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DISCOVERY

The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences

Vol. 19

Fall 2018

*Double-Cover Issue
Featuring:
Horticulture-Food Science
Research Collaboration*

U of A
DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

 **UNIVERSITY OF
ARKANSAS**
DALE BUMPERS COLLEGE
OF AGRICULTURAL, FOOD
& LIFE SCIENCES

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Double Cover: Features the collaborative research projects between the Departments of Horticulture and Food Science of Mary Siebenmorgen et al., which looks at the ripeness attributes of Arkansas-grown peaches and nectarines, and Aubrey Dunteman et al., which evaluates consumer sensory and compositional attributes of Arkansas-grown fresh-market blackberries. Photo credits: Paula Siebenmorgen (peaches) and Brendan Krause (blackberries).

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Letter from the Dean

This is my first year as Dean of the Dale Bumpers College of Agricultural, Food and Life Sciences, and it has been a pleasure, but not a surprise, to learn about the outstanding work of our students as they show the passion they have for their various fields of interest.

Our purpose is to serve the people of our state, across the country and around the world. With our innovative programs, expert faculty and outstanding students, we will continue to do everything we can to improve the quality of life for everyone as our students become scientists, innovators, managers, policy makers, entrepreneurs, and most importantly—difference makers.

Our students are preparing for successful careers, conducting impactful research, and sharing knowledge. The *Discovery* undergraduate research journal highlights the efforts of just a few of our talented students and the research they have completed. Many of our outstanding faculty work with them to produce what you see here.

We encourage undergraduate research by awarding undergraduate research grants. Our students compete for research and travel grants awarded by the University of Arkansas Honors College and the Arkansas Department of Higher Education Student Undergraduate Research Fellowship (SURF) grants program.

Projects may be designed to meet requirements for an honors project in the Bumpers College Honors Program. One of our goals is to prepare students to be responsible leaders with strong communication skills and problem-solving abilities. Inside this issue you will find studies from across the college that highlight and exemplify those qualities in our student researchers.

Congratulations to the student authors on completing this project. And thank you to the faculty mentors and editors who worked with them to make this collection possible. As a college, we are pleased and proud to present their results and findings in a citable publication as a service to them and our readers.



Deacue Fields

A handwritten signature in black ink that reads "Deacue Fields". The signature is stylized and cursive.

Deacue Fields, Dean
Dale Bumpers College of Agricultural, Food
and Life Sciences

A Message from the Department Head of Horticulture and Food Science

As Department Head for Horticulture and Interim Department Head for Food Science, I get to see the interdisciplinary nature and research that happens between these two departments from both sides. The research articles about blackberries by Dunteman et. al. and peaches/nectarines by Siebenmorgen et. al. published in this issue of *Discovery* exemplify the collaboration between the two department's faculty and students. It also highlights experiences that students can gain at an off-campus research station.

Students at research stations can study a wide range of subjects. For instance, at the University of Arkansas System Division of Agriculture's Fruit Research Station at Clarksville, students have the opportunity to be involved in fruit breeding directly or indirectly through projects in the areas of sensory science, postharvest physiology, and fruit production techniques among many other research topics.

Both Aubrey's and Mary's projects, although very different in the scope of their research, will lead to improved cultivars of blackberries, peaches and nectarines and ultimately consumer enjoyment of the fruit. These studies highlight the intersection of horticulture and food science and the broad range of experiences that come from interdisciplinary research.

Collaborations such as these give students a broad view of cultivar improvement leading to a greater understanding of the food system. In addition, the students get to interact with faculty across disciplines with mentoring from a group of faculty also enriching their experiences and knowledge. In summary, these two research experiences highlight the potential of many research experiences that students can enjoy across Bumpers College.



Wayne Mackay

A handwritten signature in black ink that reads "Wayne A. Mackay". The signature is written in a cursive, flowing style.

Wayne Mackay, Professor and Department Head, Horticulture; Interim Department Head Food Science.

New for Discovery: ScholarWorks@UARK

Journal management and submissions are now facilitated through ScholarWorks@UARK, the institutional research repository for the University of Arkansas:

<https://scholarworks.uark.edu/discoverymag/>

Bumpers College undergraduate student research now reaches a worldwide audience via this powerful database, with its extensive search engine and analytics, and ease in downloading individual articles, we are already seeing the results. Here's a peek at readership distribution across the globe and most popular *Discovery* articles by download in recent months.



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Nutraceutical snack prepared from sprouted rough rice and green gram and its physicochemical properties and in vitro glycemic index

Meet the Student-Author



Rachel Browder

I am from Frisco, Texas. After graduating from high school in 2015, I attended Collin Community College, before transferring to the University of Arkansas in the summer 2016, where I graduated in May 2018 with a major in Food Science. While most of my time spent at the University was dedicated to my honors research project, I also had the opportunity to be part of the Food Science Club and two national food product development competitions. As a student, I interned with the food and beverage industry and helped develop protein beverage stabilization solutions with a special emphasis on protein hydrocolloid interactions. After graduation, I plan on working in the food and beverage industry in research and development, product development, or technical sales. I would like to thank Dr. Navam Hettiarachchy for serving as my honors mentor and advisor for this project and I wish to recognize her tireless persistent efforts and motivation, and Dr. Han-Seok Seo and Dr. Nick Anthony for serving as committee members. I would also like to acknowledge Dr. Ronny Horax for his help and technical assistance in completing this project.

Research at a Glance

- This study aims to develop a healthy and nutritional snack chip from germinated rice and germinated green gram (a combination that will have the 8 essential amino acids in right proportions) for health and wellness.
- Rough rice and green gram were germinated and then their nutritional composition, anti-nutrient components, and glycemic index (indicator of how foods affect blood sugar level) were evaluated. A lower glycemic index was observed.
- These chips are low in carbohydrates, rich in protein and nutrients, and may make a healthy alternative snack food.



Rachel holding a snack chip made from cranberry for a national product development competition.

Undergraduate Research Articles

Nutraceutical snack prepared from sprouted rough rice and green gram and its physicochemical properties and in vitro glycemic index

*Rachel M. Browder**, *Navam Hettiarachchy*[†], and *Ronny Horax*[§]

Abstract

Snacks make up a large portion of U.S. meals, but unhealthy snacks are a concern that can lead to being overweight or obese. Healthy alternatives can be germinated cereals and legumes, which undergo chemical compositional changes producing smaller size molecules for easier digestion and generate bioactives that can have health benefits. The objective of this research was to develop a healthy, nutritional snack chip from germinated rough rice and germinated green gram that will be easier for the body to digest, and provide much higher protein than conventional chips or crackers with low glycemic index. Rough rice and green gram were germinated for 1, 3, 5, and 7 days. There was a significant difference ($P < 0.05$) in the changes in nutrient composition, antinutrient (trypsin inhibitor and lipoxygenases) activities, and physical properties: increase of protein and lipids, decrease of starch, change in water activity, decrease in trypsin inhibitor, lipoxygenase-1, and lipoxygenase-3 activity, and decrease in glycemic index. The results indicate that snack chips prepared using sprouted rough rice and green gram are a healthier alternative to the snack chips currently on the market and have the potential for marketing and an impact on wellness.

* Rachel M. Browder is a May 2018 Honors program graduate with a major in Food Science.

† Navam Hettiarachchy, faculty mentor, University Professor, Department of Food Science.

§ Ronny Horax, Post-Doctoral Research Associate, Department of Food Science.

Introduction

People all over the world are changing their eating habits; many people are no longer eating the traditional three meals a day. For example, in the United States in 2016, snacks represented more than 50% of all eating and drinking occasions (Hartman, 2016). Many consumers are also demanding healthier and better-quality snacks. Frequent consumption of unhealthy snacks may be causing consumers to become overweight or obese and have other health issues, and it may be why Arkansas' obesity rate ranks 6th nationally in 2015 (Segal et al., 2016). In North America, 66% of consumers eat snacks to provide nutrition (Nielson, 2014). Roughly two-thirds of consumers prefer snacks with low sugar, salt, fat, and calories and beneficial ingredients: fiber, protein, and whole grains (Nielson, 2014).

Germinating cereal grains is a way to reduce its anti-nutrients—such as lipoxigenase and trypsin inhibitor—which interfere with the human body's ability to digest grains (Moongngarm and Saetung, 2010). During germination, the chemical composition of the grains changes drastically due to their biochemical activity, which provides essential compounds and energy for the formation of seedlings (Tortayeva et al., 2014). However, cereal grains do not form a complete nutritional protein due to the absence of limiting essential amino acid lysine; but by combining a cereal grain with a legume—such as soybean, lentils, or green gram—they can form a complete protein.

Lysine and methionine, which are the limiting essential amino acids in rice and green gram, respectively, supplement each other and make a complete protein. Not only is the protein content of germinated rough rice higher than the protein content of brown rice, but the lipid content, γ -aminobutyric acid (GABA), dietary fiber, vitamin E, niacin, thiamine, and magnesium, and lysine have been reported to be higher than those of brown rice due to germination increasing free sugars, crude protein, many essential amino acids including lysine (the limiting amino acid in rice), isoleucine, leucine, phenylalanine, threonine and valine, total free amino acids, and some bioactive substances (Tortayeva et al., 2014; Kim et al., 2012; Lee et al., 2007; Moongngarm and Saetung, 2010; Saman et al., 2008).

The anti-nutrients in green gram greatly limit its protein digestibility and nutritional benefits, but this limitation can be overcome by germinating the green gram (Frias et al., 2005; Mubarak, 2005). Many studies have shown a significant nutritive improvement in amino acids, digestible protein, carbohydrates, sugars, and antioxidants such as vitamins C and E in germinated green gram (Frias et al., 2005; Fernandez-Orozco et al., 2008; Mubarak, 2005; Tang et al., 2014). Also, studies have shown that germinated green gram has lower amounts of

anti-nutrients such as trypsin inhibitors and reduced or eliminated amounts of indigestible factors such as phytic acid, stachyose, and raffinose (Fernandez-Orozco et al., 2008; Mubarak, 2005; Tang et al., 2014).

Since 2016, more than 50% of the U.S. daily meals are made up of snacks, and the snacking industry sells hundreds of billions of dollars of snacks each year (Hartman, 2016; Nielson, 2014). The purpose of this study was to develop a healthy and nutritional snack chip from germinated, Arkansas produced rough rice and germinated green gram that will be easier for the body to digest, much higher in protein than regular chips or crackers, low on the glycemic index, that still meets consumer demand for more nutritious and innovative snacks using local ingredients.

Materials and Methods

Rough rice was provided by Riceland Foods (Stuttgart, Arkansas, U.S.) and green gram seeds, baking soda, and salt were food grade purchased from a local store. All chemicals (analytical grade) for analysis were procured from VWR (Radnor, Pennsylvania, U.S.), Sigma Aldrich (St. Louis, Missouri, U.S.), and Fisher Scientific (Pittsburgh, Pennsylvania, U.S.).

Germination, Drying, Dehulling, and Milling

Rough rice (RR) (~100 g) was weighed, rinsed with deionized (DI) water, placed in a water bath (34 °C), and soaked for approximately 24 h in order to soften the hull. The softened RR was placed on the paper hydrated towels in a tray, sprayed with DI water, covered with a tray, and incubated in a humidifier (Hotpack, Philadelphia, Pennsylvania, U.S.) (27 °C, 100% humidity). The RR was germinated for a period of 7 days and germinated sprouts were collected at 1, 3, 5, and 7 days. The green gram (GG) underwent the same process as the RR, except for the soaking time was 2 h. The soaked GG (SGG) then went through the same procedure as the germinated RR (GRR).

The soaked RR (SRR), SGG, GRR, or germinated GG (GGG) in a metal tray were dried in an oven (Equatherm 267-914, Curtin Matheson Scientific Inc., Houston, Texas, U.S.) at 37 °C (~24 h), cooled, and refrigerated.

The sprouts were removed from GRR before being dehulled (STHU-35S Rice Huller, U-SHINE). The dehulled GRR combined with its sprouts and GGG were separately ground using a mill (Ika Universal Mill M20, Tekmar Company, Mason, Ohio, U.S.), and sifted through a 60-mesh strainer to obtain uniform particle size flours.

Moisture Content of the Flours

Moisture contents of the sample flours were determined using the method approved by the AACC International (2000). Samples of the flours were placed in the

oven at 110 °C (~5 h) to constant weight. The percentage of moisture content was calculated as:

$$\text{Moisture (\%)} = \frac{\text{evaporated water weight}}{\text{sample weight}} \times 100$$

Protein Content of the Flours

The Kjeldahl Method 46-13.01 (AACC, 1990) was used to determine the protein. Each flour (~0.5 g) was digested with concentrated sulfuric acid, H₂SO₄ (5 mL), with Kjeldahl catalyst (0.5 tablet) using a digestion heater unit (Labconco 60011, Labconco Corp., Kansas City, Missouri, U.S.). Sodium hydroxide (NaOH) (40% w/v, 10 mL) was added to the digested sample (5.0 mL) and distilled using a Distillation unit (Labconco Corp., Kansas City, Missouri, U.S.) and 4% boric acid, H₃BO₃ containing methyl red/bromocresol green as an indicator was used as the receiver solution. The released ammonia, NH₃, was titrated with hydrochloric acid, HCl, and the nitrogen content was calculated as:

% Nitrogen =

$$\frac{\text{vol. HCl (mL)} \times \text{M of HCl} \times \text{atom. wt. nitrogen} \times \text{F}}{\text{Mass dried flour (mg)}} \times 100$$

% Protein =

nitrogen-to-protein (N:P) conversion factor × % Nitrogen

where F was a dilution factor of 5 and the N:P conversion factors of 6.25 for RR (Tortayeva et al., 2014) and 6.40 for GG (Estrella, 2008) were used to calculate the percent protein content.

Lipids Content of the Flours

The soxhlet extraction procedure by the AACC (1990) was followed. A flour sample (2.0 g) in a Whatman filter paper No. 4 was placed in a thimble and a soxhlet apparatus was used for extracting the lipids. The petroleum ether that contained soluble lipid in the soxhlet was distilled to remove the petroleum ether. The lipid content was calculated using the equation:

$$\text{Lipid (\%)} = \frac{\text{lipid weight}}{\text{sample weight}} \times 100$$

Starch Content of the Flours

The AACC Method 76-13.01 (AACC International, 1999) was used to determine the starch content. A flour sample (~100 mg) was placed in a centrifuge tube with aqueous ethanol (80% v/v, 10 mL) and incubated for 5 min (80–85 °C). The tube was centrifuged for 10 min at 1800 g (~3000 rpm) on a bench centrifuge. Then, the supernatant was discarded. The pellet was resuspended in aqueous ethanol (80%v/v, 10 mL), stirred on a vor-

tex mixer, centrifuged as above, and the supernatant was carefully removed. Thermostable α-amylase (3 mL; 100 U/mL in sodium acetate buffer, pH 5.0) was added and incubated in the water bath (100 °C) for 6 min with stirring. The tube was then placed in the water bath at 50 °C, amyloglucosidase (0.1 mL, 3300 U/mL) was added, vortexed, and incubated for 30 min (50 °C). The contents of the tube were transferred into a 100-mL volumetric flask and made up to 100 ml with distilled water. An aliquot of this solution was centrifuged at 3000 rpm (~1800 g) for 10 min. The clear, undiluted supernatant was used for the assay. Duplicate aliquots (0.1 mL) of the supernatant were transferred to glass test tubes, GOPOD (glucose oxidase/peroxidase) Reagent (3.0 mL) was added to each tube. D-glucose standard solution (0.1 mL; 1 mg D-glucose/mL) and DI water (0.1 mL) were included as standard and blank, respectively. The tubes were incubated for 30 min (50 °C). The absorbance for each sample and the standard was read at 510 nm against the blank. The percent Starch was calculated using the following formula:

$$\begin{aligned} \text{Starch (\%)} &= \Delta_A \times F \times \frac{FV}{0.1} \times \frac{1}{1000} \times \frac{100}{W} \times \frac{162}{180} \\ &= \Delta_A \times \frac{F}{W} \times FV \times 0.9 \end{aligned}$$

where ΔA is the absorbance against the blank, F is the conversion from absorbance to μg, FV is 100 mL, and W is the weight in mg of the flour analyzed.

Water Activity of the Flours

A dew point water activity meter (AquaLab) was used to determined water activity (aw). The aw was automatically measured and recorded.

Lipoxygenase and Trypsin Inhibitor Activity of the Flours

The method described by Zhu et al. (1996) with modifications was used to determine lipoxygenase activity. A linoleic acid stock solution was prepared (140 mg), and Tween 20 (140 mg), DI water (8 mL), and NaOH (0.55 mL, 1.0 N) were added and diluted to 50 mL using DI water. The solution was diluted 1:40 with sodium borate buffer (0.2 M, pH 9.0) for the lipoxygenase-1 activity and with sodium phosphate buffer (0.2 M, pH 6.5) for lipoxygenase-3 activity determination. Dispersions containing sodium phosphate buffer (50 mL) and flour (1.0 g) were incubated (25 °C, 2 h) and centrifuged at 15,000 g for 30 min (20 °C; Model J2-21, Beckman). The mixture of the supernatant (50 and 10 μL for lipoxygenase-1 and -3 activity determination, respectively) and substrate (2.5 mL) after 5 min incubation was transferred into a cuvette for absorbance reading using a UV-1601 spectrophotometer

(Shimadzu Model UV-1601, Kyoto, Japan) at ambient temperature and at the wavelength of 234 nm and 280 nm for lipoxygenase-1 and -3 activity determination, respectively. The non-germinated RR (NGRR) and non-germinated GG (NGGG) controls were set as 100%. The lipoxygenase-1 and -3 activities were calculated using the following formula:

$$\text{Lipoxygenase activity (\%)} = \frac{\text{absorbance sample}}{\text{absorbance control}} \times 100$$

Using AACC (1990) method 22-40.01 with modifications, 60-mesh flour (1 g) was added to NaOH (50 mL, 0.01 N, pH 8.4) and stirred for 3 hours. The sample dispersion (1.4 mL) was diluted to 2 mL with DI water. Trypsin solution (4 mg, Porcine pancreas, Sigma, in 200 mL 0.001 M HCl) (2 mL) was added into the sample solution and placed in the water bath at 37 °C. To start the reaction, 5 mL of BAPA (Na-benzoyl-DL-arginine 4-nitroanilide hydrochloride) solution (40 mg BAPA in 100 mL 0.05 M Tris buffer containing CaCl₂, pH 8.2) was added. The reaction was stopped after 10 min by adding acetic acid solution (1 mL, 30% v/v), and the absorbance was measured at 410 nm using the spectrophotometer at ambient temperature. The NGRR flour (NGRRF) and NGGG flour (NGGGF) controls were set as 100%. The trypsin inhibitor activity was calculated using the following equation:

$$\text{trypsin inhibitor activity (\%)} = \frac{\text{absorbance sample}}{\text{absorbance control}} \times 100$$

In vitro Glycemic Index of the Flours

The protocol described by Goñi et al. (1997) was used to determine the in vitro Glycemic Index (GI). Flour samples (50 mg) in KCl-HCl buffer (10 mL, pH 1.5) were added with pepsin solution (0.2 mL; 0.1 g pepsin from porcine gastric mucosa per mL KCl-HCl buffer) and incubated in the water bath (40 °C) for 1 h for protein digestion, and then diluted to 25 mL with Tris-Maleate buffer (pH 6.9). Then, α-amylase (5 mL; from *Aspergillus oryzae* in Tris-Maleate buffer containing 2.6 UI) was added and incubated in the water bath (37 °C). Every 30 min up to 3 h, an aliquot (1 mL) was taken and placed in the water bath (100 °C) for 10 min. Then, sodium acetate buffer (3 mL, 0.4 M, pH 4.75) and amyloglucosidase (*Aspergillus niger*, 60 μL) were added and diluted to 5 mL with DI water. The samples were centrifuged at 20,000 g for 5 min, and the glucose content of the supernatants was determined using a glucose assay kit (Sigma, St. Louis, Missouri, U.S.) with the spectrophotometer at 540 nm. Using 0.9 as the conversion factor from glucose to starch, the starch digestion rate was calculated as the percentage

of starch hydrolyzed at different times. The area under the hydrolysis curve was determined. The hydrolysis index (HI) was calculated as a relation between the area under the sample curve and the area under the reference curve (white bread). GI was calculated as:

$$\text{GI} = 0.862 * \text{HI} + 8.198.$$

Preparation of Snack Chips

The moisture, protein, lipids, and starch content, the trypsin inhibitor and lipoxygenase-1 and lipoxygenase-3 activity, and GI were analyzed to determine the optimal germinating conditions of RR and GG for preparing the snack chips. Based on the results above, the 5-day GRRF and 5-day GGGF were considered as the optimized germinating time and picked to prepare the sample snack chips (SSC).

The experimental designs for the SSC were confined to using the 5-day GRRF and 5-day GGGF at a 1:1 ratio (flour to water), baking soda (1.2%), and salt (1%) to form a dough, kneading, pressing and stretching until well mixed and passed through a pasta maker until ~1 mm. The flattened dough was cut into 2 × 2 cm chips and baked in an oven at 149 °C for 8 mins. The above process was repeated for the NGRRF and NGGGF, which served as the control snack chips (CSC).

Statistical Analysis

Statistical analysis of the protein, moisture, and lipids content, water activity, lipoxygenases inhibitor activity, trypsin inhibitor activity, color, textural properties, and shelf-life study was performed using a one-way analysis of variance utilizing JMP 13 Pro 2016 (SAS Institute Inc., Cary, N.C.). The values represented the means ± the standard deviation (SD) of each sample in triplicate. When a significant difference ($P < 0.05$) occurred, Student's *t*-test was performed to compare the means and differences considered significantly different ($P < 0.05$).

Results and Discussions

Proximate Nutrient Composition of the Rough Rice Flours

There is a significant difference ($P < 0.05$) in the proximate nutrient composition of GRRF, protein (%), $P < 0.0001$, lipids (%), $P < 0.0001$, and starch (%), $P = 0.0002$ along with moisture (%), $P < 0.0001$ and water activity ($P < 0.0001$); all results are compared to the NGRRF (Table 1). By day 5 and day 7, the protein content (%) had increased to 10.8% and 11.6%. The increase in protein content may be due to microbial endophytes, which have a symbiotic relationship with RR seeds and their emerging radicles and coleoptiles and may influence the

growth development in their hosts through fixation of N₂ (Hardoim et al., 2012). The increase in lipids could be due to the synthesis of structural lipids occurring during germination (Ching, 1972). The decrease in the starch content could be due to the starch being hydrolyzed into free sugar, which could then be used as fuel for other metabolic functions. The moisture content of the 5-day GRRF (7.7%) and 7-day GRRF (7.3%) decreased by approximately 37% and 40%, respectively, and were significantly different ($P < 0.05$) compared to the NGRRF. The lower water activity relates to a higher amount of water being bound.

Proximate Nutrient Composition of the Green Gram Flours

The proximate nutrient composition of GGF, protein ($P < 0.0001$), lipids ($P < 0.0001$), and starch ($P < 0.0001$) along with moisture ($P < 0.0001$) and water activity ($P < 0.0001$) had an overall significant difference ($P < 0.05$); all results are compared to the NGGGF (Table 2). This increase in protein throughout the duration of the sprouting period could be due to N-fixing rhizobia bacteria, which hold a symbiotic relationship with the green gram seeds and sprouts, produces NH₃ for the sprouts, which the sprouts use to manufacture protein and other nitro-

Table 1. Proximate nutrient composition (on dry weight basis) of non-germinated (NGRRF), soaked (SRRF), and germinated rough rice flours (GRRF).

Germination	Protein (g/100 g)	Lipids (g/100 g)	Starch (g/100g)	Moisture (g/100g)	Water Activity
0-day (NGRRF) [†]	10.2 ± 0.3 c [¶]	0.77 ± 0.20 c	26.1 ± 0.9 a	12.2 ± 0.2 a	0.51 ± 0.01 a
0-day (SRRF) [‡]	9.6 ± 0.0 e	1.09 ± 0.10 c	25.9 ± 0.1a	8.4 ± 0.1 c	0.34 ± 0.02 e
1-day [§]	9.8 ± 0.1de	1.10 ± 0.17 c	25.2 ± 0.1a	8.4 ± 0.2 c	0.39 ± 0.01 d
3-day [§]	10.1 ± 0.2 cd	2.00 ± 0.43 b	24.5 ± 1.5 a	9.1 ± 0.1 b	0.46 ± 0.01 b
5-day [§]	10.8 ± 0.2 b	2.30 ± 0.09 b	22.6 ± 1.4 b	7.7 ± 0.1 d	0.41 ± 0.01 c
7-day [§]	11.6 ± 0.0 a	2.73 ± 0.20 a	21.2 ± 0.6 b	7.3 ± 0.1 e	0.45 ± 0.00 b
<i>P</i> -value	< 0.0001	< 0.0001	0.0002	< 0.0001	< 0.0001

[†] NGRRF = control non-germinated rough rice without soaking before being processed into flour.

[‡] SRRF = control non-germinated rough rice underwent soaking [water bath (34 °C), 24 h] before being processed into flour.

[§] Rough rice underwent soaking [water bath (34 °C), 24 hr] before being germinated and then processed into flour (GRRF).

[¶] Values are mean ± SD of triplicate analysis. Mean values followed by different letters in the same column are significantly different ($P < 0.05$).

Table 2. Proximate nutrient composition (on dry weight basis) of non-germinated (NGGGF), soaked (SGGF), and germinated green gram flours (GGGF).

Germination	Protein (g/100 g)	Lipids (g/100 g)	Starch (g/100 g)	Moisture (g/100 g)	Water Activity
0-day (NGGGF) [†]	27.6 ± 0.2 d [¶]	0.84 ± 0.23 d	52.4 ± 1.1 a	10.4 ± 0.2 d	0.51 ± 0.00 a
0-day (SGGF) [‡]	28.9 ± 0.2 cd	0.94 ± 0.07 d	50.7 ± 1.5 a	8.6 ± 0.1 e	0.42 ± 0.01 e
1-day [§]	29.3 ± 0.3 cd	1.13 ± 0.17 d	47.9 ± 1.6 b	8.9 ± 0.1 e	0.48 ± 0.00 c
3-day [§]	32.7 ± 0.5 bc	2.36 ± 0.10 c	44.8 ± 0.7 c	11.1 ± 0.0 c	0.44 ± 0.00 d
5-day [§]	39.2 ± 0.1 b	2.90 ± 0.19 b	40.0 ± 1.1 d	14.1 ± 0.2 b	0.50 ± 0.00 b
7-day [§]	44.3 ± 0.3 a	5.68 ± 0.15 a	35.7 ± 0.7 e	12.2 ± 0.2 a	0.45 ± 0.00 d
<i>P</i> -value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

[†] NGGGF = control non-germinated green gram without soaking before being processed into flour.

[‡] SGGF = control non-germinated green gram underwent soaking [water bath (34 °C), 2 h] before being processed into flour.

[§] Green gram underwent soaking [water bath (34 °C), 2 h] before being germinated and then processed into flour (GGGF).

[¶] Values are mean ± SD of triplicate analysis. Mean values followed by different letters in the same column are significantly different ($P < 0.05$).

gen-containing components, and takes photosynthesis-derived sugars and other nutritional factors from the sprouts (Glover and Lindemann, 2015). The lipids content in the GGGF increased over time starting with the 0-day soaked GGGF (0.94%) and showed an increase to 5.68%. As with the GRRF, the increase of lipids could be due to the increase of structural lipids during germination (Ching, 1972). The starch content decreased throughout the 7-day germination process, possibly as the radicles and plumules converted the starch into energy. As with the GRRF, the decrease in the starch content could be due to the starch being hydrolyzed into free sugar, which could then be used as fuel for other metabolic functions. The moisture content of the 5-day and 7-day green gram flour was significantly different ($P < 0.05$). The water activity of the GGGF were all lower than the NGGGF (0.51), with the lowest being the SGGF (0.42).

Antinutrients of the Rough Rice Flours

In the RRF, the trypsin inhibitor activity (% , $P < 0.0001$), lipoxigenase-1 activity (% , $P < 0.0001$), and lipoxigenase-3 activity (% , $P < 0.0001$) had an overall significant difference ($P < 0.05$); all results are compared to the NGRRF, which was set at 100% (Table 3). Throughout the germination process of the RR, the trypsin inhibitor activity decreased from the NGRRF (100%) to 90.3% at the 7th day of germination. The 7-day GRRF had the lowest percentage of lipoxigenase-1 activity (62.6%) and lipoxigenase-3 activity (56.1%) followed by the 5-day GRRF (76.9% and 74.6% for lipoxigenase-1 and lipoxigenase-3 respectively). The decrease in the trypsin in-

hibitor, lipoxigenase-1, and lipoxigenase-3 could be due to these enzymes, which are proteins, being hydrolyzed during germination. A decrease in trypsin inhibitor and lipoxigenase activities in germinated flours has the advantage of better digestion of proteins by the gastrointestinal system and preventing lipid oxidation (rancidity) in flours.

