How Does It Smell?

An Experimental Approach to the Odor of Crude Oil

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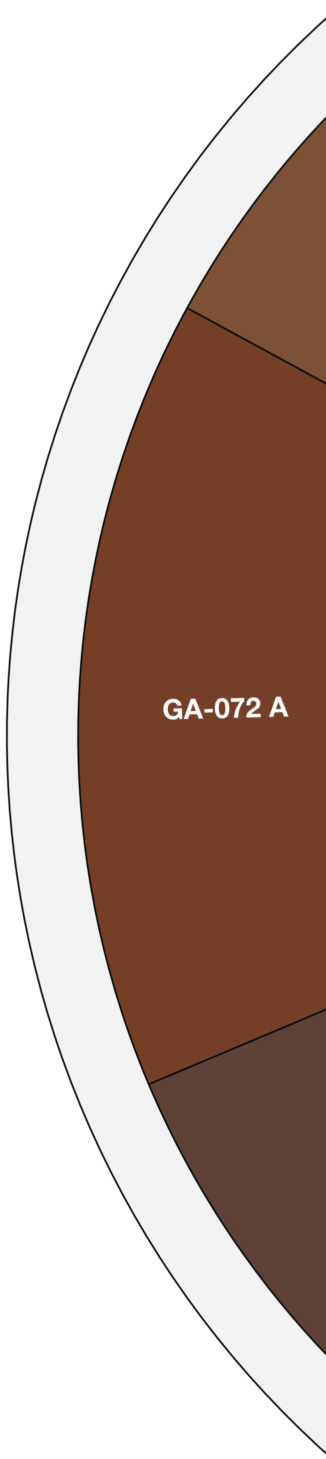
experiment
smell
crude oil
fragrance wheel
odor analysis
gas-chromatography
spectrometry
toxicity
olfactory crude oil wheel



For a very long time, the human sense of smell was neglected by scientists. Humans were believed to be “microsmatics” with an indiscriminate olfactory ability. However, starting from the 1980s, researchers became increasingly interested in the nose and the underlying mechanisms of olfaction. This peaked in 2004, when Linda Buck, a US-American neurophysiologist, and Richard Axel, a US-American physician, were awarded the Nobel Prize in Physiology or Medicine for their investigations on the olfactory receptor gene family.[1] Meanwhile, scientific research has confirmed that the human sense of smell is better than its reputation and, further, that odors have a noticeable psychological impact, a finding that has been discussed in various journals and books.[2]

In 1997, the German psychologist and perfumer J. Stephan Jellinek published his model of the psychodynamic mechanisms of odors, pointing out the powerful, individual psychological effect of fragrances on humans. These reactions are mainly due to a person’s attraction to certain smells (be they pleasant or unpleasant—the “mechanism of hedonic valence”) as well as past emotional experiences of a particular scent (the “semantic mechanism”).[3] Furthermore, a high overlap and strong connection between the olfactory and emotional regions of the brain were discovered, confirming and explaining this psychological impact. This makes smells important in the treatment of minor psychological disorders, such as anxiety, depression, and insomnia.[4]

In recent years, olfaction and/or odors have been the subject of various art projects, including the piece *Fear of Smell / Smell of Fear_12_24* performed by Norwegian artist and olfaction researcher Sissel Tolaas in St. Pölten, Lower Austria.[5] This investigation aims to characterize the scent of crude oil within an art context. To this end, two approaches were performed: first, to smell the target oil sample and describe its odor, and second, to fragment the mixture of volatiles into their individual components and characterize the sample by the sum of odors released by its main compounds.

