Characterization of Sensory Differences in Mixing and Premium Rums Through the Use of Descriptive Sensory Analysis

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Abstract: This study identified and quantitated perceived sensory differences between 7 premium rums and 2 mixing rums using a hybrid of the Quantitative Descriptive Analysis and Spectrum methods. In addition, the results of this study validated the previously developed rum flavor wheel created from web-based materials. Results showed that the use of the rum flavor wheel aided in sensory term generation, as 17 additional terms were generated after the wheel was provided to panelists. Thirty-eight sensory terms encompassing aroma, aroma-by-mouth, mouthfeel, taste and aftertaste modalities, were generated and evaluated by the panel. Of the finalized terms, only 5 did not exist previously on the rum flavor wheel. Twenty attributes were found to be significantly different among rums. The majority of rums showed similar aroma profiles with the exception of 2 rums, which were characterized by higher perceived intensities of brown sugar, caramel, vanilla, and chocolate aroma, caramel, maple, and vanilla aroma-by-mouth and caramel aftertaste.

Keywords: descriptive analysis, flavor, rum, sensory

Practical Application: These results demonstrate the previously developed rum flavor wheel can be used to adequately describe the flavor profile of rum. Additionally, results of this study document the sensory differences among premium rums and may be used to correlate with analytical data to better understand how changes in chemical composition of the product affect sensory perception.

Introduction

Rum is a complex and ill-defined spirit. With its only standard of identity being that it must be produced from a sugarcane by-product, numerous production variations have been developed. These differences in production methods include variations in starting material, the length and type of fermentation, distillation apparatus, type of barrels used for aging and length of maturation. The resulting rum products are highly varied, making it difficult to identify and describe typical rum flavor.

Sensory descriptive analysis (DA) methods enable the identification and quantitation of sensory differences among food samples (Powers 1988; Zook and Pearce 1988; Stone and Sidel 1993; Lawless and Heymann 1999a). A number of different DA methods exist including Flavor Profile (Cairncross and Sjöström 1950; Caul 1957), Quantitative Descriptive Analysis® (QDA) (Stone and others 1974; Stone 1992), Spectrum TM Descriptive Analysis (Muñoz and Civille 1992), and Free-Choice Profiling (Williams and Langron 1984). The QDA and spectrum methods are the 2 most frequently used methods.

Research characterizing the sensory properties of rum is limited. Previous studies have typically only evaluated 1 modality (aroma) or only characterized 1 or 2 rum samples (Gómez 2002; de Souza and others 2006; Magnani 2009; Franitza and others 2016a, 2016b). The first and most complete sensory study to date was a DA done by Gomez (2002). Nine commercially available rums and 1 experimental sample were evaluated for 22 sensory attributes and 4 chemical sensations. Rums samples were chosen to include a variety of raw materials, processing protocols, production regions and price points. All rum samples were able to be distinguished from each other with samples having significant differences in woody, ethanol, caramel, honey, smoke, vanilla, banana, prune, cardboard, and ocean-like aroma attributes. This study was the first to demonstrate the significant variation in rum aroma across a larger and more complete rum sample set.

De Souza and others (2006) later performed a limited DA to describe the aroma differences between rum and cachaça through the evaluation of 10 terms. Results indicated that rum was higher in caramel and vanilla aroma attributes while cachaça was higher in grassy, sulfury, vinegar, spicy, citrus, alcohol, and melon attributes.

Aroma profile analysis has also been used to characterize several rum samples. The first study evaluated the aroma of 2 rum samples, a 15-y-old solera system rum and a cheap (mixing) rum (Franitza and others 2016a). Only 6 attributes were chosen to describe the samples, ethanolic, malty, butter-like, fruity, clove-like, and vanilla-like. Franitza and others (2016b) then went on to characterize the flavor changes that occur during the rum making process. Four different steps in the production process were analyzed: the starting material (molasses), the mash, distillate and final rum. Eight aroma attributes were evaluated, adding caramel-like and baked apple-like to their previous descriptors.

Only 1 study has evaluated all sensory modalities (aroma, aroma-by-mouth, taste, mouthfeel, and aftertaste) for rum (Magnani 2009). Magnani used QDA to characterize the sensory differences between 2 rum and 2 cachaça samples using 17 sensory attributes. The results indicated that cachaça was higher in woody and sweet aroma and aroma-by-mouth as well as higher viscosity, body and golden color.

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The previous work has made significant strides to identify and characterize the sensory attributes of rum flavor as well as differences that exist within the broader rum category. However, the large variation of products in the market requires sensory evaluation of a greater number of rum samples to gain a more comprehensive understanding of rum as an entire class.

The aim of this study was to evaluate and quantitate the sensory differences of a variety of premium aged rums and mixing rums as well as to validate the developed rum flavor lexicon (Ickes and others 2017). It was hypothesized that mixing rums would be easily distinguishable from the premium rums. Additionally, it was anticipated that many of the terms used to describe the difference in rum flavor would be found on the rum flavor wheel.

Materials and Methods

Sample selection

Nine commercially available rums, Bacardi Superior [BW] (Bacardi Corporation, San Juan, P.R.), Bacardi Gold [BG] (Bacardi Corporation, San Juan, P.R.), Appleton Estate V/X [AE] (J. Wary & Nephew Ltd., Jamaica), Appleton Estate Extra [AE12] (J. Wary & Nephew Ltd., Jamaica), Ron Abuelo: Añejo 7 y [RA7] (Varela Hermanos, Panama), Diplomatica Reserva Exclusiva [DR12] (Destilería Unidas S.A., Venezuela), El Dorado 12-y-old [ED12] (Demerara Distillers Ltd., Plantations Diamond, Guyana), Ron Zacapa (Centenario) XO: Solera Gran Reserva Especial [RZ] (Rum Creation & Products Inc., Guatemala), Dictador XO Insolent [DX] (Destileria Columbiana via Mamonal, Cartagena, Columbia) were purchased at a local liquor store (Champaign, Ill., U.S.A.). Bacardi Superior and Bacardi Gold were chosen to represent the category of mixing rums since Bacardi is the number 1 seller of rum in the United States. The 7 premium rums were chosen by comparing the review score on the Rum Howler blog (an industry expert) (Dykstra 2017), the number of awards and medals received by the company, making sure that a variety of different rums (in terms of production style) were evaluated and that the rums could be purchased at a local store. All 9 rums had reported ethanol concentrations of 40% alcohol by volume (ABV). Mention of the brand name of these rums does not imply any research contact or sponsorship and is not for advertisement or endorsement purposes.

Sample and reference preparation

Before testing, 20 mL of each sample was measured into a black double old-fashion glass (Threshold, Target, U.S.A.) and covered with a glass petri dish no more than 1 h before the panel assessment.

Attribute references were prepared daily and placed into 2 or 4 oz. lidded plastic soufflé cups (Dart Container Corporation, Mason, Mich., U.S.A.) and labeled with the reference identity. References were prepared no more than 24 h prior to evaluation. A complete list of attributes, definitions, references, reference scores and preparation procedures can be found in Table 1.

The following materials were purchased for initial panelist taste screening: caffeine (Fisher Scientific, Fair Lawn, N.J., U.S.A.), citric acid (Ball, Hearthmark, LLC dba Jarden Home Brands, Daleville, Ind., U.S.A.), sodium chloride (Morton Salt, Morton Salt, Inc., Chicago, Ill., U.S.A.), and sucrose (C&H Pure Cane Sugar, Domino Foods, Inc., Yonkers, N.Y., U.S.A.). Additionally, the following compounds were used for aroma screening: ethyl butyrate, eugenol, oak lactone, 2-phenethyl alcohol, and vanillin. All compounds were food grade and purchased from Sigma-Aldrich (St. Louis, Mo., U.S.A.).

