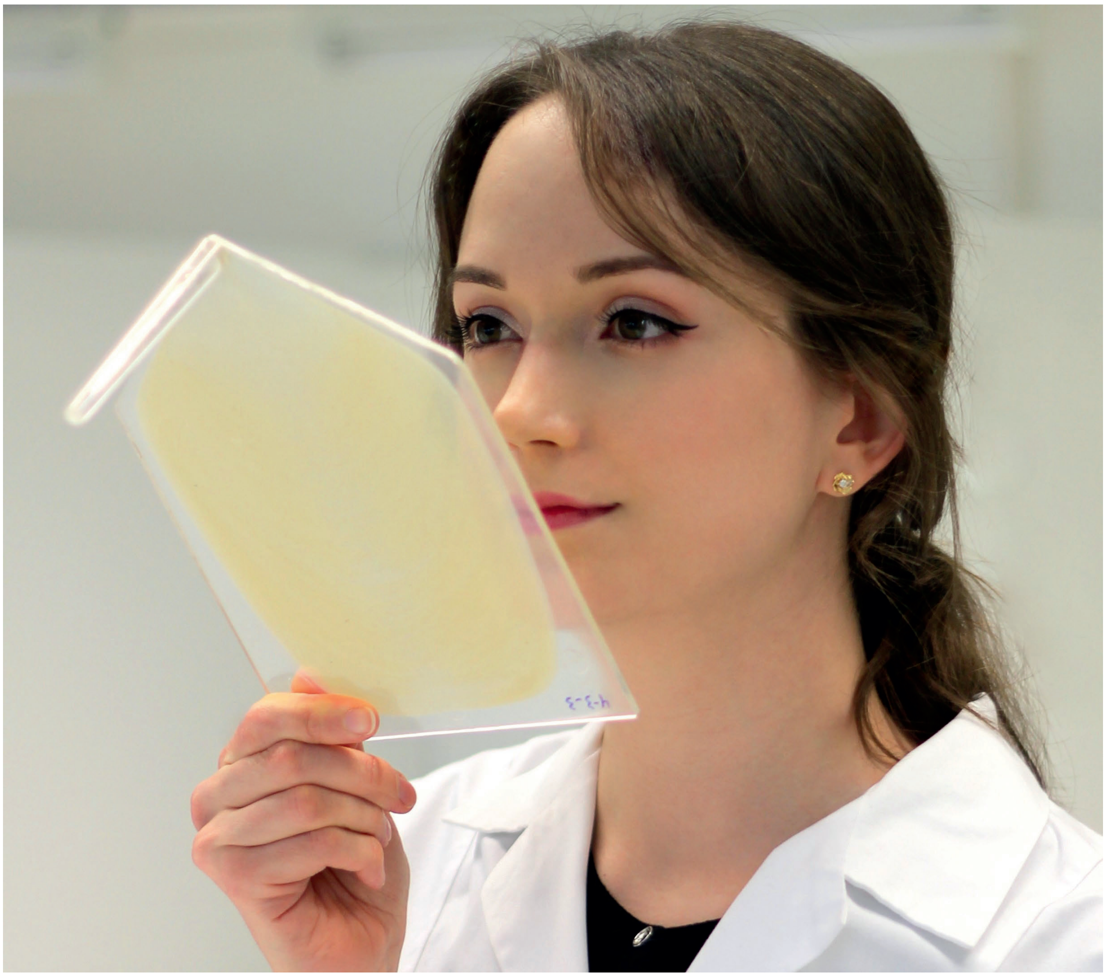
Method to Prevent Odor Emission from Plastic Recyclates

Keeping the Smell in

Plastic recyclates and plastics containing natural materials often have an unpleasant odor. This is not only a problem during production – it also severely limits the application range of the plastics concerned. However, an odor barrier layer with special additives can significantly reduce odor release.



A skin layer containing additives prevents the emission of unpleasant odors that adhere to the recyclates.
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Odors occur everywhere and they influence human perception and decisions. Aromatic food generates a positive effect. However, for other materials, such as plastic recyclates, odors are in general undesirable. A quality feature of plastics is their odor neutrality. Odors are caused by odor-active volatile organic compounds released from materials. These substances and their mixtures determine whether and how materials emit their odor.

