Title of Project: Determining Marketable Attributes of University of Arkansas Fresh-market Muscadine Grapes

Final Report

Grant Code: SRSFC Project # 2017 R-03

Research Proposal

Name(s), Mailing and Email Address(s) of Principal Investigators

Principal Investigator:

Dr. Renee Threlfall, Research Scientist, Institute of Food Science and Engineering, 2650 N. Young Ave., University of Arkansas, Fayetteville, AR 72704, rthrelf@uark.edu

Co-Principal Investigators:

Dr. John R. Clark, Distinguished Professor, Department of Horticulture, 316 Plant Science Building, University of Arkansas, Fayetteville, AR 72701, jrclark@uark.edu

Dr. Margaret Worthington, Assistant Professor, Department of Horticulture, 316 Plant Science Building, University of Arkansas, Fayetteville, AR 72701, mlworthi@uark.edu

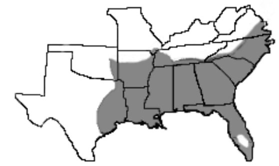
Objectives

1. Identify descriptive sensory attributes of fresh-market muscadine grapes from the University of Arkansas Fruit Breeding Program
2. Determine physiochemical attributes of fresh-market muscadine grapes from the University of Arkansas Fruit Breeding Program
3. Correlate the sensory and physiochemical data to determine key relationships between the attributes

Justification and Description

Muscadine grapes (*Vitis rotundifolia Michx.*) are a disease-resistant specialty crop native to the southeastern United States with potential for increased fresh-market expansion. There have been major advances in U.S. muscadine breeding efforts that have resulted in unique traits emerging with commercial, fresh-market potential. With the imminent release of new muscadine cultivars, there is an opportunity to strengthen the market presence for the muscadine industry as a southern region crop. This collaborative research from the University of Arkansas will **determine marketable attributes for fresh-market muscadine grapes** by providing information on the sensory and physiochemical attributes that drive marketability and address challenges that face the muscadine industry. This project is expected to establish a descriptive sensory lexicon and marketable attributes for fresh-market muscadine grapes and determine correlations between sensory and physiochemical attributes, leading to an economic boost for the muscadine industry, local agritourism and local food systems, as well as improving the standards for fresh-market muscadines.

Muscadine Grape Production. The genus *Vitis* is divided into *Euvitis* (bunch grapes) and *Muscadinia* (muscadine grapes). In the three species of *Muscadinia*, only *V. rotundifolia* is cultivated commercially. In the southern region, states with total grape production of over 500 acres include Arkansas (747 acres), Florida (916 acres), Georgia (1,646 acres), Mississippi (652 acres), North Carolina (3,185 acres) and Texas (3,835 acres) (USDA 2007). Although there is limited data on the percent of muscadine grapes as part of total U.S. grape production, substantial promise for expansion of muscadine production for fresh market, processing and value-added products exists.



Muscadine Grape Cultivars. Muscadines differ from bunch grapes because they have smaller clusters, the berries abscise (shatter) at maturity, the tendrils are unbranched, and they have 40 chromosomes as compared to 38 chromosomes of *Euvitis*. Muscadine clusters typically contain 6 to 24 berries. Muscadine cultivars are primarily classified by color, with bronze or black as the two prevalent color types (Carter et al. 2001, Conner 2010, Mortensen 2001).

Muscadine Grape Breeding. There are public and private muscadine breeding programs across the southern United States. Major advances in muscadine breeding have included the development of perfect-flowered and self-fruitful cultivars (Lane 1997), increased berry size and sugar content (Olien 1990), presence of dry picking scars (Conner 2010) and the introduction of a seedless muscadine grape (Gray et al. 2011). The introduction of a seedless muscadine grape will appeal to consumers more familiar with table grapes. Other important traits undergoing development include more cultivars with perfect flowers and large fruit, improved textures, thinner skins, seedlessness, a broader range of ripening dates and an expansion of the germplasm base used in muscadine breeding. The University of Arkansas Fruit Breeding Program has a focus on muscadine breeding with many cultivars with unique traits. These continued breeding efforts result in better grape quality for consumers and increased cultivar options and markets for growers.

Standards for Grades of Muscadines. The United States Standards for Grades of Muscadine Grapes were established in 2006, but were modeled after bunch grapes. In terms of quality, the muscadine grapes must "meet good soluble solids and the basic requirements for berries (similar varietal characteristics, mature, well colored, clean, not excessively soft, not dried, not excessively wet from juice or not crushed, split or leaking). Grapes must also be free from decay, mold, damage, or overripe". The quality of the fresh-market muscadines can vary greatly and impact the potential post-harvest storage and consumer expectations for repeat purchases.

Physiochemical Components of Muscadines. Muscadine berries offer a healthy fruit choice for consumers and a marketing opportunity for producers. A 10-berry serving of muscadines has 16% of the recommended daily fiber intake and 13 to 14% of vitamin C (USDA-ARS 2011). In addition, muscadine grapes contain many health bioactive compounds, including resveratrol, ellagic acid, anthocyanins and proanthocyanidin phenolic compounds (Barchenger et al. 2014a, 2014b, 2015a, 2015b, Ector et al. 1996, 2001, Pastrana-Bonilla et al. 2003, Threlfall et al. 2005). Anthocyanins are highest in muscadine skin and dark-colored berries (Striegler et al. 2005).

