

Brief Report

Technical Report—Applying Physics and Sensory Sciences to Spirits Nosing Vessel Design to Improve Evaluation Diagnostics and Drinking Enjoyment

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Abstract: Ethanol is the direct by-product of distillation. The vast majority of straight spirit beverages are bottled at 40%+ ABV (alcohol by volume). Aficionados, critics, spirits judges, and a significant percentage of drinkers choose to drink and evaluate spirits at bottled strength from traditional vessels. Olfactory perceptions are quickly compromised by abundant ethanol, numbing olfactory sensors and severely inhibiting aroma detection during evaluation. Traditional vessel redesigns have concentrated on minor styling changes, ignoring olfactory and physical sciences. Consumers' continued search for value and quality and increased dependency on spirits competitions as a primary source of ratings emphasizes the need for a functional diagnostic vessel which displays and delivers aromas unobscured by ethanol olfactory numbing. The application of olfactory and physical science creates an engineered tasting vessel which eliminates severe ethanol olfactory numbing, optimizes aroma definition, and significantly improves diagnostics for those who evaluate, judge, rate, distill, and enjoy flavor nuances of spirits.

Keywords: spirits; nosing vessel; ethanol; distilling; spirits evaluation; spirits diagnostics; spirits competition; spirits judging; spirits ratings; spirits quality; drinking vessel; whisky glass; whiskey glass; tulip glass; scotch glass

1. General Introduction and Importance

Published research is non-existent on the application of scientific principles to functional spirits drinking vessel design, largely due to an established mindset that the sole purpose of a drinking vessel is to deliver beverage from container to mouth. New drinking vessel concepts are initiated by glassware and beverage companies to increase sales or create a perceived style identity for a particular beverage. If scientific function holds marketing advantages, the desired science is invented or spun to fit, eventually creating general public misconceptions. Due to the lack of published scientific experimentation in a long-neglected field, the research herein is by necessity empirical or subjective, and was designed by the author and research team to:

- discover preferences and effects of ethanol on accurate diagnostics and evaluation
- examine validity of existing design assumptions through application of scientific principle
- provide general direction for identification of vessel design parameters.

Olfactory receptor numbing by overexposure to ethanol vapor is a major hindrance to accuracy for all who evaluate spirits. Discussions of the background, state-of-the-art, and recurring issues of olfactory ethanol are organized as follows:

1. ethanol effects on the human olfactory system—Section 1.1;

2. evaluation of existing common spirits vessels—Section 1.2;
3. industry application of traditional vessel designs—Section 1.3;
4. attempts to alleviate ethanol anesthesia with traditional vessels—Section 1.4;
5. erroneous design assumptions that hinder vessel development—Section 1.5;
6. gender preference and mindset regarding ethanol in aromas—Section 1.6;
7. the importance of ortho-nasal aroma detection in spirits evaluation—Section 1.7;
8. ethanol effects during multi-sample judging and evaluation—Section 1.8;

1.1. Ethanol Effects on the Human Olfactory System

Ethanol has been employed as a low-potency anesthetic for centuries, since ca 160 CE by Hua Tuo, in the form of mafeisan, an ethanol-herb mixture [1]. Highly concentrated ethanol is cited as a hazardous substance by OSHA, EPA, and NFPA, as well as many other organizations. Although its toxicity level is much lower than other anesthetics, it is the most abundant odorant in distilled spirits. Patel, Doty et al. concluded that ethanol ingestion alters olfactory sensitivity to ethanol and may influence odor discrimination [2]. In 1972, R. Nicoll [3] quantified the negative anesthetic effects of ethanol on the olfactory bulb sensor synapses. Other effects of ethanol on olfactory sensors are:

1. Causes pain to olfactory receptors especially in more sensitive noses.
2. Irritates and enflames the olfactory epithelium, causing compensating mucous congestion further hindering smell detectability.
3. Inhalation introduces ethanol through pulmonary system to the bloodstream, leading to cognitive impairment.
4. Ethanol has anesthetic consequences for any of the 636 different olfactory receptors, as estimated by Godfrey et al. [4]. Further research is needed to identify and quantify the extent of ethanol-receptor binding and the possible existence of vibrational harmonics across the many different receptor types to determine how many may be affected.

Avoiding or minimizing these effects can be achieved by engineering a vessel to separate ethanol aromas from other odorants emanating from the spirit and redirecting ethanol aromas away from the nose. Design objectives for the engineered spirits diagnostic vessel are:

- wide aroma display to facilitate separation and detection of more aromas
- avoidance of ethanol anesthesia by separating and diverting ethanol away from the nose.

1.1.1. Physical Properties of Ethanol

Ethanol is the most abundant molecule in a spirit's evaporated aromas and is the first to reach the olfactory bulb during sampling, as it is highly volatile, has high vapor pressure, and a low boiling point and surface tension. Although ethanol molar mass is over 2 times that of water, hydrogen bonding slows water evaporation, and ethanol is the most abundant molecule in the evaporation. Table 1.

Table 1. Comparison of physical properties of water vs. ethanol [5].

	Chemical Symbol	Molar Mass	Vapor Pressure	Boiling Point	Surface Tension
		g/mol	kPa at 20 °C	°C	Dynes/cm at 25°
Water	H ₂ O	18.02	2.34	100	71.97
Ethanol	C ₂ H ₅ OH	46.07	5.95	78.44	22.27

Ethanol inhibits aroma detectability and perception, yet is ignored for high% ABV spirits vessel design purposes and improvement of diagnostic methodologies. Section 1 defines the background, state-of-the-art, and problems related to olfactory ethanol, and Section 2 describes the methodology

of the experimentation and develops the design parameters necessary to engineer the vessel to meet stated objectives.

1.1.2. State of the Art of Olfactory Science and Applicable Terminology

The “lock and key” theory proposed in 2004 by Buck and Axel [6] and the receptor-molecule fit and vibration theory proposed in 2006 by Turin [7] are currently considered mechanisms describing odorant molecule-to-receptor binding that takes place to present a signal to the brain for odor identification.

Recovery time is the timespan required for replacement mucous to flush traces of prior aroma molecules from the epithelium. The mucous replacement process is the same as that required for recovery from odor adaptation. Adaptation recovery time is measured by Steinmetz et al. [8] using methyl isobutyl ketone as a control, with 70% recovery occurring at about 200 s, or over 3 min. Ethanol, as the most abundant, is the first and most likely to cause olfactory adaptation.

Terms such as olfactory fatigue, odor fatigue, olfactory adaptation, sensory adaptation, and nose blindness are commonly used by evaluators to describe aroma detectability loss after prolonged sniff-sampling of wine, spirits, or perfumes. Whether due to olfactory adaptation or ethanol receptor binding, existing terminology does not adequately describe the molecule-receptor binding process, although common use of these terms tends to validate an ethanol anesthetic effect. The author hereby introduces terminology to specifically address ethanol-receptor binding:

- Ethanol lockout is hereby defined as an ethanol molecule binding to a single receptor, thus removing that sensor from the detection process until unbinding occurs.
- Ethanol anesthesia is hereby defined as the en masse ethanol lockout of an evaluator’s olfactory receptors to an extent that impairs aroma detectability.

Ethanol anesthesia begins concurrently with ethanol adaptation, and as more receptors are locked out, the ability to smell and discern other aromas becomes more difficult as more abundant ethanol binds to receptors, leaving fewer to detect other aromas. Observations related to ethanol anesthesia are covered in detail in Section 1.8, as it is more easily discovered during panel evaluations.

1.2. Evaluation of Existing Common Spirits Vessels

Subjective panel evaluations of different vessels were conducted with several control spirits to determine which attributes were favorable or unfavorable to diagnostics (Table 2). Results of this subjective evaluation were useful to provide design direction.

Table 2. Comparison of best (green) and worst (red) nosing vessel attributes. Consensus of viability as a diagnostic vessel for three common vessel designs. Details in Section 2 Methods.

Subjective Evaluation I: Existing Common Spirits Vessels		
		
Tumbler (≈80 mm bowl diam.)	Traditional Copita, Chimney	Snifter (≈100 mm bowl diam.)
Popular for ice cubes	Most popular for straight spirits	Least popular
Swirls reasonably well Some ethanol dissipation Some aromas get to nose Unsatisfactory for 40% ABV spirits Wide rim lets nose get close to spirit Ethanol/character aromas (64/36%)	Too narrow to swirl effectively Rim concentrates ethanol at nose Pungent ethanol crowds out aromas Unsatisfactory, designed for 20% ABV spirits Small rim, keeps nose in ethanol cloud Ethanol/character aromas (90/10%)	Swirls best No ethanol dissipation Very high ethanol Designed for quick ethanol “buzz” Nose enters strong ethanol cloud Ethanol/character aromas (79/21%)

The most commonly used vessels are those of the traditional copita and tulip or chimney style vessels shown in the center column of Table 2. These dimensionally small-rim area, tall, narrow-bowl vessels inhibit objective evaluation, particularly during multiple sample evaluation sessions, due to

high ethanol concentration. Performance of both of the vessels shown and other tulip and chimney shapes are equal, as their design characteristics and size are related, as shown in Figure 1.

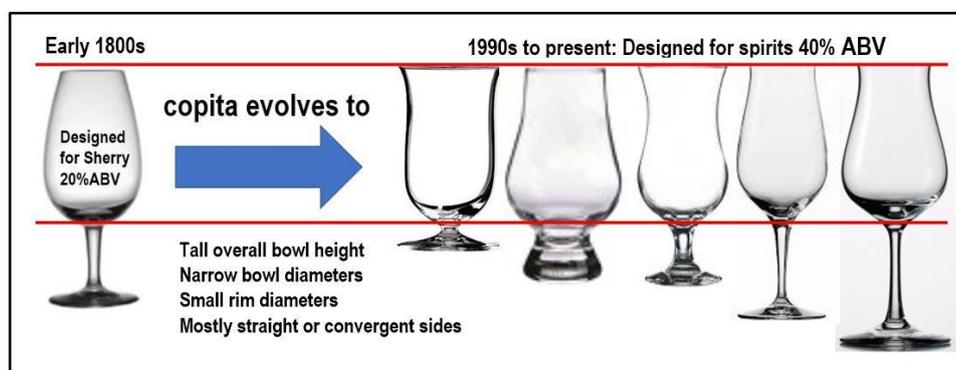


Figure 1. The copita becomes the chosen standard. The copita is a centuries-old trade tool for verifying quality by purchasing agents at loading piers and was nicknamed the “dock glass”. Similar small rim diameters, tall rim heights, and narrow bowl diameters in later designs exemplify the reluctance of vessel manufacturers to stray from the established traditional and visual identity.

