LOXIOL® VPA 1726

100 % Vegetable and Food Contact Compliant Antistatic Agent for Polyolefin Applications as an Alternative to Ethoxylated Fatty Amines

Static effect in plastics applications

Insulating materials including most types of plastics tend to build up static charge by separation of positively and negatively charged particles. This can lead to several problems, especially if it discharges spontaneously.

- Static charge promotes the attraction of dust
- Thin plastic films or other light weight plastic parts or particles can stick to each other, or to other materials
- A discharge can be painful to consumers, for example in flooring or shoe sole applications
- In those industries dealing with flammable substances or fine powders, a discharge is a severe safety hazard
- Many semiconductor devices used in electronics are highly sensitive to the presence of static electricity and can be damaged by a static discharge

Antistatic effect generated by LOXIOL® antistatic agents

LOXIOL® antistatic agents are designed to be incorporated into the plastics material in the masterbatching or compounding step. After the thermoplastic conversion like for example extrusion or injection molding, the additive migrates to the plastics surface to avoid the buildup of static charge. Residual antistatic agent in the polymer bulk serves as a reservoir in case the material at the surface is removed in any way.

The antistatic performance can be strongly influenced by the environmental conditions, i.e. mainly the humidity. This is why the reproducible determination of the antistatic effect requires defined conditions, preferably in a climate chamber.

Antistatic agents for polyolefins

Polyolefins are with regards to production volume the by far largest class of polymers and often do require antistatic agents for their numerous applications. Requirements on antistatic agents from the regulatory and Safety, Health and Environment (SHE) perspective have changed and continue to change.

Ethoxylated Fatty Amines are typically used as antistatic agents in polyolefins. After the formerly used grades from synthetic origin had been banned from antistatic applications for regulatory reasons, ethoxylated fatty amines from vegetable origin were introduced. In the meantime, this chemistry was questioned at all, so proper alternatives are requested from the market. As an industry standard from the technical point of view, an ethoxylated fatty amine from vegetable origin is used as a reference antistatic agent in this document.

Ethoxylated Fatty Alcohol was introduced as a potential substitute for ethoxylated fatty amines for polypropylene, but not explicitly recommended for polyethylene. This chemistry was included in the tests as another benchmark product.

Lauric Acid Diethanolamide, also known as LDEA, and available at Emery Oleochemicals as LOXIOL® 1010 EU, is another successfully used antistatic agent for polyolefins. Though being much less critical than ethoxylated fatty amines from the regulatory standpoint, the substance class is sometimes no longer considered for new developments due to the nitrogen-based chemistry.

LOXIOL® VPA 1726 is a commercially available antistatic agent for various demanding applications. In this respect this additive has been tested for polyolefin film extrusion and injection molding applications in comparison to the three products mentioned above. **LOXIOL® VPA 1726 shows an outstanding regulatory profile making chemical labelling obsolete. The material is 100 % bio-based, free of animal-derived materials and its food contact compliance status by far outperforms those of the other additives as shown in table 1.**

Antistatic Agent	**FDA** CFR 21	Commission Regulation **(EU) No 10/2011** Specific Migration Limit
Ethoxylated Fatty Amine*	§178.3130 For use only as an antistatic agent at levels not to exceed 0.1 percent by weight of polyolefin food-contact films	1.2 mg per 1 kg of food
Ethoxylated Fatty Alcohol*	- not mentioned	1.8 mg per 1 kg of food
Lauric Acid Diethanolamide**	§ 178.3130 Antistatic and/or antifogging agents in food-packaging materials • For polyethylene container max. 0.5 % • For polypropylene films max. 0.2 %	5 mg per 1 kg of food
LOXIOL® VPA 1726 Proprietary product**	§ 172.XXX Part 172 - FOOD ADDITIVES PERMITTED FOR DIRECT ADDITION TO FOOD FOR HUMAN CONSUMPTION The product is provided as an additive for plastic materials and articles intended to come into contact with food and therefore not necessarily fulfilling the specification of a direct food additive.	**No specific migration limit is set**

* Information from 2016's and 2018's supplier statements.
** Information from 2020's Emery Oleochemicals food contact statement. Statements on further food contact regulations other than FDA and EU 10/2011 can be provided upon request. Please always refer to the most current version of the statement.

Table 1: Overview on food contact compliance regulatories of the products tested

Process description for the test of antistatic agents

The antistatic agents were batched using a compounding extruder. The resulting masterbatches were processed used a single screw extruder for monolayer films or an injection molding machine for plaques. Finally the surface resistivity was measured after defined storage times and under defined climatic conditions. A low surface resistivity corresponds to a good antistatic effect. The process is visualized in Figures 1 and 2. All process steps and tests were done at the Emery Oleochemicals Technical Development Center in Loxstedt / Germany.