Consumer and Descriptive Sensory of Muscadine Grapes/Products. There are few harvest, sensory, storage and shelf-life guidelines to assist the muscadine grape industry in providing quality muscadine grapes and their products. The evaluation of factors that drive consumer acceptance is critical to the marketing of new products. A recent consumer sensory study at the University of Florida showed that consumer panelists familiar with muscadine grapes found skin thickness as a negative characteristic and concluded that breeding for thinner skins could increase appeal for muscadines as a fresh-market fruit (Brown et al. 2016). For fresh-market muscadines and juice, the initial taste perception of sweetness, in particular the soluble solids/acid ratio, is a key aspect for sensory acceptability. The optimum soluble solids/acid ratio for whole muscadine grapes is 28 to 30 (Flora 1979, Walker et al. 2001). Threlfall et al. (2007) developed a sensory lexicon for muscadine juice from different cultivars with major descriptive attributes including sweet, sour, cooked muscadine, cooked grape and astringent. Other than these few sensory attributes, descriptions and characteristics of the flavor components of fresh muscadines and muscadine products need to be done.

Methodologies

Harvest

Muscadines were harvested from the University of Arkansas Fruit Research Station in Clarksville, AR. Approximately 2.2 kg of fruit of each genotype were harvested in September. The fruit was harvested prior to 10 am and then transported in coolers to the Food Science Department, Fayetteville, AR where the muscadines were randomly selected and placed into 453 g-vented clamshells. The fruit was stored at 2 °C and 90 ± 5% RH overnight for sensory analysis. The genotypes evaluated in this study included three advanced selections (AM-9, AM-74, AM-83) and three cultivars (Ison, Nesbitt and Summit).

Descriptive Sensory Analysis

Descriptive sensory analysis of the six fresh-market muscadine grape genotypes was conducted at the Sensory Research and Consumer Center, in the Food Science Department at the University of Arkansas. The descriptive panelists (n=8) developed a fresh-market muscadine lexicon of sensory terms through consensus during orientation sessions. The panelists used a modified Sensory Spectrum® method, an objective method for describing the intensity of attributes in products using references for the attributes. The panelists were served five berries per genotype. The descriptive panel identified fresh-market muscadine attributes for appearance, basic tastes, feeling factors, aromatics, texture and uniformity of sample and evaluated those attributes using a 15-point scale (0=less of an attribute, 15=more of an attribute).

Physiochemical Analysis

Approximately 250 g of berries were placed in freezer bags for each muscadine genotype in triplicate. Color, firmness, and berry attributes were measured on grapes prior to freezing. The grapes for the other physiochemical analysis were placed in plastic storage bags and stored at -20°C until analyses. Physiochemical analysis was done on three to five berries in triplicate per genotype.

Color . Exterior skin color measurements were determined on each whole berry using a Chroma Meter CR 400 series (Konica Minolta Holdings Inc., Ramsey, NJ). The Commission Internationale de I'Eclairage Laboratory transmission ''L*'' value indicates how dark or light the skin is with 0 being black and 100 being white. Hue angle describes color in angles from 0_ to 360_: 0_ =red; 90_ = yellow; 180_ = green; 270_ = blue; and 360_ = back to red. Chroma is the aspect of color by which the skin colors appear different from gray of the same lightness and corresponds to intensity of the perceived color.

Firmness. Firmness, or the maximum force to penetrate skin and flesh tissues, was determined on each whole berry. Elasticity, or distance to skin penetration, was also determined. A TA-XT2 Texture Analyzer (Stable Micro Systems, Haslemere, UK) with a 2-mm-diameter probe was used to penetrate the skin and mesocarp tissues (flesh) to a depth of 15 mm in each berry at a rate of 1 mm.s-1 with a trigger force of 0.05 N. Measurements of flesh and skin firmness were expressed as force in Newtons (N) and elasticity was expressed a distance in millimeters (mm). The data was analyzed using Texture Expert Version 1.17 (Texture Technologies Corp., Scarsdale, NY).

Berry attributes. Berry attributes (individual berry weight, berry length, and berry width) and seed attributes (number/berry and weight/berry) were measured. The berries were weighed on a digital scale and the width and height of each grape were measured with digital calipers. To determine seed attributes, seeds were extracted from the grapes and placed onto paper towels and dried at ambient temperature (21°C) for 1.5 hours. The seeds for each three-berry sample were counted, weighed, and measured.

Soluble solids, pH, and titratable acidity. The soluble solids, pH, and titratable acidity of the berries were evaluated. Samples were thawed and placed in cheesecloth to extract the juice from the berries. Titratable acidity and pH were measured with an automated titrometer 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.

