Revista RIVAR Vol. 8, nº 24. Setiembre 2021: 56-75.
DOI https://doi.org/10.35588/rivar.v8i24.4886 · ISSN 0719-4994

Methanol in Mezcal: Is it Possible to Increase the Current Thresholds Allowed by Mexican Standards?[1]

Metanol en el mezcal: ¿es posible aumentar los umbrales permitidos por la normativa mexicana?

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Abstract

The allowed limits of methanol by Mexican norms for mezcal set the maximum at 300 mg/100 ml of alcohol 100%. The standard was established in 1986 taking wine as reference. The Norm NOM-142-SSA1-1995 maintains that value today, although in Europe, then and now, the limits for methanol in distilled fruit beverages are well above the content permitted by Mexican Standards. We review the toxicology of methanol and the process of making norms about the allowed contains in alcoholic beverages in Mexico and other countries, and concluded that is possible a revision of standards on methanol maintaining health requirements. The article proposes the revision of the current Norms for the agave distillates, taking mezcals as a case study. We remark that it represents an opportunity for certain traditional beverages (fermented and distilled) that exceed the present standard level.

Keywords: mezcal, agave, standards on alcoholic beverages, methanol, toxicity.

1 Project "Applied Science and Society. Food Quality Standards, Economic Interest, and Local Productions: The Case of Traditional Mezcal and Tequila". El Colegio de Michoacán, 2019. This research has been provided as part of the scientific advice to different parliamentary groups (Movimiento Ciudadano, Movimiento de Regeneración Nacional, Partido Revolucionario Institucional) in the Senate of the Republic, for the initiative with a draft Decree called "Federal Law of Traditional Mezcales".

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Resumen

Las normas mexicanas para destilados de agave como el mezcal establecen los límites máximos de metanol en 300 mg/100 ml de alcohol 100%. Esos límites se establecieron en 1986 tomando como referencia el vino. La Norma NOM-142-SSA1-1995 mantiene ese valor hoy, a casi 40 años, aunque en Europa, entonces y ahora, los límites de metanol en bebidas destiladas de frutas están muy por encima del contenido permitido por las Normas Mexicanas. Revisamos la toxicología del metanol y el proceso de elaboración de normas sobre los contenidos permitidos en bebidas alcohólicas en México y otros países, y concluimos que es posible una revisión de las normas sobre metanol sin provocar un problema de salud pública. El artículo propone la revisión de las Normas vigentes para los destilados de agave, tomando los mezcales como caso de estudio. De paso, la discusión representa una oportunidad para ciertas bebidas tradicionales (fermentadas y destiladas) que exceden el nivel estándar actual.

Palabras clave: mezcal, agave, normas sobre bebidas alcohólicas, metanol, toxicidad.

Introduction

This article presents issues and problems related to the presence of methanol in mezcals.[3] In specific, the limits for the content of this compound in alcoholic beverages prepared of agaves (Mezcal, Tequila, Raicilla, Bacanora), which have been established by Mexican Official Standards, are discussed. Those values are considered in relation to current international provisions and scientific and technological advances.

Methanol is a toxic chemical compound that is always present in mezcals,[4] whose metabolites may pose a risk to consumers; hence it is a matter of public health, and the allowed amount should be set in compliance standards mandatory, always based on experimentation and analysis of poisoning cases.

In this article, we expose the following topics: (1) a summary of the information on metabolism, toxicity, and tolerance to methanol in human organisms, as well as historical information on poisonings, preventions, and treatments; (2) a review of literature on mezcals and alcoholic agave beverages, along with technical aspects of the production that affect the methanol content; (3) a chronology of Mexican norms, and (4) comparison of the limits allowed in the Mexican and foreign standards regarding the regulations applied to agave and fruit distillates in Mexico.

3 The article has been inspired by the presentation "Methanol in Beverages Derived from Agave and the International Regulatory Framework Regarding this Substance" by Dr. Iván Saldaña Oyarzábal and Jan Hendrik Giersiepen. Agared Annual Meeting (Red Temática Mexicana Aprovechamiento Integral Sustentable y Biotecnología de los Agaves), Oaxaca, Mexico, November 2018.

4 We take mezcals as case studies, but the discussion also applies for other distilled agave beverages such as tequila, raicilla, and bacanora, and eventually fruit brandies.

The origin of this research lies in the issue that the production of traditional mezcals is affected by the rigidity of the current standard. For example, the agave species is one of the factors influencing the final methanol content in the beverage. Nowadays mezcals made with certain species generally exceed the maximum allowed by the corresponding standard, although, comparatively, a fruit distillate in Europe with the same methanol content is legal.