As a rule, new plastics hardly have any odor. Unpleasant odors are mainly emitted by re-used or recycled plastics and by polymers containing natural substances. The sources of such odors are manifold. In plastic packaging materials, odor-active substances often migrate from the packaged contents into the polymer. These can be perfumes and fragrances from cosmetics or detergents. In addition, food residues adhering to the packaging can be responsible for unpleasant odors. After disposal, these undergo decomposition and biodegradation processes, resulting in the formation of particularly pungent odorous substances that are repulsive to the human sense of smell. These substances, which often smell cheesy, moldy or fecal, are perceived as having a negative odor even at concentrations of a few parts per billion.

Complete removal of these unpleasant odors at ppm levels, is very challenging even with modern cleaning and deodorization processes, and is sometimes very costly in terms of energy. For this reason, plastic recyclates from post-consumer food packaging waste streams (such as the "yellow bag" used

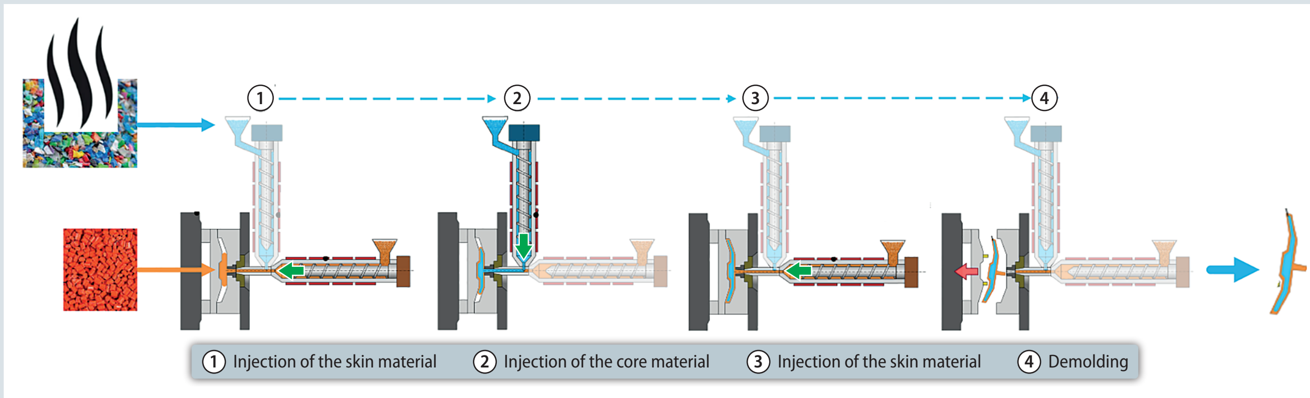

Fig. 1. Production process for the sandwich component: two-component injection molding enables the production of the components. However, due to the molten state of the polymers, odorants migrate from the core into the skin during processing. Source: [2]; graphic: © Hanser

in Germany) emit a particularly unpleasant odor during processing. In addition, they can often only be re-used in well-ventilated places, which prevents a closed-loop plastic economy. However, unpleasant odors can also be emitted, for example, by composite materials made from virgin plastics and natural fillers such as lignin [1]. Due to the strong odor of the natural substance, the materials are also limited in their application.

Odor Barrier Layer – a Skin for Recyclates

To prevent odors from plastic components, the plastic must not release volatile odor-active compounds. In the case of odor-contaminated plastics, this can be achieved by covering the manufactured component with a surface layer (skin) consisting of an odor-neutral material (**Title figure**). This has been investigated in a joint project by the four Fraunhofer institutes ICT, LBF, IAP and IVV (Fraunhofer Institute for Chemical Technology ICT, Fraunhofer Institute for Structural Durability and System Reliability LBF, Fraunhofer Institute for Applied Polymer Research IAP and Fraunhofer Institute for Process Engineering and Packaging IVV).

To ensure sufficient compatibility of the skin and core, and to enable high recyclability, the skin and core material should be made of the same class of plastic. Where this is the case, however, the skin has a comparably high affinity for odorants from the core. The component therefore develops an odor after a short time despite the skin, as the odorants migrate through the skin material and are released from the component surface.

