AN ABSTRACT OF THE THESIS OF

Laurie L. Brown for the degree of Master of Science in Food Science and Technology presented on July 30, 1999. Title: Aroma and Flavor of Cachaça, Brazilian Rum.

Abstract approved: ______________________________
Mina R. McDaniel

Cachaça is recognized as the national alcoholic beverage of Brazil, produced through the fermentation and distillation of sugar cane juice. Considered a rum by U.S. regulations, cachaça is unique in that it is made exclusively from the juice of fresh pressed sugar cane, never from molasses. Cachaça has been describe as having "tequila like" and "scotch whiskey" like sensory characters, which also differentiates it from rums produced in other countries.

Though much research has been conducted on the chemical components of rum, including two recent studies on cachaça specifically, little sensory analysis has been published. This is the first study to evaluate the sensory characteristics of cachaça.

Currently, there are very few regulations or standards for the production of cachaça in Brazil, which allows for a great variety between brands of cachaça. Efforts are being made within Brazil to establish both chemical and aroma/flavor profiles of cachaça in an attempt to encourage standards and guidelines that may help promote the exportation of the Brazilian spirit into the international market.

Sensory Analysis of distilled spirits can be difficult due to the complexity created by the hundreds of volatile components they contain. Identifying specific aroma compounds can be taxing at best, and is complicated by the interaction with other components. In addition sensory fatigue among the judges is a real concern.

The objectives of this thesis were to develop a lexicon for cachaça using a modified descriptive analysis method and to determine if differences between brands could be identified, thus aiding in the correlation between sensory characteristics and chemical composition.

A modified descriptive analysis procedure was used that accommodated the limited quantity of samples, the complexity of the products and the concern of sensory fatigue. Nine panelists were trained for twelve, one-hour sessions. Standards were an integral part of the training, as were incentives to maintain high panelist moral and cooperation.

The final lexicon developed was a two tier system composed of ten overall descriptive terms and twenty three more specific terms. The same terms were used to describe both aroma and flavor attributes: alcoholic, ethanol, solvent, woody, oaky, sweet, vanilla, honey, molasses, sherry, floral, lavender, fruity, peach, pear, tropical, banana, citrus, spicy, brown spice, anise, phenolic, medicinal, smoky, sulfury, burnt rubber, green olives, papery, wet cardboard, earthy, sour and lactic/sickly. There were four mouthfeel descriptors: cooling, burning, glycerol/oily, and astringent.

Analysis of variance suggested that the ten brands of cachaça differed in aroma and flavor. There were no obvious differences between brands sold only for export and those sold only in Brazil.

Principal Component Analysis showed that the some of the variation in the samples could be explained by specific groupings of some of the descriptors, with gold and white cachaça in separate groups. The gold cachaça samples could be best separated by the terms sweet, fruity, vanilla, pear and tropical. The white cachaça samples could best separated by the terms papery, wet cardboard, phenolic, smoky, sulfury, burnt rubber and sour. One sample, S-4, seemed to stand out from the others by being more defined as solvent, phenolic, medicinal, sulfury, burnt rubber and papery.

Due to limited time and limited quantity of samples, the chemical analysis performed with Gas Chromatography/Mass Spectrometry was inconclusive, and no direct correlation between chemical content and aroma and flavor, could be made.

Aroma and Flavor of Cachaça, Brazilian Rum

By

Laurie L. Brown

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APPROVED:

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Chair of Department of Food Science and Technology

Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Laurie L. Brown, Author

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CONTRIBUTION OF AUTHORS

Dr. Paulo H.A. Silva was the initiator of this project; in addition he was responsible for the procurement and shipment of most of the cachaça samples. He also participated in the descriptive panel for the development of a lexicon. He was a valuable resource of information concerning the production of cachaça. Dr. Mina R. McDaniel served not only as the main advisor on the project but was responsible for generating the funding necessary to see the study through to completion.

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This work is dedicated to my loving mother, Helen.

AROMA AND FLAVOR OF CACHAÇA, BRAZILIAN RUM

I. INTRODUCTION

Cachaça, is an alcoholic beverage produced exclusively in Brazil through the fermentation and distillation of fresh pressed sugar cane juice. Technically, considered a rum by U. S. regulations and definitions(27 CFR 5:21), cachaça is distinct in its sensory characteristics, sharing some similarities with tequila and scotch whiskey and also possessing some qualities recognized as " rum like" (CFR, 1996; Hamilton, 1997; Durkan, 1997).

Despite the billions of liters of cachaça produced annually in Brazil, actually less than 1% of that is exported. Recent studies at the Universidade Federal de Vicosa, and Universidade de Sao Paulo, Brazil, have attempted to develop methodology for the chemical evaluation and identification of cachaça, with the objective of establishing quality standards that will help promote cachaça as an international product (Silva and Nobrega, 1997; Nascimento et al, 1998).

Understanding the processes involved in the production of cachaça is critical to understanding the development of the aroma and flavor compounds responsible for its unique profile.

Rum in general is produced by the fermentation and distillation of molasses and/or sugar cane juice. Cachaça is produced exclusively from the fresh pressed juice which differentiates it from other rums. The sugar juice is diluted with water and allowed to undergo fermentation either by the inoculation of a pure strain of brewing yeast, and/or through open fermentation which relies on the naturally occurring wild microbial population present in the sugar mash and the distillery environment. Fermentation can be either fast (2 to 3 days) or slow (7 to 20 days), depending on the style desired. Upon completion of fermentation the brew is then distilled. Several distillation options are available depending on the desired finished product. Batch distillation is the more simple of processes and usually results in a heavier bodied rum. Continuous distillation provides more removal of unwanted fractions resulting in a lighter bodied rum. The final product can be aged or matured in oak casks for a variable amount of time. As with all other distilled beverages, batches from different farms or distilleries can be combined and re-distilled together to form a uniform product (Murtagh,1995).

Over 400 compounds have been identified in rum, they include the higher alcohols (fusel alcohols), fatty acids, esters, aldehydes, ketones, furfurals, acetals, lactones, phenolics, and to a lesser degree, sulfur and nitrogenous compounds. This results in a very complex mixture of compounds that in turn result in great variety among samples. It also offers some special challenges in sensory evaluation (Nykanen and Nykanen, 1991).

Sensory evaluation of the aroma and flavor of distilled spirits can be crucial in implementing standards and ensuring quality control. It is also a valuable tool in providing a profile of a product for marketing and product development. Descriptive analysis has been developed, revised and employed extensively through out the brewing, whiskey and wine industries (Piggott et al., 1984).

Though much research has been conducted on the chemical composition of rum, including two recent studies on cachaça, little information has been published on the descriptive analysis of rum and none to date on cachaça specifically.

The objectives of this study were: to develop a lexicon of descriptive terminology specific to cachaça, and to apply a modified version of descriptive analysis, to determine if any differences can be perceived between different brands of cachaça.

II. LITERATURE REVIEW

Cachaça

Definition

Cachaça, (pronounced ka-sha-sa), also called Aguardente de Cana, and/or caninha, is an alcoholic beverage of Brazil, produced through the fermentation and distillation of sugar cane byproducts. Cachaça is referred to by the Brazilian people as "sugar cane brandy", rather than rum, which is the word used to define most distilled beverages produced from sugar cane (Gravata 1991; Durkan 1997).

According to the U.S. Internal Revenue Service (27 CFR 5:21), rum is defined as "any alcoholic distillate from the fermented juice of sugar cane syrup, sugar cane molasses or other sugar cane by-products, distilled at less than 190^0 proof (whether or not such proof is further reduced prior to bottling to not less than 80^0 proof) in such a manner that the distillate possesses the taste, aroma and characteristics generally attributed to rum and includes mixtures solely of such distillates" (Murtagh, 1995).

Rum can be classified as a dark, heavy, or light, based on fermentation, distillation and maturation techniques, which will be discussed in more detail later within this section.

Cachaça though technically a rum by U.S. definitions, is unique in its sensory properties. It varies greatly among distilleries in Brazil, sharing some characteristics with tequila and scotch and sharing some similarities with rums from other countries. It can be white, (or clear), or golden in color.

Of the billions of liters produced annually in Brazil only approximately 1% of that is exported. Efforts to increase exportation are now in process, including the establishment of national guidelines and standards for chemical content. It is hoped that sensory and chemical profiles can be correlated for a better understanding of the how specific processes contribute to the unique quality of cachaça (Nascimento et al, 1998; Silva and Nobrega 1997).

A Brief History of Cachaça

The history of cachaça, as with all rum, can be traced to the beginning of the sugar cane industry which was closely intertwined with slave trading.

The Portuguese introduced sugar cane production into Brazil during the early 1500's, when much of the country was still a Portuguese colony. The early plantations depended on native Indian and African slave labor. Cachaça was produced on most sugar cane plantations as a way to utilize as much of the sugar cane as possible. Often when sugar prices were low, it was the sale of cachaça that brought profit to the plantations. Cachaça rations were one of the few pleasures allowed to the plantation slave workers and for centuries it was considered to be the beverage of the field workers of the lower class.

In addition to consumption as a beverage, cachaça was used for medicinal purposes, as an ingredient in many traditional recipes, and was quite effective at tenderizing meat. Over the years, production of cachaça increased and so did its popularity with the masses. No longer considered just a poor man's wine, it quickly became recognized as the unofficial drink of Brazil. By the early 1600's the production of cachaça was so big that it was believed to interfere with the trading of port and brandies from Europe. Queen Dona Maria I, queen of Portugal, actually banned the production of all cachaça, but it became apparent that this law could not be enforced because of the large number of small private stills throughout the country and because of its importance to the local sugar cane economy. Eventually it was considered a taxable commodity and legalized. By the 17[th] century, cachaça again came under scrutiny and once again a ban was attempted. As before, the ban was ineffective and by the 18[th] century, cachaça was not only legalized, but exportation began to Portugal and Africa. Cachaca was so closely tied to the cultures that resided in Brazil that it became a symbol for rebellion against Portugal (Gravata, 1991; Durkan, 1997; Hamilton, 1997).

The origin of the word "cachaça" is still debated, but one theory is that it came from the word "cachaço", meaning boar or sow, because it of its frequent use as a meat tenderizer for pork. Cachaça has a long and intimate history with the culture of Brazil and has a prominent place in songs and folklore. (Gravata 1991).

Over the centuries cachaça has overcome both social and legal obstacles to remain the national drink of Brazil. The amount of cachaça produced and consumed annually in Brazil is evidence of its popularity. In 1990, the Brazilian Association of Beverage Producers recorded a production of 1.2 billion liters. It is estimated that close to the same amount is probably produced illegally at small private stills throughout various regions in the country (Silva, 1997; Gravata 1991; Nascimento et al. 1998).

Regions of Production

Cachaça is largely produced in the Northeastern and Eastern regions of Brazil, represented by the following states: Maranhao, Ceara, Piaui, Rio Grande Do Norte, Paraiba, Pernambuco, Alagoas, Sergipe, Bahia, Minas Gerais, Espirto Santo, Rio De Janeiro, Sao Paulo, Parana, Santa Catarina, and Re Grande do Sul (Durkan, 1997; Hamilton, 1997).

Processing and Production of Rum

Raw Ingredients

Sugar Cane

The main ingredient of all rum, including cachaça, is cane sugar, from the grass *Saccharum spp*. The cane is planted between May and June and is usually harvested between February and June, taking any where from 12 to 18 months to reach peak sugar content.

The sugar cane is pressed in a sugar mill to release the sugar cane juice. The fresh pressed sugar cane juice is either used fresh or boiled. During boiling the water evaporates to leave a thick crystallized sugar, which is then clarified. The thick sugar mixture is separated from the other solids in the mixture, and the thick brown syrup that remains, is molasses. Either the fresh pressed sugar cane juice, sugar syrup, or molasses can be fermented for the production of rum, however, the main distinction between Brazilian cachaça and other rums is that cachaça is made exclusively from fresh pressed sugar cane juice and not sugar syrup or molasses.

The quality of the cane sugar has an impact on the final rum product. The quality of the cane sugar can depend on the variety of *Saccharum spp.* being used, environmental factors, such as climate and region, and the condition of the sugar cane processing and storage facilities. The more high quality fresh cane juice used, the more high quality rum can be attained. A high quality cane juice will have a high amount of fermentable sugars, and less of the non-sugar components such as pectins, gums, waxes, vitamins, and ash, all of which can interfere with the yeast performance during fermentation (Murtagh, 1995).

Water

A great amount of water is required for the production of rum. Water is used to dilute the mash; it is used for steam production during distillation, for cooling and for cutting the distillate to the appropriate proof. Water with a high amount of calcium, magnesium, chlorides or any contaminants will have an effect on the final rum product (Murtagh, 1995).

Microorganisms

It is the microorganisms used in fermentation that convert the sugars into alcohol. In addition to the production of alcohol, fermentation byproducts are also produced, which may add desirable flavor and aroma attributes to the rum but can also be a major source of contaminants. It is usually bacteria that produce many of the acids such as acetic, butyric, caproic and propionic. The acids react with ethanol to form the esters that are responsible for many of the characteristic flavors and aromas of rum. The contribution by microorganisms cannot be overstated, and much research as been dedicated to the flavors and aromas they impart in whisky, rum, wine and beer.

The microorganism used the most in alcohol fermentation is the yeast *Saccharomyces cerevisiae.* This yeast is ideal for converting sugars to alcohol and is naturally found to occur on sugar cane. There are numerous strains of *S. cerevisiae*, each with distinctive characteristics. There are at least 12 varieties of *Saccharomyces* spp. that have been isolated from sugar cane juice and molasses mashes. Many strains are chosen specifically for their fermentation performance and others are chosen for the aroma and flavors they produce as fermentation byproducts. The ideal yeast for rum production is one that most effectively ferments the sugars found in sugar cane. There are at least 34 strains of yeast that are known to exist in sugar cane and molasses, all which are able to produce a high alcohol content and ferment rather quickly. Each one adds its own distinctive aroma and flavor compounds (Table II.1). The two most common yeasts used as pure cultures within the distillation industry are *Saccharomyces cerevisiae* and *Schizosaccharomyces pombe* (Lehtonen and Suomalainen, 1977).

The bacteria *Zymomonas mobilis* has been recently studied as a substitute for yeast fermentations. *Z.mobilis* is a gram-negative bacteria that converts exclusively sucrose, glucose and fructose, the same sugars present in sugar cane. Studies at the Rum Pilot Plant of the University of Puerto Rico, by Huertas-Diaz et al (1991), reported that when compared to *S. cerevisiae*, *Z. mobilis* had a higher rate of ethanol production, and similar ethanol yield and tolerance. One of the strains used in the study was recovered from sugar mashes in Brazil. This bacteria is found on various species of agave cactus, and is one of the organisms involved in the fermentation of pulque (agave wine) into tequila, and may in fact be responsible for contributing some of the distinctive aromas and flavors associated with tequila and mezcal.

Pure cultures of the bacterium *Clostridium saccharobuytricum* are sometimes used in conjunction with pure yeast cultures to produce butyric acid, which in appropriate concentrations contributes some of the pleasant and distinct flavor compounds associated with rum (Lehtonen and Suomalainen, 1997).

Wild yeast, along with bacteria, occur naturally on the sugar cane and in the distillery environment. These may be encouraged by open fermentation vessels or they

Table II.1 *List of Yeast Strains Isolated from Molasses and Sugar Cane Juice

Candida sp.:	*Endomyces magnusii*
C. *guilliermondii*	*Hansenula anomala*
C. *intermedia*	*Hansenula minuta*
C. *krusei*	*Kleckera apiculata*
C. *mycoderma*	*Pichaia fermentans*
C. *parapsilosis*	*Pichai membranaefaciens*
C. *pseudotropicalis*	*Schizosaccharomyces pombe*
C. *saccharum*	*Torulopsis* sp.:
C. *tropicalis*	T. *candida*
Saccharomyces sp.:	T. *glabatria*
S. *aceti*	T. *glabrata*
S. *acidifaciens*	T. *globosa*
S. *carlsbergensis*	T. *saccharum*
S. *carlsbergenisis* var. *alcoholophila*	T. *stellata*
S. *cerevisiae*	T. *stellata* var. *cambresieri*
S. *chevalieri*	
S. *delbrucki*	
S. *marxianus*	
S. *microellipsoides*	
S. *rosei*	
S. *rouxii*	
S. *ludwigii*	

* (Lehtonen and Suomalainen, 1977)

can be discouraged by strict sanitation practices within the distillery. Open fermentation results in a "souring" of the mash, which is usually a result of the bacterial production of lactic and acetic acid. This is sometimes desired for certain rums, and used with other distilled beverages such as whiskey and in the production of Belgian lambic ales (Murtagh, 1995; Maarse and Van De Berg, 1994).

Fermentation

After cane juice is pressed from sugar cane, it is diluted with water to become a sugar mash. It may be mixed with the residual slurry from a previous fermentation, referred to as dunder. The dunder will contain the microorganisms used in previous fermentations, which can contain a high amount of wild flora. Often it is the bacteria that supply many of compounds such as esters and acids that give rum its identity. In a more controlled environment, a pure culture of yeast and/or bacteria will be added to the mash.

The length of fermentation can be either slow (7 to 20 days) or fast (2 to 3 days), depending on the style of rum being produced. Slow fermentations usually result in heavier bodied and fuller flavored rums as a result of all the fermentation byproducts, while fast fermentations usually develop into lighter bodied, cleaner tasting rums (Lehtonen and Soumalainen, 1997; Murtagh, 1995).

