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

Volume 21 Article 13

Fall 2020

Characterization of jasmine rice cultivars grown in the United States

Anastasia K. Mills
University of Arkansas, Fayetteville, anastasiamills@hotmail.com

Ya-Jane Wang
University of Arkansas, Fayetteville, yjwang@uark.edu

Characterization of jasmine rice cultivars grown in the United States

Meet the Student-Author

Anastasia Mills

Growing up in Benton, Arkansas, I was excited to attend the University of Arkansas. I graduated summa cum laude in May 2020 with a degree in Food Science and a Bachelor of Arts degree in Music. I play the oboe and have performed with the University Symphony Orchestra, the Wind Symphony, and the Razorback Marching Band Color Guard. During my time at the University of Arkansas, I have served as a Bumpers College Ambassador, Honors College Ambassador, and secretary for the Food Science Club. I had the opportunity to study abroad in Belgium, Austria, and France. Last summer, I worked as a Research and Development intern at Newly Weds Foods in Springdale. After graduation, I will attend the University of Wisconsin-Madison to pursue my master's degree on my path to a research and development career in the food industry. I would like to express my gratitude to my mentor Dr. Ya-Jane Wang for her patience and guidance on this project. I'd also like to thank my committee members Dr. Luke Howard and Dr. Philip Crandall for their insight, Dr. Benjamin Runkle, Dr. Andy Mauromoustakos, and Kevin Thompson for their assistance, and Dr. Sun-Ok Lee and Jia-Rong Jinn for their analysis. Thank you to the village of graduate students who worked with me along the way and helped me learn the skills I needed for this project—Annegret Jannasch, Ana Gonzalez Conde, Michelle Oppong Siaw, Seth Acquaah, and Wipada Wunthunyarat.

Measuring Arkansas jasmine rice in Dr. Wang's lab in the Department of Food Science.

Research at a Glance

- The research characterizes and compares the physical and chemical properties of newly developed U.S. jasmine rice from Arkansas, California, and Louisiana with jasmine rice samples from Thailand.
- The Californian jasmine rice sample was most similar to the Thai jasmine rice samples, while the Arkansas and Louisiana samples differed.
- These findings can help the U.S. rice industry to develop U.S. jasmine rice cultivars with properties closer to Thai jasmine rice.

Characterization of jasmine rice cultivars grown in the United States

Anastasia K. Mills * *and Ya-Jane Wang*†

Abstract

Jasmine rice from Thailand accounts for about 60% to 70% of U.S. imported rice, primarily due to its preference by ethnic Asians as well as the general American population. Recently new U.S. jasmine rice cultivars have been developed independently at three rice research stations in Arkansas, California, and Louisiana, but their properties have not been characterized. The objective of this research was to characterize and compare the physical appearance, chemical composition, thermal and pasting properties, cooked rice texture, and starch structures of the newly developed U.S. jasmine rice from Arkansas, California, and Louisiana, to be compared with jasmine rice samples from Thailand. In general, the U.S. varieties had smaller length/width ratios, darker color, and greater ash and lipid contents than the Thai controls. The Arkansas samples were similar to each other as well as one Louisiana sample, CLJ01 2017, and the other Louisiana samples were similar to each other; but rice of both origins was different from Thai jasmine. Calaroma-201 was found to be the most similar to the Thai jasmine rice out of the U.S. varieties from Ward's hierarchical cluster analysis of all attributes. These findings can help the U.S. rice industry to develop U.S. jasmine rice cultivars closer to Thai jasmine rice.

* Anastasia Mills is a senior honors student in the Department of Food Science.
† Ya-Jane Wang is the faculty mentor and a professor in the Department of Food Science.

Introduction

Rice (*Oryza sativa* L.) is the staple food of almost half of the world's population. While the U.S. accounts for only about 2% of global rice production, it exports more than 6% of global exports (USDA-ERS, 2019). The U.S. rice imports have increased over the past 30 years, and aromatic rice accounts for about 90% of U.S. rice imports (Suwannaporn and Linnemann, 2008a). Most rice imports are aromatic varieties from Asia, i.e., jasmine from Thailand and basmati from India and Pakistan. Thailand alone accounts for 60% to 70% of total U.S. imported rice. The demand for aromatic rice is expected to continue increasing in both domestic and international markets (Sakthivel et al., 2009).

Aromatic rice has characteristic taste, aroma, appearance, and texture that makes it desirable when compared with other nonaromatic varieties. Suwannaporn and Linnemann (2008a) found that eating quality attributes of hardness and stickiness were important factors in discriminating consumer preference. In another study by Suwannaporn and Linnemann (2008b) on consumer preferences, attitudes, and buying criteria toward jasmine, country of origin was frequently mentioned as an important criterion in buying rice when participants from rice-eating countries were surveyed. Currently, there are links between preferences and countries of origin in certain grain types such as Jasmine rice with Thailand.