To prevent migration and consequent release of the odorants, additives are therefore added to the skin material which interact with the odorants. In this way, an effective odor barrier layer can be created. Even with a skin thickness of 0.25 mm, odor release can be completely prevented at 80 °C continuous storage for several weeks. Extrapolation to room temperature holds out the prospect of odor prevention for a period of years. Only small quantities of the additive are required in relation to the total component.

Additives Bind the Odors

Compared to the direct introduction of additives for odor reduction, the quantity required is significantly lower. During the tests at the institutes, it was also found that the direct addition of odor-binding additives to the recyclate is less effective. The reason for this is that some odorous substances are already close to or on the surface, and their release can therefore no longer be prevented.

The odor barrier concept has further advantages. Besides preventing odors, a skin layer that completely encases the component can also be used to achieve targeted improvements in surface properties, such as appearance and haptics. This is particularly important for the acceptance of plastic recyclates in high-value applications. In addition, further additives such as light stabilizers for outdoor applications can be introduced at low cost if required.

Sandwich Structure in Injection Molding

The manufacturing possibilities for plastic components with a core and skin – so-called sandwich structures – are manifold. Sandwich injection molding was used for the odor barrier studies described below. By using a two-component injection molding machine, injection molded parts can be produced from two materials. The timing of the two injection units is set so that skin material is injected first, followed by the core material, and then finally skin material is injected again. This makes it possible to produce components completely encased in skin material (**Fig. 1**).

Due to the component geometry, there are limitations with regard to the thickness of the skin material and the maximum feasible amount of core material. In addition, the molten state of the polymers during processing favors the migration of odorants into the skin. However, the studies showed that sandwich molding can be used to produce components with a very effective odor barrier layer.

To develop suitable measures for odor optimization, a scientific evaluation of the released odors is essential. One difficulty here is an objective and at the same time standardized classification. This can be achieved by test persons specifically trained to conduct the sensory evaluation of the odors of the materials. Subjective sensations, for example caused by highly nauseating odors, are thus reduced as far as possible.

In the tests conducted on sandwich test specimens, the test persons rated »

