AROMA IN NEW MAKE WHISKEY DETERMINED BY MAIZE VARIETY AND ORIGIN

A Thesis

by

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ABSTRACT

The objective of this study was to determine the influence of different maize growth location and different maize varieties on new-make whiskey aroma development. Three maize varieties (Dyna-Gro – D57VP51; Mycogen – 2 C797; Terral Seed – REV25BHR26) were selected to grow in three geographically different locations (Calhoun County, TX; Monte Alto, TX; Sawyer Farms, Hillsboro, TX); a fourth location (Perryton, TX) was selected to grow one of the three varieties (Terral Seed – REV25BHR26). The maize was processed into new-make whiskey by the head distiller at Firestone & Robertson Distilling, Company, Fort Worth, TX. A new-make whiskey lexicon was developed and used to train a descriptive aroma panel. The lexicon was also used to test ground maize aroma with minor modifications. New-make whiskey was diluted to 40 proof (20% alcohol by volume) 15 minutes prior to analysis. Maize samples were ground less than an hour prior to trained aroma panel analysis. GC/MS – olfactory new-make whiskey and maize samples were collected on the same day and from the same batch used in sensory analysis. Results were analyzed with the main effects of a 3 x 3 + 1 factorial of a completely randomized design to include all locations and environments; and as a 3 x 3 factorial arrangement of a completely randomized design, excluding Perryton, which did not grow all maize varieties. Maize growth location and maize varieties induced differences in new-make whiskey and maize aroma. Maize growth locations and maize varieties created significant ($P < 0.05$) differences in new-make whiskey volatile composition, affecting acids, alcohols, aldehydes, alkanes, esters, furans, ketones, and sulfur-containing compounds; alcohols, aldehydes, and esters were the major volatile compound groups affected while maize varieties most affected alcohols, aldehydes, and ketones. Maize growth locations, maize varieties, and their interaction showed significant differences in volatiles, fatty acid composition, starch, crude protein, lipid content, as well as estimated alcohol by volume.

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NOMENCLATURE

ABV	Alcohol by volume
FT-NIRS	Fourier-Transformed Near Infrared Reflectance Spectroscopy
GC/MS-O	Gas chromatography/mass spectrometry – Olfactory
NIRS	Near Infrared Reflectance Spectroscopy
NMW	New-make whiskey
SWRI	Scotch Research Whiskey Institute
TAMU	Texas A&M University
TIC	Total ion count

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1. REVIEW OF LITERATURE AND INTRODUCTION

Fermentation of fruits, honey, and grains into wines, meads, and beers, respectively, began in ancient times and were used as superior beverages and medicines, as indicated by their connotations of "water of life" in different cultures (Leake and Silverman, 1971). The first person credited for distilling spirits was Jabir ibn Hayyan in 800 A.D., an alchemist who developed the first known technique for distilling (Leake and Silverman, 1971).

Although whiskey production was common, popularity of Scotch whiskey took off in the 1800s due to royal interest (Wishart, 2009). At this time, manufacturing priorities shifted from mass production to producing Scotch whiskey with improved sensory qualities, focusing on flavor and aroma. The location of where whiskey was produced began to influence consumers; the Scottish Highlands produced a different style of whiskey that focused more on flavor and aroma than the Scottish Lowlands which focused on mass production, but later began to incorporate Highland practices, such as ingredient selection and processing procedures (Wishart, 2009).

As enjoyment of whiskey continued, standardization of different quality aspects of whiskey developed. In order to test the amount of alcohol in each barrel, producers had to have proof of alcohol content, which involved lighting the spirit (Leake and Silverman, 1971). This system is measured either by proof or alcohol by volume (ABV), where ABV is measured as half the proof. Alcohol would only light if it contained at least 57.5% alcohol by volume, so that was considered 100 proof that the amount of alcohol promised was in the spirit (Leake and Silverman, 1971).

The whiskey industry in the United States developed from an overabundance of corn supply and farmers would turn their excess corn into whiskey, rather than pay taxes on the corn. Whiskey production grew, until the rising popularity of the Prohibition movement swept Congress and alcohol production and consumption in the United States was made illegal. Whiskey consumption initially decreased at the start of Prohibition, but began increasing in the later years to 70% of its pre-Prohibition quantities (Miron and Zwiebel, 1991). Whiskey consumption remained relatively similar to the levels experienced at the end of Prohibition, until the 1970s when consumption of American whiskey experienced a steady decrease until the 2000s (Wishart, 2009; Miron and Zwiebel, 1991; Distilled Spirits Council, 2017). The Distilled Spirits Council of the United States 2016 report showed the historical growth of North American whiskeys in the United States has been steadily increasing since its lowest point in 2000, with the highest amount of growth of the new millennium experienced in 2016. In the 2016 report, it was also reported that local distilleries were contributing to the growing interest of consumers in spirits and influencing commercial distillers (Distilled Spirits Council, 2017; Kahla and Crocker, 2014). Consumer spending shifted from mass spending to paying for experiences leading to the willingness of consumers to pay for higher priced spirits if a unique experience is involved (Distilling Spirits Council, 2017; Kahla and Crocker, 2014). In today's market, consumers are driving the idea of product distinction. In the whiskey industry, one way to differentiate products and build brand loyalty is to have a unique "identity" which falls mainly to aroma and taste of the product (Kahla and Crocker 2014; Piggott, 2010; Schuster, 2015).

As consumers are becoming more vocal on what drives their purchase behavior, distilleries are beginning to cater to those purchasing behaviors, but still need to consider optimal production practices. Globally, finding ways to make food production more efficient to sustain and meet the demands of a growing population has been a goal leading innovation in the crop production and food industries (Balcerek et al., 2016; Kutka, 2011). Production efficiency has taken precedence over producing variety, which has resulted in a smaller selection of food properties such as appearance and flavor (Vanbeneden et al., 2007). In distilling, the property that now often drives grain selection is spirit yield, which is the amount of ethanol obtained in a given quantity of grain (Swanston et al., 2005). An increase in 1% spirit yield in barley can lead to about 1.1 million British pounds sterling (Meyer et al., 2001). However, in order to draw more consumers, distilleries need to create distinct products or experiences. Whiskey has many marketable features, such as location of production, years aged, histories of the company, but the most important features are aroma and flavor (Schuster, 2015). A combination of factors can influence the sensory characteristics of a product, such as aging, ingredients, and weather conditions (Piggott et al., 2016).

The countries that produce the most whiskey are Scotland, Ireland, Japan, and the United States of America (Distilled Spirits Council, 2017). Each country has laws regulating ingredients and processes that allow spirits to be called whiskey. In the most basic form, whiskey is a distilled spirit made from grain or cereals that is aged in oak casks. Grains are ground, have their starches broken down and are fermented into beer, distilled into new-make whiskeys, and aged to the final whiskey product.

Ingredients have played a big role in attracting consumers to brands because of the current movement of product information, where consumers are interested in knowing where their product was made and where the ingredients are sourced from as a way of discerning quality (Schuster 2015; Wishart 2009). The main ingredients in whiskey production are water, yeast, and grain. The classic grains used in whiskey are corn (*Zea mays* L.), wheat (*Triticum aestivum)*, rye (*Secale cereale)*, barley (*Hordeum vulgare)*, with barley and rye being prominent grain sources in Canada, Ireland, and Scotland, while corn is the most common to the American style whiskey, known as Bourbon (Agu et al., 2006; Goldberg et al., 1999). The main whiskies produced in the United States are Bourbon, rye, malt, blended, straight, and light whiskies, each of which has differences in ingredients or production procedures (Standards of Identity 27 CFR 5.22, 1969). Bourbon is identified as a grain distilled spirit/whiskey that must be comprised of not less than 51% of corn as the main grain, after which it must be aged in a new charred cask or wooden container (Standards of Identity 27 CFR 5.22, 1969). Traditionally maize was the most common grain in Scotland due to higher alcohol yield, but was replaced by wheat and barley as the main grain (Swanston et al., 2005; Swanston et al., 2007; Walker, 1986). Rye contributes a distinct flavor due to a different starch composition than corn and barley. Barley is used in malt form to contribute flavor from the grain and enzymes from the malt, and wheat replaced corn as the main grain EU due to its economic advantage over corn (Piggott and Conner, 2003). However, maize remains one of the main grains used in whiskey in the United States, Ireland, Scotland, and Canada as an adjunct base grain (Piggott and Conner, 2003).

The most commonly used corn for distilling is yellow dent corn, which is ubiquitous on the commodity market and used for biofuel, feed, food and industrial purposes, and currently constitutes 13.7% of global cropland area (Mozaffar et al., 2017. Piggott and Conner, 2003; Troyer 2004); yellow corn is often much less expensive than specialty food corns, including white or blue, which are generally grown on contract with a price premium. Plant breeders have selected yellow corn almost exclusively for higher yields, including under conditions of stress, and to a lesser extent for traits such as disease resistance, plant aesthetic appearance, and rapid dry-down. As in alcohol production, yield is the most sought after property and about $1 billion a year is spent on improving the yield (Meyer et al., 2001). Other properties, like flavor, undergo little to no consideration of plant breeding or growing for quality in corn, so long as it meets the minimum requirements set by the USDA for test weight (density), broken kernels, grain moisture and foreign matter (Kutka, 2011). The improvement in yield has primarily focused on increasing starch, which is highly fermentable, without increasing the non-fermentable protein or oil content (Kosik et al., 2017). Because of the nearly exclusive focus to produce the highest yields as efficiently and cheaply, the US produces lots of yellow corn; in 2016 alone, the U.S. produced 15.1 billion bushels, which was an 11% increase from 2015, and an increase from past years (Crop Production, NASS, 2016). Yellow corn is therefore used because it is an inexpensive grain, produces very high alcohol yield, and has easy availability which allows distillers to readily meet demands for whiskey and Bourbon (Jacques, et al. 2003). Because of the heavy use of yellow dent corn, growers concentrate on producing efficient (i.e. high grain yield) varieties of yellow dent corn, and yellow dent corn has become wide-spread in the industry. The wide-spread focus on high yield commodity corn, by a very few seed companies selling a limited number of highly related varieties, has likely weaned out other flavors from different varieties that could contribute to a wider flavor spectrum in whiskey. Corn is one of the most genetically diverse crops species, originating in Central America, and it is likely that many other flavor profiles exist that have been lost through breeding, but these would first need to be evaluated to know. While most cultivar improvement emphasizes improving yield, adapting cultivars to different conditions has also been investigated.

The Scottish Whisky Research Institute (SWRI) has carried out many investigations from grain selection and modification, environmental factors, and chemical and sensory analysis on final whiskey products, but focuses on Scotch whiskey, a distinct product from American whiskey due to the processing steps and ingredient composition. The transition to using wheat as a main grain has led to many studies on adapting processing procedures to produce the greatest spirit yield. Research carried out by the SWRI on grains more distinct to Scotch and Irish whiskey showed that there exists an impact on variety of grain, as well as location, or terroir, and weather patterns (including deviation from typical weather patterns) of where the grain is grown (Awole et al., 2012; Malfonet et al, 2016; Taylor and Roscrow, 1990). Much research has been undertaken to understand how to handle different varieties of grains, but little research has been done on maize, regardless of maize producing consistently higher spirit yield than other grain alternatives (Agu et al., 2008). Terroir, year, and variety impacting the product are important concepts in the wine industry as well, and have been shown to affect aroma and flavor of the product, as well as be an influencing factor in consumer marketing (Ferrari et al., 2004).

Exogenous conditions, such as growing conditions, location/environment, weather experienced throughout the seasons/year, soil type, fertilization and crop treatment, as well as endogenous conditions like genetic resistance against detrimental factors (pests, disease, fungus), minerals, and macronutrient content have an effect on the grain and can extend their influence on the final product (Ferrari et al., 2004; Meyer et al., 2001) also found that region can play an important role in positive distilling traits. Genetic processes present in grain that affect desirable distilling traits can experience modification through environmental influence (Meyer et al, 2001). Spirit yield, one of the most important factors as discussed previously, is determined by variety/genotype of grain and environmental factors (Swanston et al., 2005). The presence of different alleles in the genetic code of corn can affect factors such as fermentability, as seen in barley (Meyer et al., 2001). Different alleles contributed by differences in variety can also affect other phenotypic variations, such as aroma and flavor. Some phenotypic properties have been used to predict spirit yield for wheat in Scotch whisky. Along with an increased alcohol yield, differences in fermentation caused by either variety or location growth factors, nonvolatile substrates can be formed that may be used as metabolites by yeast during fermentation that will contribute to aroma or flavor after distillation (Hucker et al., 2011; Taylor and Roscrow, 1990).

Carbohydrate content can influence the aroma and flavor development based on how it interacts with the yeast strain used for fermentation. Certain grains have a starch composition that is more easily broken down by enzymes, which allows for smaller starch chains that are more readily available for yeast to convert to alcohol (Balcerek et al., 2016; Vriesekoop et al., 2010). During different processing steps, macronutrients, from the grain are carried over and contribute to the flavor and aroma by acting as precursors in yeast metabolism (Paterson et al., 2003). Starch is found in the endosperm of grain and comprised of two main structures: linear amylose and branched amylopectin. Amylase exists in a linear form comprised of α-1, 4-D glucan units and amylopectin is made of α-1, 4-D glucan units (chain) and α-1, 6-glucan units (branch points). During mashing, different regions of the starch granule undergo gelatinization and leach, making enzyme access to the starch easier. Degradation of cell walls in the endosperm is necessary for optimal extraction of starch (Paterson et al., 2003). The differences observed in the same type of grain used for distilling can be due to the different composition and structural arrangement of macronutrients, such as the degree of polymerization within the same population of grain, and differences in starch composition can affect starch's functionality with enzymes and yeast (Balcerek et al., 2016).

Although the most considered factors for alcohol production are polysaccharides, yeast cells still require proteins in the form of amino acid, peptides, minerals, and vitamins, and lipids in anaerobic conditions for optimal growth (Berry and Slaughter, 2003). Protein, and associated nitrogen content, is usually undesirable from a distillation view as higher nitrogen content has been associated with lower alcohol yield, but also because increased protein in a grain means that less of the grain is carbohydrate (Bathgate et al., 1978). Swanston et al. (2007) found that environment impacted the alcohol yield, primarily through protein content, in wheat; when grain nitrogen levels rose, spirit yield declined. Awole et al. (2012) also confirmed that protein concentration affects the amount of spirit yield from a grain. Nitrogen content from the environment was found to be negatively associated to alcohol production, and was more impactful than nitrogen content in maize (Agu et al., 2008; Swanston et al., 2007). In barley, environment can affect the proportion of macronutrient composition within the same variety, and even the same grain, affecting the amount of starch heavy grains and protein heavy grains (Agu et al., 2012). Inconsistent, complex composition of grains, such as Oxbridge barley make it difficult to process the grain into mash or wort, due to the different proportions of starch-rich (mealy grains), and protein-rich (steely grains) in the individual grains (Agu et al., 2012). Higher protein, steely grain has reduced accessibility to the endosperm and therefore is less accessible for enzymes to break down the starch fraction (Paterson et al., 2003). Increased grain nitrogen will affect spirit yield during the initial processing stages. The grains must be heated to release starch to be broken down by enzymes and yeast. Maillard reactions can also occur depending on processing, and will reduce the amount of reducing sugars for yeasts to convert to alcohol (Agu et al., 2008). Malt has a similar relationship with nitrogen content as wheat, and it was postulated by Bathgate et al. (1978) that excess nitrogen can be involved in melanoidin-producing pigments (i.e., Maillard reactions) reducing the amount of available reducing sugars.

Paterson et al. (2003) identified the zeins as the important proteins in maize endosperm, comprised of glutamine, leucine, alanine, proline, and methionine, but low in lysine. And while wheat has become more prominent in distilling, it has required more information on how to properly process it. For example, wheats' spirit yield is affected by nitrogen content, grain size and grain shape, and residue viscosity impacts later stages of processing (Agu et al., 2008; Awole et al., 2012).

Paterson et al. (2003), outlined the three types of fat found in grain as non-starch, which primarily function as part of the membrane, starch-surface, which are produced from non-starch lipids are responsible for starch-lipid complexes, and internal lipids, lysophospholipids comprised in different concentrations according to grain. Although lipids do not contribute to fermentability, they are vital in the formation of flavor active ketones (Paterson et al., 2003).

Thousand corn weight, and the grains' length-to-width ratio were good predictors for spirit yield (Swanston et al., 2005). Variety in wheat was a better predictor of starch content and release of starch granules than environment, but not a good predictor for alcohol yield, and testing for varietal differences is difficult to perform (Swanston et al., 2007). Grain size and its ability to absorb water at a constant rate can affect spirit yield. Agu et al. (2012) studied the differences in water uptake in barley and saw that different varieties have different rates of water absorption needed in the malting process, and the optimal amount of water for good quality malt depended on the rate; rapid water absorption required less steeping time and water, which is an advantage when properly controlled. It is conceivable that this grain would have some negative effects, however, such as pre-harvest sprouting in the head in the field.

Environment has also been held responsible for differences in specific weight, the product of the grain's density and its packing efficiency, considered to be a good predictor of spirit yield, and was affected by weather during the stages of grain growth and ripening (Awole et al., 2012). The presence of herbicides, minerals, and fertilizers used in the field can affect grain, but it may also affect the grains fermentability, as found by Basso et al. (2011). These factors can affect the grains fermentability based on changes to the grain that will inhibit or promote alcohol production through yeast metabolism. If the environment contributed minerals, nitrogen from fertilizers, or external compounds from herbicides that exceed the yeasts' metabolic requirements or induce stress on the yeast cells, alcohol production could decrease compared to a non-stressed cell (Basso et al., 2011).

Other factors that Swanston et al. (2007) state influenced alcohol production was the size of the starch granule, texture of the endosperm, and the accessibility/release to the starch granules. Kosik et al. (2017) also investigated the changes in arabinoxylan in wheat compared to corn before and after the fermentation and distillation process and described differences in concentration as a mechanism of molecular structure of the starch.

Balcerek et al. (2016) lists factors that affect spirit quality as the type and quality of raw materials, method of starch release from raw materials starch degradation, type of yeast, and fermentation and distillation conditions. As in most agricultural and food products, moisture content is the leading quality determining factor as it can impact the growth of microorganisms and molds on raw materials and finished products. Grain is inspected and must meet a certain quality standard in order to be accepted for distillation use. Grain is ground to produce a grist, which is not too fine of a grind as to reduce the necessary number or filtrations (Paterson et al., 2003; Piggott and Conner, 2003). Reducing the grain size allows easier starch leaching from the grain and easier access for enzymes added in during the mashing phase to more easily break down starch to smaller chains that yeast can ferment. Green et al. (2015) confirmed that grinding to a coarse grind for maize was optimal over a finer grind. Mashing is a critical phase in processing, where the grain undergoes heating in water in order to release starch content (Paterson et al., 2003). Maize is heated to high temperatures to gelatinize and release starch from the grain and make it accessible to yeast fermentation (Agu et al., 2008). Maize requires higher heating conditions than wheat, because of the higher resistance to degradation observed in wheat (Green et al., 2015). Due to the ordering of starch, different parts of the granule will gelatinize faster (Paterson et al., 2003).

Temperature processing can also affect the amount of spirit yield and residue in maize, though not as drastically as in wheat. Agu et al. (2008) tested maize samples and found that different processing temperatures generated different amounts of alcohol, and differences in alcohol yield were attributed to differences in variety.

In spirit processing, enzymes are either added from an external source or are already present in a cereal grain (e.g., malted grains) and are used to hydrolyze starch.

The most common sources of starch degrading enzymes are fungi, microorganisms, and plants (Parkin, 2008). Depending on the country of origin, the enzymes used may be from an external source, such as a commercial amylase enzyme, or they must be endogenous enzymes provided by malted grain (Balcerek et al., 2016). Malted grains, which are grains that have begun to germinate, are one of the main sources of enzyme addition in spirit processing. Different starch hydrolyzing enzymes have different mechanisms through which they act on the starch during hydrolysis of a starch.

The main enzymes used during starch hydrolysis are α-amylase, β-amylases, glucoamylase, and their isoamylases (Berry and Slaughter 2003; Hanes, 1932; Parkin, 2008). α-amylase is an endo-acting enzyme used to rapidly decrease molecular weight of starch; it works by cleaving α-1,4-glucosydic bonds, leaving small polysaccharide chains of 2 – 12 glucose units with a reducing and non-reducing end (Parkin, 2008). Exo-acting β-amylases begin hydrolyzing starch units from non-reducing ends, either from amylopectin or amylase or from polysaccharides created from α-amylase activity. The results of α-amylase is higher quantity of glucose and maltotriose, whereas β-amylase results in higher quantities of maltose (Balcerek et al., 2016; Hanes, 1932). Glucoamylase (also known as β-glucose amylase) is an exo-acting enzyme, but differs from β-amylase in that it can hydrolyze both α -1,4- and α-1,6-glycosidic linkages, and theoretically is the sole enzyme capable of hydrolyzing starch oligosaccharides to singular glucose units through exhaustive enzymatic use (Parkin, 2008). Both β-amylases and glucoamylase cause the bonds to mutaroate from α-glucose bonds to β-glucose bonds, and both require non-reducing ends (created rapidly by α-amylase) in order to function. Finally, pullulanase, is a debranching isoamylase that acts on > 3 glucose unit dextrins hydrolyzing α-1,6- bonds creating linear dextrin units (Parking, 2008).

Through combined use of all enzymes, starch can be hydrolyzed to small dextrin units and made accessible to yeast as a nutritive source during fermentation. However, high amounts of products created by each enzyme cause decreased enzyme function, inhibiting complete hydrolysis of starch. Enzymes of the same class from different sources (e.g., fungal vs. microbial vs. plant material) have different functional operating procedures and temperature and pH ranges. Distillation generally occurs at different temperature steps to allow different enzymes, which function at different temperature ranges, to hydrolyze starch through different mechanisms to hydrolyze as much of the starch as possible (Balcerek et al., 2016). Enzymes, combined with a heated pressurized process, act on starch granules by cleaving the long amylose chains or amylopectin branches into shorter, fermentable sugars. This is an important step because yeast is only able to use short polysaccharides or low molecular weight dextrins in the fermentation process (Basso et al., 2011).

Once the mash is depleted of oxygen, anaerobic fermentation and alcohol production begin. Just as different sources of enzymes had different functional properties, different strains of *Saccharomyces cerevisiae* (*S. cerevisiae*) will display different operative stress tolerance properties, and contribute a different flavor profiles based on metabolites created during fermentation (Basso et al., 2011). The typical fermentation time for maize fermentation in whiskey processing is about 40 to 50 hours, but type of batch can affect the total time, as well as the amount of alcohol produced by the yeast (Basso et al., 2011). Yeast ferments dextrins to alcohol and carbon dioxide in an anaerobic environment. The most fermentable sugar by yeast is maltose, followed by maltotriose and glucose, which are common mono- and di-saccharides produced through enzymatic hydrolysis of starch (Berry and Slaughter, 2003; Hanes, 1932; Parkin, 2008). Yeast has the highest dextrin consumption rate at its optimal operating ranges, but an excess of fermentable sugars will not drastically increase the consumption rate at its optimal function. However, if the starch content is not properly hydrolyzed to fermentable sugars, rate of fermentation will be inhibited; yeast has enzymes capable of hydrolyzing polysaccharides, but yeast enzymatic hydrolysis is much slower, and the presence of specific sugars will further affect the rate.

Along with starch, protein and fat, the mineral content also affects the yeast's ability to ferment the simple carbohydrates. Protein in the form of peptides and amino acids are necessary for yeast metabolism and access to sufficient free amino nitrogen will reduce the occurrence of stuck fermentation (Balcerek et al., 2016). Stuck fermentation is the end of all fermentation functions, due to lack of substrates for yeast metabolism (Berry and Slaughter, 2003). Besides producing alcohol, yeast is credited for contributing a large component of aroma components and substrates that will later be converted to aromatic compounds. An example of yeast contributing aroma compounds is the presence of 3-methylbutanol and 2-phenylethanol, which occur due to amino acid degradation by yeast (Poisson and Schieberle, 2008). *S. cerevisiae* is capable of undergoing alcohol production efficiently and produces mostly ethanol, but will also produce byproducts, including glycerol, organic acids, and flavor compounds (Berry and Slaughter, 2003). Fermentation can continue to produce alcohol as long as a polysaccharide source is available, but the high content of alcohol will reduce the rate of alcohol production. The end of fermentation is marked by the autolysis of the yeast cells, during which the cell will decompose into peptides, amino acids, fatty acids, and other cell products (Berry and Slaughter, 2003). Most of these decomposition products will carry over during distillation and affect flavor and aroma development.

Alcohol production acts as a feedback inhibitor, because yeast will be unable to survive in a high alcohol environment. Alcohol content is measured by specific gravity, and typical fermentation continues until specific gravity is less than 1 (~12% alcohol), but some yeasts have been selected specifically for very high alcohol tolerance (Pereira et al., 2010).

Basso et al. (2011) describes how alcohol produced during fermentation decreases yeast cell growth, interrupts the electrochemical gradient of the cell membrane, and decreases cell viability. Osmotic pressure (i.e., amount of soluble and insoluble solids in the solution), temperature, and pH will also act as enzyme regulators, as yeasts will have optimal functioning ranges (Basso et al., 2011). The amount of sugar and other soluble and insoluble solids in the solution determine the osmotic pressure of the solution and affect yeasts rate of consumption of polysaccharides and other macronutrients (Basso et al., 2011). Minerals contribute to osmotic pressure in the solution. Mineral content, particularly magnesium, potassium, calcium, and salts, can affect the yeasts' biological functions, and if the minerals exceed the yeasts' requirements, yeasts undergo stress and lower alcohol yield is observed (Basso et al., 2011).

The most common types of fermentation batch processes are continuous-fed fermentation and fed-batch fermentation. In fed-batch (i.e batch) processing, the grain is mashed then transferred to allow for cooling before malt is introduced; in continuous processing, the mashing and malt or enzyme introduction occur simultaneously (Piggott and Conner, 2003)

There are two common distillation methods that contribute different characters to the new-make whiskey: batch or pot distillation and continuous distillation. Pot distillation is comprised of a pot, swan neck and lyne arm, and a condenser. The mash or wort is heated in the pot and components of lower boiling evaporate up the swan neck and lyne arm. The cooling applied to the condenser return the gas to liquid to be collected. Continuous distillation occurs in a Coffey still, which contains two columns mounted side by side (Piggott and Conner, 2003). Continuous distillation allows for the separation of the fusel alcohol portion or tails, to be collected separately from the foreshot (also referred as the heads) and feints. Continuous distillation results in a higher alcohol strength and lighter character new-make whiskey, whereas pot distillation has a highly-flavored distillate (Piggott and Conner, 2003). The first collection is referred to as a wash and produces low wine. The low wines will undergo distillation a second time in a similar process as the wash, in which the middle cut, known as the hearts, is collected. The hearts are what comprise new-make whiskey. Copper is used in a still due to its ease of heat conduction, but has also been associated with the reduction of undesirable sulfur aroma and improved ester aroma (Piggott and Conner, 2003).

Distillation can affect flavor in several ways. The type of distillation, such as continuous or batch distillation can lend the whiskey a different character. Kew et al. (2017) note that in Scotch whisky, grain whiskey is generally distilled through continuous process, and malt whisky is distilled through batch distillation. This creates several differences, which may be attributed to different factors (grain versus malt as a distilling grain, and distillation strength being higher in continuous distillation), but the overall effect is that grain new-make whiskey has a lighter sensory profile (Kew et al., 2017).

Poisson and Schieberle (2008) researched the impact of each processing step on aroma compound formation, but stated the difficulty of identifying all aroma compounds at all steps. The presence of external bacteria may also affect yeast efficacy and the bacterial metabolites may taint the final products. *Lactobacillus* is the most common microorganism to find in large quantities in industrial processing settings (Basso et al., 2011). In fed-batch or batch fermentation, bacteria that survive the mashing temperatures will be viable during fermentation and may compete with yeast for nutrients (Balcerek et al., 2016). The presence of the bacteria can increase production costs, interfere with normal processing functions, and affect final product palatability, and troubleshooting the effects of the bacteria can be a costly endeavor.

One of the major influences of aroma and flavor in finished whiskey is wood aging. Depending on the country of origin, whiskey must be aged for a minimum of three years in order to be called whiskey. Since the early 1900s, the effects of aging and flavor were investigated, and the wood from the charred cask was seen to act as a membrane, which would interact with water, short chain alcohols, long chain alcohols, and other chemical constituents at different rates (Crampton and Tolman, 1908). Two of the most important and distinct chemicals from wood aging that contribute aroma are cis-whisky lactone and vanillin (Connor et al., 2001), with the former being higher in Bourbon due to the use of a new charred barrel. Sensory assessment is the most reliable way to track the progress of aging (Piggott and Conner, 2003). Bourbon and rye whiskies require a new charred cask for aging, whereas Scotch whiskey and Irish whiskey repurpose casks used in different maturations (bourbon, sherry, wine). The amount of char, as well as the amount of times a cask has been reused will affect the amount of extractables from wood and the flavor and aroma development capable of being imparted on the whiskey. Piggott and Conner (2003) stated that volatile compounds are developed throughout fermentation and distillation, with the addition of a wood or oak volatile attribute. However, the major contribution of aging lies in the nonvolatile fraction and their effect on the congeners already present from fermentation and distillation (Piggott and Conner, 2003). Aging can also help smooth the volatile compounds, specifically sulfur compounds, to yield a less pungent spirit (Masuda and Nishimura, 1981).

"All of the variables involved in whisky production contribute to the overall chemical composition and sensory profile of the final product," (Kew et al., 2017).

Despite the heavy use of corn as a main grain in most whiskey production, not much work has been done on the impact of corn on aroma and flavor in whiskey and Bourbon production, when compared to that of rye, barley, and wheat by the SWRI (Agu et al., 2012; Bringhurst et al., 2008; Waugh, 2010).

The raw ingredients can contribute a large component of the chemical composition of whiskey. Crampton and Tolman (1908) found that rye whiskey and bourbon aged in the same warehouse and in the same conditions had higher solid content, which consisted primarily of acids and esters. The norisoprenoids R- and -ionone found in whiskey samples were also identified as important volatiles, and the precursor was discovered to be contributed by maize grain (LaRoe et al., 1970). The formation of the aromatic compound, (*E*)-β-damascenone, contributing a desirable, cooked apple aroma was traced back to the acid catalyzation of 3-hydroxy-7,8-dihydro-β-ionol, an alcohol found in cereal grains used for distilling (Baderscheider et al., 1997). Grains contribute to the character and aroma of a whiskey by contributing material for congener creation (Goldberg et al., 1999).

During fermentation, the synthesis of ethanol and carbon dioxide, and intermediates of flavor and aroma, such as alcohols, esters, organic acids, fatty acids, and carbonyl compounds were created (Balcerek et al., 2016). Ethanol, higher alcohols, and their isomers were the main products produced after fermentation. Higher alcohols were produced under optimal fermentation conditions from amino acid degradation, and contribute different aromas based on the specific amino acid base (Berry and Slaughter, 2003). Amino acids also served as substrate for the development of fusel alcohols, which contributed volatile compounds formed during distillation (Nykänen, 1986). Fusel alcohols are aliphatic and aromatic alcohols, and their presence was higher in spirits with high amyl alcohol content, such as Bourbon whiskey (Nykänen, 1986).

Congeners in distilled spirit often impact the aroma and flavor directly by contributing to the flavor and aroma composition or as metabolites during aging process that interact with wood products to render the final whiskey product (Jack and Fotheringham, 2004). They may also influence the intensity at which aroma and flavor were detected; they may act as a barrier for aroma if congener levels were too high at a higher proof, or be below detection if they are present in low levels. Conner et al. (1999) found that higher chain length esters could decrease volatile activity in the headspace of a sample, muting the intensity of aroma experienced. Congeners can vary throughout production, either through presence in the starting material (i.e., corn, yeast) or developed during fermentation or distillation processes.

Differences from variety or environment in macro and micronutrients can lead to the development of different levels or types of congeners (Aylott, 2003). Congeners, such as higher-alcohols, are contributed to the unique identity of a whiskey and can be used as key compounds for authentication and differentiation between whiskeys of different origins, ingredients, and processes (Fitzgerald et al., 2000; González-Arjona et al., 1999;).