Suwansri et al. (2002) evaluated 3 U.S. and 12 imported commercial jasmine rice varieties from Thailand using a trained sensory panel and 105 Asian families who lived in the State of Arkansas. They found that Asian consumers preferred imported Jasmine rice more than the domestic products, and the sensory characteristics most important to the acceptance of cooked Jasmine rice were color, followed by flavor, aroma, stickiness, and hardness. Suwansri and Meullenet (2004) further investigated the physiochemical properties of the same 15 jasmine rice varieties and found that the U.S. jasmine rice samples were associated with high amylose, high surface lipid, and high protein contents, resulting in cooked rice of harder texture, darker color, and inferior flavor.

Recently, several jasmine rice cultivars have been released from different states. There has been no study comparing jasmine rice cultivars grown in the U.S. with Thai jasmine. Therefore, the objective of this study was to characterize and compare the physiochemical properties and sensory attributes of these newly released jasmine rice cultivars to be compared with two commercial Thai jasmine samples.

Materials and Methods

Materials

Nine jasmine rice samples were used for this study, including seven from the United States and two from Thailand. The U.S. cultivars included ARoma17 from 2017 and RU1701105 from 2018, grown in Stuttgart, Arkansas, provided by Dr. Karen Moldenhauer of the University of Arkansas System Division of Agriculture's Rice Research and Extension Center (Stuttgart, Arkansas); Calaroma-201 from California from 2018 and grown in Richvale, California, Butte County provided by Dr. Kent McKenzie of the California Rice Experiment Station, California Cooperative Rice Research Foundation, Inc. (Biggs, California); and CLJ01 and Jazzman from both 2017 and 2018 crop years grown in Crowley, Louisiana provided by Dr. Adam Famoso of the Louisiana State University Agricultural Center, H. Rouse Caffey Rice Research Station, (Rayne, Louisiana). The two commercial Thai jasmine rice samples were Golden Phoenix purchased in Bangkok, Thailand, and Three Ladies Brand HOM MALI 105 purchased in Springdale, Arkansas, in 2018.

Kernel Appearance

Head rice color was measured by the $L^*a^*b^*$ color system (ColorFlex, Hunter Associates Laboratory, Reston, Virginia). Kernel dimensions (length, width, and thickness) were measured using a digital image analysis system (SeedCount 5000; Next Instruments, New South Wales, Australia).

Chemical Composition

Milled rice flour samples were obtained by grinding head rice with a laboratory mill (cyclone sample mill, Udy Corp., Ft. Collins, Colorado). The flour was used to determine apparent amylose content (Juliano, 1971), moisture content by Approved Method 44-15A (AACC, 2000), crude protein (AACC Method 46-13), lipid content (Soxtec Avanti 2055, Foss North America, Eden Prairie, Minnesota) according to AACC Method 30-20 with modifications by Matsler and Siebenmorgen (2005), and ash content (AACC method 08-03). Duplicate measurements were conducted for each flour sample. Starch was extracted from milled rice flour following the method of Patindol and Wang (2002).

2-acetyl-1-pyrroline and Hexanal Analysis

Samples were analyzed for levels of 2-acetyl-1-pyrroline (2-AP; Santa Cruz Biotechnology, Dallas, Texas) and hexanal (Sigma-Aldrich, St. Louis, Missouri) through solid-phase microextraction (SPME). Hexanal and 2-acetyl-1-pyrroline were quantified by performing linear regression from reference standards.

Characterization of Amylopectin Structure

The chain-length distribution of amylopectin was determined by high-performance anion-exchange chromatography with pulsed amperometric detection (HPAEC-PAD) according to Kasemsuwan et al. (1995) using a

Dionex ICS-3000 ion chromatography system (Dionex Corporation, Sunnyvale, California).

Gelatinization Properties

Milled rice flour gelatinization properties were determined with a differential scanning calorimeter (DSC; Pyris Diamond, Perkin Elmer Instruments, Shelton, Connecticut) following the method of Wang et al. (1992) with some modification. Onset, peak, and conclusion gelatinization temperatures (T_o, T_p, and T_c, respectively), and gelatinization enthalpy were calculated from each thermogram using the Pyris software.

Pasting Characteristics

Flour pasting properties were determined using a Rapid ViscoAnalyser (RVA; Model 4, Perten Instruments, Springfield, Illinois) according to AACC Method 61-02.01. The pasting properties measured include peak viscosity, hot paste viscosity (trough), final viscosity, breakdown, setback, and total setback.

Cooked Rice Texture

Rice was cooked and evaluated following a modified method of Sesmat and Meullenet (2001). Ten cooked rice kernels were compressed using a texture analyzer (TA. XT Plus Texture Analyzer, Texture Technologies, Hamilton, Massachusetts). The maximum compression force (peak force, g) and adhesiveness (area of negative force, g·s) were recorded as cooked rice hardness and stickiness, respectively. Six replications were performed for each cooked sample, and two cooked samples were prepared for each rice sample.

