Systematic Misinformation about Thujone in Pre-ban Absinthe

Dirk W. Lachenmeier[1#] and David Nathan-Maister[2]

[1] Chemisches und Veterinäruntersuchungsamt (CVUA) Karlsruhe, Weißenburger Str. 3, D-76187 Karlsruhe (www.cvua-karlsruhe.de)

[2] Oxygenee Ltd, 22 Baylis Crescent, Burgess Hill, RH15 8UP/UK (www.oxygenee.com)

Summary

The media coverage about absinthe, a bitter spirit containing wormwood (*Artemisia absinthum* L.), continues to repeat unsubstantiated myths and legends and the public is systematically misinformed. Especially, the theory about a significant thujone content in absinthe must be put into perspective as there are a number of different wormwood chemotypes with a large variance in thujone content (0–70.6% in essential oil) from which a mean thujone content of about 20 mg/l in distilled absinthe with a large standard deviation of up to 20 mg/l may be calculated. However, a higher thujone amount of 260 mg/l derived from erroneous and out-of-date calculations is generally presented as "historical content" in addition to reports about unsubstantiated psychoactive or aphrodisiac properties. Other studies used unauthentic recipes with unrealistically high amounts of wormwood that would produce undrinkable bitter products. In general, a previous overestimation of the thujone content of pre-ban absinthe was detected.

Zusammenfassung

Die Medienberichterstattung über Absinth, einer Bitterspirituose mit Wermut (*Artemisia absinthum* L.), verbreitet fortgesetzt unbewiesene Gerüchte und Legenden und die Öffentlichkeit wird auf systematische Weise falsch informiert. Insbesondere die Theorie über einen signifikanten Thujongehalt in Absinth muß wesentlich differenzierter beleuchtet werden, da eine Reihe von verschiedenen Wertmut-Chemotypen existiert, die eine große Streubreite ihrer Thujongehalte aufweisen (0–70,6% im ätherischen Öl). Davon ausgehend kann ein durchschnittlicher Thujongehalt von 20 mg/l in destilliertem Absinth berechnet werden mit einer großen Standardabweichung von 20 mg/l. Allerdings wird immer wieder ein höherer Thujongehalt von 260 mg/l als „historischer Gehalt" angeführt, oft im Zusammenhang mit vermeintlichen psychoaktiven oder aphrodisierenden Wirkungen von Absinth. Andere Studien verwenden unauthentische Rezepturen mit unrealistisch hohen Wertmutgehalten, die zu untrinkbar bitteren Produkten führen würden, um einen größeren Thujongehalt zu belegen. Im Allgemeinen konnte in dieser Arbeit eine frühere Überschätzung der Thujongehalte von historischem Absinth nachgewiesen werden.

Keywords: absinthe, thujone, *Artemisia absinthium* L., wormwood, public misinformation / Absinth, Thujon, *Artemisia absinthium* L., Wermut, Falschinformationen

1 Introduction

Absinthe – a bitter spirit containing wormwood (*Artemisia absinthium* L.) and other herbs – was one of the most popular alcoholic beverages in late 19th century Europe. Renewed interest in absinthe has been raised by the fact that after a century-long prohibition in many European countries, wormwood was re-legalised as an ingredient of alcoholic beverages in 1988, and currently over 100 types of absinthe are legally available[1,2].

It is remarkable that the media coverage about absinthe continues to repeat unsubstantiated myths and legends, and in the scientific as well as in the lay literature the public is systematically misinformed.

2 Absinthe and thujone

The first and foremost mistake about absinthe is the theory about significant thujone content in the spirit. One of the most widely cited articles about absinthe is entitled "Absinthe: what's your poison" by *Strang* et al.[3]. The authors of the article claim that "the thujone content of old absinthe was about 0.26 g/l" and *Duplais*' French distilling guide[4] is given as reference. This citation is misleading. Duplais' recipes merely give the wormwood content used for absinthe making, and there is no mention of thujone (or any other terpene) in both volumes of Duplais' work. In this context, it must also be pointed out that the exact composition of wormwood oil was unknown in Duplais' time. The composition of wormwood oil was first studied by *Leblanc* in 1845[5], and a constituent with the empirical formula $C_{10}H_{16}O$ was identified. The substance was called absinthol by *Beilstein* and *Kupffer* in 1873[6]. It was later proven by *Wallach* in 1902[7] that absinthol in wormwood was the same substance as both tanacetone found by *Semmler*[8] in tansy oil, and a compound in thuja oil that *Wallach*[9] had named thujone. The correct structure was discovered by *Semmler* in 1900[10]. Only at the beginning of the 20th century, therefore, did it become common knowledge that thujone is a constituent of wormwood oil as documented in *Gildemeister's* and *Hoffmann's* classic textbook of the volatile oils[11]. Knowledge of the exact composition of wormwood oil has become available only with modern chromatographic methods. The first systematic gas chromatographic (GC) study of wormwood oils was conducted by *Chialva* et

Dr. D. W. Lachenmeier, email: Lachenmeier@web.de, Tel.: 0721-926-5434 Fax: 0721-926-5539

Tab. 1 Essential oil and thujone content of *Artemisia pontica* L. (nd: not detected, SD: standard deviation)

