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Review

# Ethanol and its Halal status in food industries

Jawad Alzeer [a, b, *], Khaled Abou Hadeed [a, b]

[a] Department of Chemistry, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland
[b] Halal Certification Services, Salinenstrasse 18, 4310 Rheinfelden, Switzerland

A R T I C L E I N F O

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A B S T R A C T

*Background:* Ethanol is an important organic solvent and substrate which extensively used in research and industries. It is the main ingredient produced during fermentation of carbohydrates derived from fruits and other biomass substances. Halal status of ethanol is controversial and it is rational use is ambiguous.

*Scope and Approach:* In this review the issue of ethanol in food industries is addressed. Ethanol is a sensitive, controversial and main issue in the production of Halal (Permitted, Allowed) products. Setting the limit of ethanol in Halal food industries is needed to facilitate food production and complied with certain religious demands. This review gives an overview of ethanol, types, application, advantages and disadvantages. An attempt to set a limit of ethanol in food industries, supported by scientific facts and Islamic rules, is described.

*Key Findings and Conclusion:* Halal status of ethanol is highly controversial but rarely classified based on its source and concentration. Any ethanol produced by anaerobic fermentation and ranging between 1 and 15% is considered to be Haram (non-Halal, Forbidden), whereas ethanol produced by natural fermentation and less than 1% is considered as preserving agent and its Halal status is allowed. Any ethanolic solution higher than 15% is treated as a toxic solution but still could be used in industries, meanwhile ethanolic solution prepared by dilution from absolute or denatured ethanol is allowed for industrial used but toxic for human consumption. However, any concentration varied from 0.1 to 100% prepared with intention to be used as beverage drink is consider non-Halal.



## 1. Introduction

Since the beginning of recorded history, a complex relationship between human and ethanol was developed. This complex relation continues today, probably because of its being the essence of wine and the intoxicating ingredient in many beverages, and one of the most important chemicals available to industry. The solvent power of ethanol makes it particularly useful for extraction of valuable natural products from plant and animal tissues (Park, Kim, Kim, & Song, 2015). As an industrial raw material, ethanol is involved in the manufacture of adhesives, toiletries, detergents, explosives, inks, chemicals, hand creams, plastics, paints, thinners, textiles, vinegar and other (Equistar, 2003). Two types of ethanol are produced worldwide, namely fermented and synthetic ethanol. Fermented ethanol (bioethanol) is produced from corn or other biomass material (Erdei, Hancz, Galbe, & Zacchi, 2013; Gnansounou & Dauriat, 2005; Vijayalaxmi, AnuAppaiah, Jayalakshmi, Mulimani, & Sreeramulu, 2013), mainly used for fuel, though a small part is used by the beverage industry. Synthetic ethanol is produced from ethylene, a petroleum by-product (Chu, Echizen, Kamiya, & Okuhara, 2004), and is used mainly in industrial application (Yue, Ma, & Gong, 2014). As alcohol is extensively applied in food, pharmaceutical, cosmetic and other industrial applications, therefore Halal status of alcohol used in industries need to be subjected for discussion. Ethanol is a controversial and main issue in the production of Halal products (Khattak et al., 2011). Traditionally, consumers and Islamic jurist have identified ethanol as non-Halal (Haram, forbidden) substance, and hence Halal certified products are usually alcohol free. In this review, we will highlight the advantages and disadvantages of ethanol, meanwhile compare the alcohol content in fruits and deduce alcohol limit for Halal production. Quran was revealed that, alcohol contains some good and some evil, but the evil is greater than good: “They ask you about intoxicants and games of chance. Say: In both of them there is a

* Corresponding author. Department of Chemistry, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland.
*E-mail address:* jawad.alzeer@chem.uzh.ch (J. Alzeer).

