Additives to Improve Antifog Performance

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Background

The formation of “fog” on plastic film or sheet is the result of the condensation of water vapor on the surface of transparent sheet or film. The physical condition that causes this may be the result of a number of things:

- The temperature of the film surface on the inside falls below the dew-point temperature of the air and water vapor that is within the headspace of the article
- Air near the film’s surface cools to a temperature at which it can’t retain all the water vapor; as a result, excess water condenses on the film’s surface. This effect is based on the relationship between the temperature of enclosed air, the relative humidity of the air, and dew point temperature
- The difference between the surface tension of the condensed water and the critical wetting tension of the film’s surface

In packaging applications, food that is being wrapped or stored in a plastic article usually has high moisture content. When this packaged item is stored in a cool environment, the moisture condenses on the surface causing fog to occur. Depending upon the application, this fog is typically not considered aesthetically pleasing and may impact food spoilage.

There are two routes the packaging industry uses to minimize the formation of fog on sheet, film, or thermoformed articles: internal additives or external topical coatings.

Internal Additives

Internal antifog additives are generally non-ionic surfactants. These additives are added at the film producers mainly in form of concentrates or master batches. These additives usually have a certain level of incompatibility with the polymer matrix they are blended into, and as a result, migrate to the surface. The internal agents have a level of durability over time with regards to maintaining the antifog performance since there is a source of the agent in the polymer which has a chance to replenish the surface through migration effects over time.

These additives usually are surface activators which help decrease the surface tension of the water droplets that may form on the film’s surface due to condensation. As a result, the surface tension between the water and the substrates surface is reduced. This reduces the contact angle of the water molecules, and the water is able to spread out more creating a more uniform layer of water. This effect helps improve the transparency of the water droplets on the film’s surface, and the result minimizes any lens effects the water droplets cause.

There are many commercially available internal antifog agents for polyolefin systems, but not many for polyester systems. This is because polyolefin is more hydrophobic and typically exhibit surface tensions around 30 dynes/cm versus polyester that is around 40-44 dynes/cm.

The hydrophobic nature of polyolefin allows for a broad selection of agents, many of which are incompatible and readily migrate to the surface. Polyesters, however, are more polar and typically have a better level of compatibility with the antifog additives. As such, less migration occurs which prevents any change in the wetting tension of the film’s surface.

External Coatings

Coatings can be applied to the surface of the plastic sheet or film. These agents are like internal additives in that they are designed to help wet out the substrate’s surface, which decreases the contact angle of the water droplets and improves transparency. These agents are usually supplied as viscose liquids which are then diluted down with water, or used neat. The liquid is coated to the surface of the sheet or film, either by a dip coating and roller process or by spray application. The sheet is typically dried to evaporate the water and help cure the coating to the surface.

External coatings are more commonly used for PET versus using internal agents. This is due to the compatibility issue PET has with the internal agents (the compatibility being too good, which prevents migration to the surface) and also because of the high processing temperatures for PET which may degrade the additives during melt extrusion.

Selection Criteria

The parameters that must be considered when selecting the type and level of antifog to use for packaging applications include:

- Type of polymer
- Thickness of film
- Processing conditions
- Temperature at which sheet or film will be used
- Other downstream unit operations that may affect performance (e.g. – thermoforming)
- Food contact/government regulations for food packaging applications

Antifog requirements are application specific and there can be a level of subjectivity involved when describing this property, since it is based on visual appearance. Also, the environmental conditions (temperature and humidity) play a key role in how this physical effect occurs. Food contact compliance on these products can also differ. If for food contact, antifog agents should be checked with the supplier to verify that they can be used with Ingeo biopolymer (PLA) as an antifog agent in food contact with the appropriate use conditions and food types of the intended end use considered. If compostability is an option for end-of-life in the design criteria, the supplier should be contacted to determine their dataset for the appropriate geographic composting standards is appropriate, as NatureWorks has not conducted laboratory compost testing on these materials.

Antifog Options

Since PLA is an aliphatic polyester, it is more similar to PET in terms of surface energy characteristics and polarity versus olefins. See **Table 1** for surface energy comparisons. As such, topical coatings may be considered a better route to improve antifog performance for sheet, film or thermoformed articles made out of Ingeo biopolymer. Internal additives may also work, but an experimental approach may be needed in order to find the most effective use level and balance of compatibility and migration properties.

In general, corona treatment of sheet and film typically helps aid in the antifog coating process because the surface energy of the substrate is increased which helps to wet the surface out. For external coatings, concentration effects may exist which impact how well fogging is prevented. An experimental approach may be needed to understand which dilution levels work best to achieve the desired antifog performance requirements. Also, it is important to ensure the coating process applies the liquid agent in a uniform and consistent manner. Otherwise, the desired antifog effect may not be achieved due to poor coating application.

Table 1 – Surface energy comparison

Substrate	Surface Energy [dynes/cm]
Polyolefins	29-31
PET	41-44
Polystyrene	38
Ingeo biopolymer	38
Silicone	24
Water	72
Methanol	23

Other factors that may impact antifog performance include additives in the polymer matrix or other surface modifiers, such as silicone. These agents may have a negative effect on the antifog performance.

The thermoforming process may also impact the antifog performance of the external coating or internal antifog additive. Typically, as the thermoforming temperature increases, the antifog effect gets erased. This loss of antifog performance after thermoforming is dependant not only upon the thermoforming times and temperatures that are used, but also the concentration of the antifog agent. In some instances, however, it has been observed that the antifog effect does come back

after the thermoformed articles have had a chance to equilibrate over time (typically >24 hrs). This should be kept in mind when testing for antifog effects after thermoforming.

Appendix A has company contact information for sourcing both external and internal antifog agent options for Ingeo biopolymer.

Appendix A *– Supplier Information for Sourcing Antifog Options for Ingeo Biopolymer*

Company	**Product(s)**
MECO **Energie-Kollektoren GmbH** Radolfzeller Strasse 56 D-78476 Allensbach / Germany Tel: +49 (0) 75 33 / 94 98 3 – 0 Fax: +49 (0) 75 33 / 94 98 3 – 33 Internet: http://www.mecostat.com	Mecostat-3/725 and Mecostat-3/723 [external topical coatings]
GOULSTON TECHNOLOGIES, INC. P.O. Box 5025 Monroe, NC 28111-5025 U.S. Subsidiary of **Takemoto Oil & Fat Company** Tel: (704) 296-6060 Fax: (704) 296-6400 Internet: http://www.goulston.com	PETAFD-20 [external topical coatings]
TAKEMOTO OIL & FAT COMPANY	ELECUT C-031L (FDA approval pending) [external topical coatings]
PolyOne 33587 Walker Road PolyOne Center Avon Lake, OH 44012 United States Tel: (866) 765-9663 www.polyone.com	[Internal agents]
Sukano Polymers Corporation 295 Parkway East Duncan, SC 29334 Tel: (864) 486-1478 www.sukano.com	[Internal agents]
Polyvel, Inc 100 Ninth Street Hammonton, NJ 08037 Tel: (609) 567-0080 Fax: (609) 567-9522 www.polyvel.com	[Internal agents]