Southern Region Small Fruit Consortium

Final Report Research

Title: Determining Consumer Acceptability of New Fresh-Market Muscadine Grape Releases from the University of Arkansas System Division of Agriculture Fruit Breeding Program

Grant Code: SRSFC Project # 2022-R-05

Grant Period: March 1, 2022-February 28, 2023

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Public Abstract
Fresh-market muscadine grapes (*Vitis rotundifolia* Michx.) are an important regional crop in the Southeast United States with a loyal consumer base that value their unique flavor and pronounced floral and foxy aromas. The University of Arkansas System Division of Agriculture (UA) Fruit Breeding program is focused on developing new muscadine cultivars for the fresh-market and processing industries. Four fresh-market muscadine genotypes (AM-70, AM-231, AM-223, and Supreme) were harvested from the UA Fruit Research Station and evaluated for consumer sensory and physiochemical attributes in 2022. For consumer sensory attributes (n=58), there was no difference in overall impression, texture, sourness, or flavor of the four genotypes, but panelists liked the appearance of the three black-fruited genotypes (AM-70, AM-223, and Supreme) compared to the bronze-fruited genotype (AM-231). AM-70 and AM-231 had a higher liking for sweetness than AM-223. AM-70 had the highest JAR score in color (82%), appearance (74%), and sweetness (65%). In terms of ranking, AM-70 (37%) was highest, followed by Supreme (27%), AM-231 (20%), and AM-223 (16%). AM-70 had the largest berries (11.60 g), highest soluble solids (16.50%) and pH (3.87), while AM-223 had the highest titratable acidity. There was not a difference in berry firmness (N), but AM-231 and AM-70 had higher skin elasticity than AM-223 and Supreme and AM-223 had the highest skin firmness. These muscadine genotypes had 78 volatile compounds including 26 Esters (33%), 15 Aldehydes (19%), 12 Alcohols (15%), 11 Terpenes (14%), 6 Aromatic Hydrocarbons (8%), 5 Other (7%), 2 Ketones (3%), and 1 Sesquiterpenes (1%). AM-70 (8.69 µ/g) had the highest total volatiles, followed by AM-231 (3.57 µ/g), AM-223 (2.92 µ/g), and Supreme (2.42 µ/g). As a fresh-market muscadine grape, AM-70 performed comparably to Supreme, an established commercial fresh-market cultivar, demonstrating its potential utility as a cold-hardy, perfect-flowered fresh-market cultivar.

Introduction

Fresh-market muscadine grapes (*Vitis rotundifolia* Michx.) are an important regional crop in the Southeast US with a loyal consumer base that value their unique flavor and pronounced floral and foxy aromas. However, some traits, including thick skins, gummy pulp, and large, bitter seeds, need improvement to appeal to a broader base of consumers. Despite the relatively small number of founders used to establish the germplasm base used in modern muscadine breeding programs, there is substantial variation for flavor and texture attributes in commercial cultivars and breeding selections.

The University of Arkansas System Division of Agriculture (UA) Fruit Breeding program established a muscadine grape improvement program in 2007. Our breeding program is focused on developing new cultivars for the fresh-market and processing industries with improved consumer quality traits, disease resistance, and cold hardiness. Our primary breeding and evaluation site is in Clarksville, AR, at the very northern extent of the native range of muscadine grapes. Therefore, we have an excellent environment to select for cold hardy cultivars that are well-adapted for production in Arkansas, Tennessee, North Carolina, and other environments that frequently experience winter lows below 10 °F. Since the program was initiated, we have planted over 20,000 seedlings and made 343 seedling selections, including 12 new stenospermocarpic seedless selections between 2020 and 2022. We have yet to make a commercial release, but we are currently propagating vines of one advanced fresh-market selection, which we hope to offer for sale in the winter of 2024-2025.

This potential upcoming release from the UA Fruit Breeding Program, AM-70, is a large black-fruited fresh-market selection with excellent fruit quality, vine health, and cold hardiness. AM-70 was one of only a handful of fresh-market breeding selections that survived the historically low temperatures (-15 °F) in Clarksville in 2021 and had acceptable fruit yield in the 2021 season, while most other fresh-market cultivars and selections were killed to the ground. In addition to AM-70, we have a number of other advanced selections moving through the pipeline, including selections with distinctive 'rosy' and 'tropical' flavors, thin skins, firm flesh, and lobed 'Southern Home' type leaves.