Origin of plant	N	Total essential oil [%]	α-thujone [%]	β-thujone [%]	Total thujone [%]	Reference
Italy	5	(no data)	10–25 (mean: 20)	nd	10–25 (mean: 20)	15)
Italy	1	0.34	20.9	4.2	25.1	16)
Bulgaria	1	0.40	nd	nd	nd	17)
Kazakhstan	1	0.20	23.2	2.7	25.9	18)
(no data)	1	0.25	30.0	nd	30.0	19)
Siberia	14	0.20–0.85 (mean: 0.44)	nd–20.1 (mean: 2.7)	nd–2.0 (mean: 0.4)	nd–22.1 (mean: 3.1)	20)
Overall	Min	0.2	nd	nd	nd	
	Max	0.9	30	4.2	30	
	Mean	0.3	15.4	1.5	16.8	
	SD	0.1	12.0	1.8	12.7	

al.[12]. Here, the pre-GC view that thujone is the chief constituent of wormwood[13] was shown to be over-simplified as there are a number of different wormwood chemotypes – a fact that is willingly ignored even in current literature.

3 The Thujone myth – an educated guess?

As there was no mention of 0.26 g/l in Duplais' book it can only be presumed how *Strang* et al.[3] derived this concentration. Most probably they meant by the 1855 citation, that an educated guess as to the thujone content of absinthe can be made from Duplais' recipe. This becomes clearer by the fact that such a guess was made by *Arnold* (a co-author of Strang's article) in his book "Vincent van Gogh: chemicals, crises, and creativity"[14]. On the assumption that 100 l of pre-ban absinthe employed 2.5 kg of dried *Artemisia absinthium* L. (1.5% oil, of which 67% is thujone; corresponding to 251 mg/l of thujone in the final product) and 1 kg of dried *Artemisia pontica* L. for coloration (0.34% oil, of which 25% is thujone, corresponding to 9 mg/l of thujone in the final product), the concentration of 260 mg/l may be calculated.

However, Arnold failed to mention the wide variations in the oil content of wormwood and the even wider variations of the thujone content in the oil determined in Chialva's and other GC studies. We thoroughly reviewed the literature on the composition of wormwood oil and found 29 references1[2,15–42], which are summarised in Table 1 for *A. absinthium* and Table 2 for *A. pontica*. A wide variation in the oil content of wormwood and even wider variations of the thujone content in the oil is notable. A number of different chemotypes was found in the studies with β-thujone, *cis*-chrysanthenyl acetat, *cis*-chrysanthenol, *cis*-epoxyocimene, sabinyl acetate or bornyl acetate as principal component. Some chemotypes did not contain thujone at all, for example chemotypes from France[41], Italy[12,33], Spain[31], Lithuania[23], and Egypt[28]. It is therefore possible to produce absinthe without any thujone.

The mean essential oil content of *A. absinthium* and *A. pontica* is 0.6 ± 0.3% and 0.3 ± 0.1% and the mean total thujone content in the essential oil is 17.6 ± 18.0% and 16.8 ± 12.7%, respectively. Therefore, it can be concluded that the calculation of 260 mg/l was done with exceptionally high values for both parameters and was an overestimation. If the values from our literature review are used for calculation and considering the distillation behaviour (max. yield 80% according to ref.[43]) as well as losses in the maceration and colouration steps (a yield of thujone of approx. 90% was determined by *Gimpel* et al.[44]), the thujone concentrations of distilled absinthe would be as detailed in Table 3. The distribution of the thujone concentrations is shown in Figure 1. Dependent on the recipe, the mean thujone content of absinthe may have been ranged around 17–23 mg/l with large standard deviations of 16–21 mg/l, the median content may have been around 10–14 mg/l.

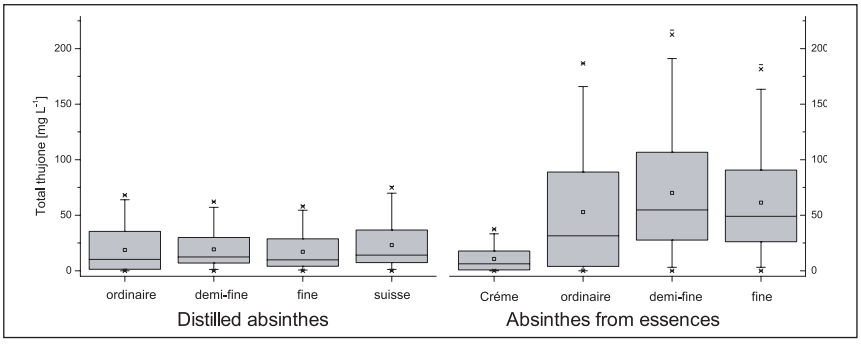

Fig. 1 Box chart of possible thujone concentration in different recipes for pre-ban absinthe (data from Tab. 3 and 4)

4 Error propagation the absinthe way

In the years following the publication of *Strang* et al.[3], the imprecise citation of 260 mg/l led to further propagation of an inaccurate assumption. The estimated thujone content is now presented as a known fact, e.g. "Absinthe contains a number of terpenes and terpene derivatives, includ-

Tab. 2 Essential oil and thujone content of *Artemisia absinthium* L. (nd: not detected, SD: standard deviation)

