Correlation between vapers behavior and production of degradation products (carbonyls, VOCs)

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1. Introduction

Electronic cigarette (EC) is a promising tool for a safer consumption of nicotine. Although there is no combustion in EC and much less cancerogenic products in e-liquids than in tobacco cigarettes[1], some studies about vapor composition found important levels of aldehydes[2]. Globally, studies about vapor composition are lacking of information (conditions of use, devices, e-liquid composition…). In order to prove that each information about the conditions of emission generation is important, we have studied the influence of puff duration, power, resistor surface and e-liquid composition on aldehydes and BTEX production *(BTEX: Benzene, Toluene, ethyl-benzene, xylene).*

2. Method

For the generation of emission, we used our vaping machine U-SAV, dedicated to vaping products[3]. Thanks to a cryogenic trap and an impinger with DNPH solution, we collected the vapor and made all required analysis for target molecules. We also analyzed the nicotine recuperation rate to ensure the correct running of the experiment. The following parameters have been fixed for all the experiments: flow (1.1L/min) and interpuff duration (60s).
Other parameters have been changed, one by one, to study their impact as follows:

-Power (15/50/80 Watts)
-Resistor surface : 2 different surfaces for one value : 0.5Ω
-Puff duration : 4s/9s
-E-liquid composition :
N° 1 : PG/VG *(v/v)* : 70/30, 1% of water, 1% of ethanol, 0.1% vanilline, 0.2% isoalamic alcohol, 0.1% acid methyl 2 butyrique, 10mg/mL of nicotine
N°2 : PG/VG *(v/v)* : 50/50, 2% de menthol, 6mg/mL of nicotine

3. Influence of e-liquid composition

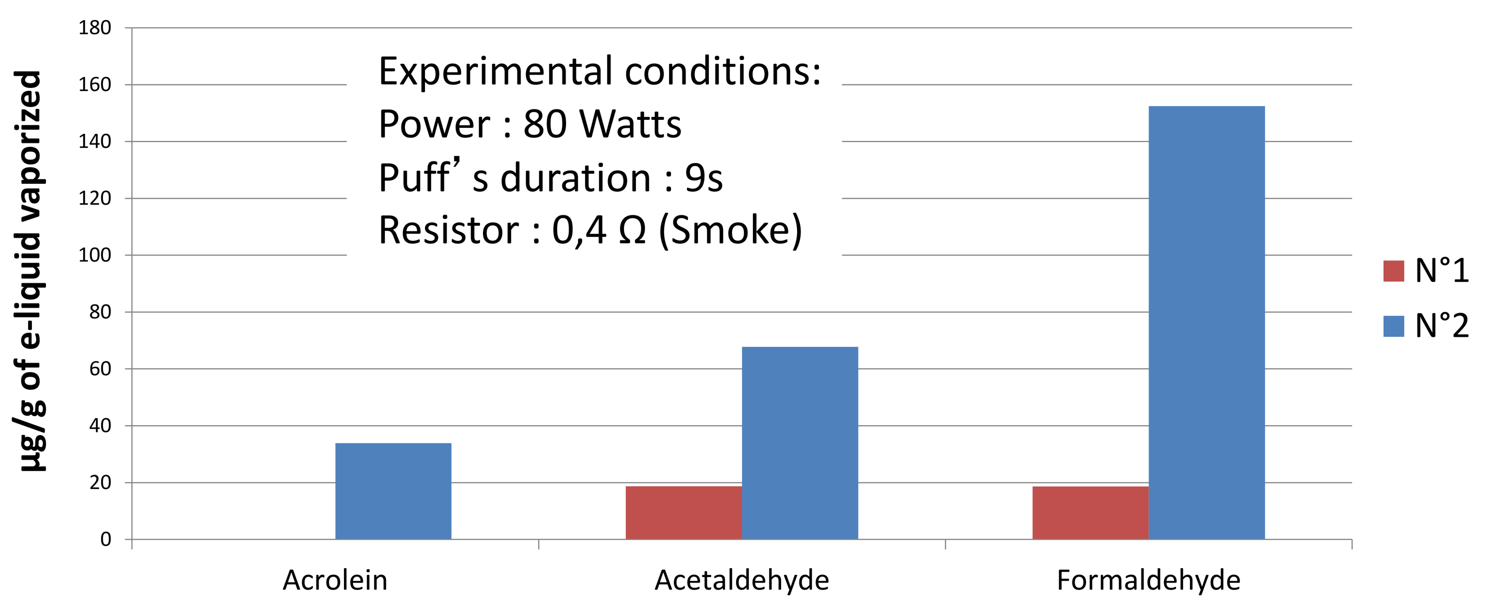

Figure 1 : Mass of degradation products according to e-liquid composition
(None BTEX have been founded)