Sugar and acid analysis. Organic acids and sugars were determined using HPLC. Glucose, fructose, and citric, tartaric, malic, succinic and lactic acids of the muscadine were measured using procedures described in Walker et al. 2003. The HPLC was equipped with a Bio-Rad HPLC Organic Acid Analysis Aminex HPX-87H ion exclusion column (300 x 7.8 mm) and a Bio-Rad HPLC column (150 x 7.8 mm) in series. A Bio-Rad Micro-Guard Cation-H refill cartridge (30 x 4.5 mm) was used for a guard column. The peaks were quantified using external standard calibration based on peak height estimation with baseline integration.

Correlations

Determining correlations between the sensory and physiochemical data will be critical especially with the advancement of "crispy" muscadines selections to determine if berry firmness will be correlated with descriptive sensory attributes related to texture (particularly skin thickness). Analyses was conducted using JMP® (version 12.0; SAS Institute Inc., Cary, NC). Tukey's HSD (Honestly Significant Difference) will be used for mean separation. Pearson's correlation will be used to test the relationship between/within attributes.

Results

Descriptive Sensory Analysis

The lexicon developed by the descriptive panel included references used by the panelists to evaluate the appearance, basic tastes, feeling factors, aromatics and texture of fresh muscadines (Table 1). This lexicon can be used by other programs to evaluate the attributes of fresh muscadines or modified for use with other fresh fruit.

Aroma attributes. The panelist evaluated the aroma attributes of the muscadines including grape-overall, grape-muscadine, grape-other, fruity, floral, earthy/dirty, green/unripe, and mold/mildew. (Table 2). Grape-overall and grape-muscadine aroma were more prevalent than the other aromas with AM-74 with the highest and AM-83 the least.

Appearance attributes. The appearance attributes of muscadines are an important attribute for fresh market because consumers can purchase muscadines based on appearance in a clamshell container. The appearance attributes of the muscadines evaluated included color-purple, color-bronze, glossiness, size, amount of blemishes, stem scar tear, visual separations, number of seeds and size of seeds (Table 3). AM-74 and Summit were the only bronze cultivars. AM-74 was the biggest berry. AM-83 was the hardest to detach the pulp from skin of berry. There were about three seeds per berry.

Basic tastes. The panelists evaluated the basic tastes (sweet, sour, and bitter) of the muscadines (Table 4). The panelists found the sweetness of the muscadines ranged from 6.3 to 7.9 with a 5=5% sucrose solution and 10=10% sucrose solution. In terms of sourness, the berries ranged from 2.7 to 3.9 with 2=0.05% citric acid solution and 5=0.08% citric acid solution. There was not a difference for the genotypes for bitterness. AM-74 was the sweetest, while 'Ison' was the sourest.

Feeling factors. The panelists evaluated the feeling factors (astringent and metallic) of the muscadines. There was not difference in the astringent feeling factor for these genotypes. The metallic feeling factors (biting into tin foil as a reference) of the muscadines were low (<1.6)

Aromatic attributes. The aromatic attributes (volatiles perceived by the olfactory system while chewing a sample in the mouth) of the muscadines included overall aromatic impact, grape-overall, grape-muscadine, fruity, floral, and green/unripe (Table 5). The intensity of overall aromatic impact ranged from 7.1 to 8.4 with 'Summit' having the highest intensity. AM-83 had the highest grape-muscadine aromatic. There was no difference in the genotypes for grape-muscadine fruity, floral, and green/unripe aromatics. The aromatic attributes play a key role in the "taste" of the muscadines, and overall, grape-overall, and grape-muscadine were the highest scored intensities in the mid-range of the 15-point scale.

Texture attributes. The texture attributes included hardness, moisture release, awareness of skins, pulp crispness, detachability, fibrousness between the teeth and seed separation (Table 6). There was not difference in the genotypes for any of the texture attributes.

Physiochemical Analysis

The six muscadine genotypes were evaluated for physiochemical attributes (physical and composition), and physiochemical attributes varied significantly for most attributes. In terms of physiochemical data of the fruit, the color, firmness, berry attribute, basic composition (soluble solids, pH, and titratable acidy) and the organic acid (isocitric, isocitric lactone and malic acid) and sugar (glucose and fructose) content were measured (Tables 7 and 8).

Color . The darkest berry was the black genotypes, AM-9, AM-83, Ison, and Nesbitt, while the lightest were AM-74 and Summit, the bronze genotypes.

Firmness. AM-83 had the highest skin firmness (1.48 N/mm) and flesh firmness (2.14 N). AM-9 (0.85 N/mm) had the lowest skin firmness, and 'Nesbitt' (0.89 N) had the lowest flesh firmness. In this study, AM-83 was the most *V. vinifera*-like with respect to flesh firmness, but AM-9 was the most *V. vinifera*-like with respect to skin firmness.

Berry attributes. AM-74 (14.38 g) had the highest berry weight and seed weight (0.12 g). 'Summit' (9.25 g) had the lowest berry weight. AM-83 (0.09 g) had the lowest seed weight. There were no significant differences in seed number between these genotypes, but berries had about three seeds (ranging from one to four).