Origin of plant	N	Total essential oil [%]	α-thujone [%]	β-thujone [%]	Total thujone [%]	Reference
Turkey	1	0.67	0.2	0.5	0.7	21)
Iran	2	0.63–0.81 (mean: 0.72)	41–60 (mean: 51)	3.0–5.5 (mean: 4.3)	44–65.5 (mean: 55.3)	22)
Lithuania	10	(no data)	<0.05–23.5 (mean: 8.1)	<0.05–30.7 (mean: 13.0)	<0.05–36.6 (mean: 21.1)	23)
Iran	1	0.65	3.3	35.1	38.4	24)
Canada	1	(no data)	2.9	32.1	35.0	25)
Iran	1	0.60	6.93	nd	6.93	26)
	1	0.50	(no data)	(no data)	4.8	27)
Egypt	1	0.78	nd	nd	nd	28)
Iran	1	0.92	nd	5.12	5.12	29)
France	6	(no data)	2.55–21.60 (mean: 12.7)	3.75–28.33 (mean: 16.0)	6.30–49.87 (mean: 28.7)	30)
Spain	14	0.28–0.42 (mean: 0.35)	nd	nd	nd	31,32)
Italy	49	0.11–0.82 (mean: 0.28)	nd–2.70 (mean: 0.4)	nd–69.68 (mean: 10.1)	nd–70.63 (mean: 10.5)	33)
Cuba	1	1.25	nd	0.29	0.29	34)
Italy	1	(no data)	<0.1	1.3	1.3	35)
Argentina	1	(no data)	2.34	59.90	62.24	36)
USA	2	(no data)	nd–3.42 (mean: 1.7)	nd–33.11 (mean: 16.6)	nd–36.53 (mean: 18.3)	37)
Several localities	19	0.25–1.60 (mean: 0.78)	nd–1.68 (mean: 0.9)	nd–40.60 (mean: 8.7)	nd–42.28 (mean: 9.6)	12)
India	1	0.27	9.22	nd	9.22	38)
Serbia	1	0.29	0.9	19.8	20.7	39)
Russia	1	(no data)	20.8	13.7	34.5	40)
France	8	0.38–0.89 (mean: 0.59)	nd	nd	nd	41)
Croatia	10	0.39–1.45 (mean: 0.95)	nd–2,5 (mean: 0.9)	14.0–48.6 (mean: 28.7)	14.0–51.1 (mean: 29,6)	41)
Several localities	19	0.1–1.1 (mean: 0.5)	1.1–10.9 (mean 4.16)	0.1–64.6 (mean 8.73)	1.5–67 (mean 12.89)	42)
Overall	Min	0.3	nd	nd	nd	
	Max	1.6	60.0	69.7	70.6	
	Mean	0.6	5.8	12.5	17.6	
	SD	0.3	11.4	15.2	18.0	

ing thujone (ca. 2.4 mM)"[45]. The working group of *Casida* at Berkeley[46–48] derived that thujone is best known as the active ingredient and toxic principle of absinthe, which is a presumption unsupported by literature data. In the next step, the "guessed" thujone content was given as "historical" content[49]. One of the authors has to admit that in an own study, this wrong information was repeated, and it was imprecisely indicated that thujone concentrations as high as 260 mg/l were reported in the 19th century[50]. *Hutton*[51], also falling for this mistake, pointed out that analytical techniques in the 19th century were not capable of separating thujone from many of the related compounds and it was therefore likely that concentrations were grossly overestimated. It is now clear, that there are in fact no analyses from the 19th century. If there is an overestimation, it took place in the 1990's during Arnold's calculation. Experimental evidence pointing to this overestimation was provided by a number of studies. Absinthes produced according to historic recipes only contained relatively low concentrations of thujone (mean: 1.3 ± 1.6 mg/l, range: 0–4.3 mg/l)[50]. Concentrations below 10 mg/l were also found in a number of tests of vintage absinthes[50–53]. In contrast, experimental evidence is still lacking to confirm Arnold's calculation of high thujone content.

Tab. 3 Wormwood content in historic distilled absinthe recipes and possible resulting thujone concentration in absinthe (SD: standard deviation)

Recipe after Duplais (1855)[4]	*A. pontica* [kg/hl]	*A. absinthium* [kg/hl]	Thujone concentration [mg/l]*				
			Min.	Max.	Mean	SD	Median
Absinthe ordinaire	–	2.5	0	68	19	21	10
Absinthe demi-fine	1.0	2.0	0	62	19	17	13
Absinthe fine, Absinthe Suisse de Montpellier ou Lyon	0.5	2.0	0	58	17	16	10
Absinthe Suisse de Pontarlier	1.0	2.5	0	76	23	21	14

* Assumptions: 90% yield during maceration and colouration, 80% yield during distillation and removal of heads and tailings (5% of the distillate)

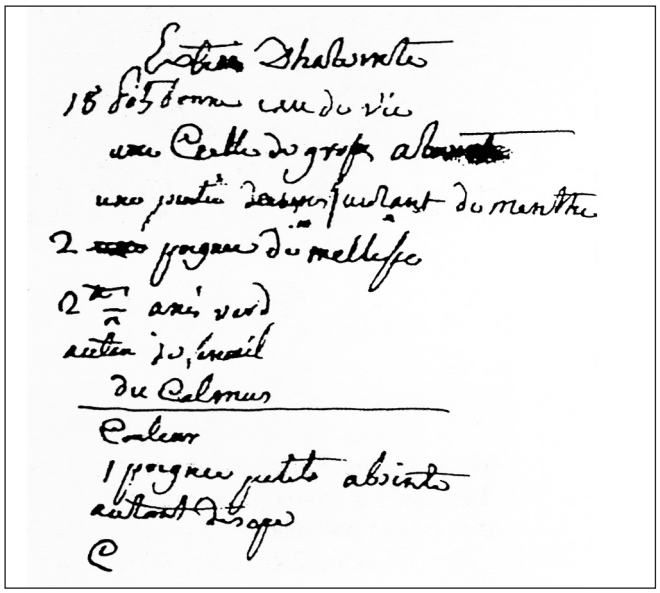

Fig. 2 Original 1794 recipe of absinthe. For 18 pots of eau-de-vie (approximately 34 litres), a large bucket of common wormwood (*Artemisia absinthium*), some mint, two handfuls of lemon balm and two of green anise, the same amount of fennel, some calamus. To colour: a handful of roman wormwood (*Artemisia pontica*) and the same amount of hyssop (reproduced from ref. [55])