Panelists

Eight panelists, (4 male and 4 female, age range 23 to 66 y) participated in the DA panel. Panelists were selected based on interest, sensory acuity, and availability. Panelists were University of Illinois Students and members of the local community. Potential panelists completed an initial recruitment questionnaire to screen for availability and familiarity with distilled beverages. After passing the initial questionnaire, potential panelists then completed a sensory screening for basic taste perception and aroma identification which took place in a conference room under incandescent light and maintained at 22 °C. Potential panelists were required to identify several basic taste solutions: caffeine (0.024% wt/vol), citric acid (0.05% wt/vol), sodium chloride (0.1% wt/vol), and sucrose (0.7% wt/vol). The solutions (10 mL) were placed into 1 oz. lidded plastic cups. Panelists were also screened for their ability to detect and correctly identify aromas common to rum: fruity (ethyl butyrate, 1.03 mg/mL), cloves/baking spices (eugenol, 6.00 mg/mL), coconut (oak lactone, 0.0396 mg/mL), floral/rosy (2-phenethyl alcohol, 1.05 mg/mL), and vanilla/sweet (vanillin, 2.46 mg/mL). The odorant solutions were prepared in deodorized water and then spiked (10, 2, 10, 10, and 5 μL, respectively) onto an odorless cotton ball and placed into a 5.5 oz lidded plastic cup. All samples were labeled with random 3 digit codes. Panelists were selected if they achieved at least 70% acuity on the identification screening, consumed distilled spirits at least once a month, and were available to meet during the designated time. Panelists were also required to present a valid form of identification at the screening to verify that they were over 21 y of age.

Test design

The panel methodology was a hybrid of the Quantitative Descriptive Analysis® (Stone 1992) and the Spectrum™ method (Muñoz and Civille 1992; Meilgaard and others 2007). The 9 samples were evaluated over a total of 23 d. On the first day, panelists were introduced to the specific DA method used in this study. The first 6 sessions (1 h each) consisted of term and reference generation, followed by reference refinement. The panelists were presented with 3 random rum samples each day and asked to generate terms for the attributes they perceived in the samples for aroma, aroma-by-mouth, mouthfeel, taste and aftertaste modalities. Through group discussion, panelists identified the terms to be used, determined corresponding references and developed a precise definition for each attribute. The first 3 d of the panel consisted of free term generation, where the panelists were unaided in the identification of the attributes present in the sample. During days 4 to 6 panelists were provided with the previously developed rum flavor wheel (Ickes and others 2017) to aid in term generation.

After the terms and references were established, panelists spent 5 sessions (1 h each) determining the reference intensities of each attribute. Panelists were asked to scale the references based on a 15 point scale, where zero is no perception of a given attribute and 15 is the strongest perception of that attribute in the rum samples. Determined reference scores can be found in Table 1.

Panelists then spent 6 d practicing scoring the rums, using the references as anchor points for the scale, to aid in panel uniformity. On one of the days, panelists conducted individual booth practice sessions in Bevier Hall on the Univ. of Illinois at

Table 1–List of final attributes, definitions, references, reference scores, and reference preparations determined for the descriptive analysis panel on rum.

Modality	Attribute	Definition	Reference	Reference score	Preparation
Aroma	Brown sugar	Aroma of brown sugar	Dark brown sugar (Meijer Distribution Inc.; Grand Rapids, MI)	**13.5**	1 packed teaspoon in 2 oz. cup
	Caramel	Aroma of caramelized sugar	Caramel syrup (the j.m. smucker company; orrville, oh)	**14**	10 g in 2 oz. cup
	Maple	Aroma of maple syrup	Maple extract (mccormick & co., inc.; hunt valley, md)	**11.5**	1 3/4 teaspoon in 500 mL volumetric flask, dilute to volume, 10 mL in 2 oz. cup
	Brown spice	Aroma of nutmeg	Ground nutmeg (mccormick & co., inc.; hunt valley, md)	**14**	1 g in 600 mL of water, stir 5 min, 10 mL in 2 oz. cup
	Vanilla	Aroma of vanilla extract	Natural vanilla extract (mccormick & co., inc.; hunt valley, md)	**10.5**	1/4 teaspoon in 500 mL volumetric flask, dilute to volume, 10 mL in 2 oz. cup
	Alcohol	Aroma associated with 40% or greater alcohol	190 proof ethanol (decon labs, inc.; king of prussia, pa)	**11.5**	10 oz. in 2 oz. cup
	Cherry	Aroma of cooked cherries	Cherry pie filling (meijer distribution inc.; grand rapids, mi)	**14.5**	1 cherries and syrup to 5 g in 4 oz. cup
	Citrus	Aroma of lime zest	Lime peel	**12**	soak 0.5 g in 200 mL of hot water for 5 min, 10 mL in 2 oz cup
	Coconut	Aroma of toasted coconut	Toasted coconut flakes (marx brothers, inc.; birmingham, al)	**14**	0.1 g in 4 oz. cup
	Dried fruit	Aroma of prunes	Prunes (sunsweet growers inc.; yuba city, ca)	**14.5**	0.8 g (~1/8) prune in a 2 oz. cup
	Almond	Aroma of almonds	Almonds (Meijer Distribution Inc.; Grand Rapids, MI)	**13.5**	1 whole almond in 4 oz. cup
	Walnut	Aroma of walnuts	Chopped walnuts (Meijer Distribution Inc.; Grand Rapids, MI)	**12.5**	1 g in 2 oz. cup
	Roasted	Aroma of medium roasted malted barley	Brown roasted barley (The Country Malt Group; Castleford, West Yorkshire, England)	**15**	0.2 g in a 2 oz. cup
	Smoky	Aroma associated with a hardwood smoked products	Smoked bacon (John Morrell & Co; Cincinnati, OH)	**15**	0.02 g piece of bacon, just muscle tissue, in a 4 oz. cup
	Woody	Aroma of a wood barrel	Oak wood chips (LD Carlson Company; Kent, OH)	**11**	1 g in 2 oz. cup
	Phenolic	Aroma of a Band-Aid	Band-Aid (Meijer Distribution Inc.; Grand Rapids, MI)	**13**	1 unwrapped Band-Aid in a 2 oz. cup
	Butter	Aroma of melted butter	Melted butter (Meijer Distribution Inc.; Grand Rapids, MI)	**13**	2 TBS of better melted over low heat, 0.2 g in a 4 oz. cup
	Chocolate	Aroma of dark chocolate	Baker's chocolate (Kraft Foods Group, Inc.; Northfield, IL)	**13**	0.01 g of shaved chocolate in a 2 oz. cup
Mouthfeel	Astringent	A drying sensation in the mouth associated with a high tannin wine	Over-brewed green tea (Lipton, Unilever; Englewood Cliffs, NJ)	**8.5**	steep 1 tea bag in 300 mL of boiling water for 5 min, place 15 mL in a 2 oz. cup
	Slick	A smooth tongue coating	Glycerin (Heritage Store; Virginia Beach, Va., U.S.A.)	**9.5**	20 g of glycerin + 60 g water, ~10 g in a 2 oz. cup
	Warming	The increase in temperature perception in the mouth as a result of alcohol concentration	190 Proof Ethanol (Decon Labs, Inc.; King of Prussia, Pa., U.S.A.)	**14**	1:2 dilution, 10 mL in 2 oz. cup (alcohol)

(*Continued*)

Table 1–Continued.