Antinutrients of the Green Gram Flours

The trypsin inhibitor activity (% , $P < 0.0001$), lipoxigenase-1 activity (% , $P < 0.0001$), and lipoxigenase-3 activity (% , $P < 0.0001$) of GGF had an overall significant difference ($P < 0.05$); all results are compared to the NGGGF, which was set at 100% (Table 4). The greatest percentage in decrease of the lipoxigenase-1 and lipoxigenase-3 activities occurred in the 7-day GGGF (78.9% and 63.6% for lipoxigenase-1 and lipoxigenase-3 respectively) followed by the 5-day GGGF (85.5% and 76.6% for lipoxigenase-1 and lipoxigenase-3 respectively). As with the GRRF, the decrease in the trypsin inhibitor, lipoxigenase-1, and lipoxigenase-3 could be due to these enzymes being hydrolyzed during germination.

In vitro Glycemic Index of the Flours

The rough rice flour samples had overall significantly different ($P < 0.0001$) in vitro GI (Table 5). The in vitro GI among the NGRRF (49.46), the SRRF (49.32), and the 1-day GRRF (48.81) was not significantly different ($P > 0.05$). However, the in vitro GI of the 7-day GRRF (46.48) was lower and significantly different ($P < 0.05$) from the in vitro GI of the NGRRF, SRRF, 1-day GRRF, 3-day

Table 3. Trypsin inhibitor and lipoxigenase-1 and -3 activities (%) of non-germinated (NGRRF), soaked (SRRF), and germinated rough rice flours (GRRF).

Germination	Trypsin Inhibitor Activity	Lipoxigenase-1 Activity	Lipoxigenase-3 Activity
0-day (NGRRF) [†]	100.0 ± 0.0 a [¶]	100.0 ± 0.0 a	100.0 ± 0.0 a
0-day (SRRF) [‡]	99.3 ± 0.6 ab	94.3 ± 1.6 b	95.7 ± 2.1 a
1-day [§]	99.2 ± 0.2 bc	92.4 ± 1.6 bc	92.4 ± 4.5 a
3-day [§]	97.1 ± 0.1 c	89.9 ± 1.3 c	83.1 ± 1.3 b
5-day [§]	94.8 ± 0.8 d	76.9 ± 1.6 d	74.6 ± 1.0 c
7-day [§]	90.3 ± 0.7 e	62.6 ± 1.7 e	56.1 ± 3.2 d
<i>P</i> -value	< 0.0001	< 0.0001	< 0.0001

[†] NGRRF = control non-germinated rough rice without soaking before being processed into flour.

[‡] SRRF = control non-germinated rough rice underwent soaking [water bath (34 °C), 24 h] before being processed into flour.

[§] Rough rice underwent soaking [water bath (34 °C), 24 h] before being germinated and then processed into flour (GRRF).

[¶] Values are mean ± SD of triplicate analysis. Mean values followed by different letters in the same column are significantly different ($P < 0.05$).

GRRF, and 5-day GRRF. The 5-day GRRF had the second lowest in vitro GI and was significantly different ($P < 0.05$) than the other rough rice flour samples. A lower GI indicates a slower digestion of the food.

The green gram flour samples had overall significantly different ($P < 0.0001$) in vitro GI (Table 5). The in vitro GI of the 7-day GGGF was lower and significantly different ($P < 0.05$) than the in vitro GI of the NGGGF, the SGGF,

the 1-day GGGF, the 3-day GGGF, and 5-day GGGF. The 5-day GGGF had the second lowest in vitro GI and was significantly different ($P < 0.05$) than the other green gram flour samples.

In vitro Glycemic Index of the Snack Chips

The control snack chips (CSC) were found to have a higher in vitro GI (48.48 ± 0.17) and were significantly

Table 4. Trypsin inhibitor and lipoxygenase-1 and -3 Activities (%) of non-germinated (NGGGF), soaked (SGGF), and germinated green gram flours (GGGF).

Germination	Trypsin Inhibitor Activity (g/100g)	Lipoxygenase-1 Activity (g/100g)	Lipoxygenase-3 Activity (g/100g)
0 day (NGGGF) [†]	100.0 ± 0.0 a [¶]	100.0 ± 0.0 a	100.0 ± 0.0 a
0 day (SGGF) [‡]	98.8 ± 0.4 ab	98.9 ± 1.7 a	98.7 ± 3.2 a
1-day [§]	97.8 ± 1.4 b	97.6 ± 1.6 a	95.8 ± 2.9 a
3-day [§]	91.9 ± 1.3 c	91.2 ± 1.7 b	90.0 ± 3.7 b
5-day [§]	85.1 ± 0.8 d	85.5 ± 0.5 c	76.6 ± 3.1 c
7-day [§]	76.1 ± 1.1 e	78.9 ± 2.0 d	63.6 ± 2.8 d
<i>P</i> -value	< 0.0001	< 0.0001	< 0.0001

[†] NGGGF = control non-germinated green gram without soaking before being processed into flour.

[‡] SGGF = control non-germinated green gram underwent soaking [water bath (34 °C), 2 h] before being processed into flour (GGGF).

[§] Green gram underwent soaking [water bath (34 °C), 2 h] before being germinated.

[¶] Values are mean ± SD of triplicate analysis. Mean values followed by different letters in the same column are significantly different ($P < 0.05$).

Table 5. In vitro glycemic index of non-germinated (NGRRF), soaked (SRRF), and germinated rough rice flours (GRRF) and non-germinated (NGGGF), soaked (SGGF), and germinated green gram flours (GGGF).

Germination	Rough Rice Flour [†]	Green Gram Flour [†]
0 day (NGF) [‡]	49.46 ± 0.39 a [#]	47.38 ± 0.13 a
0 day (SF) [§]	49.32 ± 0.59 a	47.55 ± 0.17 a
1-day [¶]	48.81 ± 0.33 ab	47.44 ± 0.26 a
3-day [¶]	48.22 ± 0.27 b	46.67 ± 0.14 b
5-day [¶]	47.57 ± 0.15 c	46.22 ± 0.24 c
7-day [¶]	46.48 ± 0.32 d	45.44 ± 0.08 d
<i>P</i> -value	< 0.0001	< 0.0001

[†] *In vitro* Glycemic Index (GI) of the flours were calculated using the best-curve fit equations and white bread (94.61 ± 0.00) as a reference.

[‡] NGF = control non-germinated rough rice and green gram without soaking before being processed into flour.

[§] SF = control non-germinated rough rice underwent soaking [water bath (34 °C), 24 h] and green gram underwent soaking [water bath (34 °C), 2 h] before being processed into flour.

[¶] Rough rice underwent soaking [water bath (34 °C), 24 h] and green gram underwent soaking [water bath (34 °C), 2 h] before being germinated and then processed into flour (GRRF, GGGF).

[#] Values are mean ± SD of triplicate analysis. Mean values followed by different letters in the same column are significantly different ($P < 0.05$).

different ($P = 0.0004$) than the sample snack chips (SSC), whose in vitro GI was 46.64 ± 0.22 . This was expected since the 5-day GRRF and GGGF used to make the SSC had a lower in vitro GI than the NGRRF and NGGGF used to make the CSC. Based on its GI value, this snack chip produced from germinated mung bean and rice could be considered as a low-GI food which is classified for the foods with the IG value of <55 (Famakin et al., 2016).

Conclusions

The protein (%) and lipids (%) content of germinated rough rice and germinated green gram was significantly different ($P < 0.0001$) overall and increased over the germination period. The overall antinutrients, trypsin inhibitor, lipoxygenase-1, and lipoxygenase-3 activity (%), in both the germinated rough rice and green gram were significantly different ($P < 0.0001$) and decreased over the germination period. The in vitro glycemic index of the rough rice and green gram flours changed and was significantly different ($P < 0.0001$) over the length of the germination time. The increase in the nutritional value of the GRRF and the GGGF compared to the RRF and the GGF control give optimal conditions to provide consumers with healthier and better-quality snacks. It also can fulfill consumers' needs for snacks with increased protein and use local ingredients as well as additional health benefits. So, the use of GRRF and GGGF can be used in the growing snack market and meet the consumers demands for more nutritious and innovative snacks using local ingredients.

Acknowledgements

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Evaluating consumer sensory and compositional attributes of Arkansas-grown fresh-market blackberries

Meet the Student-Author

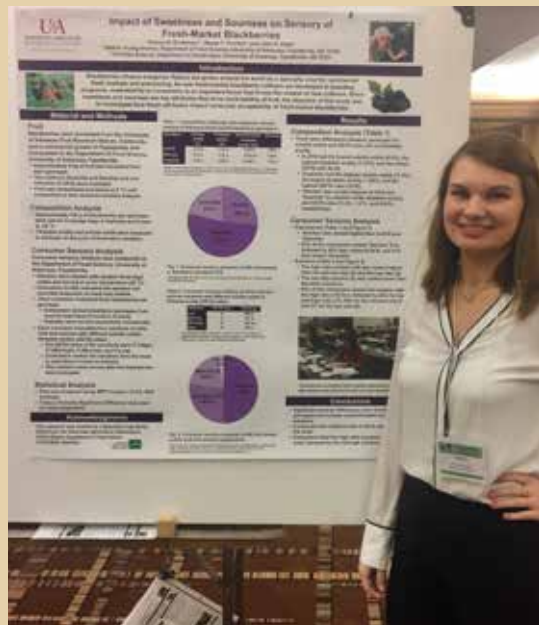


Aubrey Dunteman

Research at a Glance

- Consumers appear to prefer fresh-market blackberries with a medium-level balance of sweetness to sourness.
- Consumers are not strictly sweet-lovers or sour-lovers when it comes to fresh-market blackberries.
- The fresh-market blackberry, “Natchez”, was the most liked of the three blackberries tested and it had a medium level of perceived sweetness.

My interest in food began at a young age, and I pursued it by taking all the cooking and nutrition courses offered in high school. I knew I wanted to study one of the sciences, though I was conflicted about which one. It wasn't until I began looking at colleges that I became aware of the Food Science track; once I looked into it, I immediately knew it was what I wanted to study. I chose to attend the University of Arkansas because the Food Science Department made what I considered to be a giant university feel more personal. The opportunity to do research allowed me to gain invaluable experience in the field of Food Science, collaborate with the Horticulture department, and compete in the Southern Region American Society for Horticultural Sciences (ASHS) poster and oral competitions. My goals after graduating in 2019 are to pursue a master's degree in Food Science and then a career in Food Science focusing on either fruit or sensory science. Thank you to Dr. Renee Threlfall for mentoring me throughout this research experience, to Dr. John Clark for allowing me to conduct research on his blackberry genotypes, and to Dr. Luke Howard and Dr. Margaret Worthington for being part of my Honors committee and giving feedback on my work. Finally, thank you to Molly Felts for teaching me numerous analytical techniques essential for my research.



Aubrey presenting her poster at the Southern Region ASHS annual conference. She won second place in the undergraduate student oral presentation competition.

Evaluating consumer sensory and compositional attributes of Arkansas-grown fresh-market blackberries

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and *Margaret L. Worthington*[‡]

Abstract

Blackberries are grown worldwide for commercial fresh markets. Three Arkansas-grown fresh-market blackberry genotypes (Natchez, Ouachita, and A-2418) were evaluated for consumer sensory and compositional attributes at the University of Arkansas System Division of Agriculture's Food Science Department, Fayetteville. The compositional attributes of the blackberries were within an acceptable range for commercial markets (soluble solids = 8.20-11.90%, pH = 2.79-3.18, titratable acidity = 1.09-1.32%). In terms of soluble solids-to-titratable acidity ratio, Ouachita (10.92) had the highest ratio, followed by Natchez (8.93) and A-2418 (6.25). A consumer sensory panel (n = 80) evaluated fresh-market blackberry attributes using a 9-point hedonic scale for overall impression, overall flavor, sweetness, and sourness and a 5-point Just-About-Right scale for sweetness and sourness. The participants also ranked the blackberries in order of overall liking from most to least liked. For overall impression, overall flavor, and sweetness, Natchez scored higher than Ouachita and A-2418, but the panelists did not detect differences in sourness. In terms of Just-About-Right for sweetness, 64% of consumers scored Natchez Just-about-Right, followed by Ouachita (39%) and A-2418 (34%). Whereas, 42% percent found A-2418 "Too Sour", followed by Ouachita (33%) and Natchez (25%). In terms of ranking the blackberries, Natchez was the most liked blackberry followed by Ouachita and A-2418. When looking only at blackberries ranked first, 53% of consumers ranked Natchez as their most-liked berry, compared to A-2418 (26%) and Ouachita (21%). The results from this research suggested that fresh-market blackberries with medium-level sweetness-to-sourness ratios were preferred though more consumers than expected preferred the blackberries with the more extreme ratios.

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Introduction

Blackberry plants (*Rubus L. hybrids*) are grown around the world, and the fruit is used in both fresh and processing markets. Blackberry cultivars produce berries with variations in traits such as size, shape, color, and flavor, along with many other new and unique attributes. Fruit with high antioxidant capacity, including blackberries, have gained consumer interest due to health-conferring qualities such as the potential to prevent illness and reduce the effects of aging (Lewers et al., 2010). With the growing demand for healthy foods, the significance of identifying consumers' perceptions of fresh-market blackberries has increased as their impression impacts the commercial marketability of the fruit. According to the United States Department of Agriculture (USDA, 2017), 1620 ha of blackberries were harvested in the United States with ~2,740,000 kg for fresh market with a value at \$5 million, though these data are primarily from Oregon. Fresh-market blackberry production in the top three caneberry producing counties in California was valued at \$78.7 million in 2016 (Monterey County, California Agricultural Commissioner, 2017).

There are major differences among fresh-market blackberry cultivars for traits that may affect consumer perception and acceptance. Traits that may affect the perceptions that consumers have of fresh-market blackberries differ between genotypes in part due to blackberry genetics. Over 60 blackberry cultivars have been released since 1985 from breeding programs in the United States. One of the largest public blackberry breeding programs is conducted at the University of Arkansas System Division of Agriculture (Clark, 1999; Clark and Finn, 2008). As new blackberry cultivars are developed in breeding programs, the need to identify their marketing potential is important as it can influence whether or not the genotypes will be released. Attributes of blackberries that may affect marketability include:

- sweetness, tartness, flavor, color, firmness, and seediness,

as they are important to consumers (Clark et al., 2007; Clark and Finn, 2008; Hall et al., 2002). Sweetness, in particular, has been shown to affect marketability and sales of fresh-market blackberries in the United Kingdom (Barnett, 2007).

The marketability of food is driven by consumers' acceptance, and one of the key factors determining acceptability is the sensory characteristics a food imparts (Laaksonen et al., 2016). Sensory analysis can be used to identify various qualities of fruit that may be difficult to quantify and analyze. There are typically four types of sensory analysis panels:

- highly trained experts, trained laboratory panels, laboratory acceptance panels, and large consumer panels (Poste et al., 1991).

The type of sensory panel used is dependent on the information researchers need about the product. Large consumer panels (typically more than 75 people for statistical validity) can be used to determine the consumer's reaction to the product evaluated (Poste et al., 1991).

Sensory analysis can be implemented to gain consumers' opinions on the five basic taste attributes of a food:

- sweetness, sourness, saltiness, bitterness, and umami.

An important sensory evaluation focus in fruit is how the flavor is affected by the sweetness (percent sugar measured by soluble solids) and sourness (percent acid measured by titratable acidity), and the sweetness and sourness relationship (soluble solids-to-titratable acidity ratio) (Crisosto and Crisosto, 2005; Laaksonen et al., 2016; Poll, 1981; Sandell et al., 2008). Blackberries tend to have a lower soluble solids-to-titratable acidity ratio when compared to other fruits. Previous research has shown an average ratio of 6.7 for blackberries (de Souza et al., 2014), while muscadine grapes have an optimal ratio of 30 (Flora, 1979). Since different fruits have different levels of soluble solids-to-titratable acidity ratios, determining levels that consumers prefer in blackberries helps to identify which blackberry genotypes may succeed commercially.

By investigating consumers' perception of fresh-market blackberries, we can determine if consumers prefer blackberries with high sourness/low sweetness, low sourness/high sweetness, or a balance of sourness and sweetness. In addition, this information on fresh-market blackberries will provide insight for the University of Arkansas System Division of Agriculture's blackberry breeding program to identify desirable traits. The objective of this study was to determine the potential of various fresh-market blackberry genotypes (two cultivars and an advanced selection) by identifying sensory and compositional attributes that impact marketability.

Materials and Methods

Fruit. The blackberries were harvested prior to 10:00 AM on 29 June 2017 at the shiny-black stage of ripeness. The advanced breeding selection, A-2418, was harvested from the University of Arkansas System Division of Agriculture's Fruit Research Station in Clarksville, Arkansas, and the blackberry cultivars, Natchez and Ouachita, were harvested from a commercial grower in Fayetteville, Arkansas. These genotypes were selected because they had a wide range of sourness and sweetness levels. Blackberries were hand-harvested directly into 240-g clamshells and

placed into chilled coolers. After harvest was complete, the blackberries were transported to the Department of Food Science in Fayetteville, Arkansas. Fruit was then randomly sorted into new clamshells for the compositional and sensory analysis.

Compositional Analysis. Three blackberries were placed in a plastic zip-type freezer bag in triplicate for each genotype and stored at -20 °C until analysis. Juice was extracted from each three-berry sample by thawing and squeezing the juice of the berries through cheesecloth. The compositional attributes of the juice included:

- soluble solids, pH, titratable acidity, and the soluble solids-to-titratable acidity ratio.

Compositional analysis of the juice was done at room temperature (24 °C). The soluble solids percent (%) was measured using a Bausch & Lomb Abbe Mark II refractometer (Scientific Instrument, Keene, New Hampshire). The pH and titratable acidity were measured using an 877 Titrimo Plus titration and pH unit (Metrohm AG, Herisau, Switzerland) standardized to pH 2.0, 4.0, 7.0, and 10.0 buffers prior to analysis. The titratable acidity (%) was determined by diluting ~6 g of juice with 50 mL of deionized, degassed water, and titrating with 0.1 N sodium hydroxide to an endpoint of pH 8.2.

Consumer Sensory Analysis. Blackberries for consumer sensory analysis were stored at 2 °C overnight for sensory analysis the day following harvest. Prior to serving, the blackberries were rinsed and allowed to air dry until they reached room temperature (24 °C). Eighty consumers were recruited to participate in the study. Consumer responses were collected via hard-copy ballots. Three berries per genotype were placed on a plate labeled with a random three-digit code. Each genotype was served sequentially, monodically (one at a time) with a random serving order. Consumers were instructed to cleanse their palates between samples with water and unsalted crackers. Consumers evaluated the blackberries using a 9-point hedonic

scale for overall impression, overall flavor, sweetness, and sourness:

- 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like extremely

and a 5-point Just-About-Right scale for sweetness and sourness

- 1 = much too little; 2 = too little; 3 = just about right; 4 = too much; 5 = much too much

Blackberry genotypes were then ranked for overall liking from most to least

- 1 = most liked, 3 = least liked

Statistical Analysis. After harvest, the fruit from each genotype was randomized for sensory and compositional analysis. Statistical analysis was conducted with JMP® v. 12.0 (SAS Institute, Inc., Cary, North Carolina). A univariate analysis of variance (ANOVA) was used to determine the significance of main factors. Tukey's honest significant difference (HSD) test was used for mean separation ($P \leq 0.05$) of compositional data, while least significant difference (LSD) was used for mean separation ($P \leq 0.05$) of sensory data. Compositional attributes were evaluated in triplicate, and sensory analysis was done in duplicate.

Results and Discussion

Compositional Analysis. The compositional analysis consisted of measuring the pH, titratable acidity, and soluble solids of the blackberry genotypes, as well as calculating the soluble solids-to-titratable acidity ratio (Table 1). The soluble solids ranged from 8.20% to 11.90%, the pH values ranged from 2.79 to 3.18, and the titratable acidity ranged from 1.09% to 1.32% (Table 1). Ranges similar to these have been shown in other blackberry research where

Table 1. Compositional attributes of Arkansas-grown blackberry genotypes, 2017.

Genotype [†]	Soluble solids (%)	pH	Titratable acidity (%) [‡]	Soluble solids-to-titratable acidity ratio
A-2418	8.20 b [§]	3.03 a	1.32 a	6.25 b
Natchez	11.20 a	2.79 b	1.27 a	8.93 ab
Ouachita	11.90 a	3.18 a	1.09 a	10.92 a
<i>P-Value</i>	<0.0005	0.0010	0.1400	0.0069

[†] Three berries per genotype were evaluated in triplicate.

[‡] Calculated as percent citric acid.

[§] Means with different letter(s) for each attribute are significantly different ($P < 0.05$) using Tukey's honestly significant difference.

pH ranged from 2.5 to 4.1, titratable acidity ranged from 1.26% to 1.54%, and soluble solids ranged from 6.19% to 11.11% (de Souza et al., 2014). The soluble solids content of A-2418 (8.20%) was significantly lower than Natchez (11.20%) and Ouachita (11.90%), and Natchez and Ouachita soluble solids were not significantly different. Natchez was the most acidic genotype with a pH at 2.79 and was significantly lower than the other genotypes. Ouachita with a pH of 3.18 was not significantly different from A-2418 with a pH of 3.03. There were no significant differences found among the genotypes for titratable acidity. In general, the goal of the University of Arkansas' blackberry breeding program is to release blackberries with a titratable acidity not greater than 1% (J.R. Clark, pers. comm.); however, all three genotypes had an average titratable acidity over 1%.

As noted earlier, the soluble solids-to-titratable acidity ratio plays a large part in the consumer acceptance of certain fruits (Crisosto and Crisosto, 2005; Laaksonen et al., 2016; Poll, 1981; Sandell et al., 2008). The ratio is the balance between the two attributes that helps determine perceived sweetness and sourness of the fruit (Threlfall et al., 2016; Poll, 1981). Ouachita (10.92) had the highest ratio, indicating a higher perceived sweetness and was significantly higher than A-2418 (6.25), which had the lowest ratio, indicating a lower perceived sweetness. Natchez had a ratio of 8.93 and was not significantly different from either Ouachita or A-2418 (Table 1). These results were consistent with other research where Natchez had a similar soluble solids-to-titratable acidity ratio of 9.0, though inconsistent for Ouachita, which had a lower ratio than Natchez at 7.3 (Segantini et al., 2017). In previous research in Arkansas, Ouachita had the highest soluble solids-to-titratable acidity ratio, followed by Natchez, and then A-2418 (15.4, 11.8, and 6.9, respectively) (Segantini et al., 2017), indicating that the fruit harvested for our study was less ripe.

Consumer Sensory Analysis. All of the sensory attributes evaluated were scored an average between 5 and

8, where 5 is “neither like nor dislike” and 8 is “like very much”. Natchez was liked significantly more than the other genotypes for overall impression, overall flavor, and sweetness (7.3, 7.4, and 6.9, respectively; Table 2). The panelists did not detect differences in sourness in the genotypes, though sourness ranged from 5.6 to 6.5. Overall impression, overall flavor, and overall sweetness were not significantly different between A-2418 and Ouachita.

The Just-About-Right data from the 5-point scale was collapsed to a 3-point scale (“Not Sweet/Sour”, Just-About-Right, and “Too Sweet/Sour”) for analysis. According to Threlfall et al. (2016), an ideal product would be rated Just-About-Right by at least 75% of consumers, as well as that any attributes with over 15% in the “Too Low” or “Too Much” selections should be reexamined. The consumer analysis in this study did not identify any of the genotypes as ideal with 75% for Just-About-Right, but Natchez had Just-About-Right values in the mid-sixties (Figs. 1 and 2). In terms of the sweetness attribute, 64% of consumers scored Natchez Just-About-Right, followed by Ouachita and A-2418, rated 39% and 34%, respectively (Fig. 1). Only 4–5% of the consumers identified the genotypes in this study as “Too Sweet”. About 56% and 61% of the consumers found Ouachita and A-2418 “Not Sweet”, respectively. Regarding the sourness attribute, 66% of the consumers scored Natchez as Just-About-Right, followed by Ouachita (50%) and A-2418 (44%) (Fig. 2). Consumers found these genotypes “Not Sour” (9–17%). Forty-two percent of the consumers found A-2418 “Too Sour”, followed by Ouachita (33%) and Natchez (25%).

Lastly, consumers ranked their liking of the three blackberry genotypes from their most to least liked. Natchez was ranked higher than Ouachita and A-2418, but Ouachita and A-2418 were not ranked significantly different from one another (Fig. 3). When looking only at the blackberries ranked first by the consumers, 53% of consumers ranked Natchez as their most liked berry, compared to 26% and 21% selecting A-2418 and Ouachita, respectively (Fig. 4).

Table 2. Consumer sensory attributes of Arkansas-grown blackberry genotypes evaluated on a 9-point hedonic scale[†], 2017.

Genotype [‡]	Overall impression	Overall flavor	Sweetness	Sourness
A-2418	6.8 b [§]	6.4 b	5.8 b	5.6 a
Natchez	7.3 a	7.4 a	6.9 a	6.5 a
Ouachita	6.6 b	6.7 b	6.2 b	5.9 a
<i>P-Value</i>	0.0341	0.0034	0.0030	0.0957

[†] Hedonic scale (1 = dislike extremely; 9 = like extremely).

[‡] Genotypes were evaluated by 80 consumer panelists.

[§] Means with different letter(s) for each attribute are significantly different ($P < 0.05$) using least significant difference.

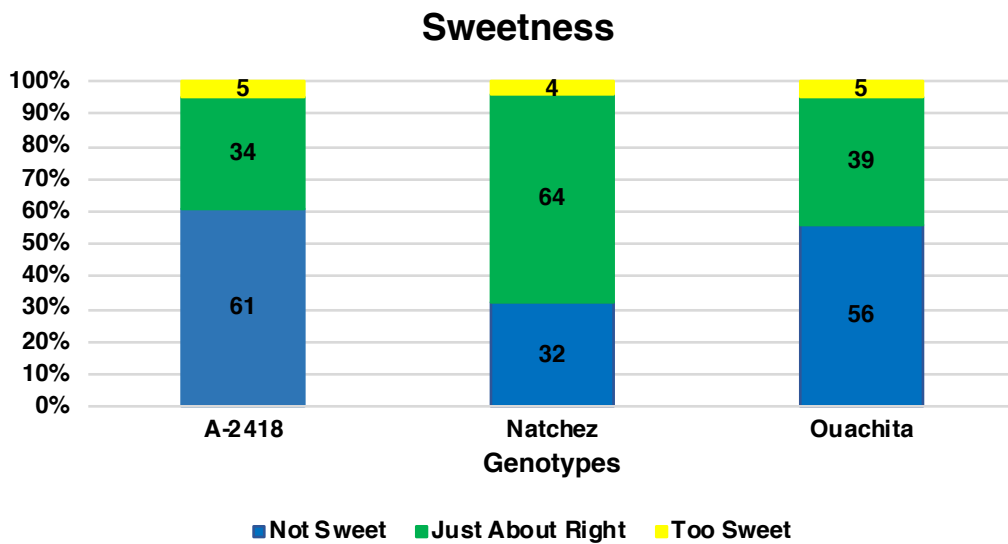


Fig. 1. Percent (%) of consumer responses for the sensory evaluation of sweetness on a collapsed 5-point Just-About-Right scale of Arkansas-grown blackberry genotypes, 2017. The 5-point Just-About-Right scale (1 = much too little, 2 = too little, 3 = just about right, 4 = too much, 5 = much too much) was collapsed to Too Low, Just-About-Right, and Too Much. Genotypes were evaluated by 80 consumer panelists.

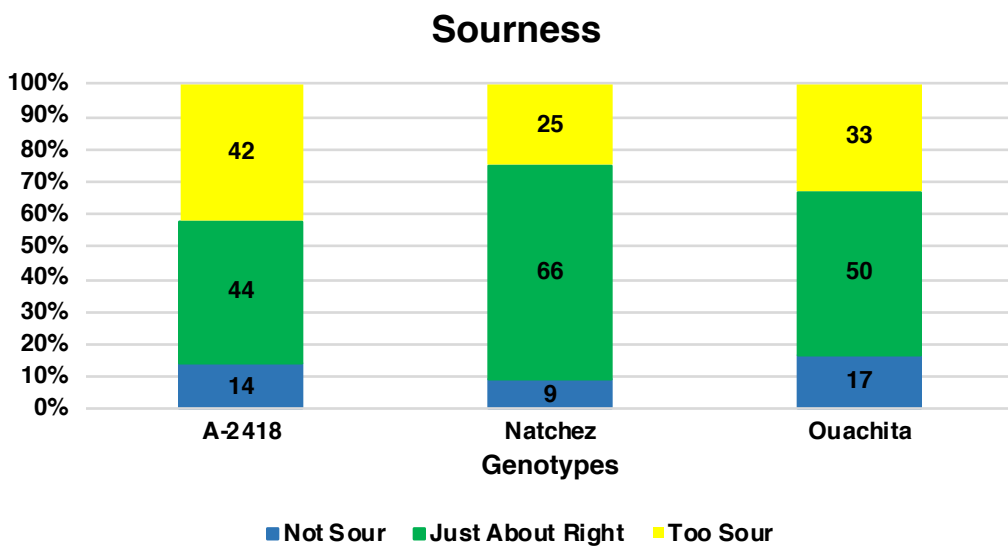


Fig. 2. Percent (%) of consumer responses for the sensory evaluation of sourness on a collapsed 5-point Just-About-Right scale of Arkansas-grown blackberry genotypes, 2017. The 5-point Just-About-Right scale (1 = much too little, 2 = too little, 3 = just about right, 4 = too much, 5 = much too much) was collapsed to Too Low, Just-About-Right, and Too Much. Genotypes were evaluated by 80 consumer panelists.