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great sin and means of profit for men, and their sin is greater than their profit" (Chapter (2) Surat al-baqara). Although the above verse does not prohibit ethanol directly, but it expresses the harmful effect of intoxicant to human, and advice for abstaining from the usage of alcohol. "O you who have believed, indeed, intoxicants, gambling, [sacrificing on] stone alters [to other than Allah], and divining arrows are but defilement from the work of Satan, so avoid it that you may be successful" (Chapter (5) Surat al-maidah). In this review, we describe the various types of ethanol, why ethanol is a potential risk (Gulbinat, 2009), and correlate science with Shariah to explain why not all ethanol types can be treated as Khamr (alcoholic beverage, non-Halal) and propose a set of limits for ethanol use in food industries.

## 2. Ethanol production

Ethanol is the most common volatile compound produced since ancient times by the fermentation of sugars. All beverage ethanol and more than half of industrial ethanol is still made by the same process. Zymase is an enzyme from yeast, which is responsible for the changes of simple sugars into ethanol and carbon dioxide. The fermentation reaction, represented by the simple equation, Fig. 1:

During the process of fermentation, in the absence of oxygen, ethanol concentration is increased until it is reached about 15%, above this concentration, yeast is toxified and zymaze enzyme is inhibited and fermentation process stopped (Thamilvanan & Selvi, 2013).

Ethanol used for industrial purpose, not for drinking, is commercially prepared from one of the following starting materials: ethylene (Chu et al., 2004), ethane (Kawakami, Shoji, & Watanabe, 2013), ethylacetate (Fuentes et al., 2015), ethylperoxide (Arasasingham, Balch, Cornman, & Latos-Grazynski, 1989), ethylene oxide (Ushakov, 1937), ethylene glycol (Kaneda & Hirokazu, 2014), acetic acid (Xu, Chunli, Fengyi, Chunlei, & Yonggang, 2015), acetaldehyde (Morooka, Wakai, Matubayasi, & Nakahara, 2008), aceticanhydride (Walsh, Mertel, & Miwa, 1983), acetylene (Radloff, 2014), carbon mono oxide (Wang, Ang, Liu, Zhang, & Liu, 2016), carbon dioxide (He et al., 2016), dimethylether (Tan, Qingde, Yizhuo, Hongjuan, & Caihong, 2012), propylene glycol (Samson et al., 2015), cellulose (Gunasekar, Apoorva, Sailaja, & Ponnusami, 2014), glucose (Keera, Foukia, Kahil, Fadel, & Abedo, 2014). Synthetic ethanol is chemically and physically indistinguishable from ethanol produced by fermentation. Ethanol concentrations above 15% is normally obtained by distillation of aqueous solutions, but at 95.6% concentration, water and ethanol form a constant boiling mixture and distilled together even though they have different boiling points. A common method to produce ethanol with concentration higher than 95% is to use either dehydrating agents or additives that disrupt the azeotrope composition and allow further distillation. Absolute ethanol is hygroscopic (it attracts water), therefore 100% ethanol is expected to decrease overtime (Gil, Uyazan, Aguilar, Rodríguez, & Caicedo, 2008).

## 3. Energy source

The simple structure of ethanol molecule makes it appropriate alternative biofuel energy source to fossil fuel. The main raw materials used for bioethanol production are wheat straw in Europe, corn stover in the USA, and straw in China. Use of either sugar cane or corn to produce ethanol is problematic, because of their high production cost and the competition with food and feed production. To increase the productivity and cost effectiveness of ethanol production, many process and cheap raw materials have been investigated and developed (Dong, Zhao, & Zhang, 2012). Ethanol is an efficient energy source compared to fossil fuel. Fossil fuel required more energy for its production and has a finite resource, not renewable and will no longer be able to rely on as our source of supply whereas ethanol fuel, with high oxygen content (35% oxygen by weight), it allows the engine to achieve more combustion, resulting in fewer emissions. Ethanol fuel is more useful and renewable and could be reproduced chemically and biologically from different raw materials. Ethanol emits lower levels of greenhouse gasses, which in turn reduce global warming. However the atmospheric oxidation of ethanol produces acetaldehyde, which is a very dangerous substance at high levels of exposure (Andradea & Miguela, 1985).

$$\text{Simple sugars} \xrightarrow{\text{Zymase}} \underset{\text{Ethanol}}{CH_3CH_2OH} + \underset{\text{Carbon dioxide}}{CO_2}$$

