FROM FOOD EMULSIFIERS TO POLYMER ADDITIVES

The renewable technology

of Palsgaard's plant-based additives for the plastics industry

Palsgaard®

Circular and renewable solutions

As the plastics industry seeks to reduce reliance on fossil resources, there is growing interest in circular and renewable solutions. This includes not only base polymers but also additives. Palsgaard's plant-based polymer additives offer an alternative to conventional fossil-based formulations, designed to maintain functionality, performance and quality. This paper discusses the technology and its potential benefits for industry and environmental goals.

There is a strong awareness among consumers for healthy and natural products today. People show a growing preference for 'bio' foods and other products with 'wholesome' ingredients. Especially plastics are being increasingly scrutinised for potentially harmful effects on human health.

At the same time, brand owners are asking for more sustainable product and packaging solutions from their designers and suppliers to meet these challenges and lower their carbon footprint in compliance with strict environmental regulations.

By Christina Normann Christensen, Product & Application Manager, Palsgaard A/S (2015-2021)

Plant-based additives for responsible applications

Naturally derived fatty acid esters from palm, sunflower, rapeseed and other vegetable oil form the renewable backbone of Einar® functional polymer additives.

For plastics and food-contact packaging, in particular, all of these health and sustainability demands are addressed by Palsgaard's portfolio of Einar® plant-based polymer additives, which can be seen as a renewable technology building directly on the company's broad expertise in natural emulsifiers for food applications.

Invented back in 1917 by Einar Viggo Schou, the founder of Palsgaard, the original focus of the technology was on products such as margarine, bakery, confectionery and ice-cream, where emulsifiers add stability, mouthfeel and texture. The plant-based alternatives soon also played an instrumental role in reducing spattering, preventing thermal shock, controlling viscosity, facilitating aeration and extending the shelf-life of food.

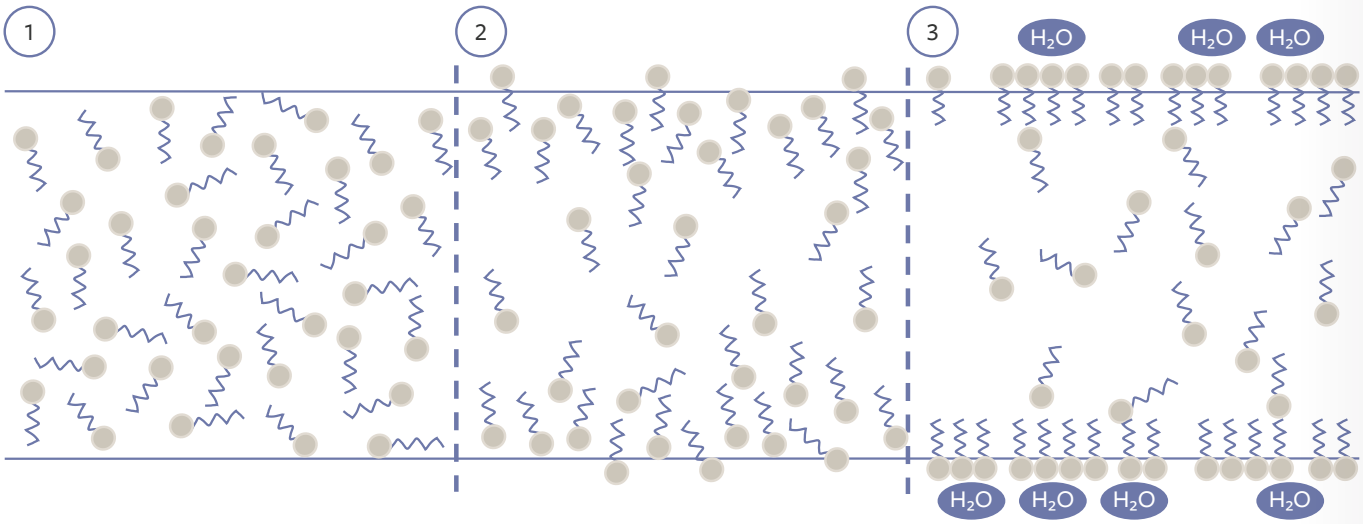
Emulsifiers have different building blocks on their opposite molecular ends: one with affinity to fats, the other with affinity to water. This is what makes them ideal for mixing oily and aqueous substances into a smooth emulsion. Over the years, they were found to offer similar benefits as functional ingredients in personal care, cosmetics and other non-food applications. In plastics, such as packaging polymers, they serve as highly sustainable anti-fog and anti-static surfactants, anti-fouling additives, pigment dispersing aids, ageing modifiers, EPS coating additives, and mould release agents.