It is notable that Natchez, the most liked blackberry by ranking, had the most liked sweetness in both the 9-point hedonic scale and the Just-About-Right scale while it had a soluble solids-to-titratable acidity ratio in between the other genotypes. Interestingly, Natchez had a 16.5% higher titratable acidity than Ouachita and 3.8% lower titratable acidity than A-2418, but also had 5.9% lower soluble solids than Ouachita. These findings for fresh-

market blackberries indicate that consumers are not strictly sweetness-likers or sweetness-dislikers and that other flavor aspects may influence their perception of sweet flavor. Further, since there were no differences among genotypes for sourness-liking on either scale or between titratable acidity content levels, it is possible that few, if any, other factors influence consumers' sourness perception and that titratable acidity may be the most related factor to the attribute.

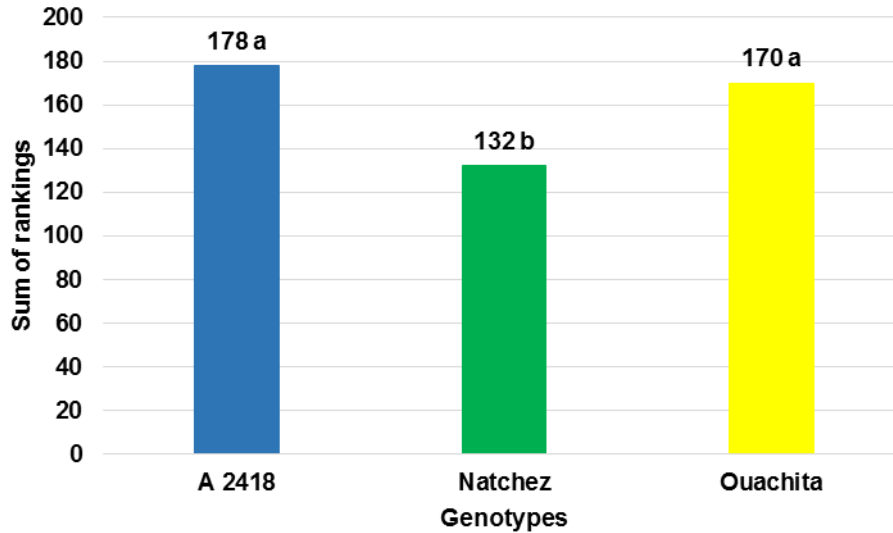


Fig. 3. Sums of consumer sensory evaluation of overall liking rankings for Arkansas-grown blackberry genotypes, 2017. Consumers ranked the genotypes for overall liking, the lower the rank sums, the sample was ranked higher. Genotypes were evaluated by 80 consumer panelists. Means with different letter(s) for each attribute are significantly different ($P < 0.05$) using least significant difference.

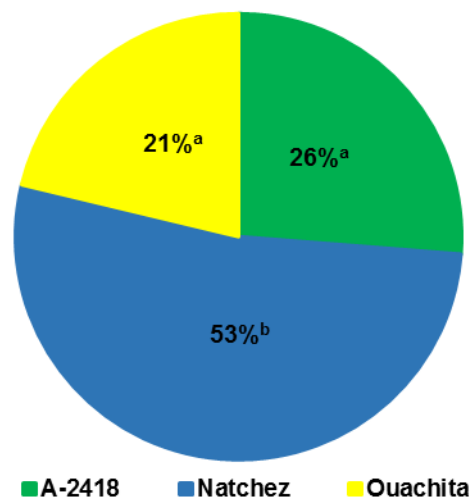


Fig. 4. Percent (%) of consumer sensory panelists that ranked each Arkansas-grown blackberry genotype as most liked, 2017. Genotypes were evaluated by 80 consumer panelists. Means with different letter(s) for each attribute are significantly different ($P < 0.05$) using least significant difference.

Conclusions

The attributes of sweetness and sourness in blackberries are important to consumers as they play a large role in consumer acceptability and therefore in marketability. Natchez was the most liked blackberry and had a medium level of soluble solids-to-titratable acidity ratio (medium level of perceived sweetness). Significant differences were found among blackberry genotypes for sweetness-liking, overall impression, overall flavor, and ranking. Other factors likely influence the sweetness perception of blackberries as the genotype with the most Just-About-Right evaluations for sweetness, Natchez, was not significantly different from the other genotypes and had a soluble solids content that was not different than Ouachita. The titratable acidity of the genotypes were not significantly different nor were the sourness evaluations indicating a possible relationship between titratable acidity and consumers' liking of sourness. These observations introduce the importance of how other factors influence consumers' perceptions of sweetness and sourness in fresh-market blackberries. Based upon the results of this study, it can be said that consumers prefer blackberries with a medium-level balance of sweetness and sourness over blackberries with high or low sweet/sour ratios, though due to personal preference and other flavor aspects, there can be consumers that prefer the more extreme ratios. Further studies would be beneficial to determine the relationship between the attributes of perceived sweetness and sourness and blackberry liking.

Acknowledgements

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Predicting kidding date using prepartum milk calcium concentrations and comparing kid growth to colostrum quality in goats

Meet the Student-Author



Justin Hamm

Research at a Glance

- There is a need for meat goat related research because there is a growing demand in the United States.
- There does not seem to be a relationship between goat milk calcium levels two days prior, one day prior, and on the day of birth that would assist producers in predicting an expected kidding date.
- An increased colostrum density in goats does not indicate an increase in kid weight gain.

I am an Eagle Scout and was homeschooled on my parent's cattle ranch in Alpena, Arkansas. I also raise a small goat herd, work with horses, and help manage my family's herd of cattle. I graduated from North Arkansas College with an Associate of Arts degree in 2016, where I was an active member of the Ag club and Phi Theta Kappa. My major is in Animal Science with a Pre-Professional concentration, and I will graduate magna cum laude from the University of Arkansas in December 2018. I have also been an active member of the Pre-Vet club, and had the opportunity to participate in a faculty led study abroad program to New Zealand and Australia. I would like to thank my mentor Dr. Jason Apple and my committee members Dr. Kathy Jogan and Dr. Charles Rosenkrans. I am grateful to Dr. Apple and Jogan for providing me with their resources and support throughout the Honors program process, and Dr. Rosenkrans for encouraging me to pursue my interests while developing my thesis. I would also like to thank my academic advisor Dr. Jeremy Powell for being willing and able to answer all of my questions and my family for their unfailing support while conducting my study.



Justin at Maits Rest Rainforest Walk in the Great Otway National Park near Apollo Bay, Victoria, Australia while on a study abroad trip in Jan. 2017 to study human and animal interactions in New Zealand and Australia.

Predicting kidding date using prepartum milk calcium concentrations and comparing kid growth to colostrum quality in goats

Justin M. Hamm^{} and Jason Apple[†]*

Abstract

Goats have an ancient history with humankind and are used as a red meat source around the world. This provides an opportunity in Arkansas agriculture. There is a gap in goat research that facilitated the conception of the study's objectives to determine whether prepartum milk in goats showed a rise in calcium levels within 24 to 48 hours of kidding and to ascertain whether an increased colostrum density is indicative of increased weight gain in kids. Eleven does were bred out of season and monitored for mammary development. Then, 5 to 15 mL of prepartum milk were collected, and the calcium content was measured using a Chemetrics K-1700 system. Postpartum, a 20 mL sample of colostrum was collected and the density was tested using an Equine Colostrometer, antifreeze tester, and a Refractometer. Each kid was also weighed at birth, 30, 60, 90, and 120 days of age using a *Premier 1* 110-lb scale. The weight was adjusted for age of dam, sex of kid, and birth type/rearing. The relationship between adjusted weights and colostrum quality and the relationship between calcium levels 24 and 48 hours prior to kidding with calcium levels at birth were analyzed using correlation and regression procedures. There was a negative correlation between the adjusted weights and colostrum quality; however, the relationship was not significant ($P > 0.05$). Positive correlations between calcium levels at 24 and 48 hours prior to kidding and at birth were not significant ($P > 0.05$). Moreover, the colostrum quality did not have an impact statistically on kid growth, and there was no significant rise in the calcium concentration of prepartum milk samples that could be used to estimate the time of birth.

^{*} Justin Hamm is an honors program December 2018 graduate with a major in Animal Science with a Pre-Professional concentration.

[†] Jason Apple is the faculty mentor and a Professor in the Department of Animal Science.

Introduction

Goats have been domesticated for an estimated 10,000 years (Zeder and Hesse, 2000). Furthermore, there are approximately 450 million goats across the globe (McKenzie-Jakes, 2007), as opposed to the population of cattle which has reached almost a billion (USDA, 2016). However, this is a 50% increase in the number of goats while the total population of cattle has increased by only 9% over the past twenty years (Anaeto et al., 2010). One of the advantages that goats have over other species of domestic livestock is that they are browsers, which allows them to survive on low quality forage. Due to their unique physiology, they can consume noxious weeds that may be toxic or unpalatable to other species. In addition, they commonly produce litters of one to three kids (McKenzie-Jakes, 2007). In some breeds, although it is not recommended, females can become pregnant as young as four to six months of age, which makes them “the most prolific of all domesticated ruminants” (Anaeto et al., 2010).

Goat meat is nutritious. It is relatively low in fats, sodium, and cholesterol in comparison to other livestock species (Anaeto et al., 2010), in part because goats tend to store less external fat deposits than sheep or cattle (McKenzie-Jakes, 2007). The meat contains a high concentration of iron and potassium. Furthermore, the protein content is compatible to other ruminants (Anaeto et al., 2010). As a result, their meat is the most commonly utilized source of red meat in the world (Harper, 2010).

In the United States, goats are produced predominantly for the management of invasive plant species and the production of chevon and cabrito, which are commonly used French and Spanish terms for goat meat (Glimp, 1995). In addition, the utilization of goats to manage invasive plant species has a long history in the United States. Some of America’s first goats were introduced in Texas by the Spanish to develop and improve pasture quality for other livestock, and to control brush that competes with crops (Glimp, 1995). As a result, goats can be utilized as a more sustainable and environmentally friendly alternative to the use of herbicides. The U.S. supply of goat meat does not currently meet the demand of the increasing ethnic populations (Glimp, 1995). Consequently, the meat goat industry in the United States is expanding (Glimp, 1995).

According to data collected by the United States Census Bureau, 23% of the population of Arkansas is made up of ethnic minority groups (DADS, 2010), thereby serving as a potential economic opportunity for Arkansas farmers. The rocky soil and pervasiveness of weeds and brush in the Arkansas Ozarks provides goats with an environment to which they are well adapted (Arkansas Geological Survey, 2010).

Additional experimentation and analysis would benefit the meat goat industry by providing the public with a better understanding of the industry’s significance (Dubeuf, et al., 2004). The average gestation for goats is 150 days. However, the gestation period varies widely depending on the age of the goat, time of year, and breed of goat. The expected kidding date may occur at any time within a two-week window (Barkley, et al., 2017). Because multiple births are common, a better method is needed to narrow down a goat’s expected kidding date to improve efficiency. This information is especially critical when goats are kidding for the first time or they are elderly, to prevent loss due to reproductive difficulties, such as dystocia and ringwomb (Hussain and Zaid, 2010). Furthermore, a thorough review of literature revealed that there has not been research investigating the effect that the colostrum density in does has on weight gain in kids.

To meet the purpose of the study, the following objectives were created:

1. To ascertain whether an increased colostrum density is indicative of increased weight gain in kids.
2. To determine whether prepartum milk in goats showed a sudden rise in calcium levels within 24 to 48 hours of kidding.

Materials and Methods

Eleven Kiko/Spanish cross does had conceived and were available to utilize in the study. The goats were on average three years of age. The goats were first exposed to a buck out of season, and all the goats but one had previously kidded in the same calendar year. They were observed daily for signs of mammary development. During the day, they were allowed to forage, then herded into a 24 × 36-ft pen which contained a 12 × 36-ft shelter with straw bedding each evening. Once signs of mammary development were observed, a 5- to 20-mL prepartum milk sample per doe was collected into a 50-mL plastic tube every evening. Following collection, each sample was refrigerated before being tested for calcium content using Chemetrics K-1700 testing system (Chemetrics, Inc., Midland, Virginia). Post-kidding, a 20-mL colostrum sample was collected from each doe, refrigerated, and tested for density using an Anti-freeze tester (Custom Accessories, Richmond, Illinois), refractometer (Animal Reproduction Systems, Inc., Chino, California), and an Equine colostrometer (Jorgensen Laboratories, Inc., Loveland, Colorado). Weights of the kids were collected at birth, 30, 60, 90, and 120 days using a *Premier 1* 110-lb Digital scale (Premier 1 Supplies, Washington, Iowa).

The weights of each kid at 30, 60, 90, and 120 days were multiplied by published adjustment factors according to

sex of kid, age of dam, and birth type (the number of kids carried to term)/rearing (the number of kids that the doe is able to raise). These adjustment factor values were provided by David R. Notter, Ph.D., Virginia Tech (as cited in Browning, 2014). Additionally, the data were analyzed to compare total weight per doe and adjusted kid weights to colostrum quality measurements taken with the colostrometer, anti-freeze tester, and the refractometer using linear regression and correlation procedures of Excel and SAS (SAS Institute, Inc., Cary, N.C.). Correlation r values less than 0.5 were described as weak, and values greater than 0.5 were described as strong.

Results and Discussion

To compare weight gain, the adjusted kid weights were also calculated to give a more accurate representation of gain in kids (Fig. 1). When analyzing the correlation between the adjusted total weights to the data measured by the colostrometer, the r -value indicated that there was

a weak correlation ($r < 0.5$; Table 1). The r -values when correlating the adjusted total weights to the refractometer percentages were slightly higher at birth and 30 days than the other days measured; however, all the correlations were weak ($r < 0.5$; Table 1). The regression procedure was used to determine if the relationship between the adjusted total weights at each time interval and the colostrum density, measured by the colostrometer and the refractometer, was significant. None of the P -values given in the procedure were less than the significance level of 0.05, indicating that the relationships between the adjusted total weights and colostrum density were not significant. This is supported by the weak trendline fit of the regression plot in Figs. 2 and 3.

The calcium levels of the samples collected two days prior to birth were correlated with the calcium levels of the samples collected one day prior and on the day of birth. Each of the correlations was weak and positive ($r < 0.5$; Table 2) with the relationship between one day and two days prior to birth being the strongest, and the day

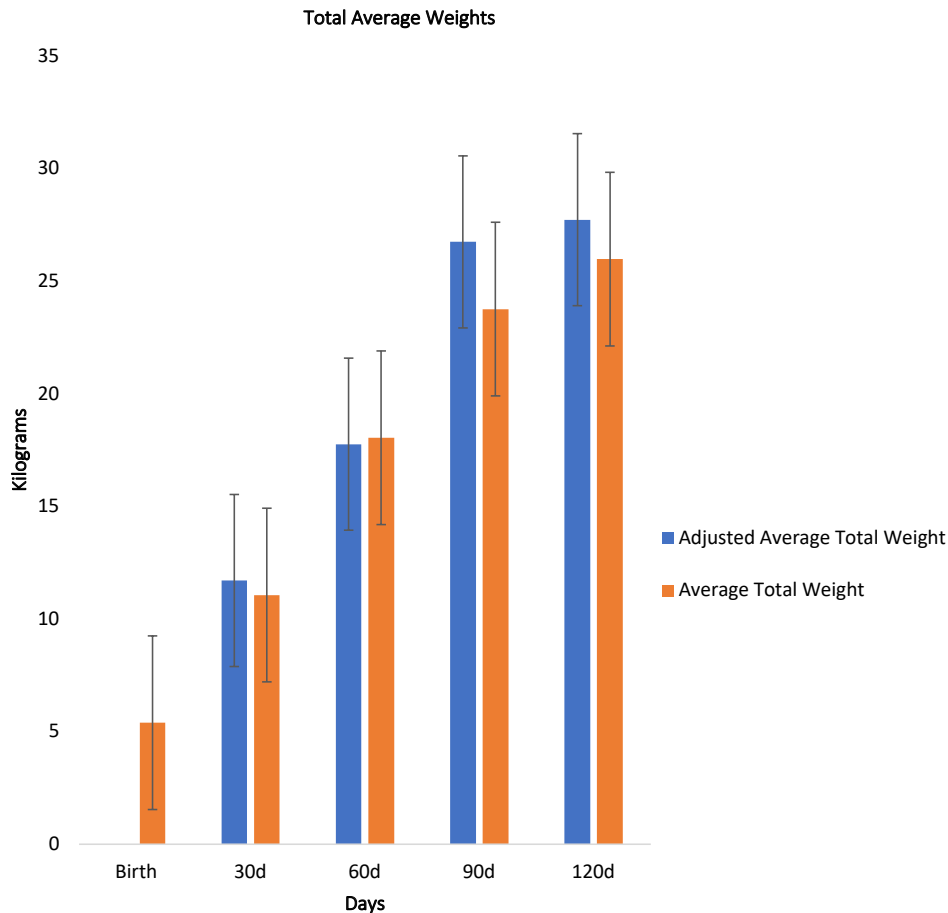


Fig. 1. Average and adjusted kid body weights per the eleven does utilized for the study from birth to 120 days of age.

Table 1. Pearson correlation coefficients (*r* values) between age of Dam (AoD), Birth Type (Btype), rearing type (Rtype), colostrometer (ColM), refractometer (Refr), anti-freeze tester (AnFz), birth (Bwt), 30-d, 60-d, 90-d, and 120-d adjusted weights.

Characteristic	AoD	Btype	Rtype	ColM	Refr	AnFz	Bwt	30-d	60-d	90-d	120-d
AoD	-	0.42	0.69	0.76	0.22	0.77	0.22	-0.14	-0.10	0.23	0.30
Btype		-	0.87	0.24	0.20	0.33	-0.39	-0.27	-0.35	0.08	-0.05
Rtype			-	0.50	0.07	0.62	-0.33	-0.35	-0.33	0.13	0.05
ColM				-	0.04	0.89	0.32	0.07	-0.09	0.17	0.22
Refr					-	0.20	-0.33	-0.23	-0.14	-0.08	0.00
AnFz						-	0.06	-0.20	-0.19	0.18	0.22
Bwt							-	0.63	0.53	0.42	0.42
30d								-	0.88	0.60	0.61
60d									-	0.76	0.79
90d										-	0.95
120d											-

Blue – ($P < 0.10$).
 Red – ($P < 0.05$).

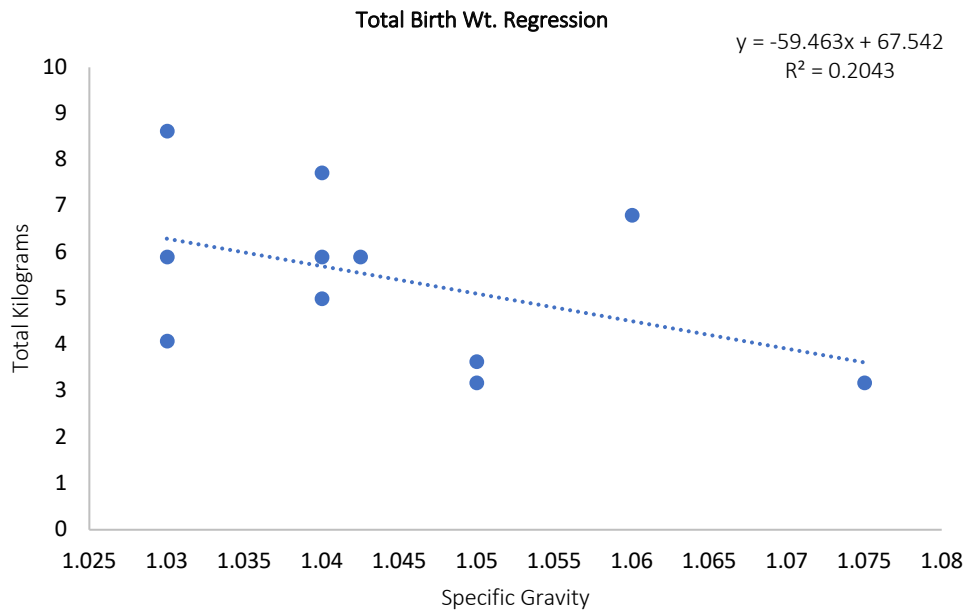


Fig. 2. The relationship between total kid birth weight per doe to colostrometer measurements (specific gravity).

of and two days prior to birth being the weakest (Table 2). The relationships between calcium concentrations were also analyzed for significance using the regression procedure. However, none of the *P*-values indicated that any of the relationships were significant ($P > 0.05$). To the authors' knowledge there are no similar studies that have been previously performed in meat goats.

Conclusions

The results of the study indicated that there was no significant relationship between weight gain in kids and colostrum density. There was also no significant increase in calcium levels of prepartum goat milk within 24 or 48 hours prior to birth. Furthermore, colostrum quality does not seem to influence kid growth, and calcium concentrations are not an indication of imminent birth.

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Table 2. Pearson correlations between the calcium concentrations measured at birth, one day, and two days prior to kidding.

Timing	Birth	1 Day	2 Days
Birth	-	0.22	0.07
1 Day		-	0.45
2 Days			-

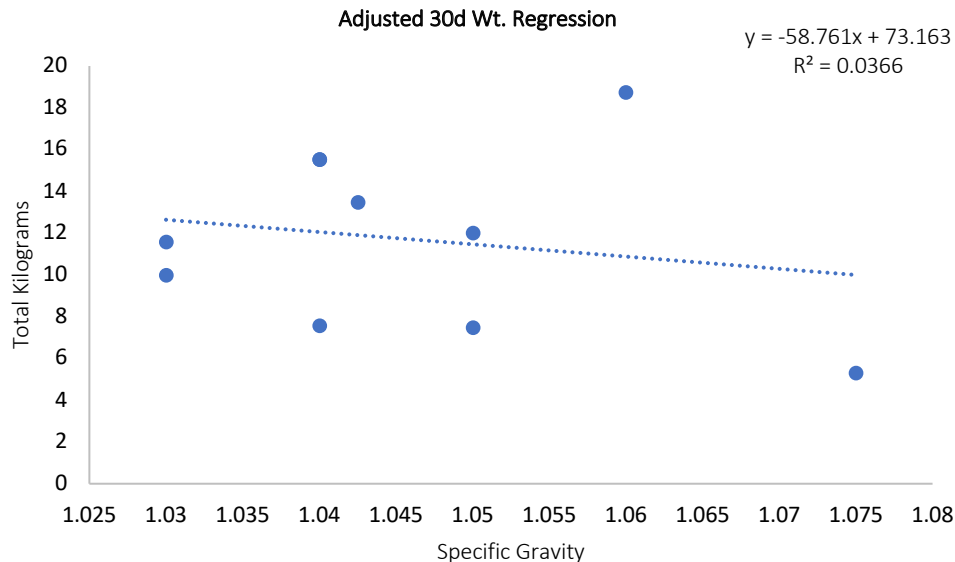


Fig. 3. The relationship between adjusted 30-d kid body weight per doe to colostrum measurements (specific gravity).

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Agricultural information needs and food access in the Stann Creek district of Belize

Meet the Student-Author



Sam Harris

Research at a Glance

- Farmers in Belize often consult with the Extension officers for information.
- The lack of new technology use by farmers in the Stann Creek District of Belize has serious implications for farm productivity and regional food security and poverty alleviation.
- The influx of foreign investment into the grocery sector has potentially negative effects for building local commerce and opening market activity for local producers in Stann Creek.
- Smallholder farmers and the general public have very similar levels of food access and availability; both groups reported mild to severe food insecurity.

I graduated in 2015 with highest honors from Greenbrier High School in central Arkansas. I graduated from the University of Arkansas Dale Bumpers College of Agricultural, Food and Life Sciences with a degree in Agricultural Business Pre-Law and a minor in Agricultural Leadership. This research was conducted as part of an Honors College Research Grant in Dangriga, Belize during the summer of 2017. During my time at the U of A, I have evaluated extension services in rural India, lead community development programs in Vietnam, and studied information access and agricultural enterprise opportunities for smallholder farmers. I served as President of Students Organization Outreach Involvement Experience, Assistant Director of Sponsorship for the Student Alumni Board, and an active member of the of FFA Alumni Association. In April of 2017, I was named a recipient of the 2017 Harry S. Truman Scholarship because of interest and commitment to leadership and a career in public service. Determined to alleviate global food insecurity through international development and public policy, upon graduation I plan to pursue a master's degree in Development Studies before going to law school. I am thankful to Dr. Donna Graham for her assistance throughout this research project as well as Drs. Jennie Popp, Amy Farmer, and Don Edgar for their guidance throughout this process.



Sam Harris alongside Belize Ministry of Agriculture extension officers while collecting data in Dangriga, Belize.

Agricultural information needs and food access in the Stann Creek district of Belize

*Sam E. Harris** and *Donna L. Graham*[†]

Abstract

The purpose of this study was to describe agricultural information sources available to farmers and to describe food access and availability for the people of Dangriga, Stann Creek, Belize. This study used descriptive survey research methods with convenience sampling of the general public (n = 22) and of farmers (n = 38) in the summer of 2017. Farmers use a variety of agricultural information sources with the extension service cited most often, followed by friends and fellow farmers. Weather, lack of information, pests, and inadequate access to capital were of primary concern for farmers. Face-to-face meetings were used most often by extension officers for disseminating agricultural information. Smallholder farmers and the general public have very similar levels of food access and availability. No significant difference was found between the smallholder farmers and the general public on food insecurity with both groups reporting mild to severe food insecurity. Recommendations focused on practical operational strategies for the local Department of Agriculture, as well as the Belize Ministry of Agriculture to eradicate hunger and increase overall food access and availability throughout Belize.

* Sam Harris is a 2018 honors program graduate with a major in Agricultural Business and a minor in Agricultural Leadership.

† Donna L Graham is the faculty mentor and a University Professor in the Department of Agricultural Education, Communication and Technology.

Introduction

Located on the Caribbean coast of Central America, Belize has a small, essentially private enterprise economy based primarily on agriculture, agro-based industry, and merchandising, with tourism and construction recently assuming greater importance (United Nations Development Programme [UNDP], n.d.). Agriculture employs over one-third of Belize's workforce, over 23% of the nation's gross domestic product. Sugar cane is the largest agricultural export accounting for nearly half of arable land use (UNDP, n.d.). Small-scale operations exist across the country with 74% of farms in the country occupying less than 20 hectares (~49 acres) (UNDP, n.d.).

Forty one percent of the country's population lives in poverty, with a per capita income of \$4681 (Statistic of the Nation, 2017). The National Poverty Assessment of 2002 indicated Belize's agricultural workers are poorer than non-agricultural laborers, with most rural producers farming for subsistence only, using very little technology because of lack of resources and information. As a result, their levels of production are very low (Rural Poverty in Belize, n.d.). Traditionally, farmers who receive technical support produce more and profit more; however, agricultural research and extension services have been reduced over the past two decades (Obidike, 2011). Balit et al. (1996) pointed out the least expensive input for improved rural agricultural development is adequate access to knowledge and information. However, there have been shortcomings of traditional print and library-based methods providing agricultural information to rural farmers who are largely illiterate and relatively removed from formal sources of information (Van and Fortier, 2000). As the poverty rate continues to rise because of adverse economic conditions, climate change, and corporatization of farming operations, the prevalence of food insecurity rises across Belize (Rural Poverty in Belize, n.d.).

The FAO (2017) concluded the dimensions of the experience of food insecurity appear to be common across cultures. A person is food insecure when he or she does not have access to enough food for an active, healthy life (Smith et al., 2000). Furthermore, a household is considered food secure when their food supply is sufficient, secure, and sustainable (Maxwell, 1996). Ultimately, all factors of food insecurity can be summarized by two general causes: insufficient national food availability and insufficient access to food by individuals and households. Because of the country's small size and population, little research exists regarding food availability, especially protein sources, as well as the common sources of agricultural information rural farmers are most likely to access for improving production practices.

The research objectives were to:

- Identify what information sources farmers utilize for agricultural knowledge.
- Identify the food production concerns or barriers faced by farmers in Stann Creek.
- Describe food security regarding food availability and access for farmers and the general public.
- Determine community interest and opportunities for future small agricultural operations for farming and non-farming families.

Materials and Methods

This study used a descriptive survey research design including face-to-face interviews and observation. The data collected were based on a convenience sample of smallholder farmers and the general public. Initial contact for the study occurred during the summer of 2017 arranged by Peacework and the Belize Ministry of Agriculture Department.

For contact with smallholder farmers, the researcher attended various cooperative meetings with extension officers and visited farmers engaged in a variety of production areas. The general public survey data were collected via street interviews in Dangriga Town (Stann Creek District). The researcher informed each respondent of the privacy policies protecting their responses as noted in the policies approved by the University of Arkansas Institutional Review Board.