Modality	Attribute	Definition	Reference	Reference score	Preparation
Taste	Bitter	Bitter taste of caffeine solution	Caffeine solution (Fisher Scientific; Fair Lawn, N.J., U.S.A.)	**10**	1 g caffeine in 500 mL of water, 15 mL in each cup
Aftertaste	Bitter	Aftertaste associated with a caffeine solution	Caffeine solution (Fisher Scientific; Fair Lawn, N.J., U.S.A.)	**11.5**	1 g caffeine in 500 mL of water, 15 mL in each cup
	Brown spice	Aftertaste associated with brown spices	Nutmeg (McCormick & Co., Inc.; Hunt Valley, Md., U.S.A.)	**14**	1 g in 600 mL of water, stir 5 min, 10 mL in 2 oz. cup
	Caramel	Aftertaste associated with caramel	Caramel syrup (The J.M. Smucker Company; Orrville, Ohio, U.S.A.)	**13**	caramel solution, 10 g of caramel dissolved in 200 mL of water ~10 mL in a 2 oz. cup
	Cherry	Aftertaste associated with cooked cherries	Cherry pie filling (Meijer Distribution Inc.; Grand Rapids, Mich., U.S.A.)	**13**	1 cherry and syrup to 5 g in 4 oz. cup
	Coffee	Aftertaste associated with coffee	Dark roast coffee (8 O'clock Coffee Company; Montcale, N.J., U.S.A.)	**12**	1 1/2 teaspoons of coffee, in teabag, in 300 mL of boiling water for 5 min
Aroma-by-mouth	Caramel	Aroma-by-mouth of caramelized sugar	Caramel syrup solution (The J.M. Smucker Company; Orrville, Ohio, U.S.A.)	**10**	10 g of caramel dissolved in 200 mL of water ~10 mL in a 2 oz. cup
	Maple	Aroma-by-mouth of maple syrup	Maple extract (McCormick & Co., Inc.; Hunt Valley, Md., U.S.A.)	**13**	1 3/4 teaspoon in 500 mL volumetric flask, dilute to volume, 10 mL in 2 oz cup
	Brown spice	Aroma-by-mouth of nutmeg	Nutmeg (McCormick & Co., Inc.; Hunt Valley, Md., U.S.A.)	**15**	1 g in 600 mL of water, stir 5 min, 10 mL in 2 oz. cup
	Vanilla	Aroma-by-mouth of vanilla extract	Natural vanilla extract (McCormick & Co., Inc.; Hunt Valley, Md., U.S.A.)	**11**	1/4 teaspoon in 500 mL volumetric flask, dilute to volume, 10 mL in 2 oz cup
	Alcohol	Aroma-by-mouth associated with 40% or greater alcohol	190 Proof Ethanol (Decon Labs, Inc.; King of Prussia, Pa., U.S.A.)	**14**	10 oz. in 2 oz. cup
	Cherry	Aroma-by-mouth of cooked cherries	Cherry pie filling (Meijer Distribution Inc.; Grand Rapids, Mich., U.S.A.)	**13**	1 cherries and syrup to 5 g in 4 oz. cup
	Coconut	Aroma-by-mouth of toasted coconut	Toasted coconut flakes (Marx Brothers, Inc.; Birmingham, Ala., U.S.A.)	**14**	1 g in 2 oz. cup
	Walnut	Aroma-by-mouth of walnuts	Chopped walnuts (Meijer Distribution Inc.; Grand Rapids, Mich., U.S.A.)	**13.5**	3 g in 2 oz. cup
	Roasted	Aroma-by-mouth of medium roasted malted barley	Brown roasted barley (The Country Malt Group; Castleford, West Yorkshire, England)	**15**	0.2 g in a 2 oz cup
	Smoky	Aroma-by-mouth associated with a hardwood smoked products	liquid smoke (B&G Foods, Inc.; Parsippany, N.J., U.S.A.)	**14.5**	0.5 g in 1000 mL volumetric flask, dilute to volume, 10 mL in 2 oz cup
	Woody	Aroma-by-mouth of a wood barrel	Oak Wood chips (LD Carlson Company; Kent, Ohio, U.S.A.)	**8**	1 g in 2 oz. cup

Table 2–Analysis of variance (ANOVA) *F*-ratio for sensory attributes rated for 9 rums.[a]

Modality	Attribute	Rum	Panelist	Rep	Rum x P[b]	Rum x Rep[b]	Rep x P[b]	Adjusted sample *F*
Aroma	Brown sugar	7.44***	5.53***	0.11	1.30	0.78	1.67	
	Caramel	31.87***	9.07***	2.88	2.01**	2.15*	2.86*	15.82***
	Maple	13.15***	7.73***	0.00	1.71*	1.31	1.80	7.67**
	Brown spice	1.48	6.60***	2.54	2.45***	1.26	2.04	0.61
	Vanilla	11.64***	6.00***	0.14	1.89**	2.09	0.92	6.16*
	Alcohol	3.62**	5.82***	0.04	1.05	0.77	0.87	
	Cherry	1.77	19.85***	0.48	2.05**	1.24	2.43*	0.86
	Citrus	3.52***	16.91***	4.41*	1.09	0.68	1.26	
	Coconut	4.15***	6.11***	0.10	1.33	0.96	0.74	
	Dried fruit	1.26	8.54***	2.57	2.25**	1.28	1.88	0.67
	Almond	5.16***	16.84***	0.01	2.44***	0.99	2.42*	2.12
	Walnut	1.49	5.56***	1.26	0.91	0.31	1.08	
	Roasted	2.40*	7.37***	4.30*	0.98	0.73	1.48	
	Smoky	3.83**	2.51*	0.70	1.06	1.75	0.71	
	Woody	0.99	4.88***	0.79	1.55	1.31	1.04	
	Phenolic	9.00***	9.14***	0.69	2.22**	1.48	0.49	4.06**
	Butter	7.44***	7.30***	0.73	2.14**	1.46	0.92	3.48
	Chocolate	4.65***	5.79***	0.04	1.27	0.44	1.36	
Mouthfeel	Astringent	1.48	1.03	3.22	1.38	0.25	1.31	
	Warming	2.65*	5.29***	0.03	0.92	0.74	1.29	
	Slick	3.18**	9.34***	0.51	1.20	0.51	0.53	
Taste	Bitter	3.47**	3.05**	0.04	1.22	1.67	1.31	
Aftertaste	Brown spice	3.73**	5.54***	2.52	2.33***	0.85	0.57	1.60
	Caramel	23.19***	5.28***	1.89*	1.40	1.59	1.35	
	Cherry	0.77	14.10***	0.86	2.52***	1.18	2.71*	0.30
	Coffee	1.90	5.35***	0.60	1.09	0.79	1.77	
Aroma by Mouth	Caramel	29.65***	14.34***	5.54	2.05**	1.42	1.22	14.48***
	Maple	8.02***	5.84***	0.50	1.20	1.08	1.04	
	Brown spice	3.32**	12.07***	0.67	3.10***	1.79	1.84	1.07
	Vanilla	12.22***	12.59***	1.44	1.31	0.88	2.40*	
	Alcohol	2.65*	4.68***	0.32	1.18	2.01	0.74	
	Cherry	0.72	17.17***	0.02	2.02**	0.59	4.61***	0.26
	Coconut	7.50***	5.35***	1.95	2.46***	0.99	1.11	3.05
	Walnut	1.39	31.99***	0.01	1.71*	1.08	3.03*	0.82
	Roasted	0.88	9.02***	8.65**	1.28	1.45	1.06	
	Smoky	1.37	7.86***	1.03	1.18	1.18	1.43	
	Woody	0.93	6.13***	0.21	1.89**	0.86	0.80	0.49

[a]F-ration are shown as a source of variation.
*, **, *** stand for significance at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively.
[b]Rum x P, Rep x P, and Rum x Rep represent the interaction between rum samples and panelists, replications and panelists, and rum samples and replications, respectively.

Urbana-Champaign campus for two 30-min sessions using the Compusense 5 (Version 5.0: Guelph, Ont., Canada) data acquisition system. Panelists were routinely provided with their scoring results from the previous day to help identify and correct for attributes they were rating inconsistently with the rest of the group.