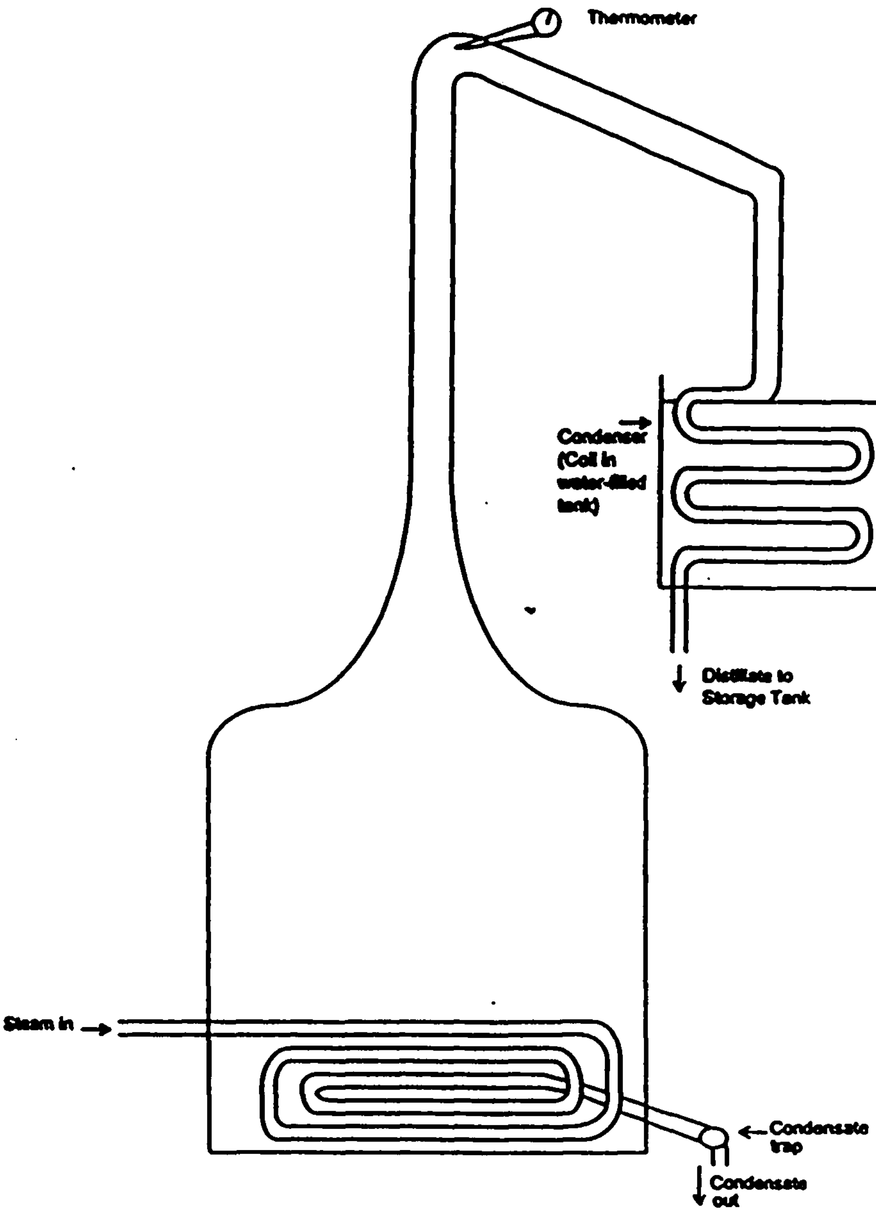
Distillation

When fermentation is complete, the brew is distilled. Distillation involves the heating of the fermented brew/wine and collecting the volatiles such as ethanol and fusel oils. There are two types of distillation: batch distillation, often used in the production of heavy rums, and continuous distillation, more often used for the production of lighter rums.

Batch distillation can be achieved with a variety of different still arrangements. The most basic set-up is the Simple Pot Still (Fig. II.1). The fermented brew/wine is placed in a large boiling kettle, and is either heated internally with a coil or externally from underneath. A pipe is connected to the top of the tank, carrying the vapors to a condenser surrounded by water. The volatiles rise through the pipe as vapors and condense back into liquid in the condenser. The liquid is then collected in a separate vessel. The first volatiles to rise are referred to as the "heads". This fraction is usually discarded, due to the presence of pungent unpleasant compounds, however, that is at the discretion of the rum maker. The distillate that is collected can then be distilled again to gain a higher purity and a higher alcohol content. The distillate that is collected toward the end of the process is considered the "tails" and can also be discarded. It is the "center" fraction of the distillate that usually contains the compounds that contribute to the rum-like character. The distillate can be distilled a third time if an even purer product is desired.

The other type of distillation system employed in production of spirits is continuous distillation. This system is a little more complicated, incorporating two or more stills, and a series of strippers and condensers (Fig. II.2). Continuous distillation allows for the removal of unwanted fractions before the mass of the distillate reaches the condenser column, creating a cleaner or more neutral product. Any combination of systems can be used to achieve the desired result. It is possible to run a fraction from a pot still through a continuous still. Often rum, including cachaça, is produced by local farmers on a small scale and is collected by large distilleries.

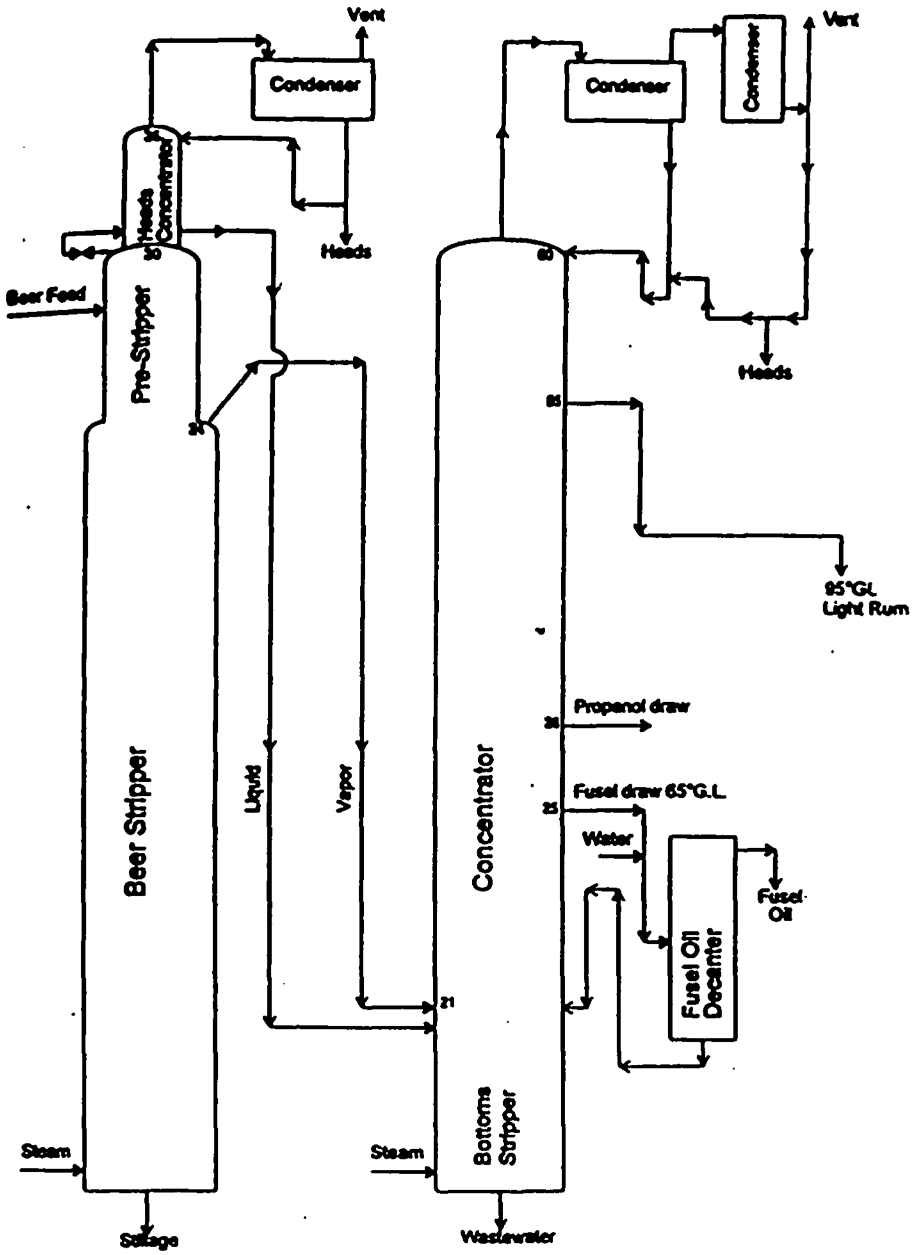
Figure II.1 Simple Pot Still



Simple pot still for heavy rum production

*(Murtagh, 1995)

Figure II.2 Continuous Still



Modified Barbet beerstill for light rum production

*(Murtagh, 1995)

The distillates are mixed and re-distilled in a batch or continuous system to produce one uniform product. Just as in the making of whiskeys and brandies, different fractions from different batches of rums can be blended to achieve the desired end product(Murtagh, 1995; Ingledew, 1995).

Maturation and Blending

Rum can be aged in oak barrels ranging from a few weeks to five or more years. Some light or white rums are not aged at all. The heavier bodied and fuller flavored rums are usually aged for at least a short period in oak barrels which allows for the extraction of flavor and color enhancing compounds from the wood. The quality of the barrel (new or used) has a enormous effect on the flavor and color of the rum. New oak will have more extractable compounds available than a previously used barrel. The amount of toasting on the barrel also will have an effect on the finished product. The length of time the rum spends in contact with the wood and the temperature during the maturation both have an effect on the esterification, condensation and oxidation reactions that are responsible for many of the flavors and aromas characteristic of rum.

As with most distilled spirits, distilleries may choose to blend one or more rums together to create a specific result (Murtagh, 1995, Lehtonen and Suomalainen, 1977; Durkan, 1997; Hamilton, 1997).

Origin of Aroma and Flavor Compounds Present in Rum

There have been over four hundred volatile compounds identified in various rums from around the world. As mentioned previously, the quality of the finished rum product is dependent on the quality of the raw ingredients and the type of fermentation, distillation and maturation techniques employed. More specifically the sources of the volatile compounds responsible for the aroma and flavor of rum are derived from biochemical, physical and chemical processes that take place during production of distilled spirits (Nykanen and Nykanen 1983 and 1991; Rijek and Heide, 1983; Lehtonen and Suomalainen, 1977).

Biochemical Processes

Alcoholic fermentation is the process responsible for most of the compounds that are characteristic of distilled alcohol beverages. *Saccharomyces cerevisiae* is the yeast used most by the wine, beer and distilled spirits industry for the production of alcoholic beverages. There are however, many other strains of yeast and strains of bacteria that are used for fermentation, each contributing a unique sensory and chemical profile in the finished product.

In addition to converting complex carbohydrates to alcohol, yeast and fermenting bacteria produce many other compounds that are crucial for the life of the microorganism, such as amino acids and lipids. These compounds are instrumental in the production of esters and the higher (fusel) alcohols which quantitatively are the most important constituents of distilled beverages. The amount of fusel alcohols produced depends on the microorganism used and the condition of the microorganism. For example, *Saccharomyces cerevisiae* usually produces many fusel alcohols, but one study showed that a mutant strain of *S. cerevisiae* did not produce two of the most common higher alcohols, 1-propanol and 2-methyl-1-butanol. It is also known that *Schizosaccharomyces pombe* produces very small quantities of fusel alcohols (Nykanen and Nykanen 1983 and 1991; Rijek and Heide, 1983; Lehtonen and Suomalainen, 1977).

It is important to note that even though the esters and fusel alcohol may be the most important quantitatively, that does not imply that the minor compounds do not contribute to the aroma and flavor of distilled spirits. On the contrary, the composition of distilled spirits, specifically rum, is so complex that it is almost impossible to isolate a few specific compounds that are responsible for the sensory attributes that characterize rum (Nykanen and Nykanen 1983 and 1991; Rijek and Heide, 1983; Lehtonen and Suomalainen, 1977).

Physical Processes

Maturation in oak barrels results in the physical extraction of many components from the wood, which are responsible for the production of important aroma and flavor compounds such as phenols and lactones.

The distillation process itself is also a physical process that obviously determines the final aroma and flavor of distilled spirits. However, the process is beneficial in removing unwanted fractions or components rather than contributing them. Simple pot still distillation usually results in quantitatively more fusel alcohols than does distillation in continuous stills (Mutagh, 1995; Nykanen and Nykanen 1983 and 1991; Rijek and Heide, 1983).

Chemical Processes

The Maillard reaction is a very important process in the production of flavor compounds such as furans, pyroles, pyridines and pyrazines. It is a reaction between sugars and amino acids. The Maillard reaction is temperature dependent and therefore it takes place during distillation.

Many chemical reactions take place during maturation in oak barrels when the extracted wood components react with fermentation products. Acetalization, esterification and oxidative reactions create many of the compounds that contribute to the aroma and flavor of the final product (Mutagh,1995; Nykanen and Nykanen 1983, 1991; Rijek and Heide, 1983).

Chemical Components of Rum

The volatile compounds responsible for the aroma and flavor of rum include higher alcohols (fusel alcohols), fatty acids, fatty acid esters, carbonyl compounds (aldehydes, ketones, and furfurals), phenolics, lactones and to a lesser degree nitrogenous and sulfur compounds(Schoeneman et al, 1971; Maarse and Van De Berg, 1994).

Alcohols

Quantitatively the most important compounds in distilled spirits are the higher alcohols, such as 3-methyl-1-butanol, 2-methyl-1-butanol, 2-methyl-1-propanol and phenethyl alcohol. Whiskey, cognac and rum are very similar in composition with regard to higher alcohols, with rum usually having a little less than whisky and cognac. These compounds are responsible for contributing alcoholic, vinous, banana-like, sweet, rose, honey and perfumy sensory characteristics (Lehtonen and Suomalainen, 1977; Nykanen and Nykanen 1991).

Esters

Probably one of the most important contributors to rum aroma and flavor are the fatty acid esters. These compounds are responsible for many of the pleasant fruity and sweet aromas. At least 73 esters have been identified in rum. They include compounds like methyl acetate, butyl acetate, isoamyl acetate and ethyl deconate (Lehtonen and Suomalainen, 1977; Nykanen and Nykanen 1991).

Carbonyl Compounds

The carbonyl compounds present in rum include aldehydes, ketones, furfurals and acetals. This group includes familiar compounds such as acetone, diacetyl, acetaldehyde, benzaldehyde, formaldehyde, and furfural. The aromas associated with these compounds are solvent/nail polish, buttery, green apple, almond, chemical and papery respectively (Lehtonen and Suomalainen, 1977; Nykanen and Nykanen 1991).

Fatty Acids

Volatile fatty acids make up an important fraction of the composition of rum. Some of these compounds contribute very strong aromas, even at low levels of concentration.

The acid content in rums varies a great deal and depends on whether it is a light or heavy rum and also on the country of origin. A light rum produced in Puerto Rico may have 100 mg/L of volatile acids, while a heavy rum from Martinique may have up to 600 mg/L. Acetic acid makes up approximately 75 to 80% of the total acid content of most rums. Studies conducted at the Universidade Federal de Vicosa, and Universidade de Sao Paulo , Brazil, looked at the volatile acid content of 31 and 56 different brands of cachaça, respectively. Both studies revealed that acetic acid made up a much larger percentage of total acid content (90 to 95%) of Brazilian cachaça than for other rums or distilled spirits (Silva and Nobrega, 1997; Nascimento et al, 1998).

In addition to acetic acid, some of the most common volatile fatty acids identified in rum are propionic, butyric, caproic, lauric and palmitic acid. Rum in general tends to have more propionic and butyric acids than other distilled spirits. Nascimento, et al (1998), concluded that the following fatty acids were most important in cachaça based on concentration: acetic, isocaproic, caprylic, capric, lauric and palmitic acid. These compounds contribute vinegary/sour (acetic), goaty, sweaty, rancid, tallowy, vegetable oil, soapy (isocaproic, caprylic, capric) and oily, coconut (lauric, palmitic) sensory properties to rum (Silva and Nobrega, 1997; Nascimento et al, 1998 ; Lehtonen and Suomalainen, 1977; Nykanen and Nykanen 1991).

Phenolic Compounds

Rum does not differ much in phenolic composition from other distilled spirits such as whisky and cognac. The phenolic compounds can be produced during fermentation or during maturation in oak barrels. Some of the more common phenolic compounds identified in rum are guiacol, eugenol, phenol, m-cresol, vanillin and cinnamal. These compounds are know for contributing spicy, cloves, medicinal, Band-Aid, vanilla and cinnamon notes (Lehtonen and Suomalainen, 1977; Nykanen and Nykanen 1991).

Lactones

Lactones are compounds that also originate from maturation in oak barrels and they can contribute some very important aromas to rum. Compounds such as 4-butanolide can add a foul, pungent, rubbery aroma; 5-decanolide and 5-dodecanolide add peach and apricot like aromas; while 4 -carboetheoxy - 4 - butanolide is known for a sherry like aroma and flavor (Lehtonen and Suomalainen, 1977; Nykanen and Nykanen 1991).

Sulfur Compounds

Sulfur compounds occur in almost all alcoholic beverages to some degree. They are usually formed during fermentation and can differ greatly depending on the type of microorganism and the fermentation temperature. Sulfur compounds can have extremely low threshold values, and can be detected at extremely low concentrations. Two of the most common sulfur compounds are ethanethiol which is recognized as onion or rubber-like, and dimethyl sulfide which has been described as canned corn, canned green beans, oysters or old molasses. At low levels this can be a positive attribute, but can also easily become an off aroma at slightly higher concentrations (Lehtonen and Suomalainen, 1977; Nykanen and Nykanen 1991).