Results and Discussion

Kernel Appearance

Jasmine rice typically has translucent slender kernels. Calaroma-201 shared a similar kernel length with the two Thai jasmine rice samples (Golden Phoenix and 3 Ladies HOM MALI), which were greater than the others (Table 1). Apart from Jazzman 2017, the Louisiana cultivars were shorter than the other cultivars, with CLJ01 2018 being the shortest. The cultivar RU1701105 was wider than the others, whereas Calaroma-201 had a much smaller kernel width. The kernel thickness exhibited less variation, with Arkansas cultivars slightly thicker than the Golden Phoenix. Both commercial Thai jasmine rice samples had the greatest lightness (L^*) values, followed by Calaroma-201, whereas ARoma17 and Jazzman 2017 had the lowest lightness values. Calaroma-201 was lower in yellowness (b^*) than the other cultivars. The Federal Grain Inspection Service (FGIS) of the United States Department of Agriculture classifies milled rice with kernels having a length-to-width ratio (L/W) of greater than 3 as a long-grain type, and 2.0–2.9 as a medium-grain type (USDA, 2014). The L/W of RU1701105 was 2.63, which was smaller than the other cultivars and classified as a medium-grain type. Based on the kernel dimension and color, Calaroma-201 was most similar to Thai jasmine.

Chemical Composition

The cultivar RU1701105 had the greatest protein content, 1.8 percentage points greater than the next greatest one, CLJ01 2017 (Table 2), while Calaroma-201 and Jazzman 2018 had the lowest protein contents. The cultivars RU1701105 and Calaroma-201 had the greatest amylose

Table 1. Kernel appearance of jasmine rice samples from Thailand and grown in the U.S.

Sample	Kernel Dimension				Kernel Color	
	Length (L) (mm)	Width (W) (mm)	Thickness (mm)	L/W ratio	L^*	b^*
Golden Phoenix	7.22 ± 0.02 a[†]	2.14 ± 0.00 cd	1.84 ± 0.03 b	3.37 ± 0.01 a	75.2 ± 0.5 a	17.0 ± 0.6 ab
3 Ladies HOM MALI	7.22 ± 0.01 a	2.14 ± 0.01 cd	1.86 ± 0.02 ab	3.38 ± 0.01 a	73.9 ± 0.1 b	16.9 ± 0.2 b
ARoma17	6.80 ± 0.02 b	2.22 ± 0.01 b	1.95 ± 0.04 a	3.07 ± 0.00 b	68.8 ± 0.0 f	18.1 ± 0.3 a
RU1701105	6.73 ± 0.03 b	2.56 ± 0.01 a	1.95 ± 0.01 a	2.63 ± 0.03 c	70.4 ± 0.1 de	17.4 ± 0.2 ab
Calaroma-201	7.21 ± 0.06 a	2.07 ± 0.04 e	1.89 ± 0.00 ab	3.49 ± 0.09 a	72.2 ± 0.1 c	12.7 ± 0.0 e
CLJ01 2018	6.30 ± 0.01 d	2.11 ± 0.01 de	1.90 ± 0.01 ab	2.99 ± 0.00 b	69.6 ± 0.1 e	16.8 ± 0.2 bc
CLJ01 2017	6.48 ± 0.03 c	2.15 ± 0.01 cd	1.91 ± 0.05 ab	3.01 ± 0.01 b	70.9 ± 0.2 d	17.8 ± 0.4 ab
Jazzman 2018	6.53 ± 0.08 c	2.19 ± 0.02 bc	1.91 ± 0.02 ab	2.99 ± 0.01 b	71.0 ± 0.3 d	14.6 ± 0.3 d
Jazzman 2017	6.83 ± 0.05 b	2.21 ± 0.02 b	1.89 ± 0.02 ab	3.09 ± 0.01 b	68.6 ± 0.2 f	15.7 ± 0.5 cd

[†] Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

contents, while CLJ01 2018 had the lowest amylose content. Cultivars ARoma17 and RU1701105 had the greatest lipid contents, while the two Thai jasmine samples had the lowest. Jazzman 2018 had a lower lipid content than Jazzman 2017, while CLJ01 2018 and CLJ01 2017 were similar to each other, indicating cultivar and crop year interaction. Cultivar RU1701105 had the greatest ash content, followed by ARoma17, and the two Thai jasmine rice samples had the lowest ash contents. The two Arkansas cultivars generally had greater protein, lipid, and ash contents, whereas the two Thai jasmine rice samples had lower lipid and ash contents. Jazzman 2018 seems the closest to the Thai varieties out of all chemical characteristics, due to its relative similarity in 3 out of 4 chemical attributes. The Thai jasmine samples were commercial samples, which were likely milled to a greater extent, compared with the U.S. grown rice cultivars that were milled in the laboratory, thus resulting in lower protein, lipid, and ash contents, which could account for their lighter color (greater L^*). The greater b^* values (yellowness) of ARoma17, RU1701105, and CLJ01 2017 could be attributed to their greater protein contents (Wang et al., 2014). Calaroma-201 had the lowest protein content and exhibited the lowest b^* value among all the cultivars.