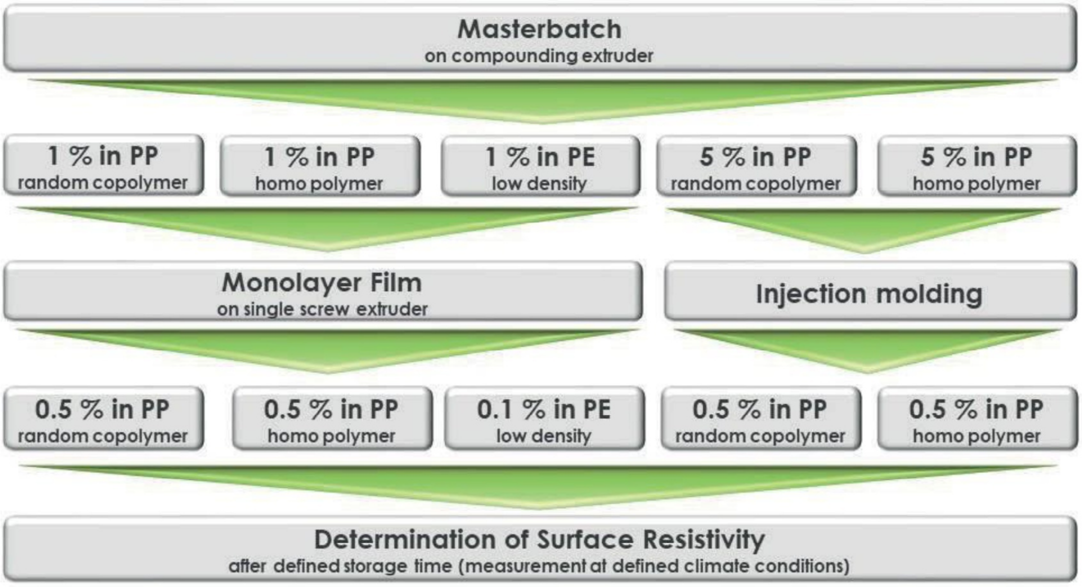

Figure 1: Process scheme for the evaluation of antistatic agents in polyolefins

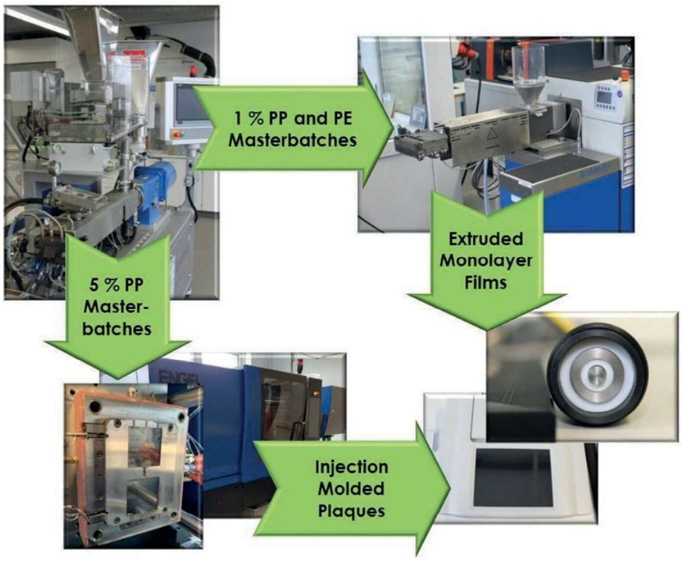

Figure 2: Devices used for the evaluation of antistatic agents in polyolefins

For the film extrusion processes, a very low masterbatch concentration of 1 % only was used leading to a let down ratio of 2 to reach 0.5 % active concentration in PP (10 for 0.1 % in PE, respectively). The single screw film extrusion unit has little ability to properly distribute the additive in the polymer, so when targeting a homogeneous distribution of additives in the film the low masterbatch concentration was highly supportive. For injection molding, a much better dispersion of the additive in the polymer could be achieved in the process, so a higher masterbatch concentration of 5 % could be utilized. This concentration is still too low to be comparable to industrial standard masterbatches, but it helped to ensure a reliable fundament for the scientific data.

Films were tested immediately after production as well as after certain storage times. Prior to measurement of the surface resistivity after storage, the films were kept at defined climate conditions for 48 h. The standard conditions were 23 °C and 50 % relative humidity. Additionally,15 % and 80 % relative humidity were applied at the same temperature. This set-up reflects dry and humid climate conditions. Humidity clearly has the potential to influence surface resistivity. Each resistivity value reflects an average value of at least 5 measurements.

Polyolefin grades

The following polyolefin grades were used to prepare both the masterbatches and the films or injection molded plaques, respectively. Blending different polymers was avoided in order to exclude any influence of blending on the antistatic performance.