To face this and other crossroads we offer this study, in order to expand the normative vision with strict interest in the health of consumers, contemplating the social organization and productive and cultural aspects of the different mezcal regions. We recommend contributing to a debate between experts from different disciplines and varied producers on current regulations, as well as suggest the necessary update of the methanol levels in beverages made from agave, based on the most recent advances.

The consulted bibliography comes from various disciplines. We try to respect to the maximum the languages used by specialists and achieve clarity for the various readers. Another difficulty is the use of different units of measurement since we cite authors and standards that come from different countries and organizations. We have tried as far as possible to introduce tables and explanatory notes. We adhere, in any case, to the Mexican standards on metrology, which in turn are based on the International System of Units (SI) (see Nava Jaimes *et al.*, 2001).

We find and expose an existing crossroad between public health issues, technical processes for making mezcals given the biocultural diversity, as well with the technological innovations.

Alcohols and methanol

Alcohols[5] are naturally or industrially produced organic compounds. The most known is ethanol, "drinking alcohol", whose formula is CH_3CH_2OH; it constitutes the basic component of all alcoholic beverages.

Methanol—formula CH_3OH—formerly known as "wood alcohol", has physical and sensorial properties like ethanol. However, methanol is more toxic than ethanol and its content in beverages is heavily restricted in all countries through quality and public health standards.

Metabolism and toxicity of methanol

Methanol is present in the human body. An adult produces between 0.3 and 0.6 grams per day; it is also generated by the digestion of fruits, juices, or sweets that contain pectin; by the sweetener Aspartame or the preservative dimethyl dicarbonate (Lindinger *et al.*, 1997; Clary, 2013; Shindyapina *et al.*, 2014). In small quantities (Table 1), methanol is eliminated without

5 Chemical definition: carbon compounds with one or more functional hydroxyl groups (OH).

consequences, but ingestion of larger amounts—for example 2 ml for an adult—causes damage to the organism (Kruse, 1992).

Poisoning occurs by ingestion, through contact with the skin, or by breathing of vapors. When methanol degrades, it produces formaldehyde and formic acid which results in a fatal acidosis with sequelae such as loss of sight (Clary, 2013: 50; Kavet and Nauss, 1990; Kruse, 1992: 393).

Methanol is metabolized with the intervention of the liver enzyme alcohol dehydrogenase, which also participates in the degradation of ethanol with which it reacts with higher affinity (a ratio of 20: 1 in favor of ethanol over methanol). That is why the presence of ethanol retards acidosis, which was known practically since the beginning of the 20th century: those who drank alcohol and got intoxicated with methanol took longer in manifesting symptoms, compared to those who did not drink alcohol frequently. It is currently known that about 36 grams of ethanol (the content of 100 ml of 40% vol/vol alcoholic beverage) can delay the metabolism of methanol—and the acidosis—up to 10 hours. Since the 1940s, ethanol has been used to treat methanol poisoning (Röe, 1946; Jacobsen and McMartin, 1997: 133; Paine and Dayan, 2001: 566).

The concentration of methanol in the body decreases as it is metabolized or eliminated by breathing or via urine. In an experiment in men injected with non-dangerous doses of methanol, its concentration decreased by half every three hours (Leaf and Zatman, cited in Kavet and Nauss, 1990: 34).

Tolerable and lethal doses

The toxicity of methanol has been studied for over a hundred years (see Wood, 1906), but it is difficult to compare cases since many times there are unknown details about the incident (amount ingested, time elapsed before going to hospital, patients' previous health status, alcohol consumption habits, and other conditions). There is still disagreement about which doses are tolerable and which ones need treatment, despite efforts to systematize the information. Kostic and Dart (2003) reviewed data dating back to 1879: 372 articles in 18 languages that comprised 2433 methanol poisoned patients.

According to the United States Food and Drug Administration (FDA) "the tolerable (safe) level of exposure to methanol is 7.1 to 8.4 milligrams per kilogram body weight per day (mg/kg body weight/day), or approximately 426 to 504 mg/person/day for a 60 kg adult" (FDA, 1996). Other studies show results ranging from half to twice that value. Clary quotes a WHO report and notes that formic acid does not accumulate if there is 20 mg of methanol per kg of weight of whoever ingests it (for 60 kg of weight = 1200 mg = 1.52 ml) (Clary, 2013: 49). Paine and Dayan argue that 1 mg per deciliter of blood is a normal value and five times more is tolerable (Paine and Dayan, 2001: 564). We can examine a comparison of data in Table 1:

DOI https://doi.org/10.35588/rivar.v8i24.4886 · ISSN 0719-4994

Table 1. Comparison chart: tolerable doses of methanol
Tabla 1. Cuadro comparativo: dosis tolerables de metanol

Organization/ authors	Tolerable doses (amount ingested)/day	Tolerable doses (blood test)/ day	Our calculation (adult 60 kg of weight–5L of blood)/day	Source
FDA–USA	7.1 to 8.4 mg/kg of weight	-	500 mg = ~ 0.63 ml	FDA, 1996: 26786
OIS–ONU	20 mg/kg of weight	-	1200 mg = ~ 1.50 ml	Clary, 2013: 49
Paine and Dayan	-	5 ml/dl	250 mg = ~ 0.32 ml	Paine and Dayan, 2001: 564

Source: own elaboration. Fuente: elaboración propia.