2-Acetyl-l-pyrroline and Hexanal

Buttery et al. (1982) identified and determined the concentration of 2-acetyl-l-pyrroline (2-AP) as an important compound contributing to a popcorn-like aroma in several Asian fragrant rice varieties, including jasmine rice. Calaroma-201 had the greatest level of 2-AP, followed by CLJ01 2017, while the two Thai samples had lower levels of 2-AP. The greatest amount of 2-AP in Calaroma-201 could be attributed to its genetic makeup, as certain alleles have been isolated to account for this compound, which Calaroma-201 may possess (Niu et al., 2008). Although the exact crop years of both Thai samples were unknown, it is speculated that their low 2-AP

Table 2. Chemical composition (%, dry basis) of jasmine rice samples from Thailand and grown in the U.S.

Sample	Protein	Amylose	Lipid	Ash
Golden Phoenix	7.61 ± 0.01 d†	16.08 ± 0.14 d	0.15 ± 0.00 g	0.26 ± 0.01 d
3 Ladies HOM MALI	7.65 ± 0.01 d	16.18 ± 0.07 cd	0.19 ± 0.00 f	0.23 ± 0.00 d
ARoma17	8.39 ± 0.02 c	16.65 ± 0.21 bc	0.56 ± 0.02 a	0.48 ± 0.01 b
RU1701105	10.89 ± 0.15 a	19.57 ± 0.07 a	0.54 ± 0.01 a	0.60 ± 0.02 a
Calaroma-201	6.99 ± 0.03 e	19.37 ± 0.14 a	0.31 ± 0.01 d	0.33 ± 0.00 c
CLJ01 2018	7.87 ± 0.01 d	14.13 ± 0.11 f	0.43 ± 0.01 bc	0.37 ± 0.00 c
CLJ01 2017	9.09 ± 0.02 b	16.76 ± 0.07 b	0.40 ± 0.01 c	0.34 ± 0.02 c
Jazzman 2018	6.87 ± 0.00 e	16.66 ± 0.21 bc	0.26 ± 0.01 e	0.36 ± 0.01 c
Jazzman 2017	8.41 ± 0.13 c	14.71 ± 0.11 e	0.45 ± 0.01 b	0.37 ± 0.01 c

† Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

Table 3. Hexanal and 2-acetyl-1-pyrroline (2-AP) in raw milled jasmine rice samples from Thailand and grown in the U.S.

Sample	2-AP (ng/g)	Hexanal (ng/g)
Golden Phoenix	977.4 ± 54.6 fg†	344.8 ± 21.9 b
3 Ladies HOM MALI	396.2 ± 35.6 h	364.1 ± 9.9 b
ARoma17	1331.5 ± 68.1 cdef	197.8 ± 5.6 cd
RU1701105	1608.7 ± 88.7 c	44.1 ± 2.8 g
Calaroma-201	3434.3 ± 60.2 a	167.8 ± 9.7 def
CLJ01 2018	1385.1 ± 60.7 cde	233.9 ± 12.5 c
CLJ01 2017	2328.7 ± 191.8 b	437.6 ± 34.8 a
Jazzman 2018	1092.4 ± 28.0 efg	111.4 ± 8.4 f
Jazzman 2017	1167.7 ± 38.9 defg	154.4 ± 12.8 def

† Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

contents could be due to storage conditions and/or duration. Hexanal content is directly related to oxidative off-flavors and is easily recognized because of its low odor threshold (5 ng/g) in rice (Buttery et al., 1988). Cultivar CLJ01 2017 had greater levels of hexanal than the other varieties (Table 3), followed by the two Thai samples, and RU1701105 had the lowest concentration of hexanal. Cultivar CLJ01 2017 had greater levels of hexanal than its respective 2018 counterpart, implying the association of high hexanal content and storage duration. The high hexanal content in the two Thai samples supports the speculation that they may have been stored for a long period of time.

Chain-Length Distribution of Amylopectin

When amylopectin chain-length distribution was characterized by HPAEC-PAD (Table 4), CLJ01 2018 had the longest average chain length, which can be ascribed to its greater proportion of B2 and B3+ chains. The 3 Ladies HOM MALI, ARoma17, RU1701105, Calaroma-201, and CLJ01 2017 had shorter average chain lengths, which can be attributed to their smaller proportion of B2 and B3+ chains. Jazzman 2018 and Jazzman 2017 were most similar to the Thai varieties in their average chain length.

Gelatinization Properties

Overall, Jazzman 2018 and Jazzman 2017 exhibited greater gelatinization temperatures; whereas Calaroma-201 displayed lower gelatinization temperatures (Table 5). It has been shown that elevated growing temperature is associated with reduced amylose content and increased amylopectin long chains, which result in greater gelatinization temperatures (Patindol et al., 2014; Asaoka et al., 1985). Jazzman had the greatest gelatinization temperatures, which could be ascribed to its greatest average amylopectin chain length. Calaroma-201

Table 4. Amylopectin chain-length distribution of jasmine rice samples from Thailand and grown in the U.S.