**Fig. 1.** Zymase convert carbohydrates into ethanol and carbon dioxide.

## 4. Ethanol types

There are several types of ethanol, but not all types of ethanol are suitable for all tasks:

**A 95% (95.6%) ethanol**: This is the highest concentration of ethanol one can obtain by distillation, 95.6% ethanol is an azeotrope, which means the vapour state has the same ethanol:water ratio as the liquid state. This alcohol could be obtained either synthetically in the lab from a variety of starting materials or by fermentation process of different biomasses. The quality of this alcohol is considered to be compatible with food industries and could be used in flavours, candy, personal care products and as a carrier for a wide spectrum of medicines such as cough, decongestants and iodine solutions.

**Absolute (99–100%) ethanol**: Certain experiments are sensitive to water, therefore absolute ethanol is required. A common method to produce ethanol with concentration higher than 95% is to use additives, such as toluene, heptane, cyclohexane, and 2-butanone that disrupt the azeotrope composition and allow further distillation. For this reason, absolute ethanol contains trace amounts of these additives. As ethanol is hygroscopic, water can be easily absorbed by ethanol therefore absolute ethanol need to be prepared freshly or kept over magnesium metal and distilled when it is needed.

**Denatured ethanol**: It is made to be unhealthy for human consumption by adding one or more chemicals. Denatured ethanol (either 95% or absolute) contains chemical, such as methanol and isopropanol, therefore it is not safe to drink. Usually it is cheaper than pure ethanol, as it is exempted from beverage taxes and frequently used as cleaning and disinfectant agents. Ethanol is an effective disinfectant at concentrations between 70 and 90%, aqueous ethanol is a more effective protein denaturant than absolute ethanol. Denatured ethanol is commonly used in perfume industries.

## 5. Relative risks of ethanol

Ethanol is completely soluble in water, when drank as beverage, the ethanol molecules are rapidly absorbed through the stomach by small intestines and bloodstream then supplied to tissues such as brain. Small amounts of alcohol act as a stimulant to many organs, but with increasing levels it begins to act as a depressant in the body and increase the risk of developing disease.

### *5.1. Alcoholism*

Alcoholism is a disease affect many tissues and can be classified as a brain disease that leads to adduction (Mehta, 2016; Dudley, 2004). Brain is more susceptible to the five key risk factors for developing alcoholism: genetics, childhood trauma, social environment, mental illness, and early use. The most significant risk factor is early use that may cross the line from alcohol abuse to alcoholism (Jennison and Johnson 2001; Perkins and Perkins 2001). Alcoholism is a major public health problem impacting individuals, their families and society (Haverfield & Theiss, 2015). It is associated with the development of variable and complex alterations of the immune system affecting both innate and adaptive immune responses (Cook, 1998). Such immune alterations are very broad and may range from immunosuppression with an increased risk of infection, to induction of organ damage. Treatment may take several steps includes psychotherapy and pharmacotherapy, alcohol detoxification should be carefully controlled. After detoxification, support such as group therapy or support groups used to provide heavy drinkers with positive feedback and help to reduce their alcohol intake. The medications like acamprosate, disulfiram, or natrexone are used primarily in the management of alcohol dependence (Baumgartner & Soyka, 2015).