The panel concluded with 5 d of individual booth testing. Panelists attended two 30-min sessions per day, evaluating 2 samples at each session. Panelists were provided with their reference tray when they arrived and encouraged to evaluate all references before proceeding into the booth for testing. Testing took place in a room with partitioned booths maintained at 22 °C. Rum samples were presented in black double old fashions glasses covered with a petri dish and labeled with random 3-digit codes. Samples were evaluated under red lighting to mask the color differences among rums. Compusense 5 software was used to record panelists responses. Sample presentation was randomized between all panelists. Panelists were free to leave the booth at any time to re-evaluate a reference.

Statistical analysis

Statistical analysis of the data was performed using Statistical Analysis System (SAS)® (Version 9.4, SAS Inst. Inc., Cary, N.C., U.S.A.). Analysis of variance (ANOVA) was conducted on each of the 38 attributes evaluated during the DA panel to determine the presence of overall significant differences ($P < 0.05$) using the PROC GLM function for variations within the rums, panelists, replications and their corresponding interactions: rum-by-panelist (Rum x P), rum-by-replication (Rum x Rep), and replications-by-panelist (Rep x P). The calculated probabilities were compared to significance levels $\alpha = 0.05$, 0.01, and 0.001. When significant Rum x P interactions existed, adjusted F-ratios were calculated using Microsoft® Excel® 2016 (Version 16: Microsoft Corporation, Redmond, Wash., U.S.A.) by dividing the rum mean square by the Rum x P interaction mean square and calculating the new probability using the F.DIST function. Fisher's least significant difference (LSD) test was conducted on all attributes determined as significant by ANOVA.

Principal component analysis (PCA) biplots were produced using SAS and Microsoft Excel to create a visual representation of the data to allow further examination of the relationship of the rums to individual attributes that characterized the samples. Pearson correlations were calculated using the same SAS software, with significance determined at $\alpha = 0.05$, 0.01, and 0.001. Cluster analysis was also conducted using SAS software using the PROC CLUSTER function.

Table 3–Mean intensity rating for significant aroma, mouthfeel, taste, aftertaste and aroma-by-mouth attributes of the 9 rums

Modality	Attribute	BW	BG	AE	RA7	AE12	DR12	ED12	RZ	DX
Aroma	Brown sugar	3.06^{D}	$4.69^{C,D}$	$4.69^{C,D}$	$6.71^{B,C}$	5.88^{C}	$8.38^{A,B}$	5.75^{C}	5.63^{C}	9.94^{A}
	Caramel	3.06^{E}	$5.31^{C,D}$	$4.25^{D,E}$	$5.88^{C,D}$	$4.44^{D,E}$	11.19^{B}	$4.88^{C,D}$	6.44^{C}	13.75^{A}
	Maple	3.21^{D}	$4.81^{C,D}$	$4.88^{C,D}$	$6.38^{B,C}$	5.75^{C}	7.81^{B}	$6.00^{B,C}$	5.63^{C}	12.31^{A}
	Vanilla	4.44^{C}	$6.13^{B,C}$	$5.75^{B,C}$	7.19^{B}	$5.43^{B,C}$	11.06^{A}	6.81^{B}	6.81^{B}	11.81^{A}
	Alcohol	9.69^{A}	9.75^{A}	$9.06^{A,B}$	$9.00^{A,B}$	$8.88^{A,B}$	$7.25^{B,C}$	$8.38^{A,B}$	$8.38^{A,B}$	5.56^{C}
	Citrus	$4.50^{A,B}$	4.81^{A}	$3.31^{A,B,C}$	$2.94^{B,C,D}$	$2.94^{B,C,D}$	$2.31^{C,D}$	$2.28^{C,D}$	$4.13^{A,B}$	1.50^{D}
	Coconut	$2.50^{C,D}$	$2.94^{B,C,D}$	$2.69^{C,D}$	$4.94^{A,B}$	2.19^{D}	5.06^{A}	5.75^{A}	$4.31^{A,B,C}$	6.06^{A}
	Roasted	$2.69^{B,C}$	$3.44^{A,B}$	$3.31^{A,B}$	2.88^{B}	1.19^{C}	4.50^{A}	$2.44^{B,C}$	$2.63^{B,C}$	$3.00^{A,B}$
	Smoky	$2.19^{B,C}$	3.38^{B}	5.44^{A}	$2.63^{B,C}$	$2.06^{B,C}$	1.00^{C}	$2.75^{B,C}$	$2.00^{B,C}$	1.25^{C}
	Phenolic	$7.50^{A,B}$	5.63^{B}	8.19^{A}	5.38^{B}	8.06^{A}	2.69^{C}	5.50^{B}	5.81^{B}	1.31^{C}
	Chocolate	1.50^{B}	1.63^{B}	1.13^{B}	2.25^{B}	2.31^{B}	4.06^{A}	2.31^{B}	2.44^{B}	4.69^{A}
Mouthfeel	Warming	$8.56^{A,B,C}$	$9.25^{A,B}$	$8.81^{A,B,C}$	$8.69^{A,B,C}$	9.38^{A}	$7.69^{B,C,D}$	$7.63^{C,D}$	$8.56^{A,B,C}$	6.50^{D}
	Slick	4.44^{D}	$5.81^{C,D}$	$7.18^{A,B,C}$	$6.38^{A,B,C}$	$6.13^{B,C,D}$	8.00^{A}	$7.81^{A,B}$	$6.00^{C,D}$	$6.69^{A,B,C}$
Taste	Bitter	$8.06^{A,B}$	$7.81^{A,B,C}$	$8.31^{A,B}$	$7.75^{A,B,C}$	8.94^{A}	$6.50^{C,D}$	$6.94^{B,C,D}$	$8.13^{A,B}$	5.75^{D}
Aftertaste	Brown spice	4.75^{D}	$6.31^{B,C}$	$5.50^{C,D}$	$6.56^{B,C}$	$6.13^{B,C,D}$	$7.56^{A,B}$	$7.56^{A,B}$	$6.88^{A,B,C}$	8.19^{A}
	Caramel	1.50^{D}	$2.88^{C,D}$	$2.75^{C,D}$	4.13^{C}	4.00^{C}	10.31^{A}	6.13^{B}	$4.38^{B,C}$	10.75^{A}
Aroma By Mouth	Caramel	3.00^{E}	$3.88^{D,E}$	$4.56^{D,E}$	6.88^{B}	$5.19^{B,C}$	12.19^{A}	7.25^{B}	$6.63^{B,C}$	11.13^{A}
	Maple	2.75^{C}	$3.88^{B,C}$	$4.00^{B,C}$	5.31^{B}	5.13^{B}	8.19^{A}	6.00^{B}	5.69^{B}	9.69^{A}
	Vanilla	4.31^{D}	$5.56^{C,D}$	$6.81^{B,C}$	7.56^{B}	$6.88^{B,C}$	11.31^{A}	8.56^{B}	$7.00^{B,C}$	11.00^{A}
	Coconut	1.31^{D}	$3.38^{B,C}$	$2.56^{C,D}$	5.06^{A}	$2.63^{C,D}$	5.25^{A}	$4.81^{A,B}$	$4.31^{A,B}$	5.56^{A}

Superscripts of the same letter within an attribute indicate no significant difference by Fisher's Least Significant Difference (LSD) test at $\alpha = 0.05$.
"BW" is Bacardi White, "BG" is Bacardi Gold, "AE" is Appleton Estate V/X, "RA7" is Ron Abuelo 7 y, "AE12" is Appleton Estate 12 y, "DR12" is Diplomatico Reserva Exclusica, "ED12" is El Dorado 12 y, "RZ" is Ron Zacapa Centurio, "DX" is Dictador XO Insolent.

Results and Discussion

Term generation and lexicon validation

The DA panel was conducted to describe and quantitate the sensory differences perceived in the 9 rum samples, 2 mixing and 7 premium rums. Additionally, the DA panel provided validation for the rum lexicon that was previously developed through the use of web-based material (Ickes and others 2017).