Application	Polymer	Melt Flow Rate	Standard
Film Extrusion	PP random copolymer	8.0 g/10 min 230 °C; 2.16 kg	ISO 1133
	PP homo polymer	10.5 g/10 min 230 °C; 2.16 kg	ASTM D 1238
	LDPE	20 g/10 min 190 °C; 2.16 kg	ISO 1133
Injection Molding	PP random copolymer	40 g/10 min 230 °C; 2.16 kg	ISO 1133-1
	PP homo polymer	12 g/10 min 230 °C; 2.16 kg	ISO 1133-1

Table 2: Polyolefin base polymers used for the evaluation of antistatic agents. Further details on the polymers can be provided upon request.

PP random copolymer (with a few percent by weight of ethylene) and PP homo polymer are often used in parallel for multilayer films. In this study they are used as sole polymers to make single layer films. The average thickness of films was approx. 50 µm. Similar grades, but with higher melt flow rate, were used for injection molding of 100 mm x 100 mm and 3 mm thick plaques. An LDPE film (approx. 40 µm) was made to create a complete view on antistatic performance of the additives.

Results – PP films

Ethoxylated Fatty Amine, Ethoxylated Fatty Alcohol, Lauric Acid Diethanolamide (LDEA) and LOXIOL® VPA 1726 were tested in PP films according to the procedure described above. The results for the antistatic performance for the four antistatic agents in random copolymer PP films tested at 50 % RH are shown in Figure 3.

The surface resistivity values for Ethoxylated Fatty Amine, LDEA and LOXIOL® VPA 1726 are quite similar and do not change significantly over time, given the measurement inaccuracy of this method which results in a standard deviation of one power of ten on average. Ethoxylated Fatty Alcohol proves to be no suitable antistatic agent in this polymer application, as the surface resistivity remains close to the upper detection limit of the device and so cannot be distinguished from a film without any antistatic agent.

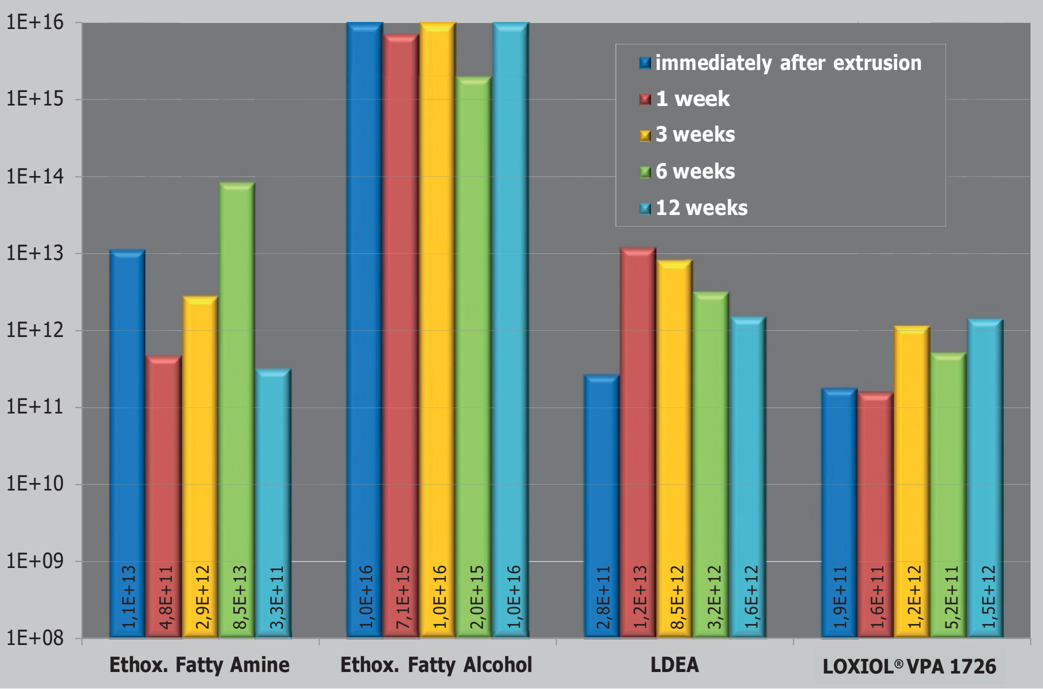

Figure 3: Surface resistivity [Ω] of random copolymer PP films, 0.5 % of antistatic agent, over time (50 % RH)

In Figure 4, the antistatic performance in random copolymer PP at different humidity levels is compared, which represent a very dry (15 % RH) and a very humid environment (80 % RH). The values at 50 % RH (already shown in Figure 4) are included as well; all values have been generated after 3 weeks storage time.