As we prepare to release the first fresh-market muscadine cultivar(s) from the UA Fruit Breeding Program, it would be helpful to assess the consumer acceptability of the new potential release(s) compared to industry standards and to investigate potential correlations between consumer sensory assessments and physicochemical measurements of color, composition, texture, and flavor volatiles. Very few scientific studies have investigated the consumer acceptability of fresh-market muscadine grapes. Striegler et al. (2005) assessed the quality and flavor of 20 muscadine cultivars grown in Arkansas, but the quality assessments were based on subjective breeders' ratings, as compared to randomized and replicated consumer trials. Breman et al. (2007) conducted a small consumer study with five cultivars grown in North Florida and showed variation in acceptability. Felts et al. (2018) evaluated the physical, composition, and sensory attributes of a group of six fresh-market genotypes (Nesbitt, Ison, Summit, and three early UA breeding selections that have since been discarded from the program). However, Felts et al. (2018) conducted the sensory analysis with a trained descriptive panel focused on quantitative descriptions of fruit attributes, such as basic tastes, aroma, and texture, rather than assessing consumer preferences.

To date, the most comprehensive consumer study of fresh-market muscadine grapes was conducted by Brown et al. (2016) who evaluated 22 commercial cultivars and University of

Georgia breeding selections for consumer acceptability. A large group of consumer panelists rated the genotypes on -100 (strongest disliking) to +100 (strongest liking) scale for overall liking and liking of flavor, skin, pulp and appearance. The same group of genotypes was also evaluated for pH, soluble solids, and berry texture parameters. They found that the overall liking of muscadines ranged from 12.2 to 32.1, while three *V. vinifera* table grape checks were rated from 32.9 to 39.6. Overall liking was correlated with flavor (r = 0.95), pulp texture (r = 0.87), and skin texture (r = 0.80) liking. Overall liking was also correlated with instrumental measures of texture, including puncture force (r = - 0.67), elasticity (r = - 0.54), and work (r = - 0.67).

The goals of this study were to conduct a small randomized and replicated consumer study to assess how AM-70 and other advanced selections compare to 'Supreme', a popular fresh market cultivar and to identify physicochemical and consumer sensory attributes of fresh-market muscadine genotypes from the UA Fruit Breeding Program.

Materials and Methods

Harvest and Plant Materials

Supreme and three advanced fresh-market breeding selections (AM-70, AM-223, and AM-231) were harvested on the morning of September 19, 2022 from vines grown at the UA Fruit Research Station, Clarksville. AM-231 was bronze and the other genotypes were black. The chosen genotypes represent a popular cultivar and potential new releases with a range of textures and flavors. Approximately six quarts of fruit from each genotype were harvested at optimal ripeness. Damaged and diseased fruit were discarded during sorting and fruit was randomized for consumer sensory, physicochemical, and volatile analyses.

Consumer sensory analysis

Consumer sensory analysis of the fresh-market muscadine genotypes was conducted during the UA Muscadine Field Day and Workshop on the afternoon of September 19, 2022. The consumer study consisted of, visual, texture, and tasting evaluations of fruit. The sample presentation order of the genotypes was randomized. Sample cups were labeled with three-digit codes, and each panelist was served three berries of each cultivar. Unsalted crackers and water were provided for palate cleansing between samples. Each consumer was asked to evaluate overall impression, appearance, flavor, sweetness, acidity, and texture on the 9-point verbal hedonic scale (1 = dislike extremely; 9 = like extremely) and a 5-point Just About Right (JAR) scale (1 = not nearly enough 3 = just about right; 5 = much too much). Additionally, consumers were asked to rank their favorite and least favorite genotypes. Consumers were also asked demographic questions about their gender, age, place of residence, level of education, and muscadine consumption habits.

Physicochemical attributes

Physical and composition attributes of each of the fresh-market muscadine genotypes were evaluated at the Department of Food Science, UA, Fayetteville. The experiment was organized as a completely randomized design with three replicates per genotype. Three replicate samples of approximately 300 g of berries were collected for each genotype for physicochemical analyses.

Five berries per genotype and replication were used to determine berry size, shape, and color attributes (individual berry weight, berry length, and berry width). The five-berry samples were weighed on a digital scale and the width and height of each berry was measured with digital calipers. Skin color at the equator of each individual berry was measured using a CR 400 colorimeter (Konica Minolta, Ramsey, NJ). Color was measured as L* a* b* coordinates and transformed into chroma (C*) and hue angle (h°) using the equations: C* = (a*2 + B*2)1/2 and h° = tan–1(b*/a*) (McGuire 1992).

Firmness was measured by compression using a TA.XTPlus Texture Analyzer (Texture Technologies Corporation, Hamilton, MA) with a 5 kg load cell. Penetrations with 2-mm flat cylindrical probe were made on the equatorial plane of each berry with a probe speed of 1 mm.sec-1. After the probe contacted the berry surface, it continued a further 9 mm to penetrate the skin. Penetration data were used to estimate work to rupture, skin elasticity, and skin thickness following methods described by Worthington et al. (2020).

