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Exploring Sustainability Claims: Biodegradable Fragrances

A. Stampa, M. Pájaro

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Stampa Alberto, Pájaro Marta

abstract

With consumers increasingly concerned about sustainability, and new claims constantly arriving on the market, Kao Chemicals Europe investigates what should be taken into account to create a biodegradable fragrance. The differences between anaerobic and aerobic biodegradation are stated, as well as the different aerobic biodegradation methods that can be used and the classification according to the results of this test. The OECD Ready Biodegradability tests are explained in more detail to better understand how to determine the biodegradation of a substance. After all of this, it is explored when a fragrance can be considered biodegradable, although it is not currently implemented at a legislative and mandatory level, and what should be done to pursue and push this kind of claim into the market. Finally, some actions taken in the regulatory field regarding the biodegradation topic in personal care and home care formulations are outlined to exemplify how this type of claim is gaining momentum.

Introduction

In recent years there has been an undeniable growing tendency to talk about sustainability in most industry articles and studies around the world. The term "sustainability" is a trending topic in all sectors and this is not only imposed by the industry itself and the consumers, but also by the authorities, who follow the market demand. A clear example of this can be seen in Europe with the appearance of the European Green Deal, since one of its main goals is to boost innovation for safe and sustainable chemicals.

Nowadays, there is no specific definition of sustainability, and multiple concepts can fall within this general term. It is quite difficult to define this term because sustainability encompasses the entire life cycle of a product and many different variables must be considered. Sustainability starts in research and development departments, where technicians have to design products based on the raw materials and production processes that will have less impact on the environment, until the end of their life, when the impact on the ecosystems should be studied to avoid any kind of harmful or alteration.

From Kao Chemicals, we consider that one of the most important aspects to be aware of when talking about sustainability is the emission of persistent or bio-accumulative substances to the environment, which is not legislated as such in countless market sectors, including cosmetics. In this regard, the biodegradation of the substances we use to produce our fragrances is essential. Fragrances are used in a wide range of products which will end in nature at the end of their life. For this reason, work begins with the development of fragrances where biodegradable ingredients must be used in order to avoid any accumulation when their get to the different ecosystems.

Anaerobic and Aerobic Biodegradation

Going into more detail on this matter, a clear distinction must be made between anaerobic and aerobic biodegradation. Anaerobic biodegradation occurs without oxygen, where microorganisms have to use other elements available in the environment to perform the process of respiration and consumption of nutrients. On the contrary, aerobic biodegradation occurs in normal conditions, where oxygen plays a major role and is used by microorganisms for respiration and the consumption of nutrients.

The main condition found in the environment is aerobic and it is also the first step in a water treatment plant. Aeration is performed in sewage plants, where water is treated in a large aeration tank under continuous stirring to stimulate aerobic biodegradation. Therefore, if the substance used is aerobically biodegradable, complete biodegradation will occur before entering into the anaerobic process, which is the second step found in a water treatment plant, as sludge is precipitated. Due to this, in Kao Chemicals we believe that the future does not depend on anaerobic biodegradation and this is why we focus this paper and our main developments on studying aerobic biodegradation.

Aerobic Biodegradation Test

Aerobic biodegradation can be measured through an easy process but, as the characteristics of substances or mixtures may differ, several biodegradability tests have been developed to determine whether a chemical substance is potentially easily biodegradable or not. Furthermore, as the industry is evolving and new substances with completely different characteristics are appearing on the market, new tests are also being

developed in order to adapt to each condition. An example of this test variation can be seen in **Table 1**, where all OECD Ready Biodegradability tests are listed. As it can be seen, suitability differs according to the different chemical characteristics. From the table it can be inferred that information on the solubility of chemicals, vapor pressure and adsorption characteristics is essential to select the most appropriate method for the sample.This leads to the conclusion that biodegradation can differ considerably between substances.