A single engineered vessel which displays aromas and eliminates ethanol anesthesia is constructed in Section 2 Methods to overcome high concentration problems of traditional vessels.

1.3. Industry Application of Traditional Vessel Designs

Traditional vessels originated with the copita and also include more recent derivatives which share design features that prevent aroma display and concentrate anesthetic ethanol (Figure 1).

The rationale for adopting the copita as the standard tasting vessel is simple and unscientific:

- it is highly visible as the standard sherry tasting vessel, merchants’ quality verification tool, and has ready availability, public familiarity and acceptability;
- it was designed for higher ABV beverages, 22% vs. 12% ABV for wine, with smaller vessels more effectively controlling overindulgence than larger-sized vessels;
- it holds a 45 mL spirits serving, the common bar serving, while providing a small headspace, which is considered to be important for collecting and detecting aromas.

Vessel manufacturers’ restyling attempts within the last four decades have maintained the recognizable design features of the copita-style vessel, perpetuating the dependency on traditional identification for public acceptability over function, such as:

- small rim diameters restricting the nose from entering the vessel and concentrating ethanol;
- convergent, vertical or nearly vertical sidewalls, which concentrate ethanol;
- bowl diameters too small to accommodate swirling and the attendant tall headspaces;
- vessel rim heights too tall to detect some large-mass aromas.

Technical discussion of these flawed design parameters is covered in Section 2, to directly relate drawbacks to the parameters necessary to construct the engineered vessel.

Vessel shape’s effect on aroma is not a new concept, beginning with the notable introduction of large air volume wine glass by Riedel in 1958 to promote quick oxidation of red wines. Our extensive research discovered no published scientific research on spirits vessel design.

Scotch Blenders Support Traditional Vessel Designs

Scotch distillers and blenders have entrenched the copita as the accepted spirits tasting vessel despite noted design flaws. The best-selling spirits are blends of different age or flavor characteristics

to achieve tastier expressions. Blending is difficult due to exposure to olfactory ethanol, unless care is taken to keep the effects of olfactory ethanol in check.

Recognizing that the copita focuses high ethanol concentrations at the nose, blenders have long attempted to control nose burn by diluting spirits with water to 20% ABV. This dilution coincides with ethanol levels for which the sherry copita was best suited, as sherry is 18–22% ABV, and with dilution the copita has become the accepted standard blenders tool for scotch whisky. Dilution of blending spirits to approximately half their original strength with water confirms that olfactory ethanol effects have long been recognized by the industry as a significant problem for spirits evaluation. Dilution reduces olfactory and palate pain. However, dilution at 1:1 ratio creates other problems. Diluting to 20% ABV ignores consumer drinking habits and changes aroma profiles:

- Bottled at 40%+ ABV, dilution of 1 serving with an equal amount of water yields 20% ABV. Consumers drink spirits straight at bottle strength, undiluted.
- 50% dilution forms a continuum mixture of ethanol and water, releasing some compound micelles while masking others. According to Conner et al. [9], Lersch [10] and Karlsson et al. [11], this degree of dilution frees long-chain fruity esters and masks short chains, smoky phenols, and oily, soapy, grassy, nutty, and cereal aromas, altering the aroma profile to one not experienced by consumers who drink straight spirits.

As acknowledged by blenders and distillers, 50% dilution persists as the blending standard. Tradition has precluded consideration of an alternative vessel to eliminate ethanol anesthesia, improve ortho-nasal diagnostics, or to relate blending to consumers' straight drinking preferences.

1.4. Attempts to Alleviate Ethanol Anesthesia with Traditional Vessels

Experts, critics, brand ambassadors and other marketers have developed methods and altered tasting procedures to reduce prevalent olfactory ethanol effects and preserve traditional vessels. The most common are underlined, and have proven short-sighted for *reasons* provided in italics:

- Breathe through mouth and nose simultaneously to avoid inhaling nose-numbing ethanol. *Alleviates initial olfactory pain but delivers smaller air-diluted samples, affecting aroma detection. Ethanol concentration remains high, occupying more olfactory receptors with each consecutive sniff.*
- Do not swirl. *Swirling is the "engine" that propels evaporation. No swirling yields much less evaporation and fewer aromas to evaluate. Swirling is discussed in Section 2.1.*
- Waft. *Place vessel 15–20 cm from the nose, slightly below nostril level, wave aromas over the top of the glass toward nose to avoid pain and numbing. Wafting acclimates the olfactory receptors to prevent initial pungency of concentrated ethanol, ethanol lockout continues during sniffing.*
- "Shake hands". *Position the glass about one foot away from the nose while sniffing, subsequently repositioning successively closer while sniffing, until rim is directly under nostrils. Gradual acclimation avoids initial nose burn but does not avoid lockout when sampling from small-rim diameter vessels. Ethanol vapor concentration remains at same high levels during sampling.*
- Add water to open up aroma. *Water raises liquid surface tension shutting down evaporation of all aromas, including those important to identification and evaluation. "Opening up" is the perception of relief occurring due to less pungent ethanol on the olfactory receptors.*

These methods attempt to relieve numbing in traditional vessels, but only soften the initial sensation as the olfactory receptor acclimates. Blenders mix their spirits to their own satisfaction, and only they are privy to altered aroma profiles created by high dilution. The effects of water on aroma profile are ignored by blenders, and Karlsson [12] agrees that although his research places micelles close to the surface of the liquid, surface tension is a major restriction to the evaporative process.

An engineered vessel which diverts ethanol from the nose eliminates the need for acclimation to pungent, nose-numbing ethanol of high % ABV spirits, and relates to consumer preferences.

1.5. Erroneous Design Assumptions Hinder Vessel Development

Scientific development of spirits vessels has been hindered by several misleading yet common assumptions gathered by the author and research team from discussions with vessel manufacturers and spirits industry brand ambassadors, presented herein to explain the prevalent mindset and attitude toward a scientific approach to vessel design and application. Each assumption is underlined, directly followed by its *fallacy* in italics:

- Ethanol cannot be separated from other aromas. *Scientific rationale for separation has existed since 1848 with Graham's Law: Until now, Graham's Law has not been applied to aroma separation.*
- Convergent sides and small rim diameters are necessary to collect and concentrate aromas under the nose so none escape detection. *Perhaps logical at first take, the most abundant molecule is ethanol with an attendant anesthetic effect. Convergent rims fail to focus aromas, and concentrate ethanol in a "cloud" which obscures and masks aromas at the rim where nosing occurs, forcing the evaluator to "pick and sort" through the cloud to find definable character aromas.*
- Swirling releases nose-numbing ethanol, do not swirl. *Swirling is necessary to create sufficient aromas for sampling, as many are obscured by the pungency of abundant ethanol. Proven with wine, swirling spirits is the "engine" that releases evaporation, transferring aromas to the nose.*
- Tall, thin vessels focus aromas. *Height restricts higher mass molecules from reaching vessel rims and detection. Lower vessel heights improve likelihood of higher mass aroma delivery. Gravity has some effect on aroma detection in tall, open container vessels.*

These assumptions are explored in more detail in Section 2.2, as they are proven to be misconceptions through methodical vessel engineering.

1.6. Gender Preferences and Mindset Regarding Ethanol Aroma in Spirits

The research team conducted side-by-side consumer vessel comparison tests, sample size $n \approx 2914$, in 2011–2015, performed at spirits events with participating attendees and which clearly demonstrate that 13% of polled male spirits drinkers believe ethanol is an important component of spirit aroma while less than 2% of females prefer ethanol. Repeatability across events and over nearly five years validates the results. The total results by gender are described in Table 3.

Table 3. Male vs. female preferences for ethanol aroma (% by gender). Participants at spirits events were randomly invited to sniff sample the same spirit in a traditional vessel versus the engineered vessel, in a side-by-side comparison without suggestive comment. Spirits varied by event and control spirit choice did not affect participants' preference for ethanol. 13% of the tested male population preferred ethanol in the aromas, as did 2% of the females tested. Approximately 30% of females asked to participate declined because they did not want to smell straight spirits. Study details are presented in Section 2 Methods.

Consumer Test I: Male vs. Female Preferences for Ethanol Aromas					
Event Location	Total Challenges	Male Prefer Ethanol Interviews	Male Prefer no Ethanol Interviews	Female Prefer Ethanol Interviews	Female Prefer no Ethanol Interviews
Las Vegas, Jun 2010 (c)	24	2	14	0	8
Las Vegas Jul 2011 (c)	181	14	112	2	53
New York Feb 2011 (c)	162	18	111	1	32
Monterey Oct 2011 (c)	167	17	82	1	67
San Francisco Mar 2012 (c)	198	15	125	1	57
Santa Barbara Sep 2012 (c)	210	18	142	1	49
Portland Oct 2012 (c)	191	16	141	0	34
Miami June 2013 (c)	182	13	106	1	62
Santa Barbara Sep 2013 (c)	166	19	111	0	36

Table 3. Cont.

Consumer Test I: Male vs. Female Preferences for Ethanol Aromas					
Event Location	Total Challenges	Male Prefer Ethanol	Male Prefer no Ethanol	Female Prefer Ethanol	Female Prefer no Ethanol
		Interviews	Interviews	Interviews	Interviews
Portland Oct 2013 (g)	213	21	136	0	56
New York Nov 2013 (g)	226	24	156	0	46
San Diego Aug 2014 (g)	231	17	118	3	93
Las Vegas Mar 2014 (g)	204	21	123	2	58
New York Nov 2014 (c)	188	23	135	0	30
San Diego Aug 2014 (g)	140	11	89	1	39
Orlando Mar 2015 (c)	159	14	88	1	56
Las Vegas Mar 2015 (g)	72	9	41	0	22
Total by Gender	2914	272/(12.9%)	1830/(87.1%)	14/(1.7%)	798/(98.3%)
Standard Deviation (σ)		2.23%		1.37%	

Female olfactory sensitivity is significantly greater than male. Olivera-Pinto et al. [13], using an isotropic fractionator to count olfactory sensors post-mortem, determined that women have a 43% better sensor count than men. The large difference between male and female preference for ethanol aroma in Table 3 supports significantly higher female sensitivity to olfactory ethanol.

A vessel designed to alleviate olfactory ethanol anesthesia and pain improves participation of more sensitive noses, and could tend to balance gender weighting among straight spirits drinkers.

1.7. The Importance of Ortho-Nasal Aroma Detection in Spirits Evaluation

During evaluation, two different paths of aroma detection deliver different perceptions, ortho-nasal and retro-nasal, and both are subject to ethanol lockout and therefore ethanol anesthesia.