Instrumentation

Two forms of instruments administered in face-to-face interviews were used for data collection. The General Public instrument consisted of 24 questions directed toward measuring food security as well as the demographics of the public interviewed. The Farmer Questionnaire consisted of 28 questions that directly targeted existing access to agricultural information and how farmers in Stann Creek utilize these outlets. Both of the instruments included the Food Insecurity Experience Scale (FIES) developed by the Food Agricultural Organization (FAO, 2017) to gauge food security and access. The FIES instrument consists of 8 questions focused on food-related behaviors and experiences associated with accessing food and resource constraints to measure mild to severe food insecurity (Table 1).

Results and Discussion

Smallholder Farmers

For the local farmers ($n = 38$), 92.1% were male with 47.4% between the ages of 40 and 59 years of age. An equal number was under 30 years old or over the age

of 60 years representing 26.3% each of the respondents. There was variation in the education of farmers with a majority (57.9%) having a high school (34.2%) or post-secondary education (23.7%). Families varied in size with households ranging from 1 to 3 members (36.8%); 4 to 6 members (39.5%) or over 7 members (23.7%) living in the household. Some 28.9% reported being engaged in farming less than 10 years, but 68.4% of the farmers surveyed had been farming over 11 years. Finally, over 31.6% of farmers reported farming for 31 years or more.

Objective 1

Farmers (n = 38) were asked what information sources they used regarding their operation. Over 20.0% of farmers reported they rely on extension workers or the Ministry of Agriculture on-farm training seminars, while slightly over 17.0% report they also get information from friends and surrounding farmers in the area. The radio, internet, and family members were each reported as an information source by more than 10% of respondents.

Over 70.0% of the farmers (n = 38) indicated they had not implemented any new technologies into their operations in the last 10 years of production, but for the 28.9%

(n = 11) who had added some new technology, the source of learning about this technology was from mass media (57.9%). The extension officers were the least frequently cited source for learning about new technology.

Objective 2

Of the farmers (n = 37), 56.8% maintained row crop operations, while over 35.1% reported operations with both row crops and animal production. Of the row crop farmers, the majority of respondents reported rice as their main cash crop. Farmers were asked to identify their interest in diversifying or expanding their operations. For respondents who answered “No,” (n = 10) over 66.0% of farmers had considered expanding their operations while 51.8% reported capital was the largest barrier to diversifying they faced.

Over 55.0% of producers indicated their farm productivity had decreased as opposed to 44.4% reporting an increase. More than two-thirds indicated they had considered diversifying their crop or animal production to alleviate production decreases, but the financial means (51.9%) to diversify was listed as the main reason preventing this from occurring.

Table 1. Global food insecurity experience scale questions and response totals.

Global Food Insecurity Experience Scale ^a		
Now I would like to ask you some questions about food. During the last 12 MONTHS, was there a time when:		
	Farmers	Public
Q1. You were worried you would not have enough food to eat because of a lack of money or other resources?	14 No 8 Yes	22 No 16 Yes
Q2. Still thinking about the last 12 MONTHS, was there a time when you were unable to eat healthy and nutritious food because of a lack of money or other resources?	15 No 7 Yes	20 No 18 Yes
Q3. You ate only a few kinds of foods because of a lack of money or other resources?	11 No 11 Yes	23 No 15 Yes
Q4. You had to skip a meal because there was not enough money or other resources to get food?	14 No 8 Yes	33 No 5 Yes
Q5. Still thinking about the last 12 MONTHS, was there a time when you ate less than you thought you should because of a lack of money or other resources?	14 No 8 Yes	28 No 10 Yes
Q6. Your household ran out of food because of a lack of money or other resources?	17 No 5 Yes	32 No 6 Yes
Q7. You were hungry but did not eat because there was not enough money or other resources for food?	18 No 4 Yes	33 No 5 Yes
Q8. You went without eating for a whole day because of a lack of money or other resources?	18 No 4 Yes	33 No 5 Yes

^a The global food insecurity experience scale is a quantitative tool to measure the prevalence of food insecurity in a given population. Food and Agriculture Organization of the United Nations (FAO, 2017). <http://www.fao.org/3/a-i7835e.pdf>.

Objective 3

To gauge food availability and access, the general public and smallholder farmers were asked where they mainly obtained their food. Respondents selected whether they obtained all, most, some, or none of their food from the options of grocery store, farmers' market, local producers, or other sources. A majority of the general public indicated they purchased most (54.5%) or all (9.1%) of their food from local grocery stores. In comparison, only 13.6% revealed they purchased most of their food from farmers' markets, local producers, or other sources. Over 90.0% of respondents reported grocery stores, farmers' markets, and local producers were all within one mile from their residences.

Each general public respondent was asked to gauge how much protein, dairy, bread/grains, and fruits/vegetables were purchased from each source. Almost 55.0% of the public reported they buy all or most of their protein foods from grocery stores. Similarly, 63.7% purchase all or most dairy products from local grocery stores. For respondents who reported getting food from local farmers' markets, 66.7% reported buying no protein foods from this source. Similarly, 85.7% bought no dairy products from farmers' markets. Fifty percent of the general public (n = 21) indicated they purchased fruits and vegetables from the farmer's market, but very few purchased other foods from local producers in the Dangriga-area.

Participants were asked whether or not meat (protein) was available to eat each day. Over 95.0% of the public reported having access to meat (protein) each day while 85.7% revealed they had access to fresh fruits and vegetables.

When asked about their own food availability, 36.9% of the farmers report they get most or all of their food from their farm or garden, while 28.9% indicated most

of their food is purchased at grocery stores. There were 14 farmers (36.8%) who reported they got none of their food from farmers markets or other local producers.

To assess food insecurity prevalence rates, respondents were asked if in the last 12 months a lack of money or other resources meant they were unable to eat enough food or healthy food, ran out of food, were forced to cut portions or skip meals altogether, or were hungry but did not eat (Table 1). The response to the 8 questions on the Food Insecurity Experience Scale (FIES) positions the respondent as experiencing mild to severe food insecurity. Both the farmer and general public respondents have individuals who were experiencing some level of food insecurity (Fig. 1). Some 11–18 farmers have none or little food insecurity reporting 'no' to the food insecurity experience questions (Table 1). However, 4–11 of the farmers and 5–18 of the general public respondents answered "yes" to different questions ranging from mild to severe levels of food insecurity experiences.

To determine the overall level of food insecurity, the "yes" responses were totaled and averaged to produce an average raw score for each group of respondents. The average raw score for the farmer group was 2.1 with five farmers having a raw score above five on the FIES scale (experiencing hunger) while 20 farmers had a raw score of 4 or less (worrying about food and compromising on quality and variety). There were 13 farmers who reported no problems with food insecurity. The average raw score of the general public was 2.5 with 5 individuals of the public having a raw score of 5 or above on the FIES scale (experiencing hunger) while 8 public respondents had raw scores of less than 4 (worrying about food and compromising on quality and variety), and 9 who reported no problems with food insecurity. The Chi Square test revealed a $\chi(1) = 3.79, P = 0.73$. Therefore, the groups

Public								Avg. 2.5
9	2	3	2	1	0	0	3	2
<i>Mild food insecurity</i>				<i>Severe food insecurity</i>				

<i>Worrying about running out of food</i>		<i>Compromising on quality and variety</i>		<i>Reducing quantities, skipping meals</i>		<i>Experiencing hunger</i>		
13	6	5	6	3	2	0	0	3
Farmers								Avg. 2.1

Fig. 1. The level of food insecurity from the public sector (n = 22) and farmers (n = 38) based on raw score totals of 8 questions from the FIES scale. Each cell (from left to right) represents the number of respondents in each category of food insecurity from none followed by 1 = mild food insecurity to 8 = severe food insecurity. An average is shown in the far right column of the Public sector and Farmers rows.

were not different and no comparisons could be made of the results gained.

Objective 4

While living in an area where agriculture employs over 20% of the population and large-scale production occurs, when asked if they had any exposure to food production, almost 41.0% reported they had at least some exposure. When asked whether or not they had considered growing their own food for self-consumption, as well as for additional income, 45.5% report they had considered growing food for additional income. A majority (54.5%) reported that they would consider growing food for self-consumption. Less than half (45.5%) of the respondents indicated they are open to raising backyard poultry. Access to capital was reported as the number one reason for not producing their own foods reported by 91.3% of respondents.

Many farmers reported they obtained information through the extension services but also contacted fellow farmers and friends for agriculture-related assistance. However, the Ministry of Agriculture did not use an organized system for utilizing “contact farmers”. As noted by Kipkurgat (2015), contact farmers, respected leaders and producers within a geographic area, are effective vehicles for disseminating information to rural farming communities because of the existing trust and lack of competition among farmers in homogenous regions. The use of opinion leaders would be perfect points-of-contact for the Department of Agriculture in Stann Creek to utilize when sharing information in a way that is quick, effective, and applicable.

Implementing a system for contact farmers to help with the transfer of vital production information could be an effective way to make contact more consistent, thus increasing the relevancy of extension services. It was observed that most farmers, even those in the most remote areas, had access to cell phones and mobile broadband technology. Knowing this, the Department of Agriculture could utilize these devices to get information to farmers in real time. With mobile technology, extension officers could equip farmers across Stann Creek with weather updates and warnings, current market prices, and other input-related information. Utilizing this channel of communication could create potential partnerships between private companies and the Department of Agriculture to get product-specific information to farmers.

It seemed most farmers grew similar commodities because of the lack of local competition. The consuming public is obtaining their food from foreign owned grocery stores more frequently than from local producers (refer to objective 3). Therefore, local farmers can produce the

same products and still access export markets. This phenomenon should highlight the Agriculture Department’s opportunity to expand their reach beyond local producers and begin communicating with the general public to build a connected food system within Stann Creek.

The results of the food security assessment portion of the study raises questions as to why Stann Creek locals depend on foreign retailers to provide their food when local producers are available near most major communities and villages. For the general population, it appears access to healthy foods such as protein and fresh fruits and vegetables were not of major concern. With food access closely tied to proximity to grocery stores and other food retailers (FAO, n.d.), it is interesting that both smallholder farmers and the general public report living less than one mile from a food retailer even though national statistics suggest the country is off target at eradicating extreme hunger and reducing food insecurity (MDG, 2016). The limitations of financial resources should be investigated further.

When comparing the raw scores of the two populations, there was no significant difference regarding food insecurity. Both groups had experienced food insecurity in the last 12 months. By emphasizing the importance of nutritional quality and local food access, agriculture workers and government officials could consider promoting a more localized food system and provide realistic alternatives for attaining enough food to live a healthy and active lifestyle. Chen et al. (2010) report bridging food insecurity with an increased opportunity for local production has real potential to alleviate hunger and improve the quality of life of numerous people.

Conclusions

Farmers in the Stann Creek District of Belize face a variety of agricultural issues ranging from pest management to market access. Farmers continue to utilize a variety of agricultural information sources, with extension services being the number one resource for on-farm assistance. Regarding food security and access, there was a marginal difference between smallholder farmers and the general public. Both groups displayed mild food insecurity, with a few participants reporting severe food insecurity. The Belize Ministry of Agriculture and other stakeholders should focus on strengthening local communication channels and establishing a sustainable method for disseminating vital agricultural production information to farmers. This continued development could have lasting effects on productivity, food security, and access throughout the region.

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Importance of portfolio building for students with creative majors

Meet the Student-Author



Zoe Lauer

I am from Frisco, Texas and graduated from Wake-land High School in 2014. In May 2018, I graduated from the Dale Bumpers College of Agricultural, Food, and Life Sciences in the School of Human Environmental Sciences with a degree in Apparel Merchandising and Product Development and a minor in Journalism. I graduated Magna Cum Laude with a 3.78 GPA. I served on the Executive Council of Zeta Tau Alpha as Panhellenic Delegate. In the summer of 2016, I studied abroad in Milan, Italy at Nuova Accademia di Belle Arti. In August 2017, I went on a study tour to Las Vegas to see the MAGIC tradeshow, the largest tradeshow in the world. I interned at Riffraff in Fayetteville, Arkansas as a creative intern as well Mizzen+Main in Dallas as a marketing intern.

I am thankful for the help from my mentor, Casandra Cox, with my thesis. She was with me every step of the way from the creative process to research. I would also like to thank my committee members Stephanie Hubert, Lance Cheramie, and Dr. Laurie Apple.

Research at a Glance

- Portfolio building is necessary for creative majors, including apparel merchandising and product development; graphic design; architecture; interior design; and elementary education, who want to enter into their industry.
- Quality photography and editing creates a more professional looking portfolio which is a necessity for creative employment.
- E-portfolios are becoming a staple for many universities and employers, with classes being taught specifically in e-portfolio building and sections of job applications specifically for attaching an e-portfolio link.



Zoe at Lake Como, Italy, during a study abroad summer 2016 trip, class weekend getaway.

Importance of portfolio building for students with creative majors

Zoë Lauer^{} and Casandra Cox[†]*

Abstract

A portfolio showcases work samples that may include visual and auditory content. Portfolios are becoming a priority for graduates entering creative career fields. Electronic portfolios or e-portfolios are on the rise due to advancements in technology. These e-portfolios give students and graduates the ability to showcase and highlight specific attributes they have acquired inside and outside the classroom in one place. Electronic-portfolios give employers the opportunity to view a potential employment candidate's skills, experience, and creativity in one place. Portfolios and e-portfolios can also be used inside of the classroom to assign grades and determine how the curriculum is being used by students. This creative project provided portfolio work samples from a project-based upper level Apparel Merchandising and Product Development (AMPD) course. Photographs were taken during the Futuristic Floral Fashion Show in April 2017, which is an annual event of the Apparel Program of the University of Arkansas, Dale Bumpers College of Agricultural, Food and Life Sciences to showcase the work of students. Photos were edited and distributed to students. It is recommended that final garment photography become a part of the AMPD program's annual fashion show because a photograph can showcase a student's abilities in a way words cannot. Early emphasis on portfolio building paired with formal portfolio building through coursework is essential for creative majors.

* Zoe Lauer is an honors program May 2018 graduate with a major in Apparel Merchandising and Product Development and a minor in Journalism.

† Casandra Cox, the faculty mentor, is an Instructor in the Agricultural Education, Communications and Technology program.

Introduction

Portfolio building has become a staple for creative majors wanting to enter into creative careers. Yao et al. (2008) define a portfolio as “a systematic and purposeful collection of work samples that document student achievement or progress over time”. Millennials are facing a higher unemployment rate than other generations, and need to differentiate themselves from other potential employees. One solution is to create online portfolios (Keist and Bruer, 2016). Portfolios are important for students entering creative career fields such as Apparel Merchandising and Product Development (AMPD).

The AMPD students gain jobs after graduation “through internship placements, career development center on-campus interviews, networking with AMPD advisory board, [and] networking with alums” (K. Smith, pers. comm., 2017). The graduate school and employment average placement rate is 95% for AMPD at the University of Arkansas (Career Development Center, 2017; AMPD, 2017). Career options for AMPD graduates include buying and merchandising, brand management, technical design, quality assurance, retail or wholesale management, textiles, product development, and computer-aided design (CAD) specialization (AMPD, 2017).

Ball et al. (2010) examined more than 3500 graduates from creative degree programs from 26 higher education institutions in the United Kingdom. Based on the study, “just over half the graduates (52%) felt their courses had prepared them very or fairly well for the world of work. Respondents would have liked a better appreciation of what creative employment would be like, improved understanding of client needs, training in IT/software, business skills and the practicalities of working freelance” (Ball et al., 2010). More than four out of five graduates had at one point in their college career participated in shows or exhibitions of their work, self or peer evaluations, teamwork, and teachings by experts in their field of study. The respondents rated most of their course activities as very useful. Respondents considered “Personal and Professional Development (PPD), teamwork and teaching by practitioners as the most useful in relation to their careers” (Ball et al., 2010).

According to Keist and Bruer (2016), the academic content that Apparel Merchandising majors have to get them ready for the industry includes the courses they have taken and how they apply them to the fashion industry, any class projects they may have had that could have been presented by PowerPoint presentations, Word documents, or photography and visual displays, as well as organization events or certification programs. Due to the skills acquired, graduates from creative degree programs placed themselves at the lead for commencing changes in

the creative jobs sector. Graduates who are able to adapt easily to changing situations and continue learning allow themselves to fit into modern creative careers (Ball et al., 2010). Due to an increase in competency-based curriculum for college students, portfolios, specifically e-portfolios, have grown in use for students in higher education (Ward and Moser, 2008). According to Rhodes (2011), e-portfolios not only allow professors to collect assigned student work, e-portfolios also allow students to present accomplishments outside of the classroom allowing university faculty and internship and career supervisors to assess the student or graduate’s accomplishments.

The creative industry, specifically in apparel, is a difficult industry in which to gain employment after graduation. Ball et al. (2010) found that when it comes to obtaining a career in fashion or in another creative industry, self-confidence and self-management were the most important skills for potential employees. Many apparel graduates gain entry into the fashion industry through unpaid internships or voluntary positions where they gain valuable experience that they cannot obtain in the classroom (Ball et al., 2010). Students share industry experiences “from internships and employment, writing samples, and links to personal blogs” to gain entry into a career in the industry (Keist and Bruer, 2016).

With technology advancing, many believe the best kind of portfolio for students to create is an electronic portfolio or an e-portfolio. Abrami and Barrett (2005) define an electronic portfolio as “a digital container capable of storing visual and auditory content including text, images, video and sound”. According to Miller and Morgaine (2009), a well-done e-portfolio is an amazing tool for universities. Electronic-portfolios accurately display student learning and promote deeper learning and education. “Forty percent of campuses of all types – large and small, public and private, research and liberal arts, and community colleges—recently reported using student e-portfolios” (Rhodes, 2011).

Portfolios can be shared with human resource managers who can view work samples relating to the position in one place. Universities can also use portfolios to assess their students learning and reflection through the student’s work (Ward and Moser, 2008). “Portfolios are viewed as a way of determining not just how much students know, but also how they are able to apply and use what they know” (Whitworth et al., 2011). According to Black and Cloud (2009), a portfolio serves a creative student the same way a thesis proposal serves a research student. An online portfolio heightens the information from a student’s resume. Unlike a resume, a student’s personality, skills, and experience are presented creatively in an online portfolio (Keist and Bruer, 2016).

Keist and Bruer (2016) suggest the following for qual-

ity portfolios: keeping a professional URL using one's full name, keep the portfolio simple and readable, use a monochromatic color scheme and an easy-to-read, professional font. Additionally, include pictures of your work, update constantly, connect your email and social media accounts, avoid using large group photos, and keep everything appropriate and professional (Keist and Bruer, 2016). An apparel merchandising student's portfolio may include a student's biography, a description of a concept or theme, photographs or designs, garments, exhibitions, and projects (Black and Cloud, 2009). Ward and Moser (2008) believe "students can create e-portfolio artifacts from video/audio streaming of their presentations, examples of their writing, or demonstrated competencies in specific professional/regulatory standards for viewing by faculty and potential employers". Ward and Moser (2008) surveyed companies to determine if e-portfolios would be utilized in the future and what type of information employers would find valuable in a student's e-portfolio. Responses revealed that 56% of respondents said they planned to use e-portfolios in the future. Items described as valuable for inclusion in e-portfolios by the percentage of employer respondents are as follows: 93% valued resumes and references, 39% valued written work, 37% valued projects, 33% presentations, 23% lesson plans, 7% case studies, and 6% valued artistic performances (Ward and Moser, 2008).

The purpose of this creative project was to document AMPD junior and senior students' garment creation in the AMPD 4063 Advanced Apparel Production course for integration into their professional portfolios. The project included photographing and editing students' progress as the garments were created. The finished garments modeled at the 2017 Enclothe Fashion Show for program stakeholders, potential employers, and the public were also photographed for inclusion in the portfolios.

Materials and Methods

The need for quality portfolios in creative careers has increased in recent years and helps students get ahead of their competition when applying for jobs. Portfolio content is particularly important and must be of high quality. The following outlines this project's process of creating high quality content for AMPD students to add to their creative portfolios.

The AMPD students at the University of Arkansas participated in the spring 2017 AMPD Futuristic Floral Fashion Show event. The purpose of the fashion show event was to push students to create a garment on a deadline and showcase their design and development skills. Participation in the fashion show and the garment creation process are resume and portfolio builders. Design

and production of garments, showcased in the AMPD fashion show, occurred during enrollment in Advanced Apparel Production during the spring 2017 semester.

Prior approval was secured from the fashion show directors as well as the AMPD Advanced Apparel Production instructor, Stephanie Hubert, to take photographs. Phase One included photographing student work during classes, back stage at the fashion show and models after the show. Phase Two included identifying images appropriate for professional portfolio use and editing those images. Phase Three included securing contact information and distributing the edited, professional portfolio-ready images.

Phase One: Photographing Work

- Photographs were taken during the Advanced Apparel Production class time while students were working on their garments.
- Photographs were taken backstage prior to the Futuristic Floral Fashion Show.
- Staged photographs were taken after the fashion show of the models wearing the garments in front of a backdrop.
- Approximately 90 photographs were captured during the 16-week course and the fashion show event.

Phase Two: Editing

- Staged fashion show photos were edited for use in student portfolios.
- Edits improved digital image quality and made enhancements to demonstrate professionalism and editing skills.
- Adobe® Photoshop® Creative Cloud was used and each photo was edited individually.
- Common edits that were used were brightness/contrast, vibrance, hue/saturation, and the healing brush tool to diminish any face shine.
- Multiple editing layers were created and the model was selected and made specifically brighter than the background so the garment would "pop".
- Each image required between 10 to 20 minutes of editing time.

Phase Three: Distribution

- Edited photos of the garments were sent to respective student designers and creators.
- Any feedback was unsolicited.

- Backstage and classroom photos were edited and sent to Ms. Hubert to promote the 2018 Fashion Show.

Results and Discussion

This project was developed out of experiences in the AMPD program and AMPD students' interests in building a professional portfolio along with experiences with photo shoots and editing. Common edits that were used were brightness/contrast, vibrance, hue/saturation, and the healing brush tool to diminish any face shine (Figs. 1-3). Before (Figs. 1A, 2A, and 3A) and after (Figs. 1B, 2B, and 3B) photos illustrate the improvement in quality result-

ing from editing. Allowing AMPD students to have edited, quality photos of garments they created enhances their portfolios which should aid them when applying for internships and jobs (Keist and Bruer, 2016). It also provided a strong body of work for the primary author to include in a portfolio, and provided a service to the AMPD students that had not occurred previously. Through review of literature, it became clear that the inclusion of quality work is a key element for portfolio creation, and portfolios are key in demonstrating skills for those in creative careers as they seek employment opportunities (Keist and Bruer, 2016; Miller and Morgaine, 2009; Ward and Moser, 2008).

When attempting to take photographs of the models after the show, obstacles were faced. Many people were



Fig. 1. Photo taken at the Futuristic Floral Fashion Show event in spring 2017, which is an annual event of the Apparel Merchandising and Product Development Program of the University of Arkansas Dale Bumpers College of Agricultural, Food and Life Sciences. (A, left) shows photo before and (B, right) shows photo after editing with PhotoShop to improve quality for electronic portfolio use.

in a hurry to leave, were overwhelmed by the fashion show process, or were trying to connect with family and friends who came to support them, and models did not come to the photo area for me to photograph them wearing the garments. Thus, only 18 of the 75 garments in the show were photographed. As an AMPD student having a garment modeled in the show, I had to balance fashion show and photography responsibilities. Once editing of the photos began, it took multiple attempts to figure out the best process to edit the photographs to highlight the garment as the focal point. Expertise of the co-author, Ms. Cox, who instructs the graphic design course, was instrumental in discovering how to best make the models and garments stand out. The final images demonstrate growth in editing skills (Figs. 1B, 2B, and 3B).

Conclusions

Allowing AMPD students the opportunity to have quality photos taken of their garments benefited them when creating or updating their professional portfolios. However, after the fashion show, students were so focused on being finished that they did not think about photographing their garments on their model to add to their portfolios. The AMPD Fashion Show should hire someone or ask a skilled student to take photographs of the models in the garments after every show in front of a professional background in addition to action and candid photographs during the show. This would add value to the student's experience in the AMPD program as they would have quality documentation of real work to include in e-portfolios.



Fig. 2. Photo taken at the Futuristic Floral Fashion Show event in spring 2017, which is an annual event of the Apparel Merchandising and Product Development Program of the University of Arkansas Dale Bumpers College of Agricultural, Food and Life Sciences. (A, left) shows photo before and (B, right) shows photo after editing with Adobe Photoshop to improve quality for electronic portfolio use.

The edited, quality photographs of the designed garments are imperative for student portfolio building. Portfolio building should become a larger part of the University of Arkansas AMPD curriculum, specifically e-portfolio building. Currently, AMPD students only have to create a portfolio in their pre-internship and graphic design classes. Portfolio building, specifically e-portfolio building, should be a major component of AMPD curriculum. Electronic-portfolio development should be introduced to students early in their college careers so they understand the significance and future impact of the portfolio. Students should be briefed their freshman year on the importance of building an e-portfolio within their major and it should be revisited throughout their academic

program. This would allow students to keep records of all projects created in and outside of the classroom. Properly documenting these projects from start to finish is a key component of a quality portfolio because it demonstrates the learning and developmental process. Five of the students who received edited photographs provided positive feedback through their unsolicited correspondence. Many online job applications provide a place to link an online portfolio; thus, educating students about this aspect of the job search process may help improve placement rates in the fashion industry in positions that the literature identifies as difficult to obtain. Moreover, it could help students maintain a competitive edge over other apparel programs across the nation.



Fig. 3. Photo taken at the Futuristic Floral Fashion Show event in spring 2017, which is an annual event of the Apparel Merchandising and Product Development Program of the University of Arkansas Dale Bumpers College of Agricultural, Food and Life Sciences. (A, left) shows photo before and (B, right) shows photo after editing with PhotoShop to improve quality for electronic portfolio use.

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Impact of teat order on feed consumption in swine from birth to nursery

Meet the Student-Author



Callan Lichtenwalter

Research at a Glance

- Swine producers have assumed that pigs that nurse from the cranial portion of the udder will be more dominant and consume more milk, and later more feed.
- Using growth performance values and blood hormone levels that assess satiety, there was no observed relationship between teat order and feed consumption except during the beginning of the nursery phase of production.
- Accommodating the needs of pigs based on the time it takes them to adjust to a new environment seems to be a viable option in feeding pigs. Since the cranial pigs take more time to adjust, they struggle with average daily gain while eating the same amount of feed, so allowing them access to more feed could remedy their poor gains.

I grew up in Conway, Arkansas, and graduated from Conway High School in 2014. Since pursuing a degree in Animal Science I have been able to become very involved within the department as a member of Block and Bridle, Pre-Vet Club, and the Meats Quiz Bowl team and also as a staff member in the equine program and in the animal science nutrition lab.

Thanks to the Bumpers College and the Honors College I have had the opportunity to study abroad twice. My first time was for four weeks in the summer after my sophomore year in Scotland attending an equine science program. My second time was during the spring semester of my junior year when I attended the University of Sussex in Brighton, England. These experiences allowed me to take courses not offered here and travel all over Europe.

I would like to thank all of my coauthors and Liz Palmer, Josh Knapp, Jase Ball, and Doug Galloway. Thank you also to Bumpers College and the Honors College for their financial support of my research.



Callan holding the first of many pigs born for her research project.

Impact of teat order on feed consumption in swine from birth to nursery

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and Tsung Cheng Tsai[‡]*

Abstract

A relationship between teat order and feed consumption has been assumed in pigs, but no study has looked at this exact relationship. Pigs were observed shortly after birth to be in either a cranial, middle, or caudal teat position. Growth performance data and active and total plasma ghrelin concentrations were analyzed at birth, weaning, and at the end of the nursery stage of production to see if a relationship with teat order was present. Overall, no effect of teat order was found on average daily gain, average daily feed intake, gain-to-feed ratio, or body weight among pigs from each section of the udder. Differences did occur during certain stages of nursery, which can be of economic importance to producers. Ghrelin was measured so a consistent measure of satiety could be observed throughout the study. No difference was seen in active or total ghrelin levels or the active-to-total ghrelin ratio in relation to teat order, although there were differences in active and total ghrelin concentrations among the sampling days. Further research should be carried out to investigate what factors would contribute to these data contradicting previous inferences about the relationship of teat order and feed consumption in pigs.

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Introduction

The goal of this experiment was to observe whether there was connection between teat order and feed consumption from birth through the end of the nursery phase of production. Teat order, the dominance hierarchy established just after birth and maintained throughout life, has been assumed by people in the industry to lead to an increase in feed consumption past the suckling stage.

The percentage of nursery-only sites in the U.S. increased from 0.4% in 1995 to 8.2% in 2012 (USDA, 2012). The all-in/all-out by room management style (all pigs come in at once and leave at once) increased from 24.4% in 2000 to 31.7% in 2012, and all-in/all-out by building increased from 32.3% in 2000 to 41.2% in 2012 (USDA, 2012). With a shift in the industry to more specified production, it is important for producers to know how their pigs are likely to perform so the pigs' needs can be met and the producer can realize the largest economic return. With an all-in/all-out system, if there is a variance in pig's weight at the end of nursery, the producers will not optimize their economic return per pig. If producers know how to feed individuals within the whole herd so that each animal reaches its maximum potential, greater profits could be realized.