Palsgaard's Einar® polymer additives are exclusively derived from animal-free and edible plant sources. This includes RSPO-certified palm oil – which provides the greatest yield per hectare – as well as rapeseed, sunflower, coconut and other vegetable oils. In fact, they are sold as 'dual use' plant-based additives with worldwide regulatory food-contact approvals. Moreover, while they are highly effective in comparably low concentrations, they match or exceed the functional performance of many conventional synthetic additives, such as ethoxylated amines or amides. This can also help to minimise the overall additive concentration in polymer formulations.

Made with a strategic focus on reducing energy consumption and CO_2-emissions

Einar® plant-based polymer additives are glycerol and polyglycerol esters made from vegetable fatty acids, with no animal derivatives. Developed with attention to responsible resource use, they are suitable for innovative packaging solutions and can replace fossil-based additives in polymer formulations.

Their renewable content helps reduce reliance on fossil resources. By supporting shelf-life extension, they may help reduce food waste in packaging applications.



Driven by their hydrophilic ends, the additive molecules in the polymer matrix migrate towards the polymer surfaces to act as surfactants e.g. against fogging and static build-up.

Einar® surfactant solutions

The two most important product lines of Palsgaard's plant-based polymer additives are surfactants used to reduced fogging and the accumulation of static electricity on plastic packaging material.

Both properties rely on the migration of the Einar® additives from within the polymer matrix to the surface of the packaging material. There, in anti-fog and anti-stat applications, they interact with condensed droplets or attract ambient moisture to the surface, respectively. Although migration here is a desirable effect of surfactant additives, there are strict migration limits that must be adhered to in food packaging to eliminate health hazards and prevent that the taste or odour of the packaged food is altered.

In this context, it is important to recognise that most Einar® products are not subject to specific migration limits.

Palsgaard offers its Einar® anti-fog and anti-static additives in a comprehensive range of customised grades tailored to the specific needs of polyolefins and other plastics for packaging applications from food and personal care to medical and electronic products, where they replace conventional additives such as anti-static ethoxylated amines and amides.

Anti-Static additives for polyolefin and PVC moulding compounds

Static electricity on polymer surfaces attracts dust and other fine particles, which results in lower transparency and compromises the hygienic appeal of packaged products, such as food. Just as important, however, the build-up of static charges on plastic surfaces can result in a number of serious problems during processing, conveying, stacking and packaging. For example, high static is known to reduce the acceptable rolling speed in film production, create handling problems during stacking, cause congestions on conveyor belts, and complicate the sealing of packages for powdery products. In electronics packaging, it may even damage the packaged product.