Nitrogenous Compounds

Nitrogenous compounds in their free base state can have powerful and pungent aromas, but the acidity of rum causes them to occur as protonated cations, which decreases their contribution to the aroma of rum. An example of some nitrogenous compounds that can occur in rum include pyridine, picoline and thiazole, all of which would be considered foul, fecal, decaying aromas (Conner et al, 1994; Ingledew, 1995; Jennings et al, 1972; Maarse and Van de Berg, 1994. Nykanen and. Nykanen, 1983 ,1991; Rijek and Heide, 1983; Wobben et al., 1971).

Aroma and Flavor Perception

The sense of smell has a very powerful influence on our lives, not just because it helps us to perceive the flavor of foods but because smells are so closely associated with emotions and memories; this makes aroma identification a very subjective process. An entire branch of psychology known as psyhcophysics is dedicated to understanding human responses to physical stimuli, including smell. It has been shown that individual ability to evaluate aroma and flavor can be influenced by gender, age, culture, experiences, genetics, personality, menstruation, pregnancy and by habits such as smoking.

The entire process of smelling, called olfaction, is a result of volatile components penetrating tens of millions of olfactory cells that are present in the epithelial lining of the nose. Volatile compounds can be perceived by humans in two different ways: they can enter through the nose into the nasal cavity where the volatile compounds come into contact with olfactory cells that have nerve fibers connecting them to the end of the brain, or they may enter through the mouth and travel up the back of the oral cavity via the nasopharynx, where they once again reach the olfactory receptor cells. This leads to the perception of flavor. Therefore flavor is not necessarily separate from odor as it relates to volatile compounds. The term taste is used to describe the physiological responses of the tongue and back of the throat to the what we perceive as sweet, sour, salty and bitter. Mouthfeel is a term used to describe the mechanical responses to compounds and can result in sensations such as drying, cooling, burning or slippery. Flavor is better defined as a combination of the aroma, taste and mouthfeel of a substance (Lawless, 1984; Meilgaard, et al, 1991; Ohloff, 1994).

It is common to find the terms aroma and flavor used synonymously throughout the literature on distilled spirits when describing the volatile components detected in the product. Often flavor evaluation is found to be redundant of aroma evaluation. However, there may be tastes, such as sweet or sour, and mouthfeel attributes that can only be detected by actually tasting the product. (Jounela-Eriksson, 1983).

Sensory Evaluation

Sensory science has become an integral and growing discipline within the food and beverage industry. Many different testing and analytical techniques have been developed and revised over the years to provide valuable and reliable tools that aid in product development, marketing and quality control.

There are many sensory evaluation techniques designed specifically for the profiling of the aroma, flavor, color and texture of food. However, because each product has its own unique qualities and each study its own objective, there is no one method that works in all situations.

Flavor Profiling Method

The flavor profiling method was designed by Arthur D. Little, Inc. to allow evaluation of the aroma and flavor of many different types of samples by four to eight well trained judges or panelists. The panelists are screened and pre-tested on their ability to discriminate basic taste and flavor characteristics. The panelists are also chosen based on their level of interest and commitment to the project.

Panelists work together as a group to determine terms to be used to describe the specific attributes of the samples. References are provided by the panel leader that best represent those attributes. The panelists rate their perceived intensities of each attribute. With this method, the panel leader acts as a facilitator allowing the panelists to interact as a group. The panelists undergo long-term intensive training. They must, as a group, come to a consensus on the terms used, and ultimately agree on the final profile of the samples. The data is usually presented in tabular or graphical formats (Meilgaard et al, 1991; Stone and Sidel, 1993; Gacula, 1997).

The Quantitative Descriptive Analysis (QDA®) Method

The quantitative descriptive analysis method was developed by the Tragon Corp., in collaboration with the department of Food Science at the University of California, Davis. An important aspect of this method is the use of statistical analysis to measure panelist performance and ability during training.

Panelists are evaluated on their ability to differentiate between specific attributes for specific products. Like the Flavor Profile Method, the panelists interact as a group and the panel leader serves only as a facilitator. Unlike the Flavor Profile Method however, the panelist use a different type of scaling system, (15 cm, line scale) and they are allowed to use it at their individual discretion. This is potentially one of the disadvantages of this method for it can result in great variability between panelists when rating intensity levels.

After training is complete, the panelists conduct the final product evaluation in private testing areas, separate from each other, allowing no panelist interaction.

The data are usually analyzed statistically and presented in a graphical spider web type graph, depicting branches that evolve from a central point (Meilgaard et al, 1991; Stone and Sidel, 1993; Gacula, 1997).

The Spectrum Method ™ of Descriptive Analysis

This is a customized version of the Quantitative Descriptive Analysis Method, designed to accommodate specific needs for a specific project or objective, not addressed by previous techniques (Meilgaard et al., 1991; Acree, 1993).

Panelists are introduced to the particular type of sensory attributes of interest before training with the specific samples begins. This prolonged training may also involve teaching the panelist about the processing techniques used in production, which may account for the differences between samples. In other words, the panelists become trained in a much more specialized way than in other methods.

As with the other methods previously discussed, the panelists interact together during training and decide as a group on the final lexicon to be used. Reference standards are provided as well, helping to keep the use of the terms consistent between panelists. In addition to reference standards for attributes, standards are also provided for rating the intensity of the attributes. Intensity standards facilitate in anchoring the panelists to specific numbers correlated to specific levels of intensity, and help to eliminate the variability between how panelists use the intensity scale. A variety of scaling methods are available to be used at the discretion of the panel leader (Meilgaard et al., 1991; Acree, 1993).

Free Choice Profiling

Free Choice Profiling was developed at the Agriculture and Food Council of the United Kingdom, by Williams and Arnold in 1989(Meilgaard et al, 1991).

The objective of this method is to accommodate the use of different terminology generated by different individuals to describe the same attribute, as may be the case with consumer testing. Panelists are allowed to determine their own list descriptors and use them to evaluate the samples. One big advantage of this method is that little or no time is spent in training. However, one of the potential disadvantages is that once all of the data has been gathered from all of the panelists, it is up to the panel leader to group like terms together for analysis. This may result in a biased interpretation of the results by the panel leader.

The data are usually analyzed using generalized Procrustes Analysis, which correlates like terms with specific attributes and also accounts for variation between panelists on the use of the intensity scale.

Free choice profiling has been used as a tool by the Food Science and Technology Department at Oregon State University, in several studies evaluating the effects of different treatments on wine production (Dumont, 1994; Goldberg, 1998). The wine is usually evaluated by professionals within the wine industry who have a great deal of knowledge about enology, viticulture, and wine style. Using Free Choice Profiling allows for a great number of professionals to meet for one day and evaluate a large number of wine samples. It eliminates the need for panel training, and allows each individual to use their own terminology. Fortunately, the individuals doing the evaluating in this situation have a fairly common vocabulary base for describing wine, although the way they rate the intensity of the attribute may vary a great deal.

Piggot et al (1992) used free choice profiling in a study on dark rum to better understand how a specific consumer base, young adult women, interpreted the flavor and aroma of dark rum compared to whisky and light rum. By allowing the consumers to describe the products in their own terms, they could determine how they perceived the products in comparison to each other (Meilgaard et al, 1991; Piggot et al, 1992; Williams and Langron, 1984).

Evaluating Alcoholic Beverages

Descriptive analysis of alcoholic beverages involves some specific challenges, and over the years much research has been dedicated, for developing and refining techniques that are best suited for work with alcoholic beverages. Much of the research conducted on descriptive techniques in general has been within the brewing, whisky and wine industry (Meilgaard et al, 1982; Meilgaard et al 1992; Burke et al, 1997; Mecredy, J.M., 1974;Woolley, 1987; Durr, 1987; Noble et al, 1987; Powers, 1988).

Distilled spirits are very complex mixtures of volatile compounds and require modified descriptive techniques in order to accommodate those complexities, avoid sensory fatigue and still be able to distinguish any differences between samples.

Piggot and Canaway (1981) came up with the following suggestions for conducting descriptive analysis on distilled beverages: allow the list of terms to be long enough to accommodate all of the different attributes being detected, yet not too long as to burden or fatigue panelists (e.g. 24 to 35 terms), and provide reference standards for as many of the descriptive terms as possible. The quality of the reference standards are crucial in helping to eliminate the variability of word use among panelists.

Identifying and naming perceived aromas and flavors can be a difficult and taxing process. As mentioned previously, there are many genetic, physiological and cultural factors that effect a person's ability to detect volatile compounds.

Though detection of a compound can occur within seconds of reaching the olfactory system, the actual identification and naming of the compound may take much longer and repeated exposure. The olfactory system is easily fatigued, and once it becomes saturated with a specific volatile aroma, it can take anywhere from a few minutes to hours to recover.

The purpose of reference standards is to help eliminate fatigue by creating an aroma library for the panelists allowing them to refresh their memory before testing the sample and thus resulting in more accurate and rapid identification of specific compounds.

The brewing, wine and whisky industries recognized the need for establishing some guidelines or criteria that would assist panelists in the identification of common aromas associated with those products. They came up with the Flavor Terminology System. These systems are composed of "flavor wheels", a collection of descriptive terms with corresponding reference standards. The flavor wheels are a network of descriptive terminology separated into three tiers, in which none of the terms are repeated. The first tier is referred to as classes. The beer flavor wheel, created by Meilgaard et al (1982), contains 14 classes, 44 first tier terms, and 78 second tier terms. Similar "wheels have been created for wine and whisky. The terms are coded with numbers that correlate to established reference standards.

The reference standards used in the beer flavor terminology system are pure compounds diluted in beer. Though this may be appropriate in some cases, using pure compounds can have some disadvantages. The compounds themselves may cause sensory fatigue, they may be costly, and some can be hazardous to work with. Diluting pure compounds with ethanol for descriptive work with distilled spirits may also result in overwhelming the olfactory system.

Burke at al (1997) performed a study using the beer flavor terminology system, in which seven different panels within seven different breweries, did descriptive analysis on the same beer samples. They discovered that the different panels did in fact use the same terms to describe to the beer samples, but they used the intensity scales very differently. Differences in the use of scales can be reduced by increased training with intensity standards, and monitoring panelist performance. Statistical tools, such as the generalized Procrustes method, can be used to adjust for the differences in use of the intensity scale.

Several descriptive analysis studies with whisky and rum revealed that very little difference was found between the evaluation of aroma and flavor of distilled spirits and that the flavor results typically duplicated that of aroma results. Taste (salt, sweet and sour), did not play a role in the profile of whisky, and therefore the necessity of evaluating flavor separately from aroma might be considered redundant (Meilgaard et al, 1991; Piggott and Canaway, 1981; Williams and Langron, 1983).

Instrumental Analysis of Volatile Compounds

The volatile aroma and flavor compounds of food can collect and separate within the headspace of a closed container. The gases within the headspace can then be identified. Before the gases can be analyzed, they must reach an equilibrium to encourage stability. Equilibrium of volatile headspace gases is dependent on several factors: temperature, vapor pressure, solubility of the compounds and enzymatic influences from non-volatile fractions of the food being analyzed. There are many different methods and techniques available for the identification of the aroma and flavor compounds. They include gas chromatography (GC), mass spectrometry (MS), infrared spectroscopy (IR) and nuclear magnetic resonance spectroscopy (NMR). Combining one or more of these techniques together can result in highly accurate identification that may not be possible with one method alone. The system that has proven very effective with the analysis of distilled spirits is the combination of gas chromatography and mass spectrometry (GC-MS) (Martin et al, 1981; Been and Peppard, 1996).

Gas Chromatography

Gas Chromatography is a technique used to separate different compounds that occur either within a pure substance or a mixture, based on the time it is retained on the column.When conditions are held constant, compounds have a specific retention time, identified as a peak on the chromatogram. The retention times can be used to identify those compounds. However, because many compounds have the same or similar retention time, a method has been developed for comparing the retention time of the unknown compound to the known retention times of standards. Two commonly used systems of standard retention indices are Kovats and McReynolds (Mussinan, 1993; Hartman et al, 1993; Acree, 1993a).

Mass Spectrometry

The mass spectrometer operates by projecting an electron stream at the compound which causes the chemical bonds to break apart into ion fragments. The ions are then collected by the mass analyzer. Similar to the idea of retention times, each compound tends to fragment into a specific pattern that can be used to identify it. This method also relies on the comparison of the unknown compound to a library of known compounds. Many different data base libraries exist for identification. MS works exceptionally well with pure compounds, but mixtures are more complicated. Combining the GC/MS together is a powerful tool for the accurate identification of congeners in alcohol beverages.

The GC is used to first separate the compound, and then those fractions are sent to the mass analyzer as they are eluted from the GC. GC/MS has been used successfully to identify the composition of rum, whisky and tequila (Mussinan, 1993; Maarse, and Noever de Brauw, 19; Martin et al, 1981; Benn and Peppard, 1996).

Gas Chromatography / Ofactometry (GCO)

GCO is a method that combines the use of gas chromatography with sensory analysis. This is accomplished by attaching a sniff port to the GC which allows a sensory scientist to smell the effluents as they are separated by the GC. There are many GCO methods being used within the food industry to date. Dilution analysis methods such as Charm Analysis ™ and Aroma Extraction Dilution Analysis (AEDA), were developed to better understand threshold values by determining the potency of a particular odor compound using a series of dilutions (Hartman et al., 1993; Acree et al 1984 ; Acree, 1993b; Ullrich and Grosch,1987).

Other GCO methods employ maximum perceived intensity of the odor compounds by matching the perception of the changing intensities of the compound throughout it's elution from the GC, using a numeric scale (Casimir and Whitfield, 1978; Chamblee and Clark, 1993; Hartman et al., 1993).

OSME is a GCO technique first introduced by Oregon State University. The word osme originates from the Greek for "smell". This particular technique does not involve any dilutions. The subject is asked to record the intensity of the odor, and the duration that the odor is perceived while concurrently describing the odor. One main advantage to this method is that it allows the evaluation of the odor compound as it occurs naturally (McDainel et al., 1990; Sanchez et al., 1992; Hartman et al., 1993).

Benn and Peppard (1996) used a combination of GC/MS, GC/IR and GCO to characterized the flavor of tequila. They were able to identify 175 constituents present in tequila using GC/MS and GC/IR. GCO resulted in the identification of 60 odor compounds, of which 30 could be correlated specially with GC peaks. Interestingly enough, they were unsuccessful in trying to simulate the flavor of tequila based on those results, and concluded that the complexity of this distilled beverage could not be completely explained by the chemical composition alone.

III. LEXICON DEVELOPMENT FOR CACHAÇA, BRAZILIAN RUM

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Abstract

Nine commercial brands of Brazilian cachaça, were evaluated for aroma and flavor, using a modified descriptive analysis method. A panel of six individuals participated in nine – one hour training sessions. The panelists were able to develop a lexicon specific for cachaça that resulted in twenty six aroma and twenty seven flavor terms. The terms generated for flavor were identical to the terms generated for aroma, with the exception of the term astringent, being a flavor term only.

The lexicon was composed of the following terms: ethanol, sherry, solvent, smoky, woody, pine, cedar, vanilla, nutty, brown spice, floral, musty, earthy, lactic/sour, plastic, cardboard, tropical fruit, pear, peach, caramel, dimethyl sulfide, minty, menthol and sweet.

Analysis of Variance ,based on panelists as replication for each sample, suggested that differences did exist between the samples for the terms smoky, nutty and tropical fruit. Panelists were unable to separate samples based on flavor attributes. Principal component analysis on aroma was helpful in explaining the aroma profile of the nine samples.

Introduction

There have been recent attempts by the Universidade Federal de Vicosa, and Universidade de Sao Paulo, Brazil, to establish a chemical profile and quality control standards for cachaça,. It is hoped that such standards and profiles will assist Brazil in promoting cachaça within an international market. Though technically a rum, by U.S. standards, cachaça is unique in that it is produced exclusively from fresh pressed sugar cane juice and not molasses. It is also unique in its sensory properties, sharing many similarities with tequila and scotch whisky and also maintaining some characteristics that are recognized as "rum like" (CFR 27, 1996; Durkan, 1997, Hamiltion, 1997, Silva and Nobrega, 1997).

Though extensive chemical analysis has been performed on rum, little sensory evaluation has been published. This is the first descriptive work performed on cachaça specifically. Descriptive analysis has long been employed by the brewing, whisky and wine industry for both product development and marketing and as a tool in quality control management (Silva and Nobrega, 1997; Nascimento et al, 1998).

The technique that has proven to be effective in the evaluation of alcoholic beverages, is a modified descriptive analysis method. The method relies heavily on the use of reference standards based on terminology developed by the panelists. Intensity ratings of each attribute are based on a 16-point intensity scale and anchored to intensity standards allowing panelists greater continuity in their use of the scale. Once training has been completed as a group, the panelists evaluate the samples individually, in private booths, without interaction. If replication is employed in testing, Analysis of variance can be applied to the data to determine if differences exist for specific attributes across the samples (Meilgaard et al, 1991; Piggott et al, 1992; Williams, 1983).

The objective of this study was to establish a lexicon of descriptive terminology that could be used specifically for the evaluation of cachaça and to provide a preliminary profile of the samples for future studies.