Starvation is the second leading cause of death during the nursery phase, with producers reporting that starvation accounted for 22.1% of their losses (USDA, 2012). One way to decrease this loss is to understand if the needs of pigs vary based on factors such as dominance, or teat order, and then accommodate for individuals who would normally experience a decrease in feed intake. Having strong early growth rates is extremely important in pigs. For every one pound under the ideal weight a pig is at 10 weeks old, it may take up to an additional 5 days to reach ideal market weight later in life (Pitcher and Springer, 1997). Pigs that are lighter at weaning can be more labor intensive to manage in the nursery, and have a greater risk of death than pigs that weigh more at weaning (Drits, 1998). With a variation in weaning weight comes the need to divide pigs into pens and feed them based on their needs. When producers better understand the divisions within their nursery pigs, each pig can be fed to match its own needs and reach an appropriate weight along with all the other pigs in the nursery (Drits, 1998).

Total feed cost is the largest production cost per pig sold in most nurseries, and it is influenced heavily by feed efficiency (DeRouchey et al., 2014). The goal of the nursery phase is to adjust pigs to the dry feed they will be consuming in the grow-finish stage of production. The faster this diet can be introduced, the lower feed costs will be overall. One feeding strategy is for pigs that are heavier at weaning to be fed less once in the nursery so that their smaller litter mates have the opportunity to catch up in

body weight. This saves costs and prevents over-feeding larger pigs, so all pigs end nursery at a more consistent weight (DeRouchey et al., 2010).

Understanding how best to feed pigs during the nursery stage is vital for both production efficiency and costs. Knowing if there is a relationship between teat order and feed efficiency and weight gain in the nursery can help producers to best divide their pigs and allocate rations for each nursery phase. When each pig is fed appropriately, pigs will end nursery and enter the grow-finish stage at a more consistent weight in an all-in/all-out system.

Materials and Methods

Observational Study

All sows used farrowed (gave birth) on 10 November 2017 between 10:00 and 19:30 h. Sows were individually housed in farrowing crates (1.22 m × 2.13 m). Seven second-parity sows (sows on their second litter of piglets), that had at least 8 piglets by the end of parturition (process of giving birth), were observed in this experiment. Piglets were observed during birth and individually marked with a non-toxic, permanent marker identifying them and approximately denoting birth order. This was their primary identification until processing occurred. Teat order was observed in litters 2 to 4 hours after birth and recorded as a preliminary teat order. Processing occurred 24 ± 4 hours after birth, and at this time pigs were assigned a unique identification number (ears were notched) that was recorded with their corresponding birth order. Processing also included docking of pig's tails and receiving an injection of hydroxydextran at this time, while males were surgically castrated 7 days after birth. A birth weight was recorded at processing as well. Teat order was again assessed at 24 ± 4 and 48 ± 4 hours after birth. By 48 hours, the teat order had stabilized (86% of pigs consistently remained on the same teat pair during feedings), and this was regarded as the final teat order. From this final order, 6 pigs from 6 litters were selected (1 sow lost a pig, resulting in fewer than 8 pigs and was removed from the study). The 6 pigs from each litter were chosen based on their position along the udder. Two pigs were chosen from the cranial portion of the udder, 2 from the middle portion, and 2 from the caudal portion. When all 36 piglets were identified, 33 were selected for blood sampling. Ghrelin was measured throughout so a consistent measure of satiety could be observed throughout the study. In the 3 litters where only 5 piglets were selected for a blood sample, a single pig from the caudal portion of the udder was chosen for sampling. Blood was sampled via anterior vena cava puncture using a 23 gauge (2.54 cm) needle and transferred into tubes containing Ethylenediamine tetraacetic acid (EDTA) and aprotinin before

being placed on ice until centrifuged (2000 × g, 20 minutes, 4 °C). Plasma was then transferred into duplicate aliquots. Half of the aliquots for each individual sample contained 50 µL of 10 M HCl. All aliquots contained 500 µL of plasma. Aliquots containing acid were vortexed, and then all samples were stored at -80 °C until assayed. This process was repeated at weaning (21 days), and at the end of the nursery phase (62 days).

Performance Data

At weaning (21 days of age), pigs were weighed before being moved to off-site housing and placed in 1.6 m × 1.2 m nursery pens. There were 2 pigs per pen, and each pig was placed with a litter mate that suckled from the same region of the udder. The pigs chosen for the study (n =

36) were thus divided into 18 pens. Feed consumption was monitored during the 6 weeks of the nursery period. Nursery was divided into 3 two-week phases. Phase-1 feed was offered after weaning and feed was weighed for each pen before placing in feeders. Pigs had ad libitum access to feed and water. Records of any feed added to feeders before the end of the two week phase were kept. At the end of the two weeks, the feed remaining for each pen was weighed and subtracted from the total feed added. The pigs then received a phase-2 diet, followed by the phase-3 diet for the last two weeks of the trial, and feed disappearance was recorded at the end of each phase. Average daily feed intake was calculated by dividing the amount of feed consumed by the number of pigs in the pen and the number of days in the phase. Pigs were also

Table 1. Growth performance data.

	Treatment			SE	P-value		
	Cranial	Middle	Caudal		Treatment	Linear	Quadratic
Average daily gain, grams/day							
Birth to Weaning	258	258	247	27.7	0.96	0.80	0.88
Nursery Phase 1	116	149	168	21.2	0.25	0.11	0.77
Nursery Phase 2	481	536	458	32.0	0.25	0.63	0.11
Nursery Phase 3	770	725	771	27.8	0.43	0.97	0.20
Nursery	457	473	465	22.0	0.87	0.79	0.66
Overall	394	405	396	19.2	0.91	0.92	0.68
Average daily feed Intake, grams/day							
Nursery Phase 1	258	236	249	22.0	0.79	0.79	0.53
Nursery Phase 2	737	725	606	42.7	0.09	0.05	0.32
Nursery Phase 3	1077	1129	1128	65.9	0.82	0.59	0.75
Nursery	693	698	658	33.3	0.67	0.48	0.59
Gain to feed							
Nursery Phase 1	0.428	0.634	0.648	0.06	0.02	0.01	0.18
Nursery Phase 2	0.661	0.744	0.771	0.05	0.34	0.17	0.68
Nursery Phase 3	0.720	0.650	0.691	0.03	0.22	0.46	0.12
Nursery	0.661	0.682	0.707	0.02	0.33	0.14	0.95
Weight, kilograms							
Birth	1.44	1.39	1.45	0.11	0.91	0.96	0.66
Weaning	6.40	6.28	6.15	0.54	0.95	0.75	0.99
Nursery Phase 1	7.91	8.23	8.33	0.60	0.87	0.62	0.88
Nursery Phase 2	15.1	16.3	15.2	0.95	0.65	0.95	0.36
Nursery Phase 3	25.1	25.7	25.2	1.21	0.94	0.95	0.74

weighed at the transition of every phase change and at the end of the nursery period to calculate average daily gain and gain-to-feed ratio.

Plasma Analysis

Active ghrelin was assessed from the acidified plasma samples using a commercial RIA kit (GHRA-88HK; Active Ghrelin; EMD Millipore, Billerica, Massachusetts, U.S.). This kit uses a specific antibody for the biologically active form of ghrelin with the octanoyl group on Serine 3. The assay has successfully tested for active ghrelin in previous studies (Brown-Brandl et al., 2015). Whereas total ghrelin was assessed from the acidified plasma samples using a commercial RIA kit (GHRA-89HK; Total Ghrelin; EMD Millipore, Billerica, Massachusetts, U.S.). This kit has also been successfully utilized in the same study as the active ghrelin (Brown-Brandl et al., 2015). To better fit a normal distribution, plasma data is presented using log-transformed means.

Statistical Analysis

Data were analyzed as a randomized complete block design, with sow/litter as the blocking factor (random effect), and piglet as the experimental unit. To better fit a normal distribution, plasma data are analyzed and presented using log-transformed means. The analysis of variance was generated with PROC GLIMMIX, with teat order as the lone fixed effect in the model. Least square means

were calculated and separated using the PDIF option when a significant ($P \leq 0.05$) F-test occurred. In addition, contrasts were included in the analysis to determine the linear or quadratic effect of teat order on pig performance.

Results and Discussion

No difference in body weight was observed at birth ($P = 0.91$), at weaning ($P = 0.95$), or at the end of any nursery stage ($P \geq 0.65$; Table 1). Furthermore, no effect of teat order was found on average daily gain (ADG) overall ($P = 0.91$) or throughout the nursery phase ($P = 0.87$). However, in nursery phase 1 (N1), there appeared to be a linear relationship ($P = 0.11$) between teat order and ADG. Although not significantly different, pigs in the cranial teat position had the lowest ADG, and pigs in the caudal teat position had the greatest ADG.

There was no effect of teat order ($P = 0.67$) on average daily feed intake (ADFI) of pigs for the overall nursery period (Table 1). During nursery phase 2 (N2), however, a linear relationship ($P = 0.05$) between teat order and feed intake was observed, with pigs in the cranial teat position having had the greatest ADFI, and pigs in the caudal teat position had the lowest ADFI ($P = 0.09$).

Overall feed efficiency, as measured by gain-to-feed ratio (G:F), was not affected ($P = 0.33$) by teat order (Table 1). A strong linear relationship between G:F and teat position was observed in N1 ($P = 0.01$) during NI,

Table 2. Log-transformed means of active ghrelin, total ghrelin, and active to total ghrelin ratio.

Item	Treatment [†]			SE [‡]	P-value		
	Cranial	Middle	Caudal		Treatment	Day	Treatment × day
Active	-----picogram/mL-----						
D 7 a [†]	3.66	3.71	3.49				
D 21 b	3.46	3.53	3.37				
D 62 a	3.64	3.59	3.57	0.1	0.18	0.04	0.79
Total							
D 7 a	6.94	6.89	6.76				
D 21 b	6.49	6.55	6.53				
D 62 a	6.80	6.91	6.84	0.1	0.63	<0.01	0.65
Active:Total							
D 7	-3.29	-3.19	-3.27				
D 21	-3.04	-3.00	-3.22				
D 62	-3.17	-3.32	-3.26	0.1	0.68	0.12	0.58

[†] Columns without common letter superscripts differ, Main effect of day, $P < 0.05$.

[‡] Pooled standard error of the mean for the interaction.

and pigs in the cranial teat position had the lowest G:F; whereas pigs in the caudal teat position had the greatest G:F ($P = 0.02$).

Overall, no relationship between teat order and growth performance was found. A linear relationship between teat order and ADG in the first phase of nursery would be consistent with previous observations (Cardoso et al., 2015). The pigs that nursed on the caudal portion of the udder are perhaps more independent because the contact they had with their dam was less direct. This would make the transition of weaning easier on the piglets. Because ADFI did not differ during this phase, but the G:F linearly favored caudal piglets, the results suggest that the more caudal, less dominant pigs had the ability to better adapt to a new environment and continue growing undeterred. Cranial pigs having the greatest ADFI in nursery N2 suggests that those piglets had time to adjust to their new environment and were able to catch up to their conspecifics. Average daily gains and G:F not differing for N2 would suggest that the more cranial pigs were still adjusting during this time period, and had to consume more to stay on track with the other pigs.

No difference was observed among treatment groups for active ghrelin (AG; $P = 0.18$), total ghrelin (TG; $P = 0.63$), or active-to-total ghrelin ratio (A:T; $P = 0.68$) (Table 2). There were also no treatment by day interactions ($P \geq 0.58$) for AG, TG, or A:T. The only difference observed was when comparing values \times day for AG ($P = 0.04$) and TG ($P < 0.01$). No difference was observed for A:T ($P = 0.12$) when comparing by day.

Because no difference was observed among treatment groups for AG, TG, or A:T, it can be assumed that all pigs maintained comparable levels of satiety. This is especially relevant for samples taken on day seven when pigs were nursing and no accurate way of measuring feed intake was possible. The results suggest that pigs in the cranial, middle, and caudal regions of the udder were all able to obtain an amount of milk that lead to similar hormonal levels of satiety. This strays from previous assumptions that maintained that cranial piglets consume the most milk and continue to consume the most feed in later stages of production (Cardoso et al., 2015). The only way to know if the pigs from each region of the udder were receiving a similar amount of milk would be to analyze samples from the sow. Further research could be done to analyze both quantity and quality of the milk in each region and then relate it growth of pigs nursing in each of these regions.

A difference in both AG and TG was seen over the different days, specifically on day 21 when piglets were weaned and transported to the offsite nursery. The lower levels of both forms of ghrelin at this time may indicate a decrease in appetite at weaning. The piglets were under a high

level of stress at that time, which may have influenced the decrease in ghrelin levels, and thus appetite stimulation. This would be consistent with observed decreases in feed intake after weaning (Cardoso et al., 2015).

Both the growth performance and plasma results seem to suggest that the assumed relationship between teat order and feed consumption and growth does not hold true. At birth, pigs from each litter were observed competing for a spot along the udder. This suggests that there is still competition for a preferred spot and that more dominant pigs are able to obtain this position; however, the advantages of this preferred position are now questionable.

Because there has been a trend towards all-in/all-out systems recently, having a consistent drove at the end of a production stage is essential for the viability of an operation. Pigs that nursed on the cranial portion of the udder appear to have the hardest time transitioning into the nursery phase. Accommodating the needs of pigs based on the time it takes them to adjust to a new environment seems to be a viable option in feeding pigs. Because the cranial pigs take more time to adjust, they struggle with ADG while eating the same amount of feed, so allowing them access to more feed could remedy their poor gains.

Conclusions

Overall, there was no difference in the growth performance or plasma ghrelin levels of pigs from the cranial, middle, or caudal portion of the udder, even though previous studies suggested otherwise. One explanation for this could be the changing genetics of pigs used in modern production systems. Many of the studies done in this area were conducted several decades ago, and the genetics of the pigs used in those studies have been altered to meet the needs of the current production systems. With years of artificial selection, it is possible that modern pigs are able to produce more uniform litters and a more uniform distribution of milk throughout the udder. This would explain the lack of difference in growth performance and plasma ghrelin levels, although further study would be needed for a more definite conclusion.

Acknowledgments

I would like to thank The Honors College and The Bumpers College of Agricultural, Food and Life Sciences for awarding me research funding. Support was also provided by the University of Arkansas Division of Agriculture.

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Characterization of short-grain rice cultivars grown in Japan, California and Arkansas

Meet the Student-Author



Michiyo Nishiwaki

Research at a Glance

- The research characterizes short-grain rice properties grown in Japanese, Arkansas, and California.
- The three short grain rice cultivars showed significantly different properties despite shared genetic background.
- The research demonstrates the effect of rice growing environments on the properties of rice.

I transferred to the University of Arkansas from Gaku-shuin University in Japan in 2016 Spring. The reason that I was interested in Food Science was that my family grew a short-grain rice cultivar in Japan and thought that learning this field in English could be exciting for me. Fortunately, I was given the chance to engage in research in May 2017. This research was awarded the 2nd prize at the 2018 Gamma Sigma Delta Poster Competition at the University of Arkansas. I also won 3rd place at the Bumpers Honors Student Board Poster Competition in April 2018.

During my time at the University of Arkansas, I was an active member in Gamma Beta Phi and Tau Sigma. I served for one year as an officer of the Japanese Student Association. As an international student, I have engaged in the International Cultural Team and played the violin for two years. During this summer, I am planning to do an internship in a food industry in California in Research & Development.

I would like to thank Dr. Wang for serving as a mentor and guiding me throughout this research. Without her, it would not have been completed successfully. Dr. Mauro-moustakos supported this project with statistical knowledge. Eric Lii helped me conduct experiments in a lab.



Michiyo holding her second place award in the University of Arkansas Chapter Gamma Sigma Delta Honor Society of Agriculture's undergraduate poster presentation category.

Characterization of short-grain rice cultivars grown in Japan, California and Arkansas

Michiyo Nishiwaki^{*}, Eric Lii[†], Andy Mauromoustakos[§], and Ya-Jane Wang[‡]

Abstract

Arkansas and California are the two leading rice-producing states in the U.S. Arkansas grows predominantly long- and medium-grain rice and California, primarily medium- and short-grain rice. Although short-grain rice accounts for less than 2% of U.S. rice production, the demand for short-grain rice is rising because of increasing popularity of sushi and sake. Short-grain rice may open new opportunities for rice farmers in Arkansas because of its premium price and different applications. The objective of this study was to characterize the physical, physicochemical and textural properties of rice cultivars grown in Arkansas versus in Japan and California. Three short-grain rice cultivars from the 2016 crop year were collected, including RU9601099 from Arkansas, CH-202 from California, and Koshihikari from Japan. The rice cultivars were characterized for kernel appearance, chemical composition, amylopectin chain-length distribution, and gelatinization, pasting and textural properties. Cultivar RU9601099 was found to have a smaller width and a greater length/width ratio and whiteness than the other cultivars; it was high in protein and ash contents, but low in amylose content. Cultivars RU9601099 and CH-202 shared a similar average chain-length of amylopectin. Cultivar RU9601099 had significantly greater gelatinization temperatures and enthalpy and peak and trough viscosities. When cooked, RU9601099 exhibited greater stickiness, whereas Koshihikari exhibited greater hardness. The results reveal significant differences in some properties among the three short-grain rice cultivars, although both RU9601099 and CH-202 are crosses of Koshihikari, and demonstrate the importance of environmental factors affecting rice properties.

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Introduction

Rice cultivars in the U.S. are characterized as long-, medium-, and short-grain according to grain dimensions. Long-grain rice is typically used for entrees and is dry and fluffy when cooked. Medium-grain rice is more moist and tender than long-grain rice, and typically used for risotto and sushi. Short-grain rice is soft, plump, and almost round, and mostly used in sushi, desserts or puddings. Short-grain rice is defined as such if the kernel length-to-width ratio is 1.9 to 1 (USDA, 2014). Short-grain rice is favored for sushi because the sticky and soft texture is important to Japanese preference for food. Short-grain rice is also used for alcohol production, such as sake, because of its large grain size that is suited for polishing to remove at least 40% of its weight for a cleaner flavor. Koshihikari from Japan has been recognized as a premium quality, short-grain cultivar because of its flavor and texture. The current short-grain rice cultivars in the United States are Koshihikari crosses. For example, cultivar RU9601099 from Arkansas is a cross of Koshihikari and Mars (Norman and Johnson, 1999) and CH-202 from California is derived from Koshihikari and Hitomebore (Andaya and McKenzie, 2014).

Although short-grain rice only accounts for 1-2% of total U.S. rice production and is exclusively grown in California, its demand is expected to continue growing because of the increasing sake brewing industry and international trade. If the quality of Arkansas short-grain rice is similar to those cultivars from Japan and California, the economic impacts of short-grain rice to Arkansas will be significant. This is because it is used in different markets than long- and medium-grain rice and it commands a premium price. However, the short-grain rice cultivars developed in Arkansas may be different from those grown in Japan and California because of different genetic backgrounds and growing environments, which are hypothesized to result in differences in chemical composition and starch fine structures. Therefore, the objective of this study was to compare the physical, chemical and textural properties of rice cultivars grown in Arkansas, California, and Japan to provide breeders information to develop suitable short-grain cultivars for Arkansas.

Materials and Methods

Three short-grain milled rice samples from the 2016 crop year, including one cultivar (Koshihikari) grown in Nagano prefecture, Japan and purchased in a grocery store in Japan, one cultivar (CH-202) grown in California and provided by Dr. Stanley Samonte of Texas A&M University and Dr. Kent McKenzie of California Cooperative Rice Research Foundation (Biggs, California), and one cultivar (RU960-

1099) grown in Arkansas and provided by Dr. Karen Moldenhauer of the University of Arkansas System Division of Agriculture's Arkansas Rice Research and Extension Center (Stuttgart, Arkansas), were used for this study.

Kernel Appearance

Head rice color ($L^*a^*b^*$) was measured using a colorimeter (ColorFlex, Hunter Associates Laboratory, Reston, Virginia). Kernel dimensions (length, width, and thickness) of duplicate samples containing approximately 1000 kernels were measured using a digital image analysis system (SeedCount 5000; Next Instruments, NSW, Australia).

Chemical Composition

Milled rice flour samples were obtained by grinding head rice in a laboratory mill (Cyclone Sample Mill, Udy Corp., Ft. Collins, Colorado) fitted with a 0.5-mm screen. The flour was used to determine apparent amylose content by iodine colorimetry (Juliano, 1971), moisture content by an oven-drying method (AACC Method 44-15A), crude protein by a micro-Kjeldahl method (AACC Method 46-13), lipid content by a lipid extraction system (Soxtec Avanti 2055, Foss North America, Eden Prairie, Minnesota) according to AACC Method 30-20 (AACC International, 2000) with modifications by Matsler and Siebenmorgen (2005), and ash content by a dry-ashing method (AACC Method 08-03). Duplicate measurements were conducted for each flour sample. Starch was extracted from milled rice flour with 0.1% NaOH, followed by lipid removal with water-saturated n-butyl alcohol (Patindol and Wang, 2002).

Amylopectin Chain-length Distribution

Starch was debranched and analyzed according to Patindol and Wang (2002). The amylopectin chain-length distribution in the supernatant was analyzed by high performance anion-exchange chromatography with pulsed amperometric detection (HPAEC-PAD) analysis using a Dionex ICS-3000 ion chromatography system (Dionex Corporation, Sunnyvale, California) with an AS40 automated sampler, a 50-mm CarboPac PA1 guard column, and a 250-mm CarboPac PA1 analytical column. Amylopectin chains were divided into A chain (DP, degree of polymerization in glucose unit, 6-12), B1 chain (DP 13-24), B2 chain (DP 25-36), B3+ chain (DP 37-65) (Hannashiro et al., 1996).

Gelatinization Properties

The gelatinization properties of milled rice flour were determined using a differential scanning calorimeter (DSC; Pyris Diamond, Perkin Elmer Instruments, Shelton, Connecticut). Approximately 8 mg of rice flour was weighed into an aluminum pan and added with 16 μ L of deionized

water. The pan was hermetically sealed and equilibrated at room temperature for 1 h prior to scanning from 25 to 120 °C at a rate of 10 °C/min. The instrument was calibrated with indium, and an empty pan was used as a reference. Onset, peak, and end gelatinization temperatures (T_o , T_p , and T_c , respectively) and gelatinization enthalpy were calculated from each thermogram using the Pyris software.

Pasting Properties

The pasting properties of milled rice flour were characterized using a Rapid ViscoAnalyser (RVA; Model 4, Perten Instruments, Springfield, Illinois) according to AACC Method 61-02.01. The pasting properties measured included peak viscosity, hot paste viscosity (trough), final viscosity, breakdown, setback, and total setback. Paste breakdown was calculated as peak viscosity minus trough viscosity, setback as final viscosity minus peak viscosity, and total setback as final viscosity minus trough viscosity.

Cooked Rice Texture

The cooked rice texture was evaluated following the method of Patindol et al. (2010) with modifications.

Head rice (20 g) was placed in a 100-mL beaker with 30 g of deionized water and soaked for 30 min. Thereafter, rice was cooked in a household rice cooker (Aroma, model ARC-707, San Diego, California, U.S.) containing 350 mL of water for 30 min, and cooked rice was kept at a warm setting before the texture test within 30 min. Cooked rice hardness and stickiness were analyzed by a texture analyzer (TA-XT2 Plus, Texture Technologies, Scarsdale, New York, U.S.). Ten cooked rice kernels were compressed at a speed of pre-test 2.0 mm/s, test 0.5 mm/s, and post-test 0.5 mm/s to a distance defined to compress the kernels to 90% of their original height using a 5-kg load cell on a flat aluminum plate (100 mm dia.) under the Texture Profile Analysis test mode. Six replications were performed for each cooked sample, and two cooked samples were prepared for each rice cultivar.

Results and Discussion

Kernel Appearance

Cultivars Koshihikari and RU9601099 shared a similar kernel length, whereas CH-202 was shorter (Table 1).

Table 1. Physical properties, chemical composition and amylopectin chain-length distribution of three short-grain rice cultivars†

	Koshihikari Nagano, Japan	RU9601099 Arkansas, U.S.	CH-202 California, U.S.
Physical properties			
Length (L) (mm)	4.92 a	4.95 a	4.77 b
Width (W) (mm)	2.87 a	2.72 b	2.87 a
Thickness (mm)	2.05 a	2.03 a	2.04 a
L/W ratio	1.72 b	1.82 a	1.67 c
Whiteness (L*)	72.69 b	77.09 a	73.08 b
Yellowness (b*)	15.23 b	16.09 a	15.88 a
Chemical compositions			
Amylose (% db)	14.89 a	11.90 b	15.68 a
Protein (% db)	5.65 b	8.53 a	5.20 c
Lipid (% db)	0.43 a	0.31 b	0.42 a
Ash (% db)	0.38 b	0.64 a	0.40 b
Amylopectin Chain-Length Distribution			
Average Chain Length	20.2 c	20.9 a	20.7 b
A (DP 6-12) (%)	27.9 a	27.0 c	27.4 b
B1 (DP 13-24) (%)	47.5 a	46.0 c	46.5 b
B2 (DP 25-36) (%)	13.2 c	14.1 a	13.5 b
B3+ (DP 37-65) (%)	11.5 c	13.0 a	12.6 b

† Means of duplicate measurements followed by a common letter across a row are not significantly different at $P < 0.05$.



Koshihikari

RU9601099

CH-202

Fig. 1. Milled rice kernels of three short-grain rice cultivars Koshihikari (Japan), RU9601099 (Arkansas), and CH-202 (California).

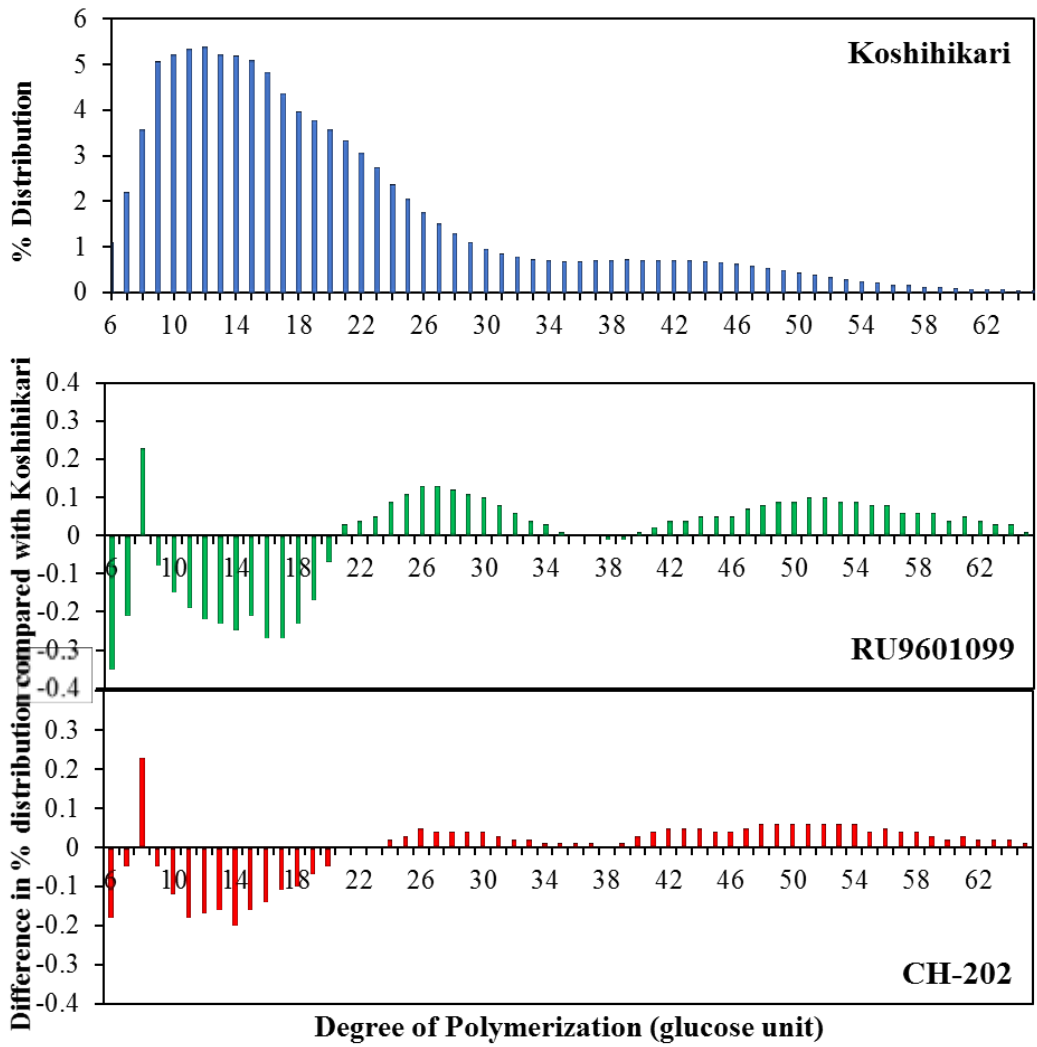


Fig. 2. Amylopectin chain-length distribution of the control short-grain rice cultivar, Koshihikari, and the differences in the percentage distribution of amylopectin chains between the control cultivar and short-grain rice cultivars RU9601099 or CH-202.