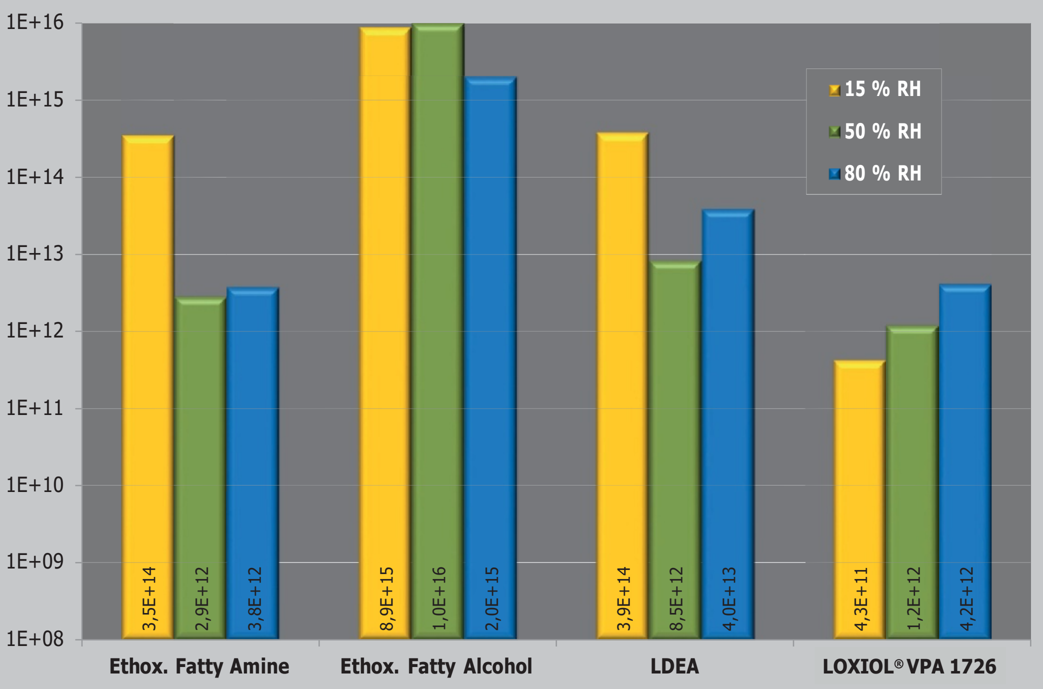

Figure 4: Surface resistivity [Ω] of random copolymer PP films, 0.5 % of antistatic agent, different relative humidities (3 weeks)

The overall picture stated for Figure 3 is also valid for Figure 4. Ethoxylated Fatty Alcohol continues to fail in this application, while the other three products continue to provide a decent antistatic effect. However, LDEA and especially Ethoxylated Fatty Amine show increased surface resistivity at low humidity (yellow bars). In contrast, LOXIOL® VPA 1726 provides a stable level considering the measurement accuracy, rather independent from air humidity.

Same tests as described for random copolymer PP (Figure 3 and 4) were made with films extruded from homo polymer PP. The trend of surface resistivity over time for this polymer is shown in Figure 5. Again, Ethoxylated Fatty Amine, LDEA and LOXIOL® VPA 1726 prove to be suitable antistatic agents, although some additional storage time is required for the surface resistivity to decrease (Figure 5 vs. Figure 3). The reason for this phenomenon is the higher degree of crystallinity of a homo polymer vs. a random copolymer to decrease migration rate. While in random copolymer a sufficient antistatic effect is provided immediately after film production, it takes approx. 3 weeks in homo polymer to reach a similar level. Ethoxylated Fatty Alcohol again fails in this trial. The result for Ethoxylated Fatty Amine after 12 weeks storage time cannot be considered for evaluation, as the single values show a very high standard deviation.