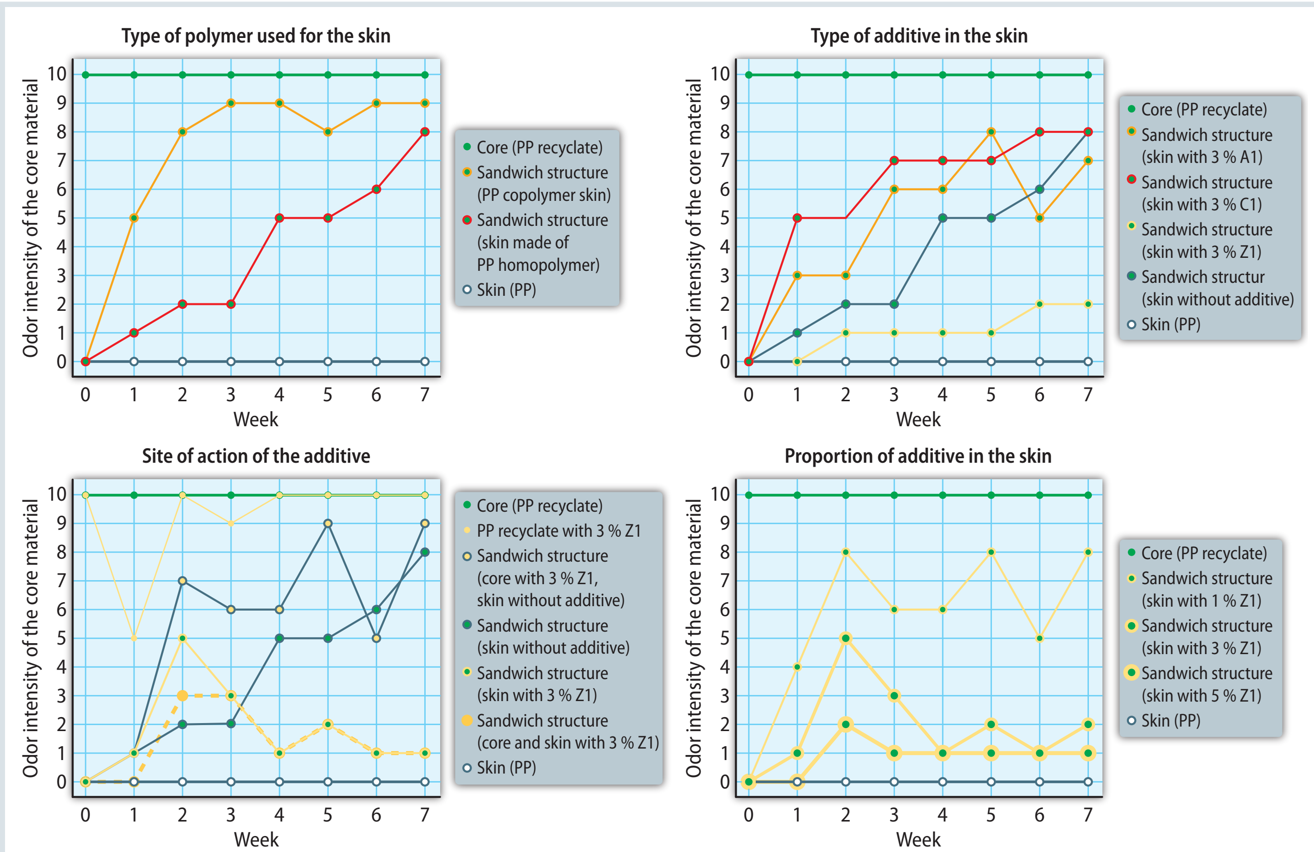

Fig. 2. Sensory characterization of the odor release of the core material from PP recycled sandwich test specimens with an odor barrier layer (storage at 80 °C): it is clear that odor reduction is highly dependent on the material and additive, its location and the amount used. Source: Fraunhofer ICT; graphic: © Hanser

the perceived overall odor on a specified intensity scale. Minimum and maximum were defined with reference to corresponding sample materials. The investigated material with off-odor represented the highest intensity (10 points), and odor-optimized materials were evaluated in comparison. In addition to the specific training of the test persons, attention must also be paid to maintaining consistent environmental conditions during the sensory evaluation. This ensures that objectivity is as consistent as possible, and is the cornerstone of a scientific approach to odor evaluation.

Plastic recyclates from food packaging waste have a particularly pungent odor and are therefore ideal for investigating possible odor reductions. An odor barrier layer can prevent odor release from a polypropylene (PP) recyclate. This was shown by sensory analyses carried out at 80 °C (**Fig. 2**). Four questions were considered:

Type of polymer used for the skin: A skin made of PP homopolymer showed a significantly delayed odor release compared to a skin made of PP copolymer. This was demonstrated by comparing sandwich test specimens with additive-free skin. Since the PP copolymer is less effective in inhibiting the migration of the odor-active substances, PP homopolymer was used as skin material for all further studies.

Type of additive in the skin: The comparison of odor barrier layers, each with 3 % of different additives, showed that both cyclodextrins (C1) and acid scavengers (A1) actually increased the release of unpleasant odors compared to a skin without additives. Of the additives investigated, only zeolite (Z1) improves the effect of the odor barrier layer.

Site of action of the additive: The direct incorporation of 3 % zeolite into the PP recyclate without a skin or odor barrier does not result in any improvement compared with the additive-free recyclate. Even 3 % zeolite in the core material, combined with a skin without additives, shows no improvement in odor compared with the additive-free combination of a recyclate core and a skin. If, in addi-

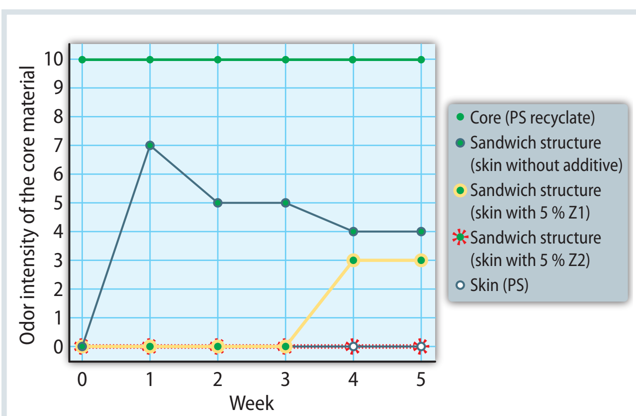

Fig. 3. Odor release of sandwich test specimens, with PS core material made from fishing sector recyclates and odor barrier layer (storage at 80 °C): the best effect can be achieved with hydrophilic zeolite. Source: Fraunhofer ICT; graphic: © Hanser

tion to 3 % zeolite in the skin, a further 3 % of the additive is incorporated into the core, there is an improvement in odor release during the first two weeks of storage at 80 °C. However, from the third week onwards, both this combination and sandwich test specimens with 3 % zeolite in the skin only, show the same odor-preventing effect. Accordingly, the most efficient use of the odor-reducing additive is exclusively in the skin, both in terms of effect and the total additive quantity.