Ortho-nasal smell occurs through nostrils to the anterior of the olfactory bulb and olfactory nerve without palate or mouthfeel sensor input. Ortho-nasal detection is the first exposure and tone-setter for spirits flavor and:

1. assures the evaluator prior to tasting that no known aromas are poisonous or harmful, changing the evaluator's mindset from trepidation "Is it safe to taste?" to relaxed and curious investigation "What do I smell?" "Can I recognize it?" "Do I like it?".
2. previews the aroma set to create anticipation of retro-nasal evaluation, "I smell orange on the nose, I will seek it in the finish". Aroma memories have an effect on perception through disposition to particular aromas. Predispositions are well-known to panel administrators, who disallow conversation during primary evaluation, forcing reliance on individual diagnostic perception to capture first impressions without external suggestive influence.

Ortho-nasal perception is discounted by Carmer's C-STEM method [14], which introduces spirit into the oral cavity first without ortho-nasal sampling, and evaluating from retro-nasal experience only. C-STEM provides a method to avoid ethanol anesthesia by eliminating aroma manipulation of the vessel entirely and eliminating ortho-nasal contact with ethanol aroma.

Subjective evaluations clearly demonstrate that C-STEM consistently and repeatedly yields fewer detectable aromas than traditional sampling which utilizes both ortho-nasal and retro-nasal Table 4. The difference is probably attributable to the importance of ortho-nasal tone-setters 1 and 2 described in the previous paragraph. Although C-STEM is effective in decreasing the probability of ethanol anesthesia by eliminating the ortho-nasal component, it does so at the expense of a well-defined aroma profile by eliminating recognizable aromas, and is not a preferable solution. As in Section 1.4, another attempt to alleviate ethanol anesthesia by manipulation of procedure or evaluation method is adversely consequential to performing high quality diagnostics.

Table 4. Aroma detection comparison. Using a copita vessel, C-STEM evaluations were performed first to eliminate ortho-nasal contributions. Thirty-minute pause, followed by traditional evaluation performed with each control spirit. Testing repeated and verified. Conclusion: Ortho-nasal evaluation may provide a useful benefit to accurate evaluation. Details in Section 2.1 Methods.

Subjective Evaluation II: Methods Comparison—Traditional vs. C-STEM		
Control Spirit	Traditional Evaluation (Ortho-Nasal + Retro-Nasal)	C-STEM Evaluation (Retro-Nasal Only)
Bourbon	10	7
Scotch	7	5
Gin	5	3

Since there is a lack of evaluation methods which provide viable solutions to observed ethanol anesthesia, vessel design must be explored. Retro-nasal contribution to ethanol anesthesia cannot be controlled, but ortho-nasal ethanol can be diverted through engineered vessel design.

Role of Flavor in Vessel Design

Flavor is the combination of smell, taste, and mouth-feel transmitted to the brain's orbital frontal insula and piriform cortex regions for identification or registration. Five basic tastes are attributable to taste buds: sweet, sour, salty, bitter, and umami. Other receptors present throughout the oral cavity affect flavor and mouthfeel such as minty, cool, tannins, hot pepper, metallic, oily, grainy, other textures, temperatures, and chemical receptors are present from lips to gut. The human olfactory can discriminate at least 636 different aromas, according to Godfrey, Buck et al. [4].

Flavor has been described as 90% aroma, 10% taste and mouthfeel. Spence [15] estimates from 75 to 95% aroma contribution to flavor. Food flavors are more diverse than spirits, and the case is hereby made for a 90% aroma contribution to flavor with spirits. With only 5 tastes and significantly fewer mouth-feels and other flavor contributors for spirits versus food, a 90% weighting of aroma for spirits flavor is deemed representative. At 75%, aroma contributes significantly to flavor.

Put simply, one does not taste raspberries, one tastes sweet, 5%, smells raspberry, 90%, and feels the fuzzy fruit and light acids in the mouth, 5%. Signals from the palate and flavor receptors travel through the mandibular nerve, and olfactory and upper oral cavity receptors from the maxillary nerve, along with sight from the ophthalmic nerve combine in a single inseparable information packet transferred to memory for recognition, identification or cataloging. Visual and emotional influences are notable components of evaluation, but must be disregarded, as they relate to personal and individual experiences and are unquantifiable and uncontrollable by known methods. Olfactory perception is the major contributor to flavor.

Engineered vessels which divert ethanol improve detectability and accurately present spirits quality unencumbered by anesthetics. The 90% contribution of aromas to spirit flavor emphasizes the need to control ethanol lockout and anesthesia to prolong evaluator effectiveness and display all available aromas for detection.

1.8. Ethanol Effects during Multi-Sample Judging and Evaluation

Competitions offer unique observation opportunities for simultaneous comparison of evaluators notes, ratings, and variances, and examination of procedures which are key to identifying ethanol anesthesia and improving diagnostic vessel design.

For distillers, competitions are key to quick validation and a cost-effective alternative to traditional advertising. Competitions have developed into profitable businesses, vying to become the consumers' chief source of tasting notes, awards, and ratings. Successful competitions amass large numbers of entrants, and time management is imperative to cost control. Eight or more flights per day with 6–12 samples are common, and evaluators are pushed to judge quickly, with greater risk of ethanol anesthesia.

1.8.1. Observed Ethanol Anesthesia

Ethanol anesthesia is easily detected during panel judging, yet the exact point of onset is difficult to determine. Examination of judges' tasting notes and observations of interactive conversations during judging provide early indications of ethanol anesthesia with traditional vessels and flights of 5 or more samples. During the third flight, written tasting notes frequently lack critical detail.

Near the end of the third flight, many judges have expressed difficulties in recalling descriptive words, and some comment on unrecognizable aromas, note fewer aromas, or describe aroma availability as "tight". Time allotted between individual sample evaluations in a single flight is generally much less than Steinmetz' [8] lower end of range recovery time of 3 min. The results of 4 events with copita vessels conducted by the Arsilica Inc. research team are shown in Table 5.

Table 5. Aroma sensitivity during successive blind panel evaluations (aromas/samples). Panel evaluation events with copita vessels. Number of aromas is the sum total of *different* aromas collected from individual notes. Brown, barrel-aged spirits generally display significantly more aromas than clear. In all events, during the third flight, fewer brown spirit aromas were noted than from clear spirits in prior flights. Audible comments regarding aroma detectability began early during the third flight for each event. Red denotes fewer identified aromas than the previous flight despite a more aroma-laden category. Conversations with evaluators using traditional vessels indicate awareness of difficulty during the third flight of an event. Details in Section 2 Methods.

Simulation I: Aroma Sensitivity During Successive Blind Panel Evaluations						
Judging Event	Flight 1 Vodkas	Flight 2 Gin	Flight 3 Whiskeys	Flight 4 Whiskeys	Lunch Break	Flight 5 Rums
A (4 judges)	4/5	6/6	4/6	3/5	45 min	6/6
B (5 judges)	5/6	7/5	5/8	3/5	1 h	8/8
C (3 judges)	4/7	5/6	3/6	3/4	1 h	5/6
D (4 judges)	5/6	5/6	4/6	4/5	30 min	6/6

Initially appearing as mild intoxication, this is not the case, as evaluators sample less than 22 mL of spirit per sample, spit excess, dump post-sampling residuals, and refrain from swallowing. If lack of attention to key aromas is not due to intoxication, the most probable explanation is the onset of ethanol anesthesia preventing aroma detection. Post-break notes exhibit a return to specifics.

Direct acknowledgments of ethanol anesthesia are few during actual events, either due to reluctance to admit dysfunction, pressure on timely completion, or because evaluators are unaware of their quickly degrading sense of smell. Ethanol anesthesia appears in multiple evaluators simultaneously. Precise point of onset is difficult to establish, but compromised samples would include all in the flight and perhaps some prior, leaving many entrants with flawed evaluations. This research clearly needs additional experimentation to identify precise onset and validate ethanol anesthesia as the suspected issue or discover other possible causes for desensitization.

1.8.2. Collective Ethanol Anesthesia may be a Potential Cause of Competition Event Ratings Disparities

Case Study: A gin distiller, awarded a double gold medal from a prestigious competition, chose to seek an additional medal the following year. The gin was sample 2 of 5 in the second flight for the first competition, and sample 5 of 8 in flight 3 for the second competition, evaluated by 4 judges, it received no recognition. Two evaluators had rated the gin in both competitions. Alerted of the disparity, administrators chose to override judges' opinions and award a gold medal. Probable conclusion: Numerous prior samples may have imparted ethanol anesthesia.

As a consultant to spirits competitions, the author and research team has closely observed and personally monitored over 40 events gathering data on tasting methods and procedures, noting frequent disparities in year-over-year rankings of the same spirit. Some administrators quickly identify

anomalies during the event and correct by encouraging evaluators to adjust to panel peers, and some adjust ratings post-event prior to publication to avoid criticism.

The importance of competition ratings as a reliable consumer reference demands precautions to protect integrity, provide entrants with equal opportunity to receive recognition, and provide consumers with accurate information.

This research presents the case for standardization of an engineered evaluation vessel for all spirits across competitions. Regardless of a spirit's specific material source for ethanol—grain, fruit, agave, cane, or other—coping with ethanol anesthesia is the major hindrance to effective diagnostics and evaluation whether for individual tasting or competition settings.

A functional, standardized vessel levels the playing field for entrants, contributes to ratings comparability across competitions, and improves evaluation quality. A vessel which diverts olfactory ethanol unmasks subtle aromas, improves character aroma detection, alleviates ethanol anesthesia and prolongs evaluator effectiveness in fast-moving competitions. Over 100 competition events using the engineered vessel over 6 years have reported no instances of ethanol anesthesia or aroma detection difficulties (See Supplementary Website S1).

2. Method

2.1. Cited Experimentation Methods: Discussion of all Experiment Methodology in Order of Experiment Appearance

Regarding All Experiments, Tests, and Subjective Evaluations

Validity: Subjective Evaluations I, II, and III of small sample size utilized qualified panelists chosen for their olfactory abilities established the design direction to optimize aroma display and minimize ethanol aroma.

Panelist Qualifications: Panelists chosen for all evaluations except Consumer Test I are persons well-known to the author to have extensive experience in wine and spirits evaluation either as industry executives, avid collectors or aficionados, spirits judges, accomplished mixologists, well trained brand ambassadors, knowledgeable spirits distributors and buyers, sommeliers with a level or degree of certification, tastings and competition organizers or administrators, key peer-respected members of prestigious international spirits clubs, or professional associations. Unless otherwise noted, test panels consisted of 8 selected from a pool of 23 who possess one or more of the above-listed qualifications.

Consumer Test I Participants Were All Random Attendees at Spirits Events

Reliance upon Human Sensory Subjective Evaluations: Spirits diagnostics lacks testing equipment with acceptable correlation to human sensory perception and testing and evaluations continue to rely upon subjective human sensory opinion and taste, which differs depending on the personal experiences of panelists. For this reason, all subjective testing cited must be regarded as directional pending greater sample size studies or suitable equipment to replace human evaluators.