Materials and Methods

Sample Storage

Nine samples of commercially produced cachaça were evaluated for aroma and flavor. The samples were produced within the following states of Brazil: Minas Gerais (MG), Sao Paulo (SP), and Pernambuco (P), Ceara (C), Four of the samples were designated for "export only" and purchased in New York: Toucano (C), YPIOÇA (C), PITU (P), and 51 (SP). The other five samples were purchased in Brazil: Vale Verde (MG), Germana (MG), Velha Aroera (MG), Velho Barreiro (MG), and Havana (MG) (Table III.1)

The samples arrived in 1 liter commercial bottles and were stored at 4^{0}c upon arrival to Oregon State University.

To protect and respect the identity of the brand names and the distilleries, the samples were randomly labeled "A" through " I ".

Sample Preparation

Only one bottle of each brand was available, so batch effect was not a consideration in the study. The cachaça samples were 40% or 43% ethanol (wt/vol), as

Table III.1 Nine Commercial Brands of Cachaça Evaluated for Aroma and Flavor

Brand	Region	Exported	Color	%Alcohol (wt./vol.)
Germana	Minas Gerais	No	Gold	43%
Havana	Minas Gerais	No	Gold	43%
Velha Aroeira	Minas Gerais	No	Gold	47%
Vale Verde	Minas Gerais	No	Gold	43%
Velho Barreiro	Minas Gerais	No	White	40%
Toucanao	Ceara	Yes	Gold	40%
YPIOçA	Ceara	Yes	White	40%
PITU	Pernambuco	Yes	White	40%
51	Sao Paulo	Yes	White	40%

appeared on commercial labels stored at 7°C. Portions of each sample were diluted with spring water[1] at 1:1 ratio, resulting in a 50% dilution which was approximately 20% 23% alcohol. The 50% dilutions were stored in brown 500-ml ez-Cap bottles[2] with airtight locking lids, and stored at 7°C.

Panelists

The descriptive panel was composed of six individuals from the Food Science Department at Oregon State University (three women, and three men). All of the panelists had some previous sensory evaluation experience; only one of the panelists had previous experience with cachaça.

Panel Training

The training incorporated a modified descriptive analysis procedure. During this study the panel leader acted as a facilitator. The intention of this experimental technique was to develop a lexicon in which minimal time and expense was occurred during training, but which allowed the panelists to reach their own conclusions concerning descriptive terminology through group interaction, without influence by the panel leader. The six panelists met for 9 one-hour training sessions. The training sessions were conducted in the Sensory Science Laboratory at OSU. The panelists were seated around an oval table within a quiet room with white light. The table had a separate rotating center that allowed easy access to all of the reference standards. The panelists received a total of two samples per session, served one at a time (monadically), and labeled with a random

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[1]Aqua-Cool pure bottled water, Portland OR
[2] ezcap™, F.H. Stienbart, Portland, OR

three-digit code. The samples were served at room temperature in 1-oz (approx. 30 ml) portions, in 250 ml tulip shaped clear wineglasses, with aluminum lids.

The panelists evaluated the aroma and then the flavor of each sample. They did not cross-reference the samples. Spring water[1] and unsalted saltine crackers were provided as palate cleansers between samples. Unlike the standard procedure followed in the Flavor Profile Method, panelists were not given a set of reference standards initially. Instead panelists were allowed to evaluate the samples and suggest the descriptive terms they thought best represented the attributes they detected.

At this phase in the training no terms were eliminated or consolidated. The panel leader provided aroma reference standards for as many of the terms as possible. Panelists were asked to evaluate the quality and effectiveness of each standard at the beginning of each training session. The reference standards were prepared using common ingredients such as canned fruit and vegetables, and spices. Some chemicals, such as 95% ethanol and 95% acetone, and Terpinen-4-ol, were used as reference standards (Table III.2). Flavor standards were not provided, due to the sensory fatigue that is experienced when testing high percent alcohol samples, and fear that residual flavor attributes remaining in the mouth would interfere with evaluating the flavor of the sample. Panelists were asked to familiarize themselves with each aroma standard before evaluating the samples. The reference standards functioned to calibrate the panelists with the selected attributes and to lower the variability associated with panelists using terms differently. This procedure was repeated until each panelist evaluated each cachaça sample that would be tested. Once all of the samples had been evaluated, the group discussed all terms accumulated. Terms were either eliminated or like terms consolidated, based on the unanimous

Table III.2 Aroma Reference Standards[1]

Aroma Descriptor	Reference Standards
Ethanol	30mls 95% ethanol + 10 mls distilled water
Sherry	40 mls Fairbanks Cream Sherry, (Fairbanks Cellars, Modesto CA)
Solvent	10mls 95% acetone + 10 mls 95% ethanol +20mls Distilled water
Smoky	40 mls of Monte Alban Mezcal
Woody	French and American oak chips in 10 mls of 95% Ethanol + 10 mls of distilled water
Pine	1 gram fresh lodge-pole pine needles, broken in half, collected on OSU campus, Corvallis, OR
Cedar	1 ml of Cedar Pet Spray in 40 mls distilled water, (Seder Co. International Natural Products, Portland, OR)
Vanilla	1 ml Schilling ® pure vanilla extract + 39 mls Distilled water, (McCormick & Co. Inc., Huntvalley MD)
Brown Spice	0.5 grams of each of the following Schilling ® spices, combined together: cinnamon, nutmeg, and cloves (McCormick & Co. Inc., Huntvalley MD)
Nutty	4 chopped dry roasted hazelnuts, (Hunts Farm, OR.)
Musty	25 ppm of Terpinen-4-ol in 40 mls distilled water
Earthy	1 fresh white mushroom cut into quarters
Lactic/Sickly	1 ml 80% lactic acid + 1ml 10% acetic acid + 40 mls of distilled water
Plastic	1 plastic shower cap, cut into pieces
Wet cardboard	10 cm x 10 cm piece of cardboard soaked in water

[1]Individual aroma standards were placed in 50 ml pyrex jars with lids.

Table III.2 continued Aroma Reference Standards[1]

Aroma Descriptor	Reference Standards
Estery/Tropical Fruit	1* drop each of the following food flavorings by Melchers, Fairfield Ohio: Pineapple orange #160566 + peach #1650519 +mango #160554, in 40 mls of distilled water
Pear	1 half of an Albertson's® canned pear, cut into quarters (Albertson's Inc. Boise, ID)
Peach	1 half of Albertson's® canned peach cut into quarters (Albertson's Inc. Boise, ID)
Caramelized sugar	10 mls of Smuckers ® fat free Caramel flavored topping(Orrville, Ohio)
DMS (Dimethyl Sulfide)	20 mls of liquid from Albertson's® canned green beans +20 mls liquid from Albertson's® canned sweet corn. (Albertson's Inc. Boise, ID)
Minty	1 teaspoon of dried mint, Schilling® (McCormick & Co., Inc., Huntvalley, MD)
Menthol	1 (Halls Mentho-Lyptus) drop

[1] Individual aroma standards were placed in 50 ml pyrex jars with lids.
* drop using disposable Pasteur pipette

decision of the panel. Panelists also evaluated the quality and relevance of each reference standard. It was critical to this training method that the reference standards matched the descriptive terms as closely as possible. The panel decided as a group, on the final list of terms to be used during testing. Panelists rated the intensity of each attribute (term) on a 16 point intensity scale (0= none, 3=slight, 7= moderate, 11 = large and 15= extreme). Intensity standards were provided in addition to reference standards. The intensity standards are universal recipes that are anchored at intensity levels 3, 7, 11 and 15 (Table III.3).

The panelists evaluated all of the samples using the final list of descriptive terms and the 16 point intensity scale. Any discrepancies within the panel with the use of a term, or the intensity level assigned to an attribute was discussed as a group until the discrepancy was rectified. Panelists were involved in the design of the final ballot used during testing.

Panel incentives played an integral role in panel training. Descriptive analysis can be a taxing process, and to expect panelists to perform consistently, and to maintain a positive attitude and enthusiasm for the project, requires effort on the part of the panel leader to provide encouragement and positive feedback. Incentives were provided in the form of food and beverages at the end of every training session, a gift certificate to a local merchant at the completion of the testing, and most importantly, the panelists received constant praise and appreciation for their efforts.

Testing/Descriptive Analysis

Testing took place within the testing booths of the Sensory Science Laboratory within the Department of Food Science and Technology, OSU. The panelists were in

Table III.3 Overall Intensity Standards[2]

Intensity Level	Standard Recipe
Overall Intensity (3)	2 Tablespoons Safflower Oil, (Saffola Quality Foods Los Angeles, CA)
Overall Intensity (7)	1 Tablespoon + 1 teaspoon Hi-C® Orange Drink (Coca Cola Co. Houston TX)
Overall Intensity (11)	1 Tablespoon + teaspoon Welches ® Grape Juice, (Welches Foods Inc., MA)
Overall Intensity (15)	1 stick unwrapped Wrigleys Big Red ® Cinnamon Chewing gum, (Wm.Wrigley Jr. Co., Chicago, IL)

[2] Overall Intensity Standards were placed in 0.25 liter clear, tulip shaped wine glasses with Aluminum lids.

private individual booths and had no interaction with each other. The testing was conducted over a one-week period with panelists testing two samples per session, and up to two sessions per day, with a 30-minute break between sessions. Panelists were asked to rinse with pure water and eat unsalted saltine crackers, between samples. Due to the odd number of samples the first test session consisted of three samples and all concurrent sessions included two samples. The samples were served just as they were during training, at room temperature, monadically (one at a time), and labeled with a random three-digit number. The serving order was randomized among all panelists. No two panelists received the same serving order.

Experimental Design and Data Analysis

The experiment was set up as a balanced complete block design. Each panelist represents a block. All six panelists evaluated all nine samples for 24 aroma, and 25 flavor attributes. The testing was conducted over the course of a week. Panelists were considered a random effect in the experimental design and concurrently any possible interactions between panelists were also considered to be random. Samples were fixed treatments. Panelists and samples were designated as explanatory variables. This was a pilot study and was subjected to limited time, so replicate testing was not conducted on the samples during testing. Replication is necessary if one is to infer significant differences exist between the samples. Analysis of variance (ANOVA) was performed on the data with panelists as replications for each sample.

Results

Means were calculated for the intensity ratings of each attribute over each sample for both aroma and flavor (Table III.4 and III.5). A limited quantity of sample prevented replication during testing, allowing panelists to evaluate each sample only once. Analysis of Variance (ANOVA) was performed using panelists as replications for each sample.

Lexicon

Twenty-six words were assigned by the panelists for aroma attributes and twenty-seven for flavor attributes (Table III.6). The descriptive terms were the same for both aroma and flavor, with the exception of the term astringent for flavor only.

Analysis of variance, based on panelists as replications, indicated that differences may exist between the samples for the terms smoky, nutty, and tropical fruit. ANOVA did not indicate that there were significant differences between the samples for flavor. Differences can also be supported by examining the standard deviations of the mean ratings. High standard deviations suggest that the samples were rated differently for specific attributes. There were some very high standard deviations as seen in Table III.4, for many of the aroma attributes, however none of the standard deviations for flavor appeared to be abnormally high.

Flavor

Because few or no differences were detected for flavor for any of the nine samples, the remaining results will focus on the aroma attributes. Principal Component Analysis was performed on the aroma data for the nine samples (Figure III.1). Principal Axis 1 accounted for approximately 35% of the variability between the samples. The attributes that composed the positive end of the Principal Axis 1 were; brown spice,

Table III.4 Mean Ratings of the Aroma Descriptors for Nine Commercial Brands of Cachaça

Aroma Descriptors	A	B	C	D	E	F	G	H	I
Ethanol	7.83 (1.33)	6.83 (2.40)	7.17 (1.17)	7.83 (1.94)	7.17 (1.32)	8.00 (1.26)	9.50 (1.51)	7.17 (3.66)	8.33 (2.84)
Sherry	2.67 (2.66)	1.83 (2.40)	2.17 (2.56)	1.33 (2.42)	1.67 (1.86)	1.00 (1.67)	3.00 (2.36)	1.33 (2.07)	1.50 (1.76)
Solvent	3.67 (2.34)	2.67 (1.21)	3.83 (4.02)	5.50 (2.17)	2.50 (2.17)	4.50 (1.38)	4.17 (1.17)	3.50 (1.98)	5.50 (1.38)
Smoky	2.67^{ab} (2.73)	2.17^{c} (2.23)	1.33^{c} (1.51)	3.50^{bc} (1.87)	2.33^{bc} (1.97)	6.33^{a} (2.42)	4.00^{abc} (2.28)	5.00^{ab} (2.97)	3.17^{bc} (2.64)
Woody	2.33 (1.86)	3.00 (2.28)	1.00 (2.00)	2.50 (2.07)	4.67 (3.08)	3.16 (2.14)	3.33 (1.75)	2.50 (1.52)	2.33 (2.07)
Pine	0.50 (1.22)	0.83 (2.04)	1.33 (2.08)	1.67 (3.20)	1.00 (2.45)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Cedar	1.00 (1.55)	1.33 (1.97)	0.83 (1.60)	0.00 (0.00)	2.00 (2.53)	0.33 (0.82)	2.17 (2.79)	0.67 (1.03)	0.67 (1.67)
Vanilla	1.00 (1.55)	2.17 (1.83)	0.33 (0.82)	1.50 (2.35)	1.83 (2.56)	0.00 (0.00)	0.67 (1.63)	1.50 (1.76)	0.67 (1.63)
Nutty	0.17^{c} (0.41)	0.33^{c} (0.82)	1.00^{abc} (1.67)	0.50^{bc} (1.22)	2.50^{a} (3.02)	2.00^{ab} (2.28)	0.50^{c} (1.22)	0.00^{c} (0.00)	0.00^{c} (0.00)
Brown spice	2.17 (2.56)	1.00 (2.45)	2.50 (3.02)	2.00 (3.16)	2.00 (2.90)	0.00 (0.00)	0.33 (0.82)	0.83 (1.33)	0.00 (0.00)
Floral	0.00 (0.00)	0.50 (1.22)	0.00 (0.00)	0.00 (0.00)	1.50 (2.81)	0.00 (0.00)	0.00 (0.00)	0.50 (1.22)	0.00 (0.00)
Musty	0.50 (1.22)	0.83 (2.04)	0.83 (1.60)	1.33 (2.16)	1.00 (2.45)	3.17 (1.60)	0.83 (2.04)	0.83 (2.04)	1.83 (2.14)
Earthy	0.00 (0.00)	0.00 (0.00)	1.50 (2.35)	1.00 (1.55)	1.00 (2.45)	1.83 (2.04)	0.33 (0.82)	0.00 (0.00)	1.00 (1.55)
Lactic/Sour	1.67 (2.86)	1.67 (2.88)	1.83 (4.02)	2.00 (2.29)	1.33 (2.07)	3.17 (3.60)	2.83 (4.40)	2.33 (3.61)	2.17 (3.38)
Plastic	3.50 (0.84)	3.67 (1.03)	2.17 (1.83)	2.17 (3.71)	1.00 (1.67)	2.67 (2.17)	4.67 (0.82)	4.17 (2.48)	3.67 (2.94)
Cardboard	1.00 (1.55)	1.33 (2.07)	0.00 (0.00)	0.67 (1.03)	0.50 (1.22)	2.00 (2.28)	2.00 (2.28)	2.33 (2.66)	2.83 (1.60)
Tropical Fruit	1.83^{bc} (2.40)	1.17^{bc} (2.40)	4.50^{a} (1.37)	1.00^{bc} (1.68)	2.50^{ab} (2.07)	0.33^{c} (0.82)	1.17^{bc} (2.04)	0.67^{bc} (1.21)	1.00^{bc} (1.10)

^{abc} Means with the same superscript within rows, are not significantly different from each other

Table III.4 continued Mean Ratings of the Aroma Descriptors for Nine Commercial Brands of Cachaça

Aroma Descriptors	Samples A	B	C	D	E	F	G	H	I
Pear	3.17 (1.94)	2.00 (2.76)	3.67 (2.30)	1.33 (1.75)	2.17 (3.71)	0.67 (1.63)	2.00 (1.90)	0.50 (1.22)	0.67 (1.21)
Peach	1.83 (2.23)	0.67 (1.63)	1.50 (1.76)	0.00 (0.00)	1.83 (2.04)	0.00 (0.00)	0.83 (1.33)	0.67 ((1.21)	0.00 (0.00)
Caramel	0.00 (0.00)	0.33 (0.82)	0.33 (0.82)	0.00 (0.00)	0.33 (0.82)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
DMS	0.50 (1.22)	0.83 (1.33)	2.17 (3.71)	2.83 (3.25)	1.17 (1.83)	0.85 (1.33)	1.50 (2.35)	0.50 (1.22)	1.17 (1.83)
Minty	1.33 (1.51)	1.50 (1.67)	1.17 (2.04)	0.33 (2.04)	0.17 (2.25)	0.50 (1.76)	1.33 (1.67)	1.33 (1.90)	050 (2.68)
Menthol	1.33 (1.50)	2.00 (1.68)	1.83 (2.04)	2.17 (2.04)	1.67 (2.26)	1.50 (1.77)	1.00 (1.67)	2.00 (1.90)	3.00 (2.68)
Cooling	0.67 (1.63)	0.00 (0.00)	1.00 (2.45)	0.83 (2.04)	0.33 (0.82)	0.67 (1.63)	1.17 (2.86)	1.67 (2.88)	0.67 (1.63)
Burning	0.50 (1.22)	0.00 (0.00)	0.50 (1.22)	0.50 (1.22)	0.50 (1.22)	0.50 (1.22)	1.00 (2.45)	0.67 (1.63)	0.00 (0.00)
Sweet	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.33 (0.82)	0.83 (2.04)	0.00 (0.00)	0.00 (0.00)	0.50 (1.22)	0.00 (0.00)