Koshihikari and CH-202 were similar in kernel width, whereas RU9601099 was slightly narrower in width. All three cultivars had a similar thickness value. Cultivar RU9601099 appeared less rounded in shape than Koshihikari and CH-202 according to L/W ratio. Cultivar RU9601099 was significantly greater in whiteness (L*) and yellowness (b*) than Koshihikari. The presence of chalkiness in RU9601099 (Fig. 1) was presumed to be responsible for its greater whiteness. Overall, RU9601099 differed more in terms of kernel appearance from Koshihikari than CH-202. The less rounded shape of RU9601099 suggests that RU9601099 is not as suitable for sake application as CH-202.

Chemical Composition and Amylopectin Chain-length Distribution

Cultivars Koshihikari and CH-202 had similar amylose, lipid, and ash contents; RU9601099 was low in amylose and lipid contents but high in protein and ash contents (Table 1). The greater protein and ash contents in RU9601099 were proposed to be responsible for its greater yellowness (Wang et al., 2014). Cultivars RU9601099 and CH-202 had longer average amylopectin chains than Koshihikari, which was ascribed to their greater proportions of B2 and B3+ chains as illustrated by the differential plots (Fig. 2). Compared with Koshihikari, RU9601099 and CH-202 consisted of a lesser proportion of DP 6-20

and a greater proportion of DP 21-65. Furthermore, the difference in chain length distribution was less in CH-202 and greater in RU9601099, indicating CH-202 was more similar to Koshihikari in amylopectin structure. It has been shown that growing temperature affects rice amylose content and amylopectin chains. Elevated temperatures reduced amylose content but increased amylopectin long chains (Resurreccion et al., 1977; Asaoka et al., 1985; Patindol et al., 2014); whereas low temperatures supported amylose biosynthesis in the endosperm during grain ripening (Umemoto et al., 1995). Cameron et al. (2008) compared medium-grain rice cultivars grown in Arkansas and in California and found that Arkansas cultivars had higher protein contents but lower amylose contents, and their differences diminished when California cultivars were grown in Arkansas. Sushi rice with a low protein is usually preferred by the Japanese as a cleaner flavor, thus RU9601099 may not be as desirable as CH-202 for sushi application.

Gelatinization, Pasting, and Textural Properties

Cultivar RU9601099 had the highest gelatinization temperatures, followed by CH-202, and Koshihikari had the lowest (Table 2). The higher gelatinization temperatures of RU9601099 and CH-202 were attributed to their greater proportions of B2 and B3+ starch chains and a greater average chain length. It has been established that

Table 2. Gelatinization, pasting and textural properties of three short-grain rice cultivars.†

	Koshihikari	RU9601099	CH-202
Gelatinization Properties			
Onset (°C)	61.4 c	67.5 a	65.2 b
Peak (°C)	68.0 c	73.5 a	71.7 b
End (°C)	74.3 c	81.7 a	78.8 b
Enthalpy (J/g)	9.01 b	10.72 a	9.55 b
Pasting Properties			
Peak viscosity (cP)	3140 b	3398 a	3111 b
Trough viscosity (cP)‡	1569 b	1930 a	1635 b
Final viscosity (cP)	2829 a	2840 a	2827 a
Breakdown (cP) ^b	1571 a	1468 a	1476 a
Setback (cP) ^b	-312 a	-558 b	-284 a
Cooked Rice Texture			
Hardness (N)	73.2 a	54.6 b	54.6 b
Stickiness (N)	2.5 ab	3.0 a	2.1 b

† Means of duplicate measurements followed by a common letter across a row are not significantly different at $P < 0.05$.

‡ Trough viscosity = minimum viscosity achieved after holding at the maximum temperature; Breakdown = peak - trough; setback = final - peak.

starch gelatinization temperatures and enthalpy increase with elevating ripening temperature (Chun et al., 2015) and nighttime air temperature (Lanning et al., 2012; Patindol et al., 2014; Wang et al., 2014). The nighttime air temperature is higher in Arkansas, followed by California and then Nagano, Japan, which may explain their differences in their starch composition and structure and consequently gelatinization properties. The high gelatinization temperatures of RU9601099 and CH-202 relative to Koshihikari indicate that a higher temperature is required to cook them, thus the cooked rice texture would be affected.

Pasting properties of rice flour are strongly correlated with quality and stability of rice products. Peak viscosity is the maximum viscosity developed during heating; whereas trough viscosity is the minimum viscosity achieved after holding at the maximum temperature. Breakdown viscosity is the difference between peak and trough viscosities and an index of the stability of starch. It was reported that rice cultivar with the greatest breakdown viscosity was the most palatable (Tren et al., 2001). Setback viscosity is the final viscosity minus the peak viscosity and indicates the tendency of starch to retrograde during cooking. Cultivars Koshihikari and CH-202 exhibited similar pasting profiles (Fig. 3), except that Koshihikari had a lower pasting temperature; RU9601099 displayed higher peak and trough viscosities (Table 2), which were due to its lower amylose content and higher

protein content. Amylose content was reported to be negatively correlated with peak, final, and breakdown viscosity, but positively correlated with setback viscosity (Patindol et al., 2014). Besides amylose content, peak viscosity was negatively impacted by protein content (Wang et al., 2014). Therefore, the combination of higher protein and lower amylose contents resulted in a higher peak viscosity but comparable breakdown viscosity of RU9601099 compared with Koshihikari and CH-202. The similar pasting properties of CH-202 and Koshihikari suggest they may share similar sensory attributes.

In terms of cooked rice texture, Koshihikari showed significantly greater hardness, whereas RU9601099 showed greater stickiness. Cooked rice texture is strongly linked to chemical characteristics. Amylose and protein contents were positively correlated with cooked rice firmness, but negatively correlated with cooked rice stickiness; gelatinization temperature was positively correlated with firmness of core (Mestres et al., 2011). The greater stickiness of RU960199 was attributed its low amylose content, and the greater hardness of Koshihikari was proposed to be due to its high amylose content and low gelatinization temperatures that resulted in more leached amylose to increase cooked rice hardness (Ong and Blanshard, 1995). Although CH-202 also had a high amylose content as Koshihikari, its high gelatinization temperatures may limit the amount of leached amylose,

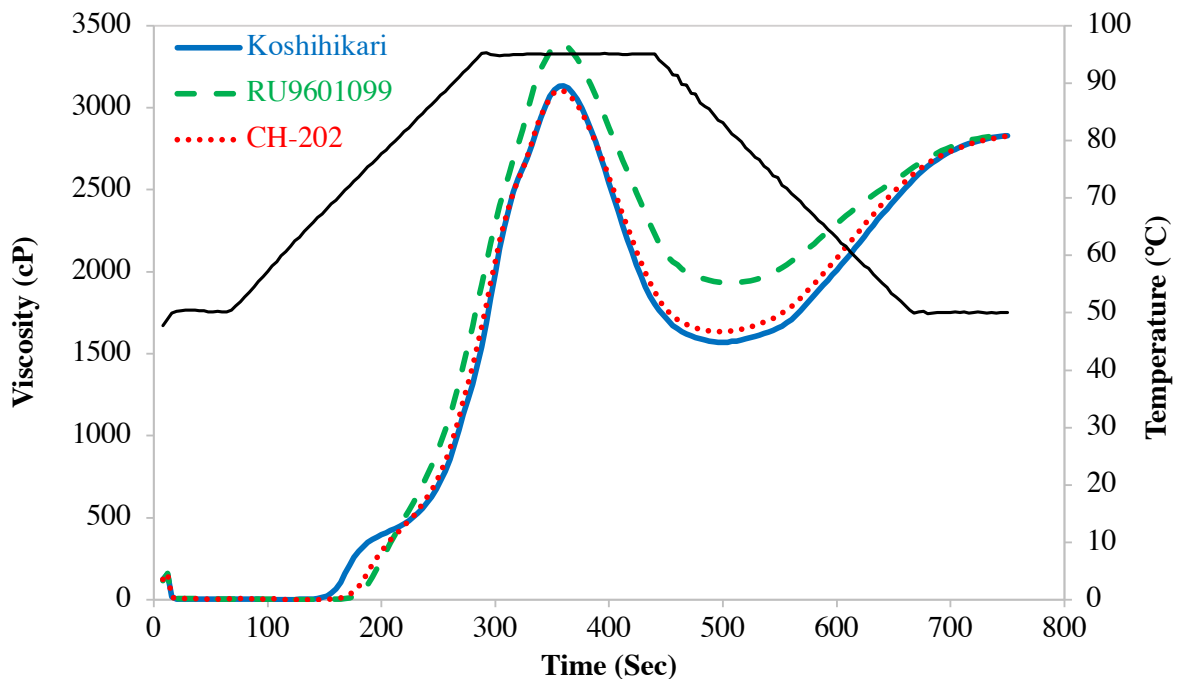


Fig. 3. Pasting profiles of short-grain rice cultivars Koshihikari, RU9601099, and CH-202 with a Rapid ViscoAnalyser.

thus reducing cooked rice hardness. The cooked rice texture results indicate that RU9601099 and CH-202 are soft and not as firm as Koshihikari when cooked and have a different texture compared with Koshihikari.

Conclusions

The results from this study revealed differences among the three cultivars, despite both RU9601099 and CH-202 being crosses of Koshihikari, and CH-202 having more similar properties to Koshihikari. It is proposed that the growing environment affects rice physical and chemical characteristics, which then alter physicochemical and textural properties. Therefore, rice quality depends on not only the genetic background but also the growth environment, and the development of new cultivars needs to take both factors into consideration.

Acknowledgements

We thank Dr. Stanley Samonte, Dr. Ken McKenzie and Dr. Karen Moldenhauer for providing short-grain rice samples, University of Arkansas Processing Program for milling facility, and the Bumpers College Honors Grant program for financial support.

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Ripeness attributes of Arkansas-grown peaches and nectarines at harvest and during postharvest storage

Meet the Student-Author



Mary Siebenmorgen

As an Arkansas native, the University of Arkansas has always been near to my heart. Growing up on a cattle farm in Scranton, Arkansas has made me conscious of the importance of agriculture to our society. After graduating from Scranton High School as the valedictorian, I attended Colorado State University. After my freshman year, I missed what Arkansas had to offer. My interest in food science and horticulture led me to Bumpers College. The University of Arkansas has opened endless opportunities. My experiences as an Honors College student, a Bumpers College ambassador, and the Food Science Club Vice President allowed me to connect with students and faculty. My interest in fruit flourished after working as a laboratory and harvest assistant at the Division of Agriculture's Fruit Research Station in Clarksville. This opportunity connected me with my mentor whom I began working with on undergraduate research in the Food Science Department. Last summer I was a viticulture and enology intern at Post Familie Winery and Vineyard in Altus, Arkansas. I intend to pursue a graduate degree and seek employment in the fruit and wine industry. I would like to thank my thesis advisor, Dr. Renee Threlfall and her graduate student, Molly Felts for the help they offered throughout my research. I would also like to thank my thesis committee, Dr. Margaret Worthington and Dr. Luke Howard, for their guidance and use of laboratories. Last but not least, I would like to thank my family for helping with harvesting the fruit and supporting me throughout my studies and research.

Research at a Glance

- The postharvest potential of the peaches and nectarines was dependent on the fruit genotype (cultivar or selection).
- When picking fruit to ripen during storage (commercially ripened fruit) the ripeness attributes were impacted. Commercially ripened fruit had higher chlorophyll, acidity, and firmness than tree-ripened fruit. However, tree-ripened fruit had slightly higher fruit weight, soluble solids, and pH than commercially ripened fruit.
- Evaluation of ripeness attributes helps determine optimal harvest time, handling, and storage of peaches and nectarines for growers in Arkansas and other regions, and provides insight into potential new peach and nectarine cultivar releases from the University of Arkansas System Division of Agriculture breeding program.



Mary Siebenmorgen measuring the firmness of a peach using a texture analyzer.

Ripeness attributes of Arkansas-grown peaches and nectarines at harvest and during postharvest storage

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Abstract

Since peaches and nectarines are a valued fresh-market crop worldwide, evaluating postharvest potential helps determine feasibility for commercial markets. The ripeness attributes of 10 peach and nectarine genotypes (cultivars and advanced breeding selections) were evaluated at harvest (day 0) and after 7 and 14 days storage at 4 °C. Five cultivars (Amoore Sweet, Bowden, Bradley, Effie, and Souvenirs) and five advanced selections (A-663 CN, A-811 CN, A-794 CN, A-819, and A-885) were evaluated. The fruit was hand harvested at tree ripeness (ripened on the tree) and commercial ripeness (ripened during storage). The attributes of the tree-ripened fruit and commercially ripened fruit varied at harvest and included chlorophyll [0.04–0.86 absorbance (abs)], peach weight (132–264 g), soluble solids (7.23–12.57%), pH (3.18–4.66), titratable acidity (0.16–1.21%), and flesh firmness [6.92–35.72 newtons (N)]. In general, tree-ripened fruit had higher fruit weight, soluble solids, and pH and lower chlorophyll, titratable acidity, and firmness than commercially ripened fruit at harvest. For the tree-ripened fruit, A-811 CN was the largest (247.67 g), A-794 CN had the highest soluble solids (12.57%) and titratable acidity (0.88%), Souvenirs (6.92 N) had the lowest firmness, and Amoore Sweet (18.28 N) was the firmest. During storage of commercially ripened fruit, chlorophyll and fruit weight decreased, while soluble solids increased, but there were no changes in pH or titratable acidity. During storage, A-885 (0.35 abs) had the lowest chlorophyll, and Effie had the largest fruit (203.11 g) and highest soluble solids (12.02%). Some ripeness attributes of the commercially ripened fruit, such as chlorophyll and weight, were not achieved as compared to the tree-ripened fruit. The results of this study provide insight on the potential for releasing new peach and nectarine genotypes from the University of Arkansas System Division of Agriculture's Fruit Breeding Program.

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Introduction

Peaches and nectarines (*Prunus persica* L.) are a valuable fresh-market crop worldwide and are classified as climacteric fruit, fruit that ripens after harvest. Peaches and nectarines can vary greatly in shape (round, flat, or beaked), skin type (pubescent or smooth-skinned), stone type (freestone or clingstone), flesh color (white, yellow, or red), and flesh type (melting, slow melting, or non-melting) with a wide range of sweetness and acidity (Brovelli et al., 1999). Melting-flesh peaches are commonly used in fresh market, and the tertiary ripening phase is generally called the “melting” stage (Ghiani et al., 2011). The difference between melting and non-melting peaches is increased enzymatic capacity for pectin degradation in melting-flesh types (Maw, 2003). Peaches and nectarines are the same genetically, except nectarines lack the gene variant responsible for the fuzzy exterior.

Peaches and nectarines are soft-fleshed and highly perishable fruits, with a limited market life. The maturity at which peaches are harvested greatly influences their flavor, market life, and quality potential. Crisosto and Valero (2008) found that peaches harvested too soon for commercial storage can fail to ripen properly and green ground color (greenish skin around the stem) may never fully disappear. Generally, immature and low-maturity fruit can have inadequate flavor development, which can lead to decreased consumer acceptance. However, over-ripe fruit can have a shortened postharvest life by the time this fruit reaches the consumers.

Optimum maturity must be defined for each peach cultivar for maximum taste and storage quality, but in all cases, it should assure that the fruit has the ability to ripen satisfactorily (Kader and Mitchell, 1989). The ideal maturity of the fruit varies according to markets; for example, a tree-ripened peach will be recommended for local markets while a commercially ripened peach is for distant markets. Maturity indices used from different production areas have reported that flesh color, firmness, and background color changes are correlated to chemical and physical fruit changes during maturation and ripening (Brovelli and Sims, 1998).

A key factor in understanding the fruits' potential for commercial markets is evaluating the postharvest attributes. Postharvest can be defined as the period of time from the moment of harvest to the point of consumption (Florkowski et al., 2014). Post-harvest attributes of fresh-market produce can be related to aroma, texture, flavor, nutraceuticals, composition, and transportation and handling of the product. Peaches immediately begin to deteriorate after harvest, but this process can be delayed when the fruit is refrigerated during storage. However, cold storage can cause damage to fruit quality through

browning (both skin and flesh), flesh breakdown, loss of juiciness (mealiness or woolliness), discoloration, and loss of flavor (Lauxmann et al., 2014).

The Fruit Breeding Program at the University of Arkansas System Division of Agriculture was founded in 1964 by Dr. James N. Moore. Since then, the program has released over 50 different fruit cultivars including blackberries, table grapes, wine grapes, peaches/nectarines, strawberries, and blueberries (J.R. Clark, pers. comm.). The program focuses on developing fruit cultivars for commercial markets and nurseries with production extending beyond Arkansas to other states and countries. The Fruit Breeding Program, located at the Fruit Research Station in Clarksville, Arkansas, is actively evaluating fruit, including peaches and nectarines, for potential release, and has released 12 fresh-market peach and nectarine cultivars.

The objective of this study was to evaluate ripeness attributes of Arkansas-grown peaches and nectarines at harvest and during postharvest storage and to provide insight for release of new peach and nectarine cultivars from the University of Arkansas System Division of Agriculture's Fruit Breeding Program.

Materials and Methods

Plants and Harvest

Ten peach and nectarine genotypes (cultivars and advanced selections) were grown and harvested from the Fruit Research Station, Clarksville Arkansas in 2017. Five cultivars (Amoore Sweet, Bowden, Bradley, Effie, and Souvenirs) and five advanced selections (A-663 CN, A-811 CN, A-794 CN, A-819, and A-885) were evaluated in this study (Table 1). The peaches and nectarines were hand harvested on 23 June in the morning (about 7:00-10:00 AM).

Twelve fruit were harvested per genotype, nine commercially ripened fruit (fruit picked early to ripen during storage) and three tree-ripened fruit (fruit ripened on the tree). The fruit ripeness was screened using a Delta Absorbance (DA) meter (Sintéleiax, Bologna, Italy) to analyze the Chlorophyll A content of the fruit skin (difference of absorbance between 670–720 nm). The standard for commercially ripened fruit using the DA meter was an I_{AD} value of 0.5 to 1.0, and a value below 0.25 indicated physiological maturity of tree-ripened fruit. The peaches and nectarines were harvested for each genotype and placed randomly onto pre-labeled corrugated pulp trays with individual wells for each fruit, with one tray per genotype. The fruit was evaluated for physiochemical attributes at day 0, 7, and 14 at 4 °C with 85–89% relative humidity.

Physiochemical Analysis

Fruit for physiochemical analysis was evaluated in triplicate per ripeness and genotype. Each replicate was

an individual peach or nectarine. The physiochemical analysis included fruit weight, flesh firmness, and composition evaluated at 0, 7, and 14 d at 4 °C. After harvest, fresh fruit weight, and firmness were evaluated at the Fruit Research Station, then fruit for compositional analysis was frozen (-10 °C) for analysis at the Food Science Department in Fayetteville, Arkansas.

Weight. Fruit weight was measured on a digital scale (Mettler Toledo JL6001GE, Columbus, Ohio) in triplicate. Fruit weight was the weight of a whole, intact peach or nectarine.

Firmness. Flesh firmness was measured using a Stable Micro Systems TA.XT2 Texture Analyzer (Texture Technologies Corporation, Hamilton, Massachusetts). Prior to the firmness measurement, a section of the fruit skin was removed by slicing off a 5-mm section. The fruit was then placed on a flat surface. Firmness of the fruit flesh was evaluated at three locations per fruit (90°, 180°, and 270° to the right of the suture) using the 2-mm-diameter probe, at a rate of 2 mm/s with a trigger force of 0.02 N. Force to penetrate the fruit flesh was measured in Newtons (N).

Composition. The fruit half for composition was frozen (-10 °C) then thawed for analysis of soluble solids, pH, and titratable acidity. The other half of the fruit was used for analysis not reported in this manuscript. Each fruit half (skin and flesh) was macerated in a blender, then the juice was centrifuged at 5000 rpm for 8 min and strained through cheese cloth. The pH and titratable acidity were measured using the Titrino plus 862 compact titrosampler (Metrohm AG, Herisan, Switzerland) with the electrode standardized to pH 4.00, 7.00, and 10.00 buffers. Titratable acidity was determined using ~6 g of juice diluted with 50 mL deionized, degassed water with a titra-

tion using 0.1 N sodium hydroxide to an endpoint of pH 8.2. Titratable acidity was expressed as percentage of malic acid. Soluble solids (expressed as percent) were measured using an Abbe Mark II refractometer (Bausch and Lomb, Scientific Instrument, Keene, New Hampshire).

Statistical Design and Analysis

After harvest, the fruit from each of the two ripeness types and ten genotypes were completely randomized. The fruit was stored at 4 °C for 0, 7, and 14 d. Statistical analyses were conducted using JMP® v. 13.2.0 (SAS Institute, Cary, North Carolina). A univariate analysis of variance (ANOVA) was used to determine the significance of main factors and interactions. Tukey's Honestly Significant Difference (HSD) test was used to detect significant differences ($P < 0.05$) among means and verify interactions at 95% significance level. Physiochemical attributes were evaluated in triplicate.

Results and Discussion

At harvest and during storage, the peaches and nectarines were within a commercially acceptable range for the attributes evaluated (chlorophyll, fruit weight, soluble solids, pH, titratable acidity, and firmness). The tree- and commercially ripened fruit were evaluated for physiochemical attributes at harvest, and the commercially ripened fruit was evaluated for physiochemical attributes during storage.

Physiochemical Attributes at Harvest

At harvest for the tree-ripened fruit, the peaches and nectarines had a chlorophyll of 0.04–0.17 abs, fruit weight of 142.33–247.67 g, soluble solids of 7.80–12.57%, pH

Table 1. Fresh-market peach and nectarine genotypes harvested 23 June 2017 from the University of Arkansas System Division of Agriculture's Fruit Research Station, Clarksville, Arkansas.

Genotype	Type	Flesh color	Flesh type	Acid type
A-663 CN	Nectarine	Yellow	Non-melting	High
A-794 CN	Nectarine	White	Non-melting	High
A-811 CN	Nectarine	Yellow	Non-melting	High
A-819	Peach	Yellow	Melting	Low
A-885	Peach	White	Melting	Low
Amoore Sweet	Nectarine	Yellow	Non-melting	Low
Bowden	Nectarine	White	Non-melting	High
Bradley	Nectarine	Yellow	Non-melting	High
Effie	Nectarine	White	Non-melting	Low
Souvenirs	Peach	Yellow	Melting	Low

of 3.43–4.66, titratable acidity of 0.17–0.88%, and firmness of 6.92–18.28 N (Table 2). There were no significant differences between genotypes for chlorophyll or fruit weight. The average chlorophyll level and fruit weight for these genotypes were 0.12 abs and 204.90 g, respectively. These chlorophyll levels at harvest were expected since the DA meter was used to screen the fruit. Although not significantly different, A-811 CN was the largest fruit and Effie, the smallest. Previously reported fruit weight for Amooore Sweet, Bowden, Bradley, and Souvenirs was lower than fruit in this research (Clark and Sandefur, 2013a; 2013b, Clark et al., 2001). There were significant differences between genotypes for soluble solids, pH, titratable acidity,

and firmness. A-663 CN (7.80%) and A-819 (8.33%) had lower soluble solids than A-794 (12.57%). A-885 (0.17%) had lower titratable acidity than A-794 CN (0.88%). Clark and Sandefur (2013a) reported two-year averages of soluble solids for Amooore Sweet (17.3%), Bowden (14.9%), Bradley (14.8%), and Souvenirs (14.1%), which were higher than the soluble solids of fruit in this study. There was a high incidence of rainfall in Clarksville in 2017 prior to harvest of the fruit, which could have caused the lower soluble solids in this study. A-819, Souvenirs, A-885 and Amooore Sweet had higher pH values than the other genotypes. Souvenirs and A-819 had lower firmness than Amooore Sweet and Effie. Amooore Sweet is

Table 2. Physiochemical attributes of tree-ripened and commercially ripened fresh-market peach and nectarine genotypes at harvest (day 0), University of Arkansas System Division of Agriculture's Fruit Research Station, Clarksville, Arkansas (2017).

Ripeness	Genotype	Chlorophyll† (abs)	Fruit weight (g)	Soluble solids (%)	pH	Titratable acidity‡ (%)	Firmness (N)
Tree	A-663 CN	0.09 a [§]	177.33 a	7.80 b	3.77 b	0.63 abc	10.61 ab
	A-794 CN	0.15 a	207.67 a	12.57 a	3.55 b	0.88 a	9.42 ab
	A-811 CN	0.04 a	247.67 a	9.30 ab	3.52 b	0.51 a-d	10.61 ab
	A-819	0.15 a	214.33 a	8.33 b	4.66 a	0.40 cd	7.81 b
	A-885	0.15 a	199.67 a	10.60 ab	4.56 a	0.17 d	9.15 ab
	Amooore Sweet	0.12 a	232.67 a	10.40 ab	4.43 a	0.48 bcd	18.28 a
	Bowden	0.17 a	207.33 a	9.40 ab	3.43 b	0.84 ab	12.90 ab
	Bradley	0.05 a	210.00 a	9.17 ab	3.56 b	0.76 abc	11.36 ab
	Effie	0.18 a	142.33 a	10.90 ab	3.80 b	0.39 cd	18.03 a
	Souvenirs	0.07 a	210.00 a	10.77 ab	4.57 a	0.41 cd	6.92 b
<i>P-value</i>		0.2468	0.0599	0.0119	<0.0001	<0.0001	0.0045
Commercial	A-663 CN	0.86 a	132.00 b	8.15 bc	3.49 c	0.78 bc	23.37 ab
	A-794 CN	0.52 abc	135.33 b	9.30 bc	3.18 c	1.21 a	32.67 a
	A-811 CN	0.51 abc	198.00 ab	8.83 bc	3.39 c	0.93 b	20.97 ab
	A-819	0.59 abc	178.33 ab	7.23 c	4.62 a	0.46 d	9.06 b
	A-885	0.39 bc	163.00 ab	12.17 a	4.54 a	0.16 e	20.14 ab
	Amooore Sweet	0.63 abc	217.67 ab	8.70 bc	4.33 a	0.58 cd	28.09 ab
	Bowden	0.71 abc	212.33 ab	9.70 abc	3.29 c	0.94 ab	22.95 ab
	Bradley	0.82 ab	191.67 ab	7.70 bc	3.33 c	0.74 bcd	15.72 ab
	Effie	0.80 ab	264.00 a	9.60 bc	3.61 bc	0.49 d	27.48 ab
	Souvenirs	0.32 c	181.67 ab	9.90 ab	4.15 ab	0.47 d	35.72 a
<i>P-value</i>		0.0029	0.0064	<0.0001	<0.0001	<0.0001	0.0075

† Chlorophyll A of fruit skin measured by Delta Absorbance (DA) Meter (difference of absorbance between 670–720 nm) as an indicator of fruit ripeness.

‡ Calculated as percent malic acid.

§ Genotypes were evaluated in triplicate. Means with different letter(s) for each attribute within ripeness are significantly different ($P < 0.05$) using Tukey's honestly significant difference.

a non-melting flesh nectarine with a flesh type that is very firm and rubbery in texture (Sandefur, 2011).

At harvest for the commercially ripened fruit, the peaches and nectarines had a chlorophyll of 0.32–0.86 abs, fruit weight of 132.00–264.00 g, soluble solids of 7.23–12.17%, pH of 3.18–4.62, titratable acidity 0.16–1.21%, and firmness of 9.06–35.72 N. There were significant differences among genotypes for all of these attributes. A-663 CN (0.86 abs) had higher chlorophyll than Souvenirs (0.32 abs). Effie (264.00 g) was larger than A-663 CN (132.00 g) and A-794 CN (135.33 g). A-885

(12.17%) had higher soluble solids than A-819 (7.23%). A-819, A-885, Amore Sweet, and Souvenirs had higher pH than A-663 CN, A-794 CN, A-811 CN Bowden, and Bradley. A-794 CN (1.21%) had a higher titratable acidity than Souvenirs (0.47%). Souvenirs (35.72 N) and A-794 CN (32.67 N) were firmer than A-819 (9.06 N).