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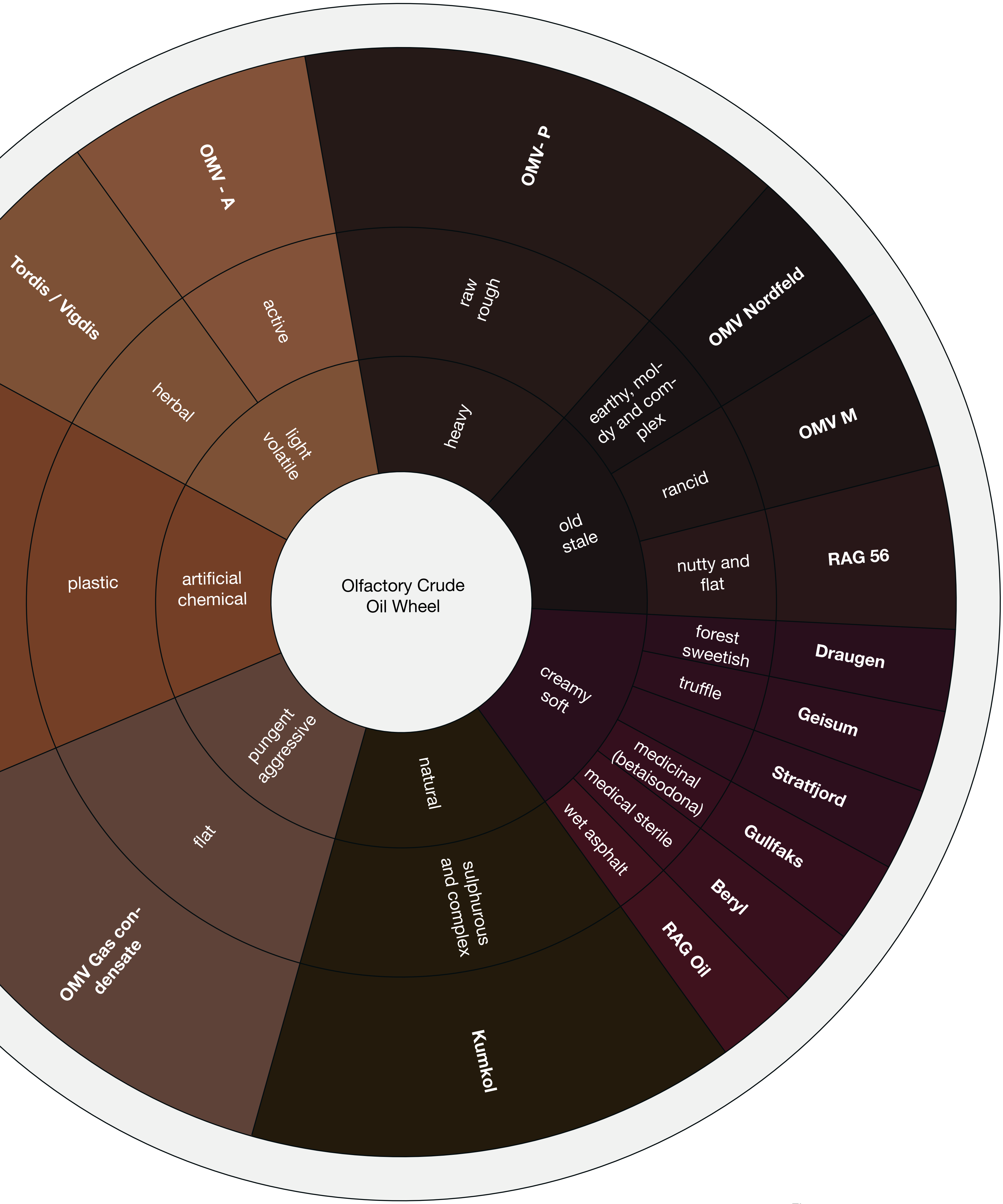

Figure 1
Crude Oil Olfactory Wheel with descriptors for the odors of oil fractions

Crude oil smell experiment, Department Petroleum Engineering (DPE) laboratory, University of Leoben, 2024

Odor Description

Crude oil is a complex mixture of hundreds of organic compounds. Some of these substances are volatile and therefore emit an odor. This odor depends on the oil's composition, which varies widely depending on the region it was extracted from.

As a starting point, we asked colleagues and friends to describe the smell of crude oil. First, most of them experienced it as unpleasant. Second, they started comparing the smell to something they know, for example, "it smells like petrol/a petrol station" or "it resembles the odor of the [heating] oil tank in our basement." People do not have the words to describe the smell of crude oil because this important raw material has never been looked at from an olfactory point of view. This had to be changed.