- Snifter, 80 mm inside rim diameter, 130 mm inside height to rim plane;
- Glencairn 45 mm inside rim diameter, 90 mm inside height to rim plane;
- Copita, 40 mm inside rim diameter, 85 mm inside height to rim plane;
- Engineered Vessel, 79 mm inside rim diameter, necked, 35 mm inside height to neck plane;
- Tumbler, 80 mm inside rim diameter by 85 mm inside height to rim plane.

The Glencairn, copita and engineered vessel are designed to hold 45 mL, approximately 1 common retail serving at their best fill at maximum bowl diameter. Unless otherwise noted, all experiments were performed with 45 mL spirit in each vessel, including snifter and tumbler.

Subjective Evaluation I: Existing Common Spirits Vessels

- **Purpose:** Identify and quantify favorable and unfavorable olfactory characteristics due to design and/or shape aspects of nosing and tasting spirits in each of three vessels commonly used in evaluations, particularly regarding the presence of detectable ethanol aroma.

- **Objective:** To identify existing design factors of common evaluation vessels which contribute or detract from objective spirits evaluation due to olfactory ethanol.
- **Materials:** Vessels for each evaluation shown in Figure 2: Control spirits of bourbon, scotch, aged rum, reposado tequila, VSOP cognac, gin, vodka, 45 mL per sample.



Figure 2. Testing vessels utilized in all experimentation.

- **Conditions:** Ambient temperature 24–25 °C, isolated room, free from abnormal noise and distraction, well ventilated and free from perceptible air currents.
- **Methodology:** Subjective evaluation by experienced panelists to assess and estimate ethanol contribution to aroma profiles of various common vessels. These tests are qualitative opinions conducted for experienced internal design direction only.
- **Procedure:** Maximum of three control spirit evaluations were held in a single day, and multiple evaluations were spaced at least 30 min apart to ensure complete olfactory recovery from aroma adaptation prior to subsequent trials. Repeat trials with the same control spirit were performed on different days. Two trials were performed for each control spirit. No taste sampling of spirits was allowed during olfactory evaluations, or between multiple evaluations. Brands, bottles and labels of control spirits were hidden from panelists to avoid familiarity influencing outcome. Each panelist evaluation was individually secluded and monitored to ensure adherence to procedures and enforce the ten-minute time limit per trial. Immediately after individual evaluation completion, notes were collected and panelists were assembled to discuss vessel shape characteristics affecting results. One evaluation consisted of one control spirit, four evaluation vessels sampled in order in anticipation of the effect of shape on induced ethanol anesthesia: tumbler, Glencairn, copita, and snifter. All vessels were covered to prevent ambient aroma mixing and all remained covered except sample being evaluated. Participants were instructed not to swirl, then uncover, smell, recover, and evaluate; then to repeat with swirling for each vessel, noting:
 1. estimated percentage of ethanol vs. other aromas before and after swirling.
 2. rank vessels in order of lowest to highest ethanol detection.

Additionally, ease of swirling was ranked 1–5 for each vessel, 1 being easiest to swirl.

- **Results and Conclusions (Table 2):** Collective comments are summarized in the table. Estimated ethanol aroma percentage is the numerical average of all trials with all control spirits except vodka, for which data was discarded due to high variance in character aroma detection. Estimated ethanol percentage data for all other control spirits were averaged together (individual highest to lowest numerical variance 8%). Panel agreement was unanimous regarding three major design issues: (1) small rim area vessels tend to concentrate ethanol, creating difficulty with specific aroma detection; (2) Glencairn and copita exhibit identical issues with aroma detection, i.e.,

high ethanol concentration, swirling difficulty; (3) snifter vessel promotes ethanol over character aromas by creating an ethanol dominant aroma mixture impeding specific aroma detection. Vessel rank from lowest to highest ethanol was unanimous: tumbler best, snifter second, and Glencairn and copita last, but equal. Swirling is best in snifter, then tumbler, with Glencairn and copita last, but equal. Trial repeats verified results for each vessel with each control spirit.

Consumer Test I: Male vs. Female Preferences for Ethanol Aroma

- **Purpose:** Determine preference for ethanol in the aromas of spirits from two different vessels, a prototype of the subject engineered vessel which dissipates ethanol aroma and a standard tulip vessel which concentrates ethanol.
- **Objective:** To test market the radical design and appearance of the engineered vessel against the widely accepted industry standard vessel and to discover ethanol aroma preferences of men and women who drink spirits “neat”, without water, ice or mixer.
- **Materials:** Standardized vessels used for each evaluation: (1) standard copita, and (2) engineered vessel. Control spirits were always bottled at 40% ABV; bourbons, scotch, rums, blanco and reposado tequilas and gins, 45 mL per sample, approximately a standard single serving which is design capacity or “best fill” for all vessels. Early experimentation from Table 2, Consumer Test I exhibited no difference in ethanol perception between copita and Glencairn, and Glencairn was used in many subsequent trials due to familiarity with event attendees. For reference, (c) denotes copita and (g) Glencairn in Table 2. Additionally, there were no differences in perceptive ethanol for 40% ABV spirits of different origin, grain, fruit, sugarcane, or agave. Control spirits were donated by spirits manufacturers attending the events.
- **Conditions:** Ambient temperature 24–26 °C, large auditoriums, exhibit halls, and hotel ballroom suites, crowded and noisy.
- **Background:** Over a span of nearly five years, Arsilica, Inc. researchers attended spirits industry tradeshow to present a version of the well-known “Pepsi Challenge” at random to those who agreed to participate. Multiple challenges with as many as three stations were employed at several events.
- **Methodology:** AB consumer discrimination testing. Real-world setting with naïve, random, non-screened spirits event attendees with an interest in tasting spirits, no incentives to participate were offered.
- **Procedure:** No taste sampling of spirits allowed, evaluation was restricted to olfactory. All samples remained covered between samplings. Control spirits bottles and brands were visible to participants. Each participant was asked to first swirl and sniff the engineered glass sample keeping nose at the rim plane holding glass level, then to sniff the tulip glass. This order ensured that strong, higher velocity sniffs of concentrated ethanol did not numb noses prior to detecting aromas from the engineered glass. Challenge station moderators asked which was preferred and reasons for choosing, and responses were recorded by gender. Further questioning was directed to males who preferred the tulip aromas with strong ethanol to discover reasons for their preference.
- **Results (Table 3):** The total number of recorded trials is 2914. Of the males who participated, approximately 13% preferred ethanol on the nose, standard deviation 2.23%, and less than 2% of females preferred ethanol on the nose, standard deviation 1.37%, both with 2σ and 95% confidence level confirming previous assertions that women are more sensitive to pungent concentrated ethanol aroma. Further questions were asked of those males who preferred ethanol in the aroma to determine mindset. Results of these questions uncovered a particular attitude among male spirits drinkers, which is noteworthy and should inspire additional research to determine reasons for preference of ethanol. Polled participants attended events for the purpose of sampling straight spirits offerings from distillers or distributors and were familiar with drinking spirits straight, neat, no ice, water, or mixer.

1. How old are you? Two-thirds of polled males preferring ethanol aroma are over age 45, suggesting a cultural difference toward ethanol for younger males. Unfortunately, the importance of this question was lost on the research team, and ages were not recorded for the entire polled population.
2. When do you generally drink straight spirits? Most common responses were: with friends and acquaintances, “guys night out”, happy hour after work, bachelor and birthday parties, watching sports, and other male gender-specific activities. Many commented that females seldom attended spirits drinking group activities.
3. The mindset of males who preferred ethanol is summarized in comments after sniffing the engineered vessel. Of the 13% of males who preferred ethanol aroma, many insisted that the engineered vessel must contain a lower-quality spirit and 63% of those commented that higher presence of ethanol indicated higher quality. Of males preferring ethanol, just over a third considered themselves above average in knowledge of their favorite spirits. Additionally, the 13% of males preferring ethanol disliked the engineered vessel for the most common reasons in order of frequency (1) “I use the Glencairn”; (2) “There is no aroma”; and (3) “...it looks like a flower vase or spittoon or goldfish bowl”. Preference and intent to follow the vessel identified with and supported by industry was well apparent in the responses of the majority of the 13% of males who preferred ethanol aromas.

Not all subsequent questions were exactly the same and were asked by monitors as attitudinal probes into casual conversation without structure, as the single-minded objective was to determine ethanol preference by gender. For this reason, comments reported in items 1, 2, and 3 are indications subject to further research for substantiation, and are included to note potential difficulties of changing straight spirits drinkers’ mindsets.

- **Conclusions:** The vast majority of participants preferred no ethanol on the nose, and most of those that preferred ethanol had opinions that ethanol belongs in the aroma of spirits. The vast majority of females preferred no ethanol, supporting the referenced study that females have more sensitive noses than males.

Subjective Evaluation II: Methods Comparison—Traditional vs. C-STEM

- **Purpose:** Compare spirits aroma detectability of retro-nasal spirits evaluation only versus traditional evaluation which includes both ortho-nasal and retro-nasal sampling.
- **Objective:** To determine if retro-nasal CSTEM evaluation method provides as much aroma information as long-held method which utilizes ortho-nasal first, then retro-nasal evaluation sometimes called “finish”.
- **Materials:** Copita used for all evaluations, with control spirits of bourbon whiskey, scotch whisky, and gin, all 40% ABV. Aged and botanical spirits demonstrate higher aroma availability for evaluation, and unaged spirits and vodka were not considered.
- **Background:** Proposed C-STEM method introduced by Adam Carmer [14] to eliminate vessel shape effects on spirits aroma presentation, and alleviate ethanol olfactory fatigue. The C-STEM method is performed in three steps: (1) do not smell or swirl spirit prior to tasting, as different vessels deliver different aroma presentations; (2) place liquid sample directly in oral cavity; (3) slosh around, over and under tongue, and hold long enough to mix saliva secretion with spirit until palate pain subsides; (4) swallow, note retro-nasal aromas.
- **Conditions:** Ambient temperature 24–25 °C, isolated room, free from abnormal noise and distraction, well lit, well ventilated and free from perceptible air currents.
- **Methodology:** Subjective evaluation by experienced panelists to determine aroma detectability excluding ortho-nasal evaluation to determine ortho-nasal aroma contribution.
- **Procedure:** Multiple evaluations were spaced at least 30 min apart to ensure complete olfactory recovery from possible aroma adaptation. No taste sampling of spirits was allowed during

olfactory evaluations or between multiple evaluations held on the same day. Each panelist was monitored by a member of the research team to ensure compliance with procedure. Brands and labels of control spirits were not disclosed to panelists. Panel of eight participants evaluated three control spirits. C-STEM evaluations performed in accordance with the C-STEM method, recording each different aroma detected during each control spirit trial. Trials were repeated with the traditional method, smell and evaluate ortho-nasally, taste and evaluate retro-nasally.