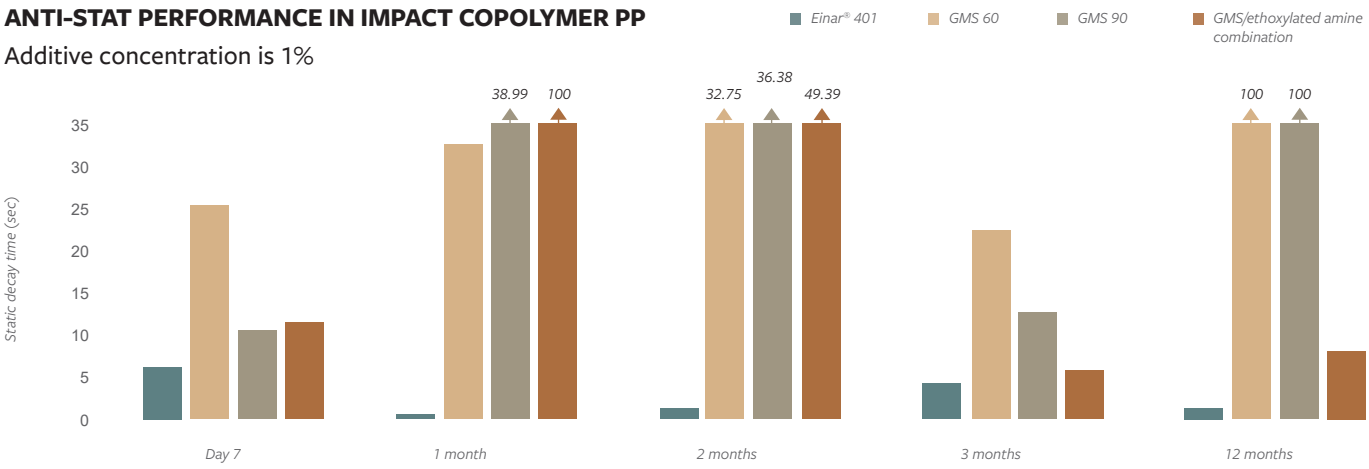
As they migrate to the polymer surface, Einar® anti-static additives interact with ambient moisture to create a conductive layer that will effectively dissipate the static below critical levels. Palsgaard's anti-static portfolio for LDPE, LLDPE and HDPE injection moulding compounds and masterbatches spans from simple glycerol monostearates (GMS) to highly advanced polyglycerols that can rival the efficiency of conventional fossil-based anti-static additives.

One of the most successful and widely used products in this range is **Einar® 601**, that has also been successfully used to add a more sustainable profile to both plasticized and rigid PVC applications at recommended loading levels of 0.5 to 1.0 percent. It enables a clean and dust-free production of anti-static PVC articles while minimising the risk of electrostatic discharge during processing and subsequent handling.

In tailored formulations for PP moulding compounds, anti-static additives such as **Einar® 201** and **Einar® 401** have shown to facilitate the mould release and denesting of applications in production and handling. With high heat resistance and low volatility, they offer efficient solutions in a wide range of PP formulations – from homopolymers to random, barrier and impact copolymers – at concentrations as low as 0.1 percent.

Particularly in impact PP copolymers achieving good anti-static performance with conventional anti-static agents can be a challenge and as packaging designs are getting thinner, the challenge becomes even bigger, since the overall amount of the anti-static agent added is generally reduced relative to the surface wall-thickness of the packaging.

Einar® 401 works exceptionally well in this particular polymer and application range. Apart from preventing the build-up of static charges on the surfaces of injection moulded PP packaging, it also works as an internal lubricant and thereby helps manufacturers optimise their moulding process and reduce cycle times. Likewise, it can effectively eliminate friction problems that are often created by high static energy during mould release, on conveyor belts and during stacking.



Anti-stat performance in impact copolymer PP

Superior immediate and long-term anti-static coverage: Static decay testing shows that **Einar® 401** anti-static additive is able to outperform traditional less safe additive offerings, such as GMS combinations with ethoxylated amine.

Anti-Static additives for PE and PP foams

In PE foams, the use of efficient anti-stats is particularly important in the packaging of sensitive electronics, where static buildup may result in electrostatic discharge that can be detrimental to circuit boards and other electronic components. Here again, **Einar® 601** is a proven performer, delivering excellent anti-stat protection even under low humidity conditions. Recommended for loading levels of 0.2 to 0.5 percent for most applications, the product is available in paste form. It has no adverse effect on foam stability, is a 100 percent amine/amide-free solution and will not interact with ageing modifiers such as **Einar® 201**. In addition, it contributes to the efficient release of excess blowing agent, preventing foam collapse and ensuring high foam quality.