In 1984, feeling the need to help retailers suggest perfumes to their customers, fragrance expert Michael Edwards published the largest independent guide for fragrance classification: *The Fragrance Manual*. In 2000, it was renamed *Fragrances of the World* and since then it has been reprinted annually. Edwards noticed that the smell of perfumes do not necessarily fall into the four main, previously defined olfactory groups (woody, floral, oriental, and fresh) but could be more precisely characterized by additional subgroups that are linked to each other (e.g., soft oriental, oriental, woody oriental etc.). He created the Fragrance Wheel (also called Aroma Wheel or Fragrance Circle), a circular diagram that shows the relationships between the four olfactory groups, based on the differences and similarities between smells, and defines 14 different fragrance families. The relationships between these odors and aromas derive from similarities in their chemical compositions.[6] The wheel was adapted to include food and beverages, leading to even more descriptors for (food) aromas.[7]

Crude oil smell experiment DPE laboratory, 2024

Although a lot of fragrance or flavor descriptors exist already, we had to face the fact that—not surprisingly—the smell of none of the crude oil samples we were examining fitted any of the existing perfume or food odor descriptions. Therefore, a panel of eight men and women, professionals working in either crude oil or odors, got together at the University of Leoben, in Austria, to think of words that might best describe the smell of these oil samples, but also to try to put them in relation to each other according to the fragrance and aroma wheels. The resulting Crude Oil Olfactory Wheel can be seen in Figure 1.

Odor Analyses

Additionally, the volatiles of the oil samples underwent gas-chromatography/mass-spectrometry (GC/MS) analysis, using the headspace (HS) technique, to provide clues for possible odor-leading structures within the mixture. The aim was to underlay different smells of diverse originsof oil with chemical data. GC is an analytical technique mainly used on liquids and gases in order to separate and detect the chemical components of a sample mixture through a column in time. That way, the presence, absence, and quantity (in relation to each other) of the individual substances can be evaluated. The MS further measures the mass-to-mass ratio (m/z) of each single substance detected by GC. By comparing the MS spectra of these substances with the spectra of defined compounds from databases, these unknown chemicals could, in best cases, be identified.

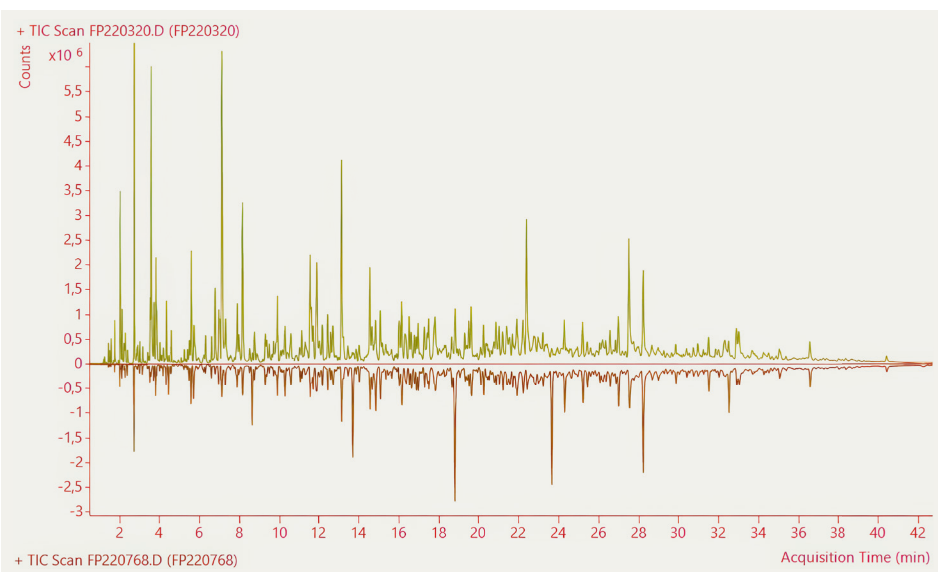

Figure 2a
Difference plot of the volatiles of two crude oils (above 'GA-072a', below 'Statfjord')