Regarding dangerous doses, the registered cases show differences. The lethal dose in humans is not precisely established. For a long time, the reference has been that more than 20 ml can cause the death of a person.

Many experiments have been carried out and there are specific references to cases in which the amount ingested and/or the concentration in the blood is known so values of the minimum risk threshold and lethal quantities could be established. In the 1970s and 1980s, experimental studies with monkeys and humans were conducted.[6] Some conclusions, summarized in Table 2, are the following:

• In 1978 hemodialysis was recommended when the patient had more than 50 mg/dl of methanol in blood.

• Kostic and Dart deducted a value of 20 mg/dl as the treatment threshold to delay acidosis (Kostic and Dart, 2003: 794).

• Röe pointed out that 1 g of methanol for every kg of body weight can cause death if the patient does not receive treatment or has not consumed ethanol (Röe, 1955; Röe, 1982: 275). This applies to a 60 kg adult person: 60 g = ~ 76 ml of methanol.

• Paine and Dayan point out that "it seems safest to adopt a "worst-case scenario" and to consider any period at a blood level of methanol greater than 20 mg/dl as risking unacceptable harm" (Paine and Dayan, 2001: 564).

Table 2. Comparative chart: lethal and dangerous dose of methanol
Tabla 2. Cuadro comparativo: dosis peligrosas y letales de metanol

Organization/ authors	Lethal doses (amount ingested)	Dangerous dose (needs treatment)	Our calculation ingestion by adult 60 kg of weight–5L of blood	Source
Kostic and Dart	-	> 20 mg/dl blood	1 g = ~ 1.26 ml	Kostic and Dart, 2003: 794
Röe	1 g/kg of weight	-	60 g = ~ 76 ml	Röe, 1955 and Röe, 1982: 275
Paine and Dayan	-	20 mg/dl blood	1 g = ~ 1.26 ml	Paine and Dayan, 2001: 564

Source: own elaboration. Fuente: elaboración propia.

6 It is not possible to experience toxicity with mice because their tolerance to methanol is much higher than that of human beings.

Review of cases of methanol poisoning

We have carried out a review that includes academic bibliography and news registered on the internet, both in Mexico and in other countries, from which we summarize the following: at the beginning of the 20th century there were frequent cases of inhalation in factories. Now, most of the incidents occur due to ingestion of liquids that contain methanol (ink thinners, for example) or alcoholic beverages to which it has been added (Clary, 2013: 48; Kavet and Nauss, 1990; Monte, 2010: 494). In the United States in 2013, 1,747 cases were reported, most of them men over 19 years of age (Nikunjkumar and Kerns, 2017). Regarding intoxication due to consumption of alcoholic beverages, the cause is the added methanol, i.e., the adulteration of the beverage with that chemical compound.

We have not found cases of methanol poisoning originated in the raw material for alcoholic beverages whether it be mezcal or other distillates at the end of our investigation. Among the data found there is only an indirect mention of chronic intoxication: "The only observation that we know with alcoholic beverages is chronic intoxication with a daily ingestion of 750 mg of methanol reported by Rasquillo-Rasposo" (OIV, 1987); and more recently, a detailed analysis of illegal beverages seized in an area of Tel-Aviv, Israel, where the connection with alcoholic beverages is not proven (Shapira *et al.*, 2019).

Until 2019 we did not find in Mexico similar news. However, in 2020 there were cases of beverages adulterated with methanol, including some agave-based, that caused deaths (Infobae, 2020; La Jornada, 2020). Those cases aren't connected with methanol originated in the production of beverages, but by addition of denatured alcohol to unauthorized drinks. Therefore, we don't have any evidence to connect the consumption of distillates made from agave with risks to public health. The incidents are referred to as adulterated beverages (Clary, 2013: 4).

Mezcals and methanol

Mezcals are alcoholic beverages that are produced from agave plant tissues, which are subjected to cooking and extraction of the juice, which is then fermented and later distilled. From this process, a liquid, rich in ethyl alcohol is obtained. The more known of the mezcals is Tequila, whose original name is "mezcal wine from Tequila". It is made of the Agave tequilana Weber blue variety and is ruled by a different norm from the rest of the mezcals.