An example of varietal and environmental contribution is the differences experienced in fatty acid content and carbohydrate constituents. Fatty acids present in the cereal can provide aromatic chemicals through oxidation processes, as well as through the generation of fatty acid ethyl esters. Fatty acids can be oxidized in malting of the cereal grain, during yeast fermentation, and during aging interaction with wood components (Poisson and Schieberle, 2008). When fatty acids, such as linoleic and linolenic acids, are oxidized during malting and distillation, different aldehydes are created, such as (*E*)-2-nonenal (Poisson and Schieberle, 2008). Fatty acids unique to a grain can carry over to the distilled product and contribute as a volatile or semi volatile compound, such as lauric and capric acids (Fitzgerald et al., 2000). Fatty acids react with ethanol during fermentation and distillation to form fatty acid ethyl esters, which are major aromatic compounds in new make spirit and whiskey (Goss et al., 1999; Jounela-Erikson and Lehtonen, 2012). During distillation, the fatty acid ethyl esters react and contribute ester-y characters, which can range from desirable fruity, floral notes, to chemical/solvent-like such as acetone and plastic depending on the chain length (Willnert et al., 2013; Conner et al., 1998; Poisson and Schieberle, 2008). Fatty acids directly contribute to ester flavor development during distillation, and can be enhanced by promoting conditions that reduce oxygen to the yeast cells (Berry and Slaughter, 2003).

Free fatty acids can also complex with starch (amylose) creating V complexes (Paterson et al., 2003). This complex increased the presence of fatty acids in fermented products that can be used in the formation of ethyl esters during distillation (Nykänen, 1986). V complex may also decrease the amount of fermentable sugar for alcohol conversion by yeast.

Poisson and Schieberle (2008) stated that more than 300 volatile compounds can be identified in a variety of whiskies, most of which are donated or altered during aging in wooden casks. The main classes of compounds that contribute aroma are alcohols, aldehydes, ketones, acids, esters, and phenols (Leake and Silverman 1971; Nykänen and Suomalainen, 1963; Poisson and Schieberle, 2008). Balcerek et al. (2016) investigated the production of several volatile compounds and found that processing influenced the propagation of key volatile compounds, such as diacetyl and furfural. Esters were also found to be a prominent volatile compound, but were not significant to either the ingredients or the processing (Balcerek et al., 2016). Carbonyl compounds have a low threshold and are undesirable in large quantities. Nykänen (1986) identified acetaldehyde and ketoacids as the leading carbonyl compounds produced during fermentation. Sulfur-containing compounds are products of the raw materials, but can also be created through yeast fermentation depending on the strain. Similar to carbonyl compounds, high quantities of sulfur compounds can be undesirable, but can be mediated by process manipulation and carbon dioxide production (Berry and Slaughter, 2003).

Not all volatile compounds are detectable by human odor receptors, so many researchers have identified odor-contributing compounds and paired them with a sensory descriptor to be able to identify which volatiles are key odorants (Poisson and Schieberle, 2008).

Sensory science techniques help connect consumer and distiller communications. Sensory techniques were developed to characterize and differentiate whiskeys, as well as to understand the resulting beverage of the distillation process. Piggott and Jardine (1979) conducted a study to develop terminology that properly described attributes in whiskey without the use of redundant terms, and were then able to categorize different whiskeys with different base ingredients and produced in different geographical locations on the aromas present in the whiskeys. The development of sensory terms with an associated chemical compound facilitates communication between consumers and whiskey producers (Piggott and Jardine, 1979). The SWRI used the developed terms to create a flavor wheel with different tiers accessible to different audiences based on familiarity with the potable spirit. The SWRI flavor mapped the Scotch whiskeys and spirits on a biplot according to the flavor/aroma terms, but consistency among descriptions were lacking and results were subjective and relied on the evaluators' experience and preference (Lee et al., 2000a). The need for sensory analysis led to standardization of nosing techniques for consistent evaluation of samples, but a need for consistent language in evaluation will improve sample evaluation even further (Harrison et al., 2011; Piggott and Jardine, 1979). The use of clear language to describe aromas and flavors in whiskey will help distillers communicate product distinctions with consumers, and for consumers to communicate what they want in a product to distillers.

Whiskey is a complex product with a lot of aroma and flavor development at every stage of production, from crop production to aging. Though varietal and environmental effects have been explored in major distilling grains (wheat, barley, rye), not much has been done on distilling qualities of different corn varieties or growth locations (Aufhammer et al., 1993; Awole et al., 2012; Swanston et al., 2007; Swanston et al., 2012; Swanston et al., 2014; Taylor and Roscrow, 1990). Much work has been done to generate terms for flavors and aromas present in whiskey and spirits, but not much has been done in the way of developing a lexicon; past aroma studies indicated that a lexicon development would allow uniform whiskey description across the industry (Donnell et al., 2001; Lee et al., 2000b; Piggott and Jardine, 1979; Piggott and Paterson, 1988). Additionally, not much has been done for Bourbon; whereas the Scotch industry is well established and smaller distilleries contribute to innovation and research, the popularity and creation of micro distilleries has only recently begun to occur for Bourbon (Kahla and Croker, 2014). Due to different ingredient composition and processing, differences can be detected between Scotch whiskeys and Bourbon and American whiskeys (Poisson and Schieberle, 2008). Having identified attributes in Bourbon/American whiskey specific lexicons would allow producers to have deeper insight into their product and processes that influence aroma and flavor development. This would also provide the opportunity for distillers to develop recipes or processes that will allow their product to be distinguishable from others on the market and help the American whiskey/Bourbon industry to continue to grow. By understanding how aroma and flavor development are affected up to the new-make whiskey level, the aroma contributions can be investigated. The objective of this research was to develop a lexicon that could identify and quantify aroma in new-make whiskey and to determine if the aroma was influenced by differences in maize variety or geographical location. It is hypothesized that variety and environment impacted aroma of new make spirit.

2. MATERIALS AND METHODS

2.1. New-make whiskey

This component of the experiment was conducted by R. Arnold, who also contributed the text.

New-make whiskey was produced by a head distiller at Firestone & Robertson Distilling Company (Fort Worth, TX). New-make samples were made from three varieties of yellow dent corn from three commercial producers (D57VP51 – Dyna-Gro; 2C797 – Mycogen; REV25BHR26 – Terral Seed) grown in three different locations (Texas AgriLife Extension, Calhoun, Calhoun County, TX; Rio Farms, Monte Alto, Hidalgo County, TX; Sawyer Farms, Hillsboro, Hill County, TX); an additional location (Perryton, Ochiltree County, TX) was selected to grow one of the varieties (REV25BHR26 – Terral Seed).

For processing each batch, whole corn kernel samples were initially sieved through a 0.48 cm round commercial hand sieve (Seedburo Equipment Company) to remove broken kernels. Foreign material and heat-damaged kernels were manually removed via inspection. The remaining kernels were then milled using a Victoria Plate Mill, and then sieved 3X through a 2000 micrometer screen to ensure that the milled grain was fine and consistent from batch-to-batch. A 3 L beaker was then filled with 1750 g of carbon-filtered municipal water. Mixing was commenced with a mechanical mixer (100W-LAB-SM, Gizmo Supply Co.), the temperature of the water was brought to 65^{o}C using a 120V hot plate with infinite heat controls (CSR-3T, Cadco) set to medium. Then 448 g of milled corn and 2 mL of high-temperature alpha amylase (AHA-

400, FermSolutions Inc.) were added to the beaker. A cover slip that still allowed the mechanical mixer to operate was placed on top of the beaker to prevent excessive evaporation. The temperature of the mash was brought to 85°C and held for 1.5 h. After incubation, an indirect ice bath was used to bring the temperature of the mash to 32°C. Once 32°C was achieved, 1.5 mL of glucoamylase (GA-150, FermSolutions Inc.) was added. Immediately after, 0.26 g of active dry yeast (Species: *Saccharomyces cerevisiae*; Strain: RHB-422, F&R Distilling Co.'s proprietary strain) was added. The mash was further cooled to 24°C using an indirect ice bath and mixed for an additional 10 min. The pH (pH 220C, EXTECH) and specific gravity (SNAP 50 density meter, Anton Paar) were recorded using aseptic techniques. Mixing was then halted, the mash was transferred to a 2.7 L Fernback flask that had been sanitized with Star-San (phosphoric acid based, no rinse sanitizer), and the flask was covered with flame sterilized aluminum foil. The mash was then weighed to ensure that there were no major inconsistencies in starting volume from batch to batch. Fermentation proceeded for 120 h, with pH and specific gravity recorded twice during fermentation, and at the end of fermentation. The fermented mash, now called "distiller's beer" or just "beer", was frozen at -20°C.

For distillation, beer was rapidly thawed, and 1.65 L were added to the stripping still, which was a stainless steel still with an air fan cooled condenser and an electric, indirect heating element (Air Still, Still Spirits). Distillation proceeded until 550 mL of distillate (termed "low-wines" was collected in a grade A volumetric flask. The alcohol concentration by volume of the low-wines was measured using a density meter (DMA-5000, Anton Paar). Using weight, low-wines were diluted to the desired alcohol concentration with the addition of water. The spirit still, which was a copper alembic style still with a worm coil condenser and no innate heating element (heat was supplied using the Cadco CSR-3T 120V hot plate with infinite heat controls and set to medium for the spirit run), was charged with 500 mL of low-wines (weight was used to measure 500 mL). The condenser was filled with ice water. Distillation commenced, and the first 25 mL of distillate (termed the "heads") was collected using a grade A volumetric flask. Using a different grade A volumetric flask, the next 100 mL of distillate (termed the "hearts") was then collected. The condenser was monitored to ensure the temperature of the distillate was consistent from batch-to-batch. The hearts distillate was then stored in Boston round glass bottles with inert caps at room temperature until further processing.

It was determined from previous research that to ensure consistency, the stills needed to be cleaned throughout the experiment according to the following methods. Before experiment commencement and after at least every 3rd distillation, the stainless stripping still was cleaned by distilling 2% (80 mL of 50% caustic topped off to 2 L) caustic solution (50286, Chemstation) for 30 min, then scrubbed with an abrasive pad, and finally washed thoroughly with RO water. Before commencement and after at least every 3rd distillation, the copper spirit still was cleaned by distilling 2% (40 mL of 50% caustic topped off to 1 L) caustic solution (50286, Chemstation) for 15 min. The heat was then turned off and the caustic was soaked for an additional 15 min, after which the still pot and swan neck were be scrubbed with an abrasive pad and washed thoroughly with RO water.

This design resulted in ten treatments (3 maize varieties x 3 geographical location + 1 maize variety/1 geographical), and each treatment was processed in biological triplicates, creating 30 batches total. Each treatment was prepared for expert, trained descriptive attribute flavor evaluation, chemical aroma volatile analysis; and proximate analysis and fatty acid analyses.

2.2. Expert, trained descriptive whiskey aroma analysis

A whiskey lexicon was developed based on 28 commercial spirits (14 whiskeys from different grain origins, 15 miscellaneous spirits) and 21 new-make whiskeys. The focus was on whiskey and new-make whiskey, but other miscellaneous spirts (amaretto, cachaça, flavored liqueurs, gin, ouzo, rum, Sambuca, triple sec, vermouth, vodka) were used to cover attributes not commonly found in whiskey or new-make (Appendix A). An additional attribute (barnyard, Appendix B) was added for maize evaluation. Other sources used to develop attributes were from new-make whiskey published literature and existing, published lexicons to encompass alcohol and spirits (Adhikari et al., 2011; World Coffee Research, 2016). This developed lexicon focused on flavors and aromas found in American whiskey, Bourbon, and new-make whiskey. New-make whiskeys and maize were evaluated by a 7-member, expert trained whiskey aroma descriptive attribute panel that helped develop and validate the World Coffee Research (WCR) coffee lexicon and were with the WCR International Multilocation Variety Trial (IMVT). Training and testing samples were evaluated in a consensus style of testing; panelists were seated around a rectangular in a room separate from where samples were prepared. Training and testing did not employ the use of altered lighting conditions. This panel helped develop and was trained using the whiskey lexicon for 31 d or 62 hours, followed by a validation trial that lasted 3 d or 6 hours prior to testing. Following the evaluation of the new-make whiskey samples, panelists trained for 3 d on maize samples using the new-make whiskey lexicon. Whiskey and maize aroma attributes were measured using the whiskey lexicon (0 = none and 15 = extremely intense) defined in Appendix B. After training was complete, panelists were presented three to four new make samples per day for eight days, and six maize samples a day for 5 d in two-hour sessions. Panelists evaluated new-make whiskey samples individually (Appendix C, Appendix D), and reached consensus on attributes and intensities. Prior to the start of each trained panel maize evaluation day, panelists were calibrated using one orientation or “warm up” sample that was evaluated and discussed orally. After evaluation of the orientation/warm up sample, panelists were served the first sample of the session and asked to individually rate the sample for each maize/whiskey aroma lexicon attribute. References were available at all times during training and evaluation. Steamed cotton towels were available for cleansing the nasal palette during evaluation of samples. New-make samples were prepared no more than 15 minutes prior to serving by diluting original strength new-make whiskey (~125 proof, 62.5% alcohol by volume) with double distilled deionized water to testing strength used in the industry (40 proof, 20% alcohol by volume; Jack, 2003). Each panelist was served 8 mL of the diluted sample in a nosing glass (grappa or tulip glass) covered with a watch glass to concentrate volatiles. Maize samples were ground at most two hours prior to evaluation. Each panelist was served 10 g of ground maize sample in a medium snifter glass covered with a watch glass to concentrate volatiles. Samples were identified with random three-digit codes and served in random order.

2.3. New-make whiskey and maize volatile aroma evaluation

Volatiles were captured from the same new-make whiskey and maize samples evaluated by the expert, trained descriptive panel. After samples were prepared for panelists, approximately 80 g of new-make whiskey and 40 g of maize were placed in heated glass jars (473 mL, new-make; 236 mL, maize) with a Teflon lid under the metal screw-top to avoid off-aromas. The headspace was collected with a solid-phase micro-extraction (SPME) portable field sampler (Supelco 504831, 75 μm Carboxen/ polydimethylsiloxane, Sigma-Aldrich, St. Louis, Mo). The headspace above each new-make and maize sample in the glass jar was collected for 2 h for each sample at room temperature at approximately 21°C; new-make samples were mixed at low speeds on a laboratory stirrer hot plate (Model P.C.- 351,120 V, Corning Glass Works, Corning, NY).

Volatiles were evaluated using the Aroma Trax gas chromatograph/mass spectrophotometer system with dual sniff ports for characterization of aromatics (MicroAnalytics-Aromatrax, Round Rock, Tx). This technology provided the opportunity to separate individual volatile compounds, identify their chemical structure and characterize the aroma/flavor associated with the compound. Upon completion of collection, the SPME was injected in the injection port of the GC where the sample was desorbed at 280°C. The sample was then loaded onto the multi-dimensional gas chromatograph into the first column (30m X 0.53mm ID/ BPX5 [5% Phenyl Polysilphenylene-siloxane] X 0.5 μm, SGE Analytical Sciences, Austin, TX). The temperature started at 40°C and increased at a rate of 7°C/minute until reaching 260°C. Upon passing through the first column, compounds were sent to the second column ([30m X 0.53mm ID; BP20- Polyethylene Glycol] X 0.50 μm, SGE Analytical Sciences, Austin, TX). The gas chromatography column then split into three different columns at a three-way valve with one going to the mass spectrometer (Agilient Technologies 5975 Series MSD, Santa Clara, CA) and two going to the two humidified sniff ports with glass nose pieces heated to 115°C. The sniff ports and software for determining flavor and aroma were part of the AromaTrax program (MicroAnalytics-Aromatrax, Round Rock, Tx). Panelists were trained to accurately use the Aromatrax software.

2.4. Maize chemical analyses

Fatty acid composition and proximate analysis of maize samples were determined from each variety x location treatment. Total fatty acid and polar fatty acids were separated as reported in Demaree et al. (2002) and extracted by a modified Folch Method (Folch et al., 1957). Fatty acid methyl esters (FAME) were prepared from the lipid extracts as described by Morrison and Smith (1964). Approximately 5 g of ground maize was combined with 1 mL of 0.5 N KOH in MeOH and heated at 70 °C for 10 min. After cooling, 1 mL of Boron trifluoride (14%, wt/vol) was added to each sample, which was flushed with N_2, loosely capped, and heated at 70 °C for 30 min. The samples were removed from the bath, allowed to cool to room temperature, and 2 mL of HPLC grade hexane and 2 mL of saturated NaCl were added to the samples and the samples were vortexed. After phase separation, the upper phase was transferred to a tube containing 800 mg of Na_2SO_4 to remove moisture from the sample. An additional 2 mL of hexane was added to the tube with the saturated NaCl and the samples were vortexed again. The upper layer was transferred into the tube containing the Na_2SO_4. The hexane extract was transferred to glass scintillation vials. The sample was evaporated to dryness at 60 °C under N_2 gas, subsequently reconstituted with HPLC grade hexane, and analyzed using a Claus 500 GC (model Claus 500 GC fixed with a CP-8200 auto- sampler, Perkin Elmer., Shelton, CN). Separation of FAME was accomplished on a fused silica capillary column CP-7420 (100 m x 0.25 mm [i.d.]; Agilent J&W GC Columns., Santa Clara, California) with helium as the carrier gas (flow rate = 40.0 mL/min) with a split ratio of 1:100. The GC temperature started at 160°C for one minute, then increased four degrees per minute for 15 minutes until it reached 220°C with a total running time of 40 minutes. Injector and detector temperatures were at 270°C. Standard GLC-68D from Nu-Check Prep, Inc. (Elysian, MN) were used for identification of individual FAME. Individual FAME were quantified as a percentage of total FAME analyzed. All fatty acids normally occurring in maize, were identified by this procedure.

Near-Infrared Reflectance Spectroscopy was used for predicted values of protein, starch, lipid, and phosphorous of the maize samples. Whole kernels and ground maize samples were evaluated using a Thermo Scientific Antaris II FT-NIR (Thermo Fischer Scientific) using a sample spinner cup that held approximately 175g of whole kernel maize. Preparation of ground samples was as described in Meng et al. (2015). Approximately 175 grams of each maize sample were ground to 2 mm using a Polymix PX-MFC 90 D mill (Kinematica Ag, Eschbach, Germany) and further ground using a Cyclone sample mill (UDY Corporation) to 1-mm fineness. The first set of 10 whole kernels samples were run in triplicate with 128 scans and 10 ground maize samples were run in triplicate with 64 scans at ambient temperature. The predictions were made with calibrations created using primarily Texas grown maize and wet chemistry performed by Ward Laboratories in Kearny Nebraska. Reflectance measurements were taken by using a rotating cup that holds approximately 175g of maize over the instrument's integrating sphere module. Approximately, 3000 points across the spectrum, every 4 wave numbers, were collected for each sample scanned at a spectral range between 10,000 to 4,000 cm^{-1}. Predictions on starch, oil, crude protein, and phosphorus content were obtained from all ground sample spectra using an existing calibration developed on the machine.

2.5. Statistical analyses

The data was analyzed as a 3 x 3 + 1 factorial arrangement of a completely randomized design, using maize growth location and maize varieties as fixed effects for each analysis with the alpha value set at 0.05 using JMP12 (SAS Institute, Inc. Cary, NC) and SAS (v9.4, SAS Institute, Inc. Cary, NC). In the analyses containing Perryton, only the main effects were analyzed because of the unbalanced design. Additionally, Perryton was removed from the model so that the interaction effects of geographical location x variety could be tested. Trained panel results were analyzed using PROC

GLM with order included as a random effect in the model. Least squares means of maize growth location and maize variety for new-make whiskey and maize, fatty acids, and proximate analysis were reported. The alpha value was set at 0.05. Interactions were included in the model for analysis. Principle components analysis and partial least squares regression were conducted using JMP (version 13, SAS, Institute, Inc., Cary, NC).

3. RESULTS AND DISCUSSION

Maize growth locations and maize varieties were analyzed for new-make whiskey (NMW) and maize. Three locations, Calhoun County, Monte Alto, Sawyer Farms, grew three maize varieties, Dyna-Gro – D57VP51, Mycogen – 2 C797, or Terral Seed – REV25BHR26. One location (Perryton) grew only one of the varieties (Terral Seed – REV25BHR26). The complete experimental design is shown in Figure 1. During data analysis, location and variety were analyzed as main effects for all four locations and three varieties. Interaction analysis excluded the Perryton location, because it did not grow all three varieties of maize. Location and variety were run an additional time, as seen in Figure 2, without Perryton to balance the full effect of variety across locations.

3.1 Maize near-infrared reflectance spectroscopy (NIRS*)*

Near-Infrared Reflectance Spectroscopy (NIRS) was used to make predictions on ground maize (Table 1 and Table 2) and whole kernel maize (Table 3 and Table 4). The predictions of primary interest were for starch, protein, and fat.

3.1.1 NIRS by location for ground maize

Table 1 shows the analysis of four locations and three varieties for ground maize main effects (Figure 1); starch, crude protein, and fat were significant for locations and varieties. Monte Alto was highest (P = 0.01) in starch, followed by Perryton, with Calhoun County and Sawyer Farms lowest in starch. Crude protein and fat were highest (P = 0.001) in Perryton and Calhoun County, and lowest in Sawyer Farms. For ground maize varieties, starch was highest (P = 0.004) in Mycogen, and lowest in Dyna-Gro and Terral. Crude protein was highest (P = 0.001) in Terral, and lowest in Dyna-Gro and

Mycogen. Fat predictions were highest (*P* = 0.001) in Dyna-Gro and lowest in Mycogen and Terral varieties.

3.1.2 NIRS by location x variety for ground maize

Predictions of starch, crude protein, and fat were evaluated the experimental design represented by Figure 2; Perryton location was excluded from the model because it only grew Terral maize variety (Table 2). Starch content was highest (*P* = 0.001) in Monte Alto Mycogen and lowest in Calhoun County Dyna-Gro and Monte Alto Terral. The Mycogen variety tended to be high in Calhoun County and Monte Alto locations. Protein content was highest (*P* = 0.001) in Calhoun Dyna-Gro and lowest in Sawyer Farms Dyna-Gro. Fat content was highest (*P* = 0.001) in Calhoun Dyna-Gro and lowest in Sawyer Farms Terral.

3.1.3 NIRS by location and variety for whole maize kernel

Table 3 shows the starch, protein, and fat predictions of whole kernel maize divided by location and variety for the experimental model shown in Figure 1. Calhoun County, Monte Alto, and Sawyer Farms were highest (*P* = 0.01) in starch content, and Perryton was lowest in starch. Protein was highest (*P* = 0.001) in maize grown in Calhoun County and Perryton, and lowest in Monte Alto and Sawyer Farms. There were no significant values for fat content based on location. For varietal analysis starch was highest (*P* = 0.008) in Mycogen maize, than in Dyna-Gro or Terral maize. Protein was highest (*P* = 0.008) in Terral maize and lowest in Mycogen maize. Fat was highest (*P* = 0.001) in the Dyna-Gro maize variety and lowest in the Terral maize variety.

3.1.4. NIRS by location x variety whole maize kernel

For whole kernel interaction (Table 4), Perryton was excluded from the analysis (Figure 2). For whole kernel maize, starch was highest (*P* = 0.004) in Monte Alto Mycogen, and lowest in Calhoun County Terral. Crude protein was highest (*P* = 0.01) in Calhoun County Terral and lowest in Sawyer Farms Mycogen. Fat content was highest (*P* = 0.02) in Monte Alto Dyna-Gro and Sawyer Farms Dyna-Gro and lowest in Calhoun County Mycogen and Sawyer Farms Terral. The Dyna-Gro variety tended to be higher in fat content across all locations.

Starch is the highest considered factor in grain selection for predicted spirit yield (PSY) because it is fermentable. However, different factors also play a role in fermentability of starch, such as enzyme accessibility to the grains' endosperm, where starch is stored. The arrangement and composition of starch can also enzyme ability to hydrolyze starch into fermentable sugars.

3.2 Estimated percentage of alcohol by volume after fermentation

3.2.1 Estimated percentage of alcohol by volume for locations and varieties

Table 5 shows the fermentation data collected at Firestone & Robertson Distilling Co. Table 5 was used to provide explanations of ethanol, fusel alcohols, and proximate analysis. There were significant differences in estimated alcohol by volume (ABV) based on location and variety. Estimated ABV was high (*P* = 0.008) in maize grown in Sawyer Farms, and low in maize grown in Calhoun County and Monte Alto. Variety is also significant for estimated ABV. Mycogen and Terral have a higher (*P* = 0.02) estimated ABV than Dyna-Gro.

3.2.2 Estimated percentage of alcohol by volume for locations and varieties interaction

Table 6 shows the results of a location x variety interaction for estimated alcohol by volume (Figure 2). The highest (P = 0.006) alcohol content was found in Sawyer Farms Mycogen and the lowest alcohol content was Monte Alto Dyna-Gro. In Table 20 and Table 21, Sawyer Farms Mycogen did not have the highest starch prediction. The starch content and composition in Sawyer Farms Mycogen may have been more favorable to hydrolysis by enzymes or yeast, however, this study did not perform starch content or composition tests. Sawyer Farms Mycogen may have also provided different minerals and salts that would have allowed for easier breakdown of starch (Basso et al., 2015).

A factor that may affect alcohol production during fermentation is yeast. However, the NMW was produced by the same type of yeast (Species: Saccharomyces cerevisiae; Strain: RHB-422, F&R Distilling Co.'s proprietary strain), so differences experienced during fermentation are credited to differences caused by location of where maize was grown or the variety of maize. Protein can also play a role in alcohol production during fermentation. While yeast requires amino acids for proper metabolic function, an excess of protein makes starch less accessible in the endosperm as found by Paterson et al. (2003). The Sawyer Farms NMW had one of the lowest (P = 0.01) starch values of its ground maize predictions, along with Calhoun County, but also has the lowest (P = 0.001) crude protein content, which may explain why it had the highest estimated alcohol by volume. Fermentation data (Table 6) shows that estimated alcohol by volume was highest (P = 0.008) in Sawyer Farms (9.22%) and lowest in Calhoun

County (8.41), and Monte Alto (8.22%). The result from fermentation data show that while starch is useful as an alcohol predictor, it is not always reliable, or perhaps the NIRS predictions did not achieve the level of accuracy for this analysis. This was likely due to other factors affecting starch availability during fermentation. As discussed in earlier sections, protein and lipid composition can influence flavor development, and may also affect fermentation by interacting with yeast or fermentable sugar.

3.3. Maize fatty acids

3.3.1 Maize kernel lipid weight

Table 7 shows the results of the weight of the lipid portion from maize samples divided into locations and varieties. There were no significant (P = 0.29) differences in total lipid weight for either maize growth location or maize variety (Table 17). Polar lipid weight was significant for maize growth location, showing higher (P = 0.01) polar-lipid weight in maize samples from Calhoun County and lower polar-lipid weight in samples from Sawyer Farms. This agrees with Table 1, which shows Calhoun County had higher (P = 0.001) fat predictions than Sawyer Farms, however, this prediction covers total fat, not specific to polar lipid composition. There were no significant differences (P = 0.12) for polar lipid maize variety. Neutral lipid weights for maize growth location and maize variety were calculated by taking the difference of total lipids and polar lipids.

3.3.2 Maize kernel fatty acid composition by location

Calhoun County was not included in the analysis of fatty acids by location (Table 8). Palmitoleic acid was highest (P = 0.006) in total fatty acids in Perryton and Sawyer

Farms, and lowest in Monte Alto. Vaccenic acid was highest (P = 0.001) in maize grown in Perryton, and lowest in maize grown in Monte Alto and Sawyer Farms. Sawyer Farms maize was highest (P = 0.02) in Paullinic acid and maize from Monte Alto was lowest in Paullinic acid. Nervonic acid tended to be higher (P = 0.10) in Perryton than in the other growth locations. Linoleic acid was highest (P = 0.05) in maize grown in Sawyer Farms and lowest in maize grown in Monte Alto. γ-Linolenic acid was highest (P = 0.001) in maize grown in Sawyer Farms than in maize grown in Monte Alto or Perryton. Docosahexaenoic acid tended to be higher (P = 0.10) in Perryton than in the other growth locations.

For the polar fatty acid fraction, Gondoic acid tended (P =0.07) to be higher in lower in Monte Alto maize. Eicosadienoic acid tended (P = 0.09) to be high in Monte Alto maize. Nervonic acid tended (P = 0.10) to be high in Mycogen maize.

3.3.3 Maize kernel fatty acid composition by variety

Calhoun County was not included in the analysis of fatty acids by variety (Table 9). In polar fatty acid analysis for location, Fatty acid analysis for maize variety in total fatty acids had no significant differences, but γ-Linolenic acid tended (P = 0.09) to be high in Mycogen maize. Arachidonic acid tended (P = 0.09) to be high in Dyna-Gro maize. Eicosapentaenoic acid tended (P = 0.08) to be high in Mycogen maize. There were no significant differences across maize varieties for polar fatty acids.

In Table 8 and Table 9, out of 15 total fatty acids 10 are unsaturated and out 16 polar fatty acids 10 fatty acids are unsaturated. Unsaturated fatty acids oxidize more easily than saturated fatty acids, creating aldehydes, ketones, alcohols, acids, and furans

(Dashdorj et al., 2015). Also, the fatty acids which make up about 95% of the fatty acid composition are linoleic acid (~55%), oleic acid (~25%), and palmitic acid (~15%). Linoleic and oleic acid are unsaturated fatty acids, and they constituted 80% of fatty acid composition; unsaturated fatty acids are easily oxidized to produce aldehydes, ketones, and ethyl esters, which are important compounds in NMW and whiskey odor (Balcerek et al., 2016).

The results indicate that environment played an important role in fatty acid composition changes more than maize variety. Differences in fatty acids in maize can be result of stress on the plant due to the environment. Linolenic acid is recognized as a stress signal by the plant, whereas linoleic and oleic acids are necessary as functional fatty acids (Upchurch, 2008). Low and elevated temperatures, salt and drought, heavy metals, and biotic stressors can influence fatty acid composition in maize plants. In a study by Upchurch (2008), it is stated that trienoic fatty acids are useful in low temperature stress, and the increase in trienoic acids decreases dienoic acids serving as indicators of stress. This may indicate that maize grown in environments with high trienoic acid content (C18:3, γ-Linolenic acid) may be more adaptable to temperature-induced stress in those environments. Linolenic acid and linoleic acid exhibited significant differences. A possible explanation may be stress. Variation in the levels of these fatty acids may indicate the presence of different stressors inherent to growth location affecting the fatty acid composition of maize.

3.4 Trained descriptive aroma panel

3.4.1. New-make whiskey spirit sensory

New-make whiskey sensory samples were analyzed through descriptive aroma analysis with a panel of five to seven panelists using the consensus method. Panelists helped develop and then trained using the new-make whiskey lexicon that consisted of 50 sensory odor attributes and 4 nasal feeling factors (Appendix B). Each panelist recorded values on a ballot (Appendix C) and each attribute was discussed and a consensus value was recorded. Panelists always had references from the new-make whiskey lexicon available during training and testing. The attributes citrus, herb-like, burnt, caramel, banana, coconut, coffee, mint, rancid, fishy, and butyric were not present in the new-make samples and data will not be presented in tables.

For the four-location analysis for NMW (Table 10), malt was higher ($P = 0.008$) in NMW produced grown from maize in Calhoun County and Perryton, and lowest in NMW from Sawyer Farms. Anise was higher ($P = 0.002$) in NMW from Calhoun County, Monte Alto, and Sawyer Farms, and lowest in NMW from Perryton.

Table 11 shows the results of analyzing NMW produced from three maize varieties grown in four locations. Overall sweet was highest ($P = 0.04$) in Dyna-Gro and Mycogen NMW and lowest in Terral NMW. Grain complex was highest ($P = 0.05$) in Terral NMW and lowest in Dyna-Gro NMW. Woody was highest ($P = 0.01$) in Mycogen and Terral NMW, and lowest in Dyna-Gro NMW. Musty/earthy was highest ($P = 0.03$) in Mycogen NMW and lowest in Terral NMW. Only one nasal feeling factor was significant for effect of maize varieties on NMW. Prickle/pungent was highest (P = 0.01) in Terral NMW compared to Dyna-Gro and Mycogen NMW.

Table 12 shows the interaction for NMW analyzed only location x variety combinations of the locations that grew all the varieties (Figure 2). Corn, malt, roast, and lactic acid were the attributes that were significant in the NMW interaction analysis. Corn was highest (P = 0.02) in Sawyer Farms Mycogen NMW, and lowest in Sawyer Farms Dyna-Gro NMW. Malt was highest in Calhoun County Mycogen NMW and lowest in Sawyer Farms Terral NMW. Roast was highest (P = 0.02) in Sawyer Farms Mycogen NMW, and lowest in Calhoun County Dyna-Gro/Mycogen/Terral, Monte Alto Dyna-Gro/Mycogen, and Sawyer Farms Dyna-Gro/Terral NMW. Lactic acid was highest (P = 0.006) in Calhoun County Terral NMW and lowest in Sawyer Farms Dyna-Gro NMW.