5 Rebuttal of recent claims of high-thujone absinthes

In a study conducted by *Gimpel* et al. called "thujone content of absinthes spirits using historical recipes" recently published in this journal[44], three absinthes prepared according to scale model of historical recipes based on distillation contained thujone in the range of 61 and 101 mg/kg, which comprises the upper range or slightly exceeds the maximum of reachable thujone concentration of our own calculation detailed in Table 3. There are two main reasons for this overestimation by *Gimpel* et al.: (i) the failure of distinction between the use of *Artemisia absinthium* and *Artemisia pontica*, and (ii) the lack of credibility in the sources of the absinthe recipes used.

5.1 Accurate representation of manufacturing methodology of 19th century absinthe

The use of the typical recipes by large distilleries like Pernod Fils (Pontarlier, France) is well documented. For example, a 1896 booklet published by Pernod Fils themselves (available in both the original French and in English translation[54]) describes the general principles of their manufacturing process, and the constituent herbs they used. Although specific quantities are not mentioned, the information such as it is, is in exact accordance with *Duplais*[4].

Duplais was the definitive 19th century distilling reference. It went through seven editions in French (1855, 1858, 1866, 1876, 1882, 1893, and 1899/1900), two in English (translated *McKennie*, 1871 and 1875) and two in German (translated *L. Gumbinner*, 1861 and 1878). It was widely referenced at the time in other publications. Duplais' recipes are easily available in original scans and English translations at the internet site of the "Virtual Absinthe Museum"[54]. There was a second authoritative late 19th century French distilling reference: *J. Fritsch* – Nouveau Traité de la Fabrication des Liqueurs d'Apres les Procedes les Plus Récents. Published in 1891, with a further edition in 1926 (which still includes all the absinthe information) (both editions are available on ref.[54]). The recipes in Fritsch are in accordance with those in Duplais. There were three further 19th century distilling guides targeted at the popular market, all of which sold in large quantities and went through multiple editions in the 1880–1910 period: Roret, de Brevans and Bedel (all three available on ref.[54]). The recipes shown in all three books are in accordance with Duplais. There is also an absence of countervailing evidence: there are no known French publications of the 1860–1910 period, which contain any absinthe recipes significantly different from those shown in Duplais.

5.2 Problem of German absinthe recipes in the differentiation between the wormwood types

The main criticism about the article by *Gimpel* et al.[44] is the fact that the recipes used were derived from German recipe books and not from the above mentioned original French recipes. It must be considered that absinthism (if it existed) was a problem of France and French recipes appear to have lower wormwood dosages than the German recipes used by *Gimpel* et al.[44]. Of course, the question remains if these German recipes were actually used by industry (to our knowledge a case of absinthism was never documented in Germany). In general, the German recipes lack in credibility and the actual use of these recipes is not documented in contrast to the French recipes that were widely used by the large absinthe distilleries in France. Some of the German recipes were obviously translations of French recipes that did not incorporate the differentiation between *A. absinthium* and *A. pontica*.

Every known French absinthe recipe, without exception, makes a clear distinction between the use of *A. absinthium* (English: common wormwood (colloquially sometimes called grande wormwood), French: grande absinthe) in the initial maceration, and *A. pontica* (English: roman wormwood, French: petite absinthe) in the colouring step. This distinction was noted even in the very earliest recorded absinthe recipe, which dates from 1794 (Fig. 2)[55].

A. absinthium is entirely unsuitable for use in the colouring maceration, because absinthe coloured with *A. absinthium* would be unpleasantly bitter. The experiments of *Gimpel* et al.[44], however, were conducted using *A. absinthium* for colouration. As *A. absinthium* may contain significantly higher levels of thujone than *A. pontica,* the final absinthe contains higher thujone levels than if manufactured according to historic French recipes. In addition, *Gimpel* et al.[44] used fresh wormwood herb or herb that was stored only up to 4 months. No absinthe, either now or in the pre-ban era,

has ever been made with fresh wormwood herb (or any other fresh herbs – they are always dried). Based on anecdotal evidence from personal communications with absinthe distillers, there appears to be an inverse correlation between length of drying time of the wormwood and the amount of thujone in the final distillate. The longer the wormwood has been dried for, the lower the likely thujone content. But the industry standard in the modern era is that the wormwood should have been dried for at least 6 months, and it appears that this was also true in the pre-ban era.