Agaves, the raw material plants of mezcals, exist in Mexican territory, especially in Oaxaca (García Mendoza, 2007; Saldaña Oyarzábal, 2006). Between twelve and twenty species of agave are used to make distilled beverages in at least twenty of the 32 Mexican states; and in at least nine of them it can be produced under the Designation of Origin "mezcal" (Colunga-García Marín *et al.*, 2007; Hernández López, 2018: 410).

Mezcals contain methanol originated from plant tissues. The same happens in some alcoholic beverages distilled from fruits. In beverages made with agave[7], methanol also has its origin in lignocellulosic residues present in the juices that are fermented (Soto-García *et al.*, 2009), while in fermented

7 Beverages made with agave are given various names: mezcal, tequila, bacanora, raicilla, distillates or spirits.

fruit beverages methanol is produced from pectin (Bindler *et al.*, 1988; Hang and Woodams, 2010: 1396). In the reaction, the enzyme pectin-methylesterase is involved (Bindler *et al.*, 1988: 345; Zhang *et al.*, 2011). The reaction of the mezcal pectin is a demethylation (Solís-García *et al.*, 2017).

The methanol content in mezcal varies because of different reasons: species of agave used, plant maturity, geographical origin, harvest system, *jimado*,[8] cooking temperature, grinding, alembic shaping, and handling of the distilled fractions (Kirchmayr, 2014; Solís García *et al.*, 2017: 828; Giersiepen, 2017).

The methanol content in alcoholic beverages is expressed as "mg of methanol per 100 ml of anhydrous alcohol" (mg/100 ml anhydrous alcohol). At the same time, the maximum tolerated by the current Official Mexican Standard (NOM-070-SCFI-2016) is 300 mg/100 ml anhydrous alcohol.[9] If we suppose a drink that contains 50% vol./vol. of alcohol, 100 ml of alcohol are contained in 200 ml of drink. In our field research and documentary on analysis of mezcal, we have never found cases of a traditional mezcal that exceeds a methyl alcohol content of 800 mg/100 ml anhydrous alcohol; the common thing is that it does not exceed 600 mg/100 ml anhydrous alcohol. Table 3 shows an analysis of certified mezcals, made in Michoacán and Oaxaca respectively by two prestigious producers, whose values are above the limit of NOM-070-SCFI-2016.

Giersiepen presents an analysis of mezcals made with different species. Six out of sixteen exceed the 300 mg/100 ml anhydrous alcohol allowed as a maximum of methanol according to the referred Mezcal standard. In Table 4 the maximum value is 404 mg/100 ml anhydrous alcohol corresponding to Agave karwinskii. As well, Agave cupreata, Agave americana, Agave salmiana exceed the 300 mg/100 ml anhydrous alcohol of NOM-070-SCFI-2016 (Giersiepen, 2017).

Table 3. Laboratory tests of two certified brands of mezcal from Oaxaca and Michoacán
Tabla 3. Pruebas de laboratorio de dos marcas de mezcal certificadas de Oaxaca y Michoacán

Origin	Type/class of mezcal	Date (month and year)	Agave	Alcohol* (% vol 20°C)	Methanol (mg/100 ml anhydrous alcohol)	Volume of batch (in liters)
Michoacán	100%/joven	Jan 2015	*inaequidens*	25.0	343	No information
	100%/joven	Sep 2014	*inaequidens*	47.0	336	417
	100%/joven	Jan 2015	*inaequidens*	16.1	403	No information
Oaxaca	Anc./joven	Jul 2018	*marmorata*	50.5	505	24
	Anc./joven	Apr 2018	*potatorum*	49.4	447	248
	Anc./joven	Jun 2018	*americana*	50.8	387	78
	Anc./joven	Dec 2018	*angustifolia*	53.7	382	486

*Ethanol. Source: own elaboration. *Etanol. Fuente: elaboración propia.

8 Jimar is to cut the leaves or stalks of the agave and detach the heart or pineapple of the plant from the base with roots.

9 See www.dof.gob.mx/normasOficiales/6437/seeco11_C/seeco11_C.html (accessed 11/25/2019).

Table 4. Methanol content in mezcals of different agave species
Tabla 4. Metanol contenido en diferentes mezcales de diferentes especies de agave

Agave species	Methanol*
Durangensis	198
Tequilana (azul)	280
Karwinskii (barril)	404
Tequilana (azul)	323
Salmiana	349
Angustifolia Haw (espadín)	113
Cupreata	342
Inaequidens	121
Convallis (jabalí)	299
Potatorum (Tobalá)	262
Cupreata verde	363
Angustifolia (espadilla)	263
Karwinskii (cuishe)	232
Americana (arroqueño)	382
Angustifolia Haw (espadín)	230
Potatorum (Tobalá)	294

*mg/100 ml anhydrous alcohol. Source: Giersiepen, 2017: 120.
*mg/100 ml alcohol anhidro. Fuente: Giersiepen, 2017: 120.