Basic composition. At harvest, the fruit had 12.73-14.23% soluble solids, 0.54-1.01% titratable acidity, and soluble solids/titratable acidity ratio of 16.91-28.49. 'Summit' was the sweetest berry with the highest soluble solids/titratable acidy ratio and the lowest titratable acidity. 'Summit' had the highest soluble solids (15.40%) and lowest titratable acidity (0.54%). 'Nesbitt' had the lowest soluble solids (12.73%), and 'Ison' had the highest titratable acidity (1.01%). AM-83 (3.33) had the highest pH, and 'Ison' (2.88) had the lowest. 'Summit' (28.49) had the highest soluble solids/titratable acidity ratio, and 'Ison' (13.12) the lowest.

Sugar and acid analysis. Total organic acids and total sugars and individual organic acids and sugars (data not shown) were not significantly impacted by genotype. Overall, total sugars ranged from 6.17-9.75 g/100 g, and the total organic acids ranged from 0.50-0.84 g/100 g. Glucose and fructose were present in the fruit in an approximately 1:1 ratio with an average glucose content of 4.14 g/100 g and fructose content of 3.81 g/100 g (data not shown). Tartaric acid was the predominant acid in the muscadines with an average tartaric acid content of 0.37 g/100 g, isocitric acid content of 0.11 g/100 g, and malic acid content of 0.21 g/100 g (data not shown).

Conclusion

The descriptive sensory panelists differentiated between genotypes for external appearance, internal appearance, and basic taste attributes, more specifically with positive attributes rather than negative, but poorly with the selected aroma, aromatic, and texture attributes. This indicated that of the attributes evaluated in this study, descriptive sensory analysis was best suited for appearance and basic taste attributes. The intent of this study was to establish the descriptive sensory lexicon for future muscadine evaluations. Descriptive sensory analysis of muscadine grape breeding lines is not always possible due to limited amount of fruit, so establishing correlations between descriptive sensory attributes and physiochemical attributes could be useful for muscadine breeding. Physiochemical attributes such as total sugars and soluble solids/titratable acidity ratio had the most significant correlations with descriptive sensory attributes. For soluble solids/titratable acidity ratio, a higher ratio indicated that the fruit was perceived as riper and potentially more desirable as negative attributes such as green/unripe aromatics, sour basic taste, and metallic feeling factor decreased. Additionally, higher total sugar content indicated a positive effect on the pleasant aromatics of the fruit and a negative effect of the displeasing aromatics and external appearance. Retention of muscadine aroma and aromatics, while improving fruit texture is an important goal for muscadine breeding programs. Although the panelists were unable to distinguish between genotypes for texture attributes, analytical texture analysis was correlated to external and internal appearance and aromatic attributes, indicating that firmness (skin and flesh) plays a role in how the berry is perceived both visually and aromatically. A descriptive sensory lexicon for fresh-market muscadine grapes was created. Descriptive sensory and physiochemical analysis has the potential to identify important attributes of fresh-market muscadine grapes. Evaluating descriptive sensory, consumer sensory and physicochemical attributes could provide data about what attributes consumers like and dislike about muscadines.

Impact Statement

A lexicon of terms for descriptive sensory attributes for fresh-market muscadine grapes was established and can be used for research and breeding, as well as establishing the relationship between the physiochemical and descriptive sensory attributes. The data collected from this study will help characterize muscadine fruit quality for future U.S. breeding objectives.

Citation(s) for any publications arising from the project

The data is being analyzed and a journal publication will be done. Data from this project will be used to present oral and poster presentations at regional and national meetings.

Paper Published

Felts, M., R.T. Threlfall, J.R. Clark, and M.L. Worthington. 2018. Physiochemical and descriptive sensory analysis of Arkansas muscadine grapes. Hortscience 53 (11):1570-1578.

Poster Presentation

Molly Felts, Renee T. Threlfall*, Margaret L. Worthington, and John R. Clark. 2018. Physiochemical and descriptive sensory analysis of Arkansas-grown muscadine grapes for fresh market. American Society for Enology and Viticulture-Eastern Section 43th Annual Conference. July 9-11, King of Prussia, PA.

Literature Cited

Barchenger, D.W., J.R. Clark, R.T. Threlfall, and S.M. Sleezer. 2014a. Evaluation of seed and fruit characteristics of muscadine grape. J. Amer. Pomol. Soc. 68(4):204-208.

Barchenger D.W., J.R. Clark, R.T. Threlfall, L.R. Howard, and C.R. Brownmiller. 2014b. Effect of field fungicide applications on storability, physicochemical, and nutraceutical content of muscadine grape (*Vitis rotundifolia* Michx.) genotypes. HortScience 49(10):1315-1323

Barchenger, D.W., J.R. Clark, R.T. Threlfall, L.R. Howard, and C.R. Brownmiller. 2015a. Evaluation of physiochemical and storability attributes of muscadine grapes (*Vitis rotundifolia* Michx.). HortScience 50(1):104-111.

Barchenger, D.W., J.R. Clark, R.T. Threlfall, L.R. Howard, and C.R. Brownmiller. 2015b. Nutraceutical changes in muscadine grape and grape segments during storage. J. Amer. Pomol. Soc. 69(2): 66-73).

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

Carter, M., K. Striegler, J.R. Clark, and M. Phillips. 2001. Muscadine cultivar evaluation in southwest Arkansas. In *Horticultural Studies 2001*, Clark, J.R. and Evans, M.R., eds. Ark. Agric. Exper. Sta., Fayetteville. Research Series #494, pp.13.