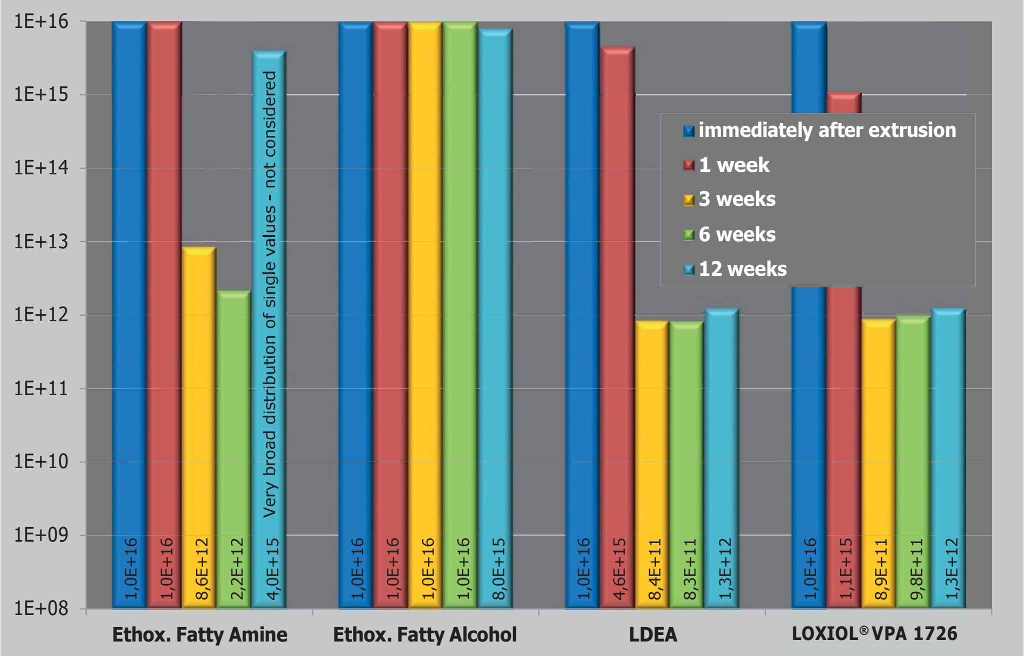

Figure 5: Surface resistivity [Ω] of homo polymer PP films, 0.5 % of antistatic agent, over time (50 % RH)

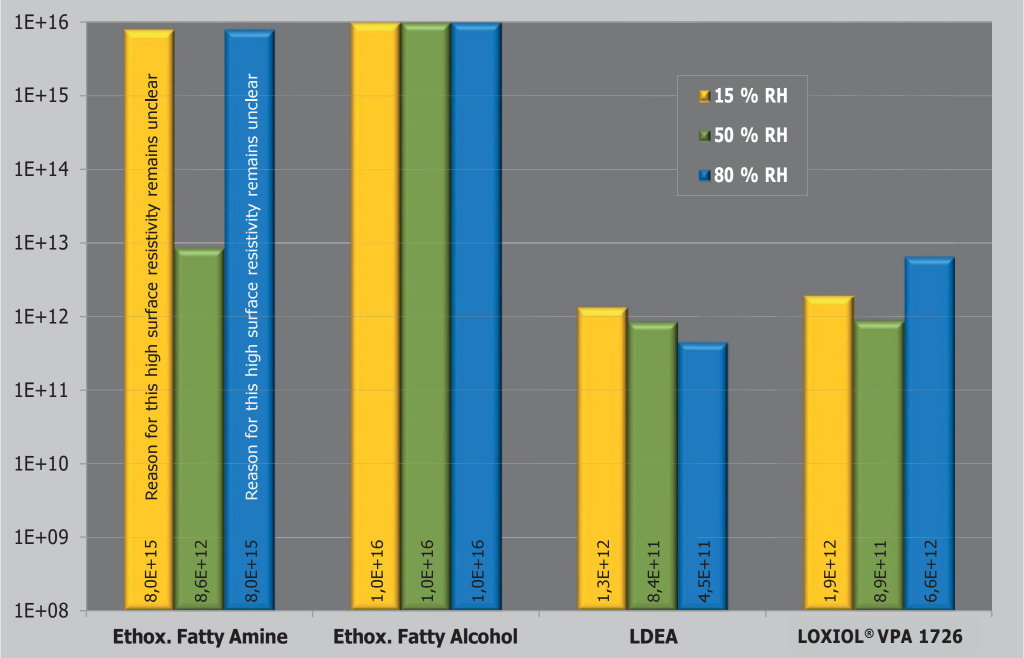

Figure 6: Surface resistivity [Ω] of homo polymer PP films, 0.5 % of antistatic agent, different relative humidities (3 weeks)

The comparison of different humidity levels is provided for random copolymer PP in Figure 4 and for homo polymer PP in Figure 6. LDEA and LOXIOL® VPA 1726 show a very constant antistatic performance actually independent from humidity. As the air humidity during application of the film cannot be predicted by the manufacturer of the film, using an additive that does provide constant performance not depending on this variable is beneficial. While the performance of Ethoxylated Fatty Alcohol is consistently poor, Ethoxylated Fatty Amine shows a very unexpected result. The surface resistivity at 15 % and 80 % RH is very high, almost at the upper limit of the scale, while the value at 50 % is in a comparable range to LDEA and LOXIOL® VPA 1726. The single measured values show a low standard deviation, so the average value can be considered trustworthy. Finally no logical explanation can be provided for this phenomenon. This result would have to be further examined.

Further test series with other polymer applications

As the performance results for Ethoxylated Fatty Alcohol in PP films proved to be very poor (see previous paragraph), this product was excluded from further testing. Concluding previous results in PP, LDEA resulted in no superior performance compared to LOXIOL® VPA 1726. As LOXIOL® VPA 1726 is superior to LDEA with regards to safety and health features, it is the product of choice and LDEA was excluded from further testing as well. In future tests LOXIOL® VPA 1726 will be compared to the market standard, which is Ethoxylated Fatty Amine.

Results – PE films

Ethoxylated Fatty Amine and LOXIOL® VPA 1726 were incorporated into PE films according to the procedures described in Figure 1. An active content in the film of only 0.1 % was sufficient to achieve a surface resistivity in the range of $10^{11}\ \Omega$ to $10^{12}\ \Omega$.