Test	Analytical method	Suitability for compounds which are:		
		poorly soluble	volatile	absorbing
DOC Die-Away (301 A)	Dissolved organic carbon	-	-	+/-
CO_2 Evolution (301 B)	Respirometry: CO_2 evolution	+	-	+
MITI (I) (301 C)	Respirometry: oxygen consumption	+	+/-	+
Closed Bottle (301 D)	Respirometry: dissolved oxygen	+/-	+	+
Modified OECD Screening (301 E)	Dissolved organic carbon	-	-	+/-
Manometric Respirometry (301 F)	Oxygen consumption	+	+/-	+

Tab. 1 Applicability of ready biodegradability test methods, from OECD guidelines

Biodegradable Categories for Chemicals

Based on these tests results, there are "Readily biodegradable chemicals", which are those that are rapidly and completely biodegraded in a short period of time, and "Inherent biodegradable chemicals", which do not achieve rapid biodegradation but are biodegradable in a longer time, and "Not readily biodegradable chemicals", that, as its name indicates, do not degrade when they are emitted into the environment and are long-lasting substances.

The OECD Biodegradable Test

In OECD Ready Biodegradability tests specifically, the biodegradation of a substance is determined in 28 days and, at the end of the test, the biodegradation of the sample must reach a pass level of 70% in Dissolved Organic Carbon methods and a 60% in Respirometry methods. In addition, these pass level values must be reached in a 10-day window within the 28-day period of the test. This means that, when the sample has reached 10% of biodegradation, it is considered that the microorganisms have adapted to the test conditions and the biodegradation of the substance has started; it must be biodegraded above pass levels within 10 days and before day 28 of the test [1]. If the substance does not pass the 10-day window but is biodegraded above pass levels within 28 days, it is considered an "Inherent biodegradable chemical". This distinction is shown as an example in **Figure 1**, which also shows the results of degradation other than microbial. Biodegradation is a type of degradation where microorganisms play an important role and they break down the substance by its enzymatic activity. That is why in the graph we always detect that biodegradation does not start immediately. However, when an ingredient breaks down by itself or by other external factors such as the sun or temperature, the process starts from day 1.

The 10-day window does not apply to all substances. Surfactants, for example, are exempt due the fact that they occur as closely related homologues and isomers with a very similar biodegradability profile and there are many conceptual and technical reasons to support the exemption [2].

- Surfactant degradation is generally characterised by multiphase kinetics that may be inevitable with a mixed microflora and possibly a multi-component substrate.
- Some surfactants yield, during the degradation, intermediate metabolites which may have catabolic kinetics (rates) different from the parent product.
- Some metabolites interfere with the degradation process by inhibiting transformation of the parent molecule.

Another point to take into account is the variability of the test. As mentioned above, it has a low reproducibility not only because of the intrinsic nature of the concept, but also due to the different range of microorganisms that an inoculum can contain or the variability of the conditions. The results can differ considerably between the tests or even the same test performed in different laboratories or at different times. Due to this poor reproducibility, biodegradation is the only ecotoxicological test that can be repeated in order to select the higher value of the performed experiments. This is the reason why we consider that results should be only given as "Readily Biodegradable" or "Biodegradation >60%", to avoid any comparison between values that do not provide any added value and can be misleading.

Biodegradable Fragrances

At Kao Chemicals, we consider that biodegradation is an extremely important concept. For this reason, and although it is

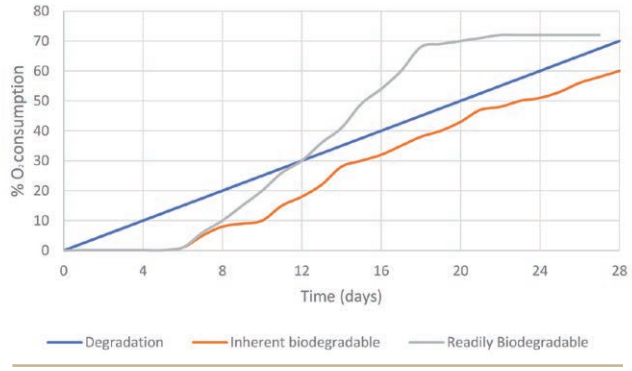

Fig. 1 Theorical example of biodegradation results (belongs to the OECD Biodegradable test part)

not implemented at a legislative and mandatory level, we are committed to offering fully biodegradable products and our fragrances are a clear example of Kao's sustainability vision. Currently, there is not a full definition of the requirements to be met by a fragrance to be considered biodegradable, but the biodegradation of these complex mixtures can be known by testing the fragrance itself or by theoretical determination, on the basis of biodegradation data of the raw materials it is composed of.