Only two attributes were significantly different in NMW for location (malt, anise), whereas five attributes were significantly different for NMW for variety (overall sweet, grain complex, woody, musty/earthy, and prickle/pungent). The different attributes for location were low on the scale used for descriptive analysis: malt was ~ 3, which falls between the word anchors barely detectable and identifiable but not intense, and anise fell between 0 to 1, depending on the location and was below barely detectable to none intensity of the attribute present (Figure 3). The intensities of the significant attributes for variety fell between 4-6 for grain complex and 3-5 for woody. The intensities for significantly different variety attributes were stronger or easier to identify than the significant attributes in location indicating that variety influenced differences in aromas in NMW more than location.

When an interaction between location x aroma was analyzed, four attributes (corn, malt, roast, lactic acid) were significant. Corn aroma fell between 4 and 6 on the descriptive analysis 16-point scale. Malt scores were between 3 and 5, roast fell between 1 and 3, and lactic acid scored between 0 and 3 on a 16-point scale (Figure 3).

Intensities were detectable for aromas but levels were not very intense. The aroma of whiskey continues to develop in charred wood casks. Cask aging contributes the characteristic aroma and flavor distinctive in whiskey, mainly from the charred wood, and allows compounds present in the NMW to mature and change composition, altering the aroma attributes (Piggott and Conner, 2003). Although nutty was not significant in our study, nutty aroma was present in the sample. Boothroyd et al. (2014) found that nutty aroma was caused by long chain esters from Maillard reactions, creating many classes of pyrazines. Based on the volatile analysis, it makes sense that there was low nutty aroma due to the lack of pyrazines or any pyrolysis products. New-make whiskey is a complex matrix of congeners that are synergistic or inhibitory, affecting the aroma of the NMW (Boothroyd et al, 2014). Congener reaction is complex and can greatly affect the aroma of perceived attributes (Jack and Fotheringham, 2004).

Development of the new-make whiskey lexicon followed standard procedure outlined in Donnell et al. (2000), however lexicons are living documents and additional attributes can be added. Several attributes were never identified during evaluation of the NMW samples; removing the unused attributes reduced the amount of redundant terms and has been shown to improve panel evaluation (Lee et al., 2000). Piggott and Jardine (1979) reduced the number of terms to have less overlap between descriptors, and Donnell et al. (2000) found that reducing the number of attributes helped panelists evaluate more effectively. Little research has been carried out on NMW whiskey sensory analysis for identification of common attributes, and the work that has been done on NMW was more common in spirits that did not require a maturation stage, such as rum, brandy, and tequila (Boothroyd et al., 2016; Franitza et al., 2016; Malfondet et al., 2016; Peña y Lilo et al., 2005)

3.4.2. Ground maize sensory

Ground maize was analyzed using the new-make whiskey lexicon, but an additional attribute, barnyard, was added for maize (Appendix B). Panelists were provided with the new attribute reference, as well as with a new ballot for training and testing (Appendix D). Brown spice complex, fermented/yeasty, berry fruit, citrus fruit, dark fruit, other fruit, herb-like, burnt, honey, molasses, caramel, banana, coconut, coffee, anise, mint, pepper, vinegar, and fishy were not present in the tested samples, and data will not be presented in tables.

Table 13 shows the results of the four-location analysis of maize (Figure 1). Oily was higher (P = 0.05) in Perryton maize compared to Calhoun County, Monte Alto, and Sawyer Farms maize. Barnyard was higher (P = 0.005) in Sawyer Farms maize, than in Calhoun County, Monte Alto, and Perryton maize. Soapy was higher (P = 0.001) in Perryton maize, and lower in Calhoun County, Monte Alto, and Sawyer Farms maize. Butyric was highest (P = 0.05) in Sawyer Farms maize and lowest in Perryton maize.

Table 14 shows the sensory results of analysis performed for three maize varieties tested by descriptive analysis (Figure 1). Overall sweet was highest ($P = 0.04$) in Mycogen maize and lowest in Dyna-Gro maize. Soapy was highest ($P = 0.04$) in Terral maize, compared to Dyna-Gro or Mycogen maize.

Table 15 shows the results of the ground maize sensory interactions only for locations which grew all varieties (Figure 2). There were no significant interactions for location x variety interactions for ground maize.

Maize aroma had more significant aromas in environments (Table 13) than in variety (Table 14). However, with the exception of oily in Table 13, and overall sweet in Table 14, the attributes scored between 0 and 1 on a 16-point scale, meaning they were below barely detectable to not present (Figure 3). Grain and corn aroma is typically evaluated for musty, moldy, acid, sour, burnt or foreign odors that are indicative of unwanted deterioration (Börjessone et al., 1996). The absence of very low levels of musty, moldy, acid, sour, burnt or foreign odors were due to inspection of maize for accepting a certain quality. Gere et al. (2014) found that differences in sweetness existed across varieties, mostly due to the sucrose content, rather than glucose or fructose content. Sugars are stored as starch in maize, so differences in starch arrangement and composition can affect the sweetness. This could help explain the significance of the overall sweet aroma in varieties and not by location. When dried maize was received for whiskey production, the moisture content is around 10% (Hiran et al., 2016). Due to the low moisture content, there is little to no microbiological activity, which could induce off-flavor. Since the samples were ground prior to analysis, more aromas could be present due to enzymatic activity (Hiran et al., 2016). Theerakljlkait et al. (1995) confirmed that aroma in ungerminated maize is low and that the presence of enzymes and oxidation products increase odor in maize.

3.5 New-make whiskey and maize volatile aroma evaluation

Table 16 through Table 20 show the results of GC/MS-O volatile analysis of NMW, and Table 21 though Table 24 show the results of GC/MS-O volatile analysis of ground maize. Technicians identified aroma events, but did not identify specific aromas. Aroma attributes found in the tables and referenced throughout volatile evaluation were found from Burdock (2010), Flament (2002), and National Center for Biotechnology Information (NCBI).

3.5.1. New-make whiskey location effects

In Table 16 the analysis of NMW produced from four growth locations are shown (Figure 1). Growth location contributed acids, alcohols, aldehydes, alkanes, esters, furans, ketones, and a sulfur compounds to NMW.

New-make whiskey produced from maize grown in the Calhoun County and Sawyer Farms locations resulted in higher ($P = 0.05$) amounts of 4-hydroxymandelic acid than NMW from Monte Alto. Calhoun County is higher ($P = 0.003$) in acetic acid than Monte Alto and Sawyer Farms. Monte Alto was high ($P = 0.02$) in n-decanoic acid compared to Calhoun County and Perryton. Acetic acid and n-decanoic acid contributed sour aroma, but acetic acid exhibits sour-fruity, whereas n-decanoic acid presents a sour-fatty aroma; no aroma was contributed by 4-hydroxymandelic acid-TRITMS (Table 16).

Calhoun County had the highest (*P* = 0.001) total ion count (TIC) of 1-octanol, compared to Monte Alto, which had the lowest TIC of 1-octanol. Isobutyl alcohol was highest (*P* = 0.001) in Calhoun County NMW, and lowest in Monte Alto and Sawyer Farms NMWs. Benzene-ethanol was highest (*P* = 0.001) in Sawyer Farms NMW, compared to Monte Alto NMW, which had the lowest benzene-ethanol content. Calhoun County and Sawyer Farms had the highest (*P* = 0.001) amount of ethanol, and Monte Alto with the least. Isoamyl alcohol was highest (*P* = 0.001) in Calhoun County and Sawyer Farms NMW; isoamyl alcohol was lowest in Monte Alto NMW. Calhoun County and Sawyer Farms also had the highest amounts of fusel alcohols, with Monte Alto having the least. Table 1, which shows ground maize NIRS starch, protein, and fat estimations, reports that Calhoun County and Sawyer Farms had the lowest (*P* = 0.01) predictions for starch of the four locations for ground maize, so it can be proposed another factor is contributing to lower ethanol production. Ethanol production is the most considered factor in grain selection and production, and is often predicted by considering starch content, however, as mentioned in the literature review starch content alone cannot predict alcohol content. The fusel alcohols are credited for giving whiskey its distinct character due to the range of aromas they provide, such as green, fatty, coconut for 1-octanol and malty and fruity for isobutyl alcohol (Table 16).

Calhoun County and Perryton had the highest (*P* = 0.001) amount of (E)-2-heptenal, with Monte Alto having the lowest amount of (E)-2-heptenal. Calhoun County, Monte Alto, and Sawyer Farms NMW had the highest (*P* = 0.001) total ion counts of (E)-2-nonenal. Calhoun County and Perryton were highest (*P* = 0.001) in (E)-2-octenal, and Monte Alto and Sawyer Farms were lowest in (E)-2-octenal. Sawyer Farms had the highest (*P* = 0.01) total ion count for 2-butenal compared to Monte Alto and Perryton. Calhoun County the highest (*P* = 0.003) amount of 2-octenal, with Monte Alto, Perryton, and Sawyer Farms having the least. The highest (*P* = 0.004) amount of 2,4-decadienal was observed in Perryton NMW, and the lowest in Monte Alto NMW. Acetaldehyde tended (*P* = 0.10) to be lowest in Perryton NMW. Benzaldehyde was highest (*P* = 0.003) in Calhoun County and lowest in Monte Alto. Sawyer Farms had the highest (*P* = 0.006) levels of decanal, and Calhoun County and Monte Alto had the lowest levels. Monte Alto had the highest levels of (*P* = 0.02) heptanal, with Calhoun County having the lowest amounts of heptanal. Hexanal was highest (*P* = 0.001) in Calhoun County, and lowest in Monte Alto, Perryton, and Sawyer Farms. Calhoun County, Perryton, and Sawyer Farms had the highest (*P* = 0.001) amounts of nonanal, and Monte Alto had the lowest amounts of nonanal. Sawyer Farms had the highest (*P* = 0.03) amounts of octanal compared to Calhoun County, Monte Alto, and Perryton. The aroma description that was consistent across the aldehydes was fatty, with fruity, floral, and green occurring to a lesser extent (Table 16).

Calhoun County NMW was highest (*P* = 0.004) in 1-ethenyloxy)-3-methylbutane, compared to Monte Alto or Sawyer Farms NMWs. Sawyer Farms was highest (*P* = 0.001) in 1-ethenyl-4-methoxybenzene, and Monte Alto and Perryton were lowest. The highest (*P* = 0.001) amount of 1,1-diethoxyhexane was found in Calhoun County, and the lowest amount was in Monte Alto. Calhoun County and Monte Alto NMWs had the highest (*P* = 0.001) and lowest amounts of 3-

methylbicyclo[4.1.0]heptane, respectively. Acetal levels were highest (*P* = 0.001) in Calhoun County and lowest all other locations. Cedr-8-ene was high (*P* = 0.001) in Perryton NMW, and low in all other NMWs. Di-Limonene was highest (*P* = 0.001) in Sawyer Farms NMW, compared to Calhoun County, Monte Alto, or Perryton NMWs. Calhoun County is highest (*P* = 0.006) in ethoxyethene compared to Monte Alto and Sawyer Farms. Monte Alto had the highest (*P* = 0.006) amounts of naphthalene of all the locations. Styrene was highest (*P* = 0.001) in Sawyer Farms NMW, and lowest in Monte Alto NMW. Many of the alkanes did not contribute an identifiable aroma based on flavor literature sources, but those that did contributed aromas associated with pungency (Burdock, 2010; Flament, 2002; National Center for Biotechnology Information).

Esters made up more than any other chemical group present in NMWs made from maize grown in different locations. The focus on esters lies mostly on fatty acid ethyl esters. Monte Alto was highest (*P* = 0.006) in 2-methylbutyl decanoate. Perryton was highest (*P* = 0.006) in 3-hydroxymandelic acid ethyl ester, compared to the other locations. Calhoun County, Perryton, and Sawyer Farms were high (*P* = 0.001) in 3-methyl-1-butanol acetate. Sawyer Farms was high (*P* = 0.001) in 3-methylbutyl octanoate compared to Calhoun County, Monte Alto, or Perryton. Perryton and Sawyer Farms NMWs were highest (*P* = 0.03) in 3-methylbutyl pentadecanoate, compared to Calhoun County, which had the lowest amount of 3-methylbutyl pentadecanoate. Ethyl (E,E)-2,4-decadienoate was higher (*P* = 0.04) in new-make samples from Perryton, than in new-make samples from Calhoun County, Monte Alto, or Sawyer Farms. Ethyl (E)-2-heptenoate was highest (*P* = 0.001) in Calhoun County NMW compared to Monte Alto

NMW. Ethyl (E)-2-octenoate was highest ($P = 0.001$) in Perryton NMW and lowest in Monte Alto NMW. Ethyl 2-nonenoate was highest ($P = 0.001$) in Perryton NMW and lowest in Monte Alto NMW. Ethyl acetate was high ($P = 0.001$) in Calhoun County and Sawyer Farm NMW, and low in Monte Alto and Perryton NMW. Ethyl cis-4-hexenoate tended ($P = 0.10$) to be low in Monte Alto. Ethyl decanoate was high ($P = 0.001$) in Perryton and Sawyer Farm NMWs, and low in Monte Alto NMW. Ethyl heptanoate was high ($P = 0.001$) in Calhoun County NMW and low in Monte Alto NMW. Ethyl hex-4-enoate was high ($P = 0.001$) in Calhoun County and Sawyer Farms NMWs, and low in Monte Alto NMW. Ethyl hexanoate was high ($P = 0.001$) in Calhoun County and low in Monte Alto. Ethyl nonanoate was high ($P = 0.001$) in Perryton and low in Mont Alto. Ethyl octanoate was high ($P = 0.001$) in Calhoun County, Perryton, and Sawyer Farms NMWs, compared to Monte Alto NMW. Perryton NMW was high ($P = 0.001$) in ethyl sorbate and ethyl trans-4-decenoate, while Monte Alto was low in ethyl sorbate and ethyl trans-4-decanoate. Ethyl undecanoate was high ($P = 0.001$) in Perryton NMW, compared to other NMWs. Isobutyl caprylate was high ($P = 0.002$) in Perryton and low in Monte Alto. Isopentyl hexanoate was highest ($P = 0.001$) in Perryton NMW and lowest in Monte Alto NMW. Ester aroma had high variation depending its origin, but the broad aromas were fruity, such as coconut, pineapple, banana, apple; floral, specifically rose; and sweet liqueurs, such as cognac, wine, brandy based on flavor sources Burdock (2010), Flament (2002), and National Center for Biotechnology Information.

Calhoun County was highest ($P = 0.001$) in 2-furancarboxaldehyde and Monte Alto was lowest in 2-furancarboxaldehyde. Perryton NMW had the highest ($P = 0.001$)

2-pentylfuran content with Monte Alto having the lowest. The typical furan aromas were pungent, sweet, caramel, cinnamon, almond, earthy, and vegetable based on flavor sources referenced in Table 16.

Calhoun County and Sawyer Farms had the highest ($P = 0.001$) amounts of 2-nonanone, with Monte Alto having the lowest amount. Perryton NMW tended ($P = 0.09$) to be high in 2-tridecanone. Sawyer Farms was highest ($P = 0.001$) amounts of 2-undecanone and acetophenone, with Calhoun County, Perryton, and Monte Alto having the lowest amounts of 2-undecanone and acetophenone. The ketones provided mainly fruity and floral aromas, with oily, pungent, and ethereal to a lesser extent based on flavor sources referenced in Table 16.

Sulfur-containing compound, 2-pentylthiopene, was highest ($P = 0.009$) in Perryton NMW compared to the NMWs produced from maize grown at other location. Fruity and woody are common aromas of 2-pentylthiopene based on flavor sources referenced in Table 16.

3.5.2. New-make whiskey locations excluding Perryton

In Table 17, only NMW from the three locations that grew all maize varieties were analyzed as seen in the design in Figure 2.

Acetic acid was the only acid present in the sample and was highest ($P = 0.004$) in Calhoun County compared to Monte Alto and Sawyer Farms. Acetic acid contributes a sour-fruity aroma (Table 17). Calhoun County NMW was higher ($P = 0.001$) in 2-octenal and acetal, than its Monte Alto and Sawyer Farms new-make counterparts. Calhoun County NMW was higher in benzaldehyde ($P < 0.006$) than in Monte Alto

NMW. Decanal was higher (*P* = 0.009) in Calhoun County NMW than in Mycogen NMW. Hexanal was highest (*P* = 0.001) in Calhoun County NMW compared to Monte Alto and Sawyer Farms NMWs. Sawyer Farms NMW is highest (*P* = 0.04) in octanal and Calhoun County NMW is lowest in octanal. Aldehyde aromas are typically described as overall fatty aroma, with lesser amounts nutty, green, fruity, and sweet based on flavor sources referenced in Table 17.

Calhoun County NMW had the highest (*P* = 0.001) amounts of 1,1-diethoxy-3-methylbutane and 1,1-diethoxyhexane compared to Monte Alto and Sawyer Farms NMW. Calhoun County had higher (*P* = 0.007) 1-(ethenyloxy)-3-methylbutane TIC than Monte Alto or Sawyer Farms. Sawyer Farms had a higher (*P* = 0.002) TIC of dI-Limonene than Calhoun County or Monte Alto. The alkanes with known aromas ranged from pungent, green, woody, and solvent, to fruity, citrus, and mint based on flavor sources referenced in Table 17.

Calhoun County had the highest (*P* = 0.03) amount of 2-nonenoate, while Monte Alto had the lowest amount of 2-nonenoate. Isobutyl caprylate was high (*P* = 0.005) in Calhoun County and Sawyer Farms NMWs, and low in Monte Alto NMW. Isopentyl hexanoate was higher (*P* = 0.05) in Calhoun County new-make than in Monte Alto new-make. The esters were overall fruity, with green and spice occurring in some esters, as well (Table 17). Calhoun County NMW was highest (*P* = 0.005) in 2-pentylfuran and Monte Alto was lowest in 2-pentylfuran.

There was a tendency (*P* = 0.08) for Monte Alto NMW to be higher n 2-propanone. Monte Alto had the highest (*P* = 0.03) amounts of 2-tridecanone, and

Calhoun County had the lowest amounts of 2-tridecanone. Furans contributed aromas associated with earthy, burnt, oily, and green odors. Ketones varied in aromas ranging from acetone, pungent, to warm, oily, fruity, woody, and herb-like (Table 17).

Calhoun County was consistently on the higher end of acids, aldehydes, esters, and furans, and Monte Alto and Sawyer Farms were lower across acids and aldehydes. Monte Alto was also on the lower end of esters for NMW.

Less volatile compounds, especially esters and alcohols, are in Table 17 than in Table 16; Table 16 compared four locations included Perryton in its analysis. Forty-five volatile compounds comprised of alcohols, aldehydes, alkanes, esters, and ketones that were present in NMW analyzed with Perryton were not significant in Table 17. In both NMW location analyses, Calhoun County had higher amounts of volatile compounds and Monte Alto had lower amounts of volatile compounds through most of the chemical groups. In the analysis with Perryton, Sawyer Farms and Perryton also showed higher amounts of volatile chemicals; when Perryton was excluded, Sawyer Farms demonstrated less pattern consistency across volatile compounds.

3.5.3. New-make whiskey varieties

Table 18 shows effects of maize variety on the volatile composition of NMW; the analysis included the Terral maize grown in Perryton, using the first experimental model (Figure 1). Dyna-Gro new-make was high (P = 0.001) in n-decanoic acid compared to Mycogen and Terral NMWs. N-decanoic acid gave off a sour-fatty odor based on flavor sources referenced in Table 18. Ethanol was high (P = 0.002) in Dyna-

Gro and Terral NMWs, compared to Mycogen NMW. Ethanol gave the characteristic alcohol-ethanolic odor (Table 18).

Mycogen was high ($P = 0.02$) in (E)-2-heptenal compared to Dyna-Gro and Terral NMW. Dyna-Gro and Terral NMWs were high ($P = 0.007$) in 2,4-decadienal and acetaldehyde, compared to Mycogen NMW. Terral was high ($P = 0.003$) in benzaldehyde, compared to Dyna-Gro or Mycogen NMWs. The aldehydic odor was fatty, nutty, and floral based on flavor sources referenced in Table 18.

Terral NMW was highest ($P = 0.001$) in 1-ethenyl-4-methoxybenzene, while Mycogen was lowest in 1-ethenyl-4-methoxybenzene. Ethoxyethene was high ($P = 0.04$) in Mycogen and low in Dyna-Gro. Naphthalene TIC was highest ($P = 0.001$) in Terral NMW, compared to the NMWs produced from Dyna-Gro or Mycogen maize. Styrene content was high ($P = 0.002$) in Mycogen and Terral NMWs, compared to Dyna-Gro NMW. The alkanes were ether-like, pungent, sweet, and floral based on flavor sources referenced in Table 18.

The highest ($P = 0.001$) amount of 2-methylbutyl decanoate was found in Terral NMW and lowest amount in Dyna-Gro and Mycogen. Terral NMW had higher ($P = 0.001$) levels of 3-methylbutyl octanoate than Mycogen NMW. Dyna-Gro NMW had higher ($P = 0.006$) amounts of 3-methylbutyl pentadecanoate than Mycogen NMW. Ethyl (E,E)-2,4-decadienoate was high ($P = 0.009$) in Dyna-Gro and Terral NMW, compared to Mycogen NMW. Ethyl acetate was higher ($P = 0.01$) in Terral and lower in Mycogen. Total ion count of ethyl cis-4-hexanoate and ethyl decanoate were higher ($P = 0.001$) and Mycogen NMWs than in Terral or Dyna-Gro NMWs. Dyna-Gro and Terral

NMWs were highest (*P* = 0.001) in ethyl dodecanoate, compared to Mycogen NMW. Ethyl hex-4-enoate was highest (*P* = 0.03) in Mycogen NMW, compared to Terral NMW. Terral was higher (*P* = 0.04) in ethyl nonanoate than Dyna-Gro and Mycogen. Mycogen and Terral had higher (*P* = 0.04) amounts of ethyl octanoate than Dyna-Gro. Ethyl sorbate was higher (*P* = 0.001) in Dyna-Gro NMW than in Mycogen and Terral NMW. Ethyl trans-4-decenoate was highest (*P* = 0.001) Terral and lowest in Mycogen. Ethyl trans-4-decenoate. The overarching odor provided by the esters was fruity, with floral, green, and sweet liqueurs being more specific to certain esters based on flavor sources referenced in Table 18.

There were only two significant furan-containing volatiles NMW. Mycogen and Terral NMWs had higher (*P* = 0.04) levels of 2-furancarboxaldehyde than Dyna-Gro NMW. Terral NMW had higher (*P* = 0.04) amounts of 2-pentylfuran than Dyna-Gro NMW. Furfural tended (*P* = 0.08) to be high in Dyna-Gro NMW. Furans added sweet and brown spice odors, along with earthy and oily odors based on flavor sources referenced in Table 18.

Mycogen NMW had higher (*P* = 0.005) amounts of 2-nonanone than Dyna-Gro NMW. Dyna-Gro new-make was higher (*P* = 0.001) in 2-propanone than Mycogen or Terral new-make. Terral had the highest (*P* = 0.001) TIC for 2-tridecanone, while Mycogen had the lowest TIC for 2-tridecanone. Dyna-Gro and Mycogen NMW had higher (*P* = 0.001) amounts of 2-undecanone compared to Dyna-Gro NMW. Geranylacetone was higher (*P* = 0.001) in Dyna-Gro and Terral NMW than in Mycogen

NMW. The ketones had fruity, pungent, oily, and floral odors based on flavor sources referenced in Table 18.

Unlike the location for NMW, variety for NMWs had less significant volatile compounds. There was also less of a pattern in volatile compounds. Terral was higher across esters and furans; Mycogen was lower across esters; Dyna-Gro was lower among furans and ketones.

3.5.4. New-make whiskey varieties excluding Perryton

In Table 19, the effect of varieties is assessed excluding the Terral maize grown in Perryton (Figure 2).

Mycogen had the highest (P = 0.02) amounts of 2-octenal compared to Dyna-Gro. Benzaldehyde TIC was highest (P = 0.007) in Terral NMW, than in Dyna-Gro or Mycogen NMW. Significant aldehyde odor varied from fatty, nutty, green, woody, sweet, and malt based on flavor sources referenced in Table 19.

Ethyl cis-4-hexenoate was highest (P = 0.03) in Terral NMW. Isopentyl hexanoate was high (P = 0.02) in Mycogen new-make and low in Dyna-Gro NMW. The significant esters' odors were fruity, green, and spice-like based on flavor sources referenced in Table 19.

Mycogen and Terral had the highest (P = 0.003) amounts of 2-pentylfuran compared to Dyna-Gro. Furfural and 2-propanone were highest (P = 0.007) in Dyna-Gro and lowest in Mycogen and Terral. Terral new-make was highest (P = 0.001) in 2-tridecanone compared to Mycogen NMW. The furan odors ranged from fruity, vegetable, and almond, spice and roast. The ketone odors spanned from acetone, pungent, solvent, oily, and warm-like based on flavor sources referenced in Table 19.

Table 19 evaluated the effects of variety, without accounting for the Terral maize grown in Perryton. There were less acids, esters, and alkanes in Table 19 compared to Table 18. Alcohols were not in Table 19 because they were significant in the NMW interaction (Table 20). Throughout Table 19, Dyna-Gro was lower in the significant volatile compounds, except ketones and furans; there was no consistent pattern for Mycogen or Terral varieties.

Comparing Table 16 and Table 18, which examine the effect of location (including Perryton and varieties including Perryton-Terral, respectively), there are more NMW volatiles in Table 16. Location contributed more to significant acids, alcohols, aldehydes, and alkanes; both location and variety had similar amounts of significant esters and ketones. The largest amounts of fusel alcohols are in Calhoun County and Sawyer Farms (Table 16). Table 1 shows that starch content and protein are significant for location. Calhoun County and Sawyer are lower in starch, and Sawyer Farms is lower in protein. Starch and protein are important because they provide the sugar and amino acids necessary for fusel alcohol production. Although starch and protein are significant for maize variety as well, fusel alcohols were not significant in Table 18. Location may induce more differences in fusel alcohols, because differences in protein content are impacted by environment (Swanston et al., 2007). Along with affecting fusel alcohol production, proteins also affect spirit yield (Agu et al., 2008), discussed later in this analysis.

3.5.5. New-make whiskey location x variety interaction

The interaction table for new make spirit (Table 20), shows the analysis of the three locations (Calhoun County, Monte Alto, Sawyer Farms) that grew all the test varieties of maize (Dyna-Gro – D57VP51; Mycogen – 2 C797; Terral Seed – REV25BHR26). Out of 61 volatile compounds, 42 were significant for interactions.

Sawyer Farms Mycogen was highest (P = 0.001) in 4-hydroxymandelic acid – TRITMS, and Calhoun County Mycogen, Sawyer Farms Dyna-Gro, and Sawyer Farms Terral were lowest in 4-hydroxymandelic acid – TRITMS. Acetic acid tended (P = 0.09) to be high in Calhoun County Mycogen. N-Decanoic acid had the highest (P = 0.009) and lowest total ion counts in the Monte Alto growth location with the highest amounts present in Monte Alto Dyna-Gro and Monte Alto Terral, and the lowest amount in Monte Alto Mycogen. The acids contributed sour-fruity and sour fatty odors.

Sawyer Farms Mycogen was highest (P = 0.03) in 1-octanol and lowest in Monte Alto Mycogen. Aside from Sawyer Farms Mycogen, the varieties in each location were related to one another (i.e., all Calhoun County varieties, all Monte Alto varieties, and Sawyer Farms Dyna-Gro and Terral were similar according to the letter report). Sawyer Farms Mycogen was highest (P = 0.001) in benzene-ethanol and Monte Alto Mycogen was lowest in benzene-ethanol. Ethanol was highest (P = 0.002) in Calhoun County Mycogen and Calhoun County Terral, and lowest in Calhoun County Dyna-Gro, Monte Alto Terral, and Sawyer Farms Mycogen. Isoamyl alcohol was highest (P = 0.009) in Sawyer Farms Mycogen. Isopropyl alcohol was highest (P = 0.005) Calhoun County Mycogen (94847), followed by Calhoun County Dyna-Gro (41873), and lowest in all other location x variety combinations. The sensory odors connected to the alcohols are oily, fruity, green, and floral based on flavor sources referenced in Table 20.

(E)-2-heptenal was highest (*P* = 0.004) in Calhoun County Mycogen and lowest in Monte Alto Dyna-Gro, Monte Alto Mycogen, Monte Alto Terral, and Sawyer Farm Dyna-Gro. (E)-2-nonenal, and acetaldehyde were highest (*P* = 0.001) in Calhoun County Mycogen and lowest in Monte Alto Mycogen. (E)-2-octenal was highest (*P* = 0.001) in Calhoun County Dyna-Gro and lowest in Monte Alto Mycogen. The aldehyde, 2-butenal, was highest in Sawyer Farms Terral, and lowest in Calhoun County Mycogen/Terral, Monte Alto Dyna-Gro/Mycogen/Terral, and Sawyer Farms Dyna-Gro. The highest (*P* = 0.03) amount of 2,4-decadienal was present in Calhoun County Mycogen, and the lowest amount was in Monte Alto Mycogen and Sawyer Farms Mycogen. Acetaldehyde was higher (*P* = 0.001) in Calhoun County Mycogen, and lower in Monte Alto Mycogen and Sawyer Farms Mycogen. Heptanal values were highest (*P* = 0.008) in Calhoun County Mycogen, Sawyer Farms Mycogen, and Sawyer Farms Terral, and lowest in Sawyer Farms Terral. Nonanal was highest (*P* = 0.001) in Sawyer Farms Mycogen and lowest in Monte Alto Mycogen; all the varieties in the Monte Alto location were statistically similar. Aldehydic compounds contributed fatty across most aldehydes, but fruity, nutty, solvent, sweet, and floral varied across specific aldehydes based on flavor sources referenced in Table 20.

Sawyer Farms Mycogen and Sawyer Farms Terral were highest (*P* = 0.001) in 1-ethenyl-4-methoxybenzene and Monte Alto Mycogen was lowest in 1-ethenyl-4-methoxybenzene. Calhoun County Mycogen was highest (*P* = 0.001) in 3-

methylbicyclo[4.1.0]heptane, while Calhoun County Terral, Monte Alto Dyna-Gro, Monte Alto Mycogen, and all Sawyer Farms varieties were lowest in 3-methylbicyclo[4.1.0]heptane. Cedr-8-ene was highest (*P* = 0.02) in Sawyer Farms Terral (33811) and lowest in all other location-variety combinations (0). Ethoxyethene total ion count was highest (*P* = 0.001) in Calhoun County Mycogen, and lowest in all other locations-variety combinations. Naphthalene was highest (*P* = 0.003) in Monte Alto Terral and lowest in all other location-variety combinations. Styrene was highest (*P* = 0.007) in Sawyer Farms Mycogen and lowest in Monte Alto Mycogen and Monte Alto Dyna-Gro. Alkane odor shared less similarities across compound group and varied more from ether, pungent, sweet, and floral across different alkanes based on flavor sources referenced in Table 20.