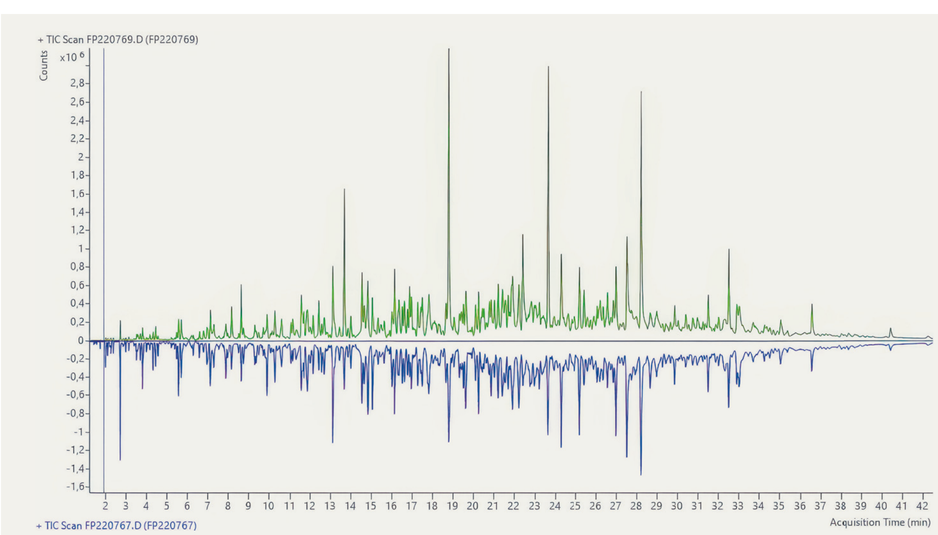

Figure 2b
Difference plot of the volatiles of two crude oils (above 'Beryl', below 'Gulfaks').

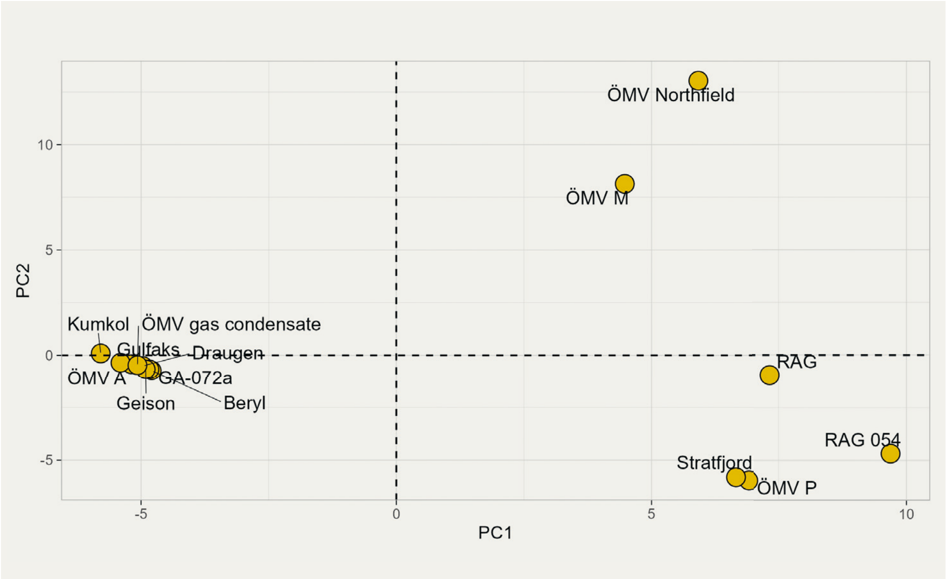

Figure 3
PCA crude oils: first two dimensions of principal component analysis of the volatiles of 14 crude oils.

Since the focus of the investigation was on the odorous (i.e., volatile) compounds in crude oil, the HS technique was used. Therefore, the oil samples were heated to either 30°C or 50°C in a closed vial for 30 minutes. The vapor was then collected by means of a special HS device. This was then injected into the GC for the volatiles to be separated and identified as described above.