### 5.2. Acetaldehyde

More than 90% of ethanol metabolism takes place in the liver catalyzed either by alcohol dehydrogenase (ADH), microsomal ethanol oxidizing system (MEOS) or catalase (Lundquist, Tygstrup, Winkler, Mellemgaard, & Munch-Petersen, 1962). While catalase is of minor importance in hepatic ethanol metabolism, ADH and MEOS produce acetaldehyde (AA), the first and most toxic metabolite of ethanol (Fig. 2). AA is an extremely reactive, electrophilic, mutagenic and carcinogenic (Seitz & Mueller, 2015) compound. It interferes with DNA synthesis and DNA repair. Most importantly, AA binds covalently to DNA and forms stable adducts (Correaa et al., 2012; Coutts & Harrison, 2015; Yua et al., 2010). Binding to DNA represents a mechanism by which AA could trigger replication errors and/or mutations in oncogenes and tumour suppressor genes. It has been shown that the major stable DNA adduct N2-ethyl-desoxyguanosine (N2-Et-dG) serves as a substrate of eukaryotic DNA polymerase (Matsuda et al., 1999). Thus, individuals who drink alcohol and have a deficient AA dehydrogenase such as 40% of the Asian population lead to increase AA levels thus increased risk for various cancers such as those of the upper aerodigestive tract and the colon (Pelucchi, Gallus, Garavello, Basetti, & Vecchia, 2006; Yokoyama et al., 1998). Indisputably, most of the known risk factors for upper digestive tract cancers appear to be associated with an enhanced exposure to acetaldehyde. Although the role of AA in the central effects of ethanol is under discussion but commonly postulated its role in the mediation of ethanol's effects. However, it is also possible that acetaldehyde induces various effects that are similar to ethanol, but by independent mechanisms.

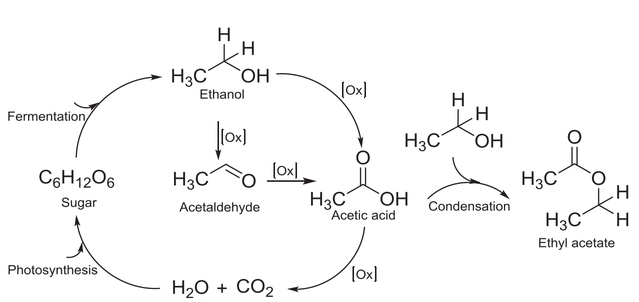


**Fig. 2.** Sugar transformation into different building blocks via fermentation, oxidation, and condensation.

### 5.3. Alcohol-food interaction

Alcohol has been shown to interact with foods to either enhance or depress the food's biological effects. Specific areas involving alcohol-related damage due to alcohol-combined effects with foods has been reviewed (Watson, Preedy, & Zibadi, 2013), specifically the interaction with nicotine in tobacco smoke (Barron et al., 2005), and caffeine in foods (Elsner, Alder, & Zbinden, 1988) and energy drinks (O'Brien, McCoy, Rhodes, Wagoner, & Wolfson, 2008). The use of energy drinks mixed with alcohol can be considered high-risk due to increased absorption of alcohol, result in further intoxication and amplify the depressant effects.

Alcohol-food interaction have impact on the absorption, storage, biologic transformation, intake and excretion of compounds which are essential for metabolism, that include folate, vitamin B6, B12, A and certain lipotropes (Mayne et al., 2001). It has also been shown that alcohol interaction may alter DNA methylation and lead to aberrant methylation of tumour suppressor genes and oncogenes, which are involve in tumour development (Varela-Rey, Woodhoo, Martinez-Chantar, Mato, & Lu, 2013). If dietary ingested along with alcoholic beverages, this may increase lipid peroxidation due to the generation of reactive oxygen species, activation of pro-carcinogens via induction of cytochrome P450 2E1 and DNA lesions derived from oxidative stress by-products (Yao et al., 2009). For colorectal cancer, diet has shown to be one of the most significant factors, and alcoholic drinks are considered a related habit for this disease. Ethanol is also considered to be a cocarcinogen by acting as a solvent for other carcinogens to penetrate the mucosa of upper aerodigestive organs, which could explain the excessive risk of esophageal cancer associated with alcohol drinking among cigarette smokers (Brooks & Theruvathu, 2005).

## 6. Ethanol contents in food

### 6.1. Alcoholic beverages

The terms alcohol and alcoholic beverages are often confused with each other, alcoholic beverages are drinks (Table 1) that contain ethanol, since the chemical structure of ethanol has hydroxyl group, therefore, ethanol scientifically is classified as alcohol which belong to a long list of organic compounds commonly used in different fields like flavouring, coloring and medicines.