The attributes of the tree-ripened fruit and the commercially ripened fruit varied at harvest. In general, commercially ripened fruit had higher chlorophyll, titratable acidity, and firmness than tree-ripened fruit (Fig. 1). However, tree-ripened fruit had slightly higher

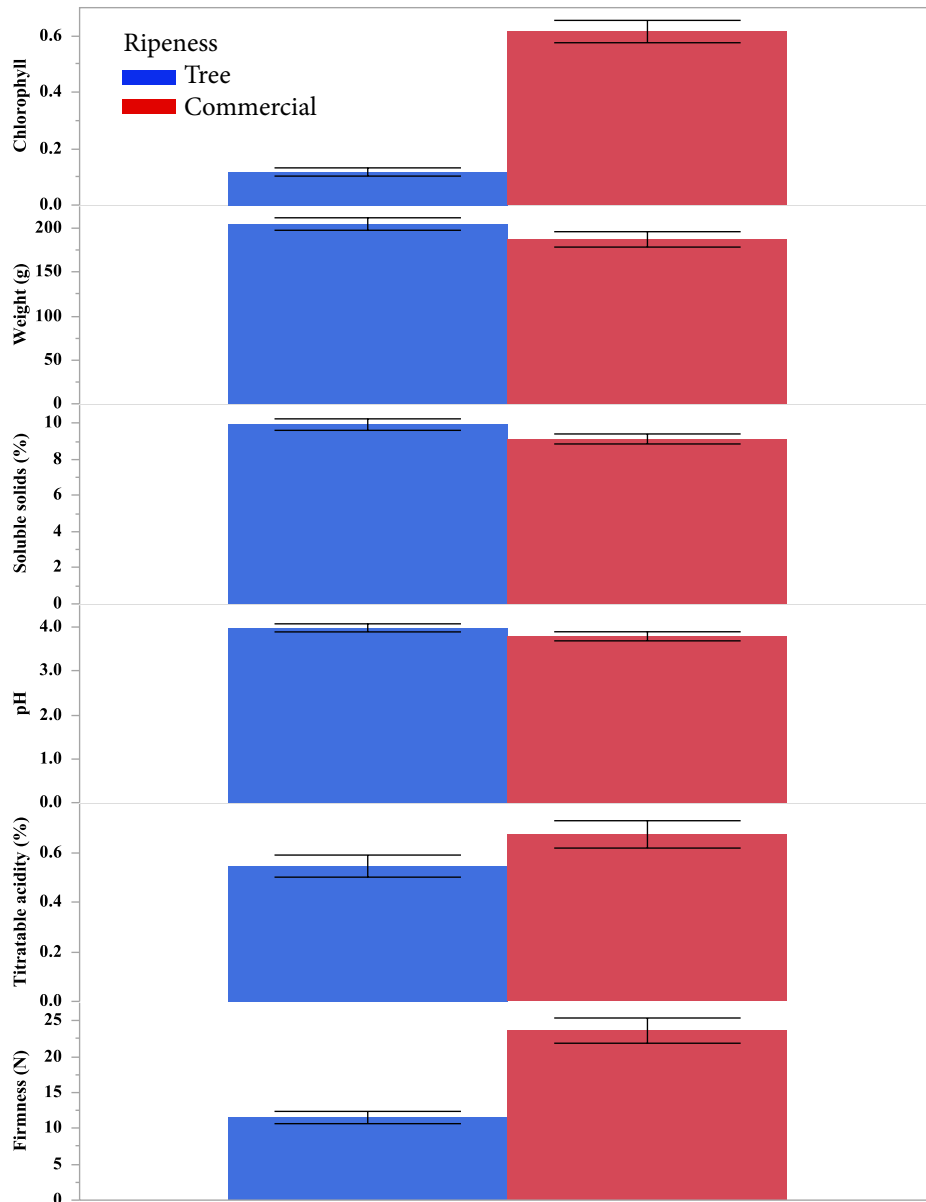


Fig. 1. Physiochemical attributes of tree-ripened and commercially ripened fresh-market peach and nectarine genotypes at harvest (day 0), University of Arkansas System Division of Agriculture’s Fruit Research Station, Clarksville, AR (2017). Each standard error bar is constructed using 1 standard error from the mean.

fruit weight, soluble solids, and pH than commercially ripened fruit. Zhang et al. (2017) showed high correlations between firmness and chlorophyll of peaches. A similar study on California free stone peaches concluded increased maturity of peaches at harvest (tree-ripened peaches) are characterized by decreasing flesh firmness and titratable acidity, as well as increasing soluble solids (Rood, 1957).

Physiochemical Attributes of Commercially Ripened Fruit During Storage

The physiochemical attributes of the commercially ripened fruit were evaluated during storage. The storage × genotype interaction was not significant for chlorophyll, fruit weight, soluble solids, pH, and titratable acidity, but was significant for firmness (Table 3 and Fig. 2). During storage, chlorophyll and fruit weight significantly

decreased, while soluble solids increased (Table 3). There were no significant changes in pH or titratable acidity during storage. The average pH and titratable acidity during storage was 3.86 and 0.66%, respectively. When compared to fruit from day 14, fruit from day 0 had higher chlorophyll (0.62 abs) and fruit weight (187.40 g). Soluble solids were significantly lower at day 0 (9.13%) compared to days 7 and 14, 10.54% and 11.08%, respectively. Cirilli et al. (2016) found that once a peach or nectarine was picked, the sugar content did not increase significantly, but the acidity decreases as the peach ripens due to enzyme metabolism.

During storage, genotypes differed significantly. A-663 CN and Bradley (0.75 abs) had the higher chlorophyll than A-885 (0.35 abs) and Souvenir (0.37 abs). For fruit weight, Effie (203.11 g) was larger than A-794 CN (120.00 g). A-794 CN had a lower pH than A-819

Table 3. Main and interaction effects for physiochemical attributes of commercially ripened fresh-market peach and nectarine genotypes stored at 4 °C for 0, 7, and 14 days, University of Arkansas System Division of Agriculture's Fruit Research Station, Clarksville, Arkansas (2017).

Storage	Chlorophyll (abs)	Fruit weight (g)	Soluble solids (%)	pH	Titratable acidity [†] (%)
0 days	0.62 a [‡]	187.40 a	9.13 b	3.79 a	0.68 a
7 days	0.60 a	163.53 b	10.54 a	3.91 a	0.66 a
14 days	0.50 b	150.83 b	11.08 a	3.89 a	0.63 a
<i>P-value</i>	<0.0062	<0.0001	<0.0001	0.1722	0.1990
Genotype					
A-663 CN	0.75 a	138.67 bc	9.12 bcd	3.55 def	0.79 cd
A-794 CN	0.46 bcd	120.00 c	11.96 a	3.21 f	1.25 a
A-811 CN	0.44 cd	178.11 ab	9.63 bcd	3.41 ef	0.93 bc
A-819	0.63 abc	175.00 ab	8.22 d	4.60 a	0.43 f
A-885	0.35 d	162.44 abc	11.41 ab	4.58 a	0.21 g
Amoore Sweet	0.65 abc	180.56 ab	10.47 abcd	4.40 ab	0.51 ef
Bowden	0.68 ab	181.89 ab	10.91 abc	3.27 ef	0.97 b
Bradley	0.75 a	171.56 ab	8.66 cd	3.62 de	0.67 de
Effie	0.64 abc	203.11 a	12.02 a	3.83 cd	0.37 fg
Souvenirs	0.37 d	161.22 abc	10.08 abcd	4.16 bc	0.42 f
<i>P-value</i>	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
<i>Storage x Genotype (P-value)</i>	0.2035	0.3353	0.2019	0.4939	0.4688

[†] Calculated as percent malic acid.

[‡] Genotypes were evaluated in triplicate (n = 3). Means with different letter(s) for each attribute within effects are significantly different ($P < 0.05$) using Tukey's honestly significant difference test.

and A-885. Effie (12.02%) and A-794 CN (11.96%) had higher soluble solids than A-819 (8.22%). A-885 (0.21%) had a lower titratable acidity than A-794 CN (1.25%).

The storage × genotype interaction was significant for firmness, but data for firmness were lost for Amooore Sweet and A-885 at day 14 of storage. Among most of the genotypes, there was a general trend for firmness to increase from day 0 to day 7, but then decrease from day 7 to day 14 (Fig. 2). This softening behavior, with an initial stage of an increase in firmness, followed by a rapid loss of firmness was also shown when assessing blueberry softening (Paniagua et al., 2013). There was a correlation between firming of blueberries during storage with very low moisture loss. Souvenirs had the highest firmness at day 0, but the lowest at day 14, and the firmness decreased during storage. Clark and Sandefur (2013b) indicated that Souvenirs, a slow-melting-flesh peach, had excellent postharvest storage potential. A-819 had the lowest firmness on day 0, but firmness increased during storage. At day 14, A-663 CN, a non-melting nectarine, had the highest firmness.

Regardless of genotype, there was a decrease in chlorophyll and weight loss, and an increase in soluble solids

during storage, but there was not much change in pH and titratable acidity (Fig. 3). There was also lower flesh firmness at day 14 when compared to day 0.

Conclusions

Understanding the postharvest physiology of the 10 peach and nectarine genotypes evaluated from the University of Arkansas System Division of Agriculture's Fruit Breeding Program has identified possible maturity indices for each genotype. The data revealed high variability in ripeness parameters between the genotypes evaluated, indicating that genotype was the most important factor for determining postharvest quality and extended shelf-life. However, picking fruit to ripen during storage does impact the ripeness attributes when compared to picking fruit at tree ripeness.

The attributes of the tree-ripened fruit and the commercially ripened fruit varied at harvest with commercially ripened fruit having higher chlorophyll, titratable acidity, and firmness than tree-ripened fruit. However, tree-ripened fruit had slightly higher fruit weight, soluble solids, and pH than commercially ripened fruit. For the

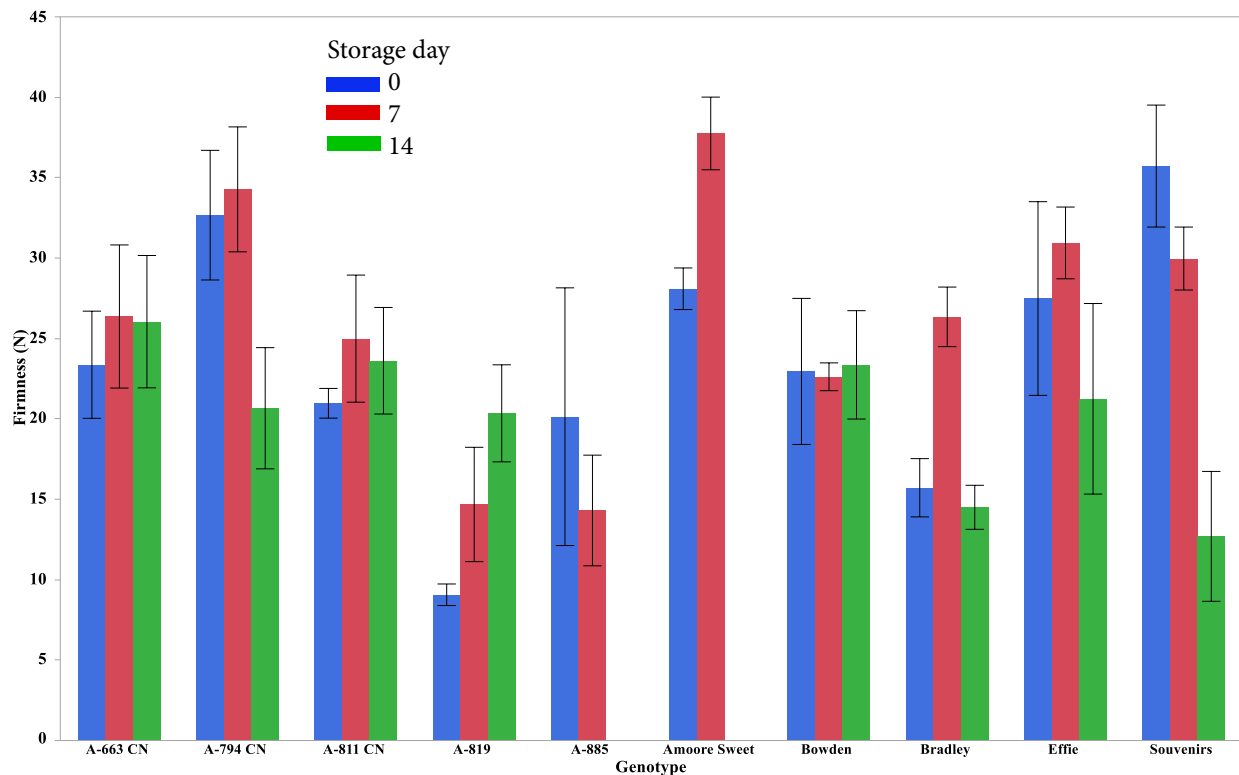


Fig. 2. Firmness of commercially ripened fresh-market peach and nectarine genotypes during storage at 0, 7, and 14 days at 4 °C, University of Arkansas System Division of Agriculture's Fruit Research Station, Clarksville, Arkansas (2017). Each standard error bar is constructed using 1 standard error from the mean. Data is missing for Amooore Sweet and A-885 at 14 days of storage.

tree-ripened fruit at harvest, A-811 CN was the largest fruit, A-794 CN had the highest soluble solids and titratable acidity, Souvenirs had the lowest firmness, and Amore Sweet was the firmest.

During storage of the commercially ripened fruit, there was a decrease in chlorophyll and weight loss and an increase in soluble solids, but there was not much change

in pH and titratable acidity. During storage, A-885 had the lowest chlorophyll, Effie was the largest and had the highest soluble solids, and A-794 CN had the lowest fruit weight, lowest pH, and highest titratable acidity. The titratable acidity and soluble solids reached the potential of tree-ripened fruit after 7 days of storage. However, some ripeness attributes of the commercially ripened fruit,

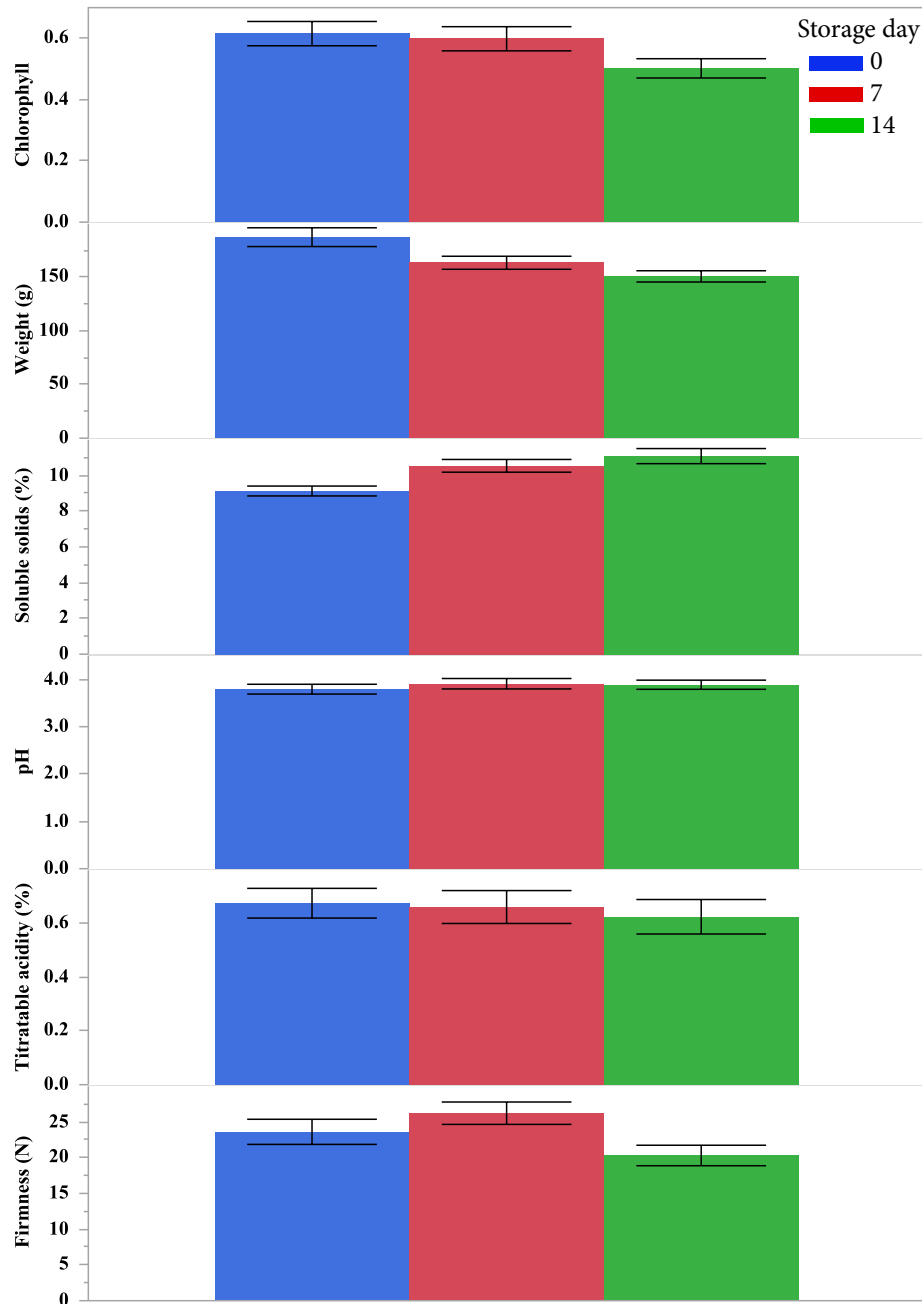


Fig. 3. Physiochemical attributes of commercially ripened fresh-market peach and nectarine genotypes during storage at 0, 7, and 14 d at 4 °C, University of Arkansas System Division of Agriculture’s Fruit Research Station, Clarksville, Arkansas (2017). Each standard error bar is constructed using 1 standard error from the mean.

such as chlorophyll and fruit weight, were not achieved as compared to the tree-ripened fruit. The firmness of the commercially ripened fruit at harvest increased from day 0 to day 7, but decreased from day 7 to day 14. Some of the genotypes evaluated performed well regardless of if the fruit was picked to ripen during storage or picked ripe from the tree. The ripeness attributes evaluated will help to determine the optimal harvest time, handling, and storage conditions of peach and nectarines for growers in Arkansas and other regions. This research will provide insight on the potential for releasing new peach and nectarine cultivars from the University of Arkansas System Division of Agriculture's breeding program.

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Soil organic carbon and mineralization rates at the Woolsey Wet Prairie mitigation site in Fayetteville, Arkansas

Meet the Student-Author



Zachary Tipton

I am a native of Fayetteville, Arkansas and graduated from Fayetteville High School in 2009. In May 2018, I graduated cum laude from the Dale Bumpers College of Agricultural, Food and Life Sciences with a major in Environmental, Soil and Water Science and minors in Chinese and Statistics. Generous funding was provided by the Honors College to present this research at an undergraduate oral paper competition during the ASA, CSSA, SSSA conference in Tampa, Florida.

As a non-traditional student, I faced many challenges to my education. But through the kindness, passion, and support from the Bumpers faculty, I quickly found my second home. During my time at the University of Arkansas, I was awarded several scholarships from the Honors College to study abroad in China, Taiwan, and Belgium.

This project would not have been possible without the guidance and patience of my advisors Dr. Lisa Wood and Dr. Mary Savin. Big thanks to Dr. Benjamin Runkle for his input and generosity in letting me borrow the LICOR LI-8100 for the duration of the study. Warmest gratitude and love to my wife Yujie for not only her emotional support but also the amazing amount of help she provided with SAS programming and statistical analysis. I would like to thank the Bumpers College for providing funding for this research. I would also like to thank the stewards of the Woolsey Wet Prairie for allowing this research to be conducted on the site.

Research at a Glance

- Wetlands can store large amounts of carbon and by storing carbon dioxide, can potentially help reduce the negative effects of high carbon dioxide levels in the atmosphere.
- At our study site, fire is used as a management tool to control the spread of invasive species, which might have negative effects by removing available food for plants, and cause soils to release large amounts of carbon dioxide into the air.
- Based on our study, the low-intensity fire management did not negatively affect the organic matter available for plant uptake nor significantly increase the amount of carbon dioxide released from the soil.



Zachary at Glacier National Park during a summer 2017 program studying Ecology at the Flathead Lake Biological Research Station with the University of Montana.

Soil organic carbon and mineralization rates at the Woolsey Wet Prairie mitigation site in Fayetteville, Arkansas

Zachary Tipton^{*}, Lisa S. Wood[†], Mary C. Savin[§], and Benjamin R.K. Runkle[‡]

Abstract

Atmospheric carbon dioxide (CO₂) levels are rapidly increasing, surpassing 400 ppm in 2013 from a pre-industrial revolution level of around 280 ppm. Researchers have been looking at methods to reduce CO₂ levels in the atmosphere, including promoting carbon sequestration in soils. Carbon sequestration is the process where CO₂ is naturally or artificially transferred out of the atmosphere and stored in the ocean, plant biomass, soils, and geologic formations. Seemingly contradictory to the notion of carbon sequestration is the use of fire as a management treatment for the restoration of native prairie grass ecosystems. Fire combusts plant biomass and produces CO₂ as one of its products, potentially leading to increased atmospheric CO₂ concentrations. The first objective of this research was to determine particulate (easily broken down) and total (easily broken down plus stable) soil organic matter content and CO₂ respiration (output) in Woolsey Wet Prairie Sanctuary (WWPS) soil that has been restored and managed with annual burning for 10 years compared to soil from non-restored adjacent fields growing tall fescue. The first objective was accomplished by taking soil samples and CO₂ respiration measurements before the 2017 annual prescribed burn. The second objective was to determine short-term impacts of the prescribed burn on soil carbon release and storage. The second objective was accomplished by comparing CO₂ respiration before the fire management in the spring, then comparing to CO₂ respiration 2, 7, 16, and 29 days post-treatment, and collecting soil samples. Soil samples were taken before the prescribed burn, two weeks after the burn, and two months after the burn to compare short-term changes in particulate organic matter (easily broken down; POM) and stable organic matter (OM). Results indicated high productivity in the wetland low-lying areas with statistically greater levels of POM and OM compared to the other sample sites. Additionally, there was no statistically significant change measured in POM following the annual prescribed burn at any sample site, or a statistically significant increase in CO₂ respiration. The results indicate that the managed wetland area is functioning as a highly productive carbon sink.

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Introduction

Carbon Cycling

Continued use of fossil fuels as an energy source plays a role in global warming, so an understanding of the carbon cycle and promoting carbon storage in soil is important to the goal of reducing atmospheric carbon dioxide (CO₂) levels (Stout et al., 2016). Soils store roughly three times more carbon than the atmosphere by capturing plant and animal matter residues, which break down and transform into soil organic matter (SOM) (Ontl and Schulte, 2012). Soil CO₂ is produced by plant root respiration, soil microorganisms around the rhizosphere (a roughly 1-mm thick area of high activity around plant roots), and microorganisms in the soil metabolizing organic matter, including particulate organic matter (POM), a fraction of soil organic matter comprising a readily available source of nutrients. The ease of breakdown of total SOM varies across different pools from readily decomposed POM to stable humus. The SOM is beneficial to plant growth by improving soil structure, which also protects against erosion, providing micro and macronutrients to plants, and helps retain water (Murphy, 2015). Carbon sequestration in SOM has the potential to reduce the levels of atmospheric CO₂ and mitigate the negative effects of global warming (Lal, 2004; Post et al., 2004). Carbon sequestration in plant biomass is beneficial; however, burning biomass and thus releasing carbon as CO₂ is promoted as a tool for prairie management to reduce invasive species and promote native seed germination (Rook et al., 2011).

Fire as a Management and Restoration Tool

Before major European settlement, large areas of northern Arkansas consisted of tallgrass prairie that were naturally sustained by fire (Brye et al., 2008). Various intensities of fire happen naturally depending on the amount of biomass (fuel) available. Prairie ecosystems evolved under a frequent, low-intensity, natural fire cycle. Due to human interference in this fire cycle, prairie ecosystems have been deprived of fire, which has led to problems such as domination of the habitat by invasive species, which can cause total ecosystem shifts (Docherty et al., 2011). Fire can be used as a management tool in ecosystem restoration by burning invasive plants, providing bare mineral soil and sunlight to native seeds for germination. Efforts are ongoing to promote using fire as a management tool to restore native tallgrass prairies. Low-intensity burning can be beneficial, by increasing nutrient availability and decreasing threats from pathogens (Neary et al., 1999). Conversely, high-intensity fires can cause severe disturbances, such as disruption of microbial communities and loss of nutrients (Neary et al., 1999).

A successful example of species restoration in tallgrass prairie is the Woolsey Wet Prairie Sanctuary (WWPS), located in Fayetteville, Arkansas. Designed by ecologists from Environmental Consulting Operations, Inc. (ECO, Benton, Ark.) and engineers from McGoodwin, Williams, and Yates Consulting Engineers, Inc. (Fayetteville, Ark.), the 46-acre WWPS was established as a wetland mitigation project following the construction of a regional wastewater treatment facility in 2006 (ECO, Inc, 2018). Engineers and city planners created a mosaic ecosystem area using earthen berms to include basin wetlands, open water, marsh, and forested wetland areas. The berms and non-wetland areas were restored in native prairie grass and forb species. The soil type is characterized by a somewhat poorly drained mound/intermound system with mounds being microtopographical features with a higher elevation than the surrounding area and adjacent intermounds, low points of elevation between mounds. The mound/intermound systems are of unique interest because of their symmetric properties; many hypotheses have been published as to the origin of prairie mounds, one such hypothesis is that the mounds developed from accumulation of wind-blown deposits and are at a state of “environmental equilibrium” with grasses protecting mounds from erosion and soil organisms seeking slightly elevated soil to reside in dryer conditions (Allgood and Gray, 1974). Environmental consultants with ECO, Inc., use a prescribed burn treatment to remove invasive grasses and emergent woody vegetation annually in the spring around mid-March (ECO, Inc., 2018).

The prescribed fire utilized on WWPS is a low-intensity, quickly moving fire. Burning in the spring kills primarily cool-season invasive grasses prior to emergence of warm-season grasses and creates a mineral bed in which native plants thrive (ECO, Inc, 2018). The approach and management plan have been successful in restoring aboveground biodiversity. Enhancing carbon storage in the soils and burning of OM to promote prairie restoration appear to be contradictory in terms of soil carbon management. However, aboveground biomass in tallgrass prairie systems can be significantly increased for up to two years after a low-intensity fire, resulting in greater amounts of carbon storage in plant residues than in unburned test plots (Docherty et al., 2011).

Research Questions

Restoration of aboveground biodiversity has been successful at WWPS, but the effect of management on soil carbon has not been studied at this site. Thus, we used this site to research the following questions:

1. How has restoration, including fire management, influenced soil CO₂ respiration and carbon storage after 10 years of prairie restoration management.

2. What is the immediate versus short-term temporal impact of the 2017 annual prescribed burn on soil carbon release and storage?

Objectives

The objectives of this research were to:

1. Determine particulate organic matter (easy to break down, POM) and SOM (easy to break down plus stable) content and CO₂ respiration rates on soil from WWPS that has been restored and managed with annual burning for 10 years compared to soil from an adjacent field that is non-restored and in which tall fescue is growing.
2. Determine immediate versus temporal impacts of burning on POM content and CO₂ respiration rates starting from two days after the 2017 annual burn treatment to two months post-burn WWPS compared to soil from an adjacent field in which tall fescue is growing.

Materials and Methods

Study Site

Two treatment sites were selected for the study, one being a section of the berm and wetland which was burned as the treatment, and the other being an adjacent fescue mound/intermound system that was not burned. The wetland soil type was anthropogenic in nature, being a blend of the primary soil type for the area that was heavily dis-

rupted during the creation of the WWPS, while the fescue area had a Taloka complex, mounded soil type as mapped by the WEB Soil Survey (USDA, 2018).

In the fescue unburned control area, four transects were established and samples were taken on representative mounds and adjacent intermounds (Fig. 1). For the wetland area, sample sites were selected along the main trails between the fescue control area and parking lot. Four samples were collected immediately adjacent to the trail but on top of the constructed berm areas. Four samples were collected downslope of the berm sample sites in the wetland cells themselves. It is important to note that while designations are assigned to landscape positions for both treatment areas, landscape positions cannot be assumed to be at the same elevation at all sample sites.

Timeline

Samples were collected between 10 February and 18 May 2017. The first CO₂ respiration measures occurred on 22 February. The prescribed burn was conducted on 25 February, and CO₂ respiration samples were measured on 27 February, 4 March, 13 March, and 26 March. Soil samples were collected adjacent to locations of soil respiration measurements on 10 February, 12 March, and 18 May.

Bulk Density

Soil bulk density, which can indicate the degree of soil compaction, was determined by using one 5-cm diameter,

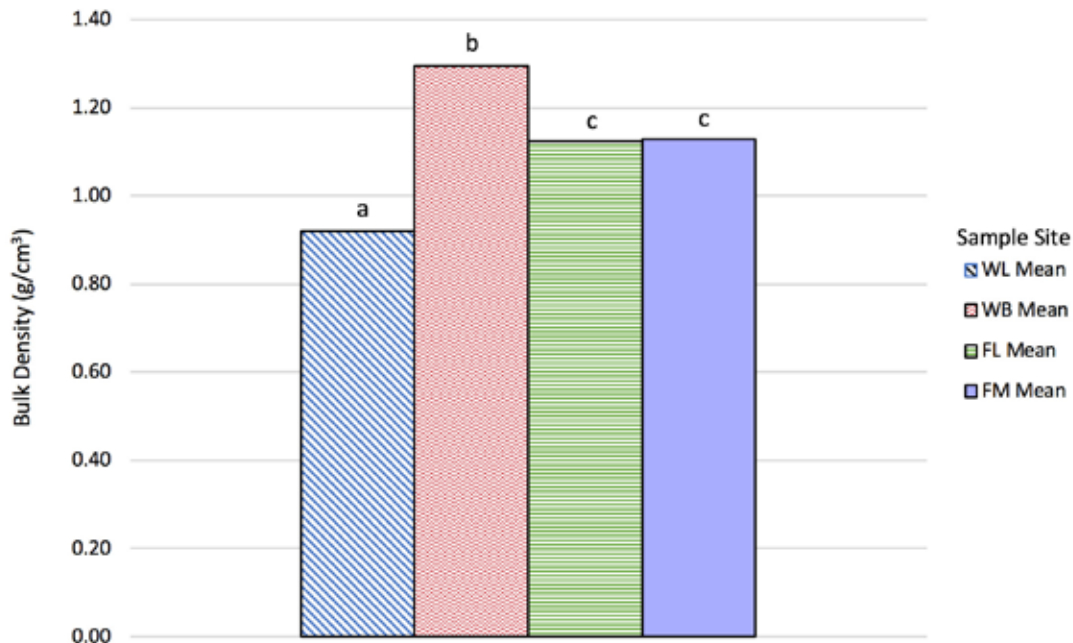


Fig. 1. Bulk density (g/cm³) of soil in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB), and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas from 10 February, 12 March, and 18 May 2017. Bulk density did not change with time and samples were averaged together (n = 12). Means with the same letters are not statistically different ($\alpha = 0.05$).