- **Results (Table 4):** Data from all eight panelists, counting only unique aromas:
 1. Bourbon:
 - a. First trial set. *C-STEM* method—the total number of different aromas detected by all panelists from bourbon sample was 7: ethanol, spice, charred oak, honey, orange, vanilla, caramel. *Traditional* method yielded 3 additional aromas of floral, butter, and nuts.
 - b. Second trial set. *C-STEM* method—the total number of different aromas detected by all panelists from same bourbon sample was 7: ethanol, honey, vanilla, orange, nuts, butterscotch, and spice. *Traditional* method yielded 4 additional aromas of caramel, butter, fruit, floral.
 2. Scotch:
 - a. First trial set. *C-STEM* method—the total number of different aromas detected by all panelists from scotch sample was 5: ethanol, honey, caramel, spice, and butter. *Traditional* method yielded 2 additional aromas of floral, lemon or citrus.
 - b. Second trial set using same scotch sample was a repeat of first trial set.
 3. Gin:
 - a. First trial set. *C-STEM* method—the total number of different aromas detected by all panelists from gin sample was 3: ethanol, juniper, and licorice. *Traditional* method yielded 2 additional aromas of floral and lemon or citrus.
 - b. Second trial set. *C-STEM* method—the total number of different aromas detected by all panelists from same gin sample was 3: ethanol juniper, and licorice or cardamom. *Traditional* method yielded 2 additional aromas of spice and floral.

All three control spirits displayed more detectable aromas using the traditional method versus the C-STEM method. Although C-STEM alleviates ethanol anesthesia, there are fewer unique aromas detected in the total aroma profile.

- **Conclusion:** C-STEM is not an acceptable evaluation method to alleviate ethanol anesthesia during evaluation diagnostics, due to unsatisfactory aroma detection most likely caused by elimination of ortho-nasal component of evaluation.

Simulation I: Aroma Sensitivity during Successive Panel Evaluations

- **Purpose:** Determine the point at which ethanol anesthesia begins to affect spirits competition judges' ability to evaluate and rate spirits through simulation of a competition event with a tulip style vessel.
- **Objective:** Simulate spirits judging competitions and evaluate unique aroma detection to determine precise occurrence of ethanol anesthesia, and possible causal factors.
- **Materials:** Copita vessels as shown in Figure 2. Various spirits in 20 mL samples supplied by Arsilica, Inc., varied by event. Dump buckets provided for each panel were replaced clean for every flight to avoid aroma pollution. Score sheets describe each sample with respect to standard competition category and construct, including pertinent details such as ABV, blended or not,

source of ethanol. Brand names, geographic distillery locations were excluded, and samples were prepared out of sight of judges.

- **Background:** By observing competitions which use a copita-style nosing glass for judging and evaluation and discussing occurrences of olfactory fatigue with competition administrators and many experienced judges, Arsilica, Inc. researchers discovered that during most competitions, judges appear to fail at detecting significant aromas and their written tasting notes begin to lack critical detail by the third flight of samples. Many judges express difficulty in describing aromas, detect unrecognizable aromas, or complain that aromas are not evaporating from the spirit because it is “tight”. Many competitions are under pressure to complete judging in a single day and push to complete as many flights as possible in a short amount of time, also increasing the number of samples per flight. During competitions, the next flight to be evaluated is poured ahead of completion of the flight being evaluated, and as tables from the completed flight are bussed clean, the new flight is being placed in front of the panelists to save time for completing the event. Recovery time from ethanol aroma adaptation is not factored into the timing of flights, sample sizes are approximately 20 mL, judges are instructed to dump and spit residual spirits, none appear to be intoxicated or inebriated, speech and eye clarity, where noted, is normal.
- **Conditions:** Ambient temperature 24–25 °C, isolated room, free from abnormal noise and distraction, well lit, well ventilated and free from perceptible air currents. White table cloth background for best lighting, all judges seated at a single table. All samples covered to prevent ambient aromas from affecting aroma counts.
- **Methodology:** Quantitative spirits evaluation simulating real-world competition event procedures and timing using experienced evaluators qualified to judge competition events. Number of judges, samples, and flight arrangements are well within the scope of most existing competitions.
- **Procedures:** Maximum number of samples set at 8 to simulate sample sizes noted through prior event participation. Flights similar to competitions with clear, unaged spirits first. Order of flights in all event simulations were (1) Vodka; (2) Gin; (3) Barrel-Aged Whiskeys; (4) Barrel-Aged Whiskeys; (5) Rums. Four flights prior to a long break could confidently provide the necessary number of evaluations to induce ethanol anesthesia as its approximate point of occurrence as determined from discovery and event experience, and a single flight post break is sufficient to ensure olfactory recovery from aroma adaptation. Although many competitions may have more than one flight of vodkas and gins per panel, whiskeys were purposely set for flights three and four to provide spirits with more inherently available aromas to detect during a time frame in which suspected ethanol anesthesia occurs in actual competitions. Judges differed for each event, but were the same for all flights of a specific event. Judges were instructed to maintain silence and note each and all aromas on their score sheets from both ortho-nasal and retro-nasal traditional evaluation, which were then removed from the tables when all judges had completed notation to prevent post-evaluation changes or additions. As in actual competition, judges were allowed to resample, discuss and assign mock award levels based on the commonly used system of double gold, gold, silver, bronze, and no award, prior to bussing and resetting for next flight. Performing this procedure accurately simulated actual competition timing. Judges were instructed to spit after sampling and dump residual spirits. Monitors ensured adherence to spit and dump procedures to prevent possibility of intoxication during evaluations.
- **Results (Table 5):** Please note that data is expressed as number of aromas/number of samples. The first flight of vodkas exhibited a high number of aromas in every event simulation, similar to actual competitions, as judges are fresh and at their best. The gin flight also produced many total aromas in all event simulations. Aged whiskeys commonly display about eight detectable aromas, yet judges determined only 3–5 unique aromas in flight three, with similar performance in flight four for each event. Aroma count correlates to discussions with experienced judges who

readily admit difficulty in aroma detection by the third flight regardless of spirit. For all events, elapsed time to complete 4 flights averaged $2\frac{1}{2}$ h, maximum variance 27 min.

- **Conclusions:** Close examination of results and procedures did not uncover specific causal factors for the apparent occurrence of ethanol anesthesia in flight three and continuing into flight four according to aroma count. Determination of the point of ethanol anesthesia onset or possible causal factors were inconclusive. The onset could have begun as early as sometime during the group discussion, post silent evaluation, of previously evaluated flight 2. No obvious flaws in procedure were noted. As suspected from discovery, simulated competitions appear to validate the occurrence of ethanol anesthesia, yet there was no conclusive determination as to point of occurrence or causal factors. Flight five results validate that a long break restored olfactory sensitivity and recovery from aroma adaptation was complete during each event. The occurrence of ethanol anesthesia could be alleviated by; (1) using a vessel which dissipates ethanol away from the nose; and (2) specified longer break periods between flights to ensure that recovery from aroma adaptation occurs prior to each flight, possibly inserting a break after every two flights.
- **Post-Simulation Field Testing of Engineered Vessel:** The engineered vessel has been used in over 100 competition events over a period of 6 years, with no reported instances of ethanol anesthesia. Over 40% of those competitions were monitored onsite by Arsilica, Inc. researchers and tasting notes and observations resulted in no degradation in expected aroma counts detected per panel prior to mid-day break, which included 4–5 flights prior, and no complaints of aroma detectability.

Subjective Evaluation III: Aromas Detected in Bourbon as a Function of Distance

- **Purpose:** Determine spirit aroma detectability as a function of nostril distance from liquid surface.
- **Objective:** Establish the maximum height from the liquid surface to the nostril at which one can detect the highest unique aroma count.
- **Background:** General assumptions of ideal gas behavior and random molecular motion in a closed system is frequently and mistakenly applied to an open system. In an open system, molecules are continually leaving the container to be replaced by those evaporating at the liquid surface. Gravitational effect on molecular mass and complex molecular shape are commonly acknowledged as the reasons that more aromas are detectable closer to the liquid surface.
- **Materials:** The tumbler pictured in Figure 2 was used with various fill levels to achieve different evaluation heights. The tumbler was chosen as the test vessel as being large enough to minimize vessel manipulation of ethanol and aroma profiles. Control spirits of bourbon, scotch, tequila, gin, cognac, aged unspiced rum, and vodka.
- **Conditions:** Ambient temperature 24–25 °C, isolated room, free from abnormal noise and distraction, well lit, well ventilated, yet free from perceptible air currents.
- **Methodology:** Monitored individual spirits evaluation in laboratory conditions by experienced evaluators to determine a critical design dimension for aroma detectability.
- **Methods and Procedures:** Eight panelists for each trial were each supplied with a single tumbler control vessel, marked with a vertical masking tape level indicator to denote liquid fill levels for surface to rim plane heights of 7, 5, 3, 2.5, 2, and 1 cm. Panelists were instructed and monitored to sniff and note aromas with vessel flat on the table, positioning nostril opening at the rim plane. Panelists were allowed to relocate nostrils to different horizontal positions within the rim plane, maintaining same vertical proximity to the spirit level. When evaluation at a single level was complete, the vessel was filled to the next level and test sniffing repeated, until the level reached 1 cm below the rim plane. Level evaluations were spaced every 10 min to ensure recovery from possible aroma adaptation. Liquid was stirred at each level to generate evaporation. Data was recorded on the same page in successive columns left to right in decreasing surface to rim plane heights. Aromas recorded from previous fills remained on the data sheet for reference. Each control spirit was evaluated twice in separate trials and repeatability was verified.

- **Results (Table 6):** The table denotes aromas detected from the single bourbon control spirit trial for all panelists, and specifies additional unique aromas noted at each successive fill for each panelist. Bourbon, scotch, anejo tequila, aged unspiced rum, and cognac all required a maximum of 2.5 cm to detect all available aromas. For vodka, all aromas, that is no additional aromas were detectable below 5 cm.

Table 6. New aromas detected in bourbon as nose moves closer to liquid surface. Determined empirically, 2.5 cm is the maximum critical distance for complete aroma detection. Fluid levels were adjusted to decrease distance between liquid surface and rim plane in a large graduated tumbler. Panelists recorded new smells detected at each level. Tests were repeated with different control spirits yielding similar results. The control spirit shown is a common 40% ABV bourbon. See Section 2, Methods. Distances above 2.5 cm significantly affect aroma detectability.