The main sources of ethanol for human consumption are:

- Beer: It contains between 3% and 7% of ethanol and several compounds with antioxidant properties (Ghiselli et al., 2000). It is the most consumed beverage worldwide, especially in Europe, North America, Oceania, and several African countries.
- Wine: Its content of ethanol varies from 9% to 15%. Wine is consumed mainly in Europe and the Americas – especially in Argentina, Uruguay, and Chile. Red wine has significant amounts of resveratrol, an antioxidant which is derived from the skin of grapes and seems to have anticancer properties (Chong et al., 2015).
- Spirits: These drinks contain between 35% and 50% of ethanol, although some reach even higher values, since they are obtained by distillation (Lachenmeier et al., 2015). Spirits include whiskey, vodka, grappa, gin, and tequila, among others (Table 1). They are consumed primarily in Asia and Europe.

### 6.2. Ethanol in vinegar

Vinegar is described as a sour liquid and has been widely used in food industry. It is produced from different natural substrate, like

**Table 1**
List of beverage drinks, classified alphabetically, with it is source, type and alcohol contents.

| Alcoholic beverages | Source | Description |
|---|---|---|
| Absinthe (distilled spirits) | Wormwood | It is a type of spirit with alcohol content 45–74%. Traditionally it has green color with anise flavor. |
| Ale (brew) | Grains | It is a type of beer with alcohol content 3.5%–12%. It has different color and flavor. |
| Araq (distilled) | Golden grapes and anis | It is a type of spirit with alcohol content 40–63%. It has a clear color with anis flavored |
| Baijiu (distilled) | Sorghum | It is a strong distilled spirit, with alcohol content 40–60%. It is a clear white sprits with and without flavor |
| Bourbon Whiskey (distilled) | Corn, wheat, rye and malt | It is a type of whiskey, with alcohol content 65–80%. It is caramel colored texture with a mellow flavored. |
| Brandy (distilled) | Grapes | It is a type of wine, with alcohol content 35–60%. It is natural golden to brown color with intense flavor |
| Cachaca (distilled) | Sugarcane | It is a type of whiskey, with alcohol content 38–48%. It is white color, if it is fresh and gold in color if it is aged |
| Chicha de jora, and chicha morada (brewed) | Yellow maize | It is a type of beer, non-alcoholic. It could be fermented or non fermented, pale straw in color with sour taste |
| Cider (wine) | Apples | It is a type of wine, with alcohol content 7–8%. Its color ranges from almost clear to brown with cider flavor |
| Cordials or flavored liquors (distilled) | Various | It is a type of spirits, with alcohol content 30–60%. It has different color with fruit, cream, herbs, spices, flowers or nuts flavor |
| Dandelion wine | Dandelion | It is a type of wine, with moderate alcohol content (12%). Its color ranges from white to golden with distinctive flavor. |
| Fortified wine | Grapes | It is a type of wine, with alcohol content 16–18%, It has a light brown color, sweet with fruity taste. |
| Fruit Beer (brew) | Grains, various forms of fruit | It is a type of beer, with alcohol content 4–18%. It has different color with wide variety of fruity tastes. |
| Gin (distilled) | Barley, Maize and juniper | It is a type of spirits, with alcohol content 30–68%. It is a clear white sprits with different added flavor |
| Huangjiu (brewed) | Rice, millet and wheat | It is a type of spirits with alcohol content of 15%. Its color is varied from clear to reddish brown with different flavor |
| Lager beer (brew) | Grains | It is a type of beer, with alcohol content 4–6%. Its color is varied from pale to golden amber with mild flavor. |
| Lambanog | Coconuts | It is a type of wine with alcohol content 40–50%. It is color is varied with different flavor. |
| Malt Liquor (brew) | Malt, grains, corn | It is a type of beer with alcohol content 4–6%. It is color is pale amber with different flavor. |
| Mead (brew) | Honey | It is a type of beer like with alcohol content 8–20%. It is color and flavors depending on the source of the honey. |
| Mezcal/Tequila (distilled) | Cactus (Blue Agave) | It is a type of spirits with alcohol content 37–55%. It has clear to light yellow color with a strong smoky flavor. |
| Palque (distilled) | Maguey Agave | It is a type of beer like with alcohol content 4–8%. It has a milky color with palque flavor. |
| Rum (distilled) | Sugar cane | It is a type of spirits with alcohol content 37%–80%. It has a white to dark color with rum flavor. |
| Rye Whiskey (distilled) | Rye | It is a type of spirits with alcohol content 40–68%. It can be colored with coloring agents with different flavor. |
| Sake (brewed) | Rice | It is a type of Japanese wine with alcohol content 15–20%. It has a color and flavor of honey. |
| Soju | Rice, potatoes, wheat | It is a type of spirits with alcohol content 17–45%. It has a clear color with soju flavor. |
| Sparkling wine | Grapes | It is a type of wine with alcohol content 11–13%. It has a different color with champagne flavor. |
| Stout (brew) | Grains | It is a type of beer with alcohol content 5–14%. It has a tan color with bold taste |
| Vodka/Poteen (distilled) | Potatoes | It is a type of spirits with alcohol content 35–50%. It has a clear color with different flavor. |