Three replicate five-berry samples of each genotype were used to determine soluble solids, pH, and titratable acidity. Samples were placed in cheesecloth to extract the juice from the berries. Titratable acidity and pH were measured with an automated titrimeter and electrode standardized to pH 2.0, 4.0, 7.0, and 10.0 buffers. Titratable acidity was determined using 6 mL of juice diluted with 50 mL of deionized, degassed water by titration with 0.1 N sodium hydroxide (NaOH) to an endpoint of pH 8.2; results were expressed as g/L tartaric acid. Total soluble solids (expressed as %) was measured. Soluble solids/titratability acidity ratio was calculated.

Volatile profiles

Eight halves of frozen seedless muscadine berries were crushed and mixed into a homogeneous slurry. Volatile detection was performed on 2.05 g of berry slurry in a 10 mL amber screw cap vial using a Shimadzu Nexis GC-2030 (Shimadzu, Japan) system equipped with a triple-quadruple mass selective detector and an AOC-6000 Autosampler (Shimadzu, Japan). The volatiles were absorbed on a 1-cm long SPME fiber coated with Divinylbenzene/Carboxen/Polydimethylsiloxane (DVB/CAR/PDMS) (Supelco, PA). The capillary column used was ZB-5MSplus (30 m x 0.25 mm x 0.25 µm) (Zebron, CA. The injection was performed on splitless mode at an inlet temperature of 230 °C. The fiber was preconditioned for 5 minutes at 240 °C, samples were incubated at 50 °C for 10 minutes, then extracted and desorbed for 10 minutes and 3 minutes, respectively. Helium was used as the carrier gas at a flow rate of 1 mL/min. The inlet pressure was 46.7 kPa. The initial oven temperature was set to 35 °C, held for 5 min, then raised to 150 °C at a rate of 5 °C/min, then raised to 280 °C at a rate of 8 °C/min and held for 5 min. The total run time was 49.25 min. The MS was operated in full scan mode (40-400 m/z) at interface and ion source temperatures of 290 and 240 °C, respectively. Compounds were identified (match rates of ≥90%) on Shimadzu LabSolution software based on mass spectral libraries using NIST2020 (National Institute of Standards and Technology, Gaithersburg, MD, USA). A linear retention index was created using an alkane standard mix solution (C7–C20) to further confirm the molecule identifications. Ten µL of hexanal-d12 (1 µg/µL) was added to each vial as an internal standard (IS). Volatile concentrations (as µg/g) were calculated based on IS and identified molecule peak areas, IS concentration and volume injected, and mass of berries into the vial, as shown in the following equation:

$$Molecule\ concentration\ \left(\frac{\mu g}{g}\right) = \frac{\frac{Peak\ area\ of\ compound}{Peak\ area\ of\ IS}\ x\ IS\ concentration\ \left(\frac{\mu g}{\mu L}\right)\ x\ IS\ Volume\ (\mu L)}{Muscadine\ berry\ mass\ (g)}$$

Results

Consumer sensory analysis

Fifty-eight attendees of the 2022 UA Muscadine Field Day and Workshop participated in the consumer sensory study (Tables 1 and 2). Overall, AM-70 was ranked as the favorite genotype by 37% of participants, followed by Supreme (27%), AM-231 (20%), and AM-223 (16%). There was no significant difference in the overall impression, texture impression, sourness impression, or flavor impression of the four genotypes (Table 1). The panelists preferred the appearance of the three black-fruited genotypes (AM-70, AM-223, and Supreme) to the bronze-fruited selection (AM-231). There were also significant differences among genotypes for sweetness. AM-70 and AM-231 were significantly sweeter than AM-223, and Supreme was intermediate. Overall, AM-70 performed comparably to Supreme, a fresh-selection that is prized for its consumer quality. In terms of JAR attributes, AM-70 had the highest JAR for color (82%), aroma (74%), and sweetness (65%). AM-70 and AM-231 had the highest JAR for flavor (62% and 70%, respectively) and sourness (55% and 56%, respectively) (Table 2).

Physicochemical attributes

Berry weight, berry length, berry width, skin elasticity and skin firmness differed for the four tested genotypes (Table 3). AM-70 had the highest berry weight, length, and width and AM-223 the smallest. The firmness (8.88 N) of these genotypes were not different. AM-231 and AM-70 had higher skin elasticity than AM-223 and Supreme. AM-223 had the highest skin firmness. For all skin color attributes, the genotypes differed (Table 4). AM-231 (bronze genotype) had the highest L*, hue angle, and chroma with AM-70 having lowest L* and chroma. Genotypes differed for all composition attributes (Table 5). AM-70 had the highest soluble solids (16.50%) and pH (3.87). AM-70 and AM-231 had higher soluble solids/titratable acidity ratio (27.57 and 27.95, respectively) than AM-223 and Supreme (15.76 and 18.23, respectively). AM-223 (0.89%) had higher titratable acidity than the other genotypes.