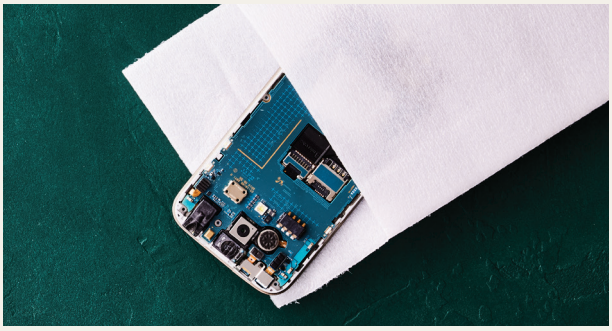
Moreover, thanks to its chemistry there are no issues with stress cracking of polycarbonate when packaging materials are in direct contact with electronic components. Similar benefits can be derived when adding **Einar® 401** anti-static to masterbatches or directly when processing PP foams to packaging products for sensitive electronic goods. The additive is a distilled monoglyceride made from selected fatty acids and glycerol, and is available in pellet form.

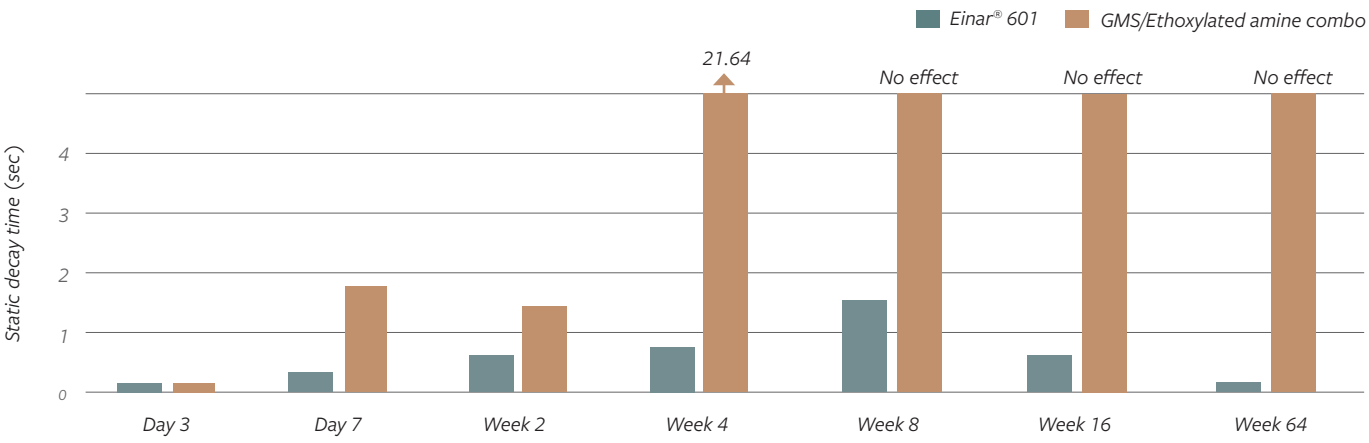
Anti-Static additives for PE and PP films

The same advantages as described above for PE moulding compounds apply to the use of Einar® anti-stats in LDPE, LLDPE and HDPE films. Notably, **Einar® 601** shows outstanding long-term anti-stat performance in LDPE blown film at only 0.1 percent concentration, clearly exceeding the stability of GMS combinations with ethoxylated amine (EA).

In random, homopolymer and biaxially oriented PP films, Einar® anti-stats have a shelf-life of up to two years. They are available in multiple physical forms, including powders and pellets. In typical 25 µm random PP cast film, for instance, **Einar® 411** delivers outstanding anti-static performance over conventional competitors at efficient concentrations of 0.4 percent.