fruits with good fermentation potential. Apple, grapes, dates, honey, barely, and red wine are frequently used for the production of vinegar, which is classically produced by two fermentation processes, first carbohydrates are fermented into alcohol then ethanol is further oxidized to produce acetic acid (Fig. 2). The rate of acetic acid production is dependent on temperature, availability of oxygen, concentration of ethanol and concentration of acetic acid (Solieri & Giudiei, 2009), therefore vinegar is considered to be a diluted form of acetic acid. The ethanol content affects the bacteria both in the beginning and at the end of fermentation. If the initial ethanol concentration is too high, bacterial vitality can decrease due to the antimicrobial effect of ethanol. If ethanol concentration is too low, down to 0.1–0.2%, the risk for over oxidation of acetic acid to carbon dioxide increases (Schwan, 1998). When the acetic acid concentration is increased during fermentation, the pH value (4.76) of acetic acid decreases, thus bacterial activities are reduced (Doede, 1945). Most bacteria have an optimum pH value near 6.8 and may grow at pH values ranging from 4 to 8; a narrow spectrum of bacteria can multiply at pH $<4$ or pH $>8$. In Europe, there are regional standards for different vinegars, but a threshold value for wine vinegar is a minimum of 6% acetic acid, obtained by acetous fermentation of wine (Heikefelt, 2011). If vinegars produced from other alcoholic bases than wine, the acetic acid concentration threshold minimum is 5% (Solieri & Giudiei, 2009). In North America, the vinegar must have an acetic acid content of at least 4%. The maximum ethanol content in vinegars has been set to a maximum 0.5% and 1% for wine vinegar (Heikefelt, 2011).

Some of the vinegars had a smell and taste of ethyl acetate, that provides an unpleasant chemical fruitiness to the vinegar. Ethyl acetate is produces as a result of chemical reaction between ethanol and acetic acid, and can be formed in vinegars during storage (Joshi, Thakur, & Walia, 2002) (Fig. 2). Higher risk formation of ethyl acetate is determined by the high ethanol content in vinegar, the lower ethanol content, the less chances of ethyl acetate formation is visible.

### 6.3. *Ethanol in fruits*

Ethanol contents in fresh fruits increases by time due to the anaerobic fermentation of their sugars (Logan & Distefano, 1998). Ethanol content for unripe and ripe hanging palm fruits, and for over-ripe fallen fruits was determined. No ethanol was detected in the pulp of unripe palm fruits, whereas about 0.6% of ethanol in the ripe palm hanging fruits and ripe fallen fruits was determine to be 0.9%, the value was increased for over ripe-fallen fruits to 4.5% (Dudley, 2004). Similarly ethanol content was increased in fresh pineapple from 0.48% to 1%, when pineapple was stored at 4 °C for ten days (Gunduz, Yalmaz, & Goren, 2013).

Most of the soft drinks, including fruit juices were determined to contain trace amount of naturally occurring alcohol. Ethanol content was significantly increased in fresh grape juice from $0.29 \times 10^{-3}$ to 2.11% after being kept at room temperature for 1 day, dramatic increase in ethanol content is observed (5.60%) if kept for 10 days at room temperature. Although natural ethanol produced by natural fermentation under aerobic condition is Halal by nature, but high ethanol content in non-fresh grape juice need to be labelled as non-Halal juice.