Volatile profiles

There were 78 volatile compounds identified in these four fresh-market muscadine genotypes, with 53 of the compounds differing between genotypes (Table 6). Analysis of volatile compounds in these four fresh-market muscadine fresh-market genotypes showed 26 Esters (33%), 15 Aldehydes (19%), 12 Alcohols (15%), 11 Terpenes (14%), 6 Aromatic Hydrocarbons (8%), 5 Other (7%), 2 Ketones (3%), and 1 Sesquiterpenes (1%). The Esters (fruity/ethereal), Aldehydes (green/vegetable), Alcohols (fruity) and Terpenes (floral) were the top classes of volatiles, followed by Aromatic hydrocarbons (spicy/clove), Ketones (fruity/berry), and Sesquiterpenes (spicy/herbal). AM-70 (8.69 µ/g) had the highest total volatiles, followed by AM-231 (3.57 µ/g), AM-223 (2.92 µ/g), and Supreme (2.42 µ/g). Principle Component (PC) analysis of PC1 and PC2 explained 87% (PC1=66.92% and PC2=20.29%) of the variation for all significant data collected for the volatile compounds of muscadine grapes. AM-70 had the highest concentration of many ester compounds, including ethyl acetate.

Conclusions
Four fresh-market muscadine genotypes (AM-70, AM-231, AM-223, and Supreme) were harvested from the UA System Fruit Research Station and evaluated for consumer sensory and physiochemical attributes in 2022. For consumer sensory, panelists liked the appearance of the three black-fruited genotypes (AM-70, AM-223, and Supreme) compared to the bronze-fruited genotype (AM-231). AM-70 and AM-231 had a higher liking for sweetness than AM-223. AM-70 had the highest JAR score in color (82%), appearance (74%), and sweetness (65%) and was ranked highest. AM-70 had the largest berries (11.60 g), highest soluble solids (16.50%) and pH (3.87). AM-231 and AM-70 had higher skin elasticity than AM-223 and Supreme, and AM-223 had the highest skin firmness. These muscadine genotypes had 78 volatile compounds including 26 Esters, 15 Aldehydes, 12 Alcohols, 11 Terpenes, 6 Aromatic Hydrocarbons, 5 Other, 2 Ketones, and 1 Sesquiterpenes. AM-70 (8.69 μ/g) had the highest total volatiles, followed by AM-231 (3.57 μ/g), AM-223 (2.92 μ/g), and Supreme (2.42 μ/g). As a fresh-market muscadine grape, AM-70 performed well in both sensory and physiochemical attributes.

Impact Statement
Fresh-market muscadine grapes (*Vitis rotundifolia* Michx.) are an important regional crop in the Southeast United States with a loyal consumer base that value their unique flavor and pronounced floral and foxy aromas. The UA Fruit Breeding program is focused on developing new muscadine cultivars for the fresh-market and processing industries. Four fresh-market muscadine genotypes (AM-70, AM-231, AM-223, and Supreme) were harvested from the UA System Fruit Research Station and evaluated for consumer sensory and physiochemical attributes in 2022. AM-70 performed comparably to Supreme demonstrating its potential as a new fresh-market cultivar.

Outreach and Education Events
Conference Implemented
Muscadine Grape Workshop and Field Day. University of Arkansas System Division of Agriculture Fruit Research Station, Clarksville, AR, September 19, 2022 (**57 attendees**)

Published Abstract
Chenier*, J., M. Worthington, and R. Threlfall. Consumer acceptability of new fresh-market muscadine grapes from the University of Arkansas System Division of Agriculture Fruit Breeding Program. HortScience 59(9) (Supplement 2) – 2023 SR-ASHS Annual Meeting. In press

Oral Presentations
Chenier*, J., M. Worthington, and R. Threlfall. Consumer acceptability of new fresh-market muscadine grapes from the University of Arkansas System Division of Agriculture Fruit Breeding Program. Southern Region-American Society for Horticulture Science Annual Meeting. February 3-5, Oklahoma City, OK.

Chenier, J., M. Worthington, and R. Threlfall*. Consumer acceptability of new fresh-market muscadine grapes from the University of Arkansas System Division of Agriculture Fruit

Breeding Program. American Society for Enology and Viticulture-Eastern Section 47th Annual Conference. June 7-9, 2023, Austin, TX.