The two antistatic agents differ slightly in their performance, as Ethoxylated Fatty Amine leads to a higher initial surface resistivity than LOXIOL® VPA 1726, but leads to a slightly lower level after storage (Figure 7). However, these differences are minor and the effect can be easily adjusted by dosage, as the 0.1 % level as used for this test is indeed very low.

The comparison at different humidity levels (Figure 8) indicates a similar trend as observed in Figure 4 for PP, i.e. a more stable antistatic performance rather independent from the humidity level for LOXIOL® VPA 1726. Ethoxylated Fatty Amine shows a slightly better performance at mid and high humidity, but a clear performance drop when it comes to low humidity.

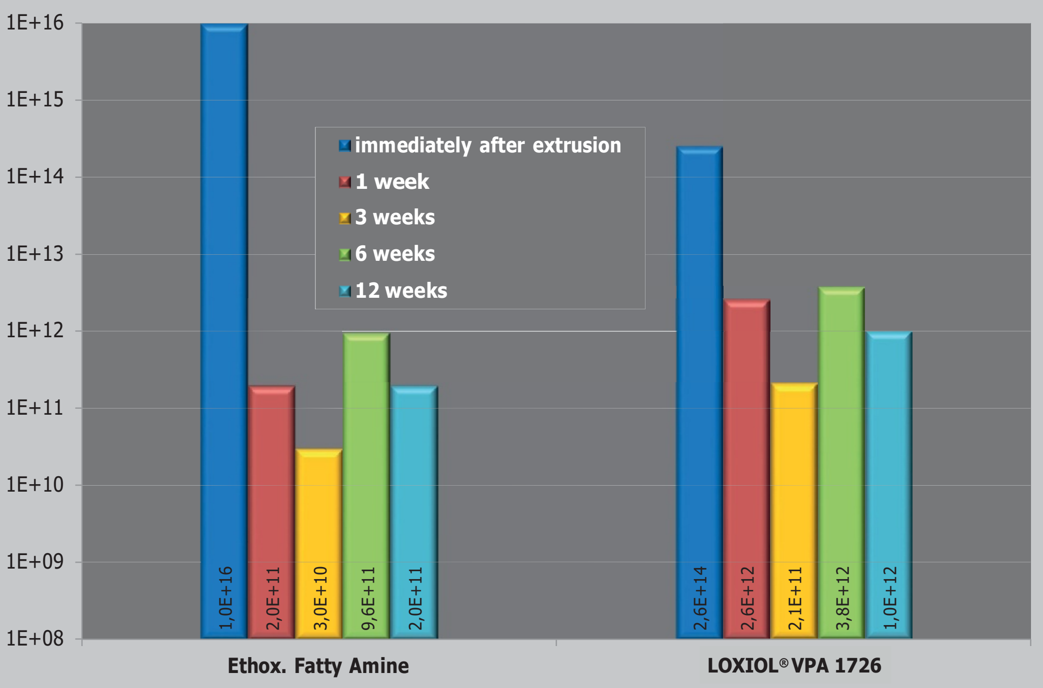

Figure 7: Surface resistivity [Ω] of LDPE films, 0.1 % of antistatic agent, over time (50 % RH)