	Percent Composition (%)				
Sample	A (DP6-12)	B1 (DP13-24)	B2 (DP25-36)	B3+ (DP37-65)	Average Chain Length
Golden Phoenix	26.71 ± 0.33 a[†]	47.98 ± 0.22 b	14.25 ± 0.15 ab	11.05 ± 0.40 abc	20.49 ± 0.17 abc
3 Ladies HOM MALI	26.87 ± 0.49 a	47.75 ± 0.37 b	14.56 ± 0.14 a	10.82 ± 0.01 abc	20.42 ± 0.05 abcde
ARoma17	26.99 ± 0.05 a	48.83 ± 0.15 a	13.69 ± 0.06 bc	10.48 ± 0.16 c	20.14 ± 0.05 e
RU1701105	27.13 ± 0.31 a	48.35 ± 0.13 ab	13.45 ± 0.49 c	11.06 ± 0.32 abc	20.29 ± 0.02 bcde
Calaroma-201	27.17 ± 0.40 a	48.32 ± 0.15 ab	13.76 ± 0.15 bc	10.74 ± 0.10 bc	20.23 ± 0.09 cde
CLJ01 2018	26.20 ± 0.16 a	47.93 ± 0.04 b	14.27 ± 0.03 ab	11.60 ± 0.09 a	20.62 ± 0.05 a
CLJ01 2017	26.77 ± 0.13 a	48.84 ± 0.22 a	13.91 ± 0.03 abc	10.50 ± 0.13 c	20.18 ± 0.03 de
Jazzman 2018	26.34 ± 0.00 a	48.39 ± 0.02 ab	13.94 ± 0.01 abc	11.33 ± 0.01 ab	20.53 ± 0.01 ab
Jazzman 2017	26.35 ± 0.07 a	48.17 ± 0.14 ab	14.24 ± 0.02 ab	11.23 ± 0.20 abc	20.45 ± 0.07 abcd

[†] Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

Table 5. Gelatinization properties of jasmine rice samples from Thailand and grown in the U.S.

Sample	Onset (°C)	Peak (°C)	End (°C)	Enthalpy (J/g)
Golden Phoenix	65.6 ± 0.7 cd[†]	71.7 ± 0.2 cd	79.1 ± 0.6 cd	8.28 ± 0.11 a
3 Ladies HOM MALI	65.8 ± 0.1 c	72.1 ± 0.0 c	79.1 ± 0.2 bcd	7.93 ± 0.08 a
ARoma17	66.4 ± 0.0 bc	73.0 ± 0.0 b	80.6 ± 0.0 abc	7.39 ± 0.32 a
RU1701105	64.9 ± 0.1 cde	71.6 ± 0.0 cd	79.1 ± 0.0 cd	6.11 ± 0.14 a
Calaroma-201	64.3 ± 0.1 de	70.1 ± 0.2 e	77.1 ± 0.4 d	7.62 ± 0.17 a
CLJ01 2018	67.4 ± 0.0 b	74.3 ± 0.0 a	82.8 ± 1.4 a	8.08 ± 0.34 a
CLJ01 2017	63.8 ± 0.4 e	71.1 ± 0.1 d	78.8 ± 0.3 cd	8.42 ± 0.02 a
Jazzman 2018	69.1 ± 0.1 a	74.6 ± 0.2 a	82.0 ± 0.1 a	8.00 ± 0.21 a
Jazzman 2017	67.7 ± 0.3 ab	74.0 ± 0.2 a	81.5 ± 0.2 ab	8.31 ± 0.08 a

[†] Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

and CLJ01 2017 had lower gelatinization temperatures, which could be explained by their shorter average amylopectin chain length. The high gelatinization temperatures of Jazzman suggest that a greater temperature is required to cook the rice, so cooked rice texture could be affected. Because the U.S. jasmine rice cultivars were grown in different regions, with temperatures greatest in Louisiana, followed by Arkansas and then California, their gelatinization temperatures reflect their respective growth temperatures. Crop year could also be a contributing factor affecting gelatinization temperatures as demonstrated by Jazzman 2018 and CLJ01 2018 both having greater gelatinization temperatures than the 2017 crop year.

Pasting Properties

Jazzman 2018 exhibited the greatest peak and breakdown viscosities, but the lowest setback and total setback viscosities (Table 6; Fig. 1). Cultivar CLJ01 2017 dis-

Table 6. Pasting properties of rice flour of jasmine rice samples from Thailand and grown in the U.S. by a Rapid ViscoAnalyser.