[abc] Means with the same superscript within rows, are not significantly different from each other

Table III.5 Mean Ratings of the Flavor Descriptors for Nine Commercial Brands of Cachaça

Flavor Descriptors	A	B	C	D	E	F	G	H	I
Ethanol	8.33 (1..37)	8.17 (1.60)	7.33 (2..00)	8.33 (1.50)	7.50 (0.84)	7.33 (0.82)	8.50 (1.05)	6.33 (3.61)	7.00 (2.68)
Sherry	0.83 (1.33)	0.00 (0.00)	1.33 (1.51)	1.17 (2.40)	1.00 (1.26)	2.33 (2.42)	1.17 (1.83)	0.50 (1.22)	1.67 (2.66)
Solvent	3.00 (1..55)	3.00 (2.37)	2.50 (3.66)	2.50 (2.07)	3.00 (2.68)	1.00 (1.67)	1.67 (1.86)	1.33 (2.42)	3.00 (2.37)
Smoky	2.33 (2.06)	3.67 (2.58)	1.83 (2.04)	2.67 (1.50)	2.33 (2.34)	2.83 (2.56)	5.17 (1.72)	3.50 (2.88)	4.33 (3.01)
Woody	3.00 (2.00)	2.17 (2..22)	1.17 (1.83)	2.17 (2..56)	2.33 (2.73)	1.50 (1..97)	2.67 (2..34)	1.50 (1.64)	0.00 (0.00)
Pine	0.00 (0.00)	0.33 (0.82)	1.17 (2.86)	0.00 (0.00)	0.67 (1.63)	0.00 (0.00)	0.00 (0.00)	0.33 (0.82)	0.33 (0.00)
Cedar	0.00 (0.00)	0.50 (1.22)	2.17 (2.23)	0.00 (0.00)	1.00 (1.67)	0.33 (0.82)	0.3 (0.82)	0.33 (0.82)	0.33 (0.82)
Vanilla	0.00 (0.00)	1.00 (2.45)	0.83 (1.33)	0.50 (1.22)	0.33 (0.82)	1.50 (2.35)	0.17 (0.41)	0.33 (0.82)	0.33 (0.82)
Brown spice	0.83 (1.33)	1.33 (2.80)	2.50 (3.02)	1.50 (3.21)	1.33 (1.63)	0.50 (1.22)	0.50 (1.22)	0.50 (0.84)	0.00 (0.00)
Musty	1.00 (1.67)	0.00 (0.00)	0.00 (0.00)	1.17 (1.83)	1.67 (1.83)	0.83 (1.33)	1.83 (2.40)	0.50 (1.22)	0.50 (1.22)
Earthy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.67 (1.63)	0.67 (1.63)	0.33 (0.82)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Lactic/Sour	0.50 (1.22)	0.50 (1.22)	0.83 (1.60)	1.00 (1.55)	1.33 (2.42)	0.83 (1.33)	2.1 (3.37)	1.83 (2.99)	3.33 (3.88)
Plastic	4.17 (2.32)	3.33 (1.75)	2.17 (3.49)	3.00 93.29)	2.17 (3.49)	3.00 (2.45)	3.67 (3.61)	3.83 (3.06)	4.17 (3.87)
Cardboard	3.50 (2.35)	2.33 (2.73)	2.50 (3.33)	2.83 (2.71)	1.83 (2.85)	2.00 (3.35)	2.33 (3.67)	2.00 (3.16)	1.67 (2.58)
Tropical Fruit	1.00 (1.26)	0.17 (0.41)	1.67 (2.88)	1.67 (2.04)	0.50 (1.22)	0.17 (1.94)	0.17 (0.41)	0.33 (0.82)	0.33 (0.82)
Pear	0.50 (0.84)	0.50 (0.84)	1.14 (2.88)	0.00 (0.00)	0.50 (1.22)	2.00 (2.19)	0.17 (0.41)	0.33 (0.82)	0.00 (0.00)
Peach	0.33 (0.82)	0.00 (0.00)	0.33 (0.82)	0.17 (0.41)	0.50 (1.22)	1.00 (1.55)	0.00 (0.00)	0.50 (1.22)	0.00 (0.00)
Caramel	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.83 (2.04)	0.00 (0.00)	0.50 (1.22)	0.00 (0.00)

Table III.5 continued Mean Ratings of the Flavor Descriptors for Nine Commercial Brands of Cachaça

Flavor Descriptors	Samples A	B	C	D	E	F	G	H	I
DMS	0.50 (1.22)	0.00 (0.00)	0.00 (0.00)	2.00 (3.16)	0.67 (1.63)	0.00 (0.00)	1.17 (1.83)	0.67 (1.63)	1.50 (2.51)
Minty	1.17 (1.60)	1.00 (1.67)	1.17 (2.04)	0.83 (1.60)	0.83 (1.33)	1.17 (1.33)	2.67 (2.88)	1.67 (2.07)	1.67 (2.04)
Menthol	1.33 (2.16)	1.00 (1.67)	1.50 (1.64)	1.50 (2.33)	1.00 (1.67)	1.83 (1.60)	1.17 (1.83)	2.00 (1.67)	1.67 (1.83)
Cooling	3.50 (0.84)	3.33 (1.97)	2.67 (1.75)	4.67 (1.21)	2.33 (1.51)	3.17 (1.83)	4.33 (2.07)	2.83 (0.75)	2.17 (1.60)
Burning	4.00 (0.63)	3.83 (2.64)	3.83 (2.48)	5.00 (1.67)	2.50 (2.17)	2.33 (0.82)	2.00 (3.10)	2.33 (2.25)	2.50 (1.87)
Sweet	1.50 (1.76)	2.67 (2.66)	2.50 (1.38)	1.67 (2.07)	1.83 (1.72)	3.17 (2.32)	2.17 (2.86)	2.50 (3.21)	1.50 (1.76)
Astringent	2.50 (1.64)	1.00 (1.09)	1.50 (1.76)	2.83 (2.48)	2.00 (2.45)	2.17 (1.72)	1.67 (2.07)	3.00 (2.28)	1.33 (2.07)

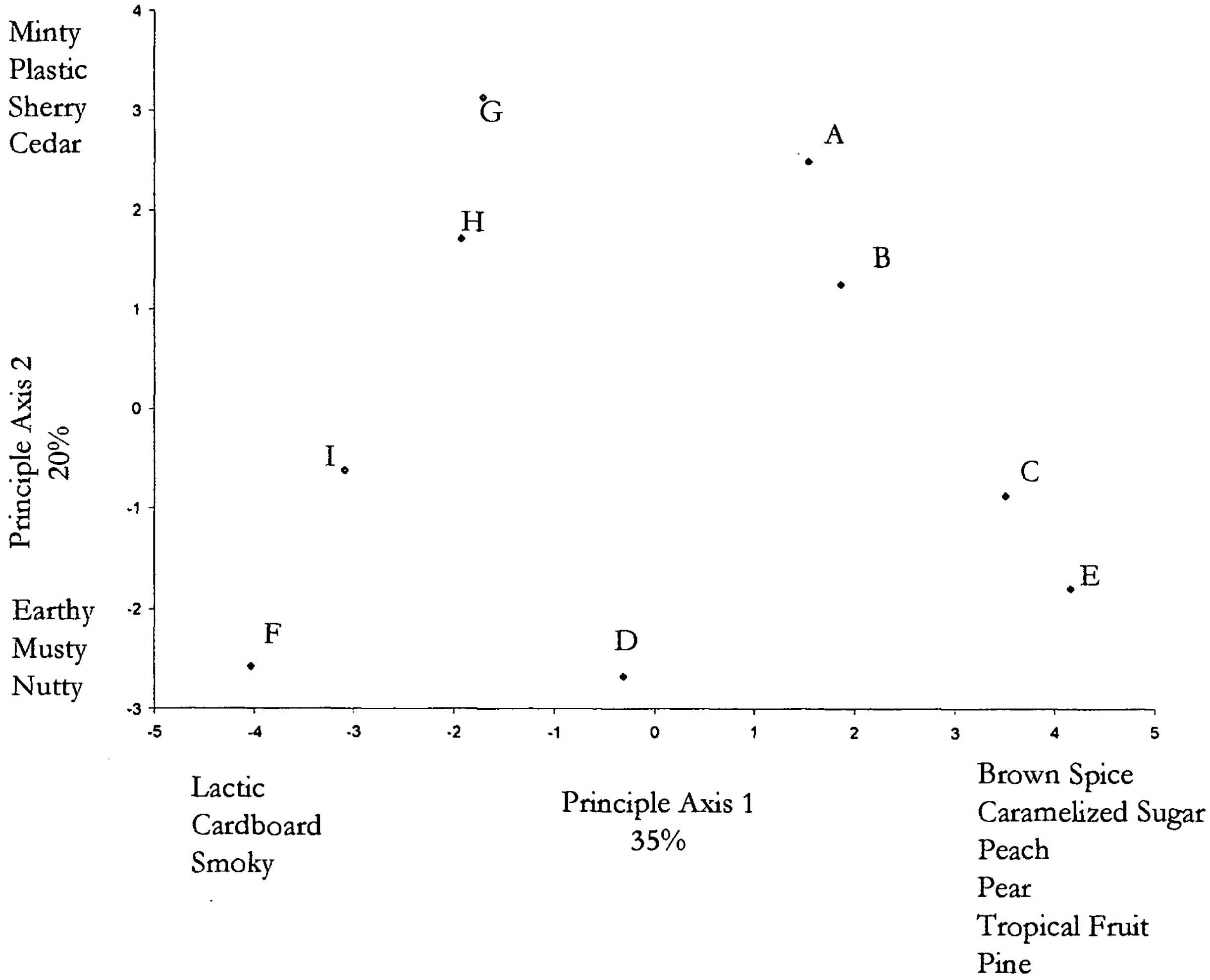
Table III.6 List of Lexicon Terms for Brazilian Cachaça

Terms	Description
Ethanol	pungent, alcohol (indicative of distilled spirits)
Sherry	sweet cooking sherry, oxidized wine, raisins, prunes
Solvent	nail polish remover, other non-ethanol alcohols
Smoky	mezcal tequila, scotch-whisky, camp fire
Woody	fresh cut wood, resin, lumber mill
Pine	pine wood resin, fresh cut Christmas trees
Cedar	fresh cedar shavings, resin
Vanilla	vanilla extract, sweet
Nutty	crushed roasted hazel nuts
Brown Spice	cinnamon, nutmeg, cloves
Musty	old wine corks, wine cellar, damp cement
Earthy	wet soil, forest floor, mushrooms
Lactic	sour milk, yogurt, sickly, dairy
Plastic	plastic shower curtains, plastic tarps, rubber ball
Cardboard	wet cardboard box, old paper
Estery/Tropical Fruit	banana, pineapple, mango, tanning oil
Pear	fresh ripe pear
Peach	fresh ripe peach
Caramelized Sugar	cooked sugar, caramel candy

Table III.6 continued List of Lexicon Terms for Brazilian Cachaça

Terms	Description
Dimethyl Sulfide	canned corn or green beans, oysters
Minty	spearmint, peppermint, refreshing, mouth cooling
Menthol	cough drops, nose tingling
Cooling	mint like, cooling sensations
Burning	hot, alcohol burning, spicy hot
Sweet	sweet taste, sugar, fruity
Astringent	mouth drying

Figure III. 1 Principle Component Plots for Aroma for Nine Commercial Brands of Brazilian Cachaça



caramelized sugar, peach, pear, tropical fruit, and pine. The negative end of the scale was defined as lactic, cardboard, and smoky. Principal Axis 2 accounted for approximately 20% of the variability between the samples. The positive end of this ax is was defined by the terms minty, plastic, sherry, and cedar. Then negative end of the axis was defined by the terms earthy, musty, and nutty.

Aroma

Of the twenty six words chosen by the panelists as the final list of descriptors for aroma, fourteen were actually used across all the samples during testing, based on mean scores. Those terms were; ethanol, sherry, solvent, smoky, woody, cedar, musty, lactic/sour, plastic, estery/tropical fruit, pear, DMS, minty, and menthol.

Samples C and E, were both gold cachaca, considered to be of high quality and sold only in Brazil. They were both considered to be spicy, fruity and sweet. Sample C was rated the highest for tropical fruit aroma and Sample E was rated the highest in nutty character.

Samples F and I, were both clear cachaca, sold only for Export. The could be defined as more lactic, cardboard, smoky, earthy and musty. Sample F was rated the highest in smoky character.

Samples A and B were rated similar across all attributes and occupied similar areas on the Principal component plots, but did not appear to stand out. Interestingly Sample A is a gold cachaca that is not exported, and Sample B is a clear cachaca that is for export only.

Likewise Samples G and H being rated very similar and also occupying a similar area of the Principal component plots. Sample G, however was rated the highest in ethanol and mouth burning. Sample G is a gold cachaça marked for export only, and Sample H, is a clear cachaca sold only in Brazil.

Sample D, was a gold cachaça, not for export, considered to be of high quality in Brazil. It was rated high in solvent and pine characters but also high in vanilla, and brown spice characters. This balance of attributes is confirmed by its placement on the Principal component plot, lying approximately in the middle of Principal axis 1 .

Conclusions

A lexicon of 26 terms was developed for Brazilian cachaça using a modified descriptive analysis technique. Panelists displayed some variability in their use of some of the terms and in their use of the intensity scale. This may be attributed to the need for additional training allowing the panelists more time to agree on some of the more complex attributes. The number of attributes may have been slightly too many for the limited time spent in training. Breaking the terms up into overall characteristics, such as "fruity", or "woody", may help to eliminate some of the discrepancies in word usage.

Panelist apparently had difficulty detecting differences between the samples for flavor. This is consistent with other research conducted on distilled spirits.

There did not appear to be consistent differences between gold or clear cachaca, or between those marked for export and those samples sold only in Brazil or the region that they were produced. The aroma profile of cachaca seems to be quite complex and variable and specific to the brand.

Additional research, with longer training sessions and enough sample for replication during testing, is suggested. A concurrent chemical analysis of the samples may also aid in understanding the compounds that are responsible for specific aromas.

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IV. AROMA AND FLAVOR PROFILE FOR TEN COMMERICAL BRANDS OF CACHAÇA, BRAZILIAN RUM

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Abstract

Ten commercial brands of cachaça, distilled sugar cane spirit, were evaluated for aroma and flavor characteristics. The evaluation was conducted using a modified descriptive analysis technique. Nine panelists were trained for twelve-one hour sessions relying heavily on reference and intensity standards. Analysis of Variance and Principal Component Analysis, revealed that the panelists were able to detect differences between the samples. Little was known about the processes involved in making each brand, so no correlation between sensory analysis and processing could be made. The only correlation made was between the color of the samples. Principal Component Analysis suggested that all of the "white" or clear samples were associated with different attributes than the gold colored samples. One sample, considered to be of high quality in Brazil, was different from all of the others.

A chemical evaluation of the samples using GC-Mass Spec supported previous research in the composition of cachaça, and did not provide strong enough results to aid in the correlation between sensory characteristics and chemical composition for this particular study.

<u>**Introduction**</u>

Of the billions of liters of cachaca produced annually in Brazil, approximately 1% is exported. There have been recent attempts by the Universidade Federal de Vicosa, and Universidade de Sao Paulo, Brazil, to establish quality control standards for cachaça, with the aid of chemical and sensory analysis, in an attempt to introduce the beverage to an international market(Nascimento et al., 1998; Silva and Nobrega, 1997).

Though technically a rum, by U.S. standards, cachaça is unique in that it is produced exclusively from fresh pressed sugar cane juice and not molasses. It is also unique in it's sensory properties, sharing many similarities with tequila and scotch whisky and also possessing some characteristics that are recognized as "rum like"(Durkan, 1997).

Though extensive chemical analysis has been performed on rum, little sensory evaluation has been published. This is the first study to evaluate the sensory characteristics of cachaça specifically(Lehtonen and Suomalainen, 1977; Nykanen and Nykanen, 1983, 1991; Rijek and Heide, 1983).

Descriptive analysis has long been employed by the brewing, whisky and wine industry for product development and marketing, and quality assurance. Often a modified descriptive analysis method is used that relies heavily on the use of reference standards, which represent the terminology assigned to the attributes as they are detected by the panelists. Intensity ratings of the attributes are based on a 16 point intensity scale and anchored to intensity standards that allow panelists greater continuity in their use of the scale. Once training has been completed as a group, the panelists evaluate the samples individually, in private booths, without interaction(Piggot et al., 1984; Piggot et al. 1991;

Nobel et al., 1987; Meilgaard et al, 1982; Powers, 1988).

The objective of this study was to establish an aroma and flavor profile for ten different brands of cachaça and to determine if any differences existed between the samples. A concurrent chemical analysis of the same samples is being conducted at the Universidade Federal de Viçosa. It is hoped the results of this descriptive analysis can be correlated with chemical profile of the samples, in attempt to better understand the specific processes that contribute to unique qualities of cachaça.

Materials and Methods

Sample Storage

Ten samples of commercially produced cachaça were evaluated for aroma and flavor (Table IV.1) The samples were produced within the following states of Brazil: Minas Gerais (MG), Sao Paulo (SP), and Pernambuco (P). The brands represented in this study are: PITU ((P), Vale Verde (MG), Massangano (MG), Java (MG), Germana (MG), Ponte Nova (MG), Velha Aroera (MG), 51 (SP), Velho Brumado (MG), and Velho Barreiro (MG). Two of the samples were designated for "export only" and purchased in New York, the other eight samples were purchased in Brazil. Six of the ten samples have been evaluated previously in a preliminary study (Chapter 1) (Table IV.1). To protect the identity of the brands, all of the samples were randomly labeled 1 through 10.