During the term generation phase of the panel, panelists were allowed to generate terms freely for the first 3 d, without the aid of the flavor lexicon. This initial term generation provided terms that panelists were able to identify on their own. Initially, 52 terms were generated consisting of 25 aroma, 16 aroma-by-mouth, 6 mouthfeel, 1 taste, and 4 aftertaste terms. Panelists were then provided with the rum flavor wheel to aid in the generation of additional terms to adequately describe the flavor of the rums being evaluated. After the panelists were presented with the flavor wheel, an additional 17 terms were generated, including 12 aroma, 4 aroma-by-mouth, and 1 aftertaste. No additional taste or mouthfeel terms were generated. Of those additional terms generated, 14 of the 17 terms are found on the flavor wheel. The addition of caramel aftertaste is likely not due to the aid of the flavor wheel, but rather refinement of the panel's ability to detect and perceive different intensities of odorants as caramel was a term that had initially been generated in the aroma and aroma-by-mouth modalities during the first 3 d of the panel.

At the conclusion of the term generation phase of the panel, 69 terms had been generated. Of the generated terms 53 were unique attributes. The other 16 terms were rated under more than 1 modality, such as aroma, aroma-by-mouth and/or aftertaste. Of the 53 unique terms generated, 37 appear on the flavor lexicon.

Throughout the reference refinement and scaling portions of the panel, panelists were encouraged to reduce the number of terms to be evaluated. Terms were removed if they were no longer perceived in the samples, panelists could not uniformly identify the attribute in the samples, or the attribute intensity did not differ among samples. The panelists decided on a final set of 38 attributes (Table 1) to describe the rum samples, consisting of 27 unique terms. The other attributes were additional references to the same term evaluated under different modalities (aroma, aroma-by-mouth, and/or aftertaste).

Of the final 38 terms used for evaluation, all but 5 terms can be found directly on the rum flavor wheel. Of those 5 remaining terms, similar forms of 3 of the terms can be found on the wheel. Alcohol appears as alcoholic, and brown spice is synonymous with baking spices. Brown sugar has both of its components (sugar and brown) found on the wheel under sugar and caramel categories, respectively. Only 2 terms were not found on the wheel in any form: phenolic and slick. When creating the rum lexicon, it was postulated that the lexicon would be deficient in some terms which would need to be added as a result of future sensory studies. Therefore, phenolic, slick and brown sugar are 3 terms that should be considered for addition to the lexicon.

Many terms included in the lexicon were not selected for the DA panel. There are several reasons for this occurrence. First, the rums selected, primarily premium aged rums, are only a selection of the available varieties of rum. There are numerous variations of rum flavor due to limited regulation requirements. As a result, the terms not included in the DA panel may likely be used to describe the other categories and types of rums. Second, the large number of terms generated to describe rum flavor needed to be simplified and condensed wherever possible so that the panelists could consistently and accurately identify the differences among samples. Attributes that were difficult to detect or did not differ among rum samples were excluded from the final evaluation. However, the large overlap between the final terms selected and those on the rum flavor wheel demonstrate that using web-material is a valid way to create a lexicon that can be used for the evaluation of a variety of rums.

DA panel results

The DA panel was used to characterize and quantitate the sensory differences among rum samples. Rums were evaluated in black glasses and under red lighting to reduce any bias that might

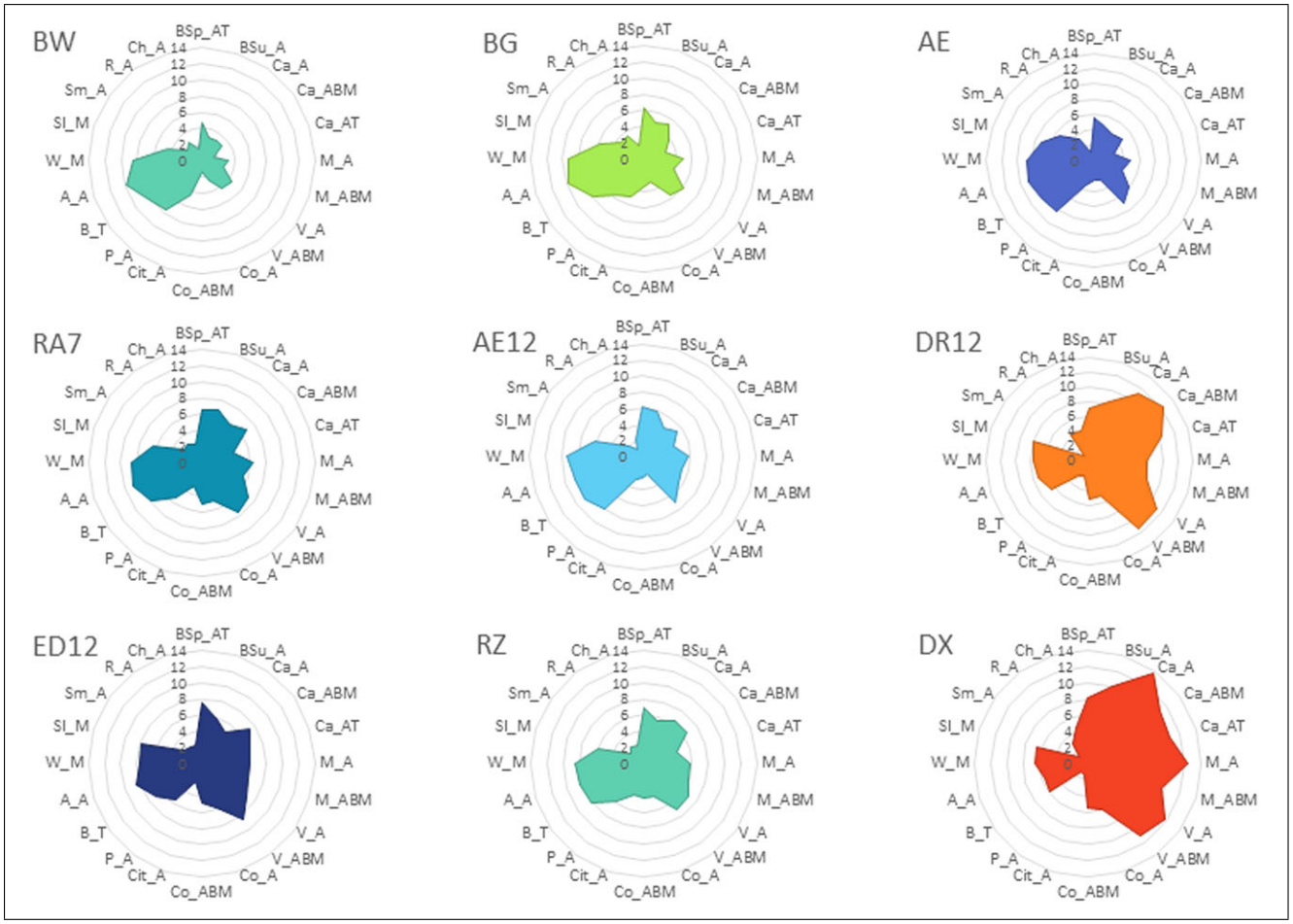

Figure 1–Spider plots of mean significant attribute intensities for 9 rums
"BW" is Bacardi White, "BG" is Bacardi Gold, "AE" is Appleton Estate V/X, "RA7" is Ron Abuelo 7 y, "AE12" is Appleton Estate 12 y, "DR12" is Diplomatico Reserva Exclusica, "ED12" is El Dorado 12 y, "RZ" is Ron Zacapa Centurio, "DX" is Dictador XO Insolent. "A" is aroma, "M" is mouthfeel, "T" is taste, "AT" is aftertaste, "ABM" is aroma-by-mouth, "BSp" is brown spice, "BSu" is brown sugar, "Ca" is caramel, "M" is maple, "V" is vanilla, "Co" is coconut, "Cit" is citrus, "P" is phenolic, "B" is Bitter, "A" is alcohol, "W" is warming, "Sl" is slick, "Sm" is smoky, "R" is roasted, and "Ch" is chocolate.