Monte Alto Mycogen had the highest (*P* = 0.001) total ion count of 2-methylbutyl decanoate (380390), with all other location-variety combinations having the lowest total ion count of 2-methylbutyl decanoate (0). Sawyer Farms Mycogen had the highest (0.005) total ion count of 3-methyl-1-butanol acetate, compared to Monte Alto Mycogen, which had the lowest total ion count of 3-methyl-1-butanol acetate. The ester, 3-methylbutyal ester octanoate was highest (*P* = 0.02) in Sawyer Farms Terral and lowest in Calhoun County Dyna-Gro and Monte Alto Mycogen; all the NMWs produced from varieties grown in Sawyer Farms were similar in 3-methylbutyal ester octanoate content. NMW produced from Monte Alto Mycogen and Sawyer Farms Terral were highest (*P* = 0.02) in 3-methybutyl ester, pentadecanoate and Monte Alto Mycogen/Terral, Calhoun County Dyna-Gro/Mycogen/Terral, and Sawyer Farms

Mycogen NMWs were lowest in 3-methylbutyl, pentadecanoate. Di-TMS 3-hydroxymandelic acid, ethyl ester was highest (*P* = 0.02) in Calhoun County Terral, and lowest in Calhoun County Dyna-Gro/Mycogen, Monte Alto Dyna-Gro/Mycogen/Terral, and Sawyer Farms Mycogen/Terral. Ethyl (E,E)-2,4-decadienoate was highest (*P* = 0.006) in Monte Alto Terral and lowest in Monte Alto Mycogen. Calhoun County Dyna-Gro had the highest (*P* = 0.004) Ethyl (E)-2-heptenoate, which was lowest in Monte Alto Dyna-Gro/Mycogen/Terral. Ethyl (E)-2-octenoate was highest (*P* = 0.007) in Calhoun County Terral, and lowest in Monte Alto Mycogen/Terral. Ethyl acetate was highest (*P* = 0.007) in Sawyer Farms Mycogen and lowest in Monte Alto Dyna-Gro and Monte Alto Mycogen; the NMW produced from all varieties grown in Calhoun County location were similar in ethyl acetate content. Ethyl decanoate content was highest (*P* = 0.007) in Sawyer Farms Mycogen NMW and lowest in Monte Alto Mycogen NMW. Monte Alto Dyna-Gro NMW had high (*P* = 0.001) total ion count of ethyl dodecanoate compared to Monte Alto Mycogen NMW; the new make spirit from Calhoun County and Sawyer Farms were similar across varieties within location. Ethyl extenuate was highest (*P* = 0.02) in Calhoun County Mycogen and lowest in Monte Alto Mycogen. Ethyl hex-4-enoate was highest (*P* = 0.001) in NMW from Sawyer Farms Mycogen, and lowest in NMWs from Monte Alto Dyna-Gro/Mycogen/Terral, and Sawyer Farms Dyna-Gro/Terral. Ethyl hexenoate was highest (*P* = 0.04) in Calhoun County Mycogen and lowest in Monte Alto Dyna-Gro and Monte Alto Mycogen. Additionally, for ethyl hexanoate, varieties within their locations were similar. Ethyl nonanoate was highest (*P* = 0.003) Calhoun County Terral and lowest in Monte Alto Mycogen. Ethyl octanoate was highest (*P* = 0.002) in NMW produced from Sawyer Farms Mycogen, and lowest in NMW produced form Monte Alto Mycogen; varieties across the Calhoun County growth location were similar. Ethyl sorbate total ion count was highest (*P* = 0.02) in Calhoun County Dyna-Gro and lowest in Monte Alto Mycogen; varieties across the Sawyer Farms location were similar, according to their letter report. Ethyl trans-4-decenoate was highest (*P* = 0.008) in Calhoun County Terral, and lowest in Monte Alto Mycogen. Varieties across the Calhoun County location were on the higher end of total ion count for ethyl trans-4-decenoate, and varieties across the Sawyer Farms location were related. Ethyl undecanoate was highest in NMW from Calhoun County Terral, Monte Alto Dyna-Gro, and Monte Alto Terral compared to NMW from Monte Alto Mycogen and Sawyer Farms Mycogen, which had the lowest amount of ethyl undecanoate. Varieties across the Calhoun County location were similar, and varieties across the Monte Alto location were similar. Pentyl hexanoate was highest (*P* = 0.02) in Calhoun County Dyna-Gro and low at Calhoun County Mycogen/Terral, Monte Alto Dyna-Gro/ Mycogen/Terral, and Sawyer Farms Dyna-Gro/ Mycogen/Terral.

All but four esters were significant for interaction of location x variety. The largest odor profile provided by esters was fruity, with floral and sweet liqueur odors being specific to certain esters based on flavor sources referenced in Table 20.

Calhoun County Mycogen had high (*P* = 0.004) TIC of 2-furancarboxaldehyde, compared to Monte Alto Mycogen and Sawyer Farms Dyna-Gro. Although only 2-furancarboxaldehyde was significant, other furans were present that provided odors associated with light roast development, such as caramel, cinnamon, almond, bread, and other odors such as earthy, oily, and vegetable based on flavor sources referenced in Table 20.

New-make whiskey from Sawyer Farms Mycogen was highest (P = 0.002) in 2-nonanone (49971 TIC) compared to NMW from Calhoun County Dyna-Gro, Monte Alto Dyna-Gro/Mycogen/Terral, and Sawyer Farms Dyna-Gro, which had the lowest amounts of 2-nonanone (0 TIC). Total ion count for 2-propanone was highest (P = 0.002) was highest in Monte Alto Dyna-Gro and lowest in Calhoun County Dyna-Gro/Mycogen/Terral, Monte Alto Mycogen/Terral, and Sawyer Farms Dyna-Gro/Mycogen/Terral. Sawyer Farms Mycogen had the highest (P = 0.001) total ion count of 2-undecanone (152927), followed by Sawyer Farms Terral (52367), then Calhoun County Dyna-Gro/Mycogen/Terral, Monte Alto Dyna-Gro/Mycogen/Terral, and Sawyer Farms Dyna-Gro (0). Acetophenone was highest (P = 0.001) in Sawyer Farms Mycogen, and lowest in Calhoun County Dyna-Gro/Mycogen/Terral, and Monte Alto Dyna-Gro/Mycogen. Geranylacetone was highest (P = 0.02) in Monte Alto Dyna-Gro, and lowest in Monte Alto Mycogen. Varieties across Calhoun County were similar, and varieties across Sawyer Farms were similar.

Fruity, pungent, floral, and herb-like odors were prevalent in ketones based on flavor sources referenced in Table 20. The sulfur-containing compounds were not significant for volatile interaction of Table 20.

The volatile compounds that contributed to the NMW aroma were acids, alcohols, aldehydes, alkanes, esters, furans, ketones, and sulfur-containing compounds. The different acids contribute to different sour profiles; acetic acid contributes a fruity, vinegar sour, n-decanoic acid contributes a fatty, rancid sour. Acid development can occur through different channels, such as deamination of an acidic amine group, lipid oxidation, or through intentional use of lactic acid in the mash to create a sour mash (Balcerek et al., 2016; Basso et al., 2011). In volatile acid compounds, there was not clear trend of a location or variety having consistently large TICs, but Sawyer Farms Terral was consistently low across different acids. However, it is interesting to note that in acids, Terral maize TIC values were similar across locations. The Dyna-Gro maize variety also exhibited interesting performance across locations. Calhoun County Dyna-Gro had larger TICs than its counterparts Monte Alto Dyna-Gro and Sawyer Farms Dyna-Gro in 4-hydroxymanelic acid and acetic acid, but the roles switched for n-decanoic acid, with Monte Alto Dyna-Gro and Sawyer Farms Dyna-Gro having larger TICs than Calhoun County. This could indicate that environment influenced the development of acids across a variety. Acids can also be affected by minerals and salts that are influenced more by growth location than by maize variety (Basso et al., 2011; Dashdorj, 2015). This observation could be supplemented by looking at locations. Across the Monte Alto location, the varieties were similar in TIC values for 4-hydoxymanelic acid and acetic acid; and the varieties grown at Sawyer Farms had similar values for acetic acid and n-decanoic acid. Both variety and location influenced acid production.

Fusel alcohols are higher carbon alcohols and are credited for contributing to more complex flavor (Berry and Slaughter, 2003; Nykänen, 1986). The most prominent fusel alcohols present in Calhoun and Sawyer NMWs, benzene ethanol and isoamyl alcohol, contribute floral and malt-like aromas. Benzene-ethanol and isoamyl alcohol are known to be produced through yeast and amino acid degradation (Ferrari et al., 2004; Poisson and Schieberle, 2008). Nykänen (1986) confirms that isoamyl alcohol and aromatic fusel alcohols are created due to amino acid degradation by yeast during fermentation. Fusel alcohol values were larger in Sawyer Farms Mycogen. Alone, neither Mycogen variety or Sawyer Farms location experienced high levels for any fusel alcohol. Both Mycogen and Sawyer Farms were low in protein and starch content (Table 1), which would drive the prediction that Sawyer Farms Mycogen would have lower amounts of fusel alcohols. However, starch content is not always an accurate predictor for accessible sugar; starch composition (amylose and amylopectin) and configuration (A, B, and C chains) can affect amount of starch that is able to be hydrolyzed and used for fermentation. Also, while nitrogen from location was found by Agu et al. (2008) and Swanston et al. (2007) to carry more impact than nitrogen from grain, yeast decomposition at the end of fermentation releases amino acids that can be used in fusel alcohol production.

Ethanol production was high in Calhoun County Mycogen and Calhoun County Terral. Table 1 shows that individually, Calhoun County and Terral variety were not high in starch; Mycogen was high in starch. Table 2 shows neither Calhoun County Mycogen nor Calhoun County Terral were high in starch content. The large TICs for Calhoun County Mycogen and Calhoun County Terral were impacted by both location and variety; Calhoun County TICs were not similar for all varieties and Mycogen and Terral TICs were not similar across locations. Spirit yield in Table 6 did not show any significant interaction, so Calhoun County Mycogen and Calhoun County Terral may have had synergistic relationships with other congeners in the NMW to have shown larger values in ethanol (Boothroyd et al, 2014; Jack and Fotheringham, 2004). Dyna-Gro NMW had similar ethanol values across location, indicating that Dyna-Gro performance was less affected by growth location for ethanol production. Similarly, Monte Alto ethanol values were similar for all varieties indicating that ethanol production was less impacted by variety in Monte Alto.

Nykänen (1986) reported that aldehydes and ketones are created during fermentation and are the leading compounds produced in this stage. Aldehydes in Table 11 did not demonstrate a consistent pattern, but Calhoun County Mycogen had larger values for many of the aldehydes. Terral varieties were similar across location for all significant aldehydes, except acetal; the maize grown in Monte Alto was similar across varieties for (E)-2-heptenal; and the maize grown in Sawyer Farms was similar across varieties for (E)-2-octenal and 2,4-decadienal. Most aldehydes are produced during fermentation in oxidation of fatty acids (Nykänen, 1986; Poisson and Schieberle, 2008). Although there were significant differences reported for Fat content of maize in Table 2, there was not a pattern that would help explain why Calhoun County Mycogen was high in aldehyde formation. Aldehyde content in Calhoun County cannot be explained without fatty acid data for Calhoun County. Terral was low in fat content (Table 1) and did not have significant differences in palmitic or oleic acid, and was low in linoleic acid (Table 9). Terral was similar across locations, but had neither large nor small amounts of aldehyde TICs. Terral was consistently low in fatty acid significant differences, but had a range of saturated and unsaturated fatty acids that could have contributed to mid-level amounts of aldehydes.

Monte Alto was high in palmitic and oleic acid (Table 8), which could explain the similar values of aldehydes across varieties; Mycogen had higher amounts of unsaturated oleic acid to oxidize into aldehydes. Compared to other odor active compounds, alkanes do not constitute a large portion based on research done by Poisson and Schieberle (2008). The alkane volatile group is comprised of alkanes and alkenes (Table 20). There was not a pattern of influence by either location or variety across alkanes. Locations and varieties had similar values throughout the interaction. The differences observed in the alkane and alkene group could be due to how alkanes and alkenes are produced. Alkanes are carbon chains with no functional groups, and alkenes are carbon chains with double bonds, but no functional groups. They are most likely produced through complete decarboxylation of sugars, oxidation of fats, and deamination of proteins. Little research has been conducted on the production of alkanes in NMW and spirits; although they do contribute odor, they are produced through many routes and cannot be tracked as easily throughout whiskey production. Emphasis on tracking compounds is directed toward other volatile compounds, such as alcohols and esters.

Esters are credited for contributing pleasant fruity, floral aromas when they complex with fatty acids during fermentation (Jounela-Erikson and Lehtonen, 2012). Ferrari et al. (2004) stated that whiskey and cognac have similar volatile compounds, and that esters, especially fatty acid ethyl esters are the most abundant group that contribute flavor and aroma. The chain length can alter aroma from fruity/floral to solvent/plastic as it increases (Conner et al., 1998; Poisson and Schieberle, 2008; Willnert et al., 2013). Furthermore, as NMW ages in oak casks to become whiskey, these fatty acid ethyl esters are capable of oxidizing, contributing to a mellow aroma and flavor (Poisson and Schieberle, 2008).

Large and small amounts of esters are scattered across location x variety treatments. The biggest patterns that emerge from the esters in Table 20 are the influence of location and variety. All locations had similar ester values across varieties for several esters. Dyna-Gro and Mycogen varieties showed similar values across locations as well for many esters. For varietal fatty acids, only linoleic acid was significant in total fatty acids; for location fatty acids, only oleic acid was significant in polar fatty acids. Palmitic, oleic, and linoleic acids were only all significant in location total fatty acids. This could explain why across different ethyl esters, varieties within a single location were similar in TIC for that ester. These fatty acid results do not give a clear explanation for the random patterns and high amount of fatty acid ethyl esters present in the NMW volatiles. A reason for there being such a large amount of ethyl ester compounds could be that the high levels of unsaturation in some fatty acids allowed for oxidation to occur easily, creating more fragments of fatty acid chains available to complex with ethanol during fermentation.

Neither furans nor thiols are present in large amounts in NMW, but their quantities increase during aging, due to compound interaction with charred wood (Masuda and Nishimura, 1982). However, low amounts of sulfur compounds contribute to NMW aroma (Ferrari et al., 2004). The development of furans is also possible through Maillard reactions from free amino acids and free reducing sugars during fermentation (Bathgate et al., 1978). Out of four furans present in the NMW, the only significant furan in location x interaction was 2-furancarboxaldehye. Dyna-Gro, and Terral varieties were similar across locations, and there were no patterns in location. The presence of amino acids and reducing sugars was confirmed in the production of fusel alcohols, but it provides the possibility of Maillard reactions occurring, explaining the presence of furans, which are a Maillard byproduct. This would also support the finding in Table 12, showing that roast was a significant NMW attribute in the location x variety analysis.

Ketones were present in consistently larger amounts for Monte Alto Dyna-Gro and Sawyer Farms Mycogen. They were also in consistently smaller amounts in Calhoun County location, Monte Alto Mycogen and Monte Alto Terral. Varieties in Calhoun County were similar for most ketones. Dyna-Gro variety across locations and Mycogen across locations were similar. Ketones are produced alongside aldehydes in fermentation. Sources of ketone production are lipid oxidation and starch hydrolysis to smaller, fermentable units (Dashdorj et al., 2015; Nykänen, 1986; Poisson and Schieberle, 2008). Besides their difference in structure from aldehydes, ketone odors tend to be more fruity and floral, compared to fatty odors from aldehydes (Burdock, 2010; Flament, 2002, NCBI).

Growth location influenced odor development more than variety, but varietal properties were vital in complete odor development. Many of the compounds that created diverse classes of odors are contributed by location, such as nitrogen content, fat content, whereas varieties biggest contribution to odor development is starch. Although ethanol is better predicted from variety due to starch content, the creation of fusel alcohols occurs from amino acid and decarboxylated sugars, and amino acids are impacted through nitrogen content from the growth location (Agu et al., 2008; Swanston et al., 2007). Protein content can also create more diverse flavors if amino acids react with reducing sugars to create Maillard odor products (Bathgate et al., 1978). Esters are a major aroma and flavor component in whiskey and NMW. Ethyl esters are created from fatty acids contributed by environment and yeast metabolism interacting with ethanol during fermentation (Goss et al., 1999; Jounela-Erikson and Lehtonen, 2012). Oxidized fatty acids also contribute to aldehyde and ketone production during distillation, and as demonstrated in Table 16 through Table 20, aldehydes can be characterized by a range of odors (Poisson and Schieberle, 2008). Two of the three fatty acids, oleic acid and linoleic acid, that make up about 90% of fatty acid composition are unsaturated fatty acids, which are more susceptible to oxidation than saturated fatty acids (Table 8 and Table 9). Chain length can influence the odors perceived in ethyl esters; short chain esters are fruity and floral, whereas long chain esters can be characterized as solvent-like and plastic (Willnert et al., 2013; Conner et al., 1998; Poisson and Schieberle, 2008). Oleic acid and linoleic acid have an unsaturated 18-carbon chains, and through oxidation they will break down into shorter chain fatty acids (Gurr and Harwood, 1991).

The biggest impact variety has on aroma development is starch content. Starch serves as a grain’s stored carbohydrate source, which is hydrolyzed into smaller, fermentable sugars used by the yeast in anaerobic fermentation to create ethanol. Because the biggest production goal is to create high amounts of alcohol, grain is usually selected based on starch content. However, starch content composition may play a bigger role than starch quantity, affecting spirit yield after fermentation. Different configuration of starch will affect the extent to which amylases can hydrolyze starch (Balcerek et al., 2016; Vriesekoop et al., 2010). This study did not conduct research on starch composition, but as seen in NIRS data and fermentation data (Table 1 through Table 6), starch quantity could not fully explain alcohol production.

3.5.6. Maize location effects

Out of 52 volatile compounds, three volatiles were significantly different for four maize locations (Calhoun County, Monte Alto, Perryton, Sawyer Farms) in Table 21. In Table 21, location main effects, 1-hexanol total ion count was higher ($P = 0.04$) in Calhoun County maize than in Monte Alto or Perryton maize. Benzaldehyde was highest ($P = 0.01$) in maize grown in Sawyer Farms, compared to maize grown in Calhoun County, Monte Alto, and Perryton. Decanal was high ($P = 0.04$) in Sawyer Farms maize, and low in Perryton maize. The presence of 1-hexanol in Calhoun County maize may be due to the oxidation of lipids in maize. It might also be present based on stress induced by the plant, causing the release of 1-hexanol (Potter et al. 2015). This stress would be influenced by location, as 1-hexanol while maize was grown, but for the study, 1-hexanol may have been released due to the grinding procedure prior to volatile collection and descriptive odor analysis. The other significant volatiles in maize location aroma for Table 21, were benzaldehyde and butanal. Both aldehydes were high in Sawyer Farms;

benzaldehyde was low in Calhoun County, Monte Alto and Terral, and butanal was lowest in Perryton. Aldehydes are produced from lipid degradation, starch hydrolysis, and Maillard reactions. In Table 8, Sawyer Farms is higher in both Palmitic acid and Oleic acid, which can be oxidized into benzaldehyde and butanal. Lipid degradation could also explain 1-hexanol being present in the sample. Lipid degradation could have occurred during handling, but most likely occurred during preparation of the samples. A reason to believe that oxidation occurred because of grinding was that there was little to no aroma present in whole maize kernels, so maize had to be ground to release volatiles. This goes back to the plant releasing volatiles during stress (Potter et al., 2015). Maize sensory can support that oxidation processes occurred after grinding, because fatty, rancid aromas would have been significant across more aldehydes.

3.5.7. Maize location effects excluding Perryton

In Table 22, the three locations (excluding Perryton) that grew all three varieties (Figure 2). Calhoun County maize was higher ($P = 0.03$) in 1-hexanol than Monte Alto maize. Thiobismethane tended ($P = 0.07$) to be higher in the Sawyer Farms location. For the same reason as in Table 21, 1-hexanol was likely produced through lipid oxidation. The exclusion of Perryton from analysis made butanal not significant for location. In Table 21, which included Perryton, Perryton had the smallest amounts of benzaldehyde and butanal. This is supported by Table 8, which show that Perryton was between the high and low values for Linoleic acid and oleic acid, and was low in palmitic acid. Perryton's small amounts of fat and fatty acids would have created less aldehydes, making aldehyde levels significant in Table 21.

Out of 52 volatile compounds, two volatiles were significant for maize variety in Table 22 (Figure 2). In Table 23, benzaldehyde was highest (P = 0.009) in Mycogen variety than in Dyna-Gro or Terral varieties. In the Terral maize variety, decanal total ion count was highest (P = 0.006), and lowest in Dyna-Gro and Mycogen maize varieties. Benzaldehyde was significantly different with Mycogen being higher Dyna-Gro and Terral, and butanal was significantly different with Terral being higher than Dyna-Gro and Mycogen. Mycogen tended to be higher in fatty acids in Table 9, but both Mycogen and Terral were higher in fat percentage in Table 1. The presence of high benzaldehyde in Mycogen agrees with overall sweet being significant in Table 14. Benzaldehyde odor is described as sweet almonds, burnt sugar, and malt, giving a difference in perception of overall sweet (Flament, 2002).

When the three varieties were analyzed, excluding Perryton (Figure 2), there were no significant volatile compounds. Perryton location only grew Terral variety. By removing it from the statistical model, the varieties are balances across locations. No other analysis tables resulted in no differences due to the removal of Perryton for analysis.

3.5.8. Maize location x variety interaction

Table 24 analyzed the interaction between the three locations that were used to grow the complete set of maize varieties. Benzaldehyde was highest (P = 0.01) in Sawyer Farms Mycogen compared to all other location x variety combinations. Decanal was highest (P = 0.02) in Sawyer Farms Terral compared to all other location x variety combinations.

The two aldehydes significant for maize interaction were both grown in Sawyer Farms, which had consistently low fat percentages (Table 2). However, Sawyer Farms did have the highest amounts of palmitic acid, oleic acid, and linoleic acid, which could have contributed to higher lipid oxidation (Table 8).

Much of the work that has been conducted on maize aroma has focused on the release of volatiles that signal herbivores and plant protection (Gouinguené et al., 2001; Molnár et al., 2015; Mutyambai et al., 2016). Gouinguené et al. (2001) found that the amounts of volatile compounds varied greatly between different varieties of maize, but the chemical compounds were similar across varieties. Degen et al. (2004) confirms the large variation in the number of volatile compounds across varieties, but unlike Gouinguené et al. (2001), also found a larger variety of volatile compounds across varieties. Mutyambai et al. (2016) found that decanal is released as a volatile organic compound used for plant defense. Potter et al. (2015), confirms that among the major volatile components, decanal was present in kernel extraction, along with other classes of aldehydes and alcohols. Molnár et al. (2015) also found aldehydes, nonanal and decanal, were important compounds in the volatile composition of maize. The limited presence of aldehydes and lack of other compounds in the results seen in Table 12 through Table 16 could be due to the collection method, and the exclusive collection of volatiles from distilling maize, rather than freshly harvested maize.

Table 25 and Table 26 summarize the GC/MS-O volatile results of NMW and maize, respectively. In summary, location had higher amounts of significantly different fatty acids than variety for NMW, and was higher in each chemical group, except ketones (Table 16, Table 18). Location also had greater amounts of volatiles produced than variety when Perryton was excluded, as seen in the experimental design in Figure 2 (Table 17, Table 19). The interaction of location x variety (Table 20) had greater amounts of volatiles than variety (Table 19), but less volatile amounts than location (Table 17). In ground maize, location influenced greater volatile production than variety, but amounts for both location and variety were low (Table 26). When Perryton is excluded from analysis, as seen in Figure 2, location produced more significantly different volatiles than variety. However, the interaction had more significantly different volatiles than location or variety for ground maize volatiles.

4. CONCLUSION

Maize growth locations and maize varieties affected flavor development in new-make whiskey odor. Growth location and variety had less of an impact on maize kernel composition than on new-make whiskey aroma. Location and variety impacted fatty acid composition and proximate analysis values of starch, crude protein, and lipids. The differences in fatty acids and proximate analysis were useful in explaining aroma development in new-make whiskey.

Throughout the study, the locations Sawyer Farms and Calhoun County, and the variety, Mycogen, displayed greater aroma development across sensory and volatile compounds. Mycogen variety grown in Sawyer Farms also had the greatest estimated ABV by the end of fermentation.

Recommendations to improve the study would be reduce the attributes of the lexicon and see if it is successful at identifying aroma and detecting differences; and run analysis of starch composition and content to see if there are differences that are reflected in ABV or aroma. More work needs to be done on the effects of maize variety and growth location on new-make whiskey aroma. By extending the length of the study, the effects of weather can also be accounted for and reproducibility of results can be examined.

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APPENDIX A

TABLES

Near Infrared Resonance Spectroscopy

Table 1. Least squares means of ground maize proximate analysis by NIRS for locations and varieties

	Starch[a]	Crude protein[a]	Fat[a]
Location			
P > F[b]	0.01	<0.0001	<0.0001
SEM[c]	0.25	0.17	0.07
Calhoun County	68.9[e]	9.86[d]	3.40[d]
Monte Alto	69.3[d]	8.96[e]	3.19[e]
Perryton	69.2[de]	9.93[d]	3.49[d]
Sawyer Farms	68.7[e]	8.68[f]	2.83[f]
Variety			
P > F[b]	0.004	<0.0001	<0.0001
SEM[c]	0.14	0.10	0.04
Dyna-Gro	69.0[e]	9.24[e]	3.50[d]
Mycogen	69.4[d]	9.01[e]	3.04[e]
Terral	68.8[e]	9.76[d]	3.15[e]

[a]Prediction of starch: 0-100%; protein: 0-100%; and fat: 0-100%; through FT-NIRS curves
[b]P value from Analysis of Variance table
[c]Standard Error of the mean, largest from LSMeans table was used
[def] Mean values within a column and effect followed by the same letter are not significantly different (P > 0.05).

Table 2. Least squares means of ground maize proximate analysis by NIRS for locations by varieties interaction

		Proximate analysis[a]		
Location	Variety	Starch	Crude protein	Fat
P > F[b]		<0.0001	<0.0001	<0.0001
SEM[c]		0.05	0.02	0.03
	Dyna-Gro	68.5^{h}	10.1^{c}	3.77^{c}
Calhoun County	Mycogen	69.3^{e}	9.47^{f}	3.06^{f}
	Terral	69.0^{f}	9.99	3.37^{d}
	Dyna-Gro	69.7^{d}	8.56^{h}	3.41^{d}
Monte Alto	Mycogen	70.1^{c}	8.57^{h}	2.98^{f}
	Terral	68.4^{h}	8.95^{g}	3.18^{e}
	Dyna-Gro	68.7^{g}	8.48^{i}	3.05^{f}
Sawyer Farms	Mycogen	68.8^{g}	8.62^{f}	2.82^{g}
	Terral	68.7^{g}	8.95^{g}	2.62^{h}

[a]Prediction of starch: 0-100%; protein: 0-100%; and fat: 0-100%; through FT-NIRS curves

[b]P value from Analysis of Variance table

[c]Standard Error of the mean, largest from LSMeans table was used

[defgh] Mean values within a column and effect followed by the same letter are not significantly different (P > 0.05).

Table 3. Least squares means of whole maize kernels proximate analysis by NIRS for locations and varieties

	Proximate analysis[a]		
	Starch	Crude Protein	Fat
P > F[b]	0.01	0.0001	0.22
SEM[c]	0.47	0.31	0.10
Calhoun County	67.8[c]	8.19[c]	4.23
Monte Alto	68.3[c]	7.42[d]	4.37
Perryton	66.5[d]	8.78[c]	4.19
Sawyer Farms	68.2[c]	7.23[d]	4.33
P > F[b]	0.008	0.0008	<0.0001
SEM[c]	0.27	0.18	0.06
Dyna-Gro	67.4[d]	7.89[d]	4.51[c]
Mycogen	68.4[c]	7.40[e]	4.25[d]
Terral	67.4[d]	8.42[c]	4.07[e]

[a]Prediction of starch: 0-100%; protein: 0-100%; and fat: 0-100%; through FT-NIRS curves

[b]P value from Analysis of Variance table

[c]Standard Error of the mean, largest from LSMeans table was used

[def] Mean values within a column and effect followed by the same letter are not significantly different (P > 0.05).

Table 4. Least squares means of whole maize kernels proximate analysis by NIRS for location by varieties interaction

Location	Variety	Proximate analysis[a]		
		Starch	Crude protein	Fat
P > F[b]		0.004	0.01	0.02
SEM[c]		0.33	0.23	0.08
	Dyna-Gro	68.3[ef]	7.62[ef]	4.42[def]
Calhoun County	Mycogen	67.9[efg]	8.18[de]	4.07[g]
	Terral	67.0[g]	8.77[d]	4.19[fg]
	Dyna-Gro	67.5[fg]	7.69[ef]	4.57[d]
Monte Alto	Mycogen	69.6[d]	6.50[g]	4.49[de]
	Terral	67.9[fg]	8.07[ef]	4.04[g]
	Dyna-Gro	67.4[fg]	7.49[f]	4.65[d]
Sawyer Farms	Mycogen	68.9[de]	6.66[g]	4.28[efg]
	Terral	68.4[ef]	7.55[ef]	4.06[g]

[a]Prediction of starch: 0-100%; protein: 0-100%; and fat: 0-100%; through FT-NIRS curves

[b]P value from Analysis of Variance table

[c]Standard Error of the mean, largest from LSMeans table was used

[defg] Mean values within a column and effect followed by the same letter are not significantly different (P > 0.05).

Table 5. Least squares means of estimated alcohol by volume (ABV) of new-make whiskey produced in different locations or produced from different maize varieties

	Estimated percent alcohol by volume [a]
Locations	
P > F[b]	0.0008
SEM[c]	0.002
Calhoun County	8.41[e]
Monte Alto	8.22[e]
Perryton	8.65[de]
Sawyer Farms	9.22[d]
Varieties	
P > F[b]	0.02
SEM[c]	0.002
Dyna-Gro	8.25[e]
Mycogen	8.74[d]
Terral	8.89[d]

[a]Estimated Percent Alcohol by volume based on specific gravity measurements provided by Firestone & Robertson Distilling Co.
[b]P value from Analysis of Variance table
[c]Standard Error of the mean, largest from LSMeans table was used
[de] Mean values within a column and effect followed by the same letter are not significantly different ($P > 0.05$).

Table 6. Least squares means of estimated percent alcohol by volume (ABV) of new-make whiskey produced in three different locations that produced three maize varieties

Locations	Varieties	Estimated percent alcohol by volume [a]
	Dyna-Gro	8.11
Calhoun County	Mycogen	8.21
	Terral	8.90
	Dyna-Gro	7.89
Monte Alto	Mycogen	8.37
	Terral	8.43
Sawyer Farms	Dyna-Gro	8.74
	Mycogen	9.60
	Terral	9.34
P > F[b]		0.54
SEM[c]		0.003

[a]Estimated Percent Alcohol by volume based on specific gravity measurements provided by Firestone & Robertson Distilling Co.

[b]P value from Analysis of Variance table

[c]Standard Error of the mean, largest from LSMeans table was used

[de] Mean values within a column and effect followed by the same letter are not significantly different (*P* > 0.

Fatty Acids

Table 7. Least squares means of lipid weight (in grams) in ground maize grown in different locations and different maize varieties

	Total lipid[a]	Polar lipid[b]	Neutral lipid[c]
Location			
P > F[d]	0.50	0.01	N/A
SEM[e]	0.04	0.01	N/A
Calhoun County	0.10	0.08[f]	0.02
Monte Alto	0.09	0.06[g]	0.03
Perryton	0.07	0.08[fg]	-0.01
Sawyer Farms	0.12	0.05[g]	0.07
Variety			
P > F[d]	0.29	0.12	N/A
SEM[e]	0.02	0.006	N/A
Dyna-Gro	0.08	0.07	0.01
Mycogen	0.06	0.06	0.0
Terral	0.12	0.07	0.05

[a]Total lipid from fatty acid Folch method, in grams
[b]Polar lipid fraction of fatty acid Folch method, in grams
[c]Neutral lipid determined by difference of Total lipid and Polar lipid, in grams
[d]P value from Analysis of Variance table
[e]Standard Error of the mean, largest from LSMeans table was used
[fg] Mean values within a column and effect followed by the same letter are not significantly different (P > 0.05).

Table 8. Least squares means of fatty acids percentages present in ground maize grown in different locations as detected by GC analysis

Component	Fatty Acid	*P* > F	SEM	Monte Alto	Perryton	Sawyer Farms
Total Fatty Acids						
C14:0	Myristic	0.39	0.02	0.02	0.004	0.03
C16:0	Palmitic	0.009	0.25	14.5^{c}	13.8^{d}	14.8^{c}
C16:1	Palmitoleic	0.005	0.02	0.06^{d}	0.11^{cd}	0.11^{c}
C18:0	Stearic	0.94	0.33	1.91	2.04	1.94
C18:1C11	Vaccenic	<0.0001	0.0001	0^{d}	0.68^{c}	0^{d}
C18:1C9	Oleic	0.0002	0.55	26.9^{c}	25.8^{cd}	24.7^{d}
C18:2	Linoleic	0.01	0.52	53.8^{d}	54.5^{cd}	55.0^{c}
C18:3	γ-Linolenic	0.0003	0.04	1.42^{d}	1.56^{c}	1.58^{c}
C20:0	Arachidic	0.02	0.02	0.36^{d}	0.38^{cd}	0.41^{c}
C20:1	Gondoic	0.03	0.02	0.22^{d}	0.25^{cd}	0.25^{c}
C20:4	Arachidonic	0.01	0.01	0.15^{d}	0.17^{cd}	0.18^{c}
C20:5	Eicosapentaenoic	0.95	0.02	0.02	0.01	0.02
C22:6	Docosahexaenoic	0.10	0.007	0.00	0.02	0.00
C24:0	Lignoceric	0.0002	0.02	0.22^{d}	0.24^{d}	0.29^{c}
C24:1	Nervonic	0.10	0.005	0.00	0.01	0.00
Polar Fatty Acids						
C14:0	Myristic	0.02	0.01	0.04^{d}	0.04^{d}	0.06^{c}
C16:0	Palmitic	0.43	2.22	13.2	15.1	15.2
C16:1	Palmitoleic	0.14	0.02	0.11	0.14	0.13
C18:0	Stearic	<0.0001	0.05	2.03^{d}	1.69^{e}	2.23^{c}
C18:1C11	Vaccenic	0.04	0.20	0.08^{d}	0.58^{c}	0.38^{c}
C18:1C9	Oleic	0.0003	0.62	26.7^{c}	26.0^{c}	24.4^{d}
C18:2	Linoleic	0.07	0.68	52.9	54.6	53.8
C18:3	γ-Linolenic	0.02	0.05	1.52^{d}	1.60^{cd}	1.63^{c}
C20:0	Arachidic	<0.0001	0.01	0.36^{d}	0.31^{e}	0.42^{c}
C20:1	Gondoic	0.20	0.01	0.26	0.26	0.27
C20:2	Eicosadienoic	0.14	0.02	0.003	0.04	0.009
C20:4	Arachidonic	<0.0001	0.005	0.16^{d}	0.15^{d}	0.20^{c}
C20:5	Eicosapentaenoic	0.24	0.01	0	0.01	0.01
C22:6	Docosahexaenoic	0.39	0.02	0.00	0.01	0.02
C24:0	Lignoceric	0.0006	0.02	0.23^{d}	0.27^{cd}	0.30^{c}
C24:1	Nervonic	0.10	0.005	0	0.01	0

[a]P value from Analysis of Variance table

[b]Standard Error of the mean, largest from LSMeans table was used

[cde] Mean values within a column and effect followed by the same letter are not significantly different (P > 0.05).