Conner, P.J. 2010. A Century of muscadine grape (*Vitis rotundifolia* Michx.) breeding at the University of Georgia. J. Amer. Pomological Soc. 64:78-82.

Ector, B.J. 2001. Compositional and nutritional characteristics p. 341-367. In: Muscadine Grapes. F.M. Basiouny and D.G. Himelrick (eds.). ASHS Press, Alexandria, VA.

Ector, B.J., J.B. Magee, C.P. Hegwood, and M.J. Coign. 1996. Resveratrol concentration in muscadine berries, juice, pomace, purees, seeds, and wines. Amer. J. Enol. and Vitic. 47:57.

Flora, L.F. 1979. Optimum quality parameters of muscadine grape juices, beverages, and blends. J. Food Qual. 2:219-229.

Gray, D. J.; C.A. Sims, M. Olmstead, L. House, R.N. Trigiano, E. Fonsah, S. Stringer, Z. Li, and T. Zimmermann. 2011. Disease-resistant seedless muscadine grape cultivars utilizing eco- and consumer-friendly cisgenic modification technologies. USDA-NIFA-SCRI award number 2011-51181-30668.

Mortensen, J.A. 2001. Cultivars. Chapt. 4 in *Muscadine Grapes*, Basiouny, F.M. and Himelrick, D.G., eds. ASHS Crop Production Series, ASHS Press, Alexandria, VA.

Olien, W.C. 1990. The muscadine grape: botany, viticulture, history, and current industry. HortScience 25:732-739.

Pastrana-Bonilla, E., C.C. Akoh, S. Sellappan, and G. Krewer. 2003. Phenolic content and antioxidant capacity of

muscadine grapes. J. Agric. Food Chem. 51:5497-5503.
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.
Threlfall, R.T., J.R. Morris, J.F. Meullenet, and R.K. Striegler. 2007. Sensory characteristics, composition, and nutraceutical content of juice from *Vitis rotundifolia* (muscadine) cultivars. Amer. J. Enol. Vitic. 58:268-273.
Threlfall, R.T., J.R. Morris, L.R. Howard, C.R. Brownmiller, and T.L. Walker. 2005. Pressing effect on yield, quality, and nutraceutical content of juice, seeds, and skins from 'Black Beauty' and 'Sunbelt' grapes. J. Food Science 79:167.
United States Department of Agriculture. 2007. Census of Agriculture. Washington, D.C.
United States Department of Agriculture, Agricultural Research Service. 2011. USDA National Nutrient Database for Standard Reference, Release 24. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl
Walker, T.L., J.R. Morris, R.T., Threlfall, G.L. Main, O. Lamikanra, and S. Leong. 2001. Density separation, storage, shelf life and sensory evaluation of 'Fry' muscadine grapes. HortScience 36:941-945.
Walker, T., J. Morris, R. Threlfall, and G. Main. 2003. Analysis of wine components in Cynthiana and Syrah wines. J. Ag. Food Chem. 51:1543-1547.

Table 1. Lexicon developed for fresh-market muscadine grape attributes by a descriptive sensory panel with eight trained panelists.

Term	Definition	Technique	Reference
Aroma (whole berry)			
Grape/overall	Smell associated with fresh grapes	Fresh grapes	Intensities based on universal scale[z]
Grape/muscadine	Smell associated with fresh muscadine	Ripe muscadine	Intensities based on universal scale
Grape/other	Smell associated with other grape species	Any grape aroma other than muscadine i.e. Concord	Intensities based on universal scale
Fruity	Smell associated with fruits other than grapes	Fruit other than grapes	Intensities based on universal scale
Floral	Smell associated with floral aromas	Floral	Intensities based on universal scale
Earthy/dirty	Smell associated with damp soil or wet foliage	Damp potting soil	Intensities based on universal scale
Green/unripe	Smell associated with freshly cut green vegetation; unripe	Unripe banana	Intensities based on universal scale
Mold/mildew	Smell associated with moldy or mildew aromas	Old mildewed clothes	Intensities based on universal scale
Overripe	Smell associated with overripe aromas	Over ripened fruit	Intensities based on universal scale

Table 1. (*Continued*)