For the same physical conditions of vaporization, two different e-liquids can have different vapor composition. E-liquid N°2 produced more aldehydes that N°1. We suppose that this is mainly due to **the high VG rate and the absence of ethanol in e-liquid N°2.** This results in **a higher viscosity,** which implies more difficulties for the e-liquid to move by capillarity into the mesh.

However, **the heat of vaporization** of the e-liquid is another key factor. More the heat of vaporization is low, more the quantity of e-liquid vaporized will be important, involving more aldehyde production.

4. Influence of puff duration

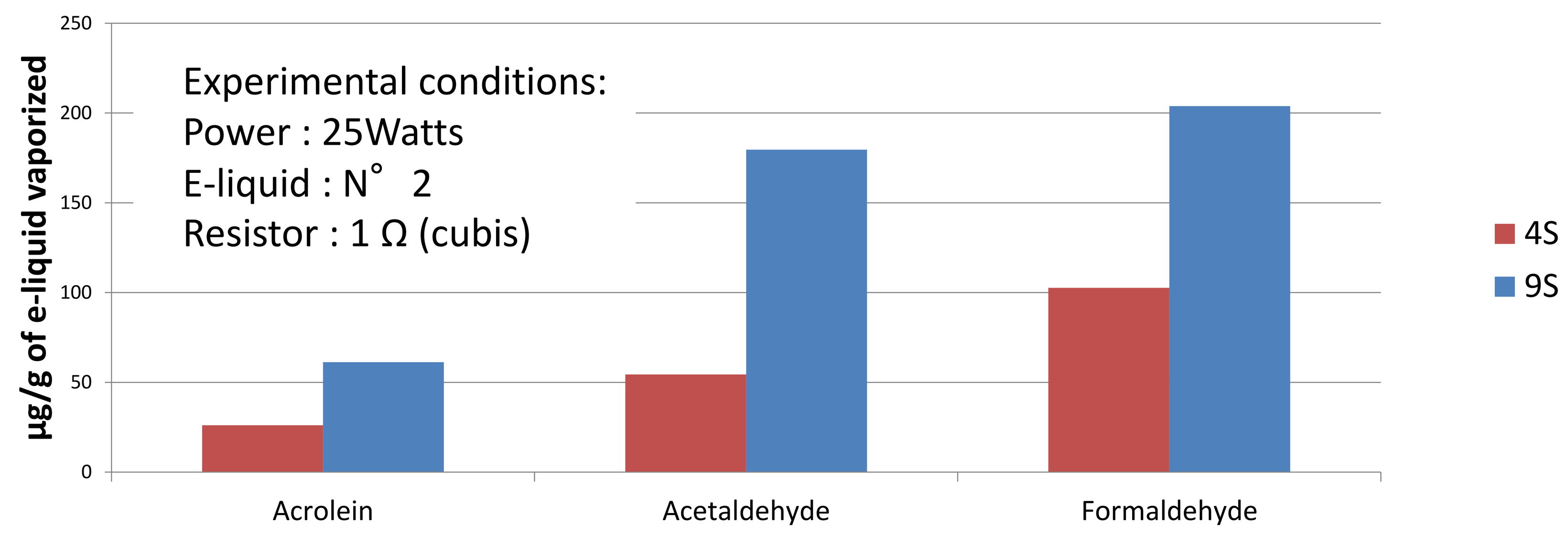

Figure 2 : Mass of degradation products according to puff duration
(None BTEX have been founded)

As we can observe on the graph, a 9s puff produced twice more aldehydes than a 4s puff.