Crude oil mainly comprises more than 500 hydrocarbons (aliphatic, aromatic, cyclic) in combination with sulfur, oxygen, and nitrogen, all showing similar molecular weights and fractions, so it was impossible to reliably identify most of the components. However, looking at the GC chromatograms (visual representations of the intensity of the individual compounds [y-axis] separated in time [x-axis]), it was noted that the samples' compositions varied more or less widely depending on the origin of the oils. Nonetheless, comparing the pattern of peaks separated by GC, one could see that some of these chromatograms resembled each other in retention time and relative quantity of single compounds. This means that the composition of the vapors escaping from these oils was similar. Figure 2a and Figure 2b show, exemplarily, two pairs of chromatograms demonstrating this similarity and disparity, respectively.

Although an identification of odor character compounds could not be achieved by GC/MS, similarities and dissimilarities in the vapor composition of oil samples were identified.

By comparing the composition of the different oils statistically, similarities and dissimilarities become obvious, as visualized in Figure 3. According to their components, as identified by GC, the Austrian and Norwegian samples were clearly separated whereas the RAG 054 and GA-072a samples were two outgroups with completely different aroma profiles.

Results and Discussion

First of all, it must be mentioned that crude oil contains many chemicals that are considered toxic. This toxicity concerns dermal and inhalation exposures. Animal cancer models subjected to long exposure durations and high concentrations showed signs of tissue hyperplasia. Mainly, it is the water-soluble fraction, with its polar chemicals, that seems to be responsible for the oil's toxicity, a toxicity which was intensified by sunlight: the hydrocarbons oxidized leading to more dangerous substances.[8] As such, the intense sniffing of crude oil and its products, such as diesel fuels and gasoline, is to be avoided! It was only performed for this investigation to characterize a raw product, one that is well known to almost everyone who comes from an industrialized country but that has never been looked at in the context of olfaction/art.

We noticed that it was difficult to describe an odor without previously defined verbal descriptors. Although the odor of crude oil is familiar to people, they lack the words to describe a smell they have never experienced from an olfactory point of view. Further, the volunteers involved in this project were not trained in olfaction. People who work with taste and smell (perfumers and "nosers") are taught to be able to detect and identify up to 3000 odor chemicals.[9] However, once we focused on the smell, verbal descriptors were found (Figure 1). Additionally, splitting the volatile fraction by GC helped us to find the similarities or dissimilarities between crude oils derived from different regions. This way, the oils could be grouped (Figures 2a, 2b) and the outcome confirmed the olfactory evaluation.

Conclusion

In contrast to vision ("reflecting oil"), olfaction ("sensing oil") is a chemical sense where molecules interact with receptors in the nose. It is also directly connected to the emotional center of the brain, which evokes an immediate response (without reflecting) after smelling odors. As we noted in this experiment, this response was mainly negative—the odor of crude oil was rated as unpleasant, with people avoiding the odor source rather than approaching it. On the "second sniff," several pleasant odor descriptors were found. The oil was looked at from another perspective and grew a body rather than being viewed as just a raw material. Therefore, the experiment of exploring crude oil from completely different perspectives, such as art or olfaction, improved the character of this product.

Furthermore, our instrumental approach provided us with data from a measuring instrument (gas chromatography) that made us more aware of the significant differences between the oils than smelling alone. The results of the data have sharpened, or rather, refined our sensitivity to the diversity of scents.

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5 Sissel Tolaas, *Fear of Smell / Smell of Fear_12_24*, 2024, July 14, 2024, Tangente St. Pölten, Austria, https://www.tangente-st-poelten.at/de/kunstparcours/Sissel-Tolaas.

6 Michael Edwards, *Fragrances of the World: The Reference Book 2020 & 2021*, https://www.fragrancesoftheworld.com/TheReferenceBook.

7 Prof. Dr. Thomas Simat et al., "Geruchs- und Aromaschulung in der Sensorik," DLG.org, January 2017, https://www.dlg.org/de/lebensmittel/themen/publikationen/expertenwissen-sensorik/geruchs-und-aromaschulung.

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9 Perfumer/in – Hintergrund: mit dem richtigen Riecher zum Erfolg – abi.de https://abi.de/studium/berufspraxis/naturwissenschaften/parfuemeur-in-hintergrund#:~:text=Eine%20staatlich%20geregelte%20Ausbildung%20zum,%2C%20Chemie%2C%20Lebensmitteltechnologie%20oder%20Pharmazie (July 14, 2024)