Table 9. Least squares means of fatty acids percentages present in different ground maize varieties as detected by GC analysis

Component	Fatty Acid	*P* > F[a]	SEM[b]	Dyna-Gro	Mycogen	Terral
Total Fatty Acids						
C14:0	Myristic	0.36	0.01	0.01	0.01	0.03
C16:0	Palmitic	0.06	0.17	14.1	14.3	14.7
C16:1	Palmitoleic	0.17	0.01	0.08	0.09	0.11
C18:0	Stearic	0.31	0.23	2.03	2.15	1.71
C18:1C11	Vaccenic	1.00	0.0002	0.23	0.23	0.23
C18:1C9	Oleic	0.20	0.39	25.4	26.3	25.6
C18:2	Linoleic	0.006	0.36	55.32[c]	53.64[d]	54.3[d]
C18:3	γ-Linolenic	0.09	0.03	1.49	1.57	1.50
C20:0	Arachidic	0.06	0.02	0.38	0.41	0.36
C20:1	Gondoic	0.0009	0.01	0.20[d]	0.26[c]	0.26[c]
C20:4	Arachidonic	0.01	0.009	0.14[d]	0.18[c]	0.16[cd]
C20:5	Eicosapentaenoic	0.44	0.02	0.02	0.02	0.01
C22:6	Docosahexaenoic	1.00	0.006	0.01	0.01	0.01
C24:0	Lignoceric	0.006	0.01	0.22[d]	0.28[c]	0.24[d]
C24:1	Nervonic	1.00	0.004	0.00	0.00	0.00
Polar Fatty Acids						
C14:0	Myristic	0.07	0.009	0.04	0.05	0.06
C16:0	Palmitic	0.47	1.57	14.9	15.5	13.1
C16:1	Palmitoleic	0.36	0.01	0.14	0.13	0.11
C18:0	Stearic	0.01	0.03	2.00[d]	2.09[c]	1.95[d]
C18:1C11	Vaccenic	0.33	0.13	0.21	0.35	0.47
C18:1C9	Oleic	0.75	0.44	25.5	25.9	25.6
C18:2	Linoleic	0.06	0.48	54.6	53.1	53.5
C18:3	γ-Linolenic	0.81	0.04	1.59	1.60	1.57
C20:0	Arachidic	0.001	0.009	0.35[d]	0.40[c]	0.35[d]
C20:1	Gondoic	0.007	0.01	0.34[d]	0.28[c]	0.27[c]
C20:2	Eicosadienoic	0.66	0.01	0.01	0.03	0.02
C20:4	Arachidonic	<0.0001	0.004	0.16[d]	0.19[c]	0.16[d]
C20:5	Eicosapentaenoic	0.07	0.007	0.00	0.02	0.00
C22:6	Docosahexaenoic	0.61	0.01	0.01	0.00	0.02
C24:0	Lignoceric	0.04	0.01	0.25[d]	0.29[c]	0.25[d]
C24:1	Nervonic	1.00	0.003	0.00	0.00	0.00

[a]P value from Analysis of Variance table

[b]Standard Error of the mean, largest from LSMeans table was used

[cd] Mean values within a column and effect followed by the same letter are not significantly different (P > 0.05).

Trained Sensory Tables

Table 10. Least squares means of trained sensory panel scores for aroma attributes of new-make whiskey aroma for maize growth locations

Attribute[a]	*P* > F[b]	RMSE[c]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
Blended	0.10	1.1	7.43	6.38	8.25	6.71
Alcohol	0.27	0.6	6.35	6.78	7.13	6.47
Overall sweet	0.53	0.6	2.78	2.41	2.71	2.75
Overall sour	0.66	0.8	2.98	3.35	3.11	2.93
Brown spice complex	0.88	0.8	0.34	0.64	0.58	0.41
Grain complex	0.94	0.7	5.23	5.17	5.40	5.33
Corn	0.70	0.6	5.19	5.08	4.63	5.06
Malt	0.008	0.5	3.90[d]	3.46[de]	3.99[d]	3.08[e]
Fermented/yeasty	0.07	0.4	2.78	3.06	2.55	2.52
Woody	0.17	0.7	4.20	3.48	4.14	3.73
Nutty	0.64	0.9	2.52	2.94	3.16	2.58
Berry fruit	0.58	0.6	0.19	0.01	0.64	0.28
Dark fruit	0.41	0.7	0.14	0.37	0.40	0.72
Other fruit	0.55	0.6	0.25	0.02	0.00	0.40
Musty/dusty	0.15	0.7	4.11	4.55	4.80	3.90
Musty/earthy	0.59	0.5	2.97	2.90	3.24	2.72
Hay-like	0.20	0.6	3.30	2.99	2.39	2.79
Green	0.86	1.3	1.03	0.50	2.06	0.62
Floral	0.46	0.6	0.22	0.05	0.82	0.21
Tobacco	0.24	0.7	3.42	3.66	2.62	3.45
Medicinal	0.44	0.6	2.00	2.72	1.95	2.43
Leather	0.40	0.8	0.97	0.74	1.04	0.31
Smokey	0.97	0.6	0.22	0.23	0.40	0.22
Roast	0.54	0.6	2.22	2.17	1.62	2.32
Brown sugar	0.41	0.8	1.94	2.58	2.31	2.14
Honey	0.39	0.9	0.93	1.19	0.48	0.50
Molasses	0.57	0.9	0.97	0.94	1.62	1.41
Vanilla	0.64	0.4	0.18	0.01	0.00	0.18
Buttery	0.65	0.9	0.56	0.77	0.00	0.64
Anise	0.002	0.3	0.00[c]	0.02[c]	1.03[d]	0.14[c]
Pepper	0.46	0.5	0.12	0.08	0.63	0.12
Vinegar	0.49	0.6	0.31	0.37	0.00	0.51
Lactic acid	0.22	0.7	1.99	2.10	1.97	1.46
Cardboard/paper	0.61	0.5	3.46	3.23	3.53	3.20
Stale	0.12	0.5	2.33	2.78	2.20	2.23
Soapy	0.72	0.7	1.34	1.52	1.60	1.14
Solvent-like	0.25	0.5	0.07	0.34	-0.30	0.29

Attribute[a]	P > F[b]	RMSE[c]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
Oily	0.33	0.4	0.01	033	0.10	0.09
Sulphur	0.33	0.2	0.00	0.00	0.00	0.10
Prickle/pungent	0.17	0.4	4.09[de]	4.27[d]	3.85[de]	3.79[e]
Nose cooling	0.69	0.8	4.66	4.77	5.38	4.67
Nose drying	0.94	0.7	4.48	4.39	4.63	4.36
Nose warming	0.18	0.5	3.45[d]	3.14[de]	3.02[de]	2.98[e]

[a]Attributes measured on 16-point scale from 0-15. Attribute: 0 = none, 15 = Extremely intense

[b]Values are significant ($P < 0.05$)

[c]Root Mean Square Error for the treatment, largest RMSE selected

[de]LSMeans in the same row with different superscripts differ ($P < 0.05$).

Table 11. Least squares means of trained sensory panel scores for aroma attributes of new-make whiskey aroma produced from different maize varieties

Attribute[a]	*P* > F[b]	RMSE[c]	Dyna-Gro	Mycogen	Terral
Blended	0.15	1.1	7.46	7.55	6.56
Alcohol	0.07	0.6	6.37	7.08	6.61
Overall sweet	0.04	0.6	2.81[d]	2.93[d]	2.24[e]
Overall sour	0.11	0.8	2.94	2.80	3.54
Brown spice complex	0.87	0.8	0.38	0.50	0.59
Grain complex	0.05	0.7	4.79[e]	5.46[de]	5.60[d]
Corn	0.18	0.6	4.80	5.32	4.85
Malt	0.26	0.6	3.43	3.81	3.58
Fermented/yeasty	0.59	0.4	2.72	2.63	2.84
Woody	0.01	0.7	3.31[e]	4.40[d]	3.95[d]
Nutty	0.32	0.9	2.94	3.04	2.43
Berry fruit	0.55	0.6	0.39	0.36	0.08
Dark fruit	0.29	0.7	0.41	0.67	0.13
Other fruit	0.24	0.6	0.15	0.00	0.41
Musty/dusty	0.39	0.7	4.17	4.59	4.26
Musty/earthy	0.03	0.5	2.93[de]	3.32[d]	2.62[e]
Hay-like	0.32	0.6	2.67	3.12	2.81
Green	0.60	1.3	0.70	1.31	1.15
Floral	0.23	0.6	0.63	0.18	0.16
Tobacco	0.19	0.7	2.96	3.38	3.53
Medicinal	0.74	0.6	2.17	2.05	2.26
Leather	0.39	0.8	0.72	0.51	1.06
Smokey	0.37	0.6	0.15	0.16	0.49
Roast	0.74	0.6	1.98	2.20	2.06
Brown sugar	0.06	0.8	2.66	2.33	1.74
Honey	0.89	0.9	0.83	0.66	0.83
Molasses	0.15	0.9	0.71	1.56	1.42
Vanilla	0.08	0.4	0.02	0.30	0.00
Buttery	0.62	0.9	0.68	0.27	0.50
Anise	0.53	0.3	0.40	0.25	0.23
Pepper	0.59	0.5	0.13	0.22	0.36
Vinegar	0.19	0.6	0.00	0.50	0.27
Lactic acid	0.61	0.7	1.90	1.71	2.02
Cardboard/paper	0.59	0.5	3.28	3.49	3.30
Stale	0.30	0.5	2.17	2.50	2.49
Soapy	0.91	0.7	1.32	1.47	1.41
Solvent-like	0.40	0.5	0.00	0.21	0.16
Oily	0.74	0.4	0.08	0.20	0.11
Sulphur	0.31	0.2	0.00	0.11	0.00
Prickle/pungent	0.01	0.4	3.77[e]	3.86[e]	4.38[d]

Attribute[a]	$P > F$[b]	RMSE[c]	Dyna-Gro	Mycogen	Terral
Nose cooling	0.54	0.8	4.94	4.62	5.05
Nose drying	0.62	0.7	4.35	4.40	4.65
Nose warming	0.31	0.5	3.29	2.96	3.19

[a]Attributes measured on 16-point scale from 0-15. Attribute: 0 = none, 15 = Extremely intense

[b]Values are significant ($P < 0.05$)

[c]Root Mean Square Error for the treatment, largest RMSE selected

[de]LSMeans in the same row with different superscripts differ ($P < 0.05$).

Table 12. Least squares means of trained sensory panel scores for aroma attributes of new-make whiskey aroma interactions produced from different maize grown in different locations

Attribute[a]	*P* > F[b]	RMSE[c]	Calhoun County			Monte Alto			Sawyer Farms		
			Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Blended	0.39	1.0	7.70	8.31	6.25	6.77	7.08	5.54	7.01	6.31	6.80
Alcohol	0.35	0.6	6.34	6.17	6.57	6.39	7.25	6.54	5.87	7.29	6.30
Overall sweet	0.96	0.6	2.95	3.17	2.17	2.54	2.71	2.02	2.99	2.89	2.43
Overall sour	0.12	0.7	2.12	2.68	4.15	3.65	2.72	3.60	2.89	2.97	2.87
Brown spice complex	0.81	0.8	0.00	0.60	0.50	0.87	0.66	0.48	0.29	0.21	0.69
Grain complex	0.26	0.7	5.11	5.62	5.01	4.23	5.26	6.09	4.88	5.36	5.65
Corn	0.02	0.5	5.00[ef]	5.61[de]	5.01[ef]	5.36[def]	4.72[ef]	5.23[def]	4.39[f]	6.00[d]	4.71[ef]
Malt	0.03	0.4	3.38[efg]	4.58[d]	3.81[def]	3.28[efg]	3.23[efg]	3.95[de]	3.11[fg]	3.26[efg]	2.68[g]
Fermented/yeasty	0.49	0.4	3.03	2.43	2.88	3.10	3.00	3.05	2.26	2.62	2.74
Woody	0.56	0.7	3.49	4.86	4.29	2.48	4.03	3.88	3.59	4.06	3.47
Nutty	0.50	0.9	2.97	2.37	2.23	3.50	3.10	2.20	2.06	3.27	2.47
Berry fruit	0.60	0.6	0.60	0.00	0.07	0.00	0.05	0.00	0.12	0.67	0.00
Dark fruit	0.66	0.8	0.00	0.51	0.00	0.64	0.20	0.28	0.52	1.31	0.22
Other fruit	0.95	0.7	0.26	0.00	0.45	0.06	0.00	0.07	0.38	0.03	0.86
Musty/dusty	0.76	0.7	3.67	4.72	3.99	4.31	4.62	4.77	3.94	4.00	3.62
Musty/earthy	0.67	0.6	3.10	3.25	2.60	2.71	3.05	2.88	2.64	3.35	2.13
Hay-like	0.23	0.6	3.04	3.61	3.26	3.26	2.76	3.00	2.20	3.49	2.65
Green	0.80	1.2	0.63	1.92	0.71	0.52	0.41	0.84	0.00	0.67	1.04
Floral	0.76	0.6	0.64	0.14	0.00	0.05	0.00	0.15	0.60	0.00	0.00
Tobacco	0.31	0.6	3.42	3.50	3.34	3.31	3.40	4.31	2.86	3.88	3.61
Medicinal	0.45	0.5	2.23	1.65	2.08	2.50	2.05	2.25	2.14	2.65	2.63
Leather	0.06	0.6	1.36	0.00	1.71	0.44	0.32	1.16	0.00	0.87	0.15
Smokey	0.78	0.6	0.61	0.02	0.36	0.00	0.00	0.72	0.00	0.34	0.28
Roast	0.02	0.4	2.32[e]	2.07[e]	2.30[e]	2.02[e]	1.97[e]	2.41[de]	1.96[e]	2.98[d]	1.98[e]

Attribute	$P >$ F[b]	RMSE[c]	Calhoun County			Monte Alto			Sawyer Farms		
			Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Brown sugar	0.56	0.8	2.08	1.98	1.71	3.37	2.90	1.47	2.55	2.06	1.92
Honey	0.18	0.8	1.62	0.64	0.48	1.34	1.59	0.77	0.02	0.05	1.50
Molasses	0.52	1.0	0.68	0.69	1.54	0.49	1.09	1.05	0.52	2.44	1.32
Vanilla	0.43	0.4	0.00	0.69	0.00	0.20	0.15	0.00	0.14	0.25	0.16
Buttery	0.20	0.9	1.01	0.95	-0.18	1.46	-0.11	1.31	0.13	0.58	0.99
Anise	0.69	0.2	0.01	0.05	0.00	0.05	0.00	0.03	0.30	0.00	0.03
Pepper	0.27	0.3	0.15	0.00	0.34	0.00	0.31	0.00	0.00	0.08	0.38
Vinegar	0.24	0.6	0.00	0.94	0.30	0.00	0.36	0.93	0.64	0.68	0.08
Lactic acid	0.006	0.5	2.04^{def}	1.29^{fg}	2.66^{d}	2.48^{de}	1.67^{efg}	1.98^{def}	0.98^{g}	2.02^{def}	1.36^{fg}
Cardboard/paper	0.29	0.5	3.54	3.15	3.61	2.97	3.70	2.86	3.24	3.41	3.16
Stale	0.12	0.4	1.88	2.32	2.85	2.52	2.62	3.07	2.11	2.70	1.80
Soapy	0.89	0.8	1.15	1.46	1.43	1.64	1.29	1.63	0.93	1.46	0.99
Solvent-like	0.95	0.5	0.00	0.31	0.00	0.15	0.48	0.43	0.18	0.27	0.46
Oily	0.21	0.4	0.10	0.00	0.00	0.35	0.67	0.00	0.00	0.00	0.42
Sulphur	0.21	0.2	0.00	0.01	0.10	0.00	0.00	0.04	0.06	0.34	0.00
Prickle/pungent	0.40	0.4	3.98	3.68	4.64	4.05	4.02	4.64	3.35	3.98	4.03
Nose cooling	0.92	0.9	4.49	4.77	4.69	5.09	4.38	4.99	4.82	4.26	4.94
Nose drying	0.39	0.7	4.17	4.08	5.19	3.84	4.56	4.53	4.74	4.34	4.06
Nose warming	0.75	0.5	3.30	3.42	3.61	3.40	3.00	3.05	3.32	2.62	3.01

[a]Attributes measured on 16-point scale from 0-15. Attribute: 0 = none, 15 = Extremely intense

[b]Values are significant ($P < 0.05$)

[c]Root Mean Square Error for the treatment, largest RMSE selected

[de]LSMeans in the same row with different superscripts differ ($P < 0.05$).

Table 13. Least squares means of trained sensory panel scores for aroma attributes of ground maize aroma of different maize growth locations

Attribute[a]	P > F[b]	RMSE[c]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
Overall sweet	0.36	0.5	2.87	2.92	3.19	2.52
Overall sour	0.26	0.8	2.37	2.23	3.65	2.67
Corn	0.06	0.6	7.31	6.65	7.18	6.43
Grain complex	0.38	0.8	4.15	4.32	3.49	4.53
Malt	0.94	0.8	1.94	1.71	1.77	1.92
Musty/dusty	0.53	0.8	6.46	6.46	5.52	6.34
Musty/earthy	0.35	0.5	2.77	2.39	1.97	2.37
Woody	0.24	0.6	6.54	5.95	6.88	6.26
Nutty	0.44	0.7	2.66	2.45	2.46	3.01
Buttery	0.49	0.7	1.60	1.06	0.80	1.22
Oily	0.05	0.4	2.08[e]	2.08[e]	3.15[d]	2.29[e]
Rancid	0.06	0.5	0.07	0.18	1.28	0.29
Hay-like	0.25	0.6	1.70	2.20	2.25	2.40
Green	0.16	0.3	0.16	0.29	0.00	0.00
Roast	0.64	0.5	2.55	2.30	2.67	2.31
Smokey	0.053	0.2	0.16	0.00	0.18	0.00
Medicinal	0.33	0.5	2.04	1.70	2.19	1.66
Leather	0.32	0.5	1.87	1.45	1.93	1.51
Barnyard	0.005	0.7	0.63[e]	0.59[e]	0.37[e]	1.97[d]
Cardboard/paper	0.17	0.5	3.36[de]	3.40[de]	4.02[d]	3.08[e]
Stale	0.51	0.6	2.29	2.39	2.46	2.72
Floral	0.25	0.2	0.00	0.05	0.19	0.10
Tobacco	0.48	0.7	0.25	0.02	0.95	0.34
Brown sugar	0.06	0.2	0.00	0.04	0.36	0.00
Vanilla	0.06	0.3	0.00	0.08	072	0.00
Lactic acid	0.51	0.4	0.00	0.04	0.08	0.24
Soapy	0.001	0.4	0.33[e]	0.08[e]	1.55[d]	0.00[e]
Solvent-like	0.10	0.4	0.17	0.07	0.66	-0.10
Butyric	0.05	0.3	0.06[de]	0.00[e]	0.00[e]	0.35[d]
Sulphur	0.35	0.5	0.13	0.01	0.00	0.44

[a]Attributes measured on 16-point scale from 0-15. Attribute: 0 = none, 15 = Extremely intense

[b]Values are significant ($P < 0.05$)

[c]Root Mean Square Error for the treatment, largest RMSE selected

[de]LSMeans in the same row with different superscripts differ ($P < 0.05$).

Table 14. Least squares means of trained sensory panel scores for aroma attributes of ground maize aroma of different maize varieties

Attribute[a]	$P > F$[b]	RMSE[c]	Dyna-Gro	Mycogen	Terral
Overall sweet	0.04	0.5	2.56[e]	3.30[d]	2.76[de]
Overall sour	0.08	0.8	2.61	3.33	2.26
Corn	0.18	0.6	6.51	6.96	7.21
Grain complex	0.75	0.1	3.73	3.99	4.65
Malt	0.29	0.8	1.44	2.03	2.03
Musty/dusty	0.39	0.8	6.07	5.95	6.57
Musty/earthy	0.09	0.5	2.00	2.63	2.49
Woody	0.59	0.6	6.40	6.22	6.60
Nutty	0.65	0.7	2.46	266	2.82
Buttery	0.29	0.7	0.95	1.52	1.05
Oily	0.29	0.4	2.63	2.35	2.23
Rancid	0.23	0.5	0.72	0.45	0.20
Hay-like	0.75	0.6	2.04	2.06	2.31
Green	0.91	0.3	0.03	0.09	0.08
Roast	0.34	0.5	2.22	2.48	2.66
Smokey	0.054	0.2	0.10	0.19	0.00
Medicinal	0.63	0.5	1.79	2.03	1.86
Leather	0.10	0.5	1.47	2.02	1.59
Barnyard	0.96	0.7	0.88	0.84	0.95
Cardboard/paper	0.27	0.5	3.45	3.71	3.24
Stale	0.92	0.6	2.52	2.41	2.47
Floral	0.09	0.2	0.06	0.18	0.00
Tobacco	0.58	0.7	0.28	0.62	0.27
Brown sugar	0.92	0.2	0.11	0.09	0.07
Vanilla	0.92	0.3	0.22	0.17	0.15
Lactic acid	0.15	0.4	0.30	0.00	0.00
Soapy	0.04	0.4	0.69[d]	0.65[d]	0.04[e]
Solvent-like	0.31	0.4	0.09	0.37	0.14
Fishy	0.56	0.3	0.0004	0.00	0.15
Butyric	0.37	0.5	0.34	0.00	0.08

[a]Attributes measured on 16-point scale from 0-15. Attribute: 0 = none, 15 = Extremely intense

[b]Values are significant ($P < 0.05$)

[c]Root Mean Square Error for the treatment, largest RMSE selected

[de]LSMeans in the same row with different superscripts differ ($P < 0.05$).

Table 15. Least squares means of trained sensory panel scores for aroma attributes of ground maize aroma interactions produced from maize varieties grown in different locations

Attribute[a]	*P* > F[b]	RMSE[c]	Calhoun County			Monte Alto			Sawyer Farms		
			Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Overall sweet	0.46	0.7	2.76	2.90	3.05	2.46	3.73	2.49	2.18	3.20	2.08
Overall sour	0.10	0.7	3.00	2.50	1.64	1.46	3.20	2.07	2.68	3.06	2.31
Corn	0.06	0.5	7.48	6.95	7.59	6.57	7.53	5.94	5.58	6.55	6.93
Grain complex	0.97	0.8	3.71	4.23	4.47	3.84	4.39	4.99	4.11	4.18	5.09
Malt	0.32	0.7	1.81	2.10	2.40	1.25	1.50	2.17	0.94	2.75	1.90
Musty/dusty	0.36	0.8	6.57	6.29	6.47	6.53	6.63	6.28	6.13	5.58	7.27
Musty/earthy	0.30	0.5	2.21	3.19	2.67	1.72	2.62	2.89	2.52	2.16	2.60
Woody	0.75	0.6	6.73	6.30	6.43	5.86	5.85	6.20	6.39	5.74	6.77
Nutty	0.95	0.7	2.40	2.63	2.90	2.42	2.39	2.66	2.67	3.26	3.02
Buttery	0.49	0.8	1.15	1..70	2.06	0.91	1.20	0.68	1.14	2.06	0.66
Oily	0.12	0.4	2.35	2.10	1.63	2.14	2.35	1.89	2.78	1.75	2.34
Rancid	0.90	0.4	0.26	0.00	0.00	0.36	0.00	0.03	0.86	0.24	0.07
Hay-like	0.19	0.5	1.67	1.84	1.64	1.80	2.20	2.40	2.68	1.73	2.97
Green	0.83	0.4	0.13	0.09	0.31	0.34	0.45	0.00	0.00	0.20	0.00
Roast	0.28	0.5	2.40	2.59	2.54	2.08	2.76	2.17	2.24	1.90	2.76
Smokey	0.29	0.2	0.11	0.28	0.07	0.08	0.11	0.00	0.05	0.09	0.00
Medicinal	0.30	0.5	1.69	2.29	2.19	1.90	1.84	1.04	1.65	1.70	1.78
Leather	0.54	0.5	1.63	1.93	2.10	1.44	2.02	0.63	1.36	1.97	1.32
Barnyard	0.11	0.7	1.11	0.53	0.35	0.00	0.32	1.89	1.79	2.00	1.92
Cardboard/paper	0.41	0.5	3.23	3.61	3.15	3.16	3.89	3.10	3.56	2.98	2.92
Stale	0.66	0.6	2.30	2.53	2.14	2.17	1.99	3.00	2.87	2.50	2.81
Floral	0.68	0.2	0.00	0.02	0.00	0.06	0.10	0.00	0.03	0.34	-0.08
Tobacco	0.52	0.5	0.10	0.21	0.38	0.00	0.00	0.15	0.69	0.69	0.09
Lactic acid	0.08	0.3	0.00	0.00	0.00	0.17	0.00	0.00	0.87	0.00	0.14
Soapy	0.37	0.4	0.92	0.38	0.00	0.26	0.34	0.00	0.01	0.00	0.00
Solvent-like	0.23	0.2	0.06	0.36	0.00	0.03	0.04	0.20	0.00	0.00	0.04

Attribute[a]	*P* > F[b]	RMSE[c]	Calhoun County			Monte Alto			Sawyer Farms		
			Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Butyric	0.95	0.3	0.03	0.05	0.11	0.00	0.00	0.27	0.30	0.26	0.49
Sulphur	0.86	0.5	0.42	0.03	0.00	0.04	0.00	0.26	0.72	0.12	0.48

[a]Attributes measured on 16-point scale from 0-15. Attribute: 0 = none, 15 = Extremely intense

[b]Values are significant ($P < 0.05$)

[c]Root Mean Square Error for the treatment, largest RMSE selected

[de]LSMeans in the same row with different superscripts differ ($P < 0.05$).

GC-MS TABLES

Table 16. Least squares means of total ion counts for volatiles present during aroma events for new-make whiskey produced from maize grown in four different locations as detected by GC/MS-O analysis

Volatile Compound	Sensory Attribute[123]	$P > F^a$	SEM[b]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
Acid							
4-hydroxymandelic acid – TRITMS	N/A	0.05	18570	26346[c]	891[d]	991[cd]	28643[c]
Acetic acid	Acid, fruit, pungent, sour, vinegar[2,3]	0.003	26889	58011[c]	-8484[d]	25281[cd]	0[d]
n-decanoic acid	Sour-fatty, rancid[2]	0.02	50492	0[d]	92188[c]	-26000[d]	38165[cd]
Alcohol							
1-Octanol	Green, fatty, coconut; fresh, orange, rose[123]	0.0001	17548	48879[c]	-5007[e]	17430[cde]	22357[d]
Isobutyl alcohol; 2-methyl-3-propanol	Malty; apple, bitter, cocoa, wine[23]	<0.0001	17070	45573[c]	-8629[d]	12315[cd]	0[d]
Benzene-ethanol	Mild, warm, rose, honey[3]	<0.0001	106134	325282[d]	33608[e]	238776[de]	498986[c]
Ethanol	Ethanol-like[23]	<0.0001	1746438	8426023[c]	3137927[d]	5279221[cd]	6646080[c]
Isoamyl alcohol; 3-methyl-1-butanol	Fusel oil, whiskey-characteristic, pungent; malty; burnt, cocoa, floral, [123]	<0.0001	961867	3367788[c]	287597[d]	2319972[cd]	3249582[c]
Aldehyde							
(E)-2-heptenal	Fatty, green[3]	<0.0001	34170	116657[c]	-22798[e]	112831[c]	30798[d]

Volatile Compound	Sensory Attribute[123]	P > F[a]	SEM[b]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
(E)-2-Nonenal	Penetrating, fatty, orris, waxy, dried orange; green; intense papery[123]	<0.0001	90829	354935[c]	37631[d]	431286[c]	258340[c]
(E)-2-octenal	Fatty-nutty[2]	<0.0001	46244	135241[c]	14346[d]	235995[c]	56169[d]
2-butenal	Pungent[1]	0.01	5978	5470[cd]	1607[d]	-3374[d]	13490[c]
2-octenal	Fatty-nutty; citrus, honey[12]	0.0003	36495	89125[c]	-16030[d]	-8628[d]	23286[d]
2,4-decadienal	Fatty; metallic, tallow[3]	0.0004	41509	130891[d]	67507[e]	233024[c]	45005[e]
Acetaldehyde	Floral, green apple[3]	0.10	7279	17029	12122	-2926	8538
Benzaldehyde	Sweet, crushed almonds; burnt sugar, cherry, malt[2,]	0.0003	185992	654810[c]	158546[e]	123710[de]	479771[cd]
Decanal	Floral, fatty, fried, orange peel, penetrating tallow (buckwheat)[123]	0.006	21267	0[d]	-5675[d]	-2740[cd]	42636[c]
Heptanal	Oily, fatty, rancid, harsh, pungent fermented fruity[12]	0.02	9773	17482[c]	38856[d]	19660[cd]	22931[c]
Hexanal	Fatty, green, grassy[23]	<0.0001	6921	21071[c]	91[d]	1712[d]	0[d]
Nonanal	Fatty, citrus, rose; soapy; metallic[123]	<0.0001	125782	385019[c]	-21094[d]	285570[c]	480186[c]
Octanal	Fatty, citrus, honey[1]	0.03	14882	8830[d]	14767[d]	2449[d]	37671[c]

Volatile Compound	Sensory Attribute[123]	P > F[a]	SEM[b]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
Alkane							
1-(ethenyloxy)-3-methylbutane	N/A	0.004	5064	10113[c]	-2138[d]	2658[cd]	0[d]
1-ethenyl-4-methoxybenzene	N/A	<0.0001	84298	360411[d]	209105[e]	141950[e]	710525[c]
1,1-diethoxyhexane	N/A	<0.0001	18336	56781[c]	-523[e]	46165[cd]	17351[de]
3-methylbicyclo[4.1.0] heptane	N/A	<0.0001	36869	113816[c]	-2312[e]	84670[cd]	8776[de]
Acetal; 1,1-diethoxy-3-methylbutane	Pungent, green, woody, solvent[2]	<0.0001	60241	266931[c]	17876[d]	-17988[d]	80589[d]
Cedr-8-ene	N/A	<0.0001	56660	0[d]	1974[d]	479957[c]	11270[d]
D-Limonene	Citrus, mint[2]	0.001	33748	26107[d]	-354[d]	-3670[d]	86946[c]
Ethoxyethene	Ether[3]	0.0006	5411	11551[c]	-3899[d]	1992[cd]	839[d]
Naphthalene	Pungent, dry, tarry[23]	0.006	21769	4186[d]	36002[c]	-35044[d]	0[d]
Styrene; ethenylbenzene	Sweet, gassy, floral[3]	<0.0001	384849	859955[d]	-5621[e]	1075897[cd]	1450132[c]
Ester							
2-methylbutyl decanoate	N/A	0.006	53905	0[d]	82389[c]	0[d]	0[d]
3-hydroxymandelic acid, ethyl ester	N/A	0.006	12623	12457[d]	4385[d]	55217[c]	7573[d]
3-methyl-1-butanol acetate; Isoamyl acetate	Apple, banana, glue, pear; woody, fruity, orris, berry[1]	<0.0001	69792	182707[c]	1491[d]	218170[c]	279793[c]
3-methylbutyl octanoate	Fruity[1]	<0.0001	290103	739031[d]	674563[d]	257594[d]	1705547[c]