Tab. 4 Wormwood oil content in historic absinthes from essences recipes and possible resulting thujone concentration in absinthe (SD: standard deviation)

Recipe after Duplais (1855)4)	Essential oil of *A. pontica* [g/hl]	Essential oil of *A. absinthium* [g/hl]	Thujone concentration [mg/l]				
			Min.	Max.	Mean	SD	Median
Créme d'Absinthe (Absinthe liqueur)	–	6	0	37	11	11	6
Absinthe ordinaire par essences	–	30	0	187	53	54	32
Absinthe demi-fine par essences	10	30	0	217	70	55	55
Absinthe fine par essences	10	25	0	186	61	46	49

The study of *Gimpel* et al.[44] must be put into perspective regarding the fact that the historic recipes used do not correspond to typical French recipes, which led to an overestimation of the thujone content.

5.3 Absinthe manufactured from essential oils

Furthermore, *Gimpel* et al.[44] calculated that absinthe made in another way of production, with essential oil of wormwood, is likely to have contained thujone concentrations between 2 and 3842 mg/kg. These calculations must also be rebutted as the recipes were likewise taken from German textbooks that prescribed significantly higher amounts to be used than the original French books. For example, Duplais' absinthe fine par essences uses 30 g of essence de grande absinthe to manufacure 100 l of absinthe with 65% vol of alcohol[4]. Other historic French recipes collected by the "Virtual Absinthe Museum"[54] also prescripe the typical amount of 30 g per 100 l of spirit. In contrast, the recipes referenced by *Gimpel* et al.[44] use amounts up to 100 g of wormwood oil per only 12 l of spirit, which explains the high calculated thujone concentration of the derived product of 3842 mg/kg. We conducted an organoleptic experiment and prepared a solution containing 8.3 g/l of wormwood oil (corresponding to Gimpel's recipe of 100 g/12 l). All members of the trained taste panel of the CVUA Karlsruhe judged this solution (even after dilution 1:4 with water) as absolutely undrinkable due to its overwhelmingly bitterness and pungent wormwood aroma. The panel concluded that such a solution has nothing whatsoever to do with a pre-ban or modern absinthe spirit. It appears more likely that the recipes cited by *Gimpel* et al.[44] were intended to manufacture an intermediate product that might be used later after further dilution to finally manufacture an absinthe even if it was stated otherwise in the cited reference. Realistic absinthe recipes that use around 0.3 g/l of wormwood oil (corresponding to Duplais' 30 g/100 l), might have contained thujone in the range between 2–11 mg/kg of thujone (if the wormwood oil contained 3% of thujone) or in the range between 34–150 mg/kg (if the wormwood oil contained 41.5% of thujone) according to *Gimpel* et al.[44]. Our own calculations of absinthes prepared with wormwood oil are shown in Table 4. We have calculated a possible concentrations range between 0 and 217 mg/l, with average concentrations between 11 and 70 mg/l and median concentrations between 6 and 55 mg/l. *Gimpel* et al.[44] are right in the one point that absinthes from essences might have contained higher thujone concentrations than distilled absinthes as is shown in Figure 1.

5.4 Conclusions about toxicity and absinthism

All in all the conclusions of *Gimpel* et al.[44] that the thujone concentrations of pre-ban absinthes might have exceeded today's maximum limit of 35 mg/kg by up to a hundredfold must be rebutted. The highest possible thujone concentration of pre-ban absinthes from essences might have been up to 217 mg/l if exceptionally thujone-rich wormwood was used. However, the consumption of as much as 1 litre of an alcoholic beverage containing 217 mg/l of thujone, would result in an intake of about 3.6 mg thujone/kg bw for a 60 kg adult. Even this unrealistically high intake of alcohol produces thujone concentrations below the NOEL of 5 mg/kg bw (for a detailed toxicological review about thujone see *Padosch* et al.[2]). The consumption of 1 glass (30 ml) of such an absinthe, containing approx. 6.5 mg of thujone, would result in an intake of 0.1 mg thujone/kg bw, which is 50 times lower than the NOEL. It should also be kept in mind that this calculation is based on a "worst case scenario" with the highest possible thujone concentration in absinthe from essences. If the median thujone concentration of about 10 mg/kg for a distilled absinthe is used, the intake would be 1000 times lower than the NOEL.

Regarding this point, the conclusion of *Gimpel* et al.[44] that it does not seem far-fetched to consider thujone as being a non-negligible cause of absinthism must also be rebutted. It is also notable that the high-thujone chemotypes of the different Artemisia species in Tables 1 and 2 were not found in France.

On the evidence of contemporary reports and marketing materials (various examples in the Virtual Absinthe Museum[54]), it is certain that all the largest manufacturers

of absinthe (e.g. Pernod Fils, Cusenier, Edouard Pernod, Berger, Jules Pernod, Junod etc.) made exclusively naturally coloured absinthes from direct herbal distillation. In addition, these large companies collectively dominated the market (Pernod Fils of course was by far the biggest producer). There were many small manufacturers making absinthes from essences and/or with artificial colouring. Although their overall market share was undoubtedly considerably less than the producers of distilled absinthes, they were over-represented at the bottom end of the market. In other words, the poorest drinkers were more likely drinking absinthes made from essences, and of course it was amongst this segment of society that the problems connected with alcohol drinking were most acute. However, it is also reasonable to assume that the manufacturers of absinthes derived from essences at the bottom end of the market would have had no incentive to use more than the recommended levels of wormwood oil in their products. Had they done so, they would simply have been pushing up their costs with no commercial benefit. The general assumption with low cost spirits is that the manufacturers will skimp on ingredients, not overuse them.