Proportion of the additive in the skin: 1 % zeolite in the skin is not sufficient for an odor barrier in the case of the investigated recyclate. A significantly reduced odor release is perceived only in the range of 3 to 5 %. A skin with 5 % zeolite achieves the best results.

Polystyrene from the Fishing Sector

The effectiveness of the odor barrier layer depends on both the type of plastic used for the core material and the odorants it contains. In addition to PP from packaging waste, polystyrene recyclate (PS) from the fishing sector was investigated as another class of plastic and another source of odor (**Fig. 3**). The sandwich with an additive-free skin releases a distinct odor of the core material after only one week of storage at 80 °C. In the course of storage over five weeks, the intensity of the perceived odor decreases again. In contrast, for sandwich structures with odor barrier layers made of two different zeolites (Z1 with hydrophobic character and Z2 with hydrophilic character), the core material odor is not perceptible during the first three weeks. However, the components have a very faint foreign odor: "medical" for Z1 and "leathery" for Z2. After four weeks, the odor barrier layer with 5 % Z1 loses its effect. The components with an odor barrier layer with 5 % Z2, on the other hand, have no perceptible core material odor even after five weeks of storage at 80 °C.

The investigations prove the transferability of the odor barrier concept to other classes of plastics. However, the selection of additives used in the skin must be adapted to the odorants and to the plastic used.

Polyolefins Containing Natural Substances

The tests also prove the effectiveness of the odor barrier layer in composite materials with the natural polymer lignin (**Fig. 4**). The zeolite Z1, which is most effective in PP recyclate, is significantly less effective in PE-lignin. However, Z2 achieves a better odor barrier effect. In comparison to Z1, Z2 shows a better interaction with the odorants of lignin, which is due to a higher affinity of this zeolite for hydrophilic compounds. The example illustrates once again that the odor-reducing additive of the odor barrier layer must be adapted to the specific plastic and the odorants concerned. The best result for PE-lignin is obtained with 5 % Z2. Even after five weeks of storage at 80 °C, the perceptible odor is in the lower intensity range. In comparison, the sandwich with additive-free skin has a much stronger lignin odor, which is clearly perceptible after five weeks of storage at 80 °C.

Outlook

To establish a sustainable and circular plastics economy, currently challenging plastics streams, including odor-contaminated recyclates and plastic-containing natural materials, must be increasingly integrated into value chains. The investigations carried out in the project show that an odor barrier layer in the component surface represents a solution for bringing odor-contaminated plastics into high-quality applications. ■

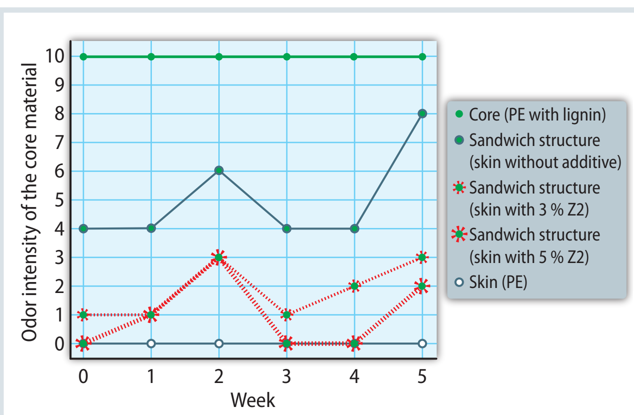

Fig. 4. Characterization of odor release from PE lignin sandwich test specimens with odor barrier layer (storage at 80 °C): hydrophilic zeolite is proving to be the additive of choice for reducing lignin odor.

Source: Fraunhofer ICT; graphic: © Hanser

Info

Text

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