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
3-methylbutyl ester pentadecanoate	N/A	0.03	145929	0[d]	167642[cd]	440570[c]	240602[c]
Ethyl (E,E)-2,4-decadienoate	Pear-like, fruity[1]	0.04	54880	71569[d]	83884[d]	208512[c]	28034[d]
Ethyl (E)-2-heptenoate	Savory[3]	<0.0001	20265	101845[c]	2009[e]	46810[de]	46753[d]
Ethyl (E)-2-octenoate	Malty[2]	<0.0001	61653	1988874[d]	105[e]	441233[c]	127997[d]
Ethyl 2-nonenoate	Fatty, nutty, oily, fruity, cognac, rosey[1]	<0.0001	30539	69964[d]	11413[e]	265235[c]	34748[de]
Ethyl acetate	Ethereal-fruity, brandy-like[3]	<0.0001	166343	823472[c]	225571[d]	203999[d]	906597[c]
Ethyl cis-4-hexenoate	Fruity, green, sweet[1]	0.10	6127	7267	2411	-8374	6500
Ethyl decanoate	Cognac, oily; fruity, brandy, grape, pear[13]	<0.0001	9499738	36741842[d]	18551283[e]	67790361[c]	55908272[c]
Ethyl dodecanoate	Bay oil[3]	0.32	1545396	2396173	3431201	5489724	2974419
Ethyl heptanoate	Fruity, brandy, wine[13]	<0.0001	88360	414609[c]	-1616[e]	301947[cd]	250334[d]
Ethyl Hex-4-enoate	Fruity[3]	<0.0001	9343	19385[c]	-5898[d]	14147[cd]	20943[c]
Ethyl hexanoate	Fruity, pineapple, banana, winey[13]	<0.0001	289788	1370027[c]	107[e]	961908[cd]	807420[d]
Ethyl Nonanoate	Floral[13]	<0.0001	629023	2385671[d]	499370[e]	4325332[c]	1918812[d]
Ethyl octanoate	Fruity, floral, wine, apricot[1]	<0.0001	6611094	24795017[c]	1418961[d]	18751499[c]	27909747[c]
Ethyl Sorbate	Fruity[13]	<0.0001	8407	32396[d]	12122[e]	54437[c]	37826[cd]

Volatile Compound	Sensory Attribute[123]	$P > F^a$	SEM[b]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
Ethyl trans-4-decenoate	N/A	<0.0001	403239	2364633[d]	916957[e]	3926725[c]	1156951[e]
Ethyl trans-4-hexenaote	Fruity, green, pulpy[1] pineapple, apple[1]	0.23	4266	0	1353	-3006	5186
Ethyl undecanoate	Coconut, cognac[13]	<0.0001	39546	117936[d]	104897[d]	405108[c]	65644[d]
Isobutyl caprylate; 2-methylpropyl ester, octanoic acid	N/A	0.002	53108	120448[c]	13358[d]	72417[cd]	132518[c]
Isopentyl hexanoate	Fruity, anise, spice[13]	0.0001	19989	30215[d]	-7570[e]	93124[c]	17015[de]
Pentyl hexanoate; amyl hexenoate	Fruit-like, banana, pineapple; fresh, floral, rose[13]	0.18	4309	6570	1151	2574	0
Furan							
2-furancarboxaldehyde	Pungent, sweet, caramel, cinnamon, almond[1]	<0.0001	39906	114908[c]	-1595[e]	5228[de]	80936[cd]
2-methyl-5-isopropenylfuran	Pungent, sweet, caramel, cinnamon, almond[1]	0.44	11687	4524	-967	329	10973
2-pentylfuran	Earthy, moldy, oily, anise; Fruity, green bean, metallic, vegetable[12]	<0.0001	48874	97064[d]	10411[e]	288807[c]	52236[de]

Volatile Compound	Sensory Attribute[123]	$P > F$[a]	SEM[b]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
Furfural	Almond, baked potato, bread, burnt, spice; penetrating[12]	0.25	20248	17380	7705	53649	15049
Ketone							
2-nonanone	Fruity, floral, slightly fatty, herb-like[3]	<0.0001	8342	14887[c]	-7040[d]	10174[cd]	19827[c]
2-Propanone; acetone	Acetone, light ethereal-nauseating aroma; Pungent, solvent-like[12]	0.47	49445	7670	52995	25833	16833
2-Tridecanone	Warm, oily, herb-like[1]	0.09	20111	9835	33468	62353	25110
2-undecanone	Fruity, rosey, orange-like, herb-like[1]	<0.0001	14990	0[d]	-14796[d]	423[d]	68431[c]
Acetophenone; 1-phenyl ethanone	Sweet, pungent, medicinal[3]	<0.0001	4911	0[d]	-1038[d]	-776[d]	14982[c]
Geranylacetone; (E) -6,10-dimethyl-5,9-undecadien-2-one	Fruit; green, rosey, floral[13]	0.88	80635	133805	167366	165492	134336
Sulfur-Containing							
2-pentylthiopene	Fruity, wood[3]	0.009	4134	0[d]	598[d]	15863[c]	883[d]

[a]Values are significant ($P < 0.05$)

[b]Standard Error of the Mean (SEM), largest SEM from model was used

[cde]LSMeans in the same row with different superscripts differ ($P < 0.05$).

[123]Sensory Attribute Sources ([1]Burdock, 2010; [2]Flament, 2002; [3]National Center for Biotechnology Information, NCBI)

Table 17. Least squares means of total ion counts for volatiles present during aroma events for new-make whiskey produced from maize grown in three different locations as detected by GC/MS-O analysis.

Volatile Compound	Sensory Attribute[123]	$P > F^a$	SEM[b]	Calhoun County	Monte Alto	Sawyer Farms
Acids						
Acetic acid	Acid, fruit, pungent, sour, vinegar[2,3]	0.004	13628	58011[c]	1240[d]	0[d]
Aldehydes						
2-Octenal	Fatty-nutty; citrus, honey[12]	0.002	18648	89125[c]	1135[d]	23286[d]
Acetal	Pungent, green, woody, solvent; fruity [13]	<0.0001	30756	266931[c]	52631[d]	80589[d]
Benzaldehyde	Sweet, crushed almonds; burnt sugar, cherry, malt[2,3]	0.006	95504	654810[c]	244389[d]	479771[cd]
Decanal	Floral, fatty, fried, orange peel, penetrating tallow (buckwheat)[123]	0.009	95504	654810[c]	244389[d]	479771[cd]
Hexanal	Fatty, green, grassy	0.0001	3814	21071[c]	258[d]	0[d]
Octanal	Fatty, citrus, honey[1]	0.04	37671	8830[d]	21474[cd]	37671[c]
Alkanes						

Volatile Compound	Sensory Attribute[123]	P > F[a]	SEM[b]	Calhoun County	Monte Alto	Sawyer Farms
1,1-diethoxy-3-methylbutane; acetal	Pungent, green, woody, solvent; fruity [13]	0.02	3985	15466[c]	1389[d]	2508[d]
1,1-diethoxyhexane	N/A	0.0005	56781	56781[c]	5780[d]	17351[d]
1-(ethenyloxy)-3-methylbutane		0.007	2588	10113[c]	0[d]	0[d]
di-Limonene	Citrus, mint	0.002	86946	26107[d]	5217[d]	86946[c]
Esters						
Ethyl 2-Nonenoate		0.03	14446	69964[c]	18201[d]	34748[cd]
Ethyl cis-4-hexenoate	Fruity, green, sweet[1]	0.15	3191	7267	0	6500
Ethyl trans-4-hexenoate	Fruity, green, pulpy[1]	0.17	2210	0	262	5186
Isobutyl Caprylate	N/A	0.005	25647	120448[c]	31441[d]	132518[c]
Isopentyl Hexanoate	Fruity, anise, spice	0.05	8672	30215[c]	2524[d]	17015[cd]
Furans						
2-methyl-5-isopropylfuran	N/A	0.48	6167	4524	1243	10973
2-pentylfuran	Earthy, moldy, oily, anise; Fruity, green bean, metallic, vegetable[12]	0.005	18279	97064[c]	15234[d]	52236[cd]
Furfural	Almond, baked potato, bread, burnt, spice; penetrating[12]	0.38	9910	17380	1191	15049
Ketones						

Volatile Compound	Sensory Attribute[123]	$P > F$[a]	SEM[b]	Calhoun County	Monte Alto	Sawyer Farms
2-Propanone; acetone	Acetone, light ethereal-nauseating aroma; Pungent, solvent-like[12]	0.08	25271	7670	74956	16883
2-Tridecanone	Warm, oily, herb-like[1]	0.03	9309	9835[d]	42089[d]	25110[cd]
Sulfur-Containing						
2-pentylthiopene	Fruity, wood	0.90	1440	0	261	883

[a]Values are significant ($P < 0.05$)

[b]Standard Error of the Mean (SEM), largest SEM from model was used

[cde]LSMeans in the same row with different superscripts differ ($P < 0.05$).

[123]Sensory Attribute Sources ([1]Burdock, 2010; [2]Flament, 2002; [3]National Center for Biotechnology Information, NCBI)

Table 18. Least squares means of total ion counts for volatiles present during aroma events for new-make whiskey produced from different maize varieties grown in four locations as detected by GC/MS-O analysis.

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Dyna-Gro	Mycogen	Terral
Acid						
4-hydroxymandelic acid – TRITMS	N/A	0.80	10930	11024	18402	13227
Acetic acid	Acid, fruit, pungent, sour, vinegar[2,3]	0.23	15826	3824	332010	19702
n-decanoic acid	Sour-fatty, rancid	<0.0001	29718	82943[c]	-56767[d]	52088[d]
Alcohol						
1-Octanol	Green, fatty, coconut; fresh, orange, rose[123]	0.32	10328	11703	28677	22364
Isobutyl alcohol; 2-methyl-3-propanol	Malty; apple, bitter, cocoa, wine	0.12	10047	13958	22987	0
Benzene-ethanol	Mild, warm, rose, honey	0.73	62468	308273	267444	246771
Ethanol	Ethanol-like[2]	0.002	1027915	6793491[c]	3606473[d]	7213973[c]
Isoamyl alcohol; 3-methyl-1-butanol	Fusel oil, whiskey-characteristic, pungent; malty; burnt, cocoa, floral, malt[123]	0.95	566133	2212536	2275596	2430572
Aldehyde						
(E)-2-heptenal	Fatty, green	0.02	20112	46670[d]	93339[c]	38107[d]
(E)-2-Nonenal	Penetrating, fatty, orris, waxy, dried orange; green; intense papery[123]	0.58	53460	233477	274804	303364
(E)-2-octenal	Fatty-nutty	0.70	27218	124736	99645	106932
2-butenal	Pungent	0.36	3518	2913	2311	7672

Volatile Compound	Sensory Attribute[123]	$P > F^a$	SEM[b]	Dyna-Gro	Mycogen	Terral
2-octenal	Fatty-nutty; citrus, honey[12]	0.07	21480	-10189	45438	30566
2,4-decadienal	Fatty; metallic, tallow	0.0007	24431	171791[c]	66204[d]	119325[c]
Acetaldehyde	Floral, green apple[3]	0.001	4284	15408[c]	-953[d]	11617[c]
Benzaldehyde	Sweet, crushed almonds; burnt sugar, cherry, malt[2,3]	0.003	109471	197539[d]	238767[d]	626327[c]
Decanal	Floral, fatty, fried, orange peel, penetrating tallow (buckwheat)[123]	0.28	12517	-3765	18135	11295
Heptanal	Oily, fatty, rancid, harsh, pungent fermented fruity[12]	0.78	5752	18715	14486	14745
Hexanal	Fatty, green, grassy	0.83	4073	6707	6441	4007
Nonanal	Fatty, citrus, rose; soapy; metallic[123]	0.20	74032	211794	354185	281283
Octanal	Fatty, citrus, honey[1]	0.09	8759	19717	4564	23417
Alkane						
1-(ethenyloxy)-3-methylbutane	N/A	0.26	2981	2672	5303	0
1-ethenyl-4-methoxybenzene	N/A	<0.0001	49616	307781[d]	193357[e]	565355[c]
1,1-diethoxyhexane	N/A	0.70	10792	26473	35265	28093
3-methylbicyclo[4.1.0]heptane	N/A	0.27	21700	65339	61717	26672

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Dyna-Gro	Mycogen	Terral
Acetal; 1,1-diethoxy-3-methylbutane	Pungent, green, woody, solvent; fruity [13]	0.19	35456	42577	94931	123048
Cedr-8-ene	N/A	.96	33349	118886	120859	130156
D-Limonene	Citrus, mint	0.12	19863	76	29409	52265
Ethoxyethene	Ether[3]	0.04	3185	-210[d]	7443[c]	629[cd]
Naphthalene	Pungent, dry, tarry	0.0001	12813	-4947[d]	-27526[d]	36330[c]
Styrene; ethenylbenzene	Sweet, gassy, floral	0.002	226514	260857[d]	994142[c]	1280275[c]
Ester						
2-methylbutyl decanoate	N/A	<0.0001	31727	-31699[d]	-76107[d]	95097[c]
3-hydroxymandelic acid, ethyl ester		0.61	7429	19343	16155	24226
3-methyl-1-butanol acetate; Isoamyl acetate	Apple, banana, glue, pear; woody, fruity, orris, berry[1]	0.12	41078	109716	190022	209646
3-methylbutyl octanoate	N/A	<0.0001	170748	807313[d]	304059[e]	1421178[c]
3-methylbutyl pentadecanoate	N/A	0.006	85891	356949[c]	56771[d]	222891[cd]
Ethyl (E,E)-2,4-decadienoate	Pear-like, fruity	0.0009	32301	121180[c]	23409[d]	149411[c]
Ethyl (E)-2-heptenoate	Savory	0.99	11928	48737	50105	49222
Ethyl (E)-2-octenoate	Malty	0.71	36288	172136	204270	199759
Ethyl 2-nonenoate	N/A	0.68	17975	94747	87059	104214
Ethyl acetate	Ethereal-fruity, brandy-like	0.01	97906	536802[cd]	381870[d]	701208[c]
Ethyl cis-4-hexenoate	Fruity, green, sweet[1]	0.006	3607	-3442[d]	-1031[d]	10325[c]
Ethyl decanoate	Cognac, oily; fruity, brandy, grape, pear[13]	<0.0001	5591336	40031153[d]	31648276[d]	62564391[c]

Volatile Compound	Sensory Attribute[123]	$P > F^a$	SEM[b]	Dyna-Gro	Mycogen	Terral
Ethyl dodecanoate	Bay oil	<0.0001	909586	5416348[c]	601894[d]	4700396[c]
Ethyl heptanoate	Fruity, brandy, wine	0.36	52007	192217	272967	258772
Ethyl Hex-4-enoate	Fruity	0.03	5499	8995[cd]	20888[c]	6550[d]
Ethyl hexanoate	Fruity, pineapple, banana, winey	0.38	170563	625747	881578	847271
Ethyl Nonanoate	Floral	0.04	370229	1828763[d]	2048924[d]	2969202[c]
Ethyl octanoate	Fruity, floral, wine, apricot[1]	0.04	3891144	11170633[d]	19784932[c]	23700854[c]
Ethyl Sorbate	Fruity	<0.0001	4948	49917[c]	24411[d]	28258[d]
Ethyl trans-4-decenoate	N/A	<0.0001	237338	2115816[d]	1350385[e]	2807749[c]
Ethyl trans-4-hexenoate	Fruity, green, pulpy[1]	0.006	3607	-3442[d]	-1031[d]	10325[c]
Ethyl undecanoate	Coconut, cognac	<0.0001	23276	205950[c]	78755[d]	235484[c]
Isobutyl caprylate; 2-methylpropyl ester, octanoic acid	N/A	0.11	31258	42240	84528	127287
Isopentyl hexanoate	Fruity, anise, spice	0.20	11765	19976	43157	36456
Pentyl hexanoate; amyl hexenoate	Fruit-like, banana, pineapple; fresh, floral, rose[13]	0.09	2536	6570	1151	0
Furan						
2-furancarboxaldehyde	Pungent, sweet, caramel, cinnamon, almond	0.04	23488	7297[d]	63411[c]	78901[c]
2-methyl-5-isopropenylfuran	Pungent, sweet, caramel, cinnamon, almond	0.39	6879	-1131	8905	3393

Volatile Compound	Sensory Attribute[123]	$P > F^a$	SEM[b]	Dyna-Gro	Mycogen	Terral
2-pentylfuran	Earthy, moldy, oily, anise; Fruity, green bean, metallic, vegetable[12]	0.04	28766	65011[d]	11879[cd]	159499[c]
Furfural	Almond, baked potato, bread, burnt, spice; penetrating[12]	0.08	11918	42497	17773	10068
Ketone						
2-nonanone	Fruity, floral, slightly fatty, herb-like	0.005	4899	237[d]	18169[c]	9979[cd]
2-Propanone; acetone	Acetone, light ethereal-nauseating aroma; Pungent, solvent-like[12]	0.001	29102	99459[c]	0[d]	0[d]
2-Tridecanone	Warm, oily, herb-like[1]	<0.0001	11837	31047[d]	1266[e]	65762[c]
2-undecanone	Fruity, rosey, orange-like, herb-like	0.001	8823	-4364[d]	31815[c]	13092[cd]
Acetophenone; 1-phenyl ethanone	Sweet, pungent, medicinal	0.27	2891	346	5462	4068
Geranylacetone; (E) -6,10-dimethyl-5,9-undecadien-2-one	Fruit; green, rosey, floral[13]	<0.0001	47460	221593[c]	16410[d]	212747[c]
Sulfur-Containing						
2-pentylthiopene	Fruity, wood	0.96	2433	3842	4440	4725

[a]Values are significant ($P < 0.05$)
[b]Standard Error of the Mean (SEM), largest SEM from model was used
[cde]LSMeans in the same row with different superscripts differ ($P < 0.05$).
[123]Sensory Attribute Sources ([1]Burdock, 2010; [2]Flament, 2002; [3]National Center for Biotechnology Information, NCBI)

Table 19. Least squares means of total ion counts for volatiles present during aroma events for new-make whiskey produced from maize varieties grown in three locations as detected by GC/MS-O analysis.

Volatile Compound	Sensory Attribute[1234]	$P > F^a$	SEM[b]	Dyna-Gro	Mycogen	Terral
Acids						
Acetic acid	Acid, fruit, pungent, sour, vinegar[2,3]	0.09	13628	1632[d]	40741[c]	16879[cd]
Aldehydes						
2-Octenal	Fatty-nutty; citrus, honey[12]	0.02	18648	0[d]	72791[c]	40755[cd]
Acetal	Pungent, green, woody, solvent; fruity [13]	0.07	30756	77523	164633	157994
Benzaldehyde	Sweet, crushed almonds; burnt sugar, cherry, malt[2,3]	0.007	95504	274372[d]	401438[d]	703160[c]
Decanal	Floral, fatty, fried, orange peel, penetrating tallow (buckwheat)[123]	0.16	11140	0	28367	15060
Hexanal	Fatty, green, grassy	0.84	3814	8043	7944	5342
Octanal	Fatty, citrus, honey[1]	0.47	7821	24210	15854	27911
Alkanes						
1,1-diethoxy-3-methylbutane	N/A	0.13	3985	0	9969	9393
1,1-diethoxyhexane	N/A	0.39	9507	21066	36161	22686
1-(ethenyloxy)-3-methylbutane	N/A	0.08	2588	2672[cd]	7441[c]	0[d]
di-Limonene	Citrus, mint	0.10	17317	10393[d]	45296[cd]	62581[c]
Esters						
Ethyl 2-Nonenoate	N/A	0.84	14446	38115	37216	47583
Ethyl cis-4-hexenoate	Fruity, green, sweet[1]	0.003	3191	0[d]	0[d]	13767[c]
Ethyl trans-4-hexenoate	Fruity, green, pulpy[1]	017	2210	0	262	5186
Isobutyl Caprylate	N/A	0.06	25647	46329[d]	106701[cd]	131377[c]
Isopentyl Hexanoate	Fruity, anise, spice	0.02	8672	0[d]	33275[c]	16480[cd]
Furans						

Volatile Compound	Sensory Attribute[1234]	$P > F^a$	SEM[b]	Dyna-Gro	Mycogen	Terral
2-methyl-5-isopropylfuran	N/A	0.30	6167	0	12216	4524
2-pentylfuran	Earthy, moldy, oily, anise; Fruity, green bean, metallic, vegetable[12]	0.003	18279	6118[d]	57809[c]	100607[c]
Furfural	Almond, baked potato, bread, burnt, spice; penetrating[12]	0.03	32430	32430[c]	1191[d]	0[d]
Ketones						
2-Propanone; acetone	Acetone, light ethereal-nauseating aroma; Pungent, solvent-like[12]	0.007	25271	99459[c]	0[d]	0[d]
2-Tridecanone	Warm, oily, herb-like[1]	0.0001	9310	21160[d]	0[d]	55875[c]
Sulfur Containing						
2-pentylthiopene	Fruity, wood	0.90	1440	0	261	883

[a]Values are significant ($P < 0.05$)

[b]Standard Error of the Mean (SEM), largest SEM from model was used

[cde]LSMeans in the same row with different superscripts differ ($P < 0.05$).

[123]Sensory Attribute Sources ([1]Burdock, 2010; [2]Flament, 2002; [3]National Center for Biotechnology Information, NCBI)

Table 20. Least squares means of total ion counts for volatiles present during aroma events for new-make whiskey interactions produced from different maize varieties grown in different locations as detected by GC/MS-O analysis.

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farms		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Acids												
4-Hydroxymandelic acid - TRITMS	N/A	<0.0001	85929	46300^{cd}	0^{e}	32739^{de}	0^{e}	3424^{e}	20169^{de}	0^{e}	85929^{c}	0^{e}
Acetic acid	Acid, fruit, pungent, sour, vinegar[2,3]	0.09	23604	4895^{d}	118502^{c}	50636^{d}	0^{d}	3721^{d}	0^{d}	0^{d}	0^{d}	0^{d}
n-Decanoic acid	Sour-fatty, rancid	0.009	208353	0^{de}	0^{de}	0^{de}	186423^{c}	0^{e}	208353^{c}	114496^{cd}	0^{de}	0^{de}
Alcohols												
1-Octanol	Green, fatty, coconut; fresh, orange, rose[123]	0.03	63319	38593^{cde}	61102^{cd}	46942^{cd}	0^{ef}	0^{f}	19882^{def}	0^{ef}	63319^{c}	3753^{ef}

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farms		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Benzene-ethanol	Mild, warm, rose, honey	<0.0001	762486	594809^{cd}	206698^{fg}	174340^{fg}	70438^{gh}	15302^{h}	161849^{fgh}	294960^{ef}	762486^{c}	439511de
Ethanol	Ethanol-like[1]	0.0002	9999476	5621502^{d}	9657092^{c}	9999476^{c}	7805193^{cd}	522544^{e}	5551591^{d}	7546871^{cd}	5707423^{d}	6683946^{cd}
Isoamyl alcohol	Fusel oil, whiskey-characteristic, pungent; malty; burnt, cocoa, floral, malt[123]	0.009	5204375	3884681^{cd}	3366723^{cde}	2851960de	1267227^{ef}	109518^{f}	1353610^{ef}	1471964^{ef}	5204375^{c}	3072409^{cde}
Isopropyl alcohol; 2-methyl-1-propanol	Alcoholic, unpleasant; malty; apple, bitter, cocoa, wine[123]	0.005	14382	41873^{d}	94847^{c}	0^{e}	0^{e}	0^{e}	0^{e}	0^{e}	0^{e}	0^{e}

Volatile Compound	Sensory Attribute[1,2,3]	$P > F^a$	SEM[b]	Calhoun County			Monte Alto			Sawyer Farm		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Aldehydes												
(E)-2-Heptenal	Fatty, green	0.0004	86550	86550^{d}	224145^{c}	39277^{de}	0^{e}	5347^{e}	0^{e}	0^{e}	70809^{d}	21584^{de}
(E)-2-Nonenal	Penetrating, fatty, orris, waxy, dried orange; green; intense papery[1,2,3]	<0.0001	482323	337605^{cd}	482323^{c}	244878^{de}	51392^{fg}	23431^{g}	271840^{de}	150696^{ef}	391688^{cd}	232635^{de}
(E)-2-Octenal	Fatty-nutty	0.0008	226421	226421^{c}	116653^{d}	62648^{defg}	0^{fg}	0^{g}	88050^{def}	22229^{efg}	101736^{de}	44542^{defg}
2-Butenal	Pungent	0.0001	30688	16410^{d}	0^{cd}	0^{cd}	0^{cd}	0^{cd}	0^{cd}	0^{cd}	9782^{de}	30688^{c}
2-Octenal	Fatty-nutty; citrus, honey[1,2]	0.06	32300	0	177174	90202	0	3404	0	0	37795	32063
2,4-Decadienal	Fatty; metallic, tallow	0.03	171167	137398^{cd}	156142^{c}	99132^{cd}	171167^{c}	8308^{f}	102802^{cd}	92891^{cde}	0^{ef}	42124^{def}

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farm		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Acetal	Pungent, green, woody, solvent; fruity [13]	0.06	53270	168675	390950	241168	26712	17723	113458	37183^{e}	85226	119358
Acetaldehyde	Solvent-like; pungent, ethereal, fruity, sour; floral, green apple[23]	<0.0001	28803	12992^{def}	28803^{c}	9292^{efg}	28652^{cd}	830^{g}	27758^{cd}	16196^{cde}	0^{fg}	9419^{efg}
Benzaldehyde	Sweet, crushed almonds; burnt sugar, cherry, malt[2,3]	0.13	165417	594129	537400	832902	152015	22768	558384	76973	644147	718193

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farm		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Decanal	Floral, fatty, fried, orange peel, penetrating tallow (buckwheat)[123]	0.17	19295	0	0	0	0	2373	0	0	82728	45181
Heptanal	Oily, fatty, rancid, harsh, pungent fermented fruity[12]	0.008	33978	18468^{cd}	33978^{c}	0de	15346^{cde}	638^{c}	17393^{cde}	18654^{cd}	26973^{c}	23165^{c}
Hexanal	Fatty, green, grassy	0.96	6606	24129	23056	16027	0	775	0	0	0	0
Nonanal	Fatty, citrus, rose; soapy; metallic[123]	<0.0001	877776	289681de	611381^{d}	253996^{ef}	192024^{efg}	15518^{g}	174446^{efg}	150526^{fg}	877776^{c}	412256de

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farm		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Octanal	Fatty, citrus, honey[1]	0.29	13547	10758	15732	0	25607	1904	36910	36264	29927	46821
Alkanes												
1-(ethenyloxy)-3-methylbutane		0.06	4483	8016	22324	0	0	0	0	0	0	0
1-ethenyl-4-methoxybenzene	N/A	<0.0001	821886	263391^{e}	309662^{e}	508180^{d}	362165^{e}	18801^{f}	603079^{d}	511334^{d}	821886^{c}	798354^{c}
1,1-diethoxy-3-methylbutane		0.17	6901	0	29258	17138	0	648	3517	0	0	7523
1,1-diethoxyhexane		0.40	16466	63197	63298	46848	0	3306	14035	0	41880	10174
3-methylbicyclo[4.1.0]heptane	N/A	<0.0001	226706	114742^{d}	226706^{c}	0^{e}	21497^{e}	2077^{e}	46568de	26329^{e}	0^{e}	0^{e}
Cedr-8-ene	N/A	0.02	33811	0^{d}	0^{d}	0^{d}	0^{d}	0^{d}	0^{d}	0^{d}	0^{d}	33811^{c}
di-Limonene		0.08	29994	31178^{d}	17823^{d}	29321^{d}	0^{d}	487^{d}	15163^{d}	0^{d}	117580^{c}	143259^{c}
Ethoxyethene	Ether[3]	<0.0001	34652	0^{d}	34652^{c}	0^{d}	0^{d}	0^{d}	0^{d}	0^{d}	0^{d}	2516^{d}
Naphthalene	Pungent, dry, tarry	0.0003	21490	0^{d}	0^{d}	12557^{d}	21490^{d}	3280^{d}	132763^{c}	0^{d}	0^{d}	0^{d}

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farm		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Styrene	Sweet, gassy, floral	0.007	2337993	283887^{fg}	887367^{ef}	1408611de	67965^{fg}	98271^{g}	388913^{fg}	199911^{fg}	2337993^{c}	1812494^{cd}
Esters												
2-methylbutyl decanoate	N/A	<0.0001	380390	0^{d}	0^{d}	0^{d}	0^{d}	380390^{c}	0^{d}	0^{d}	0^{d}	0^{d}
3-methyl-1-butanol acetate; Isoamyl acetate	Apple, banana, glue, pear; woody, fruity, orris, berry[1]	0.0005	471800	174530de	106710^{ef}	266881^{d}	28142^{ef}	13208^{f}	24204^{ef}	78102^{ef}	471800^{c}	289477^{d}
3-methylbutyl ester octanoate; isopentyl octanoate	Fruit	0.02	1988356	336261^{f}	474202^{ef}	1406630^{cd}	1034280de	90524^{f}	1455138^{cd}	1637987^{cd}	1490297^{cd}	1988356^{c}
3-methylbutyl ester pentadecanoate	N/A	0.02	560979	0de	0de	0de	560979^{c}	7069^{e}	0de	281500^{cd}	0de	440306^{c}
di-TMS 3-hydroxymandelic acid, ethyl ester	N/A	0.02	37370	0de	0de	37370^{c}	0de	1548^{e}	0de	22719^{cd}	0de	0de

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farm		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Ethyl (E,E)-2,4-decadienoate	Fruity	0.006	146504	46899[def]	77423[def]	90384[de]	146504[cd]	0[f]	222858[c]	59625[def]	0[ef]	24477[ef]
Ethyl (E)-2-Heptenoate	Savory	0.004	133557	133557[c]	65340[de]	106640[cd]	0[fg]	2998[g]	0[gh]	15198[fg]	81493[de]	43570[ef]
Ethyl (E)-2-octenoate	Malty	0.007	264536	161335[de]	170780[cde]	264536[c]	33613[fg]	8983[g]	0[fg]	72281[efg]	226148[cd]	85561[ef]
Ethyl 2-Nonenoate		0.21	25021	90751	44665	74477	23595	1524	29485	0	65459	38786
Ethyl Acetate	Ethereal-fruity, brandy-like	0.0007	1081483	1005374[cd]	703571[def]	761473[cde]	360553[g]	40523[g]	620244[ef]	580439[ef]	1081483[c]	1057869[cd]
Ethyl cis-4-hexenoate	Fruity, green, sweet[1]	0.13	5527	0	0	21800	0	0	0	0	0	19500
Ethyl Decanoate	Cognac, oily; fruity, brandy, grape, pear[13]	0.0007	65512828	26357161[f]	29202725[ef]	54665640[cd]	28572246[ef]	3383465[g]	49894752[cde]	42121630[def]	65512828[c]	60090358[cd]
Ethyl Dodecanoate	Bay oil	<0.0001	8614296	1303330[fg]	2981898[ef]	2903292[ef]	8614296[c]	47541[g]	6858971[cd]	4414573[de]	2086605[ef]	2422081[ef]

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farm		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Ethyl Heptanoate	Fruity, brandy, wine	0.02	481390	396555^{cd}	481390^{c}	365883^{cd}	48448^{ef}	15916^{f}	109597^{ef}	71020^{ef}	439777^{cd}	240207^{de}
Ethyl Hex-4-enoate	Fruity	<0.0001	62829	24982^{d}	22196^{de}	10979^{def}	0^{f}	855^{f}	6669^{ef}	0^{f}	62829^{c}	0^{f}
Ethyl Hexanoate	Fruity, pineapple, banana, winey	0.04	1656211	1326071^{cd}	1656211^{c}	1127800^{cd}	147065^{f}	53171^{f}	352964^{ef}	227063^{ef}	1311192^{cd}	884006^{de}
Ethyl Nonanoate	Floral	0.003	3117954	1784703^{def}	2254357^{cde}	3117954^{c}	712412^{fg}	160381^{g}	1963140^{cdef}	946137^{efg}	3026821^{cd}	783478^{def}
Ethyl Octanoate	Fruity, floral, wine, apricot[1]	0.0002	47082190	20205039^{def}	26216606^{de}	27963406^{de}	4902715^{gh}	1707396^{h}	13830863^{efg}	7871452^{fgh}	47082190^{c}	28775599^{d}
Ethyl Sorbate	Fruity	0.02	59298	59298^{c}	21184^{efg}	16706^{fg}	29869^{defg}	1672^{h}	13252^{gh}	40341^{d}	38561^{de}	34575^{def}
Ethyl trans-4-decenoate	N/A	0.0008	3191963	2092648^{de}	1809288^{def}	3191963^{c}	1149013^{f}	108745^{g}	2345324^{d}	1270378^{ef}	1149925^{f}	1050552^{f}
Ethyl trans-4-hexenoate	Fruity, green, pulpy[1]	0.11	3828	0	0	0	0	785	0	0	0	15558
Ethyl Undecanoate	Coconut, cognac	<0.0001	209326	57305^{def}	92734^{d}	203769^{c}	193546^{c}	3053^{f}	209326^{c}	135286^{cd}	0^{ef}	61646^{de}

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farm		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Isobutyl Caprylate	N/A	0.38	44422	53023	123730	184591	19987	9818	65418	65978	187454	144121
Isopentyl Hexanoate	Fruity, anise, spice	0.14	15021	0	58298	32347	0	0	7573	0	41527	9519
Pentyl hexanoate; amyl hexenoate	Fruit-like, banana, pineapple; fresh, floral, rose[13]	0.02	197100	19710[c]	0[d]	0[d]	0[d]	0[d]	0[d]	0[d]	0[d]	0[d]
Furans												
2-Furancarboxaldehyde	Pungent, sweet, caramel, cinnamon, almond	0.004	199239	59130[def]	199239[c]	86357[de]	7403[ef]	3740[f]	88026[de]	0[ef]	135847[cd]	106962[cd]

Volatile Compound	Sensory Attribute[123]	$P > F$[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farm		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
2-methyl-5-isopropylfuran	N/A	0.24	10681	0	0	13573	0	3730	0	.	32919	0
2-pentylfuran	Earthy, moldy, oily, anise; Fruity, green bean, metallic, vegetable[12]	0.14	31660	18354	80278	192560	0	9018	36684	0	84132	72576
Furfural	Almond, baked potato, bread, burnt, spice; penetrating[12]	0.33	17164	52141	0	0	0	3574	0	45148	0	0
Ketones												
2-Nonanone	Fruity, floral, slightly fatty, herb-like	0.0002	49971	0[e]	24945[d]	19716[d]	0[e]	0[e]	0[e]	0[e]	49971[c]	19716[de]

Volatile Compound	Sensory Attribute[1,2,3]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farm		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
2-Propanone; acetone	Acetone, light ethereal-nauseating aroma; Pungent, solvent-like[1,2]	0.06	43771	23009^{d}	0^{d}	0^{d}	224868^{c}	0^{d}	0^{d}	50500^{d}	0^{d}	0^{d}
2-Tridecanone	Warm, oily, herb-like[1]	0.20	46248	0	0	29505	34397	0	91872	29083	0	46248
2-Undecanone	Fruity, rosey, orange-like, herb-like	<0.0001	152927	0^{e}	0^{e}	0^{e}	0^{e}	0^{e}	0^{e}	0^{e}	152927^{c}	52367^{d}
Acetophenone	Sweet, pungent, medicinal	<0.0001	34789	0^{e}	0^{e}	0^{e}	0^{e}	0^{e}	11222^{d}	5106^{de}	34789^{c}	5049^{de}

Volatile Compound	Sensory Attribute[123]	$P > F^a$	SEM[b]	Calhoun County			Monte Alto			Sawyer Farm		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Geranylacetone; (E)-6,10-dimethyl-5,9-undecadien-2-one	Fruit; green, rosey, floral[13]	0.02	339412	132173[de]	137913[de]	131327[de]	339412[c]	18582[e]	333390[c]	177952[cd]	66777[de]	158280[cd]
Sulfur-Containing												
2-pentylthiopene	Fruity, wood	0.94	2494	0	0	0	0	782	0	0	0	2649

[a]Values are significant ($P < 0.05$)

[b]Standard Error of the Mean (SEM), largest SEM from model was used

[cdefg]LSMeans in the same row with different superscripts differ ($P < 0.05$).