Six of the samples arrived in 1 liter commercial bottles. They were stored at 4^0C with parafilm covering the lids of the bottles. Four of the samples had not been evaluated previously. These samples arrived from Brazil in 520 ml or 262 ml Pyrex jars wrapped in

Table IV. 1 Ten Commercial Brands of Cachaça Evaluated for Aroma and Flavor

Brand	Region	Exported	Color	%Alcohol (wt./vol.)
Germana	Minas Gerais	No	Gold	43%
Velha Aroeira	Minas Gerais	No	Gold	47%
Vale Verde	Minas Gerais	No	Gold	43%
Massangano	Minas Gerais	No	Gold	43%
Java	Minas Gerais	No	Gold	43%
Velho Brumado	Minas Gerais	No	Gold	43%
Velho Barreiro	Minas Gerais	No	White	40%
Ponte Nova	Minas Gerais	No	White	40%
PITU	Pernambuco	Yes	White	40%
51	Sao Paulo	Yes	White	40%

plastic with the lids covered in parafilm. The samples were stored at 4° C, upon arrival to Oregon State University.

Sample Preparation

Most of the samples were either 40% or 43% alcohol (wt./vol.), as appeared on the labels. One sample was labeled 47% alcohol. Portions of each sample were cut with spring water[1] at a 50:50 ratio. The cut portions were stored in brown 500-ml EZ-Cap bottles[2] with airtight locking lids. The 50% dilutions were used for all training and testing. Diluting the samples with water served a dual role; first it helped to lessen sensory fatigue during training and testing, and it also resulted in reducing the color of the gold cachaça so that it closely matched the color of the clear cachaça.

Panelists

The descriptive panel was composed of nine individuals from the Food Science Department at Oregon State University (three women and six men). Two of the men were full time research assistants and the remaining panelists were students. Five of the nine panelists had no previous sensory evaluation experience; the other four panelists had extensive experience with descriptive analysis.

Panel Training

The nine panelists met for 12 one-hour training sessions that were conducted in the Sensory Science Laboratory at Oregon State University. The panelists evaluated two

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[1]Aqua-Cool pure bottled water, Portland OR
[2] ezcap™, F.H. Steinbart Co., Portland OR

samples in 30 ml portions; served in 0.25 L tulip shaped clear wineglasses with aluminum lids.

Panelists evaluated the samples for aroma and flavor, one sample at a time. The first phase of the training involved the development of a lexicon for the samples being evaluated. The panelists were instructed to evaluate aroma first, flavor second. Initially panelists used individual descriptive terms that best described what they were smelling and tasting. The panel then discussed as a group the results of the sample evaluation and decided on the use of the descriptive terms. The panel leader prepared reference aroma standards based on the descriptive terms (Table IV.2) The panelists were instructed to smell the reference standards before evaluating the samples. The second phase of the training involved intensity ratings. Panelists were asked to rate the intensity of each aroma and flavor attribute based on a 16-point intensity scale, (0= none, 3= slight, 7= moderate, 11= large, and 15 = extreme). (Table IV.3). Bottled spring water and unsalted saltine crackers were provided as palate cleansers.

Descriptive Analysis Testing

The samples were labeled with three digit random numbers. The panelists tested one sample at a time, with two samples in a set. They were allowed to test two sets with a minimum 20-minute break between sets. Each sample was served, as it was during training, in 30 ml portions in 0.25 L tulip shaped clear wine glasses with aluminum lid. Each panelist evaluated each sample twice. Testing was completed over 1-½ weeks.

Panelist responses were recorded on a paper ballot. There were a total of 33

Table IV.2 Aroma Reference Standards[1]

Aroma Descriptor	Reference Standards
Ethanol	30mls 95% ethanol + 10 mls distilled water
Solvent	10mls 95% acetone + 10 mls 95% ethanol + 20 mls distilled water
Woody	Shavings from piece of plywood
Oaky	French and American oak chips in 10 mls of 95% ethanol + 10 mls of distilled water
Vanilla	1 ml Schilling ® pure vanilla extract + 39 mls distilled water, McCormick & Co., Inc, Huntvalley, MD
Honey	40 mls of Eastern Oregon Wildflower Honey, Joann's Honey, Reedsport OR
Molasses	40 mls of TCT Molasses, Food Ingredient Technology Corp., Woodbridge NJ
Sherry	40 mls Fairbanks Cream Sherry, Fairbanks Cellars, Modesto CA
Lavender	1 gram lavender salts, from First Alternative Grocery, Corvallis, OR+ 40 mls distilled water
Peach	¼ Fresh peach cut into 4 fractions
Pear	¼ Fresh pear cut into 4 fractions
Banana	4 slices of Fresh banana
Citrus	¼ section of each of the following fresh fruits combined together: lime, lemon, pink grapefruit
Brown Spice	0.5 grams of each of the following Schilling ® spices, combined together: cinnamon, nutmeg, and cloves(McCormic & Co. Inc, Huntvalley, MD)

[1] Individual aroma standards were placed in 50 ml pyrex jars with lids.

Table IV.2 continued Aroma Reference Standards[1]

Aroma Descriptor	Reference Standards
Anise	1ml of Schilling ® Pure Anise extract + 39 mls of distilled water(McCormic & Co. Inc., Huntvalley, MD)
Medicinal	1 ml of phenol solution(dissolve 10 mg of dichlorophenol in 100 ml ethanol) + 40 mls of distilled water (Aldrich Chemical Co. Inc., Milwaukee, WI.)
Smoky	1 ml of Wrights Natural Hickory Seasoning + 10ml of 95% ethanol + 29 mls distilled water, Nabisco Foods, In. East Hanover, NJ
Burnt Rubber	10 cm x 10 cm piece of bicycle tire tubing, burned For 1 minute
Green Olives	4 green olives, sliced in half
Wet cardboard	10 cm x 10 cm piece of cardboard soaked in water
Lactic/Sickly	1 ml 80% lactic acid + 1ml 10% acetic acid + 40 mls of distilled water

[1] Individual aroma standards were placed in 50 ml pyrex jars with lids.

Table IV.3 Overall Intensity Standards[2]

Intensity Level	Standard Recipe
Overall Intensity (3)	2 Tablespoons Safflower Oil, Saffola Quality Foods Los Angeles, CA
Overall Intensity (7)	1 Tablespoon + 1 teaspoon Hi-C® Orange Drink Coca Cola Co. Houston TX
Overall Intensity (11)	1 Tablespoon + teaspoon Welches ® Grape Juice, Welches Foods, Inc. MA
Overall Intensity (15)	1 stick unwrapped Wrigleys Big Red ® Cinnamon Chewing gum, Wm.Wrigley Jr. Co., Chicago, IL

[2] Overall Intensity Standards were placed in 0.25 liter clear, tulip shaped wine glasses with Aluminum lids.

aroma and flavor descriptors (10 overall descriptors + 23 more specific descriptors), plus 4 mouthfeel terms(Table IV.4).

Panelists were separated in individual testing booths and did not interact with each other. The sample serving order was randomized so that no two panelists evaluated samples in the same order.

The dilution of the samples with water not only decreased sensory fatigue by diluting the strength of the samples, but resulted in decreased color of the gold cachaça so that it closely matched the color of the clear cacahça. The lighting within the testing booth was kept at a minimum to also help eliminate any detection of slight color difference between the samples. Panelists were never allowed to compare samples side by side. All of these factors combined, helped to reduce the effect of color in the evaluation of the products.

Data Analysis

Analysis of Variance was performed on the intensity ratings assigned by each panelists, to each attribute across all samples. The experiment was a balanced complete block design, with each panelist representing a block. Panelist and replication, and any interaction term including them, were considered random effects. Samples were considered fixed treatments. A p-value less than or equal to 0.05, indicates a significant difference between samples for a particular attribute. For those attributes or terms that were considered to show significant difference across samples, Least Significant Difference was used to show which samples were different from each other. Principal Component Analysis was used to access if any groupings or correlation existed between the different samples.

Table IV.4 List of Lexicon Terms for Brazilian Cachaça

Terms	Description
Alcoholic	pungent, strong alcohol (indicative of distilled spirits)
Ethanol	ethyl alcohol, vodka, neutral spirits
Solvent	nail polish remover, other non-ethanol alcohols
Woody	fresh cut wood, resin, lumber mill
Woody	pine, fir, cedar wood resins
Oak	oak resins, chardonnay wine, whisky
Sweet	sweet taste, sugar, honey, molasses
Vanilla	vanilla extract, sweet
Honey	warm clover honey
Molasses	burnt sugar, molasses
Sherry	sweet cooking sherry, oxidized wine, raisins, prunes
Floral	roses, honeysuckle, hyacinth, lavender, lilac
Lavender	lavender tea, lavender soap
Fruity	overall fruity, fresh fruit, dried fruit, tree fruit, tropical fruit
Peach	fresh or dried peaches
Pear	fresh ripe pear
Tropical	pineapple, mango, coconut, tanning oil
Banana	very ripe banana
Citrus	lemon, lime, grapefruit, orange
Spicy	cooking spices, brown spices, black pepper
Brown Spice	cinnamon, nutmeg, cloves

__Underlined terms represent "overall", first tier, categories

Table IV.4 continued List of Lexicon Terms for Brazilian Cachaça

Terms	Description
Anise	anise flavoring, black licorice, burning mouthfeel
Phenolic	medicinal, smoky, scotch whisky, scotch ale
Medicinal/ Band-Aid	medicated Band-Aid, first aid kit, phenol
Smoky	mezcal tequila, scotch-whisky, camp fire
Sulfury	wet dog, snakes, rubber, plastic, onions, vegetative
Burnt rubber	burning tires, burning brakes, hot tar
Green olives	canned green olives
Papery	wet paper, old cotton, old cardboard boxes
Cardboard	wet cardboard box
Earthy	old mushrooms
Sour	sour milk, yogurt, sickly, dairy, gamy
Lactic/Sickly	sour milk, sickly
Cheesy	blue cheese, goat cheese
Mouthfeel	
Astringent	mouth drying
Burning	hot, alcohol burning, spicy hot
Glycerol/oily	slippery oily mouthfeel, mouth coating
Cooling	mint like, cooling sensations

__Underlined terms represent "overall", first tier, categories

All statistical analysis was performed with the Statistical Analysis Software (SAS®, Cary, NC).

Gas Chromatography-Mass Spectrometry

Equipment

Hewlett Packard (HP) Series II 5890 Gas Chromatograph, HP 5972 series Mass Selective detetor, and a HP 7673 GC/SFC injector. Supelco 10 Carbowax 30M column, (30m x 0.75mm x 1.0 um).

Sample Preparation

Samples were analyzed directly in 0.5 uL aliquots, no standards or solvents were used in the preparation of the samples. Not all samples were tested with GC- Mass spec due to a limited quantitiy of some of the samples. The samples that were tested were: S-1, S-2, S-3, S-5, S-6, S-7, S-8, and S- 9.

GC Methods

The temperature of the injector port was set at 250^{0}C and the detector was set at 280^{0}C. The temperature program started at 70^{0}C and held there for 2 minutes, then increased to 210^{0}C (at 20^{0} per minute), and held for 1 minute. Helium was used as carrier gas.

Results

Lexicon

The final lexicon developed by the panelists was composed of 33 aroma and flavor terms, and four mouthfeel terms. The 33 terms were separated into two tiers, with the first tier consisting of 10 overall descriptors followed by a second tier of 23 more specific descriptors (Table IV.4).

Analysis of Variance

Mean scores and least significant differences were calculated for all attributes across all samples (Table.IV.5 to IV.7). Superscript letters above each mean score indicate which means are not significantly different. Means with the same superscripts within rows, are not significantly different from each other ($p>0/05$).

There were significant differences between the samples for 17 out of 33 aroma descriptors and significant differences for 11 out of 33 flavor descriptors. The only significant differences between the samples for mouthfeel was with the term; "burning".

Principal Component Analysis

Because the flavor data offered no additional differences from the aroma results, Principal Component Analysis was performed on aroma data only (Fig.IV.1 and Fig.IV.2). Principal Axis one can explain 33.7% of the variability among the samples. The positive end of the axis is defined as sweet, fruity, vanilla, pear, and tropical. The

Table IV.5 Mean Ratings and Standard Deviations for the Aroma Descriptors for Ten Cachaça Samples

Aroma Descriptors	Samples S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10
Alcoholic	9.83^{a} (1.6)	9.22^{ab} (1.8)	8.22^{bc} (2.4)	9.83^{a} (1.7)	9.61^{a} (2.1)	9.28^{ab} (2.1)	10.00^{a} (2.0)	9.33^{ab} (1.8)	9.89^{a} (1.5)	7.78^{c} (1.9)
Ethanol	8.72^{ab} (2.8)	8.39^{ab} (1.5)	7.39^{bc} (3.2)	7.39^{bc} (3.8)	7.67^{bc} (3.0)	8.39^{ab} (2.2)	9.22^{a} (2.8)	8.11^{abc} (2.8)	8.22^{abc} (3.4)	6.89^{c} (2.5)
Solvent	4.67^{bc} (3.3)	5.67^{ab} (3.2)	3.17^{d} (3.1)	6.78^{a} (3.1)	5.39^{b} (3.5)	4.72^{bcd} (4.0)	4.56^{bc} (3.9)	4.17^{cd} (3.2)	4.94^{bc} (3.4)	3.83^{cd} (2.4)
Woody	3.61 (2.2)	4.11 (2.7)	3.61 (2.3)	2.89 (2.7)	3.50 (2.7)	3.61 (1.8)	3.83 (2.3)	3.50 (2.7)	3.50 (2.7)	2.94 (2.3)
Woody	1.72 (1.9)	2.17 (2.5)	1.56 (2.1)	1.33 (1.8)	1.61 (2.3)	1.22 (1.6)	1.11 (1.9)	1.39 (2.1)	1.78 (2.4)	1.11 (1.7)
Oaky	2.44 (2.0)	3.06 (2.3)	3.22 (2.5)	2.11 (2.3)	2.22 (2.3)	2.72 (1.9)	2.72 (2.0)	2.17 (2.4)	2.39 2.9)	2.22 (2.2)
Sweet	4.33^{d} (2.2)	5.94^{ad} (2.2)	5.17^{bcd} (2.2)	5.33^{bcd} (2.7)	5.39^{bcd} (2.3)	4.56^{cd} (2.3)	6.67^{a} (1.7)	4.28^{d} (2.7)	5.61^{abc} (2.4)	4.94^{bcd} (2.6)
Vanilla	2.00^{cd} (2.4)	3.50^{a} (1.5)	2.56^{abc} (1.9)	2.06^{bcd} (2.4)	2.72^{ab} (2.4)	1.50^{d} (1.9)	3.28^{a} (2.7)	1.33^{d} (1.5)	3.06^{ab} (2.3)	2.94^{abc} (2.2)
Honey	0.83^{c} (1.3)	2.67^{a} (2.1)	1.89^{abc} (2.1)	2.39^{ab} 2.7)	1.61^{abc} (2.1)	1.44^{bc} (1.8)	2.67^{a} (2.7)	1.22^{bc} (1.8)	1.83^{abc} (2.0)	1.89^{abc} (2.3)
Molasses	0.33 (1.0)	0.78 (1.7)	0.61 (1.5)	1.17 (1.8)	0.78 (1.6)	1.11 (1.9)	0.00 (0.0)	1.00 (1.3)	1.28 (2.0)	1.22 (1.9)
Sherry	2.44 (2.4)	3.17 (2.2)	2.83 (2.7)	2.50 (2.5)	2.89 (2.7)	2.17 (2.5)	3.28 (2.7)	1.44 (1.9)	2.06 (2.7)	1.89 (2.4)
Floral	1.28^{cd} (1.6)	1.50^{bcd} (2.1)	1.22^{cd} (1.8)	1.28^{cd} (2.1)	1.22^{cd} (2.0)	2.00^{abc} (1.9)	0.94^{d} (1.57)	2.28^{ab} (2.6)	1.67^{abcd} (2.1)	2.61^{a} (2.2)
Lavender	0.22 (0.6)	0.94 (2.1)	0.50 (1.3)	0.39 (0.9)	0.56 (1.5)	1.17 (1.9)	0.33 (0.8)	0.33 (0.8)	0.39 (0.9)	1.06 (1.9)
Fruity	4.28^{d} (3.2)	6.61^{ab} (2.80)	6.17^{ab} (2.4)	5.17^{bcd} (3.7)	6.61^{a} (2.8)	4.67^{cd} (3.1)	6.56^{a} (3.1)	5.39^{bc} (1.9)	7.06^{a} (3.0)	4.83^{cd} (2.9)

^{abc} Means with the same superscripts within rows are not significantly different from each other ($p<0.05$).