However, following the inherent constraints of the biodegradation methods mentioned above, our experts consider that in a complex mixture such as a fragrance, with a large number of ingredients, it is difficult to determine a priori the result of the biodegradation test when the fragrance is tested. Therefore, we believe that the best option to ensure the biodegradation of a fragrance is to use only readily biodegradable raw materials in the formulation, based on the data suppliers have about the biodegradability of their raw materials. With this methodology, we will avoid the bioaccumulation or persistence of any of the ingredients in the fragrance into the environment at the end of its life. Also, as an advantage, this gives more flexibility to perfumers when it comes to future regulations as biodegradability can be considered during the creative process.

To fulfil our commitment, we have developed an exhaustive database, integrated into our computer systems, which documents the biodegradation of the perfumery palette taking as biodegradable only the raw materials that are readily biodegradable. Using this new system, our R&D Department is able to create new and disruptive biodegradable fragrances.

Regardless of the method, perfumers face some issues while formulating because, as far as our experts know, many ingredients are not biodegradable or their biodegradation is unknown. For example, in our perfumery palette, this information is missing for most of the natural substances and essential oils and therefore cannot be used. However, we know that some interesting key raw materials used in fragrances are biodegradable, due to the fact that they are manufactured in-house, such as AMBROXAN®, MDJ, or ALDEHYDE C/10 among others, and therefore we have performed the biodegradation test. Thus, the democratization of this type of information from the suppliers' side will help to have more variety of raw materials that can be used to formulate under these conditions and therefore boost sustainable launches in the market around the concept and claim of biodegradable fragrances.

Conclusions

From the perfumer's perspective, the industry should move towards declaring the biodegradable properties of raw materials. This would allow for extensive knowledge of which raw materials are ready, inherent or are not biodegradable and facilitate the formulation of fragrances with 100% biodegradable ingredients, as this current lack of information limits the perfumer's creative palette.

In other contexts, few chemical industry sectors have taken the initiative to regulate the biodegradation of the ingredients. This is the case of detergency regulation in Europe, which requires rapid biodegradation of all the surfactants used in a detergent formula, or even more recently, the EU Ecolabel, which is the official European Union voluntary label for environmental performance certification and labelling widely used around the world, that goes beyond and extends the restriction, not only forbidding non-biodegradable surfactants, but also limiting the utilization of any other non-biodegradable organic substance. In its cosmetic standard, aerobic biodegradation it's not the only one required for surfactants but also the anaerobic. In addition, until the last version of the Cosmetics Ecolabel Standard, all fragrances were considered inherent following the DID list. But now, in order to demonstrate that the fragrance is biodegradable and facilitate the certification of the final formulation, it is specified that the companies involved can justify the biodegradability of the mixture by providing specific data for the ingoing substances of the fragrance or by a test result of the fragrance itself. This tendency can also be seen in regulating the biodegradation in the EU Chemicals Strategy for Sustainability (CSS), which is aimed at avoiding not only ingredients dangerous for health, but also not environmentally-friendly substances, and this includes the non-biodegradable ingredients used in a formulation.

An analysis of the perfumery market shows that there is still a lot to do. Consumers do not yet have much knowledge about fragrance composition, so they are not in a position to understand how fragrances affect the environment and what a sustainable fragrance can be. It is up to the industry and the authorities to clearly define what is needed in this field.

As mentioned, biodegradation is not the only way to define sustainability, but it plays an important role within the different aspects of this concept. In the industrial world in which we live, all sectors must work in order to avoid the accumulation of substances in the environment, so that it can be preserved, and biodegradation is the only way that we can use to assure it.

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authors

Stampa, Alberto (Product Safety & Regulations Technician)
Pájaro, Marta (Product Safety & Regulations Technician)
Kao Chemicals Europe, S.L.U. | Puig dels Tudons, 10 | 08210 BARBERÀ DEL VALLÈS (Barcelona) | **SPAIN**
marketing@kao.es
http://www.kaochemicals-eu.com