On the other hand, the standard NOM-070-SCFI-2016 establishes a minimum methanol content of 30 mg/100 ml anhydrous alcohol for the mezcal. The value was established as a standard of authenticity, suggested to differentiate 100% agave tequila from that mixed with ethanol from another origin (Bauer-Christoph *et al.*, 2003); however, agave beverages are required that minimum, which seems questionable to us, given it is not related to the protection of public health but with guaranteeing the authenticity of the tequila, which strictly speaking is not guaranteed either.

Regulations on methanol in mezcal[10]

Mezcal is regulated in Mexico by the multi-quoted "NOM-070-SCFI-2016, Alcoholic Beverages. Mezcal. Specifications" that establishes three categories: "mezcal", "mezcal artisanal", and "ancestral mezcal", based on the technology used in the process of transformation of raw material into alcohol. This mandatory rule for mezcals is based on the norm that regulates tequila, namely, NOM-006-SCFI-2012. The specifications of this last norm establish a mandatory minimum and a maximum allowed for methanol, with even values for all alcoholic beverages distilled from agave:

- Maximum methanol content: 300 mg/100 ml of anhydrous alcohol.
- Minimum methanol content: 30 mg/100 ml of anhydrous alcohol.

10 The quality standards are of two kinds: NOM and NMX. The NOMs are mandatory while the NMX are only voluntary. However, if you want to obtain an official guarantee seal such as hallmark of quality, the NMX must be met.

Our discussion is as follows:

1. The maximum methanol content comes from the first norm of alcoholic beverages in Mexico, the "NMX-V-012-1986 Alcoholic beverages. Wines. Specifications", which sets "300 mg/100 ml of 100% alcohol".[11] In the making of this norm, as in all the others, institutions or committees of private character participate, in which the representation of industrialists is greater than that of artisan producers. In the case of the 1986 regulation, wine producers were summoned nationwide.

2. In that same year of 1986, the "NMX-V-021-1986 Alcoholic distilled beverages. Methods for the determination of methanol" was published. Wine companies participated in its elaboration in addition to experts in the field and tequila companies.[12]

3. In 1995 the Official Mexican Standard "NOM-142-SSA1-1995 Goods and services. Alcoholic beverages. Sanitary specifications. Sanitary and commercial labeling" was published being the first of mandatory compliance. There, the method of determination of methanol is specified. Authorities of the health sector, beer and tequila chambers, producers of wines, spirits, charandas, mezcals, and other distillates participated in its preparation. In this norm the maximum of 300 mg/100 ml of anhydrous alcohol was specified, in addition to the requirement of 30 mg/100 ml anhydrous alcohol as minimum methanol content.

The previous overview is important because it shows how since 1986 the maximum limit of methanol for grape wines, that is, for a fermented drink, was used as a reference for distillates and it was also 300 mg/100 ml anhydrous alcohol. Furthermore, in 1995 the minimum methanol limit of 30 mg/100 ml anhydrous alcohol appeared.

In the specific case of agave distillates, "NOM-006-SCFI-1994 Alcoholic beverages. Tequila. Specifications" was published in the *Diario Oficial de la Federación* on September 3 of 1997,13 being the first to include the parameters indicated in NOM-142-SSA1-1995. From that standard, the subsequent ones and those related to beverages made with agaves maintain the same methanol values, but without mentioning the agave species used.

11 Such standard applied until April 30th, 2005, when NMX-V-012-NORMEX-2005 came into force Mexican Standard for Alcoholic Beverages. Came. Specs; methanol content continued equal to 300 mg/100 ml of anhydrous alcohol.

12 The previous standard was from 1969: Norma Oficial de Método de Prueba para la determinación de metanol en bebidas alcohólicas destiladas DGN-V-21-1969.

13 In 1949 the first Official Quality Standard for Tequila DGN-R9-1949 was published, mandatory since 1967 without specification of the amount of methanol allowed. In 1970 a new Official Quality Standard for Tequila DGN-V-7-1970 was presented in which specifications for methanol appeared. In the 1994 Standard, but published in 1997, the minimums and maximums were considered current for tequila, which was later copied for mezcal, bacanora and raicilla.

In the case of the standard for mezcals to which we have been referring (NOM-070-SCFI2016)14 obviously, those limits are also indicated, as well as the test methods established in the NMX-V-005-NORMEX-2013.15

For Mexican Official Standards the maximum limits of methanol in mezcal result from proposals of grape wine producers and distilled cereal beverages;16 and that is the reason, they used as a reference established parameters for industrialized products based on cereals, grapes, or sugar cane.