5-cm long soil core to collect soil at each site (4 replications each in Wetland Low, Wetland Berm, Fescue Low, and Fescue Mound) on 10 February, 12 March, and 18 May for a total of 48 soil samples. The known volume of the soil was removed from the soil core and dried in a pre-weighed container at 55 °C for 5–7 days until a constant weight was reached. The dry soil weight was measured and subtracted from the container weight to calculate bulk density (dry soil mass divided by total soil volume).

Soil Organic Matter (SOM)

Oven-dry soil (from the determination of bulk density) was ground with a mortar and pestle and passed through a 2-mm sieve. Ten grams of soil was transferred into a pre-weighed crucible (small ceramic bowl). Crucibles were placed in an oven at 55 °C for 5 days. After five days, the samples were removed from the oven and weighed again. Crucibles were then placed into a muffle furnace and combusted at 450 °C for 8 hours. Crucibles were weighed again, and percent organic matter was calculated using the following equation: %OM = $\left(\frac{[\text{oven-dry soil (g) after 5 days at 55 °C} - \text{ash weight (g) after being combusted in the muffle furnace}]}{[\text{oven-dry soil (g) after 5 days at 55 °C}]} \right) * 100\%$.

Particulate Organic Matter

Oven-dry soil was ground with a mortar and pestle and passed through a 2-mm sieve. Particulate organic matter, or sand-sized fraction (SSF) between 0.053-mm and 2-mm, was determined using the oven-dried soil. Sieved soil (25 g) was transferred to a 250-mL bottle and mixed with an aqueous solution of 5 g sodium hexametaphosphate ($(\text{NaPO}_3)_6$) and 100 mL ultrapure water. After being shaken for 16 hours, the solution was poured through a 53- μm sieve and rinsed with deionized water. The retained fraction was dried overnight in a pre-weighed container at 55 °C and again weighed. The oven-dry weight of the SSF was divided by 25 g to determine the SSF fraction relative to total soil weight. After weighing, dried SSF samples were transferred into pre-weighed crucibles, re-weighed, and combusted in a muffle furnace at 450 °C for 8 hours. Samples were cooled in a desiccator and the weight of the crucible and ash was determined and used to calculate percent organic matter in the SSF. The SSF fraction was multiplied by %POM in the SSF to determine %POM. The %POM was divided by %SOM determined in the previous section to calculate %POM as part of the total soil organic matter.

Carbon Mineralization

In-situ respiration (CO_2 output), or CO_2 flux, was determined using a LI-COR LI-8100A automated soil gas flux system (LI-COR, Lincoln, Nebraska, U.S.). A 20-cm diameter survey chamber was fitted over a 20-cm diameter PVC soil collar which was installed 2–5 cm into the soil surface

to create a seal. Individual collars were installed at least 24 hours prior to CO_2 flux measurements to allow the soil to normalize after the disturbance. Additionally, plant matter on the soil surface within the soil collars was cut and removed 24 hours before measuring soil flux. Flux was calculated by an infrared analyzer located in the survey chamber. The rate of CO_2 being released from the soil into the survey chamber was used to model CO_2 diffusing into the air outside of the chamber. Soil temperature and moisture were determined by inserting a temperature probe (Omega Soil Temperature Probe 6000-09TC; LI-COR, Lincoln, Nebraska) and theta probe (Delta-T ML2 ThetaProbe; LI-COR), respectively, into the soil adjacent to the survey chamber. The soil surface area within the 20-cm soil collar was 317.8 cm^2 . The temperature probe was inserted 15.24 cm into the soil, while the theta probe was inserted 6 cm into the soil. The headspace between the soil surface and top of the soil collar was measured in five locations around the inside of the collar, averaged, and entered into the LI-8100A measurement software as chamber offset in centimeters to calculate chamber volume. The LI-8100A device was set with a one-minute pre-purge time in between measurements to allow normalization of gasses, while the observation time was set for two minutes. Three measurements were collected, one minute apart, at each site. Soil flux rates were reported by the LI-8100A in $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$. The average flux was calculated for the three measurements of exponential flux for each sample site. Flux was adjusted using an assumed Q_{10} temperature coefficient of 1.4.

Data Analysis

Preliminary organization of data and graphs was conducted in Excel 2016 (Microsoft Corp., Redmond, Washington). Statistical analysis was performed using SPSS Statistics 24.0.0.2 (IBM Corp., Armonk, New York) and SAS 9.4 (SAS Institute, Inc., Cary, North Carolina). Repeated measures analysis of variance (ANOVA) were run individually for each dependent variable (bulk density, OM, POM, temperature, water content, and flux) to determine significance with $\alpha = 0.05$ of values within and across groups. Statistical analysis was performed to determine if measurements changed with time, followed by ANOVAs comparing means across the two treatment sites (fescue, wetland) and four microtopography levels (Wetland Low, Wetland Berm, Fescue Low, and Fescue Mound). Respiration was compared to soil moisture content and soil temperature recorded at the time of CO_2 respiration sampling to determine if those parameters could explain variation in soil respiration.

Results and Discussion

Three parameters (bulk density, SOM, and POM) did not change with time (all $P > 0.05$), so data from the dif-

ferent dates were combined. The bulk density in the Wetland Low treatment was 0.917 g/cm³, the Fescue Low and Fescue Mound treatments were both 1.13 g/cm³, and the Wetland Berm treatment was 1.295 g/cm³. Bulk density in the Wetland Berm was greater than all other treatments, and the bulk density of the Wetland Low was less than in Wetland Berm, Fescue Low, and Fescue Mound treatments ($P < 0.05$). The bulk density in Fescue Low and Fescue Mound values did not differ from each other ($P > 0.05$) (Fig. 1).

Soil OM values were Wetland Low at 8.94%, Wetland Berm at 5.34%, Fescue Low at 6.4% and Fescue Mound at 6.19%. The Wetland Low values were greater than the other three sites ($P < 0.05$), and the values for the Wetland Berm, Fescue Low and Fescue Mound sites did not differ ($P > 0.05$) (Fig. 2).

Particulate OM values ranged from 46.6% for the Wetland Low site, to 25.58% for the Wetland Berm site, with Fescue Low and Fescue Mound being 29.18% and 34.49%, respectively. The Wetland Low values were greater than the other treatments ($P < 0.05$) and no difference was found among the other three sites ($P > 0.05$) (Fig. 3).

Soil CO₂ respiration fluxes did change with time. The Wetland Low and Wetland Berm CO₂ respiration measurements did not differ between 22 February (pre-burn)

and 27 February (2 days after the burn); however, Fescue Low and Fescue Mound measurements decreased between these time intervals (Fig. 4; $P < 0.05$). Respiration in Wetland Low did not differ across any of the time intervals, while respiration in Wetland Berm increased from 13 March to 26 March ($P < 0.05$). For Fescue Low, respiration decreased between 22 February and 27 February ($P < 0.05$). For Fescue Mound, respiration fluxes decreased from 22 February to 27 February and between 4 March and 13 March ($P < 0.05$).

For 22 February pre-burn CO₂ respiration measurements, Wetland Low and Wetland Berm did not differ, and Fescue Low and Fescue Mound did not differ (Fig. 4). Both Wetland Low and Wetland Berm CO₂ respiration fluxes were lower than Fescue Low and Fescue Mound measurements ($P < 0.05$). On February 27, two days following the burn, CO₂ respiration measurements among the four sites did not differ. On 4 March, CO₂ respiration at the Wetland Berm site was lower compared to Fescue Low and Fescue Mound but did not differ from Wetland Low ($P < 0.05$), while Wetland Low, Fescue Low, and Fescue Mound did not differ from each other. On 13 March, respiration in Wetland Berm was greater than the two fescue sites, and on 26 March, respiration was greater in Wetland Berm than Wetland Low and Fescue Low ($P < 0.05$), while the

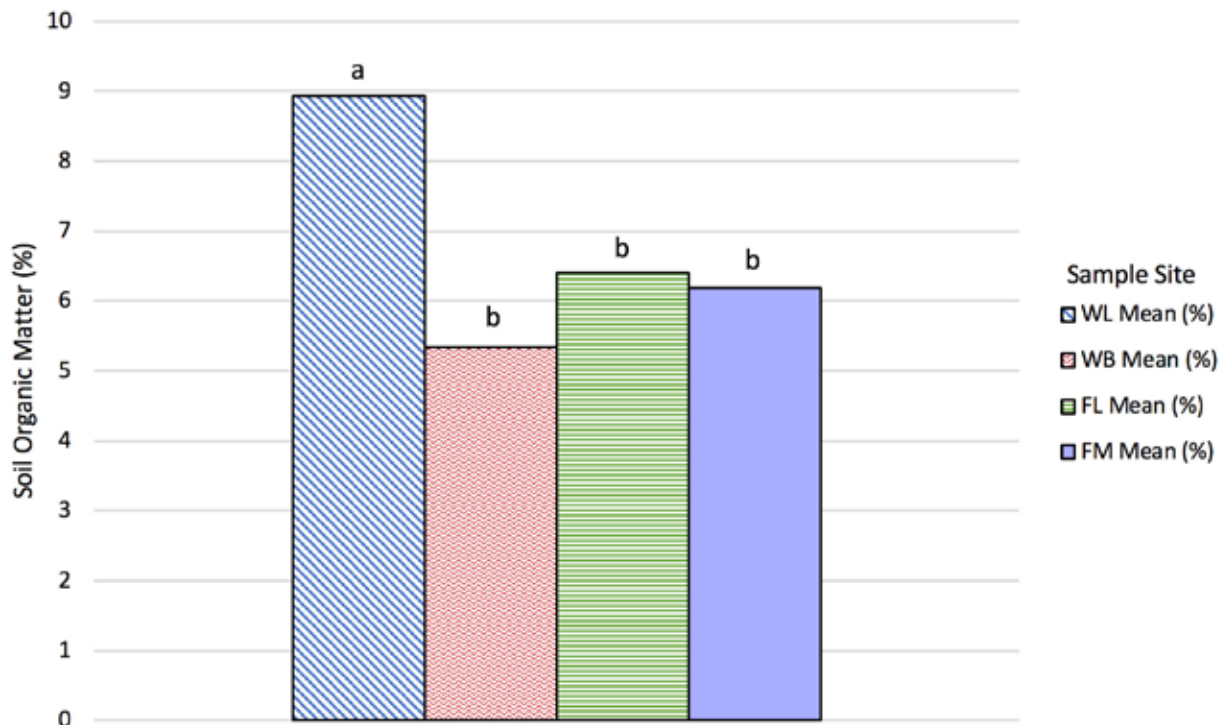


Fig. 2. Soil organic matter (%) of soil in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB) and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas from 10 February to 18 May 2017. Means with the same letters are not statistically different ($\alpha = 0.05$). Organic matter did not significantly change over time and values across dates are averaged together ($n = 12$).

other three sites did not differ from each other (Wetland Low, Fescue Low, Fescue Mound; $P > 0.05$). On the dates following 4 March, there were several major rain events (data not shown), resulting in a corresponding decrease in soil temperature (Fig. 5), increase in soil water content (Fig. 6), and decrease in CO_2 flux in Wetland Mound on 13 March (Fig. 4). Precipitation events in March resulted in increased soil water content at all sites on 13 March compared to 4 March and wetter soil in the lower elevation sites on 13 and 26 March (Fescue Low, Wetland Low, Fig. 6). Respiration increased in the higher elevation Wetland Berm (Fig. 4) between 13 and 26 March concurrent with warmer soil temperatures, even though the soil temperature did not increase significantly in the Wetland Berm (Fig. 5).

The temperature of Wetland Low was greater on 26 March from 13 March, Wetland Berm greater on 27 February from 22 February and lower on 13 March from 4 March. Additionally, Fescue Low was greater on 27 February from 22 February, lower on 13 March from 4 March, and higher on 26 March from 13 March, while Fescue Mound was lower on 13 March from 4 March, and higher on 26 March from 13 March (Fig. 5, $P < 0.05$). Regarding within-date statistical variation, differences were only measured on 27 February with Wetland Low having a

higher temperature compared to Fescue Low, while Wetland Berm and Fescue Mound did not differ from the other two sample sites (Fig. 5, $P < 0.05$). No other dates showed within-date statistical differences among the four sample sites.

Soil water content was lower in Wetland Low on 27 February than 22 February and increased on 13 March from 4 March. Soil water content in Wetland Berm was greater on 13 March than 4 March; Fescue Low was lower on 27 February than 22 February and higher on 13 March than 4 March, while water content in Fescue Mound was higher on 13 March than 4 March (Fig. 6, $P < 0.05$). Regarding within-date statistical variation, on 22 February, Wetland Low had a greater soil water content than Wetland Berm and Fescue Mound which did not differ, while Fescue Low was not different from the other three sample sites. On 13 and 26 March, soil water content in Wetland Low and Fescue Low did not differ, and were higher than Wetland Berm and Fescue Mound which did not differ from each other. No statistical variation was observed on 27 February and 4 March (Fig. 6, $P < 0.05$).

The first objective was to determine POM and SOM content and compare CO_2 respiration from WWPS soil that has been restored and managed with annual burning for 10 years compared to non-restored adjacent field soil

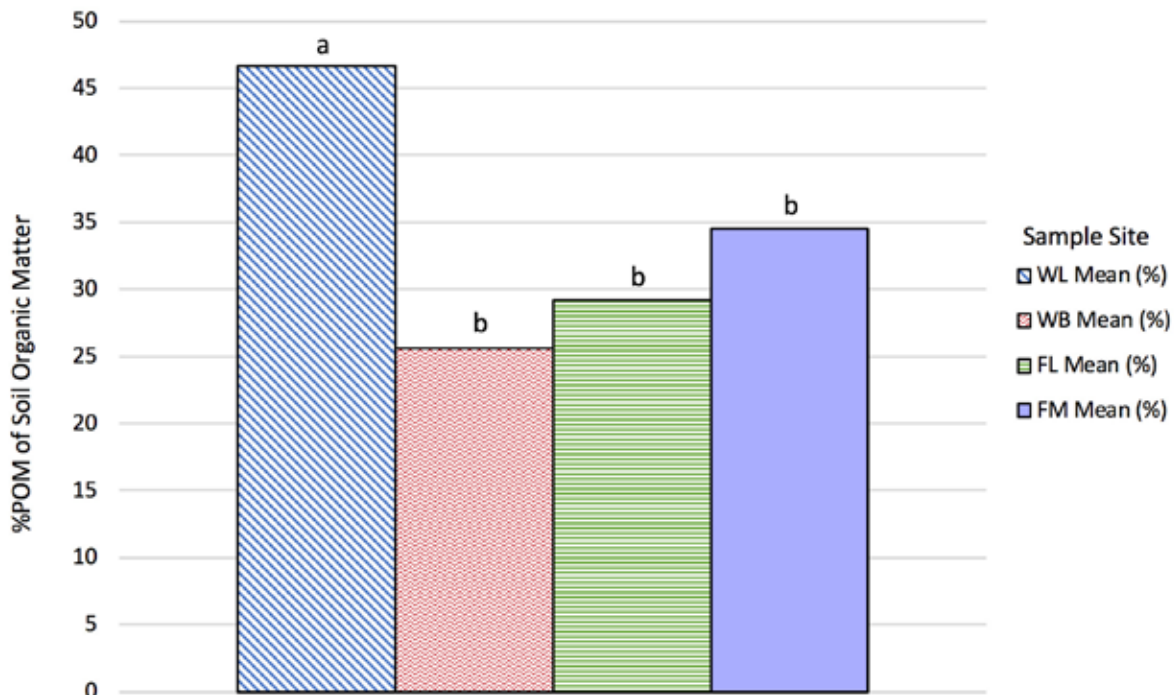


Fig. 3. Particulate organic matter as a percentage of the soil organic matter (%) in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB), and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas on 10 February, 12 March, and 18 May 2017. On each date, means with the same letters are not statistically different ($\alpha = 0.05$). Particulate organic matter did not significantly change over time and values across dates are averaged together ($n = 12$).

growing tall fescue. This was accomplished by analyzing pre-burn data measured from the treatment and control areas. Soil POM is beneficial to soil functioning by providing a food source for microorganisms, promoting soil aggregation, and can be considered as an initial catalyst to C sequestration (Kravchenko et al., 2014). The results of this study suggest the Wetland Low to be highly productive with soil aggregation (low bulk density) and metabolic conversion of POM into more stable forms of SOM (greater measured OM levels). Decomposition of organic matter in soils releases CO₂ into the atmosphere (Keiluweit et al., 2017); however, pre-burn flux values were measured as lower in the wetland area than in the fescue fields. The sample sites chosen for Wetland Low and Fescue Low were at the lowest point of the landscape, and after rain events soil collars had to be retrieved from underwater and relocated to above the water line. Keiluweit et al. (2017) reported that while mineralization occurs during anaerobic conditions, mineralization rates decrease by 60–95% compared to aerobic conditions. Anaerobic conditions are typical for a wetland system.

The second objective was to determine immediate versus temporal impacts of burning on POM content and C mineralization rates on wetland (burned) soil. Since there

was no measured change in POM before the burn, 15 days, and 83 days after the burn, it appears from these samples that there was no change in POM immediately following the burn. Regarding flux, measurements taken 2 days after the burn all decreased from pre-burn levels and did not differ from each other regardless of microtopography. It is possible that the heat from the fire and increased solar radiation resulting from the removal of surface biomass disrupted the microbiological functions in the wetland area as soil temperature in Wetland Low increased significantly 2 days after the burn compared to Fescue Low. However, flux measurements from the fescue areas were not different from the wetland 2 days after the burn, suggesting that biological functions were not altered by the prescribed fire. Additionally, major disruptions to proteins and plant tissue occur around 40–70 °C (Neary et al., 1999). Reports from the prescribed fire indicate that the fire moved very quickly through the system at a low intensity and, after the burn was completed, the ground was cool enough to walk on. Fire can have a wide range of effects on the soil system depending on intensity and duration of the fire, with duration being the main factor in how much damage a soil system receives belowground (Neary et al., 1999). Low-intensity fire events typically do not burn hotter than 100

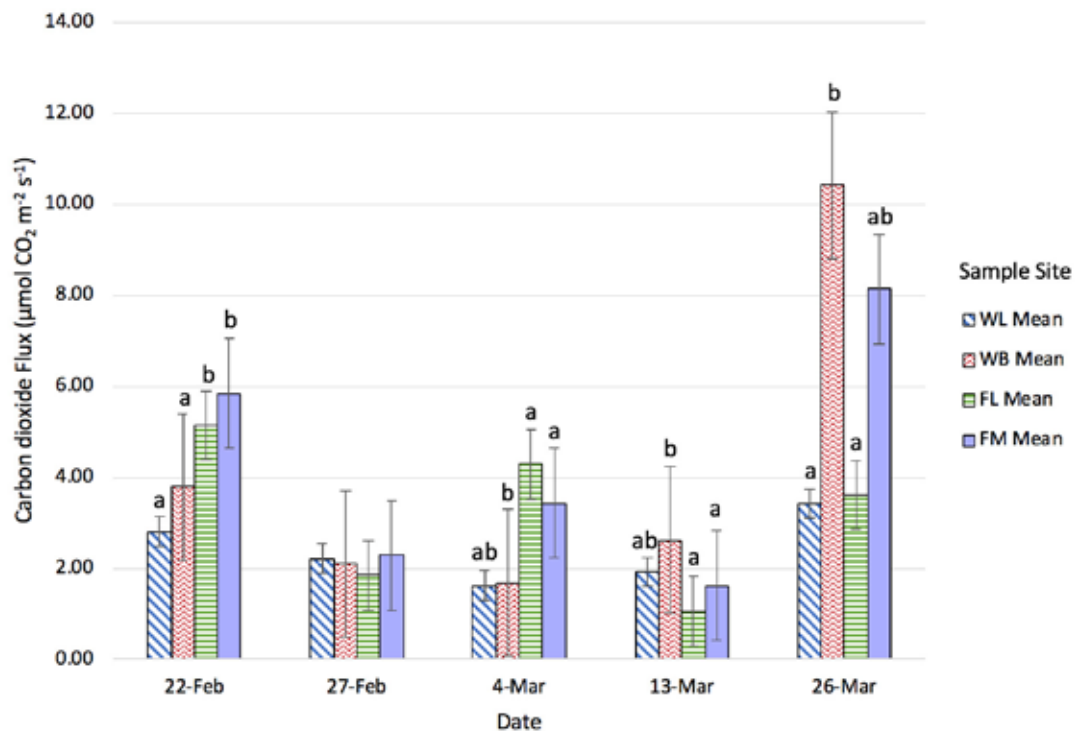


Fig. 4. Carbon respiration measurements ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) of soil in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB), and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas on 22 February, 27 February, 4 March, 13 March, and 26 March 2017 ($n = 12$). On each date, means with the same letters are not statistically different ($\alpha = 0.05$). Statistical differences among treatments were not observed on 27 February. Dates within one sample location with flux statistically different from the previous date are indicated by (*).

°C at the surface and 50 °C at 5 cm below the soil surface (Neary et al., 1999). These types of low-intensity fire can break down nutrients into forms for plant and microbial consumption, thin overcrowded biomes, and are popular as an ecological restoration practice (Neary et al., 1999). The annual burning schedule at the WWPS limits large amounts of fuel loading, thus limits the intensity of fires and damage to the soil system.

Besides the expected variability in flux measurements, there were several potential sources of measurement error. First, the PVC soil collars had to be moved twice. The pre-burn collars were removed after initial measurements, so they were not damaged by the prescribed fire treatment. Additionally, the Wetland Low and Fescue Low collars had to be relocated to slightly higher elevation on 12 March because they were completely submerged after a rainstorm. A second potential source of analysis error is that soil temperature readings were taken at 15 cm, while the PVC soil collars used for collecting the LI-8100A CO₂ respiration measurements were inserted shallowly into the soil at a depth of 2–5 cm. This may have resulted in improper analysis of the effect of temperature on flux as the temperatures measured were not exactly at the same depth as much of the microbial activity. In a study by Zhou et

al. (2013), nearly twice the microbial biomass resided at a 0–10 cm soil depth compared to 10–20 cm in a grassland. Additionally at the 0–10 cm soil depth, the microbial community was more responsive (increasing respiration) to temperature and moisture changes. Future studies should include soil texture analysis of the wetland area to measure the texture as a result of anthropogenic mixture. Additionally, C:N measurements might allow researchers to gain more insight regarding total ecosystem health.

Based on the measurements of this study, the Wetland Low area is functioning as a highly productive carbon sink with greater carbon retention in organic matter and lower CO₂ respiration. Organic matter (POM and SOM) and respiration measurements in the spring before and after an annual prescribed burn did not indicate that fire management is detrimental to carbon sequestration; therefore, prescribed annual fire appears to be a positive influence on soil carbon storage at the WWPS.

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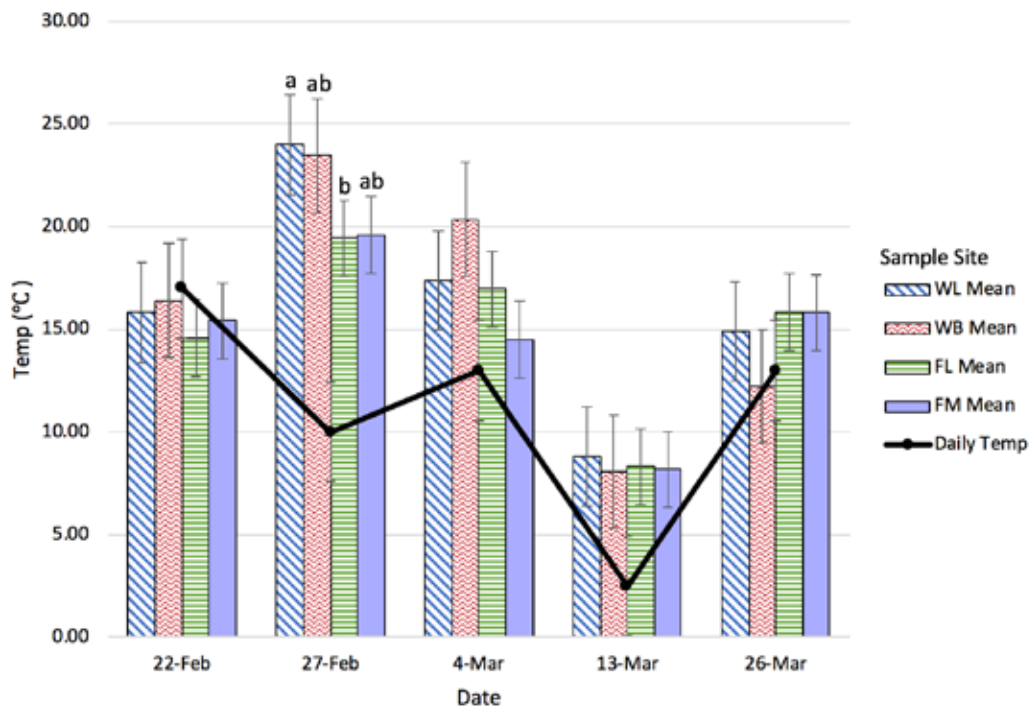


Fig. 5. Soil temperature measurements (°C) of soil in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB), and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas on 22 February, 27 February, 4 March, 13 March, and 26 March 2017 (n = 4). On each date, means with the same letters are not statistically different ($\alpha = 0.05$). Statistical differences were only observed on 27 February. Dates within one sampling location with temperature statistically different from the previous date are indicated by (*).

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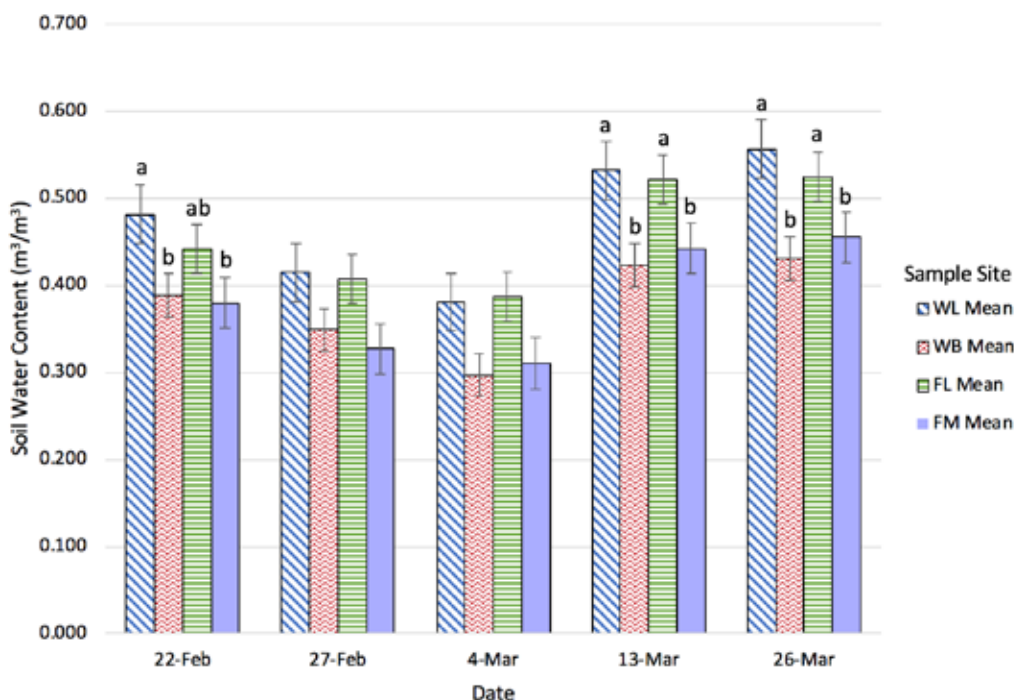






Fig. 6. Soil water content measurements (m^3/m^3) of soil in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB), and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas on 22 February, 27 February, 4 March, 13 March, and 26 March 2017 ($n = 4$). On each date, means with the same letters are not statistically different ($\alpha = 0.05$). Statistical differences were not observed on 27 February or 4 March. Dates within one sampling location with soil water content statistically different from the previous date are indicated by (*).

DISCOVERY

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Acknowledgments

The *Acknowledgment* section recognizes financial support and other assistance. Note support by any companies or parties with a vested interest in the research results. Please thank your advisor, other professors, co-authors, and other individuals who helped with your research in the *Meet the Student-Author* section *NOT* in Acknowledgments.

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