Term	Definition	Technique	Reference
Appearance (exterior of whole berry)			
Color- purple	Intensity of purple of the sample	Observe the sample and determine the intensity of purple color. (none to much)	None=0, much=15.0
Color- bronze	Intensity of bronze of the sample	Observe the sample and determine the intensity of bronze color. (none to much)	None=0, much=15.0
Glossiness	Degree to which the surface of the berry shines	Observe the sample and determine the degree to which the surface shines. (dull to wet/shiny)	Copy paper=3.0, glossy photo paper=15.0
Size of muscadine	Visual size of the sample	Observe the sample and determine the overall size of the sample. (small to large)	Photo reference of size of circles; A=15.0 (38.10 mm), B=11.0 (31.75 mm), C=7.5 (25.40 mm), D=4.0 (19.05 mm), E=1.0 (12.70 mm)
Shape of muscadine	Visual shape of the sample	Observe the sample and determine the overall shape of the sample. (oval to round)	Egg/oval=5.0, 63.5 mm ball =15.0
Amount of blemishes/ deformities	Visual ratio of blemishes/deformities on the sample	Observe the berry and determine the amount of blemishes/deformities on the surface. (none to much)	Ratio of blemishes and deformities; 0%=0, 50%=7.5, 100%=15
Stem scar tear	Visual presence of tear of the stem scar	Observe the berry and determine if there is a tear at the scar bigger than the scar. (yes or no)	Tear present=1, tear not present=0
Appearance (pulp of berry cut in half)			
Visual separation	Detachability of pulp from skin of berry	Squeeze half of berry and observe the extent of which the pulp detaches from the skin. (none to much)	None=0, much=15.0
Amount of seeds	Number of seeds in the berry	Count the number of seeds.	
Seed size	Visual size of the seeds	Observe the seeds and determine the size. (small to large)	Photo reference of size A=12.0 (5.3 x 8.5 mm), B=7.0 (4.9 x 7.1 mm), C=3.0 (3.9 x 6.1 mm)

Table 1. (*Continued)*

Term	Definition	Technique	Reference
Basic tastes (of remaining four berries)			
Sweet	Basic taste, perceived on the tongue, stimulated by sugars and high potency sweeteners	Solutions of sucrose in spring water	2%=2.0, 5%=5.0, 10%=10.0, 16%=15.0
Sour	Basic taste, perceived on the tongue, stimulated by acids, such as citric acid	Solutions of citric acid in spring water	0.05%=2.0, 0.08%=5.0, 0.15%=10.0, 0.20%=15.0
Bitter	Basic taste, perceived on the tongue, stimulated by substances such as quinine, caffeine, and certain other alkaloids	Solutions of caffeine in spring water	0.05%=2.0, 0.08%=5.0, 0.15%=10.0, 0.20%=15.0
Aromatics			
Overall aromatic impact	Overall impact of all aromatics in the muscadine grape	Combinations of all aromatics	Intensities based on universal scale
Grape/overall	Aromatic associated with fresh grapes	Fresh grapes	Intensities based on universal scale
Grape/muscadine	Aromatic associated with fresh muscadine	Ripe muscadine	Intensities based on universal scale
Grape/other	Aromatic associated with other grape species	Any grape aromatics other than muscadine i.e. Concord	Intensities based on universal scale
Fruity	Aromatic associated with fruit, other than grapes	Fruit other than grape	Intensities based on universal scale
Floral	Aromatic associated with floral attributes	Floral	Intensities based on universal scale
Earthy/dirty	Aromatic associated with damp soil or wet foliage	Damp potting soil	Intensities based on universal scale
Green/unripe	Aromatic associated with freshly cut green vegetation; unripe	Unripe banana	Intensities based on universal scale
Mold/mildew	Aromatic associated with moldy or mildew	Old mildewed clothes	Intensities based on universal scale
Overripe	Aromatic associated with overripe fruit	Over-ripened fruit	Intensities based on universal scale
Feeling factors			
Astringent	Feeling factor on the tongue or other skin surfaces of the mouth described as puckering or drying	Chew sample to point of swallow, expectorate and feel surfaces of the mouth.	0.053 g alum/500 mL, water=6.0 Swish, expectorate, wait five seconds
Metallic	Aromatic associated with metals, tinny or iron or a flat chemical feeling stimulated on the tongue by metal coins	Tin foil to bite	Intensities based on universal scale

Table 1. (*Continued)*

Term	Definition	Technique	Reference
Texture (whole berry)			
Berry hardness	Force required to compress the sample	Place the sample in the mouth with the skin facing towards the cheek. Compress or bite through the sample one time with molars or incisors. (soft to hard)	Cream cheese=1.0, Egg white=2.5, American cheese=4.5, Beef frank=5.5, Olive=7.0, Peanut=9.5, Almond=11.0
Berry crispness	Unique, strong, clean, and acute sound produced in first bite of the food with incisors and open lips	Place sample between the incisors (front teeth) and penetrate it. Evaluate the sound intensity produced at the first bite. (none to much)	Ripe banana=0.0, 'Granny Smith' apple=7.5, Carrot=15.0
Moisture release	Amount of wetness or moistness felt in the mouth after one bite or chew	Compress the sample with molars one time only. (dry to wet)	Banana=1.0, Carrot=2.0, Mushroom=4.0, Snap beans=7.0, Cucumber=8.0, Apple=10.0, Honeydew=12.0, Orange=15.0, (chew references 5 times)
Awareness of skins	How aware are you of the skins during mastication of the sample?	Place sample in mouth and chew 3-5 times. Can also be evaluated in first bite stage. (none to much)	Baked beans=4.0, Medium lima beans=8.0
Detachability	Ease with which the pulp separates from the skin of the berries	Place the sample in the mouth. Compress or bite through the sample one time with molars or incisors. Evaluate the ease that the pulp separates from the skin. (none to much)	None=0, much=15.0
Fibrousness between teeth	Amount of grinding of fibers required to chew through the sample. (not including skins)	Place sample between molars and chew 3-5 times. Evaluate during chewing, but ignore the skin. (none to much)	Apple=2.0, Apricot=5.0, Salami=7.0, Celery=9.0, Toasted oats (4-5)=10.0, Bacon=12.0, Beef jerky=20.0
Seed separation	Ease with which the seeds separate from the pulp of the berry	Manipulate the pulp in the mouth for ease to separate seeds from pulp. (none to much)	None=0, much=15.0

[z] Intensities based on universal scale (saltine = 3.0; applesauce = 7.0; orange juice = 10.0; grape juice = 14.0; Big Red Gum® = 15.0).