Student Awards/Honors

Chenier*, J., M. Worthington, and R. Threlfall. Consumer acceptability of new fresh-market muscadine grapes from the University of Arkansas System Division of Agriculture Fruit Breeding Program. Southern Region-American Society for Horticulture Science Annual Meeting. February 3-5, Oklahoma City, OK.
(*2nd place in the Place Warren S. Barham Ph.D. Graduate Student Paper Competition)*

Chenier*, J., M. Worthington, and R. Threlfall. Consumer acceptability of new fresh-market muscadine grapes from the University of Arkansas System Division of Agriculture Fruit Breeding Program. Sothern Fruit Workers meeting at the Southern Region-American Society for Horticulture Science Annual Meeting. February 3-5, Oklahoma City, OK.
(*1st place 3-min thesis competition)*

Literature Cited

Breman J.W., A. Simonne, R.C. Hochmuth, L. Landrum, M. Taylor, K. Evans, C. Peavy, D. Goode. 2007. Quality characteristics of selected muscadine grape cultivars grown in North Florida. Proc Florida State Hort Soc 12:8–10.

Brown, K., C. Sims, A. Odabasi, L. Bartoshuk, P. Conner, and D. Gray. 2016. Consumer Acceptability of Fresh-Market Muscadine Grapes, J. Food Science, in press. DOI 10.1111/1750-3841.13522

Felts, M., R.T. Threlfall.,J.R Clarkand M.L. Worthinton. 2018. Physiochemical and Descriptive Sensory Analysis of Arkansas Muscadine Grapes. HortScience, 53:1570–1578.

Striegler, R.K., P.M. Carter, J.R. Morris, J.R. Clark, R.T. Threlfall, and L.R. Howard. 2005. Yield, quality and nutraceutical potential of selected muscadine cultivars grown in southwestern Arkansas. HortTechnology 15:276-284.

Worthington, M., J.R. Clark, R. Threlfall, T.M. Chizk. 2020. Optimizing texture assessment for muscadine grape breeding. SRSFC Grant Report. https://smallfruits.org/files/2020/12/2020-R-10-Muscadine-Report-2.pdf

Table 1. Attributes evaluated by a consumer sensory panel using a nine-point hedonic scale[z] for muscadine grapes grown at the University of Arkansas System Division of Agriculture (2022).

Genotype [y]	**Appearance impression**	**Flavor impression**	**Sweetness impression**	**Sourness impression**	**Texture impression**	**Overall impression**
AM-70	7.09 a	6.71 a	6.48 a	5.51 a	6.09 a	6.45 a
AM-223	6.67 a	6.38 a	5.64 b	5.28 a	5.78 a	5.86 a
AM-231	5.65 b	6.72 a	6.53 a	5.62 a	5.83 a	6.29 a
Supreme	6.69 a	6.31 a	5.97 ab	5.43 a	5.81 a	6.05 a
P-value	*<0.0001*	*0.3924*	*0.0071*	*0.6410*	*0.7384*	*0.2367*

[z] Wines were evaluated by 58 consumer panelists using a nine-point hedonic scale (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, and 9=like extremely).
[y] Means with different letters for each attribute within location are significantly different ($p<0.05$) using Tukey's Honestly Significant Difference test.

Table 2. Percent (%) of responses for consumer sensory analysis using a collapsed five-point just-about-right (JAR)[z] scale for muscadine grapes grown in Arkansas and evaluated at the University of Arkansas System Division of Agriculture (2022).

Genotype	Color			Aroma			Flavor			Sweetness			Sourness		
	Not enough	JAR	Too much	Not enough	JAR	Too much	Not enough	JAR	Too much	Not enough	JAR	Too much	Not enough	JAR	Too much
AM-70	5	82	14	15	74	11	16	62	23	24	65	11	8	55	37
AM-223	48	48	3	46	49	5	23	45	32	11	46	43	43	32	26
AM-231	75	23	2	35	56	10	18	70	12	11	45	44	37	56	8
Supreme	2	63	35	37	54	10	11	42	47	28	38	35	32	32	37

[z] Wines were evaluated by 58 consumer panelists using a five-point JAR scale (1 = much to low; 2 = too low; 3 = JAR; 4 = too much; 5 = much too much) collapsed to Too low, JAR, and Too much.

Table 3. Physical attributes of muscadine grapes grown in Arkansas and evaluated at the University of Arkansas System Division of Agriculture (2022).

Genotype [z]	Berry weight (g)	Berry length (mm)	Berry width (mm)	Firmness (N)	Skin elasticity (mm)	Skin firmness (N/mm)
AM-70	11.60 a	26.31 a	25.93 a	8.89 a	7.66 a	1.18 bc
AM-223	7.64 c	23.41 c	22.72 b	9.49 a	6.55 b	1.45 a
AM-231	9.95 ab	25.72 ab	24.14 ab	8.55 a	8.43 a	1.02 c
Supreme	9.53 b	24.45 bc	25.17 a	8.60 a	6.54 b	1.33 ab
P-value	<0.0001	<0.0001	0.0012	0.3556	<0.0001	<0.0001

[z] Genotypes were evaluated in duplicate. Means with different letters for each attribute within location are significantly different ($p<0.05$) using Tukey's Honestly Significant Difference test.