The production of aldehydes can have several origins :
-e-liquid consumption (4s: 23mg/puff; 9s: 49mg/puff)
-e-liquid degradation
-mesh degradation due to a lack of e-liquid. *It is entierely vaporized before the end of the puff*
-inter-puff duration too short. *The e-liquid can't soak the mesh by capillarity fast enough*

5. Influence of resistor surface

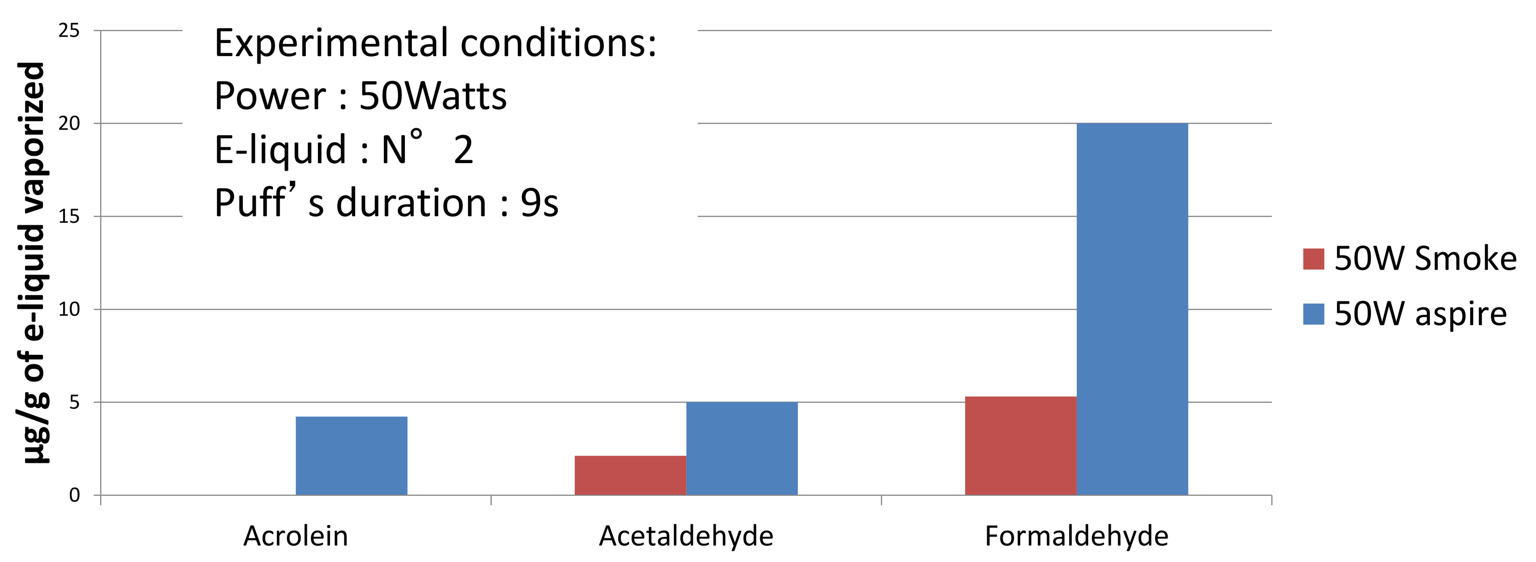

Figure 3: Mass of degradation products according to power flux density
(None BTEX have been founded)

One resistor value (0.5 Ω), two different surfaces:
Aspire©: 75.4 mm² *(clapton assembly)*
Smoke© : 88.59 mm²

As we can observe on the graph, the production of aldehydes is linked to resistor surface. This implies that the **power flux density** is a more important parameter than values of power and resistor. The variation of aldehydes production can be explained by a difference in :
-metal specific heat capacity : each metal having its own heat capacity, resistors don't have the same temperature rise,
-construction of the coil : dependent on the number of resistive wires and their assembly, the heating will be more or less focused.

In our specific case, the clapton assembly in aspire involves a heating more concentrated than in the Smoke one, implying more aldehydes production.