be caused by color differences among the samples as the rums varied significantly in color, from colorless (clear) to dark brown. Analysis of variance (ANOVA) was conducted on all 38 attributes identified and rated by the panelists, and the results are shown in Table 2. Sample replications were not a significant ($P > 0.05$) source of variation for the majority of attributes except citrus aroma, roasted aroma, caramel aroma-by-mouth and roasted aroma-by-mouth. The lack of variation shows that panelists were able to consistently rate these terms between sample replications. Significant panelist variation ($P < 0.05$) existed for all attributes except astringent mouthfeel. This type of variation is typical of DA panels and is most likely attributed to panelists only using a portion of the scale or not uniformly using the scale (Stone and others 1974; Lawless and Heymann 1999a). Rep x P interactions were not significant ($P > 0.05$) for most attributes except caramel aroma, cherry aroma, almond aroma, cherry aftertaste, vanilla aroma-by-mouth, cherry aroma-by-mouth, and walnut aroma-by-mouth. Lack of significant interaction indicates that the panelists were able to agree on the intensity of attributes in the samples across replications. No significant ($P > 0.05$) Rum x Rep interactions were found, indicating that while the panelists may have used the scale differently from each other, they rated the rum samples consistently across replications.

Twenty-four attributes differed ($P < 0.05$) across all 9 rum samples. Significant ($P < 0.05$) Rum x P interactions existed for 17 of the attributes. These interactions indicate that panelists did not agree on the order of attribute intensity across the rum samples. Adjusted *F*-values were calculated for attributes that had significant Rum x P interactions to account for this variation. The adjusted *F*-values are shown in Table 2. Of the adjusted *F*-values, 5 of the attributes (caramel aroma, maple aroma, vanilla aroma, phenolic aroma, and caramel aroma-by-mouth) were shown to be statistically ($P < 0.05$) different among rum samples. Based on the adjusted *F*-values calculated and intitial *F*-values for rums, twenty terms were determined to be significantly different including brown sugar aroma, caramel aroma, maple aroma, vanilla aroma, alcohol aroma, citrus aroma, coconut aroma, roasted aroma, smoky aroma, phenolic aroma, chocolate aroma, warming mouthfeel, slick mouthfeel, bitter taste, brown spice aftertaste, caramel aftertaste, caramel aroma-by-mouth, maple aroma-by-mouth, vanilla aroma-by-mouth, and coconut aroma-by-mouth.

Defining attributes

Mean separation analysis by Fisher's Least Significant Difference (LSD) test was performed on the attributes that were significantly different among rum samples, and results are shown in Table 3. DX

Table 4–Pearson correlation coefficients for significant attributes for all 9 rums

Attributes	BrownSugar A	Caramel A	Maple A	Vanilla A	Alcohol A	Citrus A	Coconut A	Roasted A	Smoky A	Phenolic A
BrownSugar_A	**1.000**									
Caramel_A	0.932**	**1.000**								
Maple_A	0.955***	0.932**	**1.000**							
Vanilla_A	0.945**	0.983***	0.910**	**1.000**						
Alcohol_A	−0.916**	−0.935**	−0.956***	−0.921**	**1.000**					
Citrus_A	−0.842**	−0.681*	−0.812**	−0.741*	0.820**	**1.000**				
Coconut_A	0.752*	0.701*	0.729*	0.773*	−0.743*	−0.700*	**1.000**			
Roasted_A	0.273	0.466	0.194	0.525	−0.237	−0.048	0.312	**1.000**		
Smoky_A	−0.565	−0.598	−0.511	−0.570	0.567	0.364	−0.465	−0.001	**1.000**	
Phenolic_A	−0.867**	−0.940**	−0.861**	−0.950***	0.847**	0.606	−0.827**	−0.522	0.635	**1.000**
Chocolate_A	0.936**	0.953***	0.913**	0.945**	−0.940**	−0.752*	0.726*	0.280	−0.772*	−0.908**
Warming_M	−0.730*	−0.794*	−0.811**	−0.813**	0.885**	0.740*	−0.838**	−0.325	0.488	0.827**
Slick_M	0.565	0.436	0.439	0.565	−0.490	−0.705*	0.582	0.377	0.026	−0.414
Bitter_T	−0.764*	−0.845**	−0.801**	−0.881**	0.821**	0.662	−0.850**	−0.535	0.487	0.933**
BrownSpice_AT	0.833**	0.759*	0.827*	0.790*	−0.803**	−0.711*	0.878**	0.130	−0.482	−0.812**
Caramel_AT	0.933**	0.936**	0.892**	0.966***	−0.936**	−0.823**	0.783*	0.392	−0.628	−0.902**
Caramel_ABM	0.928**	0.912**	0.841**	0.960***	−0.894**	−0.805**	0.806**	0.448	−0.623	−0.882**
Maple_ABM	0.969***	0.942**	0.945**	0.954***	−0.966***	−0.838**	0.800**	0.271	−0.619	−0.888**
Vanilla_ABM	0.934**	0.880**	0.858**	0.938**	−0.897**	−0.881**	0.792*	0.397	−0.497	−0.830**
Coconut_ABM	0.844**	0.753*	0.756*	0.821**	−0.718*	−0.674*	0.922	0.351	−0.450	−0.835**

Attributes	Chocolate A	Warming M	Slick M	Bitter T	BrownSpice AT	Caramel AT	Caramel ABM	Maple ABM	Vanilla ABM	Coconut ABM
BrownSugar_A										
Caramel_A										
Maple_A										
Vanilla_A										
Alcohol_A										
Citrus_A										
Coconut_A										
Roasted_A										
Smoky_A										
Phenolic_A										
Chocolate_A	**1.000**									
Warming_M	−0.802**	**1.000**								
Slick_M	0.424	−0.444	**1.000**							
Bitter_T	−0.813**	0.933**	−0.487	**1.000**						
BrownSpice_AT	0.789*	−0.729*	0.608	−0.757*	**1.000**					
Caramel_AT	0.961***	−0.838**	0.642	−0.867**	0.830**	**1.000**				
Caramel_ABM	0.935**	−0.788*	0.672*	−0.819**	0.798**	0.976***	**1.000**			
Maple_ABM	0.966***	−0.823**	0.596	−0.818**	0.881**	0.977***	0.958***	**1.000**		
Vanilla_ABM	0.895**	−0.782*	0.775*	−0.804**	0.821**	0.972***	0.978***	0.957***	**1.000**	
Coconut_ABM	0.752*	−0.659	0.654	−0.745*	0.916**	0.803**	0.849**	0.839**	0.839**	**1.000**

A is aroma, M is mouthfeel, T is taste, AT is aftertaste, ABM is aroma-by-mouth.
*, **, *** stand for significance at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively.

had the highest intensity score for caramel aroma and maple aroma compared to the other 8 rums. DX and DR12 had the highest scores for brown sugar aroma, vanilla aroma, chocolate aroma, caramel aftertaste, caramel aroma-by-mouth, maple aroma-by-mouth, and vanilla aroma-by-mouth. DX, DR12, RA7, ED12, and RZ were highest in coconut aroma and coconut aroma-by-mouth. DX, DR12, ED12, and RZ were highest in brown spice aftertaste, while DX, DR12, RA7, and ED12 were highest in slick mouthfeel. Interestingly, DX, DR12, AE, and BG were highest in roasted aroma while AE had the highest smoky aroma intensity which was significantly different ($P < 0.05$) from the other 8 rums. Additionally, AE12, AE, and BW were highest in phenolic aroma. BW, BG, AE, AE12, RZ, and RA7 had the highest scores for bitter taste and warming mouthfeel. BW, BG, AE, and RZ had the highest citrus aroma. Finally, DX had the overall lowest alcohol aroma and was significantly different from all other rums except DR12.