Table 4. **Color attributes of the skin of muscadine grapes grown in Arkansas and evaluated at the University of Arkansas System Division of Agriculture (2022).**

Genotype [z]	**L***	**a**	**b**	**Hue angle (°)**[y]	**Chroma**
AM-70	25.13 c	4.51 b	1.61 b	17.64 b	5.45 c
AM-223	26.85 bc	9.67 a	1.77 b	9.65 c	9.84 b
AM-231	42.09 a	0.29 c	13.87 a	88.67 a	13.94 a
Supreme	27.34 b	9.15 a	2.41 b	13.94 bc	9.52 b
P-value	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

[z] Genotypes were evaluated in duplicate. Means with different letters for each attribute within location are significantly different ($p<0.05$) using Tukey's Honestly Significant Difference test.
[y] Hue angles <90° were subjected to a 360° compensation to account for discrepancies between red samples near 0° and those near 360°.

Table 5. Composition of muscadine grapes grown in Arkansas and evaluated at the University of Arkansas System Division of Agriculture (2022).

Genotype [z]	Soluble solids (%)	pH	Titratable acidity (%)[y]	Soluble solids/titratable acidity ratio
AM-70	16.50 a	3.87 a	0.60 b	27.57 a
AM-223	13.90 bc	3.13 c	0.89 a	15.76 b
AM-231	15.67 ab	3.50 b	0.57 b	27.95 a
Supreme	12.33 c	3.28 bc	0.68 b	18.23 b
P-value	*0.0008*	*<0.0001*	*0.0013*	*0.0007*

[z] Genotypes were evaluated in duplicate. Means with different letters for each attribute within location are significantly different ($p<0.05$) using Tukey's Honestly Significant Difference test.

Table 6. **Volatile compounds (µg/g) of muscadine grapes grown in Arkansas and evaluated at the University of Arkansas System Division of Agriculture (2022).**

Compound [z]	Class	CAS #	AM-70	AM-231	AM-223	Supreme	*P-value*
1-Butanol	Alcohol	71-36-3	0.021 a	0.009 a	0.007 a	0.025 a	*0.220*
2-Hexen-1-ol, (E)-	Alcohol	928-95-0	0.462 a	0.454 a	0.583 a	0.209 b	***0.009***
1-Hexanol	Alcohol	111-27-3	0.002 a	0.004 a	0.003 a	0.002 a	*0.708*
1-Heptanol	Alcohol	111-70-6	0.008 b	0.024 a	0.000 b	0.000 b	***0.007***
1-Octen-3-ol	Alcohol	3391-86-4	0.087 a	0.074 a	0.030 a	0.040 a	***0.049***
Benzyl alcohol	Alcohol	100-51-6	0.018 a	0.015 ab	0.000 b	0.007 ab	***0.043***
2-Octen-1-ol, (EZ)-	Alcohol	18409-17-1	1.631 a	0.505 b	0.265 b	0.437 b	***0.001***
1-Octanol	Alcohol	111-87-5	0.007 a	0.011 a	0.014 a	0.010 a	*0.217*
Phenylethyl Alcohol	Alcohol	60-12-8	0.002 a	0.001 a	0.000 a	0.000 a	*0.063*
1-Nonanol	Alcohol	143-08-8	0.027 a	0.030 a	0.000 b	0.000 b	***0.020***
5-Decen-1-ol, (E/Z)-	Alcohol	56578-18-8	0.385 a	0.295 b	0.248 b	0.264 b	***0.013***
1-Decanol	Alcohol	112-30-1	0.003 a	0.000 a	0.007 a	0.006 a	*0.099*
Pentanal	Aldehyde	110-62-3	0.001 a	0.003 a	0.000 a	0.004 a	*0.570*
Hexanal	Aldehyde	66-25-1	0.021 a	0.064 a	0.072 a	0.029 a	*0.255*
2-Hexenal, (E)-	Aldehyde	505-57-7	0.006 b	0.010 ab	0.024 a	0.019 ab	***0.040***
5-Hexenal, 4-methylene-	Aldehyde	17844-21-2	0.011 a	0.000 b	0.000 b	0.000 b	***0.001***
2-Heptenal, (E)-	Aldehyde	18829-55-5	0.016 b	0.062 a	0.011 b	0.018 b	***0.013***
Benzaldehyde	Aldehyde	100-52-7	0.019 a	0.006 b	0.004 b	0.004 b	***0.004***
Octanal	Aldehyde	124-13-0	0.035 a	0.104 a	0.120 a	0.007 a	*0.073*
Benzeneacetaldehyde	Aldehyde	122-78-1	0.026 a	0.022 a	0.000 b	0.009 ab	***0.015***
(E)-Oct-2-enal	Aldehyde	2363-89-5	0.000 b	0.003 a	0.000 b	0.000 b	***0.015***
Benzaldehyde, 2-methyl-	Aldehyde	529-20-4	0.005 a	0.000 b	0.000 b	0.000 b	***<0.0001***
Nonanal	Aldehyde	124-19-6	0.886 a	0.064 b	0.017 b	0.023 b	***0.003***
2,6-Nonadienal, (E,Z)-	Aldehyde	557-48-2	0.041 a	0.011 b	0.004 b	0.011 b	***0.004***
2-Nonenal, (E)-	Aldehyde	18829-56-6	0.000 b	0.000 b	0.003 a	0.000 b	***0.000***
4-Decenal, (E)-	Aldehyde	65405-70-1	0.000 b	0.000 b	0.018 a	0.000 b	***0.000***
Decanal	Aldehyde	112-31-2	0.024 a	0.007 b	0.010 b	0.002 b	***0.011***
Ethyl Acetate	Ester	141-78-6	1.561 a	0.765 ab	0.493 b	0.076 b	***0.011***
Isopropyl acetate	Ester	108-21-4	0.002 a	0.000 b	0.000 b	0.000 b	***0.021***
n-Propyl acetate	Ester	109-60-4	0.004 a	0.002 a	0.001 a	0.000 a	*0.402*
Acetic acid, butyl ester	Ester	123-86-4	0.003 a	0.003 a	0.004 a	0.002 a	*0.314*
2-Butenoic acid, ethyl ester	Ester	10544-63-5	0.208 a	0.603 a	0.594 a	0.580 a	*0.491*
Acetic acid, pentyl ester	Ester	628-63-7	0.141 a	0.007 b	0.007 b	0.000 b	***0.001***
Ethyl 3-hydroxybutanoate	Ester	5405-41-4	0.141 a	0.007 b	0.007 b	0.000 b	***0.001***
Butanoic acid, 3-hydroxy-, ethyl ester	Ester	5405-41-4	0.000 b	0.003 ab	0.004 a	0.000 b	***0.030***
Butanoic acid, butyl ester	Ester	109-21-7	0.102 a	0.031 bc	0.053 b	0.020 c	***0.003***