Table 2. Descriptive sensory aroma attributes for muscadine genotypes evaluated on a 15-point scale (0=less of the attribute and 15=more of the attribute in terms of intensity), Clarksville, AR 2017.

Genotype [z]	**Grape overall**	**Grape muscadine**	**Grape other**	**Fruity**	**Floral**	**Earthy/ dirty**	**Green/ unripe**	**Mold/ mildew**
AM-9	4.6 b	5.2 ab	0.2 a	1.0 a	0.6 a	0.8 a	0.2 a	0.8 a
AM-74	6.1 a	6.4 a	0.2 a	0.7 ab	0.7 a	0.2 a	0.6 a	0.4 a
AM-83	0.7 d	0.5 d	0.2 a	0.0 c	0.2 a	0.8 a	0.0 a	0.6 a
Ison	3.5 c	3.4 c	0.0 a	0.4 abc	0.4 a	0.2 a	0.6 a	0.6 a
Nesbitt	4.1 bc	4.1 bc	0.2 a	0.3 bc	0.6 a	0.6 a	0.6 a	0.6 a
Summit	5.8 a	5.9 a	0.4 a	0.7 ab	0.8 a	0.4 a	0.5 a	0.6 a
P value	<0.0001	<0.0001	0.8550	0.0330	0.3880	0.1440	0.1620	0.873

[z] Trained descriptive panel (n=8) evaluated five berries per genotypes in duplicate. Means with different letter(s) for each attribute are significantly different ($p < 0.05$) using LSD.

Table 3. Descriptive sensory appearance attributes for muscadine genotypes evaluated on a 15-point scale (0=less of the attribute and 15=more of the attribute in terms of intensity), Clarksville, AR 2017.

Genotype [z]	**Color purple**	**Color bronze**	**Glossiness**	**Size**	**Shape**	**Amount of blemishes**	**Stem scar tear**	**Visual separation**	**Number of seeds**	**Seed size**
AM-9	11.5 a	0.0 b	7.1 b	7.8 ab	12.9 a	3.2 a	0.0 c	12.1 a	3.3 ab	6.9 a
AM-74	3.1 c	8.7 a	6.6 b	8.4 a	12.7 a	4.3 a	0.9 a	11.7 a	2.6 c	6.9 a
AM-83	12.1 a	0.0 b	8.3 a	7.4 bc	8.5 b	4.5 a	0.2 bc	9.2 b	3.6 a	6.3 a
Ison	10.1 b	0.5 b	7.9 a	7.3 bc	12.6 a	3.3 a	0.4 b	12.2 a	3.5 a	7.4 a
Nesbitt	9.5 b	0.6 b	8.0 a	7.2 c	12.7 a	4.0 a	0.8 a	12.1 a	3.0 bc	6.7 a
Summit	3.5 c	7.9 a	6.5 b	7.2 c	12.5 a	3.9 a	0.2 bc	11.8 a	3.4 ab	7.0 a
P value	<0.0001	<0.0001	<0.0001	0.0010	<0.0001	0.1820	<0.0001	<0.0001	0.0040	0.5080

[z] Trained descriptive panel (n=8) evaluated five berries per genotypes in duplicate. Means with different letter(s) for each attribute are significantly different ($p < 0.05$) using LSD.

Table 4. Descriptive sensory attributes (basic tastes and feeling factors) for muscadine genotypes evaluated on a 15-point scale (0=less of the attribute and 15=more of the attribute in terms of intensity), Clarksville, AR 2017.

Genotype [z]	**Sweet**	**Sour**	**Bitter**	**Astringent feeling factor**	**Metallic feeling factor**
AM-9	7.4 abc	3.2 bcd	1.4 a	6.9 a	1.4 abc
AM-74	7.9 a	2.9 cd	0.7 a	6.5 a	1.2 d
AM-83	6.3 d	3.3 bc	1.1 a	6.8 a	1.4 bc
Ison	6.7 cd	3.9 a	1.1 a	7.0 a	1.6 a
Nesbitt	7.0 bcd	3.7 ab	1.0 a	6.8 a	1.5 ab
Summit	7.6 ab	2.7 d	0.7 a	6.4 a	1.3 cd
P value	0.0020	0.0010	0.0960	0.0940	0.0010

[z] Trained descriptive panel (n=8) evaluated five berries per genotypes in duplicate. Means with different letter(s) for each attribute are significantly different ($p < 0.05$) using LSD.

Table 5. Descriptive sensory aromatic attributes for muscadine genotypes evaluated on a 15-point scale (0=less of the attribute and 15=more of the attribute in terms of intensity), Clarksville, AR 2017.