The aspect we want to highlight is that mezcals, and by extension other distilled beverages from agave or fruits, have their aroma, flavor and identity based on the volatile substances that come from the species that constitute their raw material. In the distillation process these volatile molecules are concentrated in distilled fractions in which there is also methanol. For this reason, the same parameters of wine—which is fermented juice—cannot be applied to a distillate. Furthermore, current scientific and technological advances make it possible to ensure that it is possible to increase the methanol content in genuine alcoholic beverages and ways in which the consumption of that substance is less risky, as we will see next.

International norms

Distilled beverages from fermented fruit juices such as brandy and grappa, among others, are considered in European standards as different cases of spirits that come from cereals and allow a methanol content of up to 1,500 mg[17] per 100 ml of alcohol anhydrous. The highest content of methanol is considered due to its origin in fruits or pomace (Bindler *et al*., 1988).

In this regard, both the maximum and the minimum values adopted in Mexico can be traced chronologically and institutionally. The maximum value (300 mg/100 ml alcohol anhydrous) comes from the Statutes of the vineyard, wine, and alcohols, for the Spanish case.

Regarding the modification of the methanol limits in the respective regulations due to technological reasons, we present the following: according to Decreto 2484/167 of the September 21st, 1967, the *Código Alimentario Español* (Spanish Food Code) was approved, which established the following parameters: the presence of methanol in ordinary and fine table red wines maximum 500 mg/L, while in the case of fortified and flavored wines and mistelles reached 1 g/L, and in

14 In http://dof.gob.mx/nota_to_doc.php?codnota=5472787 (accessed 26/06/2019).

15 The Mexican standard on the determination of methanol in alcoholic beverages in Mexico is the "NMX-V-005-NORMEX-2013 Alcoholic beverages. Determination of aldehydes, esters, methanol, and higher alcohols. Test methods (test)", which replaced NMX-V-005-2005, and which follows the established in NOM-142-SSA1-1995.

16 This can be seen in the lists of people and organizations participating in the beverage standard alcoholic (NOM 142), methanol (NMX-05), tequila (NOM-006), and mezcal (NOM 070), among others

17 See *aguardiente de hollejo* in Table 7.

the case of rum, whiskey and brandy it could reach 2 g/L; ciders could reach 200 mg/L.[18] Fifteen years later, in 1982, also in Spanish dispositions, pear spirits could have up to 5 g/L, that of cherry 4 g/L and pomace 3.5 g/L.[19]

Bindler *et al.* cite methanol standards for distilled fruit spirits in several countries in the late 1980s. At that time, regulatory tolerance for pear, grape, plum, and kirsch liqueurs in the United States and Canada were "700 g/hl of pure alcohol" (= 700 mg/100 ml). In Italy, the limit was 600 in equal units. In Switzerland, the standard for distillates of pear and grape spirits set a maximum of 1600 g/hl of methanol and for kirsch 800 g/hl (Bindler *et al.*, 1988: 346).

That means, the beverages that are in order with standards in Europe or the United States would not meet the Official Mexican Standards (NOM); in other words, if Mexican mezcals were European or from the United States, they would always be within the standards. The current European standard is the Regulation (EC) No 110/2008 of the European Parliament and of the Council of January 15th, 2008 (Parlamento Europeo, 2008). The values are shown in Tables 5, 6, and 7.

Table 5. Normative tolerance of methanol in distillates in European countries
Tabla 5. Normativa de tolerancia del methanol en destilados de países europeos

Brandy type	USA and Canada	Italy	Switzerland
Pear	700	600	1.600
White grape	700	600	1.600
Plum and Quetsch	700	600	800-1.600
Kirsch	700	600	360-800

The units g/hl are equivalent to mg/100 ml used in Mexican norms. Source: Bindler *et al.*, 1988: 346. Las unidades g/hl son equivalentes a los mg/100 ml usados en normativas mexicanas. Fuente: Bindler *et al.*, 1988: 346.

In the same article by Bindler *et al.* authors were cited who proposed to raise the methanol tolerance in distillates of various fruits (Bindler *et al.*, 1988: 346).[20]

A matter of equal relevance is that in 2004 the International Organization of Vine and Wine (OIV) modified the amount of methanol allowed in grape wines, due to the introduction of new compounds to limit fermentation. In the last decades of last century, the use of dimethyl dicarbonate (DMDC) was introduced in oenological practices, which increased the amount of methanol in the wine. Due to this, and after consulting the group by experts in "food safety" from the OIV, they authorized to raise the methanol limit allowed in wines, as follows:

18 Inhttps://legislacion.vlex.es/vid/decreto-aprnza-texto-codigo-alimentario-204508137 (accessed 12/01/2020).

19 See Annex, at the end of the article, on units and measurements.

20 "Examples of proposed limits are: 710 g/hl pure alcohol (p.a.) (Reinhard, 1978); 720 g/hl p.a. (Ratz, 1966) or 750 g/hl p.a. (Nosko, 1972) for quetsch distilled spirits; 400 g/hl p.a. for kirsch distilled spirits (Nosko, 1969 and 1972; Ratz ,1966); 880 g/hl p.a. for William pear distilled spirits (Nosko, 1974a y 1974b)" (Bindler et al., 1988: 346).