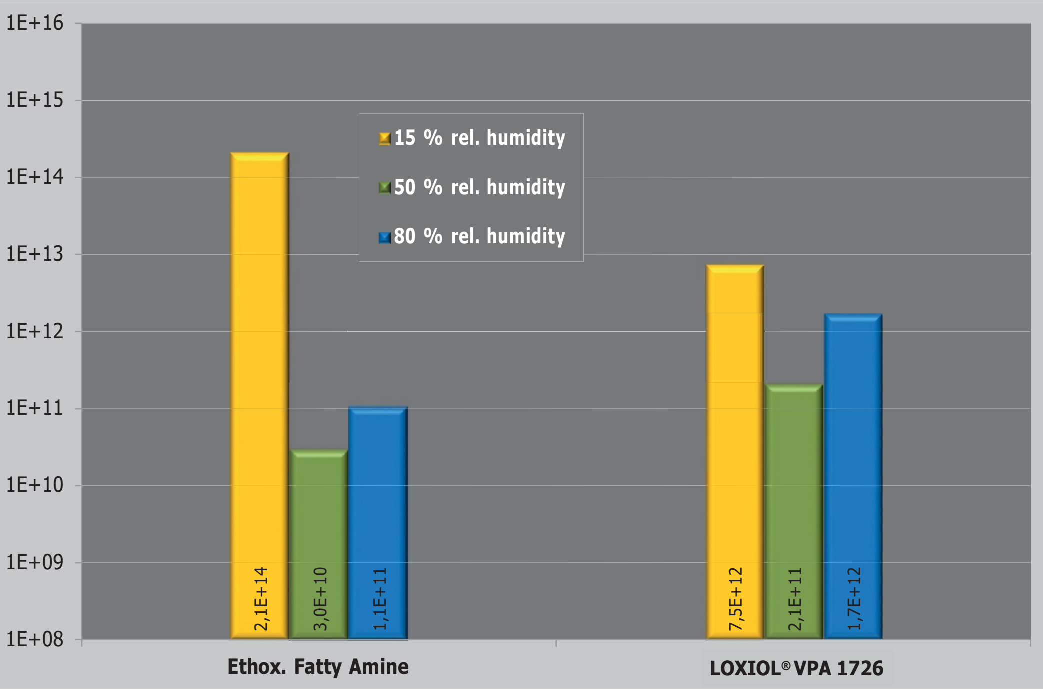

Figure 8: Surface resistivity [Ω] of LDPE films, 0.1 % of antistatic agent, different relative humidities (3 weeks)

Results – PP injection molding

Despite the high thickness of random copolymer PP injection molded plaques vs. extruded films (Figure 9 vs. Figure 3), the antistatic performance of random copolymer PP plaques is sufficient already after 1 week storage. The higher thickness of a plaque vs. a film results in a higher average distance the additive molecule needs to migrate to reach the surface in order to serve its function. However, this is apparantly compensated by the different process conditions. In case of Ethoxylated Fatty Amine the surface resistivity decreases to reach a minimum after approx. 6 weeks, then reaching the original 1 week-level again after about 1 year. This trend can be observed basically for LOXIOL® VPA 1726 as well, but the differences in surface resistivity are negligible given the accuracy of the method, so the antistatic performance is very stable and predictable over time.

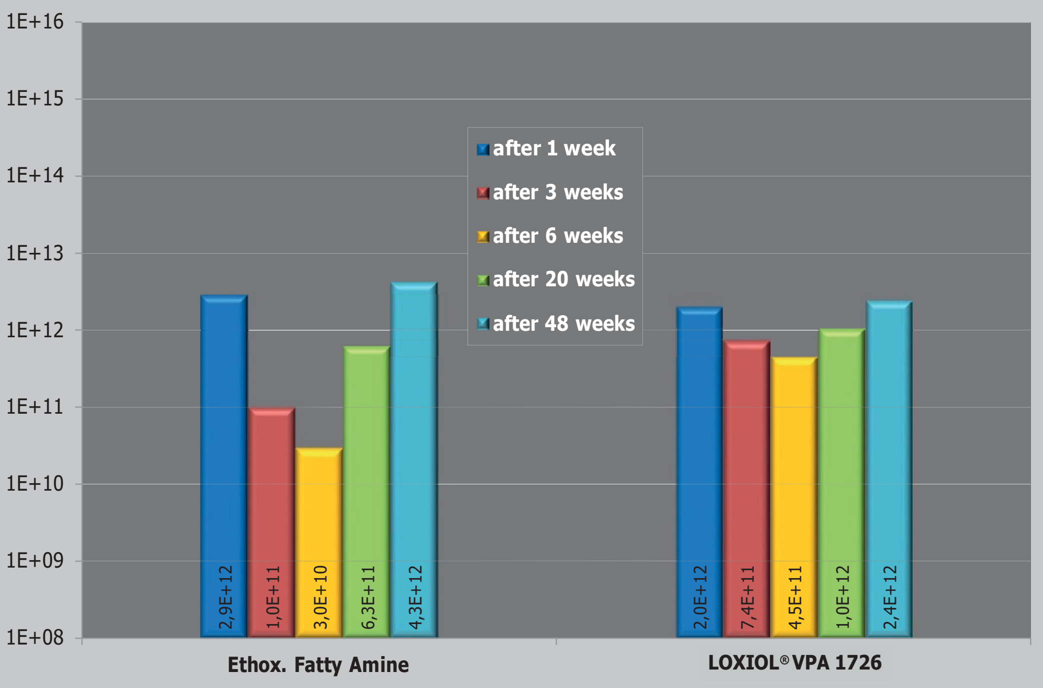

Figure 9: Surface resistivity [Ω] of random copolymer PP plaques, 0.5 % of antistatic agent, over time (50 % RH)

In case of homo polymer PP injection molded plaques (Figure 10), the result is quite similar. Although Ethoxylated Fatty Amine does provide a better performance for short storage times, the performance level of both additives align after a prolonged storage time. Obviously, LOXIOL® VPA 1726 shows a slower migration but therefore a more stable antistatic performance level. The antistatic performance of such plaques after a storage time of more than 24 weeks will be investigated further.