Recent research of 19th century studies about absinthism concluded that the so-called absinthism cannot exactly be distinguished as a distinct syndrome from chronic alcoholism[2)]. If one looks at the large amount of alcohol to be ingested without nearing the NOEL of thujone, it appeared most likely that the adverse effects of excessive absinthe consumption were exclusively due to ethanol. Interestingly, as early as 1910, it was observed in Paris that about 80% of patients with cancer of the oesophagus and cardiac region of the stomach were alcoholics who drank mainly absinthe[56)]. Years later, it was conclusively proven that alcoholic beverages in general and not only absinthes are carcinogenic to humans[57)]. Nowadays it appears most likely that in the same way alcoholism was first called absinthism, because absinthe was the main alcoholic beverage consumed in that era.

6 The final misinformation of the consumer

With the end of absinthe's prohibition and rising public interest in the product, the misinformation in scientific studies was transferred to the popular press. The 260 mg/l is presented as common knowledge, and it is given as fact that the thujone content in the mid-nineteenth century was significantly greater than it is today[58–62)]. In the worst cases, totally unsubstantiated recommendations are given to consumers, e.g. that "it is only true absinthe if it contains the wormwood with thujone (the psychoactive ingredient of wormwood)"[63)].

Nowadays, this is so widely accepted that most absinthe manufacturers advertise the thujone content and supposed psychoactive or aphrodisiac properties of their products on their websites or even on the bottle labels[2)]. Most modern absinthe has been created from a mixture of aroma and colouring with no reference to the original product and is marketed on the basis of the thujone hype. Furthermore, those who search for the mythical thujone are offered so-called absinthe essences (with high thujone contents of 750 mg/l) to „enhance" their normal absinthes above the European Union's maximum limits.

7 Solution to the thujone mystery?

So much attention is focused on absinthe's myths and supposed effects that almost everyone has forgotten that it was once a gourmet product with all the finesse of the best high-quality spirits. The figure of 260 mg/l of thujone that was repeated over and over might have kept producers at the beginning of the absinthe renaissance in the 1990s from using historical recipes such as those of Duplais. Only in recent years, have a number of authentic distilled absinthes become available on the market. Our analyses showed that such products easily do comply with the thujone maximum limits and this fact may also prove the prior overestimation of the thujone contents[64)]. Now, only the consumer has yet to learn that absinthe should be enjoyed purely for its taste like any other spirit.

References

1) *Lachenmeier, D. W., S. G. Walch, S. A. Padosch* and *L. U. Kröner*: Absinthe – A review. Crit Rev Food Sci Nutr **46**, 365–377 (2006).
2) *Padosch, S. A., D. W. Lachenmeier* and *L. U. Kröner*: Absinthism: a fictitious 19th century syndrome with present impact. Subst Abuse Treat Prev Policy **1**, 14– (2006).
3) *Strang, J., W. N. Arnold* and *T. Peters*: Absinthe: what's your poison? Br Med J **319**, 1590–1592 (1999).
4) *Duplais, P.*: Traité des liqueurs et de la distillation des alcools ou le liquoriste & le distillateur modernes. Lacroix-Comon, Paris/France (1855).
5) *Leblanc, F.*: Composition de l'essence d'absinthe. Journal de Pharmacie et de Chimie **VII**, 379 (1845).
6) *Beilstein, F. K.* and *C. Kupffer*: Ueber Wermuthöl. Justus Liebig's Annalen der Chemie und Pharmacie **170**, 290–297 (1873).
7) *Wallach, O.*: Zur Kenntnis der Terpene und der ätherischen Öle (Fünfundfünfzigste Abhandlung). Justus Liebig's Annalen der Chemie **323**, 333–373 (1902).
8) *Semmler, F. W.*: Ueber Campherarten, welche die Ketongruppe $CO.CH_3$ enthalten. Berichte Deutsche Chemische Gesellschaft **25**, 3343–3352 (1892).
9) *Wallach, O.*: Zur Kenntniss der Terpene und der ätherischen Öle; zweiundzwanzigste Abhandlung. I. Über die Bestandtheile des Thujaöls. Justus Liebig's Annalen der Chemie **272**, 99–122 (1893).
10) *Semmler, F. W.*: Ueber Tanaceton und seine Derivate. Berichte Deutsche Chemische Gesellschaft **33**, 275–277 (1900).
11) *Gildemeister, E.* and *F. Hoffmann*: The volatile oils. John Wiley & Sons, New York (1913).
12) *Chialva, F., P. A. P. Liddle* and *G. Doglia*: Chemotaxonomy of wormwood (*Artemisia absinthium* L.) I. Composition of the essential oil of several chemotypes. Z Lebensm Unters Forsch **176**, 363–366 (1983).