6. Influence of power

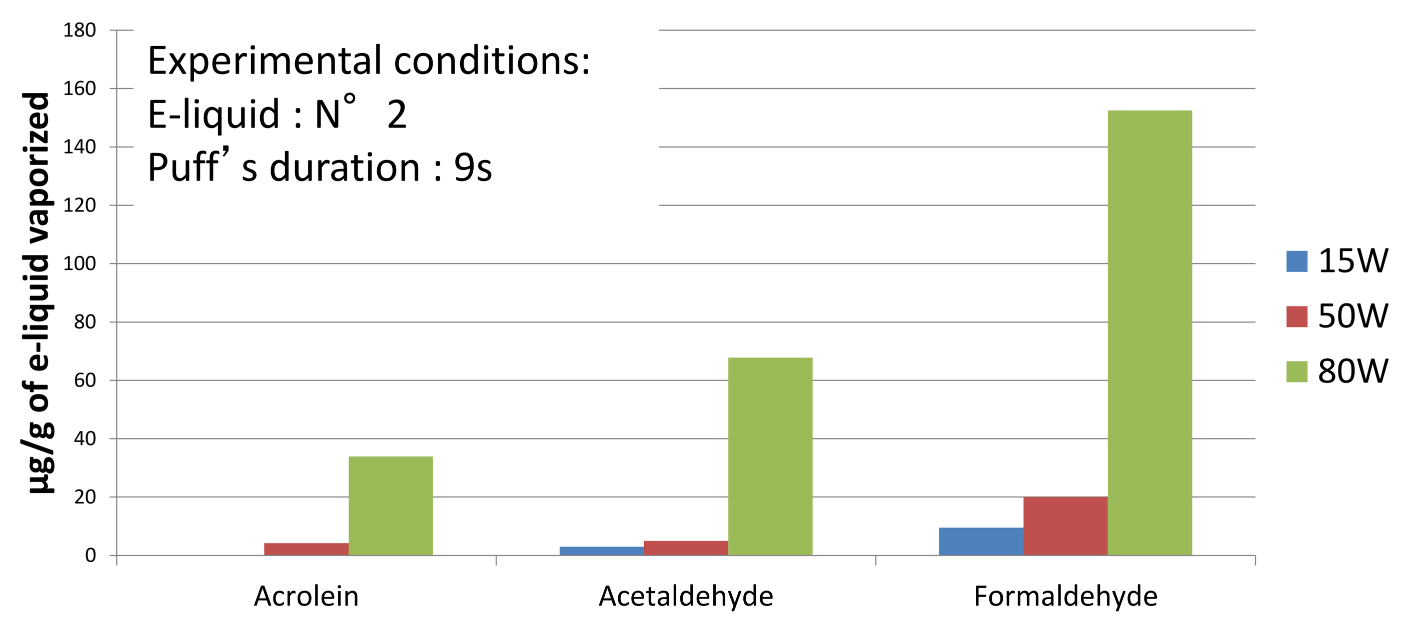

Figure 4 : Mass of degradation products according to applied power
(None BTEX have been founded)

As we can observe on figure 4, there is :
-almost no aldehyde produced at 15W
-an important production of aldehydes between 50W and 80W

This can be explained by a faster temperature elevation in the resistor involving :

-more e-liquid vaporized
-faster heating of e-liquid
-heating of the mesh due to a lack of e-liquid. *A high power involves a quick vaporization of the e-liquid in the mesh*
-interpuff duration too short. *The e-liquid can't soak the mesh by capillarity fast enough*

7. Conclusion

Through the different experiments, we have observed an increasing of aldehydes production with an increasing of : power, puff duration, viscosity of e-liquid. Moreover, we also have demonstrated taht the geometry of the resistor was a key factor. Through these experiments, we have seen that there are multiple variables to take account in vapor study. Without fixed and well defined experimental conditions, the vapor composition can be very different. Indeed, we have shown that there are multiple origins to aldehydes production: quantity of e-liquid vaporized, degradation of the e-liquid, degradation of the mesh due to a lack of e-liquid, too fast heating of the e-liquid, too focused heating…. All physical and chemical parameters can influence each of the degradation's sources. Moreover, we did not find any trace of BTEX in all the experiment, which implies that BTEX probably come from a « dry puff » phenomenon. For all these reasons, it is very important to have experimental conditions well specified. It is also important to study only one parameter at a time.

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References: 1 : Farsalinos K.E.et al *Ther. Adv. Drug Saf.* 2014, 5(2), 67-86. 2 : Jensen R.P .et al, *The New Eng. J. of Med.* 2015, 372, 392-394. 3: Soulet S. et al, *Int. J. Environ. Res. Public* Health,2017(submitted).