European Industrial Hemp Association (EIHA) paper on:

Decarboxylation of Tetrahydrocannabinolic acid (THCA) to active THC

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Motivation and Summary

The background of this study is as follows: On average hemp food stuffs contain up to 90% of the non-psychoactive THCA. Nonetheless, regulation for THC limits in food often uses total THC = THCA + THC. This leads to an overestimation of the content of psychoactive THC in hemp food. The argument is that THCA can be transformed in THC after heating (decarboxylation). This study analysed how relevant this conversion is in realistic scenarios.

Figure 2 shows the results for the complete decarboxylation depending on temperature and time. One realistic example scenario demonstrates, that the total THC measurement method can lead to an overestimation of the content of psychoactive THC of ca. 60%.

Methodology

To evaluate to what extent the THCA content of hemp food stuffs can influence their THC-levels, we performed a literature survey about the THCA carboxylation to THC (Fig. 1). In a second step we plotted these on a time-temperature graph using two different methods. On the one hand, curve fitting with various mathematical functions was applied, where logarithmic trendlines had the best R-squared values of 0.99. This was in line with the behaviour of a first order reaction and research about reaction kinetics of the decarboxylation reaction proves this (Perrotin-Brunel et al., 2011).
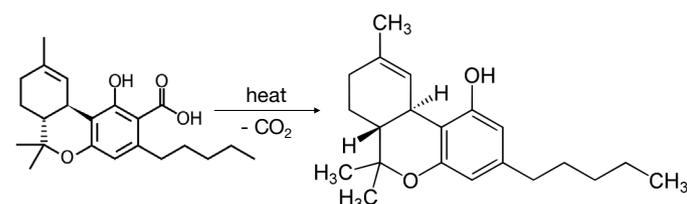
Figure 1: Decarboxylation reaction of THCA to THC (adapted from Perrotin-Brunel et al., 2011).

Results

After thorough research it became apparent that the most publications concerned with THCA decarboxylation to THC after heating, were papers describing HPLC or GC methodologies and mostly only had one timepoint and temperature where they measured THCA and THC. Figure 2 shows the results of the literature survey of studies which had at least two timepoints and temperatures.

What the graphic means
Taking the combined trendline into account, it would need 3 hours at 100 ˚C to convert THCA fully into THC and 4 hours at 98 ˚C. At high temperatures above 160 ˚C only about 10 minutes and at 200 ˚C only seconds are needed to convert THCA fully into THC.

Limitations
It has to be pointed out that various techniques were used in the THC measurements e.g. Veress and colleagues (1990) used THCA in hexane on a glass plate whereas Taschwer et al. (2015) used confiscated cannabis and heated it in a closed cabinet. These differences could explain the discrepancy in some temperatures and times.

Moreover, the different cited papers use various units of THC measurement e.g. mg/g vs. percentages. The graphic shows the assumed complete THCA decarboxylation to THC, where we used the peaks shown in the graph of Veress and colleagues (1990), for example, to indicate complete decarboxylation.

Side reactions affecting THC levels
It is important to note, that starting from ca. 157 ˚C THC evaporates. Consequently, the peak THC levels given here, are only present in the sample for a short amount of time. For instance, the highest THC content is reached at 145 ˚C after 7 min, but after 40 min the total THC amount is already halved (Veress et al., 1990). Taschwer and colleagues (2015) show in their experiments peak THC levels after 3 min heating at 150 ˚C, but a return to near zero THC percentages after 7 min.

Complete THCA decarboxylation to THC

THC vaporization beginning at 157 °C

THC degradation beginning at 85 °C

Legend:
- Taschwer et al., 2016
- Eichler et al., 2012
- US7334736B2 (Patent)
- Veress et al., 1990
- Log. (Taschwer et al., 2016)
- Log. (Eichler et al., 2012)
- Log. (US7334736B2 (Patent))
- Log. (Veress et al., 1990)
- Log. (Combined trendline)