	Pasting Viscosities (cP)					
Sample	Peak	Trough	Breakdown	Final	Setback	Total Setback
Golden Phoenix	3849 ± 22 b†	1971 ± 108 ab	1878 ± 130 bc	3411 ± 42 d	-438 ± 64 e	1441 ± 66 cd
3 Ladies HOM MALI	3603 ± 13 c	2035 ± 17 a	1568 ± 30 de	3611 ± 31 c	8 ± 44 c	1576 ± 14 b
ARoma17	3301 ± 7 d	1662 ± 5 d	1640 ± 12 cd	3058 ± 7 e	-243 ± 0 d	1397 ± 12 de
RU1701105	3106 ± 47 e	1757 ± 28 cd	1349 ± 75 e	3758 ± 27 b	653 ± 74 b	2002 ± 1 a
Calaroma-201	3368 ± 4 d	1651 ± 11 d	1717 ± 7 bcd	2947 ± 15 f	-421 ± 11 de	1296 ± 4 ef
CLJ01 2018	3654 ± 12 c	1868 ± 4 abc	1786 ± 16 bcd	3393 ± 4 d	-261 ± 16 de	1524 ± 0 bc
CLJ01 2017	2776 ± 17 f	1880 ± 62 abc	897 ± 80 f	3865 ± 27 a	1089 ± 44 a	1986 ± 35 a
Jazzman 2018	4093 ± 46 a	1856 ± 0 bc	2237 ± 46 a	2944 ± 13 f	-1149 ± 59 g	1089 ± 13 g
Jazzman 2017	3691 ± 41 c	1783 ± 30 cd	1908 ± 70 b	3066 ± 2 e	-625 ± 43 f	1283 ± 28 f

† Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

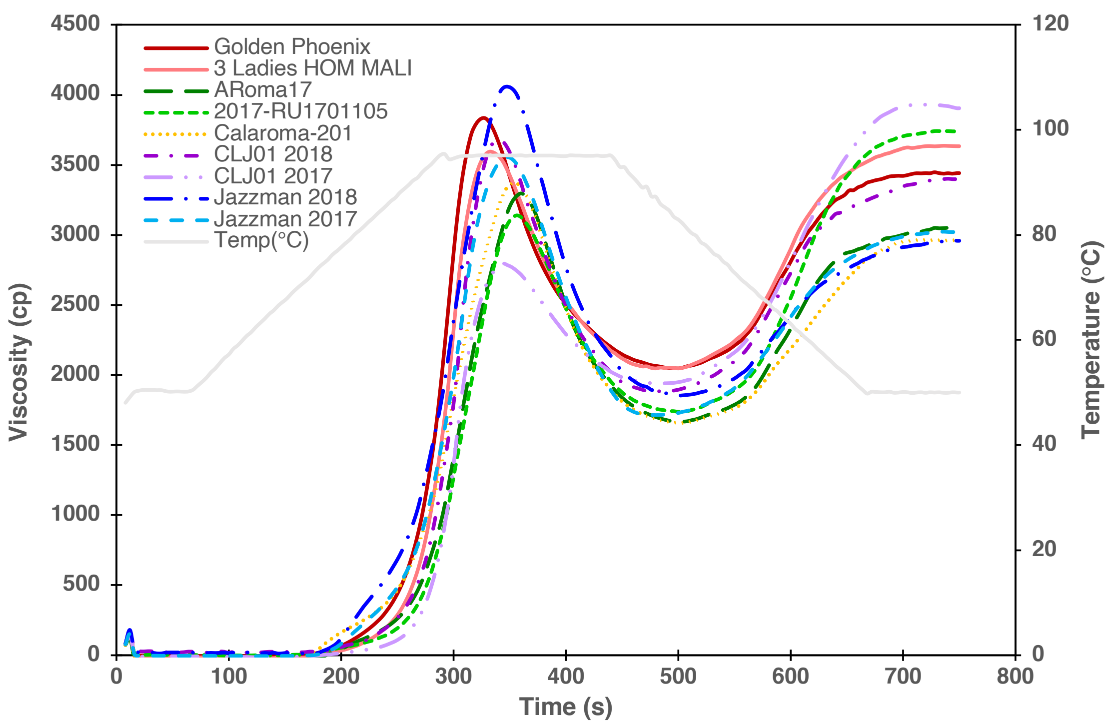

Fig. 1. Pasting profiles of jasmine rice samples from Thailand and grown in the U.S. with a Rapid ViscoAnalyzer.

played the lowest peak viscosity, the smallest breakdown, and greater final, setback, and total setback viscosities. The two Thai jasmine samples differed from each other in peak, breakdown, final, setback, and total setback viscosities. ARoma17 had greater peak and breakdown viscosities than RU1701105 but lower final, setback, and total setback viscosities. Both Arkansas cultivars had lower peak and trough viscosities than the Thai controls. Calaroma-201 was similar to ARoma17 in pasting, except for a lower final viscosity, which was similar to that of Jazzman 2018. The U.S. variety most similar to the Thai jasmine in pasting properties was CLJ01 2018.

The pasting properties of rice flour are affected by its chemical composition, including protein and lipid contents, and by starch composition and structures. Amylopectin content contributes to swelling of starch granules and pasting, whereas amylose and lipids inhibit the swelling (Tester and Morrison, 1990). Protein content may negatively impact peak viscosity (Wang et al., 2014), and protein-starch interactions may also affect viscosity (Hamaker and Griffin, 1990). Amylose content has been reported to be negatively correlated with peak, final, and breakdown viscosity, but positively correlated with setback viscosity (Patindol et al., 2014), which indicates the tendency of starch to retrograde during cooking. The lower peak and breakdown viscosities and greater final, setback, and total setback viscosities of RU1701105 and CLJ01 2017 were attributed to their greater protein and amylose contents. In contrast, the greater peak and breakdown viscosities and lower setback and total setback of Jazzman 2018 were proposed to be due to its low protein and amylose contents. The high amylose contents of RU1701105 and Calaroma-201 were correlated with lower pasting viscosities. ARoma17 and RU1701105 had high lipid contents and showed lower overall pasting viscosities.