Panelist	7 cm	5 cm	3 cm	2.5 cm	2 cm	1 cm
1	ethanol	-	butter, caramel	honey, floral, vanilla	oak	spice
2	ethanol	nuts	honey, floral, caramel	vanilla	spice	-
3	ethanol	spice	butter, honey, vanilla	flowers, wood	butterscotch	-
4	ethanol	-	almonds, honey, vanilla	caramel, orange	wood	-
5	ethanol, floral	butter	honey, vanilla	lilac, caramel	spice	-
6	ethanol	-	nutty, honey, vanilla	orange, spice	-	-
7	ethanol, floral	-	butter, caramel	vanilla, honey, spice	-	-
8	ethanol	-	roses, honey	vanilla, caramel,	wood, spice	-

- **Conclusion:** Subjective evaluation reveals that nostril height from surface of the liquid is important to detecting aged spirit aromas, and 2.5 cm is sufficient rim height for diagnostic evaluation. Larger mass aromas become more detectable as nostrils approach liquid surface. See Table 7 for molecular mass of many aromas. Molecular mass affects aroma detectability. Detectability by molecular shape is beyond the scope of this evaluation but may be important. Other chemical properties such as vapor pressure, hydrophobicity and solubility are important as well but will not be addressed here.

2.2. A Scientific Approach to Vessel Design and Dimensions

Systematic examination of vessel dimensions for state-of-the-art physical science and sensory considerations provides directional dimensional definition and functional improvement. Each key dimension plays a functional role in ethanol separation and ethanol anesthesia prevention. Ergonomics is also a major consideration when establishing dimensions to preserve vessel utility.

Aromas have been traditionally considered as a homogeneous gas, physically inseparable into its various molecular components. At the molecular level, aroma is a heterogeneous and separable mix of many different homogeneous gases. Separability redefines the aroma mixture in spirits evaporation as a heterogeneous gas. An orifice and expansion chamber provide the means and a path for ethanol separation through diffusion as described by Graham's law, which has been applied as the initial means of separating ^{235}U from ^{238}U , contributing to the success of the Manhattan Project.

2.3. Vessel Bowl Diameter Ergonomics and Improving Swirling

Bowl diameter must be large enough to permit high swirling velocities and larger wetted areas, significantly improving evaporation, yet not too large to handle ergonomically. Arsilica, Inc. (Las Vegas, NV, USA) ergonomic evaluation studies determined a maximum diameter of ≈ 80 mm achieves best swirling, or largest bowl diameter without holding and handling issues.

Swirling breaks surface tension enhancing evaporation. Large bowl diameters increase wetted sidewall area and improve evaporation through these different means:

- after swirling, downward flow of fluid on vessel sidewall results in “legs” or tears” caused by the surface tension gradient between cohesive water and ethanol, disrupting surface tension and improving evaporation as they tend to separate, known as the Gibbs-Marangoni effect.
- gravity creates vertical shear on vertical vessel sides, disrupting surface tension and improving evaporation as liquid returns to the liquid pool.
- thin wetted liquid layers on the vessel sidewalls create a quick, short path for rebounding molecules to break surface tension, improving evaporation; whereas the large volume of a liquid pool tends to absorb the motion of molecules rather rebounding to test surface tension.

Evaporation from thin fluid layers on vessel sidewalls is greater than at the pooled liquid/air interface. Increased sidewall area by increasing vessel diameter enables higher swirl velocities. Higher velocities increase liquid/air interface pressure differential, evaporation layer thickness, and horizontal liquid shear breaks surface tension, analogous to faster pool water evaporation on a windy day. Thus, larger bowls improve aroma availability when swirling.

Table 7. Diffusion rates of many aromas of distillate compounds. Comparing two of the mixed gasses, highlighted in yellow; CIS-3-Methyl-4-octanolide, mol mass 264.26 gm/mole, and ethanol, mol mass 46.07 gm/mole, the lactone rate of diffusion is 42% of ethanol, slowest to diffuse, and detected near center rim plane. Ethanol diffuses fastest and is the most abundant molecule detectable at the vessel rim lip. Slowly sniffing at the rim plane confirms aroma positions.

Compound	Aroma	Mol Mass	Diffusion Rate	Location	Type
CIS-3-Methyl-4-octanolide	spicy coconut	264.26	0.42	center	lactone
Ethyl propanoate	fruity, rum, molasses, eggnog	211.28	0.47	center	acid ethyl ester
TRANS-3-Methyl-4-Octanolide	wood, coconut, honey	208.21	0.47	center	lactone
2-methyl propanol	malty, dark chocolate	192.12	0.49	center	aldehyde
β -Damascenone	rose, grape, earthy, green floral	190.28	0.49	center	ketone
Syringaldehyde	spicy woody	182.17	0.50	center	aldehyde
Gamma-Decalactone	peach, apricot	170.25	0.52	center	lactone
Eugenol	medicinal, spicy cloves	164.20	0.53	mid	phenolic
Vanillin	sweet vanilla, creamy	152.15	0.55	mid	aldehyde
Ethyl Hexanoate	sweet apple, pineapple, waxy	144.21	0.57	mid	acid ethyl ester
2-methyl-3-(methyldisulfanyl) furan	meat, sulfur	140.14	0.57	mid	heteroaromatic
Isoamyl Acetate	banana, pear, ripe	130.18	0.59	mid	acid ethyl ester
Sotolon (caramel furanone)	caramel, maple, fenugreek	128.13	0.60	mid	lactone
Guaiacol	peat smoke, spice, leather	124.14	0.61	mid	phenolic
Phenethyl alcohol	floral, rose	122.16	0.61	mid	alcohol
Ethyl isobutyrate	butterscotch	116.16	0.63	mid	acid ethyl ester
Meta-Cresol	band-aid	108.14	0.65	mid	phenolic
Ortho-Cresol	medicinal, sweet phenolic	108.14	0.65	mid	Phenolic
Para-Cresol	medicinal, sweaty, pig-sty	108.14	0.65	mid	phenolic
Hexanal	green grass, vegetal, leafy	100.16	0.68	mid	aldehyde
Furfural	almond, grain	96.08	0.69	mid	aldehyde
Diacetyl	butter	86.09	0.73	rim	vicinal diketone
Ethyl Alcohol	ethanol	46.07	1.00	rim	alcohol

2.4. Vessel Height

Spirits are a mixture of 40%+ ABV, and water and traces of compounds which carry aromas and flavor. Ethanol has a higher vapor pressure, and lower surface tension and boiling point than water (Table 1), and evaporated ethanol concentration is much higher than evaporated water due to molecular hydrogen bonding, despite water’s lower molecular mass. Experiment: observe two identical vessels, one filled with water, one with spirit to the same level; twelve hours later, liquid level is highest in the water vessel.

As opposed to the random motion assumed in a closed system, in an open system, molecular motion is an upward flow, with aromas moving to the vessel rim and dispersing, replaced by more evaporating molecules below. Molecules of complex shape and higher mass frequently drop back into the liquid without reaching the rim, with detectability correlating with vessel rim height from the evaporation surface of the liquid Figure 3. Experiment: place 10 mL of whisky in a 100 mL

laboratory-graduated cylinder and smell, noting detectable aromas beginning with ethanol. Add new aromas to the list as they are detected during subsequent additions of whisky in 20 mL increments. Note that more aromas become detectable as liquid level rises to the rim proximity where the nose is placed to detect new aromas. Also see Subjective Evaluation III and Table 6.

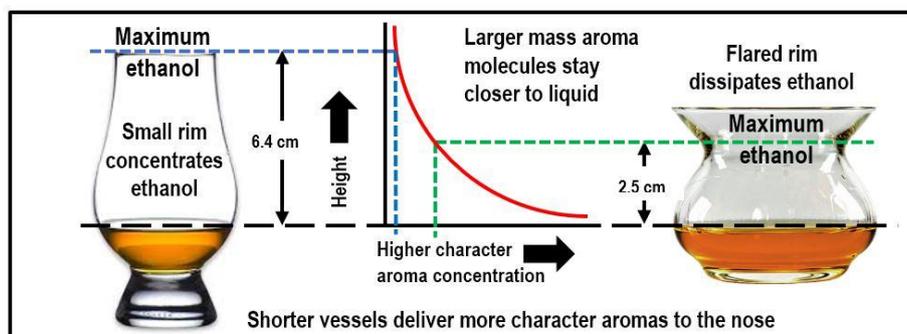


Figure 3. Short vessels deliver more character aroma. Open systems have lower concentration of higher-mass molecules near the rim than at the liquid surface. The difference in mass between ethanol at 46.07 gm/mole and an oak lactone at 264.26 gm/mole translates to larger masses directionally more abundant closer to the liquid surface. Complex molecules (long chains, higher molar mass) have greater difficulty moving upwards due to gravitational effects and imperfect molecular collisions. Ethanol concentration of total aroma increases as nostril position moves higher above the liquid surface. Short vessels improve heavier complex molecule detection. The majority of spirit aromas available are detectable when the distance between liquid surface and rim or maximum concentration plane is under 2.5 cm Table 6.

2.5. Convergent Rim vs. Divergent Rim

Convergent rim is defined as vessel sides that converge, creating a rim plane area smaller than the maximum bowl plane area. Convergent rims compress rising flow of aromas. Divergent vessels have larger horizontal rim plane areas, allowing molecules to disperse freely upon evaporation and escape, controlled by rim angle and vessel side length (ramp) (Figure 4).

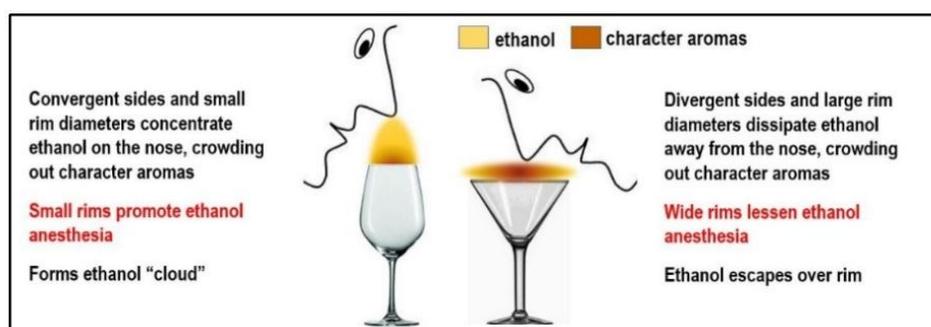


Figure 4. Small convergent rims contribute to ethanol anesthesia. Note “cloud” shapes over vessel rims. Extensive experimentation by Mitsubayashi et al. [16], using an infrared “sniffer-camera” to photograph ethanol cloud shapes created by different vessel shapes through a catalytic coated mesh validates the ethanol evaporation patterns shown. Prior to Mitsubayashi, cloud shapes could not be imaged, since infrared does not detect ethanol. Previous cloud “boundaries” were empirically determined by careful nosing.