Table 6. Existing limits of methanol in grape wine[21]
Tabla 6. Límites existentes de metanol en vinos

Wine type	Before	Resolution 2004
White and rose wine	150 mg/L	250 mg/L
Red wine	300 mg/L	400 mg/L

Source/fuente: OIV, 2004.

The current European standard is the Regulation (EC) No 110/2008 of the European Parliament and of the Council of January 15, 2008, "regarding the definition, designation, presentation, labeling and protection of the geographical indication of spirits…" (Parlamento Europeo, 2019), which will be valid until May 2021.[22] It marks the following values (Table 7):

Table 7. Maximum values of methanol content in alcoholic beverages in Europe
Tabla 7. Valores máximos de metanol en bebidas alcohólicas europeas

Alcoholic beverage	Methanol allowed	Page
Wine spirit	"Maximum methanol content of 200 g/ hl*of alcohol at 100% vol"	(p. L 39/30)
Brandy or *weinbrand*	"Maximum methanol content of 200 g/hl of alcohol at 100% vol"	(p. L 39/31)
Grape marc spirit or grape marc	"Maximum methanol content will be 1000 grams per hectoliter of alcohol at 100% vol"	(p. L 39/31)
Fruit marc spirit	"Maximum methanol content will be 1500 grams per hectoliter of alcohol at 100% vol"	(p. 39/31)
Fruit spirit	"The maximum methanol content of fruit spirit shall be 1000 g/hl of alcohol at 100% vol. Except: (i) 1200 g/hl of alcohol at 100% vol obtained from fruits '1' (apple, apricots, plum, mirabelle, peach, quetsch, pear—except Williams pear—raspberry, and blackberry). (ii) 1350 g / hl of alcohol at 100% vol obtained from fruits "2" (Williams pear, red currant, black currant, rowanberry, elderberry, quince, and juniper berries).	(pp. L 39/32 and L 39/33)
Cider spirit, perry spirit and cider, and perry spirit	"Maximum methanol content of 1000 g/hl of alcohol at 100% vol"	(L 39/34)
Vodka	"Methanol in the final product will not be greater from 10 g/hl to 100% vol"	(L 39/35)

*g/hl = mg/100 ml. Source: own elaboration. Fuente: elaboración propia.

21 1 liter of white wine corresponds o approximately 100-140 ml of anhydrous alcohol; 1 liter of red wine contains approximately 130-150 ml of anhydrous alcohol. Consequently, a red wine with 13% alcohol volume, could have 307 mg/100 ml anhydrous alcohol; that means more than a mezcal, and without distilling.

22 From May 2021 the regulation 2019/787 will maintain the tolerance values: https://eur-lex.europa.eu/legal-content/es/TXT/?uri=CELEX%3A32019R0787 (accessed 03/09/2021).

The presentation by Dwight Matthews of the University of Vermont mentions the following methanol limits in distilled fruit beverages, i.e., raw materials that, unlike cereals and sugar cane do not have pectin, can be compared with the agaves:

1. In Europe, for distilled alcoholic beverages, the limits in 2010 were "10 g MeOH/L EtOH", which is equivalent to 1000 mg of methanol per 100 ml of ethanol.

2. In the United States of America (ATF: Bureau of Alcohol, Tobacco, Firearms, and Explosives): "7 g MeOH/L EtOH", which is equivalent to 700 mg of methanol for every 100 ml of ethanol (this data is corroborated in Andraous *et al.* (2004: 199) and refers to United States Code of Federal Regulations, 2003).

3. For the grape wine standards of the International Organization of Vine and Wine (OIV): "0.2-0.4 mg MeOH/ml wine" (Matthews, 2010: 5).

The above shows that since the eighties, but significantly in the last two decades, due to technological advances and the implementation of other analytical methods in alcoholic beverages, methanol levels have been modified in favor of the production of fruit-based beverages with significant amounts of pectin. Regarding undistilled grape wine, referred to Mexican norms, fifteen years ago they increased the permitted levels, with no recorded consequences.

In this regard, Hodson and Wilkes (2016), together with vigilant organizations of Health and Food, have also concluded that a higher intake of methanol, up to 1500 mg/hl, does not pose a risk to the health of a healthy person.

Conclusions

As Hodson and Wilkes (2016) conclude, methanol limits are established by the economy of each country for technological, but not for toxicological reasons. Therefore, given the progress, the limits no longer serve a public health purpose because it has been proven that the risk of poisoning is at levels well above those currently established.