Cooked Rice Texture

When cooked, RU1701105 had greater hardness but lower stickiness compared with most other samples (Table 7). Jazzman 2018 and Calaroma-201 were slightly stickier than the other samples. In a previous study, rice high in amylose and protein contents were found to have increased cooked rice hardness, but reduced stickiness, and gelatinization temperature was positively correlated with cooked rice hardness (Mestres et al., 2011). The cultivar RU1701105 had the greatest hardness value and was the least sticky, which is attributed to its high amylose and protein contents. Calaroma-201 and Jazzman 2018 had greater stickiness values, which can be attributed to their low protein contents. For the Louisiana samples, hardness and stickiness were not significantly different between the 2017 and 2018 crop years. Cultivar CLJ01 2018 had the hardness and stickiness, which was closest to that of the Thai varieties.

Statistical Analysis

Three clusters were found among the nine rice samples based on all data according to similarities and differences by Ward's hierarchical cluster analysis (Fig. 2). Calaroma-201 was most similar to the Thai jasmine rice among the U.S. jasmine cultivars. The Arkansas cultivars were more similar to each other and CLJ01 2017, while the Louisiana cultivars were more similar to each other as well. Cluster 3 of Louisiana cultivars were more similar to the Thai jasmine than Cluster 1 of Arkansas cultivars.

Conclusions

Based on the kernel dimension and color, Calaroma-201 was most similar to Thai jasmine. Jazzman 2018 was closer to the Thai varieties in chemical attributes,

Table 7. Cooked rice texture of jasmine rice samples from Thailand and grown in the U.S. by a texture analyzer.

Sample	Hardness	Stickiness
	(g)	(g.sec)
Golden Phoenix	6048 ± 421 b†	-403 ± 6 cde
3 Ladies HOM MALI	6778 ± 233 ab	-333 ± 43 abc
ARoma17	5474 ± 519 b	-348 ± 35 bc
RU1701105	8464 ± 736 a	-206 ± 5 a
Calaroma-201	6377 ± 204 b	-521 ± 57 de
CLJ01 2018	6005 ± 245 b	-359 ± 17 bc
CLJ01 2017	5930 ± 711 b	-258 ± 59 ab
Jazzman 2018	5540 ± 46 b	-534 ± 26 e
Jazzman 2017	6896 ± 351 ab	-386 ± 26 bcd

† Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

and both Jazzman 2018 and Jazzman 2017 were similar to the Thai in average amylopectin chain length. Cultivar RU1701105 and the Thai jasmine rice samples had similar gelatinization temperatures. Cultivar ClJ01 2018 was most similar to the Thai jasmine in pasting properties and cooked rice texture. Calaroma-201 was most similar to Thai jasmine rice samples when considering all properties. The Arkansas varieties were generally similar to each other, and Louisiana varieties were similar to each other, but each of these categories is different from the Thai jasmine rice samples. This study demonstrates that the properties of jasmine rice are strongly influenced by genetics, growing location, and crop year.

Acknowledgments

I thank Dr. Kent McKenzie, Dr. Karen Moldenhauer, and Dr. Adam Famoso for providing jasmine rice samples, the Student Undergraduate Research Fellowship (SURF) for funding for this project, and the University of Arkansas System Division of Agriculture's Rice Processing Program for allowing the use of their lab equipment.

Literature Cited

AACC International. 2000. Approved Methods of Analysis, 10th Edition. St. Paul, Minn.: AACC International; Method 30-20, 08-03, 44-15A, 46-13, 61-02.01.

Asaoka, M., K. Okuno, and H. Fuwa. 1985. Effects of environmental temperature at the milky stage on amylose content and fine structure of amylopectin of waxy and nonwaxy endosperm starches of rice (*Oryza sativa* L.). Agr. Biol. Chem. 49(2):373-379.

Buttery, R.G., L.C. Ling, and B.O. Juliano. 1982. 2-Acetyl-1-pyrroline: An important aroma component of cooked rice. Chem. Industry. 958-959.

Buttery, R.G., J.G. Turnbaugh, and L.C. Ling. 1988. Contribution of volatiles to rice aroma. J. Agric. Food Chem. 36:1006-1009.

Hamaker, B.R. and V.K. Griffin. 1990. Changing the viscoelastic properties of cooked rice through protein disruption. Cereal Chem. 67(3):261–264.

Juliano, B.O. 1971. A simplified assay for milled-rice amylose. Cereal Sci. Today. 16:334–340.

Kasemsuwan, T., J.-L. Jane, P. Schnable, P. Stinard, and D. Robertson. 1995. Characterization of the dominant mutant amylose-extender (*ae*1-5180) maize starch. Cereal Chem. 72:457-464.