2.6. Synergy of Combining Both Configurations Separates Ethanol

Combining both designs and adding a restriction provides an orifice to separate ethanol and character aroma molecules. Restriction increases molecular collisions and divides vessel into two chambers:

1. lower, below the restriction, is the evaporation chamber, in which evaporated aromas are encouraged to vaporize by swirling to wet vessel side walls.
2. upper, above the restriction, is the expansion chamber, controls dispersion and diffusion of molecules compressed in the neck and directs expanded higher velocity ethanol molecules over the rim and away from the nose. The straight, linear lip from neck to rim defines a volume bounded by the orifice and rim planes, and provides an unobstructed, controlled escape path and expansion volume for diffused molecules (Figure 5).

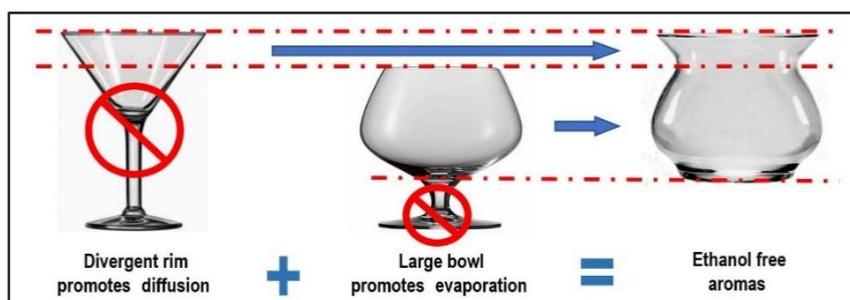


Figure 5. Advantages of combining two shapes. Large convergent vessel bowl improves swirling evaporation, ensuring that more aromas reach the orifice or neck, to be diffused by the divergent expansion chamber. Orifice height of the engineered vessel is well below 2.5 cm.

2.7. Application of Gas Kinetic Theory and Graham's Law

Applying gas kinetic theory explains the ethanol separation process:

1. Convergent sides concentrate molecules increasing collisions and small molecule velocities. From the kinetic energy equation:

$$v_p = \sqrt{2 \frac{k_B T}{m}}, \text{ where } k_B = \text{Boltzmann constant, } T = \text{temperature } ^\circ K. \quad (1)$$

Particle velocity is inversely proportional to the square root of its mass. Convergent bowl increases molecular flux and impingement rate at the orifice, imparting higher velocities to lower mass molecules, especially lowest mass and highly abundant ethanol.

2. Divergent sides allow dissipation. Applying Graham's law to compare diffusion rates of two gas components, the equation becomes:

$$\frac{Rate_1}{Rate_2} = \sqrt{\frac{M_2}{M_1}}.$$

Substituting an arbitrary diffusion $Rate_2 = 1.00$, and a molar mass of 46.07, to represent ethanol, the aroma diffusion rates of other aroma molecules are calculated as a percentage of the fastest diffuser, ethanol (1.00).

Diffusion rates serve to approximate their detection positions in the rim plane. Quick inhalation and external air currents can disrupt position. Diffusion progresses upwards above the rim plane and outward from the central axis toward the rim in order of descending mass (Table 7).

Larger rims improve detection over convergent rims, which display character aromas in an ethanol cloud (Figure 6). Ethanol falls to the ground away from the nose as it travels over the rim in a static atmosphere, as air = 29 g/mol, ethanol = 46 g/mol.

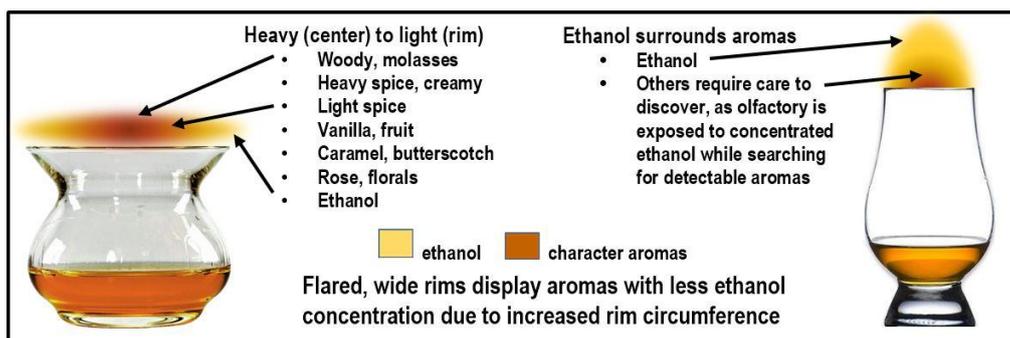


Figure 6. Engineered vessel displays aromas for easy detection. Sampling a common whiskey, aromas are empirically detectable and identifiable at positions shown in the left figure. Larger rim circumference provides a triple ethanol dilution factor, π , significantly decreasing propensity for ethanol anesthesia and distinctly displaying aromas from center to rim. Different spirits = different aromas. Using GCMS spikes as identifiers, approximate detection positions of lower concentrated aromas including unaged clear spirits may be calculated.

2.8. Ethanol Path after Separation

Abundant ethanol must have space to occupy if it is to be diverted. Linearly straight, angled expansion chamber sides control exit path and provide expansion volume and a convenient reference location at rim to position nostrils near the vessel central axis as a starting point.

2.9. Lip Angle

To provide adequate expansion volume for diffusion and diversion of separated ethanol molecules, lip angle must be sufficiently large. A 40° outward angle creates adequate expansion for 40% ABV spirits. No difference in aroma was detected by reducing angle from a theoretically ideal 45° to 40° , yet aroma display was compromised at 35° , due to incomplete ethanol separation, compromising aroma definition. Angles greater than 45° perform similarly to a rim edge termination as attendant outward angles increase. Spills increase as lip edge is angled outward, introducing an awkwardness similar to drinking from a saucer.

2.10. Nose Position

A standard position for nostril placement provides a fixed reference point to begin evaluation. Beginning evaluation with nose placed in a location of least ethanol exposure contributes to ethanol lockout avoidance. Place lips on vessel rim and tilt nose forward to the central axis-rim plane intersect (Figure 7). Average adult central maxillary incisor length and attending physiological measurements triangulate to establish diameter to 79–80 mm (Table 8). Placing lips on the rim of traditional vessels positions nostrils at or beyond the opposite vessel rim.

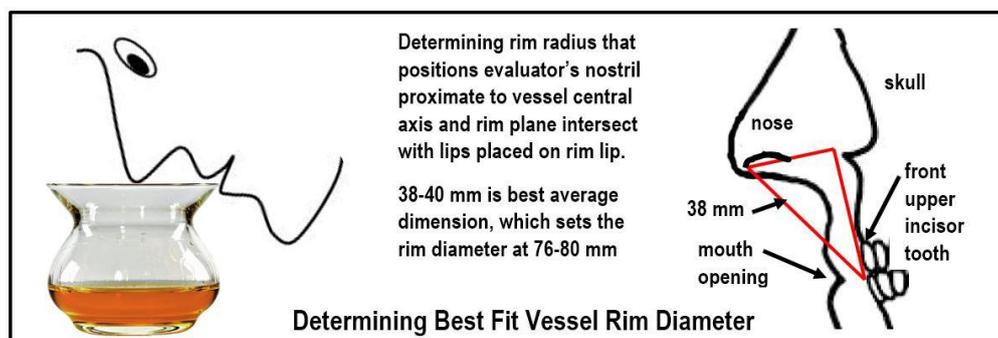


Figure 7. Establishing vessel rim size.

Table 8. Vessel rim radius calculation. Rim plane radius of the engineered vessel is 39 mm.

Source of Data	Avg. Length (mm)
Adult permanent maxillary central incisor length (7 sources)	23.5
Skull nasal opening to incisor root end (5 sources)	7
Flesh at lower nasal passage over skull (approximation)	2
Upper lip below incisor edge (approximation)	2
Total vertical leg distance (skull upright)	34.5
Total horizontal leg distance (skull upright, approximation)	17
Hypotenuse calculation (approximate vessel radius)	38.45

2.11. Sizing the Orifice

Sizing involves olfactory evaluation of different orifice area sizes to permit discernable ethanol separation and sufficient cross-sectional area to provide:

- smooth, gradual unobstructed flow from expansion chamber into orifice
- flow compression to increase molecular collisions raising lower mass particle velocities
- quick ethanol expansion, diffusion and controlled escape
- wide character aroma display inside the rim away from ethanol dispersion.

Evaluation with the wide aroma spectrum of different control spirits determined that orifice area reduction is most effective at 40%, for complete ethanol expansion and separation. Sizing rim diameter to 79 mm, slightly smaller than the 80 mm. maximum bowl diameter, and applying 40° lip angle results in a best orifice size of 51 mm.

Positioning the orifice below the rim lowers effective height between liquid surface and orifice plane where maximum aroma concentration occurs, to 2.5 cm, increasing certainty of detecting higher mass character aromas as shown (Figure 3).

2.12. Shape Curve

The most efficient shape curve is determined by:

- maximizing evaporation area of liquid surface at lower fluid levels during drinking by maintaining large bowl diameters at lower fluid levels in fill portion of evaporation chamber;
- permitting aromas to flow smoothly and uninterrupted into the orifice;
- sidewall curvature to facilitate swirling without spilling;
- providing uninterrupted ethanol flow along divergent surface to rim in expansion chamber.

2.13. Vessel Volume

Vessel maximum design capacity is 45 mL when filled to maximum bowl diameter, which is also the common pour in bars and restaurants for straight spirit servings. Higher fill reduces evaporation volume and impedes swirling. For evaluation, 14 mL provides sufficient sample to swirl and evaluate with no difference in aroma detection. A 20 mL fill provides adequate detection insurance.

2.14. Dimensions and Shape of the Engineered Vessel

Combining all engineered design parameters renders the vessel shape and dimensions described in Figures 8 and 9.



Figure 8. Spirits nosing and tasting vessel engineered by physical science. Note the advantages of the design for each specific area of the final shape (Additional description at Supplementary Video S2).