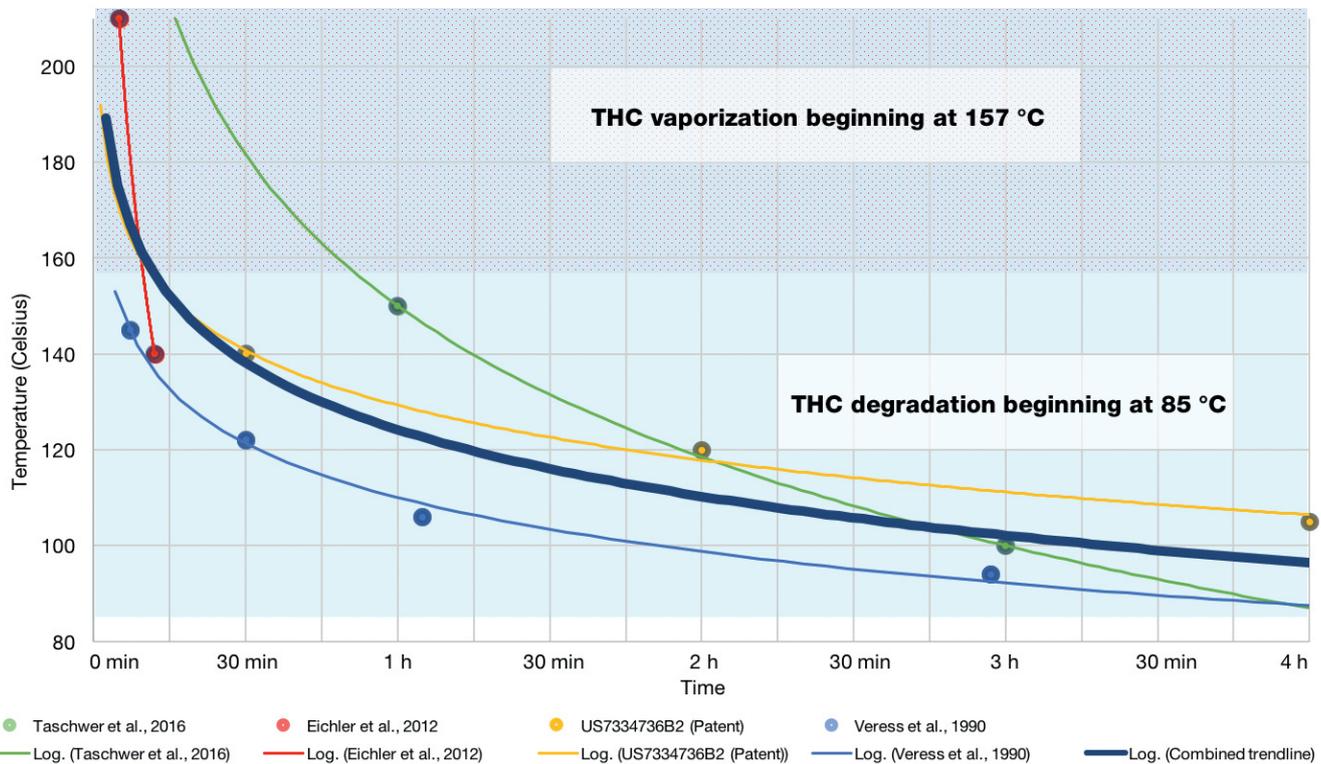© European Industrial Hemp Association 2016

Figure 2: Graph of various experiments measuring the complete THCA-decarboxylation depending on time and temperature. The bold dark blue line represents a combination of the depicted experiments.

Apart from THC evaporation, several other reactions occur when certain temperatures are reached. For example, Dussy et al. (2005), were only able to convert a maximum of 70% THCA into THC. They mention polymerization and oxidation of THCA and THC to CBN and CBNA, respectively, as side reactions. The THC degradation to CBN can already be considerable at temperatures between 85 – 100 °C (Repka et al., 2006). Having these reactions, which reduce the THC content in mind, it is interesting that the THCA decarboxylation reaction starts at 90 °C (Veress et al., 1990; Peschel, 2010).

Implications of THCA decarboxylation to real live scenarios e.g. baking

One has to differentiate between the temperatures used to heat the oven, the temperature reached on the outside of the cake, which, for instance, has a proportion of hemp flour in it, and the temperature inside. It is reasonable to assume that relevant temperatures for THC-evaporation are reached (presuming oven temperatures with an average of 180 °C) only on the outside of the cake. However, THCA and THC degradation will already play a role.

Inside the cake temperatures will not be higher than 100 °C as long as water is present in the cake. Using an average baking time of 45 min, the timepoints of the Veress et al. (1990) study and the above assumption that their peaks represent 100% decarboxylation, this would mean that only 1/3 of the THCA is converted into THC. Coming back to the currently used total THC calculations for its limits, mentioned at the beginning of this paper, this would mean that instead of the actually present THC content in the heated hemp flour of ca. 33% (THC created through THCA-decarboxylation) + ca. 10% (original THC content in hemp flour) = ca. 43% (realistic THC content in heated hemp flour), using the total THC measurement method leads to an overestimation of 57%. These calculations are only approximations, because the Veress study was carried out on heated glass plates and not with hemp flour cake in a regular oven. Nonetheless, they give an impression to what extent the total THC measurements overestimate the actual THC content.

Literature

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