
Total Thujone and Anethole Concentrations in Various Alcoholic Beverages, including Pre-ban Absinthe

Summary

After the uplifting of the ban, absinthe, a wormwood-anise flavoured macerated and/or distilled aperitif is back on the market, yet the main controversy oscillates around the exact amount of thujone (sum of α - and β -isomers) which may constitute the main part of wormwood oil used in the production.

In the first part of this article, the main characteristics of absinthe as such will be explained, and then a focus is set on the thujone and anethole as well as others' role in it and their concentrations.

Finally, a list of estimated total thujone and anethole concentrations is presented, including not only absinthe but also other alcoholic beverages, such as Pióunówka, Chartreuse or Benedictine which in fact have never been banned.

Zusammenfassung

Absinth, eine mit Wermut und Anis aromatisierte Spirituose, ist vor kurzem auf den Markt zurückgekehrt. Dabei stellt sich als wichtigste Frage, in welcher Größenordnung sich der Thujongehalt (Summe der α - und β -Isomere) bewegt, der aus dem bei der Produktion von Absinth verwendeten Wermutkraut oder Wermutöl stammt.

Im ersten Teil dieses Artikels wird die Herstellung und Beschaffenheit von Absinth beschrieben und danach die Thujon- und Anethol-Gehalte in Absinth und anderen Spirituosen abgeschätzt.

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Unter Annahme einer Thujonkonzentration im ätherischen Öl des Wermutkrauts von 67 % könnte historischer Absinth Gesamtthujongehalte zwischen 8 und 11 mg/l und Anetholgehalte zwischen 0,2 und 1,2 g/l enthalten haben.

Abschließend wird gezeigt, dass die genannten Verbindungen nicht nur in Absinth vorkommen, sondern auch in anderen Spirituosen, die zu keiner Zeit verboten waren. Dazu zählen insbesondere die polnische Spirituosspezialität Pióunówka, sowie Klosterliköre wie Chartreuse und Benedictine.

Keywords: absinthe, thujone, anethole, spirit production / Absinth, Thujone, Anethol, Spirituosenproduktion

Absinthe – the reality behind the myths

Absinthe is meant to be a strong (at least 65–68 % vol on average, usually 72–74 % vol), not always green-hued aperitif (if coloured naturally is yellowish green which within

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time changes to dead leaf – “feuille morte”¹⁾ or amber; otherwise, artificially coloured can be anything you wish, even red). However, in the 19th century we could easily come across rose or rouge (Rosinette) products as we can nowadays (vide Emile Rouge) with a wonderful anise scent and more or less bitter taste.

In some literature, absinthe is referred to as “grünlicher Branntwein” as in most of the cases its base was wine alcohol of superior quality. In fact, various brands had been produced on other cheaper alcohols (beet or potato) and in fact absinthe made from rectified grain alcohol (98 % vol) can easily compete with one wine alcohol based.

Apart from it, a certain range of herbs and roots, never spices (there has been a misconception that allegedly absinthe recipe contains nutmeg, which is however used in other spirits) are used: wormwood (*Artemisia absinthium* L., hence the name: absinthe together with *Artemisia pontica* L., used for colouration¹⁾, aniseed (*Pimpinella anisum* L.), star anise (*Illicium verum* L.), fennel (*Foeniculum vulgare* Miller) (all three correct the taste of one another and are responsible for the louching effect and pleasant scent).

Apart from them, there is angelica (*Angelica archangelica* L., adds the flavour to wormwood’s bitter note), calamus (*Acorus calamus* L., of historical value, nowadays used by for example Pernot) melissa (*Melissa officinalis* L., second after hyssop, main colouring agent), tansy (*Tanacetum vulgare* L., very rarely mentioned in recipes if in the oldest ones; perfectly hides wormwood bitter notes increasing beta thujone content), hyssop (*Hyssopus officinalis* L., adds to the taste and one of the colouring agents) and coriander (*Coriandrum sativum* L., the same purpose as aniseed and others).

