, hexanal, and acetone) were also identified in the non-peach juice containing beer. These four volatile compounds were detected at higher concentrations in the non-peach beer than were detected in the peach juice alone. This supports the claim made by First Magnitude brewers that characteristic peach volatiles were difficult to detect in the final peach beer product. Due to this, the Gose sour style beer is not an appropriate beer to showcase peach juice, particularly ‘UFSun’ peach juice, as the plain beer has primary volatile compounds in common with the peach juice, not allowing for a detection of characteristic “peach” aromas.

Overall, this research has been able to meet each objective and answer each hypothesis made. It can be concluded that thinned and unthinned peach fruits are different in sugar content, size, and juice yield – thinned being the champion of each category. Although they have different sugar contents, thinned and unthinned peaches
do have the same amount of fermentable sugars. The use of peach juice as an adjunct in brewing applications is plausible and able to create satisfactory products for profit turn. In terms of volatile content, the use of peach juice as an additive in beer fermentations is not recommended, especially specific styles of sour beers, due to the fact that peach volatiles and prepared Gose beer volatiles were similar which lead the beer aromas to overpower and blend with the peach aroma compounds. Economically, it is clear that continuing the practice of thinning peach trees is in the best interest of the farmers and growers in the industry, especially in Florida. However, with consistent working relationships with juice and beverage companies, as well as local breweries and wineries, processing ‘UFSun’ and other Florida peach varieties into juice or nectar could provide an additional revenue stream for farmers and growers looking to expand their profit base.

### 1.2 Future Work and Applications

Although this project extended its reach in the comparison between thinned and unthinned ‘UFSun’, there are a plethora of additional research avenues to evaluate. As ‘UFSun’ and other low-chill cultivar research continues, performing annual juice processing experiments to assess seasonal variability could prove useful to farmers and growers interested in that unit operation. Sensory testing on peach beverage products using Florida peaches would be an interesting way to judge consumer acceptance of alternative applications to fresh market sales.
LIST OF REFERENCES


doi:10.1080/00021369.1966.10858659
BIOGRAPHICAL SKETCH

Savanna Jo Curtis hails from Ionia, Michigan. After graduating from Ionia High School as Salutatorian in 2012, she attended Michigan Technological University in Houghton, Michigan for her undergraduate education. Upon graduation in the Spring of 2017, Savanna obtained her Bachelor of Science in chemical engineering, minor in bioprocess engineering, and Pavlis Honor’s College certificate of global technological leadership. Savanna graduated with her Master of Science in food science and human nutrition at the University of Florida (UF) in Gainesville, Florida in the December of 2019. She could not be more thankful for the education and memories that UF and Gainesville have given her.