13) *Guenther, E.*: The essential oils. Vol. V. Van Nostrand, New York (1952).
14) *Arnold, W. N.*: Vincent van Gogh: chemicals, crises, and creativity. Birkhäuser, Boston, MA/USA (1992).
15) *Nano, G. M., A. Martelli* and *P. Sancin*: Indagini chimiche sulle Artemisie coltivate in Piemonte. Riv Ital Ess Prof Piante Off Arom Sap Cosm Aerosol **98**, 409–412 (1966).
16) *Chialva, F.* and *P. A. P. Liddle*: Sur la composition de l'huile essentielle de *artemisia pontica* linnaeus cultivée en piémont. Riv Ital EPPOS **63**, 350–352 (1981).
17) *Bos, R., A. Stojanova, H. J. Woerdenbag, A. Koulman* and *W. J. Quax*: Volatile components of the aerial parts of *Artemisia pontica* L. grown in Bulgaria. Flavour Fragr J **20**, 145–148 (2005).
18) *Talzhanov, N. A., D. T. Sadyrbekov, F. M. Smagulova, R. M. Mukanov, V. A. Raldugin, M. M. Shakirov, A. V. Tkachev, G. A. Atazhanova, B. I. Tuleuov* and *S. M. Adekenov*: Components of *Artemisia pontica*. Chem Nat Comp **41**, 178–181 (2005).
19) *Hurabielle, M., F. Tillequin* and *M. Paris*: Chemical study of *Artemisia pontica* essential oil. Planta Med **31**, 97–102 (1977).
20) *Khanina, M. A., E. A. Serykh, A. Y. Korolyuk, L. A. Bel'chenko, L. M. Pokrovsky* and *A. V. Tkachev*: Composition of essential oil of Siberian populations of Artemisia pontica L. – as a promising medical plant. Khim Rast Syr'ya **2000**, 85–94 (2000).
21) *Kordali, S., A. Cakir, A. Mavi, H. Kilic* and *A. Yildirim*: Screening of chemical composition and antifungal and antioxidant activities of the essential oils from three Turkish *Artemisia* species. J Agr Food Chem **53**, 1408–1416 (2005).
22) *Gholami, M., A. Azizi* and *P. Salehi*: Variations in essential oil components in cultivated and regenrated *Artemisia absinthium* L. Asian J Chem **17**, 2229–2232 (2005).
23) *Judzentiene, A.* and *D. Mockute*: Chemical composition of essential oils of *Artemisia absinthium* L. (wormwood) growing wild in Vilnius. Chemija **15**, 64–68 (2004).
24) *Morteza-Semnani, K.* and *M. Akbarzadeh*: Essential oils composition of iranian *artemisia absinthium* L. and *artemisia scoparia* Waldst. et Kit. J Essent Oil Res **17**, 321–322 (2005).
25) *Chiasson, H., A. Belanger, N. Bostanian, C. Vincent* and *A. Poliquin*: Acaricidal properties of *Artemisia absinthium* and *Tanacetum vulgare* (Asteraceae) essential oils obtained by three methods of extraction. J Econ Entomol **94**, 167–171 (2001).
26) *Rahimizadeh, M., M. K. Hassanzadeh* and *N. M. Danesh*: Analysis of Iranian *Artemisia absinthium* L. essential oil. ACGC Chem Commun **13**, 33–36 (2001).
27) *Tegtmeier, M.* and *G. Harnischfeger*: Methods for the reduction of thujone content in pharmaceutical preparations of *Artemisia*, *Salvia* and *Thuja*. Eur. J Pharm Biopharm **40**, 337–340 (1994).
28) *Aboutabl, E. A., A. M. El Azzouny* and *S. I. El Dahmy*: Constituents of the essential oil of *Artemisia absinthium* grown in Egypt. J Essent Oil Bear Plants **1**, 82–86 (1998).
29) *Sefidkon, F., A. Jalili, M. Rabie, B. Hamzehee* and *Y. Asri*: Chemical composition of the essential oil of five *Artemisia* species from Iran. J Essent Oil Bear Plants **6**, 41–45 (2003).
30) *Carnat, A.-P., M. Madesclaire, O. Chavignon* and *J.-L. Lamaison*: *cis*-Chrysanthenol, a main component in essential oil of *Artemisia absinthium* L. growing in Auvergne (Massif Central), France. J Essent Oil Res **4**, 487–490 (1992).
31) *Ariño, A., I. Arberas, G. Renobales, S. Arriaga* and *J. B. Dominguez*: Essential oil of *Artemisia absinthium* L. from the Spanish Pyrenees. J Essent Oil Res **11**, 182–184 (1999).
32) *Ariño, A., I. Arberas, G. Renobales* and *J. B. Dominguez*: Influence of extraction method and storage conditions on the volatile oil of wormwood (*Artemisia absinthium* L.). Eur Food Res Technol **209**, 126–129 (1999).
33) *Nin, S., P. Arfaioli* and *M. Bosetto*: Quantitative determination of some essential oil components of selected *Artemisia absinthium* plants. J Essent Oil Res **7**, 271–277 (1995).
34) *Pino, J. A., A. Rosado* and *V. Fuentes*: Chemical composition of the essential oil of *Artemisia absinthium* L. from Cuba. J Essent Oil Res **9**, 87–89 (1997).
35) *Mucciarelli, M., R. Caramiello* and *M. Maffei*: Essential Oils from some *Artemisia* species growing spontaneously in North-West Italy. Flavour Fragr J **10**, 25–32 (1995).
36) *Sacco, T.* and F. *Chialva*: Chemical characteristics of the oil from *Artemisia absinthium* collected in Patagony (Argentina). Planta Med **54**, 93 (1988).
37) *Tucker, A. O., M. J. Maciarello* and *G. Sturtz*: Essential oils of Artemisia 'Powis Castle' and its putative parents, *A. absinthium* and *A. arborescens*. J Essent Oil Res **5**, 239–242 (1993).
38) *Kaul, V. K., S. S. Nigam* and *A. K. Banerjee*: Thin layer and gas chromatographic studies of the essential oil of *Artemisia absinthium* Linn. Indian Perfumer **23**, 1–7 (1979).
39) *Blagojevic, P., N. Radulovic, R. Palic* and *G. Stojanovic*: Chemical Composition of the Essential Oils of Serbian Wild-Growing Artemisia absinthium and Artemisia vulgaris. J Agr Food Chem **54**, 4780-4789 (2006).
40) *Khalilov, L. M., E. A. Paramonov, A. Z. Khalilova, V. N. Odinokov, A. A. Muldashev, U. A. Baltaev* and *U. M. Dzhemilev*: Identification and biological activity of volatile organic compounds emitted by plants and insects. IV. Composition of vapor isolated from certain species of *Artemisia* plants. Chem Nat Comp **37**, 339–342 (2001).
41) *Juteau, F., I. Jerkovic, V. Masotti, M. Milos, J. Mastelic, J. M. Re* and *J. Viano*: Composition and antimicrobial activity of the essential oil of *Artemisia absinthium* from Croatia and France. Planta Med **69**, 158–161 (2003).
42) *Orav, A., A. Raal, E. Arak, M. Müürisepp* and *T. Kailas*: Composition of the essential oil of *Artemisia absinthium* L. of different geographical origin. Proc Estonian Acad Sci Chem **55**, 155–165 (2006).
43) *Lachenmeier, D. W.* and *T. Kuballa*: Behaviour of thujone during distillation and possible concentration ranges in pre-ban absinthe. J Sci Food Agr in press (2007).
44) *Gimpel, M., Y. Hönersch, H. J. Altmann, R. Wittkowski* and *C. Fauhl-Hassek*: Absinthe: Thujone content of absinthe spirits using historical recipes. Deut Lebensm-Rundsch **102**, 457–463 (2006).
45) *Bonkovsky, H. L., E. E. Cable, J. W. Cable, S. E. Donohue, E. C. White, Y. J. Greene, R. W. Lambrecht, K. K. Srivastava* and *W. N. Arnold*: Porphyrogenic properties of the terpenes camphor, pinene, and thujone (with a note on historic implications for absinthe and the illness of Vincent van Gogh). Biochem Pharmacol **43**, 2359–2368 (1992).
46) *Höld, K. M., N. S. Sirisoma, T. Ikeda, T. Narahashi* and *J. E. Casida*: α-Thujone (the active component of absinthe): γ-aminobutyric acid type A receptor modulation and metabolic detoxification. Proc Natl Acad Sci USA **97**, 3826–3831 (2000).
47) *Höld, K. M., N. S. Sirisoma* and *J. E. Casida*: Detoxification of α- and β-Thujones (the active ingredients of absinthe): site specificity and species differences in cytochrome P450 oxidation in vitro and in vivo. Chem Res Toxicol **14**, 589–595 (2001).
48) *Sirisoma, N. S., K. M. Höld* and *J. E. Casida*: α- and β-Thujones (herbal medicines and food additives): synthesis and analysis of hydroxy and dehydro metabolites. J Agr Food Chem **49**, 1915–1921 (2001).
49) *Hein, J., G. Juckel, T. Kienast* and *A. Heinz*: „Die grüne Fee" Absinth – historische und biochemische Fakten. Sucht **51**, 19–25 (2005).
50) *Lachenmeier, D. W., J. Emmert, T. Kuballa and G. Sartor*: Thujone-Cause of absinthism? Forensic Sci Int **158**, 1–8 (2006).
51) *Hutton, I.*: Myth, reality and absinthe. Curr. Drug Discov. **9**, 62–64 (2002).
52) *Schaefer, I., F. Bindler* and *A. Lugnier*: Toxicological rehabilitation of absinthium liqueur. Toxicol Lett **74** (Suppl. 1), 75 (1994).
53) *Ashcraft, B.*: The mystery of the green menace. Wired Magazine 13.11 (2005).
54) *Nathan-Maister, D.*: The Virtual Absinthe Museum. www.oxygenee.com/absinthe-museum.html (2007).
55) *Delachaux, P. A.*: L'Absinthe au Val-de-Travers: Recherches sur ses origines. Revue Historique Neuchateloise **1/97**, 3–22 (1997).