The last group could be veronica (*Veronica officinalis* L., adds little spiciness and deepens the colour), with the same effect mint (*Mentha piperita* L.) and oregano (*Origanum vulgare* L.), Roman chamomile (*Anthemis nobilis* L., smoothens the taste), génépi (*Artemisia spicata*, *A. mutellina* or *A. glacialis* L.²⁾, common in les Bleues), juniper (*Juniperus communis* L., the same as chamomile plus adds a bit of thujone), elecampane (*Inula Helenium* L., increases the angelica’s part) and licorice (*Glycyrrhiza glabra* L., rarely used in superior brands, though adds its properties to these of aniseed and makes absinthe taste like an aged one³⁾ and many others depending on the taste and clientele it is/was served to.

However, while tasting, most perceptible are wormwood, anise, fennel, and hyssop. People claiming that absinthe is only an aniseed drink are ignorant. Absinthe contains usually 1–2 parts of wormwood to 4–5 parts of anise and fennel together. Therefore, it should be classified as wormwood aniseed drink. Other herbs constitute the remaining 20 % of the portion.

We should bear in mind that without wormwood or without aniseed, the drink cannot be given the name “absinthe”.

Absinthe division and brands

Absinthe can be divided into following subgroups:

- Swiss and French absinthes¹⁾ (made according to the best recipes, strong (65–74 % vol) extraits d’absinthe in contrast to spiritueux aux extraits de plantes d’absinthe to be discussed later, also called absinthes superieures: two types: green and white (colourless)), there was a further division:
 - Pontarlier (star anise added but in the earliest recipes, the amount of wormwood to aniseed/fennel 1:4)
 - Montpellier (coriander appears, more aniseed)
 - Lyon (a lot of aniseed)
 - Neuchâtel (the amount of wormwood the same as of aniseed, a bit of licorice and bottled usually at 65 % vol)
 - Fougerolles (the smallest amount of wormwood)
 - Nîmes (coloured with hyssop, melissa, veronica and mint).
- Les Bleues (53–70 %) illegally (now legal since the 1st of March 2005) produced white absinthes of Switzerland (the colouring step of production is omitted), the same, if not better quality of the aforementioned, their main characteristics is: usually high thujone content (claimed: 30–45 mg/l) and a dominant fennel note and bluish/whitish louche.
- Other: a) Spanish (sometimes one dimensional in taste, on the basis of star anise (thus their louche is rather opaque) varying from 45 % vol to 70 % vol, worth drinking because they were “in” business all the time) b) Czech, Austrian and German “absinths” (high in alcohol (especially Czech), usually no anise at all, some sort of curiosity), should be probably omitted as they do not represent any category.
- Adulterated absinthes: ordinaire (40–45–46 % vol), demi-fine or extra fine (49–50–53 % vol) and fine (65–66 % vol), no longer produced caused in fact the ban.
 - a) their base was cheap, impure alcohol or methanol,
 - b) that poison was cut with a lot of water so as to hide the taste and properties: ordinaire (proportion of absinthe distillate to watered alcohol: 1:5; demi-fine: 1:4 and fine: 1:1),
 - c) coloured with cupric sulphates, or with parsley and spinach, d) to enhance the louching effect, antimony chloride³⁾, was commonly used and recommended concurrently with aniline, e) to taste like an aged lots of licorice put in which in high amount can cause arrhythmia.
- Modern, so called “spiritueux aux extraits de plantes d’absinthe”. Their range starts with 45 % vol (in most of the cases more pastis than absinthe like, thujone content up to 25 mg/l), through 55–60–65 % vol (much better in quality) and finally those measuring 68–72 % vol (would be the most reliable and recommended, yet only those labelled “amère”, in a colouring step they add wormwood again so increase thujone somehow and may get 35 mg/l).
- Absinthe substitutes: all the spirits that resemble absinthe to some extent or have its characteristics *lacking* however wormwood. The best example is pastis (absinthe pastiche, so to say).

Absinthe is considered to be of good quality, no matter if only macerated or also distilled, if when water is added it louches (best if from bottom to the top) i.e. turns milky or translucent (responsible for it is anethole from aniseed/star anise, fennel, or coriander, a substance that is insoluble in water and is 70 % sweeter than sugar). Because of these “magical” properties, it has always been known under the name of la fee verte (the green fairy).