__Underlined attributes represent "overall" categories

Table IV.5 continued Mean Ratings and Standard Deviations for the Aroma Descriptors for Ten Cachaça Samples

Aroma Descriptors	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10
Peach	0.72 (1.2)	1.94 (2.2)	2.28 (2.8)	1.39 (2.4)	1.67 (2.1)	1.72 (2.3)	2.44 (2.5)	1.61 (1.8)	2.33 (2.6)	1.00 (1.5)
Pear	2.17 (2.8)	2.28 (3.2)	2.50 (3.1)	2.17 (3.1)	2.11 (3.0)	2.78 (2.9)	3.06 (2.9)	2.72 (2.4)	2.61 (2.5)	2.78 (2.7)
Tropical	2.17 (2.1)	3.11 (2.6)	2.78 (2.9)	2.61 (3.0)	2.22 (2.5)	1.22 (1.7)	2.94 (2.9)	1.72 (1.7)	3.50 (2.9)	1.72 (2.0)
Banana	1.00^{e} (1.7)	3.56^{abc} (2.8)	2.44^{cd} (2.4)	3.17^{bc} (3.6)	4.39^{a} (3.0)	0.72^{e} (1.3)	3.11^{bc} (3.4)	1.44^{de} (1.8)	3.67^{ab} (3.3)	1.56^{de} (2.1)
Citrus	1.44 (1.7)	1.17 (1.8)	1.50 (2.3)	1.11 (2.0)	1.17 (2.00	1.78 (2.1)	1.33 (2.20	2.06 (2.6)	1.83 (2.4)	1.50 (2.1)
Spicy	1.39^{cd} (1.7)	2.06^{bcd} (2.4)	4.78^{a} (3.9)	1.94^{cd} (3.0)	2.33^{bcd} (2.4)	1.28^{d} (2.1)	2.61^{bc} (3.0)	2.11^{bcd} (2.6)	3.28^{b} (3.1)	1.72^{cd} (2.2)
Brown Spice	0.78^{e} (1.4)	1.89^{cd} (2.4)	4.39^{a} (3.9)	1.67^{cde} (2.8)	2.00^{c} (2.5)	1.00^{de} (1.9)	2.33^{c} (3.0)	1.83^{cd} (2.5)	3.33^{b} (3.0)	1.44^{cde} (2.0)
Anise	0.33 (0.8)	0.00 (0.0)	0.56 (1.4)	0.17 (0.5)	0.11 (0.5)	0.67 (2.0)	0.22 (0.6)	0.28 (0.80)	0.83 (1.4)	0.00 (0.0)
Phenolic	5.00^{b} (1.4)	3.67^{cd} (2.7)	3.50^{cd} (2.9)	6.83^{a} (2.6)	4.00^{bcd} (2.4)	4.50^{bc} (2.3)	3.11^{d} (2.5)	4.33^{bc} (2.2)	3.44^{cd} (2.8)	3.94^{bcd} (2.8)
Medicinal	4.00^{b} (2.1)	2.56^{c} (2.4)	2.28^{c} (3.0)	6.22^{a} (2.6)	3.17^{cb} (2.5)	3.39^{cb} (2.3)	2.17^{c} (2.5)	3.39^{cb} (2.2)	3.00^{cb} (2.7)	2.22^{c} (2.3)
Smoky	2.28 (2.0)	1.66 (2.2)	0.89 (1.40)	1.72 (2.4)	1.50 (2.2)	1.89 (2.50)	1.78 (2.1)	1.39 (1.9)	1.17 (1.7)	1.94 (2.4)
Sulfury	2.00^{b} (2.2)	1.50^{b} (1.9)	1.61^{b} (2.1)	5.61^{a} (2.5)	2.44^{b} (2.4)	1.67^{b} (2.2)	1.33^{b} (2.1)	1.44^{b} (2.1)	1.39^{b} (2.0)	2.06^{b} (2.4)
Rubber	1.00^{b} (1.6)	1.11^{b} (1.7)	0.67^{b} (1.1)	4.17^{a} (3.1)	1.56^{b} (2.2)	0.76^{b} (1.7)	1.06^{b} (1.8)	1.11^{b} (1.8)	1.00^{b} (1.8)	1.44^{b} (2.2)
Green Olives	0.78 (1.6)	0.89 (1.6)	1.33 (2.4)	1.44 (2.6)	1.00 (1.9)	1.56 (2.4)	0.28 (1.0)	0.94 (1.9)	0.72 (1.7)	0.67 (1.4)
Papery	3.67^{a} (3.0)	2.22^{bc} (2.3)	2.56^{abc} (2.7)	2.28^{bc} (2.3)	1.89^{c} (1.9)	2.94^{abc} (3.1)	1.89^{c} (1.9)	3.39^{ab} (3.1)	1.94^{c} (2.2)	3.06^{abc} (3.1)

[abc] Means with the same superscripts within rows are not significantly different from each other ($p<0.05$).

__Underlined attributes represent "overall" categories

Table IV.5 continued Mean Ratings and Standard Deviations for the Aroma Descriptors for Ten Cachaça Samples

Aroma	Samples									
Descriptors	**S-1**	**S-2**	**S-3**	**S-4**	**S-5**	**S-6**	**S-7**	**S-8**	**S-9**	**S-10**
Cardboard	3.06^{a} (3.1)	1.89^{bc} (2.1)	2.44^{abc} (2.6)	2.00^{bc} (2.0)	1.56^{c} (1.8)	2.56^{abc} (3.1)	1.56^{c} (1.9)	2.72^{ab} (3.3)	1.89^{bc} (2.2)	2.44^{abc} (3.0)
Earthy	0.67 (1.7)	0.61 (1.7)	0.11 (0.5)	0.44 (1.1)	0.39 (1.1)	0.44 (1.5.)	0.28 (0.8)	0.39 (1.0)	0.22 (0.9)	0.61 (1.5)
<u>Sour</u>	3.17 (3.0)	2.00 (1.8)	2.22 (2.5)	3.78 (3.7)	3.50 (2.7)	2.83 (2.5)	2.44 (2.7)	2.83 (2.5)	2.28 (2.7)	3.00 (2.7)
Lactic/Sickly	3.06 (2.8)	1.72 (1.7)	2.06 (2.5)	3.72 (3.6)	3.06 (2.9)	2.72 (2.4)	2.39 (2.7)	2.61 (2.0)	2.06 (2.7)	3.17 (2.6)

[abc] Means with the same superscripts within rows are not significantly different from each other ($p<0.05$).

__Underlined attributes represent "overall" categories

Table IV.6 Mean Ratings and Standard Deviations for the Flavor Descriptors for Ten Cachaça Samples

Flavor				Samples						
Descriptors	**S-1**	**S-2**	**S-3**	**S-4**	**S-5**	**S-6**	**S-7**	**S-8**	**S-9**	**S-10**
Alcoholic	9.94^{abcd} (2.0)	9.72^{bcd} (2.2)	8.50^{de} (1.4)	10.83^{a} (1.6)	10.56^{ab} (1.7)	9.50^{cde} (2.0)	10.83^{a} (2.1)	9.17^{de} (1.4)	10.39^{abc} (1.50	8.11^{f} (1.8)
Ethanol	8.50^{a} (3.2)	8.89^{a} (2.2)	7.28^{bc} (3.0)	8.39^{ab} (3.8)	8.11^{abc} (3.6)	8.17^{ab} (3.3)	8.94^{a} (3.9)	7.94^{abc} (2.7)	8.56^{a} (3.4)	6.94^{c} (2.8)
Solvent	3.50^{cd} (3.9)	4.56^{abc} (3.8)	2.39^{d} (2.7)	5.67^{a} (4.1)	4.72^{ab} (3.7)	4.22^{bc} (3.7)	4.50^{bc} ((3.9)	3.06^{d} (3.0)	3.00^{d} (3.1)	2.67^{d} (2.8)
Woody	3.83 (2.1)	4.56 (1.6)	4.50 (2.0)	4.22 (1.8)	4.50 (1.5)	4.44 (2.1)	4.28 (2.0)	3.50 (2.5)	4.28 (1.7)	3.78 (2.1)
Woody	2.28 (2.0)	1.78 (2.2)	1.39 (2.1)	2.17 (2.3)	2.33 (2.2)	2.00 (2.5)	1.22 (2.0)	1.22 (1.6)	2.17 (2.1)	1.78 (1.9)
Oaky	2.44 (2.1)	3.44 (2.3)	3.44 (2.3)	2.67 (2.4)	2.67 (2.3)	2.44 (2.3)	2.61 (2.61)	2.94 (2.6)	2.56 (2.3)	2.78 (2.5)
Sweet	5.17 (2.6)	5.39 (3.0)	4.39 (3.1)	5.72 (2.7)	4.78 (2.0)	4.50 (3.3)	5.33 (2.8)	6.06 (2.7)	4.89 (3.1)	4.72 (3.0)
Vanilla	2.17 (1.9)	2.78 (2.3)	1.39 (1.8)	2.28 (2.2)	2.39 (2.1)	1.61 (1.6)	2.17 (2.3)	2.17 (2.0)	1.72 (2.0)	2.67 (2.4)
Honey	1.83 (1.9)	2.06 (1.9)	1.67 (2.2)	2.56 (2.6)	1.50 (2.1)	1.61 (2.1)	2.11 (2.7)	2.11 (2.3)	1.78 (2.0)	1.89 (2.1)
Molasses	0.83 (1.6)	0.56 (1.3)	1.67 (2.0)	1.94 (2.1)	0.61 (1.2)	0.94 (1.7)	0.39 (1.1)	0.89 (1.5)	1.22 (1.9)	0.83 (1.6)
Sherry	1.78 (2.4)	2.33 (2.5)	1.89 (2.4)	1.89 (2.8)	2.28 (2.3)	1.72 (2.3)	2.89 (2.7)	1.61 (2.3)	1.67 (2.4)	1.39 (2.1)
Floral	0.78 (1.6)	0.61 (1.4)	0.83 (1.7)	0.61 (1.2)	0.72 (1.4)	1.00 (1.6)	0.78 (1.3)	1.22 (1.6)	0.67 (1.3)	1.28 (1.7)
Lavender	0.00 (0.0)	0.17 (0.7)	0.28 (1.2)	0.11 (0.5)	0.50 (1..2)	0.78 (1.4)	0.22 (0.7)	0.67 (1.9)	0.33 (1.0)	0.44 (1.0)
Fruity	4.44 (3.3)	5.11 (3.0)	4.50 (3.4)	4.44 (3.9)	5.28 (3.3)	3.94 (3.7)	4.44 (3.1)	4.67 (3.6)	4.39 (2.9)	4.17 (2.9)

[abc] Means with the same superscripts within rows are not significantly different from each other ($p<0.05$).

__Underlined attributes represent "overall" categories

Table IV.6 continued Mean Ratings and Standard Deviations for the Flavor Descriptors for Ten Cachaça Samples

Flavor Descriptors	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10
Peach	0.89 (1.6)	0.78 (1.7)	0.89 (1.7)	1.44 (2.1)	0.83 (1.4)	1.00 (1.9)	0.72 (1.4)	1.00 (1.7)	1.28 (1.7)	0.89 (1.9)
Pear	2.50 (2.6)	2.17 (3.0)	1.83 (2.6)	2.44 (3.3)	1.56 (2.9)	2.44 (2.7)	1.61 (2.5)	2.56 (3.1)	2.17 (2.9)	2.56 (2.5)
Tropical	1.11 (1.89)	1.00 (1.6)	2.17 (2.4)	1.22 (1.9)	2.17 (2.2)	1.22 (1.7)	1.50 (2.1)	1.22 (1.9)	1.56 (2.3)	0.89 (1.6)
Banana	1.50 (1.9)	2.56 (2.1)	1.56 (2.1)	2.33 (2.7)	2.61 (3.1)	0.50 (1.2)	2.61 (2.5)	0.78 (1.7)	2.33 (2.8)	0.89 (1.70
Citrus	0.72 (1.5)	1.06 (1.4)	1.17 (2.2)	0.56 (1.6)	0.61 (1.5)	1.17 (1.9)	1.22 (2.0)	1.50 (2.1)	1.06 (2.0)	1.50 (2.1)
Spicy	1.94^{e} (2.5)	2.39^{cde} (2.8)	3.33^{ab} (3.2)	3.44^{ab} (3.0)	3.11^{bc} (3.1)	1.89^{e} (2.4)	2.89^{bcd} (2.7)	2.89^{cd} (2.4)	3.89^{a} (3.4)	2.22^{de} (2.4)
Brown Spice	1.44^{c} (2.1)	1.83^{bc} (2.7)	2.50^{ab} (3.3)	2.56^{ab} (3.0)	2.39^{abcd} (3.1)	1.39^{c} (2.2)	1.94^{bc} (2.8)	2.00^{bc} (2.4)	3.11^{a} (3.7)	1.56^{c} (2.4)
Anise	0.61 (1.5)	0.28 (1.2)	0.94 (1.6)	1.11 (1.9)	0.61 (1.5)	0.50 (1.3)	0.61 (1.2)	0.56 (1.4)	0.50 (1.2)	0.72 (1.8)
Phenolic	4.72^{ab} (2.6)	4.50^{b} (3.0)	4.83^{ab} (3.5)	5.89^{a} (3.7)	4.50^{b} (3.0)	5.89^{a} (3.5)	3.83^{b} (2.4)	3.94^{b} (2.6)	4.00^{b} (2.4)	4.28^{b} (2.7)
Medicinal	3.00^{bc} (2.7)	2.83^{bc} (2.8)	3.56^{ab} (2.7)	4.50^{a} 3.5)	3.06^{bc} (2.8)	3.44^{abc} (3.4)	2.17^{c} (2.2)	2.50^{bc} (2.7)	2.56^{bc} (2.7)	3.17^{bc} (2.3)
Smoky	2.67^{bc} (2.3)	2.67^{bc} (2.8)	3.11^{ab} (2.7)	2.44^{bc} (2.7)	1.72^{c} (2.4)	3.89^{a} (3.2)	2.33^{bc} (2.3)	1.89^{c} (2.6)	1.67^{c} (1.8)	1.67^{c} (2.5)
Sulfury	2.00^{b} (1.8)	1.00^{b} (1.5)	1.00^{b} (1.5)	3.78^{a} (2.0)	1.67^{b} (1.6)	1.61^{b} (1.9)	1.33^{b} (2.1)	1.39^{b} (2.0)	1.06^{b} (1.5)	1.28^{b} (2.1)
Rubber	1.39^{b} (2.0)	0.67^{b} (1.3)	1.00^{b} (1.5)	2.83^{a} (3.0)	1.50^{b} (1.7)	1.11^{b} (1.8)	1.06^{b} 91.9)	1.17^{b} (1.9)	0.56^{b} (1.3)	1.06^{b} (2.0)
Green Olives	0.56 (1.2)	0.11 (0.5)	0.22 (0.7)	0.83 (1.7)	0.33 (0.8)	0.83 (1.5)	0.28 (0.8)	0.44 (1.3)	0.33 (0.8)	0.56 (1.3)
Papery	4.28^{a} (2.9)	2.94^{c} (2.2)	3.94^{abc} (2.7)	3.39^{abc} 92.4)	3.17^{bc} 2.5)	4.17^{ab} (3.1)	3.50^{abc} (2.1)	4.17^{ab} (1.9)	2.94^{c} (2.3)	3.61^{abc} (2.5)

^{abc} Means with the same superscripts within rows are not significantly different from each other ($p<0.05$).

___Underlined attributes represent "overall" categories

Table IV.6 continued Mean Ratings and Standard Deviations for the Flavor Descriptors for Ten Cachaça Samples

Flavor Descriptors	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10
Cardboard	4.11 (3.0)	2.67 (2.2)	3.78 (2.8)	3.11 (2.5)	3.06 (2.5)	4.00 (3.0)	3.22 (2.2)	3.89 (2.3)	2.94 (2.3)	3.17 (2.5)
Earthy	0.39 (1.6)	0.33 (1.0)	0.11 (0.5)	0.83 (2.6)	0.67 (0.8)	0.56 (1.5)	0.22 (0.9)	0.33 (1.0)	0.00 (0.0)	0.67 (1.6)
Sour	2.11 (2.8)	1.78 (1.7)	2.56 (2.1)	3.28 (3.5)	2.39 (2.2)	2.11 (2.2)	2.28 (1.8)	1.83 (1.9)	1.89 (1.9)	2.56 (2.5)
Lactic/Sickly	1.94 (2.5)	1.28 (1.5)	2.50 (2.0)	2.67 (3.2)	1.83 (2.1)	2.00 (2.2)	1.72 (1.8)	2.11 (1.9)	1.72 (1.9)	2.44 (2.3)

[abc] Means with the same superscripts within rows are not significantly different from each other ($p<0.05$).