Matsler, A.L. and T.J. Siebenmorgen. 2005. Evaluation of operating conditions for surface lipid extraction from rice using a Soxtec system. Cereal Chem. 82:282-286.

Mestres, C., F. Ribeyre, B. Pons, V. Fallet, and F. Matencio. 2011. Sensory texture of cooked rice is rather linked to chemical than physical characteristics of raw grain. J. Cereal Sci. 53:81-89.

Niu, X., W. Tang, W. Huang, G. Ren, Q. Wang, D. Luo, Y. Xiao, S. Yang, F. Wang, B.-R. Lu, F. Gao, T. Lu, and Y. Liu. 2008. RNAi-directed downregulation of *OsBADH2* results in aroma (2-acetyl-1-pyrroline) production in rice (*Oryza sativa* L.). BMC Plant Biol. 8:100.

Patindol, J. and Y.-J. Wang. 2002. Fine structures of starches from long-grain rice cultivars with different functionality. Cereal Chem. 79(3):465-469.

Patindol, J.A., T.J. Siebenmorgen, Y.-J. Wang, S.B. Lanning, and P.A. Counce. 2014. Impact of elevated nighttime air temperatures during kernel development on starch properties of field-grown rice. Cereal Chem. 91(4):350-357.

Sakthivel K., R.M. Sundaram, N. Shobha Rani, S.M. Balachandran, and C.N. Neeraja. 2009. Genetic and molecular basis of fragrance in rice. Biotechnology Advances. 27:468–473.

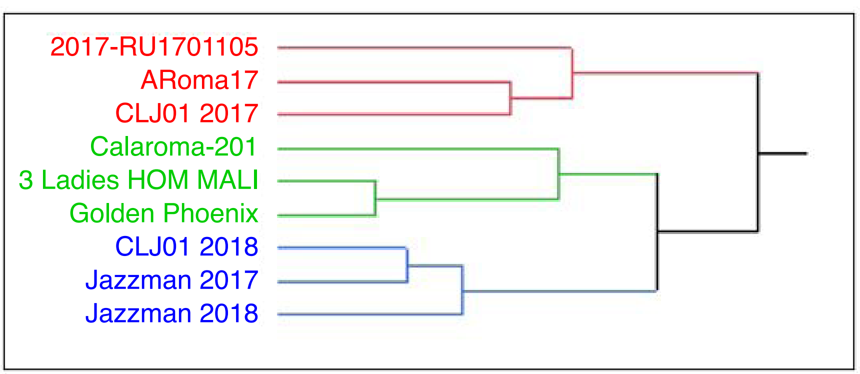

Fig. 2. A dendrogram obtained from the Ward's hierarchical cluster analysis of the kernel appearance, chemical composition, fine structure of starch, pasting characteristics, and cooked rice texture of nine jasmine cultivars.

Sesmat A. and J.-F. Meullenet. 2001. Prediction of rice sensory texture attributes from a single compression test, multivariate regression, and a stepwise model optimization method. J. Food Sci. 66:124-131.

Suwansri, S., J.-F. Meullenet, J.A. Hankins, and K. Griffin. 2002. Preference mapping of domestic/imported jasmine rice for U.S.-Asian consumer. J. Food Sci. 67:2420-2431.

Suwansri, S. and J.F. Meullenet. 2004. Physicochemical characterization and consumer acceptance by Asian consumers of aromatic jasmine rice. J. Food Sci. 69:30-37.

Suwannaporn, P. and A. Linnemann. 2008a. Rice-eating quality among consumers in different rice grain preference countries. J. Sensory Studies. 23:1-13.

Suwannaporn, P. and A. Linnemann. 2008b. Consumer preferences and buying criteria in rice: A study to identify market strategy for Thailand jasmine rice export. J. Food Prod. Market. 14:33-53.

Tester, R. F. and W.R. Morrison. 1990. Swelling and gelatinization of cereal starches. I. Effects of amylopectin, amylose, and lipid. Cereal Chem. 67:551-557.

Wang, Y.-J., J. Patindol, J.-R. Jinn, H.-S. Seo, and T.J. Siebenmorgen. 2014. Exploring rice quality traits of importance to export markets. *In*: B.R. Wells Arkansas Rice Research Studies 2013. Arkansas Agricultural Experiment Station Research Series 617:383-389.

Wang, Y.-J., P.J. White, and L. Pollak. 1992. Thermal and gelling properties of maize mutants from OH43 inbred line. Cereal Chem. 69:328-334.

USDA-ERS. 2019. United States Department of Agriculture–Economic Research Service. 2019. Rice Sector at a Glance. U.S. Rice Exports. https://www.ers.usda.gov/topics/crops/rice/rice-sector-at-a-glance/

USDA. 2014. Inspection of Milled Rice. Rice Inspection Handbook. 5:1-35. USDA: Washington, D.C. https://www.gipsa.usda.gov/fgis/handbook/rice_inspec.aspx