Thujone and anethole question unmasked

Although recognized as an aperitif, absinthe is rather seen as something that is neither an alcohol nor a drug. It is not a liqueur sensu stricto. The main ingredient of absinthe is wormwood, an aromatic perennial plant, native to Europe, whose oil's active component may be thujone (alpha and beta), a bitter substance (bitterness indicator = 500, whereas gentian root is just 250)⁴⁾.

Thujone's highest concentration is however found in various Thuja plants (2.5 g may give up to 7.9 mg/l and thuja oil may contain 99 % of thujone⁵⁾). The amount of thujone in absinthe in mg/l varies according to the producer. After the distillation (in the end-product), a decrease may occur. Other factors that affect thujone final concentration are:

- Amount of thujone in cultivated wormwood plant
- Time of harvest (temperature and weather)⁶⁾
- The process and conditions of drying
- Maceration (usually 12–48 h)
- Distillation (especially which fraction is collected)⁷⁾

Recent studies have shown that what was supposed to be responsible for alleged high thujone (alpha) content might have been linalool, which often cannot be distinguished from alpha thujone using gas chromatography with flame ionization detectors. Linalool is a very close cousin of thujone, however, not so toxic, if at all.

These studies⁸⁾ (determination of alpha/beta thujone and related terpenes in absinthe using solid phase extraction and gas chromatography with mass spectrometry) have shown that surprisingly some drinks named “absinthe” contain no thujone whatsoever.

For example, Versinthe la blanche 57 – only 10 mg/l instead of claimed 35 mg/l, classified as fine, both La Fee and modern Pernod – none, Francois Guy – 24.8 mg/l but 45 % vol so ordinaire or crème d'absinthe as it is sugared, Emile Pernod 68 – 4.1 mg/l⁸⁾.

Other studies⁹⁾ proved that Swiss les Bleues of nowadays contain from 1.7 mg/l (however, alpha thujone constitutes: 0.3–0.4 mg/l) to 9.4 mg/l, French (on the basis of wormwood' distillate) – 28.8 mg/l (here alpha is around 3.2 mg/l) and absinthes containing wormwood oil – 31.1mg/l, here just 2.2 mg/l).

There are many myths concerning it like those claiming absinthes containing 260 mg/l¹⁰⁾ or those stating that superior

brands in reality contained around 10 mg/l (actually, between 1.3–6 mg/l because of distillation) which seems to be nothing if we assume that thujone shows face only in higher doses. Nowadays any absinthe should be considered with suspicion as far as thujone content is concerned. It should be then stressed that the thujone content of absinthe has nothing to do with the spirit's quality. The most elegant way to totally avoid thujone, if it is demanded, is to use thujone-free wormwood herb, which is available in certain cultivation areas and appears to be perfect for use in the spirits industry.

Thus, the real toxicity of absinthe is rather questionable taking into consideration the aforementioned facts and that wormwood by St. Hildegarda of Bingen (one of the most famous herbalist) is believed to be a real panaceum¹¹⁾.

Absinthe substitutes

After the ban the market demanded some substitute and so we arrive at pastis' birth. Pastis (containing no wormwood and of low alcohol content (45 % vol is the strongest volume), but louching) appeared as an absinthe pastiche (thus the name) and gained popularity after the ban.

In fact, most of pastis producers were absinthe ones (such as Pernod, Berger, Perigord, Duval or Lemercier)¹²⁾ and carried on, unfortunately without wormwood plus adding various spices and no verte colour was allowed, though some (Lemercier's “la Bleue” included *Artemisia vulgaris* L. which contains small amount of thujone (especially beta).

According to CEE No 1576/89:

1) Anis: (a) contains – star anise, anise, sometimes fennel and various aromatic plants (not specified), (b) 3 methods of production – maceration and/or distillation, addition of natural distilled anise oils or a connection of all of them, (c) predominant note must be anise.