BW had the lowest intensity ratings for brown sugar aroma, caramel aroma, vanilla aroma, maple aroma, chocolate aroma, slick mouthfeel, brown spice aftertaste, caramel aftertaste, caramel aroma-by-mouth, maple aroma-by-mouth, vanilla aroma-by-mouth and coconut aroma-by-mouth. It makes sense that BW, a clear white rum, would have the lowest intensity of these attributes as these terms are typically associated with aging with the exception of coconut.

Spider plots (Figure 1) of the results were constructed to better visualize the differences among samples. Both the spider plot and LSD results illustrate that DX and DR12 were significantly different from the other rums in terms of caramel aroma, vanilla aroma, chocolate aroma, caramel aftertaste, caramel aroma-by-mouth, maple aroma-by-mouth, and vanilla aroma-by-mouth. There is no clear explanation for the increased perception of these sweet-like attributes in these samples. Further insight could be gained by an analysis of the odor-active compounds present in the rums.

The Pearson correlation coefficients are given in Table 4. The attributes brown sugar aroma, caramel aroma, maple aroma, vanilla aroma, coconut aroma, chocolate aroma, brown spice aftertaste,

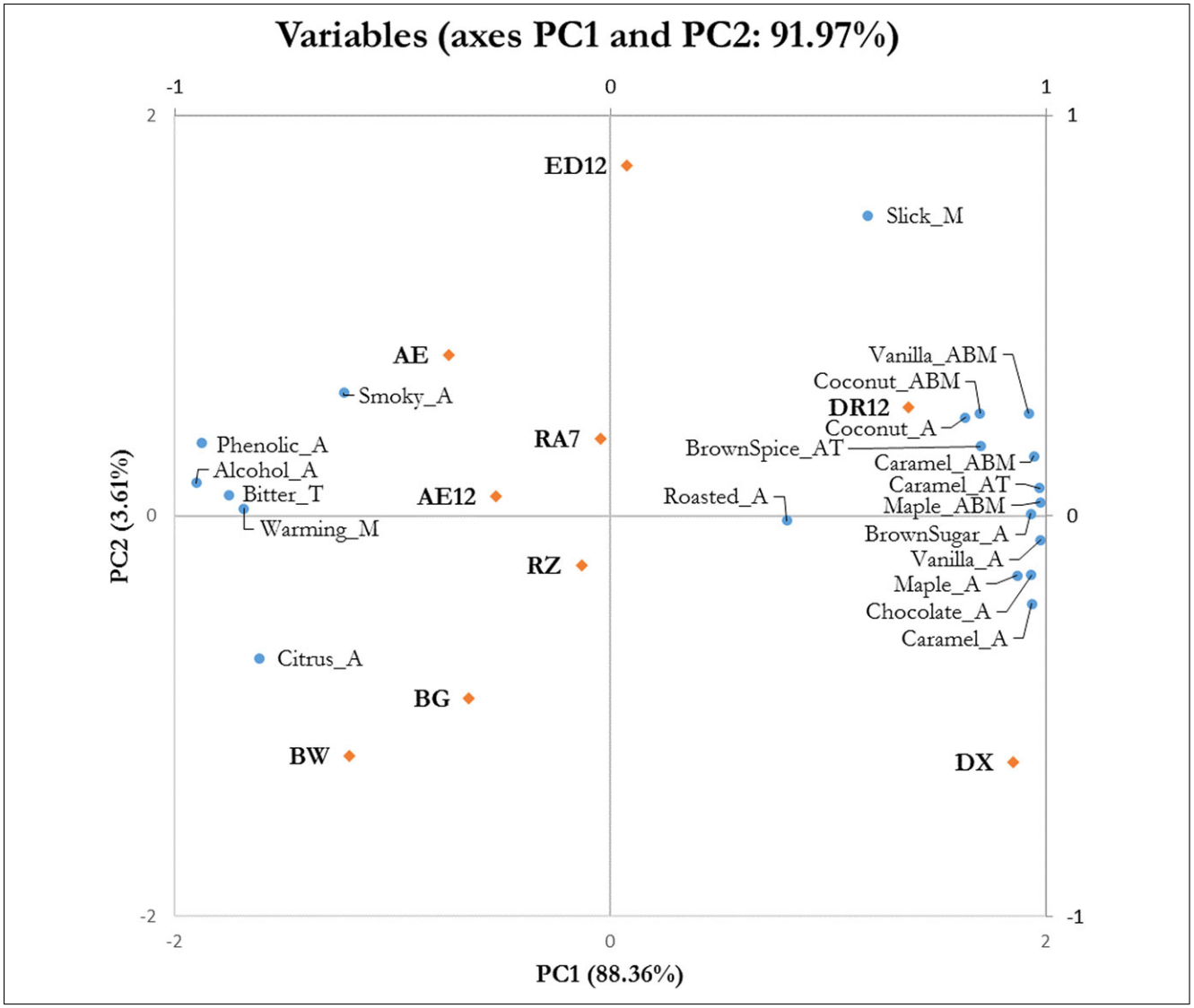

Figure 2–Principal component analysis biplot of significant attributes present on principal component 1 (PC1) and 2 (PC2) by the covariance matrix of mean significant attribute intensity rating across all 9 rums
"BW" is Bacardi White, "BG" is Bacardi Gold, "AE" is Appleton Estate V/X, "RA7" is Ron Abuelo 7 y, "AE12" is Appleton Estate 12 y, "DR12" is Diplomatico Reserva Exclusica, "ED12" is El Dorado 12 y, "RZ" is Ron Zacapa Centurio, "DX" is Dictador XO Insolent. A is aroma, M is mouthfeel, T is taste, AT is aftertaste, ABM is aroma-by-mouth.

caramel aftertaste, caramel aroma-by-mouth, maple aroma-by-mouth, vanilla aroma-by-mouth, and coconut aroma-by-mouth were all positively correlated with each other ($P < 0.05$). The terms were all negatively correlated ($P < 0.05$) to alcohol aroma, citrus aroma, phenolic aroma, warming mouthfeel and bitter taste, with the exception of coconut aroma-by-mouth and warming mouthfeel which were not correlated ($P > 0.05$). Additionally, alcohol aroma, phenolic aroma, warming mouthfeel and bitter taste were all positively correlated with each other. Citrus aroma was positively correlated to alcohol aroma and warming mouthfeel. Slick mouthfeel was negatively correlated to citrus aroma and positively correlated to caramel aroma-by-mouth and vanilla aroma-by-mouth. Finally, chocolate aroma was negatively correlated to smoky aroma.

Principal component analysis was also conducted to help reduce the complexity of the data and gain a better visual representation of the data (Figure 2) (Lawless and Heymann 1999b). The covariance matrix was chosen for sample evaluation since the samples were all scored by a trained panel (Jolliffe 2014). The first factor contained the majority of variation between the samples (88.4%), with the second factor only containing 3.6% of the variation. This indicates that the second factor was not significant in differentiating the rum samples. Principal component 1 (PC1) contrasted samples high in brown sugar, caramel, maple, vanilla, and chocolate aromas, brown spice and caramel aftertastes, caramel, maple, vanilla and coconut aftertastes with samples high in alcohol, citrus, and phenolic aromas, warming mouthfeel, and bitter taste. These correlations are similar to those indicated by the Pearson correlations. Principal component 2 (PC2) was minimally loaded with the main distinguishing attribute being slick mouthfeel ($r = 0.75$), as well as partially by citrus aroma ($r = -0.36$) and smoky aroma ($r = 0.31$).