Typical PE and PP foam applications made with Einar® anti-static additives





Anti-stat performance in LDPE blown film · Additive concentration is 0.10%, measured at 50% RH

Einar® plant-based food-grade anti-static additives offer much greater stability in LDPE blown films than GMS/EA combinations, which can significantly improve long-term anti-stat protection and performance.

Anti-Fog additives for polyolefin and PVC Films

Fogging is a particularly undesirable effect in transparent food packaging made from polyolefin or PVC films. It occurs when moisture in the food condenses to visible water droplets on the inner surface of the packaging under varying ambient conditions of humidity and temperature. Einar® plant-based anti-fog additives from Palsgaard effectively lower the surface tension on the inside so that the moisture will spread across the surface as a continuous thin transparent film. Apart from preserving the clear view on the food, this also protects its freshness and extends its shelf-life. Apart from food packaging, the technology also prevents sunburns on plants when used in greenhouse films.

As ideal alternatives to sorbitan and non-vegetable based anti-fog agents, the Einar® anti-fog portfolio for PE and PP films has full FDA and EU food-contact approvals and features high heat resistance and low volatility. As custom designed polyglycerol or glycerol esters from vegetable oils, these additives prevent fogging from chilled as well as hot packaged food at low loading levels in both cold-fog and hot-fog applications.

In PVC films, Einar® plant-based food-grade anti-fog additives replace conventional sorbitan and non-vegetable ester products. The concentration can easily be adjusted to the precise needs of various different PVC grades. Typical applications include PVC food wrap and other transparent film packaging products for cold storage.

Cold fog test of 0.4% Einar® 611
Measured in 50µm LDPE film

	1 day	7 days	1 month	2 months	6 months	18 months
1 min	E	E	E	E	E	E
5 min	E	E	E	E	E	E
15 min	D	E	E	E	E	E
60 min	D	E	E	E	D	E
180 min	D	E	E	E	D	E

Days after film manufacture

Control test of 0.4% competitor polyglycerol ester
Measured in 50µm LDPE film

	1 day	7 days	1 month	2 months	6 months
1 min	E	C	D	E	C
5 min	E	B	C	E	D
15 min	E	B	B	E	D
60 min	E	C	C	E	D
180 min	E	E	E	E	D

Days after film manufacture

Performance rating

Excellent	Acceptable	Better	Poor	Bad

Einar® 611 shows outstanding cold-fog performance vs. non-vegetable glycerol esters in LDPE film.

Coating additives for expandable polystyrene (EPS)

For EPS coating applications, the Einar® additives portfolio provides fine-powdered glyceride esters of fatty acids from vegetable oils. Custom-tailored to EPS formulations of various bead sizes, these additives are available in highly effective plant-based glycerol monostearate (GMS) and glycerol tristearate (GTS) formulations as well as in ready-to-use GMS/GTS blends – also with zinc stearate – designed to provide convenient all-in-one solutions. Palsgaard has many years of experience in the market of fine-sprayed glyceride esters and supports customers with dedicated formulation and application advice.

The safe anti-fouling alternative to ethoxylated amines

Polyolefin producers are increasingly seeking alternatives to ethoxylated amines in their polymerisation processes to address regulatory requirements and safety concerns. **Einar® 987** is a plant-based, food-grade anti-fouling process aid developed by Palsgaard to provide an effective solution for these needs, offering a renewable option for modern polymer production.

Einar® 987 is supplied as a clear and easily pumpable liquid for use in existing dosing systems. It eliminates static build-up during polymerisation and prevents fouling of the reactor wall, thus helping PP and PE producers maintain the cooling efficiency of the reactor. Building on Palsgaard's proven chemistry of renewable anti-static polymer additives, it provides high anti-fouling efficiency at low concentration (100-300 ppm) without any negative effects on catalyst mileage, productivity or final polymer performance.