56) *Lamy, L.*: Étude de statistique clinique de 134 cas de cancer de l'œsophage et du cardia. Archives des maladies de l'appareil digestif et des malnutrition **4**, 451–456 (1910).
57) IARC: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol. 44, Alcohol Drinking. International Agency for Reseach on Cancer, Lyon, France (1988).
58) *Milton, X. M.*: Absinthe minded. Baudelaire and van Gogh drank it, will you? The McGill Tribune 1/9/01 (2001).
59) *Hall, C. T.*: Absinthe was a toxic cocktail for the likes of Picasso and van Gogh. San Francisco Chronicle March 25, A3 (2000).
60) Food & Dink Europe: Germans warn of absinth risk. Food & Dink Europe 04/07/2003 (2003).
61) *Wu, C.*: Toxin in absinthe makes neurons run wild. Science News **157**, 214 (2000).
62) *Rekand, T.*: Absinthe, the nervous system and painting. Int Rev Neurobiol **74**, 271–278 (2006).
63) *Parvaz, D.*: Absinthe: This highly intoxicating liquor comes with a bad-boy image. Seattle Post-Intelligencer July 24, 2001.
64) *Lachenmeier, D. W., J. Emmert* and *G. Sartor*: Authentification of absinthe – the bitter truth over a myth. Deut Lebensm-Rundsch **101**, 100–104 (2005).

Systematische Falschinformationen über Thujon in historischem Absinth