2) Pastis: (a) contains from 0.05 to 0.5 g of licorice oil, (b) up to 100 g sugar/l, (c) from 1500 to 2000 mg anethole/l.

3) Ouzo: (a) produced only in Greece, (b) assemblage of distillates and macerates, (c) contains – anise, eventually fennel, Chios mastic gum, (d) up to 50 g sugar/l.

4) Pastis de Marseille: (a) bottled at 45 % vol, (b) up to 2000 mg anethole/l, (c) not particularly manufactured in Marseille. Note, 51 by Pernod refers mainly to 5 parts of water to 1 part of Pernod, Pernod 51 is classified twice, according to alcohol content, if bottled at 45 % vol – it is Pastis de Marseille, if at 40 % vol – it is named anis.

As far as pastis' ingredients are concerned these are: mainly star anise, then licorice, cinnamon, cardamom, cloves, black and white pepper, nutmeg as well as three thujone yielding plants: sage, mugwort and centaury¹³⁾. It is claimed that pastis had been manufactured primarily with a small amount of wormwood (here we should refer to so-called pastis ancienne which appeared around 1866, not pastis de Marseille which was manufactured by Paul Ricard for the

1st time in 1932¹⁴). Pastis had had also many problems due to laws controlling alcohol level: first only 30 % vol, then 40 % vol and finally 45 % vol¹⁵).

Absinthe overall taste and other characteristics

The taste of real absinthe is complex, floral, and/or herbal. It is not as bitter as you may imagine, but it then depends on how much wormwood and other herbs alike were used. That bitterness is very subtle because is hidden by other herbal notes those of hyssop or melissa and enriched with delicate anethole nuances. Usually it starts with aniseed and fennel accompanied by hyssop and melissa with wormwood at the back, in Swiss first detected is however fennel, it may differ from brand to brand.

Bearing in mind all the research that has been conducted and the experience some of the brands' tastes can be described:

- Pontarlier: at first seems to be very simple absinthe having no complexity. Predominantly aniseedy it does however yields a nice composition of wormwood and hyssop notes very delicately surrounded by melissa. Pontarlier per se is a standard others are to be compared with. Masculine absinthe in any case.
- Nîmes: very intriguing style of absinthe, perfect marriage of aniseed and wormwood, very little fennel in the after-taste and nice finish with coriander and angelica mix. Not definitely better than Pontarlier but different and predominantly wormwoody. Another important characteristics is slow translucent louche unlike in the previous one. Taste is rich and absinthe is masculine.
- La Parisienne: very rounded, slightly sweet what may be connected with star anise used, light and feminine to some extent.
- Neuchâtel: in the vein of the Nîmes yet striving towards Pontarlier. Unbelievable taste is composed mainly of wormwood preceded by melissa, hyssop and aniseed with the aura of licorice, Neuchâtel's trademark as well as necessity of the recipe. Strongly masculine, if produced properly and painstakingly (which unfortunately has not occurred so far) can compete or even surpass the Pontarlier one.

We already know that Pernod fils contained 8.5 mg/l, Lemerrier – 9.1 mg/l, blanche – 9.4 mg/l and Berger – 8.2 mg/l. This is not much yet take also into account that absinthe of 1895 was incomparable to absinthe of 1905 (in recipe from 1805 from Pernod, there is no star anise mentioned, whereas in the recipe of major Dubied (father-in-law of Pernod, who received the recipe from Henriod sisters in Couvet) of 1798 when Duval distillery was established, there is ref.¹⁶).

They were changing, and thus the most valuable ones would be those of the earliest production (1800–1899) when no one tried to control them and inferior brands had not appeared.

Henceforth, the following more coherent definition of absinthe might be suggested: (1) method: maceration and/or distillation (depending on the producer), (2) three colours obtained naturally: verte, blanche/la bleue and rouge, (3) at least 50–75 %, (4) at least 200–1500 mg/l of anethole, (5) at least 5–35 mg/l of thujone, (6) must contain: wormwood, aniseed, fennel and hyssop; ratio of wormwood to aniseed at maximum 1:1, (7) maximum content of licorice root (if any) 5 g/l.