Using the resulting mean intensity ratings calculated from ANOVA, cluster analysis was performed (Figure 3). DX and

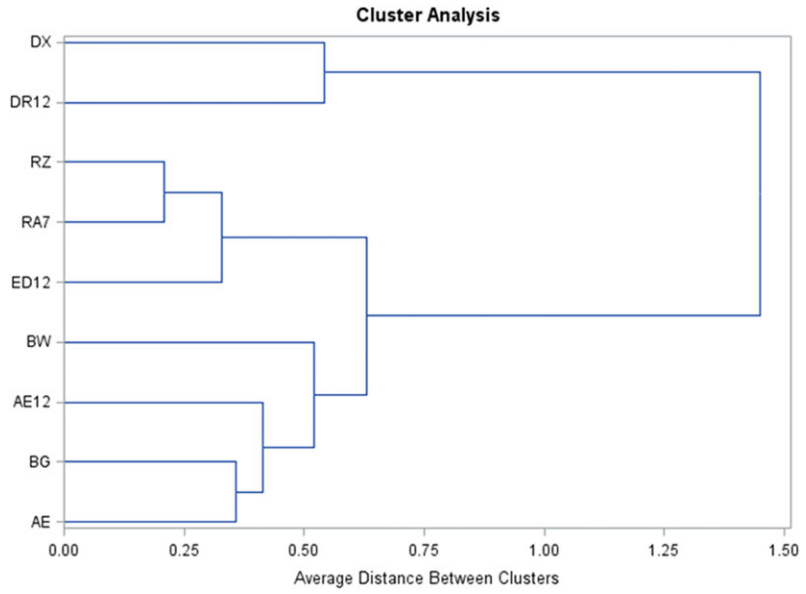

Figure 3–Cluster analysis constructed using mean significant attribute intensities for all 9 rums "BW" is Bacardi White, "BG" is Bacardi Gold, "AE" is Appleton Estate V/X, "RA7" is Ron Abuelo 7 y, "AE12" is Appleton Estate 12 y, "DR12" is Diplomatico Reserva Exclusica, "ED12" is El Dorado 12 y, "RZ" is Ron Zacapa Centurio, "DX" is Dictador XO Insolent

DR12 were more closely related to each other than any of the other 7 rums since the distances between the 2 rums was less than half the distance between that cluster and the other 7 rums. In the grouping of 7 rums, there were 2 distinct clusters, 1 containing RZ, RA7, and ED12 and a second cluster containing BW, BG, AE, and AE12 rums.

While it was expected that the Bacardi rums would be grouped more closely together, it is interesting that they are also grouped with the Appleton Estate rums. AE and BG were grouped as most similar to each other. It was hypothesized that the mixing rums (BW and BG) would be significantly different from the premium rums. However, BW, BG, AE, and AE12 were consistently grouped together for multiple attributes. Additionally, they tend to have the lowest intensity scores for brown sugar aroma, caramel aroma, maple aroma, vanilla aroma, coconut aroma, brown spice aftertaste, caramel aftertaste, caramel aroma-by-mouth, maple aroma-by-mouth, vanilla aroma-by-mouth, and coconut aroma-by mouth.

While panelists were able to differentiate rums for a number of attributes, the results demonstrate the difficultly in evaluating distilled spirits. The large number of terms chosen by the panel to evaluate the rum samples demonstrates the complexity of rum flavor. Sixty-nine terms were initially generated, and 38 of those were selected for the final analysis. However, only 20 of the 38 evaluated terms were found to be significant across samples. This indicates that the panel may have needed more training on the intensity and perception of the attributes not found to be significant. Furthermore, the high ethanol concentration (40% ABV) may lead to sensory fatigue both during training and booth testing. This fatigue may have made it difficult to accurately quantitate the differences among samples. Sensory fatigue of alcoholic beverages has been noted by other studies (Gómez 2002). While sample presentation was limited to 2 rums per session and samples order was random, it is probable that sensory fatigue may have occurred between just these 2 samples or even during the evaluation of the first sample. It is more likely that the high alcohol concentration made it difficult to identify differences in attribute intensities between samples and could be a contributing factor as to why so many attributes were not significantly different among samples.

This was the first sensory study to evaluate premium rums and the first comprehensive study to evaluate the in-mouth perceptions (aroma-by-mouth, taste, mouthfeel, and aftertaste) of rum flavor. Most studies have only evaluated rum aroma (Gómez 2002; de Souza and others 2006; Franitza and others 2016a, 2016b). The only other study to study in-mouth perception of rum only evaluated 2 rum samples with the main focus of the study being to identify the sensory differences between rum and cachaça (Magnani 2009).

Comparing the present study with the previous 5 studies, alcohol aroma has been used to differentiate and characterize rum in all studies. Additionally, 1 or more sweet associated terms have been used in each study: vanilla aroma, caramel aroma or sweet aroma. Brown spice aroma is also a commonly used term (de Souza and others 2006; Franitza and others 2016a, 2016b). While Magnani (2009) also evaluated in-mouth perceptions, only 4 attributes were evaluated in both that study and then present study: wood aroma-by-mouth, alcohol aroma-by-mouth, bitter taste, and warming mouthfeel. This lack of overlap can be attributed to the difference in objectives between the 2 studies, as Magnani was differentiating rum and cachaça samples while the current study evaluated only rum.

The previous 5 studies evaluated 23 attributes that were not included in this study. Of those terms, 15 are found on the rum flavor wheel. The difference in the terms selected between studies is most likely a result of the types of rum being evaluated. With the huge variety of rums available, it is reasonable that different attributes would be needed to discriminate different subsets of rum. This demonstrates the complexity of rum flavor across products.

Little product information is typically provided in the literature, making it difficult to compare studies and particularly the samples evaluated against each other. De Souza and others (2006) indicated that Bacardi was used as the rum sample in their study but the specific product was not mentioned. Gomez (2002) was the only other author to identify the specific rums and brands evaluated. Gomez evaluated 2 rums also evaluated in the current study, BW

and ED12. Four aroma attributes overlapped between the 2 studies: caramel, vanilla, alcohol, and smoky. While Gomez did not find any statistical difference between the 2 rums for these 4 attributes, that study and the present study both rated ED 12 as being higher in caramel, vanilla, and smoky aromas. Neither study found alcohol aroma to be significantly different between the rums as indicated by their reversed order in the 2 studies. The results, while limited, suggest that rums can be rated consistently across studies when panelists are well-trained and standard terminology, references and definitions are used.

Conclusion

The overall DA panel results indicate that for rums matured in the barrels, the brown sugar, caramel, maple, and vanilla attributes across all modalities increase with age. Additionally, alcohol aroma citrus aroma, phenolic aroma, and warming mouthfeel tend to decrease with age. However, while overall trends are visible, clear patterns do not emerge. The rums that are clearly different from the others are DX and DR12 with their higher caramel, maple and vanilla attributes. Even though the remaining rums have similar profiles to each other, they can still be differentiated on a number of attributes, demonstrating the complexity and variation present in rum products.

While this study provides significant insight into the sensory differences between premium rums and mixing rums, it is important to note that this only encompasses a subset of the available rum products on the market. It is expected that lower quality rums and particularly white and agricole rums might be defined and differentiated by different sensory terms. Additionally, DA panels quantitate the sensory differences among samples and may not be the best at characterizing the overall flavor of rums. To better evaluate the entirely of rum flavor it may be best to perform a preliminary sensory evaluation and sorting of a larger variety of rum samples using techniques such as Napping to identify similar types of rums and then select 1 sample from each category to be included in a DA panel or aroma profile analysis. This would provide greater insight into the differences among rums across the class.

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Author Contributions

C. Ickes collected and analyzed the test data and drafted the manuscript. Authors K. Cadwallader provided technical oversight of the project and contributed to the writing and editing of the manuscript.

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