Hexanoic acid, ethyl ester	Ester	123-66-0	0.265 a	0.051 b	0.016 b	0.050 b	***0.003***
Acetic acid, hexyl ester	Ester	142-92-7	0.004 a	0.000 b	0.000 b	0.000 b	***0.001***
Cyclohexene, 1-methyl-4-(1-methylethylidene)-	Ester	586-62-9	0.004 a	0.004 a	0.000 b	0.002 b	***0.004***
Octanoic acid methyl ester	Ester	111-11-5	0.010 a	0.000 b	0.000 b	0.000 b	***0.027***
Acetic acid, phenylmethyl ester	Ester	140-11-4	0.015 a	0.027 a	0.015 a	0.024 a	*0.341*
Octanoic acid, ethyl ester	Ester	106-32-1	0.018 a	0.004 a	0.013 a	0.014 a	*0.355*
Acetic acid, octyl ester	Ester	112-14-1	0.001 ab	0.002 ab	0.003 a	0.000 b	***0.020***
2-Butenoic acid, hexyl ester	Ester	19089-92-0	0.007 a	0.007 a	0.007 a	0.005 a	*0.653*
Acetic acid, 2-phenylethyl ester	Ester	103-45-7	1.590 a	0.000 b	0.000 b	0.323 b	***0.006***
Propanoic acid, 2-methyl-, 2,2-dimethyl-1-(2-hydroxy-1-methylethyl)propyl ester	Ester	74367-33-2	0.027 a	0.016 a	0.023 a	0.027 a	*0.439*
Propanoic acid, 2-methyl-, 3-hydroxy-2,2,4-trimethylpentyl ester	Ester	77-68-9	0.006 a	0.000 a	0.000 a	0.000 a	*0.067*
Hexanoic acid, hexyl ester	Ester	6378-65-0	0.038 a	0.000 b	0.000 b	0.000 b	***0.001***
5-Decen-1-ol, acetate, (E)-	Ester	38421-90-8	0.000 a	0.000 a	0.000 a	0.017 a	*0.077*
Butyl octanoate	Ester	589-75-3	0.021 a	0.016 a	0.015 a	0.000 b	***0.003***
Hexanoic acid, octyl ester	Ester	4887-30-3	0.007 a	0.003 a	0.007 a	0.007 a	*0.413*
2,2,4-Trimethyl-1,3-pentanediol diisobutyrate	Ester	6846-50-0	0.003 a	0.006 a	0.005 a	0.005 a	*0.652*
Hexanoic acid, 2-phenylethyl ester	Ester	6290-37-5	0.003 a	0.000 b	0.000 b	0.000 b	***0.002***
2,4-Dimethyl-1-heptene	Hydrocarbon	19549-87-2	0.187 a	0.069 ab	0.092 ab	0.000 b	***0.025***
1-Decene	hydrocarbon	872-05-9	0.008 a	0.000 b	0.000 b	0.000 b	***0.000***
Tridecane	Hydrocarbon	629-50-5	0.017 a	0.010 ab	0.004 b	0.007 b	***0.009***
1-Tetradecene	Hydrocarbon	1120-36-1	0.005 a	0.000 a	0.000 a	0.001 a	*0.154*
Tetradecane	Hydrocarbon	629-59-4	0.016 a	0.002 a	0.002 a	0.003 a	*0.064*
3-Hexadecene, (Z)-	Hydrocarbon	34303-81-6	0.003 b	0.000 b	0.000 b	0.017 a	***0.008***
2-Heptanone, 4-methyl-	Ketone	6137-06-0	0.001 a	0.017 a	0.000 a	0.003 a	*0.117*