## 7. Halal status of ethanol

The word Khamr (alcoholic beverage), fermented fruits, was described in Quran 6 times; Alkhamr refers to the solution, which is produced from fruits or any natural sugar source by anaerobic fermentation and potentially could be used or lead to intoxication. The main ingredient of Alkhamer is ethanol, which is the chemical substance responsible for intoxication, the physiological state induced by the ingestion of ethanol where a person usually becomes pleasantly relaxed, with an easing of tension and anxieties. The control centre in the brain becomes less active, and inhibitory centre is less efficient and may lead to mild euphoria, talkativeness, decreased attention, and impaired judgment.

Complete intoxication is achieved when blood alcohol content (BAC) is ranging between 0.08 and 0.10% depending on gender, weight and age. Utilizing Widmark's formula (Widmark, 1981), a female with 55 kg weight, if consumed 10% (w/v) ethanol (e.g. Wine), intoxication is achieved within 1 h after ingestion 500 ml volume, equivalent to 50 g of absolute ethanol, this ratio may slightly decreased or increased depending on the individual sensitivity. If ethanol content is increased by physical and or chemical means to 27% (w/v), and 500 ml volume is ingested by a 55 kg weight female, this is the fatal dose (BAC = 0.30%) and consumption of this large amount of alcohol, 135 g, within a short span of time may affect different systems of the body, namely respiration, heart rate that ultimately may lead to death of the person, this ratio may slightly decreased or increased depending on the individual sensitivity. Similar fatal dose (BAC = 0.30%) can be achieved after ingesting 900 ml of 15% (w/v) ethanol. From this analysis, we may conclude that when ethanol content is 15% (maximum concentration obtained by fermentation) or less, it is treated as fermented alcohol, its status is forbidden (non-Halal) and need to be avoided; preparing, carrying and drinking it is forbidden as mentioned in the Holy Quran. If ethanol content is higher than 15%, usually it is inaccessible via fermentation, alternative method is needed to achieve the desired high concentration, it is obtained either by distillation or addition of absolute ethanol, for effective distillation toxic additives are added. The Halal status of alcohol higher than 15% (w/v) is toxic, therefore it is strongly prohibited to drink, attempts to drink toxic substance is considered suicide attempt in Islam, which is hardened sanctity than drinking fermented alcohol. On the other hand, toxic ethanol solution is allowed to prepare, hold, transfer and use for disinfection and other industrial use (Table 2).

With regard to ethanol less than 1% (w/v), obtained by natural fermentation process under oxygen (air) atmosphere. The process goes through two steps: first the oxidation of sugar via fermentation into ethanol, followed by the oxidation of ethanol via acetaldehyde into acetic acid, air flow is not prevented during the process. The transformation of ethanol into acetic acid, carbon dioxide and ethyl acetate, is controlled by ethanol concentration (Fig. 2). If ethanol is <0.2%, acetic acid undergoes over oxidation and generate carbon dioxide (Lea, 1989), whereas higher than 1%, ethyl acetate formation is observed, as a result of ethanol and acetic acid condensation (Joshi & Sharma, 2009). In both transformations, acetic acid concentration is reduced, thus pH value is increased (>4.7, acidity decreased). Acidity is the most important factor affecting microbial spoilage of fruits and vinegar (Agular, Nascimento, Ferretti, & Gonçalves, 2005). To reduce microbial growth rate, optimum value of pH $\leq$ 4 (increase acidity) is maintained by keeping ethanol concentration between 1.0 and 0.2%. Therefore, ethanol Halal status at concentration less than 1% is allowed, and called Mubah (neither forbidden nor recommended) in Islam, and essential to maintain acidic condition and prevent growth of harmful microbes. Prophet Mohammad (PBUH) said that whatever intoxicates in large quantities, a little of it is also forbidden (Tirmidhi, 1865). If a 55 kg weight female, consumed 1% ethanol within 1 h, intoxication limit will be reached (BAC = 0.09%) after ingesting 4000 ml volume. Medically, drinking 4 L of water within 1 h will lead to rapid and severe hyponatremia (Sahay & Sahay, 2014), a condition that occurs when the level of sodium ion in blood is abnormally low. Blood dilution disable kidneys to flush water out of the body fast enough thus blood becomes waterlogged, causes entry of water into brain cells and lead to brain swelling, which manifests as coma and death. As drinking 4 L of 1% of alcohol to reach intoxication is practically impossible, therefore one may conclude that alcohol less than 1% should be treated as a preserving agents rather than forbidden for reasons described above.