Disqualified if: (1) exceeds or does not approximate any of previous regulations, (2) contains any spices or herbs never mentioned in historical recipes, (3) if sugared – creme d'absinthe, (4) instead of wormwood/mugwort is used – liqueur d'armoise, (5) artificial colouring.

Other beverages containing wormwood as one of the ingredients – short summary

Wormwood, anise through the ages

Wormwood as already mentioned by St Hildegard has been in constant usage for ages in the production of alcoholic beverages, the earliest chronicles citing the list of spirits manufactured in Poland name “piołunówka” several times as well as various anise – flavoured cordials (i.e. Dubelt Annis and Kontuszówka)^{17,18}). These two liquors are mentioned in Jędrzej Kitowicz's “Diaries” from the mid 17th CE¹⁹) as after dinner alcoholic beverages since we assume that unlike other of that type their alcohol content was higher: DA – 45 % vol (sweetened with sugar) and Kontuszówka – 56 % vol (sweetened with genuine honey).

The earliest recipe for piołunówka (requiring no distillation) from the 17th CE would produce a drink containing not less than 20 mg/l of thujone, however being sugared (168 g sugar/l). We should mention that unlike absinthe, the process of maceration applied to Polish spirits is longer (7–14 days)²⁰) what produces a more refined and concentrated product. Whereas in Poland, two main herbs: wormwood and tansy were used (Działy ski spirit recipe calls for both of them and eucalyptus), in other parts of Europe, particularly in France, thujone yielding plants had been popularised in monasteries.

Benedictine and Chartreuse liqueurs

These were the famous Benedictine (genuine recipe includes 27 herbs, roots and spices). The production requires three full stages: maceration (depending on the producer: Polish monks – 3 days²¹), French ones – 7 days and second one for 24 h) distillation, sweetening and aging (4 years in case of French, 6 months to 2 years in case of Polish); bottling at 45 % vol) and Chartreuse which at the time boasted the use of 130 herbs and secret methods of production.

The first one was known already at the beginning of 16th century and the creator of the recipe was Don Bernardo Vincelli from benedictine monastery in Fecamp, France. In

1863, wine merchant named Alexandre Le Grand found the already thought to have been lost recipe and started the production anew.

In case of Chartreuse, the recipe was a gift from Marshal Prince d'Estre for the monks who had saved his life. What we know, for sure, only the first fraction of the distillate is collected that possesses the most delicate taste and scent. One of the monks knows the genuine recipe and the other one is responsible to remember the process of production.

These recipes (their approximations can be easily found in the net) have been reduced drastically not due to the wormwood but to the fact that several ingredients proved to be carcinogenic of which no one was aware of these times.

Vermouth

Wormwood, as the sole herb played and still plays a role in vermouths. These wines, whose range starts with 14 % and can have as much as 20 % differ from country to country but it should be noted that a genuine one must contain wormwood, should contain angelica root and coriander as well as several spices. Back then and nowadays we have had two types, the French, more syrupy and containing less wormwood and the Italian, more, we would say, to the point. The examples of three perfect genuine vermouths available today are Gibo bianco (14.5 % vol), Totino bianco (15 % vol), and Punt e Mes (16 % vol) both having very pronounced wormwood note in the aftertaste.

Others

In Europe have been popularized other spirits as well, known under the general name of bitters. However, in terms of thujone and/or anethole concentrations, their content is much lower since in the production the method of assemblage is practised²²⁾.

These products remain low in alcohol (up to 45 % vol), yet high in sugar (200 g/l). Their colour is obtained thanks to caramel.

The following ones are much known in Europe: (a) English bitters – main bitter ingredients: wormwood and centaury, (b) Bitter Drops, (c) German bitters, (d) Unicum, (e) Stonsdorfer.