[123]Sensory Attribute Sources ([1]Burdock, 2010; [2]Flament, 2002; [3]National Center for Biotechnology Information, NCBI)

Table 21. Least squares means of total ion counts for volatiles present during aroma events from ground maize grown in four different locations that produced all maize varieties as detected by GC/MS-O analysis.

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
Acid							
Acetic acid	Acid, fruit, pungent, sour, vinegar[2,3]	0.52	38449	82561	68487	18850	59393
Octanoic acid	N/A	0.41	559	0	0	-352	528
Alcohol							
1-Hexanol	Herb-like, woody, sweet, green fruity[1]	0.04	23551	51151[c]	0[d]	-906[cd]	17225[cd]
1-Octen-3-ol	Sweet, oily, nutty, warm, herb-like[1]	0.55	685	0	0	216	647
1-Pentanol; amyl alcohol	Fusel-like, sweet[1]	0.70	14113	13281	2059	9315	12605
2-(hexyloxy)-ethanol	N/A	0.77	155535	132634	111543	-51101	96682
Ethanol	Ethanol-like[1]	0.18	36914	150315	122866	-6957	65658
Isoamyl alcohol; 3-methyl-1-butanol; isopentyl alcohol	Fusel oil, whiskey-characteristic, pungent; malty; burnt, cocoa, floral, malt[123]	0.55	8320	7861	0	2620	0
Isopropyl alcohol	Alcoholic, unpleasant; malty; apple, bitter, cocoa, wine[123]	0.55	3683	3479	0	1160	0
Aldehyde							
(E)-2-decenal	N/A	0.39	31634	0	39456	11033	28450
2-Dodecanal	N/A	0.41	21101	0	19935	-13290	0
3-Dodecen-1-al	N/A	0.19	29804	8595	12596	72312	40202

Volatile Compound	Sensory Attribute[123]	$P > F^a$	SEM[b]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
3-methylbutanal	Choking, powerful, acrid, pungent, apple, fruity, fatty, animal, almond[1]	0.49	3637	1095	0	339	3207
Benzaldehyde	Sweet, crushed almonds; burnt sugar, cherry, malt[2,3]	0.02	3324	5270[d]	5543[d]	1999[d]	12121[c]
Butanal	Banana, green, pungent[3]	0.54	4092	1983	0	1803	4496
Decanal	Floral, fatty, fried, orange peel, penetrating tallow (buckwheat)[123]	0.04	6655	0[de]	6297[cd]	-9923[e]	11094[c]
Heptanal	Oily, fatty, rancid, harsh, pungent fermented fruity[12]	0.62	13882	16736	6633	25202	12434
Hexanal		0.64	225477	340924	267495	24397	325234
N Heptanal	Oily, fatty, rancid, harsh, pungent fermented fruity[12]	0.41	11703	0	6680	-10747	9437
Nonanal	Fatty, citrus, rose; soapy; metallic[123]	0.53	41966	123876	147716	168730	167966
Nonenal		0.41	5739	0	5422	-3614	0
Octanal	Fatty, citrus, honey[1]	0.51	23200	32525	45789	60185	56720
Pentanal	Powerful, acrid, pungent[1]	0.82	16105	16926	14786	5071	21764
Alkane							
2-methylbutane	Gasoline-like[3]	0.31	983	0	0	1942	603
Eicosane	N/A	0.41	435636	0	0	-274380	411569

Volatile Compound	Sensory Attribute[123]	$P > F^a$	SEM[b]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
Ethoxyethene	Ether[3]	0.55	426	0	402	134	0
Heptane	Petroleum-like[3]	0.33	11990	5724	4893	3495	19266
Methylbenzene; Toulene	Sweet, gassy; paint thinner[23]	0.55	1546	0	1460	487	0
Nonadecane	N/A	0.41	427299	0	0	-269129	403693
octane	Gasoline[3]	0.64	15063	6499	17166	23526	17958
pentane	Petroleum-like[3]	0.63	49780	59449	15779	7148	31383
Ester							
Butyrolactone - lactone	Faint, sweet, buttery, fruity, peach-like[1]	0.55	5758	5440	0	1813	0
Ethyl decanoate	Cognac, oily; fruity, brandy, grape, pear[13]	0.34	85833	133643	42015	33062	25747
Ethyl Octanoate	Fruity, floral, wine, apricot[1]	0.55	4619	0	4363	1454	0
Hexyl Formate	Fruity, apple, unripe plum[1]	0.55	4521	0	4271	1424	0
Furan							
1-(2-furanyl)ethanone; 2-acetylfuran	Coffee-like; balsamic, cocoa, coffee[13]	0.41	6969	0	0	-4389	6584
2-ethylfuran	Smokey, burnt, warm, sweet, coffee; butter caramel[13]	0.41	1904	1636	911	-1698	0
2-methylfuran	Spice, smokey[1]	0.48	11924	14463	3377	-3388	5623
2-pentylfuran	Earthy, moldy, oily, anise; Fruity, green bean, metallic, vegetable[12]	0.77	10696	24096	16441	20518	17206
3-methylfuran	N/A	0.48	4289	4629	3723	973	0

Volatile Compound	Sensory Attribute[123]	$P > F^a$	SEM[b]	Calhoun County	Monte Alto	Perryton	Sawyer Farms
Ketone							
2-butanone	Sweet, apricot[1]	0.55	2470	0	2334	778	0
2-heptanone	Fruity, spicy, cinnamon, banana[1]	0.55	393	0	0	1006	3017
2-methyl-5-hepten-2-one	N/A	0.55	2524	0	2384	795	0
Nitrogen Containing							
2-hydroxy-2-phenylacetonitrile; Mandelonitrile	N/A	0.55	1758	1661	0	554	0
2-methyl-5h-dibenz[b,f]azepine	N/A	0.51	12862	2963	0	-6780	11651
N-(1-methylheptyl)-2-octanamine	N/A	0.55	1034	977	0	326	0
Phenol							
2,6-Bis(1,1-dimethylethyl)-4-(1-oxopropyl)phenol	N/A	0.41	21084	0	19920	-13280	0
Sulfur-Containing							
Dimethyl disulfide	Onion[1]	0.72	2871	0	1483	-254	2205
Dimethyl sulfide	Wild radish, cabbage-like, green[1]	0.41	9923	4978	8410	-8925	0
Thiobismethane; dimethyl sulfide	Wild radish, cabbage-like, green[1]	0.18	88490	0	53958	50626	147346

[a]Values are significant ($P < 0.05$)

[b]Standard Error of the Mean (SEM), largest SEM from model was used

[cde]LSMeans in the same row with different superscripts differ ($P < 0.05$).

[123]Sensory Attribute Sources ([1]Burdock, 2010; [2]Flament, 2002; [3]National Center for Biotechnology Information, NCBI)

Table 22. Least squares means of total ion counts for volatiles present during aroma events for ground maize produced from maize grown in three different locations that produced all maize varieties as detected by GC/MS-O analysis.

Volatile Compound	Sensory Attribute[1234]	*P* > F[a]	SEM[b]	Calhoun County	Monte Alto	Sawyer Farms
Acid						
Acetic acid	Acid, fruit, pungent, sour, vinegar[2,3]	0.74	21219	82561	68487	59393
Octanoic acid	N/A	0.39	305	0	0	528
Alcohol						
1-Hexanol	Herb-like, woody, sweet, green fruity[1]	0.03	12389	51151[c]	0[d]	17225[cd]
1-Octen-3-ol	Sweet, oily, nutty, warm, herb-like[1]	0.39	374	0	0	647
1-Pentanol; amyl alcohol	Fusel-like, sweet[1]	0.55	8014	13281	2059	12605
2-(hexyloxy)-ethanol	N/A	0.96	85959	132634	111543	96682
Ethanol	Ethanol-like[2]	0.27	36548	150315	122866	65658
Isoamyl alcohol; 3-methyl-1-butanol; isopentyl alcohol	Fusel oil, whiskey-characteristic, pungent; malty; burnt, cocoa, floral, malt[123]	0.39	4538	7861	0	0
Isopropyl alcohol	Alcoholic, unpleasant; malty; apple, bitter, cocoa, wine[123]	0.43	2009	3479	0	0
Aldehyde						
(E)-2-decenal		0.24	16369	0	39456	28450
2-Dodecanal		0.39	11510	0	19935	0
3-Dodecen-1-al		0.24	13872	8595	12596	40202
3-methylbutanal	Choking, powerful, acrid, pungent, apple, fruity, fatty, animal, almond[1]	0.51	1957	1095	0	3207

Volatile Compound	Sensory Attribute[1234]	*P* > F[a]	SEM[b]	Calhoun County	Monte Alto	Sawyer Farms
Butanal	Banana, green, pungent[3]	0.38	2224	1983	0	4496
Heptanal	Oily, fatty, rancid, harsh, pungent fermented fruity[12]	0.63	7313	16736	6633	12434
Hexanal	Fatty, green, grassy	0.88	107325	340924	267495	325234
N Heptanal	Oily, fatty, rancid, harsh, pungent fermented fruity[12]	0.60	6676	0	6683	9437
Nonanal	Fatty, citrus, rose; soapy; metallic[123]	0.38	21967	123876	147716	167966
Nonenal	N/A	0.39	3130	0	5422	0
Octanal	Fatty, citrus, honey[1]	0.38	12020	32525	45789	56720
Pentanal	Powerful, acrid, pungent[1]	0.84	8521	16926	14786	21764
Alkane						
2-methylbutane	Gasoline-like[3]	0.39	348	0	0	603
Eicosane	N/A	0.39	237620	0	0	411569
Ethoxyethene	Ether[3]	0.39	232	0	402	0
Heptane	Petroleum-like[3]	0.27	6794	5724	4893	19266
Methylbenzene; Toulene	Sweet, gassy; paint thinner[23]	0.39	843	0	1460	0
Nonadecane	N/A	0.39	233072	0	0	403962
Octane	Gasoline[3]	0.56	8253	6499	17166	17958
Pentane	Petroleum-like[3]	0.54	27544	59449	15779	31383
Ester						
Butyrolactone - lactone	Faint, sweet, buttery, fruity, peach-like[1]	0.39	3141	5440	0	0
Ethyl decanoate	Cognac, oily; fruity, brandy, grape, pear[13]	0.24	46589	133643	42015	25747
Ethyl Octanoate	Fruity, floral, wine, apricot[1]	0.39	2519	0	4363	0
Hexyl Formate	Fruity, apple, unripe plum[1]	0.39	2466	0	4271	0
Furan						

Volatile Compound	Sensory Attribute[1234]	*P* > F[a]	SEM[b]	Calhoun County	Monte Alto	Sawyer Farms
1-(2-furanyl)ethanone; 2-acetylfuran	Coffee-like; balsamic, cocoa, coffee[13]	0.39	3801	0	0	6584
2-ethylfuran	Smokey, burnt, warm, sweet, coffee; butter caramel[13]	0.57	1081	1636	911	0
2-methylfuran	Spice, smokey[1]	0.42	6135	14463	3377	5623
2-pentylfuran	Earthy, moldy, oily, anise; Fruity, green bean, metallic, vegetable[12]	0.47	4729	24096	16441	17206
3-methylfuran	N/A	0.38	2426	4629	3723	0
Ketone						
2-butanone	Sweet, apricot[1]	0.39	1347	0	2334	0
2-heptanone	Fruity, spicy, cinnamon, banana[1]	0.39	1742	0	0	3017
6-methyl-5-hepten-2-one	N/A	0.39	1377	0	2384	0
Nitrogen Containing						
2-hydroxy-2-phenylacetonitrile; Mandelonitrile	N/A	0.39	959	1661	0	0
2-methyl-5h-dibenz[b,f]azepine	N/A	0.48	6941	2693	0	11651
N-(1-methylheptyl)-2-octanamine	N/A	0.39	564	977	0	0
Phenol						
2,6-Bis(1,1-dimethylethyl)-4-(1-oxopropyl)phenol	N/A	0.39	11501	0	19920	0

Volatile Compound	Sensory Attribute[1234]	*P* > F[a]	SEM[b]	Calhoun County	Monte Alto	Sawyer Farms
Sulfur-Containing						
Dimethyl disulfide	Onion[1]	0.59	1534	0	1483	2205
Dimethyl sulfide	Wild radish, cabbage-like, green[1]	0.58	5642	4978	8410	0
Thiobismethane	Wild radish, cabbage-like, green[1]	0.07	42341	0	53958	147346

[a]Values are significant ($P < 0.05$)
[b]Standard Error of the Mean (SEM), largest SEM from model was used
[cd]LSMeans in the same row with different superscripts differ ($P < 0.05$).
[123]Sensory Attribute Sources ([1]Burdock, 2010; [2]Flament, 2002; [3]National Center for Biotechnology Information, NCBI)

Table 23. Least squares means of total ion counts for volatiles present during aroma events of ground maize varieties grown in four different locations as detected by GC/MS-O analysis.

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Dyna-Gro	Mycogen	Terral
Acid						
Acetic acid	Acid, fruit, pungent, sour, vinegar[2,3]	0.11	22449	37041	93000	41927
Octanoic acid	N/A	0.35	356	-132	-132	396
Alcohol						
1-Hexanol	Herb-like, woody, sweet, green fruity[1]	0.88	13751	12141	20687	17774
1-Octen-3-ol	Sweet, oily, nutty, warm, herb-like[1]	0.35	400	0	647	0
1-Pentanol; amyl alcohol	Fusel-like, sweet[1]	0.10	8240	5462	22483	0
2-(hexyloxy)-ethanol	N/A	0.70	90813	25651	68126	123541
Ethanol	Ethanol-like[2]	0.80	41271	63248	95735	89928
Isoamyl alcohol; 3-methyl-1-butanol; isopentyl alcohol	Fusel oil, whiskey-characteristic, pungent; malty; burnt, cocoa, floral, malt[123]	0.35	4858	0	7861	0
Isopropyl alcohol	Alcoholic, unpleasant; malty; apple, bitter, cocoa, wine[123]	0.35	2150	0	3479	0
Aldehyde						
(E)-2-decenal	N/A	0.21	18470	10033	4848	44323
2-Dodecanal	N/A	0.35	12320	-4983	-4983	14952
3-Dodecen-1-al	N/A	0.29	17401	44352	12962	42965
3-methylbutanal	Choking, powerful, acrid, pungent, apple, fruity, fatty, animal, almond[1]	0.49	2124	-274	2933	822

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Dyna-Gro	Mycogen	Terral
Benzaldehyde	Sweet, crushed almonds; burnt sugar, cherry, malt[2,3]Sweet, crushed almonds	0.009	1941	2794[d]	10903[c]	5003[d]
Butanal	Banana, green, pungent[3]	0.91	2389	2790	1894	1528
Decanal	Floral, fatty, fried, orange peel, penetrating tallow (buckwheat)[123]	0.006	3898	-2260[d]	-3930[d]	11790[c]
Heptanal	Oily, fatty, rancid, harsh, pungent fermented fruity[12]	0.58	8105	20825	14939	9990
Hexanal	Fatty, green, grassy	0.40	131650	139086	364336	215116
N Heptanal	Oily, fatty, rancid, harsh, pungent fermented fruity[12]	0.12	6833	-4030	-4030	12090
Nonanal	Fatty, citrus, rose; soapy; metallic[123]	0.20	24503	141416	130229	184571
Nonenal	N/A	0.35	3351	-1355	-1355	4066
Octanal	Fatty, citrus, honey[1]	0.39	13546	47358	37637	61420
Pentanal	Powerful, acrid, pungent[1]	0.69	9403	8832	18699	16380
Alkane						
2-methylbutane	Gasoline-like[3]	0.64	574	435	435	1038
Eicosane	N/A	0.35	254357	-102892	-102892	308677
Ethoxyethene	Ether[3]	0.35	249	0	402	0
Heptane	Petroleum-like[3]	0.47	7001	3911	6603	14519
Methylbenzene; Toulene	Sweet, gassy; paint thinner[23]	0.35	903	0	1460	0
Nonadecane	N/A	0.35	249489	-100923	-100923	302770

Volatile Compound	Sensory Attribute[123]	*P* > F[a]	SEM[b]	Dyna-Gro	Mycogen	Terral
Octane	Gasoline[3]	0.91	8795	13717	16543	18602
Pentane	Petroleum-like[3]	0.36	29065	5753	58273	21292
Ester						
Butyrolactone - lactone	Faint, sweet, buttery, fruity, peach-like[1]	0.35	3362	0	5440	0
Ethyl decanoate	Cognac, oily; fruity, brandy, grape, pear[13]	0.08	50116	5516	144779	25555
Ethyl Octanoate		0.35	2697	4363	0	0
Hexyl Formate	Fruity, apple, unripe plum[1]	0.35	2640	4271	0	0
Furan						
1-(2-furanyl)ethanone; 2-acetylfuran	Coffee-like; balsamic, cocoa, coffee[13]	0.35	4069	-1646	-1646	4938
2-ethylfuran	Smokey, burnt, warm, sweet, coffee; butter caramel[13]	0.13	1112	-637	-637	1911
2-methylfuran	Spice, smokey[1]	0.66	6962	575	6075	8407
2-pentylfuran	Earthy, moldy, oily, anise; Fruity, green bean, metallic, vegetable[12]	0.22	6245	11492	25026	22177
3-methylfuran	N/A	0.73	2504	3749	1887	1358
Ketone						
2-butanone	Sweet, apricot[1]	0.35	1442	2334	0	0
2-heptanone	Fruity, spicy, cinnamon, banana[1]	0.35	1864	0	3017	0
2-methyl-5-hepten-2-one	N/A	0.35	1474	0	2684	0
Nitrogen Containing						

Volatile Compound	Sensory Attribute[123]	$P > F^a$	SEM[b]	Dyna-Gro	Mycogen	Terral
2-hydroxy-2-phenylacetonitrile; Mandelonitrile	N/A	0.35	1026	1661	0	0
2-methyl-5h-dibenz[b,f]azepine	N/A	0.46	7510	50	-2913	8738
N-(1-methylheptyl)-2-octanamine	N/A	0.35	604	0	977	0
Phenol						
2,6-Bis(1,1-dimethylethyl)-4-(1-oxopropyl)phenol	N/A	0.35	12311	-4980	-4980	14940
Sulfur-Containing						
Dimethyl disulfide	Onion[1]	0.58	1676	-371	1834	1113
Dimethyl sulfide	Wild radish, cabbage-like, green[1]	0.13	5794	-3347	-3347	10041
Thiobismethane	Wild radish, cabbage-like, green[1]	0.29	51667	48861	121368	18719

[a]Values are significant ($P < 0.05$)

[b]Standard Error of the Mean (SEM), largest SEM from model was used

[cd]LSMeans in the same row with different superscripts differ ($P < 0.05$).

[123]Sensory Attribute Sources ([1]Burdock, 2010; [2]Flament, 2002; [3]National Center for Biotechnology Information, NCBI)

Table 24. Least squares means of total ion counts for volatiles present during aroma events for ground maize interactions produced from maize grown in different locations that produced all maize varieties as detected by GC/MS-O analysis.

Volatile Compound	Sensory Attribute[1234]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farms		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Acid												
Acetic acid	Acid, fruit, pungent, sour, vinegar[2,3]	0.50	36753	57705	133743	56236	52812	63224	89426	39080	120507	18591
Octanoic acid	N/A	0.43	528	0	0	0	0	0	0	0	0	1585
Alcohol												
1-Hexanol	Herb-like, woody, sweet, green fruity[1]	0.27	21459	54198	28161	71094	0	0	0	0	51674	0
1-Octen-3-ol	Sweet, oily, nutty, warm, herb-like[1]	0.43	647	0	0	0	0	0	0	0	1941	0
1-Pentanol; amyl alcohol	Fusel-like, sweet[1]	0.68	13880	16387	23456	0	0	6177	0	0	37814	0
2-(hexyloxy)-ethanol	N/A	0.51	148885	139364	0	258537	5633	93370	235626	55498	234549	0
Ethanol	Ethanol-like[2]	0.21	63303	100724	173992	176229	152480	41603	174514	26468	161537	8967

Volatile Compound	Sensory Attribute[1234]	$P > F^a$	SEM[b]	Calhoun County			Monte Alto			Sawyer Farms		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Isoamyl alcohol; 3-methyl-1-butanol; isopentyl alcohol	Fusel oil, whiskey-characteristic, pungent; malty; burnt, cocoa, floral, malt[123]	0.43	7861	0	23582	0	0	0	0	0	0	0
Isopropyl alcohol	Alcoholic, unpleasant; malty; apple, bitter, cocoa, wine[123]	0.43	3479	0	10437	0	0	0	0	0	0	0
Aldehyde												
(E)-2-decenal		0.53	28352	0	0	0	38800	23246	56320	0	0	58349
2-Dodecanal		0.43	19935	0	0	0	0	0	59806	0	0	0
3-Dodecen-1-al		0.22	24027	25785	0	0	37787	0	0	30597	0	90008

Volatile Compound	Sensory Attribute[1234]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farms		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
3-methylbutanal	Choking, powerful, acrid, pungent, apple, fruity, fatty, animal, almond[1]	0.36	3389	0	0	3286	0	0	0	0	9622	0
Benzaldehyde	Sweet, crushed almonds; burnt sugar, cherry, malt, sweet, crushed almonds[23]	0.01	2456	3206[d]	7600[d]	5003[d]	5079[d]	5858[d]	5692[d]	4331[d]	23483[c]	8548[d]
Butanal	Banana, green, pungent[3]	0.44	3852	0	0	5949	0	0	0	8638	0	4851
Decanal	Floral, fatty, fried, orange peel, penetrating tallow (buckwheat)[123]	0.02	5163	0[d]	0[d]	0[d]	5011[d]	0[d]	13879[d]	0[d]	0[d]	33281[c]

Volatile Compound	Sensory Attribute[1234]	P > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farms		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Heptanal	Oily, fatty, rancid, harsh, pungent fermented fruity[12]	0.96	12667	16369	19681	14157	17483	2415	0	18671	12770	5862
Hexanal	Fatty, green, grassy	0.06	185892	240512	267068	515192	271928	202105	328452	119932	838950	16819
N Heptanal	Oily, fatty, rancid, harsh, pungent fermented fruity; Citrus, fat, green, nutty[123]	0.72	11564	0	0	0	0	0	20050	0	0	28311
Nonanal	Fatty, citrus, rose; soapy; metallic[123]	0.5838047	38047	133961	106629	131036	147645	131296	164209	125984	136103	241810

Volatile Compound	Sensory Attribute[1,2,3,4]	$P > F^a$	SEM[b]	Calhoun County			Monte Alto			Sawyer Farms		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Nonenal		0.43	5422	0	0	0	0	0	16265	0	0	0
Octanal	Fatty, citrus, honey[1]	0.63	20819	43786	28046	25743	41235	37166	58966	45672	36319	88170
Pentanal	Powerful, acrid, pungent[1]	0.33	14759	14629	26713	9436	3467	3362	37531	17965	35587	11740
Alkane												
2-methylbutane	Gasoline-like[3]	0.43	603	0	0	0	0	0	0	0	0	1808
Eicosane	N/A	0.43	411569	0	0	0	0	0	0	0	0	1234708
Ethoxyethene	Ether[3]	0.43	402	0	0	0	0	1207	0	0	0	0
Heptane	Petroleum-like[3]	0.90	11768	6274	0	10897	0	0	14678	10308	24659	22832
Methylbenzene; Toulene	Sweet, gassy; paint thinner[2,3]	0.43	1460	0	0	0	0	4381	0	0	0	0
Nonadecane	N/A	0.43	403693	0	0	0	0	0	0	0	0	1211079
Octane	Gasoline[3]	0.79	14295	15750	0	3748	11699	18118	21682	6464	24273	23136
Pentane	Petroleum-like[3]	0.52	47707	0	93180	85167	38552	8784	0	0	94148	0

Volatile Compound	Sensory Attribute[12 34]	*P* > F[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farms		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Ester												
Butyrolactone - lactone	Faint, sweet, buttery, fruity, peach-like[1]	0.43	5440	0	16319	0	0	0	0	0	0	0
Ethyl decanoate	Cognac, oily; fruity, brandy, grape, pear[13]	0.41	80695	42102	324709	34117	0	57943	68102	0	77240	0
Ethyl Octanoate	Fruity, floral, wine, apricot[1]	0.43	4363	0	0	0	13090	0	0	0	0	0
Hexyl Formate	Fruity, apple, unripe plum[1]	0.43	4271	0	0	0	12814	0	0	0	0	0
Furan												
1-(2-furanyl)ethanone; 2-acetylfuran	Coffee-like; balsamic, cocoa, coffee[13]	0.43	6584	0	0	0	0	0	0	0	0	19752

Volatile Compound	Sensory Attribute[1234]	$P > F$[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farms		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
2-ethylfuran	Smokey, burnt, warm, sweet, coffee; butter caramel[13]	0.68	1873	0	0	4909	0	0	2734	0	0	0
2-methylfuran	Spice, smokey[1]	0.20	10626	0	9762	33626	10131	0	0	0	16869	0
2-pentylfuran	Earthy, moldy, oily, anise; Fruity, green bean, metallic, vegetable[12]	0.10	8190	23284	17083[c]	31922	5924	19482	23915	4316	37562	9742
3-methylfuran	N/A	0.66	4201	6869	7019	0	5736	0	5432	0	0	0
Ketone												
2-butanone	Sweet, apricot[1]	0.43	2334	0	0	0	7001	0	0	0	0	0
2-heptanone	Fruity, spicy, cinnamon, banana[1]	0.43	3017	0	0	0	0	0	0	0	9050	0

Volatile Compound	Sensory Attribute[1234]	$P > F^a$	SEM[b]	Calhoun County			Monte Alto			Sawyer Farms		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
6-methyl-5-hepten-2-one	N/A	0.43	2384	0	0	0	0	7153	0	0	0	0
Nitrogen Containing												
2-hydroxy-2-phenylacetonitrile; Mandelonitrile	N/A	0.43	1661	4982	0	0	0	0	0	0	0	0
2-methyl-5h-dibenz[b,f]azepine	N/A	0.38	12022	8889	0	0	0	0	0	0	0	34954
N-(1-methylheptyl)-2-octanamine	N/A	0.43	977	0	2930	0	0	0	0	0	0	0
Phenol												
2,6-Bis(1,1-dimethylethyl)-4-(1-oxopropyl)phenol	N/A	0.43	19920	0	0	0	0	0	59759	0	0	0
Sulfides												
Dimethyl disulfide	Onion[1]	0.33	2657	0	0	0	0	0	4450	0	6614	0

Volatile Compound	Sensory Attribute[1234]	$P > F$[a]	SEM[b]	Calhoun County			Monte Alto			Sawyer Farms		
				Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral	Dyna-Gro	Mycogen	Terral
Dimethyl sulfide	Wild radish, cabbage-like, green[1]	0.69	9773	0	0	14933	0	0	25230	0	0	0
Thiobismethane	Wild radish, cabbage-like, green[1]	0.07	73337	0	0	0	110505	15501	35868	15102	360959	32645

[a]Values are significant ($P < 0.05$)

[b]Standard Error of the Mean (SEM), largest SEM from model was used

[cde]LSMeans in the same row with different superscripts differ ($P < 0.05$).