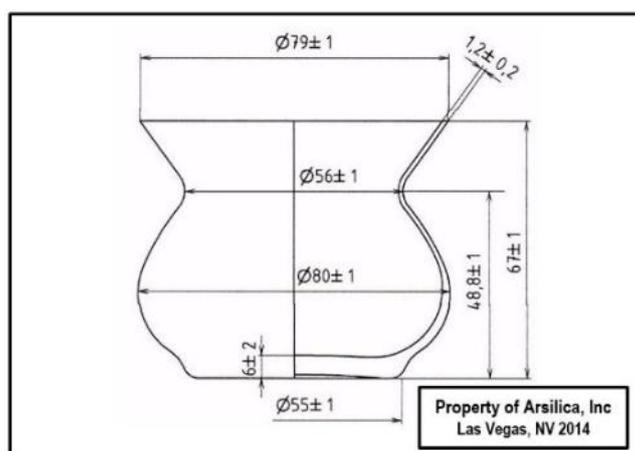


Figure 9. Manufacturing specifications (Dimensions in mm, Supplementary Video S3).

2.15. Manufacturing Dimensions of Subject Engineered Vessel

The engineered vessel is currently being produced in Europe, with dimensions as noted in Figure 9. The manufacturing process is machine blow-molded in Europe from European Union standard crystalline.

2.16. Recommended Vessel Usage and Nosing Procedure

1. Fill to maximum bowl diameter, 45 mL. Note: 20 mL sufficient for evaluation only;
2. Cover vessel when not sampling to prevent aromas from tainting atmosphere and allow equilibrium to occur, about 5–10 s, further intensifying sample aromas;
3. Swirl vigorously prior to each nosing, position vessel under nose, uncover;
4. Holding vessel level, place nostrils over rim plane intersect with central vertical axis with closed lips placed on vessel rim to aid in central nostril placement. Caution, placing nose into or below orifice plane exposes olfactory to highly concentrated ethanol;
5. Keep mouth closed, inhale lightly and slowly through nostrils only to sample;
6. Move nose radially along rim plane slowly toward rim edge to detect lighter aromas. Highly diluted ethanol and volatile aromas appear at rim edge;
7. Evaluate ortho-nasal aromas and take notes;
8. Sip, taking only enough spirit into oral cavity to completely coat oral cavity including palate, roof, sides, under tongue, bringing all available sensors into play;
9. Hold in oral cavity, slush until saliva assuages palate burn, open mouth;
10. Smack tongue against upper palate while lightly mouth breathing to break increased surface tension from saliva. Close mouth to savor, and evaluate retro-nasal finish;

11. Record notes, replace cover, return later and re-evaluate to verify or expand description;
12. Do not add water to spirits as all aromas will shut down from increased surface tension. The vessel adequately redirects ethanol to prevent nose pain or ethanol anesthesia. If palate pain is an issue, pour spirit into a separate vessel to add water to oral preference, and continue to sample original for olfactory diagnostics only.

3. Results of Testing:

Subjective Evaluation I, also described in Table 2 and Section 2.1, enumerates the advantages and disadvantages of the three most common shapes of vessels used to evaluate spirits by the public and competitions: the tumbler, the tulip shape, and the snifter. None of the three design shapes were created with consideration for ethanol anesthesia. Tulip shapes have long been set forth as the industry standard, at least in the Scotch whisky industry, for identity purposes, and diagnosticians and other spirits industry segments have followed their lead for lack of a functional vessel or scientific knowledge regarding the effectiveness of commonly utilized tulip shape vessels.

Consumer Test I, also described in Table 3 and Section 2.1, demonstrates conclusively that female noses are more sensitive to highly concentrated ethanol. Subsequent questioning reveals a mindset regarding the 13% of males that prefer ethanol on the nose, that widespread acceptance of tulip shaped vessels is completely ingrained into the public mindset; in the opinion of the author, this attitude cannot be changed without focused re-education regarding the science applied herein.

Subjective Evaluation II, also described in Table 4 and Section 2.1, validates the ortho-nasal olfactory as necessary to the diagnostic and evaluation process, emphasizing the need to use an external means, e.g., vessel design, to avoid ethanol anesthesia without compromising aroma profile.

Simulation I, recreating four competition events in laboratory conditions reported in Table 5 and Section 2.1, verifies that overexposure to ethanol using tulip shape vessels without sufficient recovery times is likely, and the occurrences of ethanol anesthesia verified the results predicted from initial discovery interviews and researchers, competition experience. However, the precise onset of ethanol anesthesia could not be determined. Diagnostic results, ratings, and rewards in competitions become unreliable, placing some entrants at a disadvantage if the problem of ethanol anesthesia in competitions is not dealt with by either choice of judging vessel or more frequent break times to allow aroma adaptation recovery. Common tulip vessels conclusively contribute to ethanol anesthesia and therefore adversely affect judging and ratings reliability, especially when compared to field experiences which cite no occurrences of ethanol anesthesia with the engineered vessel.

Subjective Evaluation III, described in Table 6 and Section 2.1, demonstrates that nostril distance from spirit surface affects number of detectable character aromas and establishes a distance of 2.5 cm maximum for complex aroma aged spirits. Detectable aromas are enhanced by vessels which allow nostril positioning closer to liquid surface, and shorter vessels improve aroma detection.

Subjective Evaluations I, II, and III are necessary to the total design process and represent subjective, yet educated, experienced judgment necessary to narrow design choices; they do not represent public opinion, and should not be held to the exact rigors of experimental procedure.

Consumer Test I, on the other hand, is composed of a disciplined testing methodology, indicative of public opinion and confirms a major aversion to olfactory ethanol in both genders, particularly the female gender, and exposes a mindset of male neat spirits drinkers that should be better explored through disciplined research techniques.

Projected Impact and Benefits of Results

Application of gas behavior, olfactory science and attention to ergonomics is a positive step toward resolving the established need for an engineered nosing vessel which presents and displays aromas for evaluation and reduces occurrences of olfactory ethanol anesthesia. The engineered vessel also positively addresses the following points:

1. largely diminishing occurrences of ethanol anesthesia for evaluators, blenders, distillers, and consumers through use of an improved diagnostic vessel;
2. providing wider, more efficient display of character aromas, desirable and undesirable to improve evaluation accuracy, diagnostics and rating, unencumbered by ethanol;
3. improving competition aroma detection by widening aroma display area;
4. eventually, awareness may raise the industry quality bar and consumer quality expectations by exposing aromas of distilling faults, as well as desirable aromas masked by ethanol;
5. creating a viable candidate for diagnostic vessel standardization to improve industry quality, allowing distillers, evaluators, and consumers to establish a uniform evaluation baseline across industry segments;
6. improving spirits marketing to include more sensitive noses and more female consumers to enjoy straight spirits without olfactory ethanol;
7. providing a useful tool to distillers to improve accuracy of head and tail cuts;
8. providing a useful tool for other aroma and scent applications such as perfumes, coffee, tea, olive oil, distilled flavor infusions and food flavor enhancers;
9. improving consumers' ability to assess spirits for purchase, collection, and consumption;
10. enhancing drinking enjoyment and displaying subtle nuances of distilled spirits, especially for noses sensitive to the painful effects of concentrated ethanol.

4. Discussion

Awareness of ethanol anesthesia effects with traditional vessels is longstanding. Physical scientific knowledge applied herein has been in existence for well over a century, and relevant olfactory science for well over two decades. Adopting a standard engineered vessel provides the opportunity to improve education, align marketing perspectives to include basic science, and raise spirits quality while supporting consumer knowledge and enhancing tasting and nosing appreciation of straight spirits. Relying on science achieves functional design, opening the glassware and spirits industries to embrace progress and growth.

The author and research team are continuing to explore the evaluation process for further improvement and is exploring vessels which enhance enjoyment and evaluation of beers and wines as well as building on spirits research to design meaningful, repeatable testing to pinpoint ethanol anesthesia onset, through reliable data gathered from competition judging panels and carefully constructed scientific experimentation rather than subjective evaluation.

5. Conclusions

Historically, vessels have been looked upon solely as a device to transfer beverage from container to mouth, and design has not focused upon scientific principles, nor dealt with abundant nose-numbing ethanol as a marketing and styling take preference. The copita and its derivatives are examples of misplaced priorities, by placing traditional vessel marketing identity ahead of scientific observation and functionality.

Physical science and ergonomic design considerations have resulted in a functionally engineered vessel which has become the established judging vessel in most major US spirits competitions over the last six years, successfully used in well over 100 judging events and has won numerous design awards. Engineered vessel popularity as a diagnostic tool is due to its acceptance as a positive contribution to competition judging, significant reduction of ethanol anesthesia, ability to display subtle spirit aromas for improved detectability, and improvement and enhancement of spirits drinking enjoyment. In addition, the development of the engineered vessel has contributed to:

- an awareness of ethanol anesthesia as a potential problem to competent evaluation, and the need for further research to quantify onset, exposure times and causal factors;

- the importance of orifice constriction and flared rim design architecture for consideration as a design method to dispersing ethanol and displaying aromas;
- the importance of considering vessel design factors which place the nose closer to the spirit, utilize rim sizes which allow the nose to detect aromas displayed by a flared rim, and permit higher-velocity swirling, which releases more aromas for detection;
- the initial basis for a mathematical model to predict aroma detectability from a flared rim vessel for any spirit;
- a basis for improved research on product design effects on aromas detection and vessel design objective prioritization of function over style;
- creation of useful, descriptive terminology, directly related to function to specifically address effects of olfactory ethanol consistent with modern olfactory theory, those terms being ethanol lockout and ethanol anesthesia;
- the need for directing specific attention to the unaddressed effect of ethanol on more sensitive female olfactory senses, to inspire additional research to include sensitive noses in evaluation and vessel design.

6. Patent

- USPTO Design patent D663165 granted, USPTO and WIPO Utility patents pending;
- People's Republic of China Utility patent ZL 2012900007787 granted.

Supplementary Materials: The following are available online at www.theneatglass.com, S1 website of the NEAT glass, which provides additional information regarding the engineered vessel. Video S2; Here's to all the Spirits Drinkers Out There, <https://www.youtube.com/watch?v=5UpDRxxx2Bg&list=PLhzxWcMeBVpjYYJ9q4CaSfkaZIL4N3jt&index=4> Displaying the engineered vessel in a noted international competition, with explanation of contributions of engineered design parameters. Video S3; NEAT: How it is Made, <https://www.youtube.com/watch?v=5UpDRxxx2Bg&list=PLhzxWcMeBVpjYYJ9q4CaSfkaZIL4N3jt&index=4> Manufacturing the engineered vessel in Europe.

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Conflicts of Interest: The author declares a possible conflict of interest as chief of research and development, and co-founder of Arsilica, Inc., a Nevada C corporation formed to explore technical aspects of evaluating alcohol beverages and to produce and market the vessel designed herein, marketed as the NEAT glass. Released in 2012, the vessel is marketed in the USA, Australia, New Zealand, Europe (EU including UK), Taiwan, Canada, and South Africa. Past and ongoing R&D has been and is presently funded only by the author and Arsilica, Inc.

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