With regard to vinegar's halal status, in general it is halal and recommended by the prophet, In a hadith narrated by Ayesha, Muslim and Ibn Maja, Prophet Muhammad (PBUH) said “Allah has put blessing in vinegar, for truly it was used by the prophets before me”. When vinegar's ethanol content reach 1% (Heikefelt, 2011), which is rare with exception of wine vinegar, it is halal as long as there is no deliberate treatment to induce the conversion of ethanol into acetic acid.

In Islam, human deeds are judged on the bases of intentions (Niyyah), Prophet Mohammad PBUH said “Verily, deeds are only with intentions” (Sahih Bukhari 54). Therefore, any ethanolic beverage or vinegar made with intention to achieve partial or complete intoxication, it is prohibited, no matter if ethanol content is <1% or >15%. Table 1 describe most types of non-Halal beverage drinks. In case of ethanol <1%, it is lower than the limited value for

**Table 2**
The Halal status of different ethanol concentrations.

| Ethanol % | Intention | Sources | Halal status |
|---|---|---|---|
| <1% | Not for beverage drinks | AF, S | Preserving agent, Halal |
| 1-15% | Not for beverage drinks | F | Khamer, Non-Halal |
| 1-15% | Beverage drinks | F | Khamer, Non-Halal |
| >15% | Not for beverage drinks | S, D | Toxic, Halal to be used in industries |
| >15% | Beverage drinks | F & S, D | Khamer, toxic, Non-Halal |
| 0.1%–100% | Not for beverage drinks | S, D | Toxic, Halal to be used in industries |
| 0.1%–100% | Beverage drinks | F, S, D | Khamer, toxic, Non-Halal |

AF: Aerobic natural fermentation, F: Anaerobic fermentation, S: Synthetic ethanol, D: Distillation.

reaching intoxication, but placebo effect will dominate and intoxication may easily be reached with minute amount of alcohol. With regards to spirit drinks, alcohol content is higher than 15%, usually prepared by fermentation followed by distillation, Halal status is forbidden and toxic, prohibited to drink and not to be used in industries. Ethanol prepared by fermentation and distillation to achieve concentration above than 95%, chemically it is identical to synthetic ethanol, thus 95%, absolute and denatured ethanol are considered as toxic substance and could be used for perfumes and other industrial applications as long as the initial intention was not made as beverage drink.

Since 15% is the limit where yeast is toxified and fermentation process is stopped, more detail studies are needed to determine the consequence of this concentration on our gut microbiota which play important role in digestion, immune system, production of some vitamins, combat aggressions from other microorganisms, and maintain the wholeness of intestinal mucosa.

## 8. Conclusion

Ethanol, the main ingredient of khamer, is a sensitive, controversial and main issue in the production of Halal products. We have classified ethanol into three categories namely preserving agent, non-Halal and toxic. If ethanol content is less than 1%, it is considered as an essential preserving agent, therefore its Halal status is Mubah, allowed as long as ethanol was formed either naturally through the process of fermentation in the presence of oxygen, or added as synthetic ethanol. If ethanol is produced by anaerobic fermentation and ethanol content is ranging between 1 and 15% is considered Haram (non-Halal) and cannot be used for industrial application. Ethanol content higher than 15% is regarded as toxic solution that can be handled for medicinal and industrial use but not for drinking purpose. Ethanol solutions, higher than 1%, and prepared by dilution from absolute or denatured ethanol (toxic) is considered as allowed ethanol only for industrial application. Any concentration varied from 0.1 to 100% prepared with intention to achieve intoxication is considered non-Halal.

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