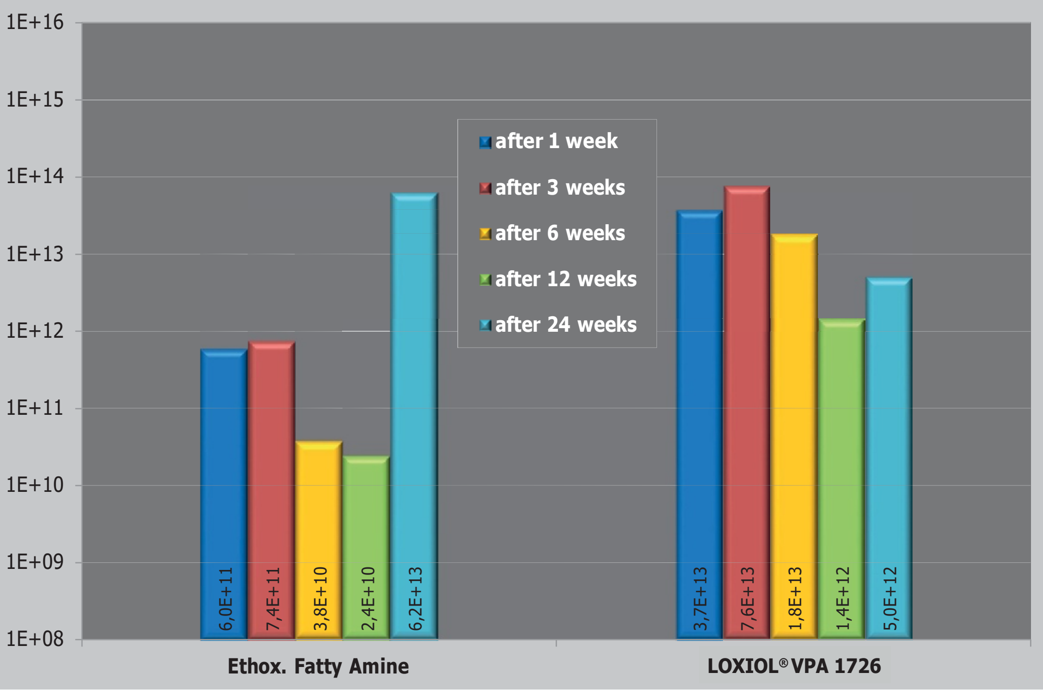

Figure 10: Surface resistivity [Ω] of homo polymer PP plaques, 0.5 % of antistatic agent, over time (50 % RH)

Summary & Conclusion

Four different antistatic agents were tested in polyolefin applications.

- Ethoxylated Fatty Amine, which is the market standard from a technical point of view, but which is questioned for regulatory and health reasons
- Ethoxylated Fatty Alcohol, a potential successor for Ethoxylated Fatty Amine
- Lauric Acid Diethanolamide (LDEA), a successfully used antistatic agent for both PE and PP applications. Its regulatory profile with regards to food contact compliance (see Table 1) is much better than the one of ethoxylated products mentioned before, but it is still a nitrogen-containing compound and its physical state as a paste makes it rather demanding to be used and dosed in a compounding or masterbatching process.

- **LOXIOL® VPA 1726** is a fully commercialized liquid antistatic agent by Emery Oleochemicals with a well-established supply chain.

  It provides an outstanding profile of regulatory, safety, environmental and sustainability aspects:

  ○ **Food contact compliance without any dosage limitations or specific migration limits**
  ○ **100 % bio-based and vegetable-derived raw material sources**
  ○ **No chemical labelling necessary**
  ○ **REACH compliance**
  ○ **Nitrogen-free, i.e. both amine- and amide-free composition**
  ○ **Long history of safe use**

These antistatic agents were tested in PP films. As Ethoxylated Fatty Alcohol did not show any effect as antistatic agent in this application and LDEA showed no superior performance, the focus for further investigations was put on Ethoxylated Fatty Amine and LOXIOL® VPA 1726.

In direct comparison, LOXIOL® VPA 1726 provides a very good antistatic performance in both random copolymer and homo polymer PP films, LDPE films and both random copolymer and homo polymer PP injection molded plaques. The surface resistivity of such articles using LOXIOL® VPA 1726 was measured to be on a similar if not the same level with the established Ethoxylated Fatty Amine. The antistatic effect provided by LOXIOL® VPA 1726 was less sensitive to storage time and change of humidity compared to Ethoxylated Fatty Amine. This is a major advantage as manufacturers of plastic articles comprising an antistatic agent cannot predict when their product is going to be used and what the climate conditions will be. A less time- and climate-dependent effect is therefore much appreciated. Given the vast number of regulatory, safety, environmental and sustainability assets, LOXIOL® VPA 1726 provides a large number of advantages for all polyolefin processing companies seeking to replace Ethoxylated Fatty Amine.

LOXIOL® VPA 1726 is fully commercialized and immediately available for testing.

Order your sample of LOXIOL® VPA 1726 today!

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Emery Oleochemicals GmbH
T | +49 211 5611 2000
E | gp.europe@emeryoleo.com

Emery Oleochemicals LLC
T | +1 513 762 2500
E | gp.americas@emeryoleo.com

Emery Oleochemicals (M) Sdn Bhd
T | +603 3326 8686
E | gp.asia@emeryoleo.com