5,9-Undecadien-2-one, 6,10-dimethyl-	Ketone	689-67-8	0.004 a	0.003 a	0.003 a	0.004 a	*0.599*
Benzene, 1,3-bis(1,1-dimethylethyl)-	Other	1014-60-4	0.080 a	0.000 b	0.000 b	0.000 b	***0.000***
2,6-Di-tert-butyl-4-methyl-phenol	Other	128-37-0	0.006 a	0.006 a	0.007 a	0.006 a	*0.493*
2,4-Di-tert-butylphenol	Other	96-76-4	0.001 a	0.000 b	0.000 b	0.000 b	***0.013***
1-Dodecene	Other	112-41-4	0.230 a	0.029 b	0.008 b	0.052 b	***0.009***
Benzyl nitrile	Other Nitrogenated compound	140-29-4	0.023 a	0.005 b	0.004 b	0.009 b	***0.004***
Caryophyllene	Sesquiterpene	87-44-5	0.001 a	0.003 a	0.000 a	0.000 a	*0.354*
.beta.-Myrcene	Terpene	123-35-3	0.012 a	0.005 a	0.006 a	0.005 a	***0.050***
D-Limonene	Terpene	5989-27-5	0.010 a	0.000 b	0.000 b	0.002 b	***0.002***
trans-.beta.-Ocimene	Terpene	3779-61-1	0.052 a	0.010 b	0.003 b	0.006 b	***0.002***
1,3,6-Octatriene, 3,7-dimethyl-, (Z)-	Terpene	3338-55-4	0.007 ab	0.009 a	0.001 b	0.005 ab	***0.047***
(+)-4-Carene	Terpene	29050-33-7	0.011 a	0.010 ab	0.000 c	0.004 bc	***0.012***
1,6-Octadien-3-ol, 3,7-dimethyl-	Terpene	78-70-6	0.039 a	0.045 a	0.016 a	0.018 a	***0.044***
Estragole	Terpene	0-00-0	0.005 a	0.000 b	0.000 b	0.000 b	***<0.0001***
2,6-Octadien-1-ol, 3,7-dimethyl-, acetate, (Z)-	Terpene	141-12-8	0.000 b	0.000 b	0.023 a	0.000 b	***0.013***
o-Cymene	Terpene (Oxygenated terpene)	99-87-6	0.023 a	0.000 b	0.000 b	0.000 b	***0.000***
NEROL	Terpene (Oxygenated terpene)	624-15-7	0.024 a	0.010 ab	0.001 b	0.000 b	***0.021***
1-Cyclohexene-1-carboxaldehyde, 2,6,6-trimethyl-	Terpene (Oxygenated terpene_	432-25-7	0.001 b	0.006 ab	0.039 a	0.000 b	***0.039***
Totals			**8.6893**	**3.5748**	**2.9167**	**2.4177**	

[z] Compounds were identified on Shimadzu LabSolution (Japan) software based on mass spectral libraries using NIST2020 (National Institute of Standards and Technology, Gaithersburg, MD). A linear retention index was created using an alkane standard mix solution (C7–C20) to further confirm the molecule identifications. Ten µL of hexanal-d12 (1 µg/µL) was added to each vial as an internal standard (IS). Volatile concentrations (as µg/g) were calculated based on IS and identified molecule peak areas, IS concentration and volume injected, and mass of berries into the vial

Figure 1. Biplot of Principle Component (PC) PC1 and PC2 explaining 87% of the variation for all significant data collected for the volatile compounds (µg/kg) of muscadine grapes grown in Arkansas and evaluated at the University of Arkansas System Division of Agriculture (2022).