Genotype [z]	**Overall Aromatic impact**	**Grape overall**	**Grape muscadine**	**Fruity**	**Floral**	**Green/ unripe**	**Earthy/ dirty**
AM-9	8.1 abc	6.7 ab	7.3 a	0.4 a	0.7 a	0.5 a	0.9 a
AM-74	8.3 ab	6.9 a	7.2 a	0.2 a	1.2 a	1.0 a	0.7 a
AM-83	7.1 d	5.9 d	9.8 a	0.5 a	0.8 a	0.5 a	0.9 a
Ison	7.7 c	6.2 cd	6.6 a	0.6 a	0.8 a	0.6 a	1.4 a
Nesbitt	7.9 bc	6.4 bc	6.7 a	0.6 a	0.9 a	0.7 a	1.5 a
Summit	8.4 a	6.8 ab	7.3 a	0.0 a	1.2 a	0.6 a	0.8 a
P value	<0.0001	<0.0001	0.6560	0.5840	0.2870	0.1260	0.728

[z] Trained descriptive panel (n=8) evaluated five berries per genotypes in duplicate. Means with different letter(s) for each attribute are significantly different ($p < 0.05$) using LSD.

Table 6. Descriptive sensory texture attributes for muscadine genotypes evaluated on a 15-point scale (0=less of the attribute and 15=more of the attribute in terms of intensity), Clarksville, AR 2017.

Genotype [z]	**Hardness**	**Moisture release**	**Awareness of skins**	**Pulp crispness**	**Detachability**	**Fibrousness between teeth**	**Seed separation**
AM-9	8.6 a	9.8 a	13.1 a	3.7 a	12.4 a	3.9 a	10.7 a
AM-74	8.0 a	10.3 a	12.8 a	3.5 a	11.6 a	4.0 a	10.2 a
AM-83	8.5 a	9.6 a	12.8 a	3.9 a	11.0 a	4.2 a	10.2 a
Ison	8.1 a	9.9 a	13.0 a	3.4 a	12.2 a	4.1 a	10.4 a
Nesbitt	8.3 a	9.8 a	13.1 a	3.6 a	12.3 a	4.2 a	10.3 a
Summit	8.3 a	9.9 a	12.9 a	3.5 a	12.1 a	4.3 a	10.1 a
P value	0.5250	0.0710	0.6180	0.4310	0.0500	0.7120	0.7220

[z] Trained descriptive panel (n=8) evaluated five berries per genotypes in duplicate. Means with different letter(s) for each attribute are significantly different ($p < 0.05$) using LSD.

Table 7. Physical attributes for muscadine grape genotypes at harvest, Clarksville, AR 2017.

Genotype [z]	**Weight (g)**	**Length (mm)**	**Width (mm)**	**L***	**a***	**b***	**Chroma**	**Hue**	**Seeds (#)**	**Seed weight (g)**	**Stem scar tear (%)** [y]
AM-9	10.68	25.29	26.28	23.85	3.61	0.88	3.72	13.89	3	0.11	1.11
AM-77	14.38[y]	28.49	27.89	47.94	-1.11	16.94	17.23	92.93	2	0.12	11.01
AM-83	9.92	28.40	24.23	25.06	2.42	0.39	2.47	34.67	4	0.09	1.08
Ison	10.01	26.36	24.61	24.86	4.48	0.89	4.58	12.39	4	0.12	8.01
Nesbitt	10.10	25.20	25.56	26.62	7.19	0.70	7.24	30.31	3	0.12	10.17
Summit	9.25	24.75	24.31	47.62	-1.40	18.14	18.36	93.39	3	0.10	2.47
P value	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	0.0017	<0.0001	0.0003	0.0441

[z] Genotypes were evaluated using three to five berries in triplicate. Means with different letter(s) for each attribute are significantly different ($p < 0.05$) using Tukey's Honestly Significant Difference.
[y] Stem Scar Tear defined as a tear twice the size of the stem diameter.

Table 8. Physicochemical attributes for muscadine grape genotypes at harvest, Clarksville, AR 2017.

Genotype [z]	**Skin force (N)**	**Flesh force (N)**	**Elasticity (mm)**	**Soluble solids (%)**	**pH**	**Titratable acidity (%)** [y]	**Soluble Solids/ titratable acidity ratio**
AM-9	5.69	1.18	6.73	14.23	3.27	0.57	24.93
AM-77	7.50[y]	1.13	5.52	13.63	3.08	0.57	24.36
AM-83	5.93	2.14	4.20	13.27	3.33	0.64	20.73
Ison	5.32	1.34	6.08	13.20	2.88	1.01	13.12
Nesbitt	7.43	0.89	5.34	12.73	3.03	0.76	16.91
Summit	6.47	1.72	5.54	15.40	3.19	0.54	28.49
P value	0.0003	0.0149	0.0324	0.0002	<0.0001	<0.0001	<0.0001

[z] Genotypes were evaluated using three to five berries triplicate. Means with different letter(s) for each attribute are significantly different ($p < 0.05$) using Tukey's Honestly Significant Difference.
[y] Calculated as percent tartaric acid.