We agree with these authors that the variation in the values for the maximums of methanol in different countries, in addition to heterogeneous measurement units, can generate a perception of different treatments and increase the possibility of error. It is therefore important to harmonize the limits, as well as the units to express them, on an international scale (Hodson and Wilkes, 2016).

However, what we are interested in suggesting is that the absence of an updated discussion on these issues has consequences on the diversity of ways of producing mezcal.

It even conditions the possibility of using some species that commonly exceed the parameters, and when used they must be blended with other agaves, thus opening the probability of cheating the consumer regarding the employed raw material, i.e., when stated on the label that certain wild agave is used to make a specific mezcal.

Although mezcals in some cases exceed the amount of methanol set by NOM-070-SCFI-2016, the registered values are below standards of the European Union, the U.S., and the World Health Organization, where there is a history of greater tolerance to methanol than in current Mexican norms. In the case of wine from grapes, more than fifteen years ago the methanol levels allowed were increased by the International Organization of Vine and Wine (OIV, 2004).

For these reasons, NOM-070-SCFI-2016 is insufficient in recognizing the particularities of mezcals. It should set different specifications on methanol content viewing the diversity of raw materials and processes. Diversity is essential in the case of Mexican mezcals. NOM 070 refers to that point by recognizing the existence of three categories, which is insufficient, as it should establish different physicochemical specifications, at least for methanol, for each of the categories.

The establishment of methanol limits considered fit for human consumption, i.e., that they are not posing a health risk, constitutes a way of classifying what characterizes institutions (in this regard, see Douglas, 1996). Through the labels, they display their official character and their capacity to control when demanding compliance of these parameters. However, that style of thought to which the establishment of measures correspond, is anchored in a certain historical time.

Thus, thirty years after having defined the maximum allowed for the intake of methanol and following new research on its toxicology, the limits result intolerable. Therefore, the current pressure is from the small producers of traditional mezcal (artisan and ancestral) to modify the parameters, which have become artificial, without livelihoods in terms of health, in order to accommodate diversity.

A discussion and update of the "NOM-142-SSA1-1995 Goods and Services. Alcoholic beverages. Sanitary specifications. Sanitary and commercial labeling" about allowed and mandatory limits of methanol without health risks is possible. That priority of public health taken care of, a review is necessary for recognition of cultural *mezcalera* diversity. Finally, the methanol content exceeding the norm in traditional mezcals can also be decreased by optimization techniques (Kirchmayr, 2014). It is a process that must be discussed separately because technological alternatives would modify both the procedure as subtle features of highly dense cultural products.

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Annex. About units and measurements

Bibliographic references sometimes differ in the use of units of measurement. We are interested in two situations in which the concentration of methanol is measured:

1. Concentration of methanol in a beverage

The NOM standards use the ratio of the amount of methanol to the total alcohol in a beverage and is usually expressed as ml of methanol with respect to 100 ml of anhydrous alcohol (which we abbreviate "anhydrous alcohol"). It specifies anhydrous alcohol = 100% alcohol. The clarification is necessary because the "pure" alcohol distillate is an azeotropic mixture of alcohol and water (96% ethanol and 4% water).

In some articles, the concentration of methanol in a beverage is usually expressed in mg/dl (milligrams of methanol in one deciliter of anhydrous alcohol).

Equivalence of values: 1 mg/dl = 1 mg/100 ml = 10 mg/L = 0.01 g/L = 1 g/hl.

In the work by Bindler *et al.* (1988) the authors write the limits in "g/hl p.a.", that is, grams per hectoliter of pure alcohol. If we understand that "p.a." is anhydrous alcohol, g/hl is equivalent to mg/100 ml anhydrous alcohol.

In the regulations of the International Organization of Vine and Wine (OIV), methanol limits are expressed in mg/L of wine (which varies in its alcoholic strength). This makes it difficult to compare with the regulations of Mexico, the United States, and Europe, which refer to anhydrous alcohol volume. Example: for red grape wine, OENO 5/2001 and OENO 19/2004 set a maximum of 400 mg/L for methanol. If we assume a wine of 11% vol/vol, its equivalent in the NOM units of measurement is 363 mg/100 ml anhydrous alcohol. For a graduation of 14% vol/vol, its NOM equivalent would be 286 mg/100 ml anhydrous alcohol.

2. Methanol concentration in the blood of an individual

The concentration of methanol in the blood makes it possible to compare values with records of other cases of intoxication. The units used in the bibliography are mg/dl (milligrams of methanol in a deciliter of blood). One deciliter equals 100 ml (one hundred milliliters) or 0.1 L (one tenth of a liter).

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Recibido: 12/04/2021
Versión final recibida: 09/06/2021
Aceptado: 14/06/2021
Publicado: 07/10/2021