Their overall characteristics are found in the table.

| Name | Total thujone [mg/l]* | Source of thujone | Total anethole [mg/l] | Source of anethole |
|---------------------------------|-----------------------|-------------------|-----------------------|--------------------|
| Absinthe ordinaire (a) | 8.5 | w | 211 | A |
| Absinthe demi-fine | 8.5 | w | 739 | A, sa, f |
| Absinthe fine | 8.5 | w | 845 | A, sa, f, o |
| Absinthe Duval | 11.1 | t, w | 1162, 1056 | A, sa, f, o |
| Absinthe Pernod fils (b) | 8.5 | w | 1056 | A, f |
| Absinthe Junod | 8.5 | w | 1056 | A, f, o |
| Absinthe Lemerrier | 9.1 | w | 739 | A, f |
| La blanche | 9.4 | w | 1109 | A, f, o |
| La Parisienne | 8.5 | w | 898 | A, sa, f, o |
| Absinthe Berger | 8.2 | W, o | 465 | A, f, o |
| Absinthe Kübler | 8.5 | W, o | 845 | Sa, f, o |
| Pastis de Marseille (c) | 1.7 | o | 475 | A, sa, f |
| Pastis ancienne (d) | 4.7 | w | 475 | Sa, f |
| Pernod anis | – | – | 2484 | A, sa, f |
| Anisette | – | – | 660 | Sa, o |
| Dubelt Annis (e) | – | – | 486 | A, sa, f |
| Kontuszówka (f) | – | – | 317 | A, sa, o |
| Benedictine (g) | 3.7 | W,o,s | 42 | a |
| Chartreuse jaune (h) | – | – | 32 | A, f, o |
| Chartreuse verte | 3.6 | W,t | 5.3 | sa |
| Chartreuse blanche | 4.8 | W,t,o | – | – |
| Goldwasser (i) | 2.5 | o | 52.8 | sa |
| Stomach elixir (j) | 1.4 | W,o | 42.2 | f |
| Piołunówka (k) | 20.0 | w | – | – |
| Italian vermouth (l) | 15.1 | w | – | – |
| French vermouth (m) | 5 ⁿ⁾ | w | – | – |
| English bitters | 0.7 | W, o | 52.8 | a |
| Bitter Drops | 0.8 | w | Depends on the recipe | – |
| German bitters | 1.05 | W, o | – | – |
| Unicum | 1.7 | W, o | 42.24 | f |
| Stonsdorfer (o) | 0.5 | W, o | 270 | A, sa |

* Maximum possible thujone concentration calculated with a thujone content of 67 % in wormwood oil (most commercial wormwood varieties have lower contents); w: wormwood; t: tansy; s: sage; sa: star anise; a: aniseed; f: fennel; o: others; (a) all absinthe recipes either from Duplais or the given producer; (b) It refers to 1805 recipe, according to French wikipedia: since 1906 the figures would be: thujone: 12 mg/l and anethole: 908 mg/l, moreover 65 % vol; (c) historical and modern recipe; (d) unlike the previous one, at least 12 ingredients; (e) From ca. 1804; (f) From ca. 1804; (g) only available recipe containing 26 ingredients (the genuine is 27); (h) French artisanal recipes, various amount (refers to all three types)²³⁾; (i) Vermollen's recipe, end of 16th CE; (j) from ca. 1804; (k) 17th CE recipe; (l) Torino recipe, the genuine vermouth containing wormwood, not gentian or other herbs alike; (m) artisanal French recipe; (n) for French type, a lower content might be assumed as it contained far less alcohol than the Italian one and in many recipes no wormwood is given; (o) Leipzig recipe

Conclusion

On the contrary, to absinthe itself, all the aforementioned spirits do contain sugar and sometimes do not undergo subsequent distillation. Moreover, their maceration is longer and sometimes doubled. The wormwood plant even if plays in them the major role is not however so concentrated as in absinthe (the only exception is piołunówka) and bearing that in mind, though thujone yielding (tiny quantities) are to considered safer as absinthe and thujone mechanism on human body are taken into consideration.

All in all, all the mentioned beverages are for people with one very important note: only for the wise ones who know how to benefit from drinking them and restore their health and bring happiness. The table below depicts thujone and anethole concentrations in most of the presented beverages. Having assumed that thujone concentration in wormwood oil was around 67%, if it was lower, obviously the calculations would have got different results.

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