[123]Sensory Attribute Sources ([1]Burdock, 2010; [2]Flament, 2002; [3]National Center for Biotechnology Information, NC

Table 25. GC/MS – O new-make whiskey volatile summary

Volatile compounds	Table 16		Table 18		Table 17		Table 19		Table 20	
Total volatiles	67		67		22		22		68	
Significantly different volatiles	58	85%	31	46%	16	73%	8	36%	46	68%
Acids	3	5%	1	2%	1	5%	0	0%	2	3%
Alcohols	5	8%	1	2%	0	0%	0	0%	5	7%
Aldehydes	12	18%	4	6%	6	27%	2	9%	8	12%
Alkanes	10	25%	4	6%	4	18%	0	0%	6	9%
Esters	21	31%	15	22%	3	14%	2	9%	20	29%
Furans	2	3%	2	3%	1	5%	2	9%	1	1%
Ketones	4	6%	5	8%	1	5%	2	9%	4	6%
Sulfur-containing	1	2%	0	0%	0	0%	0	0%	0	0%

Table 26. GC/MS – O maize volatile summary

Volatile compounds	Table 21		Table 23		Table 22		Table 24	
Total volatiles	50		50		48		51	
Significantly different volatiles	3	6%	2	4%	1	2%	2	4%
Acids	0	0%	0	0%	0	0%	0	0%
Alcohols	1	2%	0	0%	1	2%	0	0%
Aldehydes	2	4%	2	4%	0	0%	2	4%
Alkanes	0	0%	0	0%	0	0%	0	0%
Esters	0	0%	0	0%	0	0%	0	0%
Furans	0	0%	0	0%	0	0%	0	0%
Ketones	0	0%	0	0%	0	0%	0	0%
Sulfur-containing	0	0%	0	0%	0	0%	0	0%

APPENDIX B

FIGURES

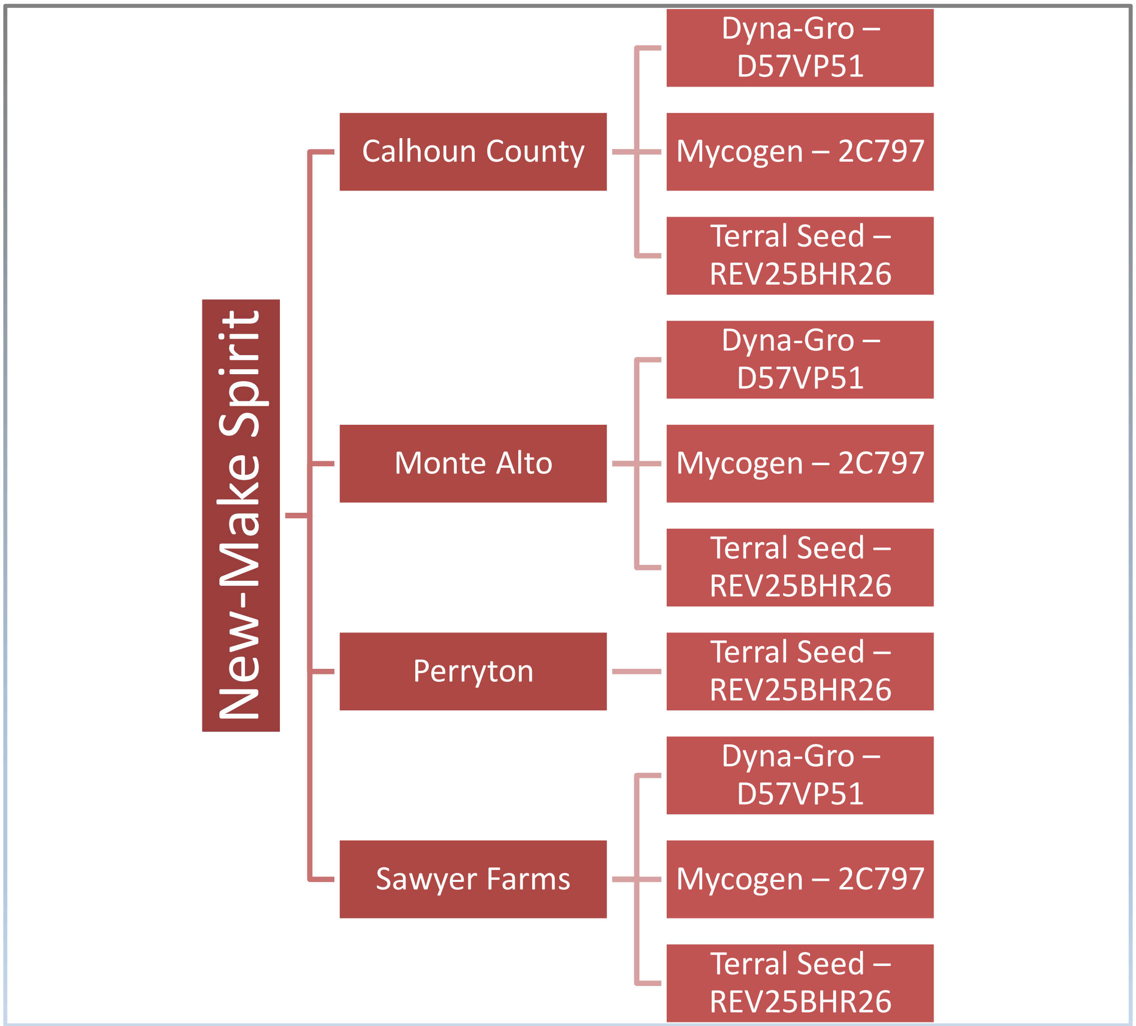

Figure 1. New-make whiskey complete experimental design. ***Calhoun County, Monte Alto, Perryton, and Sawyer Farms are locations chosen to grow the maize varieties Dyna-Gro – D57VP51, Mycogen – 2C797, Terral Seed – REV25BHR26.***

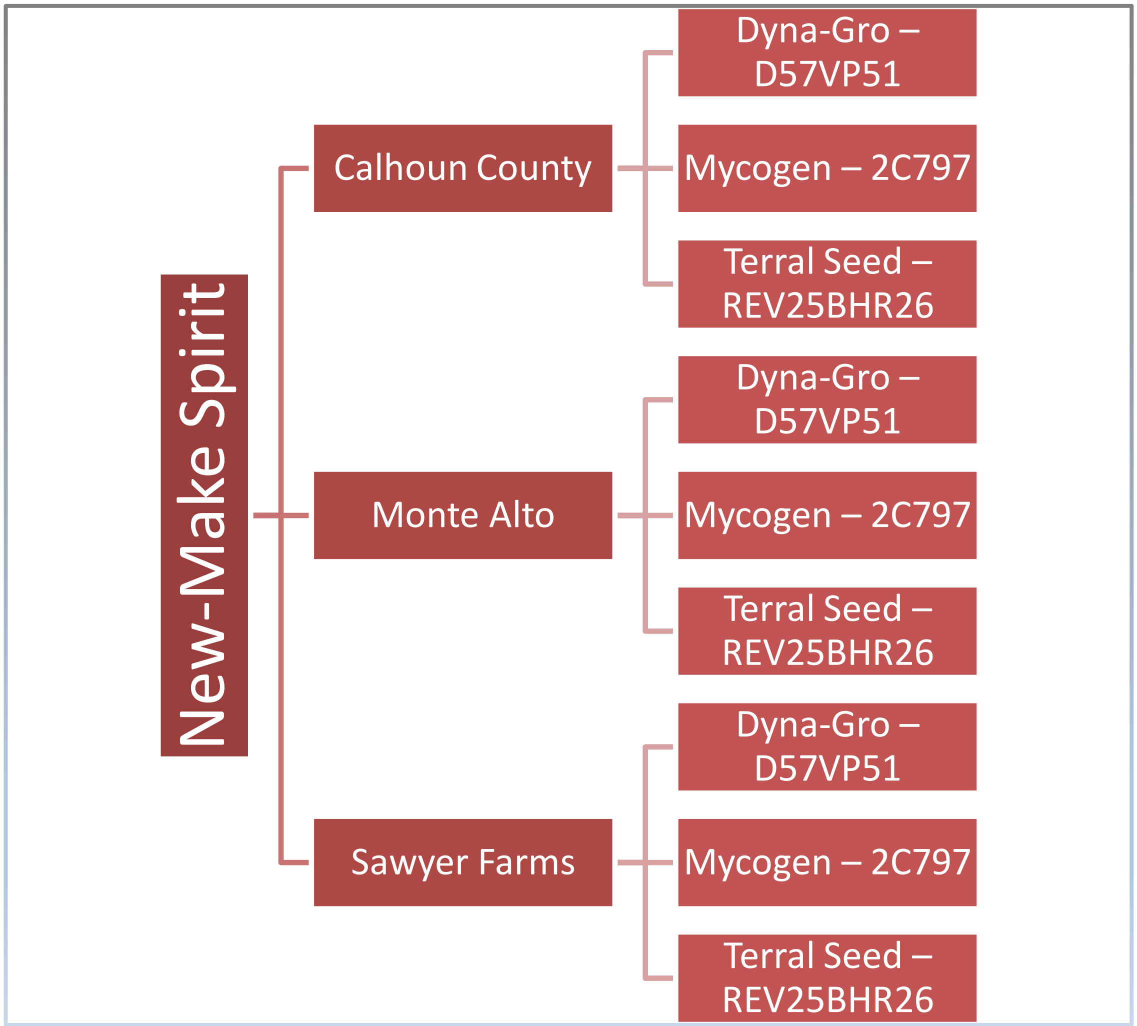

Figure 2. New-make whiskey balanced experimental design. ***Calhoun County, Monte Alto, and Sawyer Farms are locations chosen to grow the maize varieties Dyna-Gro – D57VP51, Mycogen – 2C797, Terral Seed – REV25BHR26.***

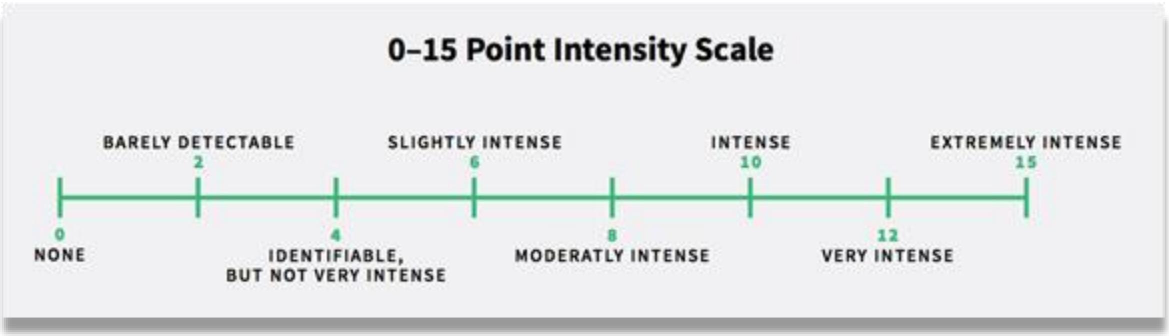

Figure 3. 16-point scale for descriptive analysis with word anchors to describe intensity.

APPENDIX C

Commercial liquors used for new-make whiskey lexicon development
Whiskey
Balcones Baby Blue Corn Whiskey
Forty Creek Premium Barrel Select Whisky
Jack Daniel’s Tennessee Rye Whiskey
John E. Fitzgerald Larceny Bourbon
Rebel Yell Kentucky Straight Bourbon
TX Whiskey
White Dog Whiskey/Unaged Whiskey
American Craft Low Gap Whiskey
Buffalo Trace Mash #1 White Dog
Georgia Moon Corn Whiskey
Maker’s Mark White Dog Whiskey
Ole Smoky Tennessee Moonshine Corn Whiskey
Ranger Creek .36 Texas Bourbon
Whitmeyer’s Moonshine
Other Liquor
Sombrero Almond Liquor
Captain Morgan White Rum
McCormick Gin
Gallo Vermouth – Sweet
Gallo Vermouth – Dry
Barsol Pisco
Metaxa Ouzo
51 Cachaça
Dekuyper Triple Sec
Romana Sambuca
Tanqueray Gin
Di Amore Amaretto
Effen Black Cherry Vodka

APPENDIX D

Whiskey Lexicon

Alcohol

A colorless, pungent, chemical-like aromatic associated with distilled spirits or grain products.

Alcohol 5.0: Absolut Vodka (80 proof)	Dilute 16 mL of Absolut Vodka in 64 mL of distilled water. Serve 15 mL in a snifter. Cover.
Alcohol 8.0: Barsol Pisco (41.3% ABV)	Serve 15 mL of Barsol Pisco Spirit in a snifter. Cover.
Alcohol 10.0: 120 Proof Neutral Spirit	Dilute 100 g of 190 proof neutral spirit in 77.25 g of distilled water. Serve 15 mL in snifter. Cover.
Alcohol 12.0: 190 Proof Neutral Spirit	Serve 15 mL of 190 proof neutral spirit in snifter. Cover.

Anise

A pungent, sweet, spicy, brown, caramelized aromatic that may contain petroleum, medicinal, floral notes, and licorice-like aromatics

Anise 7.5: Anise Seed	Place ½ teaspoon of McCormick's anise seed in a snifter. Cover.

Banana

Aromatic characteristic of ripe bananas

Banana 10.0: Banana Extract	Place 1 drop of banana extract on a cotton ball. Serve in snifter glass. Cover.

Barnyard (Added for maize aroma)

Aromatic characteristic of livestock animal housing

Barnyard 6.0: McCormick's Ground White Pepper	Place ½ teaspoon of white pepper in 1 ounce of distilled water.

Blended

The melding of individual sensory notes such that the products present a unified overall sensory experience as opposed to spikes or individual notes

Blended 3.0: Absolut Vodka (80 proof)	Dilute 16 mL of Absolut Vodka in 64 mL of distilled water. Serve 15 mL in a snifter. Cover.
Blended 5.0: McCormick Gin (40% ABV)	Serve 15 mL of McCormick Gin in a snifter. Cover
Blended 10.0 Tanqueray Gin (47.3% ABV)	Serve 15 mL Tanqueray Gin in a snifter. Cover

Brown Spice Complex

The sweet, brown aromatic associated with spices such as cinnamon, clove, nutmeg, and allspice

Brown Spice Complex 3.0	Place 1 cinnamon stick (1/2 teaspoon) in a 2-ounce glass jar with screw-on type lid
Brown Spice Complex 7.0	Place 1 whole nutmeg (2 teaspoons) and 3 clove buds (1/4 teaspoon) in a 2-ounce glass jar with screw-on type lid

Brown Sugar

A rich, full, round, sweet aromatic impression characterized by some degree of darkness

Brown Sugar 6.0: C&H Pure Cane Sugar, Golden Brown	Place 1 teaspoon brown sugar in a snifter. Cover.

Burnt

The dark brown impression of an over-cooked or over-roasted product that can be sharp, bitter, and sour

Burnt 4.5: Benzyl Disulfide	Place 0.1 gram of benzyl disulfide in a covered soufflé cup
Burnt 8.0: Puffed Wheat Cereal	Serve 1 tablespoon of cereal in a covered soufflé cup

Buttery
Aromatic associated with fresh butter fat, sweet cream

Buttery 5.0: McCormick Extract	Place 1 drop of coconut extract on a cotton ball. Serve in snifter glass. Cover.
Buttery 7.0: Land O'Lakes Unsalted Butter	Place ½ tablespoon in a covered snifter.

Butyric
An aroma associated with butyric acid, cheesy, also sickly

Butyric 6.0: Butyric Acid	Place 1 drop of butyric acid to a cotton ball. Serve in a snifter glass. Cover.

Caramel
A round, full-bodied, medium brown, sweet aromatic associated with cooked sugars and other carbohydrates. Does not include burnt or scorched notes

Caramel 8.0: Le Nez du Café no.25 "caramel"	Place 1 drop of essence on a cotton ball in a soufflé cup. Cover.

Cardboard/Paper-like
The aromatic associated with cardboard or paper packaging

Cardboard/Paper-like 3.0: White Napkin	Place a 2-inch napkin piece in a soufflé cup
Cardboard/Paper-like 7.5: Cardboard	Cut a 2-inch square of cardboard. Place in a covered soufflé cup

Coconut
The slightly sweet, nutty, somewhat woody aromatic associated with coconut

Coconut 7.5: McCormick Extract	Place 1 drop of coconut extract on a cotton ball. Serve in snifter glass. Cover.

Coffee
An aroma note associated with coffee

Coffee 3.0: Werther's Coffee	Place a single, unwrapped Werther's Coffee Flavored Caramel in a snifter. Cover .
Coffee 8.0: Folgers® Instant Coffee Crystals	Place 1/8 of a teaspoon of Folgers® Instant Coffee Crystals

Corn

An aroma note associated with corn

Corn 5.0: Canned corn	Drain and rinse canned corn and serve in soufflé cup
Corn 8.0: Amoretti Sweet Corn Essence	Place 1 drop of Amoretti Sweet Corn Essence on cotton ball and place in soufflé cup

Fermented/Yeasty

The pungent, sweet, slightly sour, sometimes yeasty, alcohol-like aromatic characteristic of fermented fruits or sugar or over-proofed dough

Fermented/Yeasty 5.0: Guinness Extra Stout Beer	Serve 15 mL **Guinness Extra Stout Beer** in a covered glass

Fruity – Berry

The sweet, sour, floral, sometimes heavy aromatic associated with a variety of berries such as blackberries, raspberries, blueberries, or strawberries

Berry 3.0: Captain Morgan Rum	Serve 15 mL in a covered glass
Berry 6.0: Tropicana Berry Juice	Serve 15 mL in a covered glass.
Berry 10.0: Private Selection Triple Berry Preserves	Place 1 teaspoon of jelly in a medium snifter. Cover

Fruity – Citrus

A citric, sour, astringent, slightly sweet, peely, and somewhat floral aromatic that may include lemons, limes, grapefruits, or oranges

Citrus 4.5: Lemon peel + lime peel	Put 0.5 grams lemon peel and 0.5 grams lime peel in a medium snifter. Cover
Citrus 7.5: Grapefruit peel	Put 0.25 grams grapefruit peel in a medium snifter. Cover

Fruity – Dark

An aromatic impression of dark fruit that is sweet and slightly brown and is associated with dried plums and raisins

Dark Fruit 3.0: Sunsweet Amaz!n Prune Juice	Mix 1 part juice with 2 parts water. This may be prepared 24 hours in advance and refrigerated. Bring to room
Dark Fruit 4.5: Sun-Maid Prunes	Chop 1/2 cup prunes. Add ¾ cup of water and cook in microwave on high for 2 minutes. Filter with a sieve. Place 1 tablespoon of juice in a medium snifter. Cover
Dark Fruit 6.0: Sun-Maid Raisins	Chop 1/2 cup of raisins. Add ¾ cup water and cook in microwave on high for 2 minutes. Filter with a sieve. Place 1 tablespoon of liquid juice in a medium snifter. Cover

Fruity – Other

A sweet, light, fruity, somewhat floral, sour, or green aromatic that may include apples, grapes, peaches, pears, or cherries

Other Fruit 5.0: Le Nez du Café n. 17 “apple”	Place 1 drop on a cotton ball in large snifter. Cover
Other Fruit 9.0: Effen Black Cherry Vodka	Serve 15 mL in a covered glass

Fishy

Aromatic associated with trimethylamine and old fish

Fishy 7.0: Canned tuna	Place 1 gram of tuna from can in a covered soufflé cup

Floral

A sweet, light, slightly fragrant aromatic associated with flowers

Floral 6.0: Welch’s 100% White Grape Juice	Mix 1 part water and 1 part juice. Place 15 mL of mixture in a snifter. Cover.
Floral 8.0: Le Nez du Café n.12 “coffee blossom”	Place 1 drop of Le Nez du Café essence on a cotton ball in a snifter. Cover.

Grain Complex

The light brown, dusty, musty, sweet aromatic associated with grains

Grain Complex 5.0:	Blend ½ cup of Rice Chex and ½ cup of Post Shredded Wheat in a food processor. Serve 1 tablespoon in a snifter. Cover.
Grain Complex 8.0: Georgia Moon Corn Whiskey	Serve 15 mL in a snifter. Cover.

Green

An aromatic characteristic of fresh, plant-based material. Attributes may include leafy, viney, unripe, grassy, and peapod

Green 9.0: Parsley water	Rinse and chop 25 grams of fresh parsley. Add 300 milliliters of water. Let sit for 15 minutes. Filter out the parsley. Serve 1 tablespoon of the water in a snifter. Cover.

Hay-like

The lightly sweet, dry, dusty aromatic with slight green character associated with dry grasses

Hay-like 7.5: McCormick Parsley Flakes	Place 1 teaspoon of flakes in a medium snifter. Cover.

Herb-like

The aromatic commonly associated with green herbs that may be characterized as sweet, slightly pungent, and slightly bitter. May or may not include green or brown notes

Herb-like 3.0: McCormick Bay Leaves, ground thyme, basil leaves	Preparation: Mix together 0.5 grams of each herb. Break the bay leaves into smaller pieces with your hands first, and then grind all the herbs together using a mortar and pestle. Add 100 milliliters of water. Mix well. Put 5 milliliters of herb water in a medium snifter, and add 200 milliliters of water. Serve 1 oz. in soufflé cup.
Herb-like 10.0: McCormick Bay Leaves, ground thyme, basil leaves	Mix together 0.5 grams of each herb. Break the bay leaves into smaller pieces with your hands first, and then grind all the herbs together using a mortar and pestle. Add 100 milliliters of water. Mix well. Serve 1 oz. in soufflé cup.

Honey

Sweet, light brown, slightly spicy aromatic associated with honey

Honey 6.0: Busy Bee Pure Clover Honey	Dissolve 1 tablespoon of honey in 250 mL of distilled water. Serve 15 mL in snifter. Cover.

Lactic Acid

A sour aroma note associated with lactic acid

Lactic Acid 5.0: Buttermilk	Serve 1 oz. buttermilk in soufflé cup
Lactic Acid 8.0: Sauerkraut	Serve 5 g sauerkraut in soufflé cup

Leather

An aromatic associated with tanned animal hides

Leather 3.0: Leather Shoe Lace	Place a 3-inch length of leather shoe lace in a covered snifter
Leather 10.0: Hazels Gifts Leather Essence	Place 2 drops on a cotton ball in a covered snifter

Malt

The light brown, dusty, musty, sweet, sour and or slightly fermented aromatic associated with grains

Malt 3.5: Post Grape Nut Cereal	Serve Post Grape-Nut Cereal in a covered snifter.
Malt 6.0: Carnations Malted Milk	Place ½ teaspoon in a covered snifter

Medicinal

A clean, sterile aromatic characteristic of antiseptic-like products such as Band-Aids, alcohol, and iodine

Medicinal 6.0: Le Nez du Café no. 35 “medicinal”	Place 1 drop of essence on a cotton ball in a soufflé cup
Medicinal 8.0: Tanqueray Gin	Serve 15 mL of **Tanqueray Gin** in covered glass
Medicinal 12.0: Iodine	Serve 1:1 iodine and distilled water solution in a covered glass (50 mL iodine tincture, 50 mL distilled water

Mint

An aromatic with mint family (sweet, green, and menthol)

Mint 4.0: Absolut Vodka/Mint Gum	Place 3 stick of mint gum in 150 mL of **Absolut Vodka** and let steep for 30 minutes. Serve 15 mL **Absolut Vodka** in covered glass
Mint 8.0: Listerine	Serve in a covered snifter

Molasses

An aromatic associated with molasses; has a sharp, slight sulphur and/or caramelized character

Molasses 6.5: Black Strap Molasses	Mix 2 teaspoons of molasses in 250 milliliters of water. Serve ¼ cup in a mason jar. Cover

Musty/Dusty

The aromatic associated with dry, closed-air spaces such as attics and closets. May have elements of dry, musty, papery, dry soil, or grain

Musty/Dusty 5.0: Kretschmer Wheat Germ	Serve 1 tablespoon wheat germ in a medium snifter. Cover.
Musty/Dusty 10.0: 2,3,4-Trimethoxybenzaldehyde	Place 0.1 gram in a medium snifter. Cover

Musty/Earthy

The somewhat sweet, heavy aromatic associated with decaying vegetation and damp, black soil

Musty/Earthy 3.0: Mushrooms	Place 2, washed 1/2 – inch cubes in a covered snifter.
Musty/Earthy 9.0: Miracle Gro Potting Soil	Fill a 2-ounce glass jar half full with potting soil and seal tightly with screw-on type lid
Musty/Earthy 12.0: Le Nez du Café no. 1 “earthy”	Place 1 drop of essence on a cotton ball in a large snifter. Cover

Nutty

A slightly sweet, brown, woody, oily, musty, astringent, and bitter aromatic commonly associated with nuts, seeds, beans, and grains

Nutty 7.5: Le Nez du Café no. 29 "roasted hazelnut"	Place 1 drop of essence on a cotton ball in a covered glass
Nutty 9.0: Almont/Walnut Puree	Puree the almonds and walnuts separately in blenders for 45 seconds on high speed. Combine equal amounts of the chopped nuts. Serve in a covered glass

Oily

An overall flavor term for the aroma and flavor notes reminiscent of vegetable oil or mineral oil products

Oily 9.0: Vegetable Oil	Serve vegetable oil in a covered glass.

Overall Sweet/Sweet Aromatics

The perception of a combination of sweet substances and aromatics

Overall Sweet 3.0:	Mix 0.5 g of vanillin into 250 mL of water in covered snifter
Overall Sweet 5.0:	Mix 2 g of vanillin into 250 mL of water in covered snifter

Overall Sour/Sour Aromatics

An aromatic associated with the impression of a sour product

Overall Sour 2.0: Bush's Pinto Beans, canned	Drain and rinse with distilled water, 1 tbsp. placed in covered snifter
Overall Sour 5.0: Buttermilk	Serve 1 oz. buttermilk in a covered glass

Pepper

The spicy, pungent, musty, and woody aromatic characteristic of ground black pepper

Pepper 13.0: McCormick Ground Black Pepper	Place ½ teaspoon pepper in a medium snifter. Cover

Rancid

Aromatic associated with oxidized fats and oils

Rancid 5.0: Vegetable oil (oxidized/rancid)	Keep oil in an open container or a warm storage place for 1 week. Place 1 oz. rancid oil in covered glass.

Roast

Dark brown impression characteristic of products cooked to a high temperature by dry heat. Does not include bitter or burnt notes

Roast 6.0: Le Nez du Café no. 34 "Roasted Coffee"	Place one drop on cotton ball. Place in covered glass.

Smokey

An acute, pungent aromatic that is a product of the combustion of wood, leaves, or a non-natural product

Smokey 6.0: Diamond Smoked Almonds	Place 5 almonds in a covered snifter

Soapy

An aroma associated with unscented soap

Soapy 6.5: Ivory Soap Flakes	Place 0.5 g bar soap in 100 ml of room temperature water. Serve in large snifter, covered snifter.

Solvent-like

General term used to describe many classes of solvents, such as acetone, turpentine, chemical solvents, etc.

Solvent-like 5.0: Acetone solution	Dilute 10 mL acetone in 100 mL distilled water until dissolved, and serve in 2 oz. soufflé cup. Cover.
Solvent-like 8.0: Lighter fluid solution	Dilute 10 mL of lighter fluid in 100 mL distilled water until dissolved, and serve in 2 oz. soufflé cup. Cover.

Stale

The aromatic characterized by a lack of freshness

Stale 4.5: Mama Mary's Gourmet Original Pizza Crust	Serve cut a 2-inch square of crust and serve in soufflé cup. Cover.

Sulphur

Aromatic associated with hydrogen sulfide, rotten egg

Sulphur 3:0: Bush's Pinto Beans	Drain and rinse the beans. Serve 1 tbsp. in a covered glass.
Sulphur 11.0: Dimethyl Trisulfide	Dilute 1 ml of dimethyl trisulfide in 100 ml distilled water until dissolved, and serve in 2 oz. soufflé cup. Cover.
Sulphur 15.0: Dimethyl Trisulfide	Place 1 drop of dimethyl trisulfide on a cotton ball. Serve in a soufflé cup. Cover.

Tobacco

The brown, slightly sweet, slightly pungent, fruity, floral, spicy aromatic associated with cured tobacco

Tobacco 5.0: Le Nez du Café no. 33 "pipe tobacco"	Place 1 drop of essence on a cotton ball in a large snifter. Cover
Tobacco 7.0: Marlboro Cigarettes, southern cut	Break cigarette and place 0.1 grams tobacco in a medium snifter. Cover

Vanilla

A woody, slightly chemical aromatic associated with vanilla bean, which may include brown, beany, floral, and spicy notes

Vanilla 2.5: Le Nez du Café no.10 "vanilla"	Place 1 drop of Le Nez du Café essence on a cotton ball in a snifter glass. Cover.
Vanilla 5.5: Spice Islands Bourbon Vanilla Bean	Place 0.5 gram chopped vanilla beans in a snifter glass. Cover.

Vinegar

A sour, astringent, slightly pungent aromatic associated with vinegar or acetic acid

Vinegar 2.0: 0.5% acetic acid solution	Dilute 5 mL distilled white vinegar in 1000 mL distilled water. Serve in soufflé cup. Cover
Vinegar 3.0: 2.0% acetic acid solution	Dilute 20 mL of white distilled vinegar in 1000 mL distilled water. Serve in soufflé cup. Cover

Woody

The sweet, brown, musty, dark aromatic associated with a bark of a tree

Woody 4.0: Diamond Shelled Walnuts	Serve 1 tablespoon of chopped walnuts in a snifter. Cover.
Woody 7.5: Popsicle Sticks	Break popsicle sticks in two and place in snifter. Cover.

Nasal Feeling Factors

Nose Cooling

The chemical feeling factor or sensation of cooling in the nasal passages when sniffing

Nose Cooling 6.0: Tanqueray Gin	Serve 15 mL in covered glass
Nose Cooling 8.0: Listerine solution	Mix 1:1 dilution Listerine and distilled water; serve in soufflé cups
Nose Cooling 12.0: Listerine	Serve 1 oz. in a covered glass

Nose Drying

The chemical feeling factor or sensation of drying in the nasal passages when sniffing

Nose Drying 4.0: Barrelstone Cellars Merlot, 2013	Serve 15 mL **Barrelstone Cellars Merlot 2013** in covered glass
Nose Drying 6.0: F&R Neutral Spirit, 120 proof	[Proof down 190 to 120] Add 100 g of F&R Neutral Spirit to 77.25 g distilled water; serve **F&R Neutral 120** in covered glass
Nose Drying 8.0: Unscented Hand Sanitizer	Serve 1 oz. in a covered glass

Nose Warming

Chemical feeling factor described as a warmth or burning sensation in the nasal passages occurring when sniffing

Nose Warming 3.0: Barrelstone Cellars Merlot, 2013	Serve 15 mL **Barrelstone Cellars Merlot 2013** in covered glass
Nose Warming 7.0: TX Whiskey Blend	Serve 15 mL **F&R TX Whiskey Blend** in covered glass
Nose Warming 9.0: F&R Neutral Spirit, 85 proof	Preparation: [Proof Down 190 to 85] Add 50 g of F&R Neutral Spirit to 79.8 g distilled water; serve 15 mL per covered glass
Nose Warming 12.0: F&R Neutral Spirit 120 proof	[Proof down 190 to 120] Add 100 g of F&R Neutral Spirit to 77.25 g distilled water; serve **F&R Neutral 120** in covered glass

Prickle/Pungent

A feeling factor that can range from tingling or irritating, sharp, physically penetrating sensation of the nasal cavity

Prickle/Pungent 5.0: McCormick Ground Black Pepper solution	Mix 10 g cracked black pepper in 100 mL of distilled water; serve in a covered glass
Prickle/Pungent 5.0: Horse Radish Solution	Serve 1/8 teaspoon in a covered glass
Prickle/Pungent 7.0: Captain Morgan Rum	Serve 15 mL **Captain Morgan** in a covered snifter.
Prickle/Pungent 9.0: McCormick Ground Black Pepper	Serve ½ teaspoon cracked pepper in a covered glass.
Prickle/Pungent 10.0: Horse Radish Sauce solution	Mix 5 g horseradish sauce in 30 mL distilled water; serve 1 oz. in labeled soufflé cups

APPENDIX E

New-make whiskey ballot for trained, descriptive aroma panel

TEXAS A&M UNIVERSITY

____
Date

Aroma Panel
Day ______

Attributes	363	784	452	351
Blended				
Alcohol Intensity				
Overall Sweet				
Overall Sour				
Brown Spice Complex				
Grain Complex				
Corn				
Malt				
Fermented/Yeasty				
Woody				
Nutty				
Berry Fruit				
Citrus Fruit				
Dark Fruit				
Other Fruit				
Musty/Dusty				
Musty/Earthy				
Herb-like				
Hay-like				
Green				
Floral				
Tobacco				
Medicinal				
Leather				
Smokey				
Roast				
Burnt				
Brown Sugar				
Honey				
Molasses				
Vanilla				
Caramel				
Buttery				
Banana				
Coconut				
Coffee				
Anise				

Recorded by________________
Entered by________________
Checked by________________

1

TEXAS A&M UNIVERSITY

____
Date

Mint				
Pepper				
Vinegar				
Lactic Acid				
Cardboard/Paper				
Stale				
Soapy				
Solvent-like				
Oily				
Rancid				
Fishy				
Butyric				
Sulphur				
Prickle/Pungent				
Nose Cooling				
Nose Drying				
Nose Warming				

Recorded by________________
Entered by________________
Checked by________________

2

APPENDIX F

Maize attribute ballot for trained, descriptive aroma panel

TEXAS A&M UNIVERSITY

Corn Testing Day 5

April 28th, 2017

Attributes	W/U	662	598	145	926	362	826
Overall Sweet							
Overall Sour							
Corn							
Grain Complex							
Malt							
Musty/Dusty							
Musty/Earthy							
Woody							
Nutty							
Buttery							
Oily							
Rancid							
Hay-like							
Green							
Roast							
Smokey							
Medicinal							
Leather							
Barnyard							
Cardboard/Paper-like							
Stale							
Brown Spice Complex							
Fermented/Yeasty							

1

Recorded by_______________
Entered by_______________
Checked by_______________

TEXAS A&M UNIVERSITY

Berry Fruit							
Citrus Fruit							
Dark Fruit							
Other Fruit							
Herb-like							
Floral							
Tobacco							
Burnt							
Brown Sugar							
Honey							
Molasses							
Vanilla							
Caramel							
Banana							
Coconut							
Coffee							
Anise							
Mint							
Pepper							
Vinegar							
Lactic Acid							
Soapy							
Solvent-like							
Fishy							
Butyric							
Sulphur							
Other:							

2

Recorded by_______________
Entered by_______________
Checked by_______________