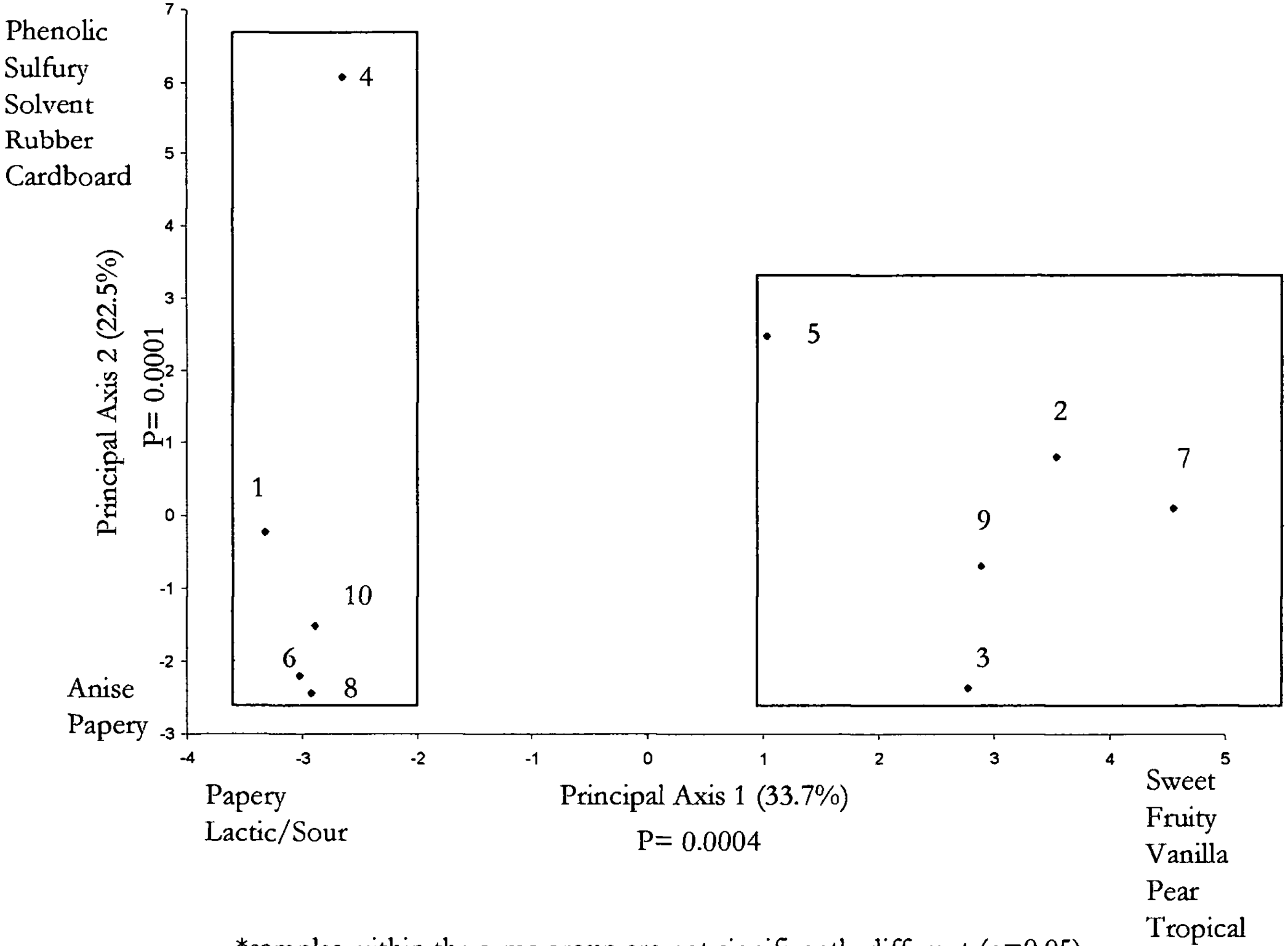
__Underlined attributes represent "overall" categories

Table IV.7 Mean Ratings and Standard Deviations for the Mouthfeel Descriptors for Ten Cachaça Samples

Mouthfeel Descriptors	Samples S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10
Astringent	2.17	2.94	2.72	2.22	2.61	1.94	2.50	1.83	2.78	2.06
Burning	3.94^{cd}	4.50^{bcd}	4.06^{cd}	6.17^{a}	5.17^{abc}	4.17^{cd}	5.67^{ab}	3.44^{de}	5.11^{abc}	2.44^{e}
Glycerol	1.22	1.44	1.94	1.89	1.94	2.22	1.83	1.56	1.17	2.83
Cooling	0.22	0.00	0.33	0.00	0.17	0.17	0.33	0.17	0.17	0.22

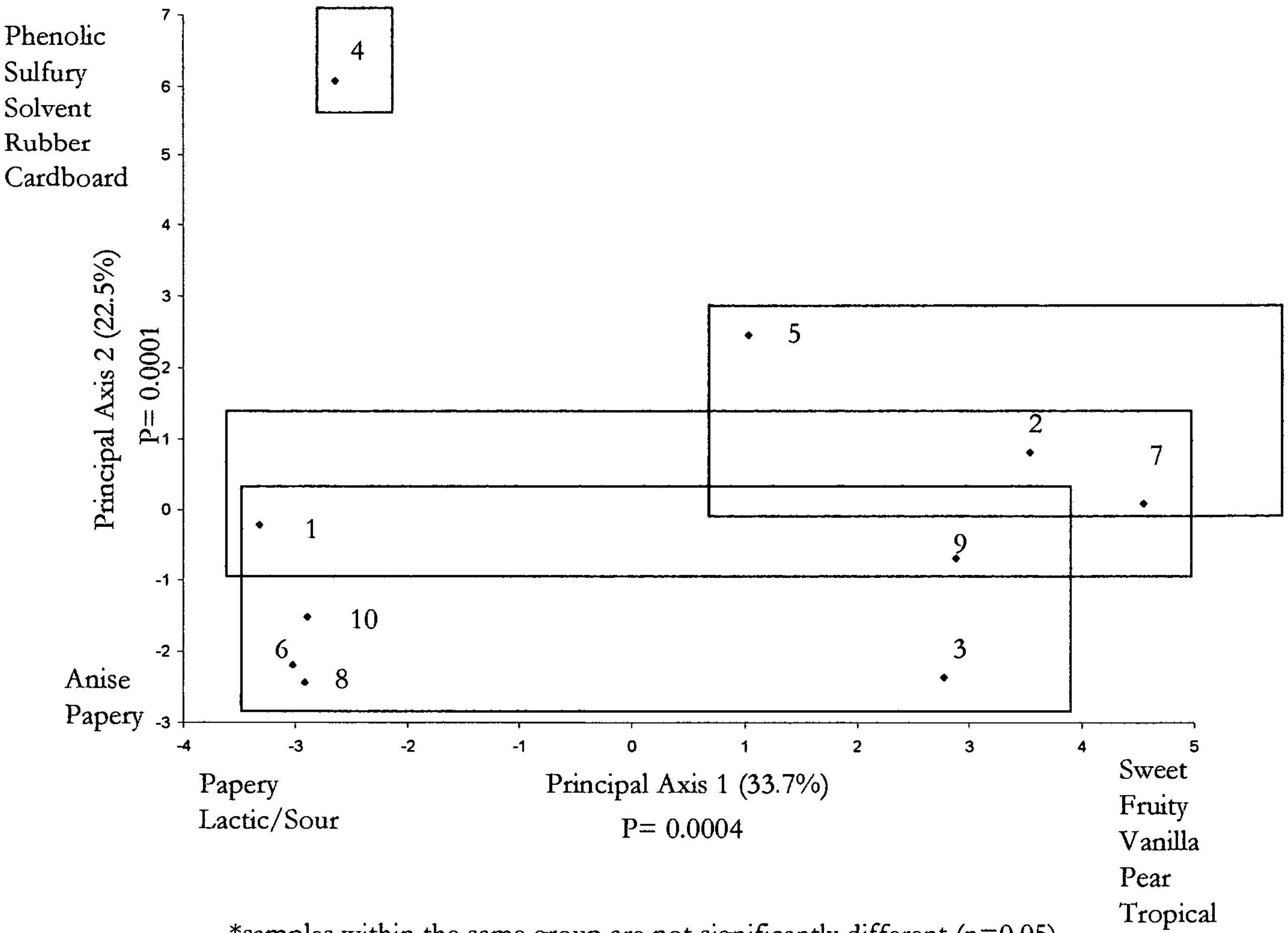
^{abc} Means with the same superscripts within rows are not significantly different from each other ($p<0.05$).

Figure IV.1 Principal Components Plot for the Aroma of Ten Brands of Brazilian CachaÇa Groupings Based on Principal Axis 1



*samples within the same group are not significantly different (p=0.05) on Principal Axis 1

Figure IV.2 Principal Components Plot for the Aroma of Ten Brands of Brazilian CachaÇa Groupings Based on Principal Axis 2



*samples within the same group are not significantly different (p=0.05) on Principal Axis 2 negative end of the axis is defined as papery and lactic/sour. Samples within the same group are not significantly different from each other ($p \leq 0.05$).

Principal Axis 2 can explain 22.5% of the variability among the samples. The positive end of this axis is defined as phenolic, sulfury, solvent, rubber, and cardboard. The negative end of the axis is defined as anise and papery. Samples within the same group are not significantly different from each other ($p \leq 0.05$).

The GC/MS analysis resulted in a total for 34 peaks across all samples. Nineteen of the peaks were identified with a $\geq$75% accuracy. Fifteen of the peaks were not accurately identified. The associated sensory character for each of the compounds was identified using flavor chemistry references(Furia and Bellanca, 1974a,b; Ash and Ash, 1995))(Table IV.8).

Sensory Profiles of Samples

Samples 1, 6, 8, and 10 appeared to be similar in their aroma/flavor profile. All of four of these samples were clear or "white" cachaça. All had an alcohol content of 40%. They were significantly different from the other samples by being rated high in papery, and wet cardboard. They were also described as having slightly woody and pear attributes. Samples 1 and 8 were designated for "export only".

Sample 6 stood out has having the highest smoky flavor of all of ten samples, panelists commented that this sample shared many similarities with mezcal tequila. Sample 10 could be considered "smooth", having the lowest rating in alcohol aroma, flavor and mouth burning. Over half of the panelist's referred to this sample as scotch like. The similarities between these samples can be seen by their groupings within the

Table IV.8 Compounds Identified in Eight Samples of Cachaça through GC-MS
Sensory Character Identified using Flavor Chemistry References

Retention Time (range)	[1]Tentative I.D.	[2]Sensory Character	S-1	S-2	S-3	S-5	S-6	S-7	S-8	S-9
7.22 - 7.92	ethanol	alcoholic	+	+	+	+	+	+	+	+
8.97 - 9.14	unknown		+	+	+	+	+	+	+	+
11.77 - 11.91	3-methyl-1-butanol	banana, sweet, fruity	+	+	+	+	+	+	+	+
13.36 -13.89	unknown		+	-	+	+	+	+	-	+
17.23 – 17.30	unknown		-	+	+	+	-	+	+	+
17.49 – 17.66	unknown		-	+	-	-	-	-	+	-
17.87 – 17.98	unknown		+	-	-	-	-	-	+	-
19.81	unknown		-	-	-	-	-	-	+	-
20.79 – 20.61	unknown		-	-	-	-	+	-	+	-
21.09 – 21.44	acetic acid	vinegar/sour	+	+	+	+	+	+	+	+
21.62	furfural	paper/cardboard	+	-	-	-	-	-	-	-
21.84	unknown		-	-	-	-	+	-	+	-
22.02	2-5-dimethyl furan		-	-	-	-	-	-	+	-
23.18 – 23.41	formic acid		-	-	-	-	+	-	+	-
23.46 – 23.82	unknown		-	-	+	-	-	-	+	-
24.13 – 24.35	2,3-butandediol	oily mouthfeel, sweet taste	-	+	+	+	-	+	-	+
25.72 – 25.77	unknown		-	-	-	-	-	+	-	+

[1]Identity based on the probablity $\geq$70%, the unknown component is correctly identified as the reference using the Wiley 138L PBM Library
[2]Identity of Sensory Characters: (Furia and Bellanca, 1975; Ash and Ash, 1995)

Table IV.8 continued Compounds Identified in Eight Samples of Cachaça through GC-MS Sensory Character Identified using Flavor Chemistry References

Retention Time (range)	[1]Tentative I.D.	[2]Sensory Character	S-1	S-2	S-3	S-5	S-6	S-7	S-8	S-9
25.81 – 25.94	ethyl deconate	brandy like	-	+	-	+	-	+	-	-
26.07 – 26.09	benzyl disulfide	burnt carmel	-	+	-	+	-	-	-	-
28.40	furfural Alcohol	cooked sugar	+	-	-	-	+	-	-	-
28.57	succinic Acid	sour taste	-	-	-	-	-	+	-	+
33.32	ethyl ester dodecanoic	fatty, dairy	-	-	-	-	-	-	-	+
	acid		-	-	-	-	+	-	+	-
33.72 – 33.79	unknown									
36.54 – 36.60	phenethyl alcohol	floral; rose hyacinth, honey	-	-	+	+	-	+	-	+
36.71 – 37.55	2-furoic acid	cardboard,paper	-	+	-	+	-	+	-	+
40.22 – 40.23	caprylic acid	fatty, dairy, rancid	-	-	-	-	+	-	+	+
40.34	cinnamal	cinnamon,spice	-	-	+	-	-	-	-	-
41. 19 – 41.70	unknown		-	-	+	-	+	-	-	-
42.09 – 42.35	unknown		+	-	+	-	+	-	+	-
43.62 – 43.83	unknown		+	-	+	-	-	-	+	-
44.04 – 44.19	unknown		-	-	-	-	-	+	+	+
44.63 – 44.72	caproic acid	Limburger cheese	-	-	-	-	-	+	-	+
45.51 – 45.53	capric acid	rancid, goaty	-	+	+	-	+	+	+	+
46.17 – 46.19	3-hydorxy-2-methyl-4H-pyran-4-one (maltol)	caramel	-	-	-	-	+	-	-	-

[1]Identity based on the probablity $\geq$70%, the unknown component is correctly identified as the reference using the Wiley 138L PBM Library

[2]Identity of Sensory Characters: (Furia and Bellanca, 1975; Ash and Ash, 1995)

Principal component plots, in which they are most separated by the attributes papery, lactic, and anise.

Samples 2, 5, 7 and 9 shared a similar aroma, flavor and chemical profile. These samples were all gold chachça, and were quite different from the clear or white cachaça. They can be described as sweet, vanilla, honey, fruity, and banana. All four of these samples were also slightly higher in alcohol content. Samples 2,5, and 9 had an alcohol content of 43%. Sample 7 had the highest alcohol content of all ten samples at 47%. This sample was also rated highest in alcohol aroma, flavor and in burning mouthfeel.

These samples contained the compound 2,3-butandediol which is associated with a sweet taste. All of these samples also contained at least one or more of caprylic, caproic or capric acids. Samples 5, 7 and 9 contained phenethyl alcohol which has been described as floral, and honey like.

Sample number 3, shared many similarities with samples 2, 5, 7, and 9. It too is a gold cachaca and has an alcohol content of 43%. Sample 3 differed from all the other 10 samples being rated high in spicy/brown spice. This is substantiated by the presence of the compound cinnamal, which was not identified in any of the other samples.

The similarities between samples 2, 3, 5, 7,and 9 can be seen in the PCA plots, where they are separated by the attributes sweet, fruity, vanilla, pear and tropical fruity (Fig. IV.1 and Fig. IV.2).

Sample 4 was quite different from all of the other samples. It is a gold cachaça. It was significantly different from the other ten samples, being rated highest in solvent, phenolic, medicinal, sulfury, rubbery, sour and lactic. It was also rated high in spicy, and burning mouthfeel. Those same attributes separate the sample from all of the others as displayed in the PCA plots (Fig. IV.1 and Fig. IV.2).

Conclusions

Based on these results, it is apparent that cachaca is highly variable in sensory character. No one aroma/flavor profile can be applied to all cachaca in general. There does appear to be a difference between the clear cachaca and the gold cachaca. This may be attributed to the contribution of important aroma and flavor compounds extracted from wood during aging.

There did not appear to be any significant differences between the clear cachaca exported to the U.S. and the clear cachaca sold only in Brazil.

The results suggest that the modified descriptive analysis method was very successful in separating the samples based on aroma, but less so for flavor. These findings are consistent with descriptive work performed on other distilled spirits.

Allocating a list of terms as overall attributes, aided in the separating of the samples. It was much easier for panelists to agree on the use of the over-all terms than it was for some of the more specific terms.

Conclusions regarding correlation between aroma/flavor and chemical composition, was inconclusive due to the large number of unidentified compounds. However, some observations could be made.

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V. THESIS SUMMARY

Cachaça is recognized as the national alcoholic beverage of Brazil. Technically a rum by U.S. standards, it is differentiated from rum produced in other countries by the fact that it is produced through the fermentation and distillation of fresh pressed sugar cane juice and never molasses or sugar syrups. There are currently very few standards governing the production of cachaça in Brazil, which results in considerable variability between rum produced at different distilleries. These differences can be supported by the results of the two descriptive analysis tests conducted in the study.

Panelists developed a lexicon of descriptors including woody, sweet, floral, fruity, spicy, phenolic, sulfury, papery, and sour. The fact that two separate panels developed similar lexicons, suggests that these terms are very effective at describing the aroma and flavor of cachaça.

The modified descriptive analysis method employed in this study, when utilizing a minimum of 12 hours of training, appears to be an effective tool in deciphering sensory differences between samples of Brazilian Rum. Employing a two tiered lexicon system which included an "overall" category also aided in better separation between samples that were different in aroma and flavor. Analysis of variance indicated that there were significant differences between ten commercial brands of cachaça for the terms alcoholic, ethanol, solvent, sweet, vanilla, honey, floral, fruity, banana, spicy, brown spice, phenolic, medicinal, sulfury, rubber, papery, and cardboard.

Principal Component analysis illustrated how the samples were separated and grouped based on those attributes. It was apparent that the white cachaca in this study were more defined as solventy, papery, sulfury, lactic and sour. Most of the gold cachaça was considered to be sweet, fruity, vanilla, and tropical. One of the gold cachaça samples was unique from all of the other samples, being rated very high in phenolic, sulfury, solvent, rubber and cardboard.

Because color was not a factor during the testing of the samples, it is assumed that any perceived differences in the samples were based on chemical composition. No artificial coloring was added to the samples in this study, which would also indicate that differences in production and aging of cachaça not only have an impact on the color of the product but on the aroma and flavor profile as well.

Some of the samples in the study were designated for export only. There did not appear to be any obvious differences between the brands marked for export, and those sold only in Brazil.

It is hoped that the results of this descriptive analysis study will be correlated with the results of a concurrent study at the Universidade Federal De Viçosa, Brazil, where chemical analysis of the same ten commercial brands of cachaça is being conducted. This correlation may reveal some of the specific chemical components, and processes responsible for the unique sensory characters of cachaça, and the distinctive differences between the aroma and flavor of white and gold cachaça.

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