The active compound of **Einar® 987** is a polyglycerol ester (PGE) blend of fatty acids derived from RSPO-certified sustainable palm oil. As a non-toxic and food-contact approved anti-fouling additive, the product offers a drop-in regulatory compliant solution to replace incumbent ethoxylated amines and can also be used as a more efficient alternative to sorbitan monooleates. This makes it an ideal process additive in the polymerisation of PP and PE materials for sensitive applications, including e.g. medical devices and baby food containers.

Other polymer tailored Einar® additive solutions

*Supported by its independently operated R&D sister company Nexus, Palsgaard continues to innovate in plant-based additive technology, expanding the application areas for **Einar®** products. These plant-based additives are designed to support processability and performance in plastics, while offering alternatives to conventional fossil-based ingredients and aligning with industry goals for resource efficiency.*

Mould release agents for PP, PE, PVC and PC moulding compounds

Tailored to meet the individual demands of PP, PE, PVC and PC injection moulding as well as PP compression moulding processes, Einar® plant-based mould release additives are a highly effective and sustainable alternative to conventional amine and amide products in these application segments.

They combine excellent mould release and denesting with high heat and processing stability. Moreover, they also add a lubricating effect to prevent stacked containers from sticking. Highly efficient performance can be achieved at low loading levels.

As internal additives for masterbatches in PP, PE and PVC and PC moulding compounds, Einar® mould release agents also improve the slip characteristics of products in handling and stacking without altering the taste or odour of packaged food.

Ageing modifiers for PP and PE foams

The production of polyolefin foams is a delicate and complex process which requires fine-tuning and attention to detail. The high-consistent quality of **Einar® 201** ageing modifier ensures reliable and dependable performance when PE and PP foam is conditioned after processing. Like all Einar® polymer additives, the product is 100 percent plant-based as well as EU and FDA approved for food contact, which meets the growing demands of foam converters for safer and more sustainable formulations.

Einar® 201 can easily be adapted to different PE and PP grades by adjusting the dosage level. Replacing synthetic modifiers, it supports the effective release of excess blowing agent from foamed articles and has no stress-cracking impact onelectronic components.

Food-contact products manufactured from PE or PP foam benefit from the high-consistent quality and effectiveness of Einar® plant-based ageing modifiers after processing.

Dispersing aid for colour masterbatches and fibre composites

One of the most impressive cases in favour of Palsgaard's plant-based technology is its applied functionality in the distribution of pigments, fillers and other additives in polymer masterbatches. Growing consumer concern over the safety and sustainability of the plastics used on a daily basis has required the polymer industry to look for more sustainable alternatives to conventional fossil-based dispersing aids.

Einar® 103 is an innovative bio-based food-grade dispersing aid with outstanding performance when compared to industry standards. As a liquid additive in colour masterbatches, it has been proven to be more efficient than waxes currently on the market at much lower concentrations. This in turn means that pigment loadings can be reduced to achieve the targeted colour strength, which saves cost, helps achieve faster colour changes and enhances the sustainability profile of both the masterbatch producer and the polymer.

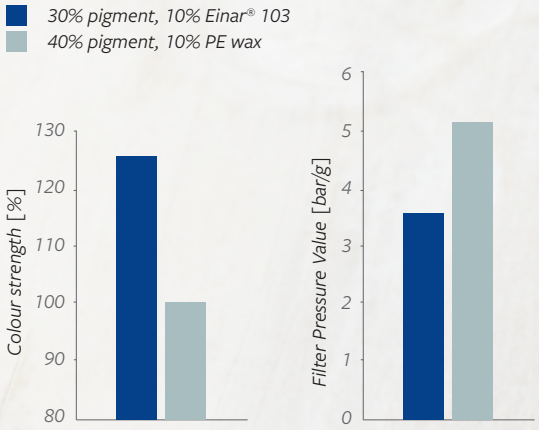
With suitability for a wide range of different polymers, including PE, PP, PVC, PET and PA, **Einar® 103** is a polyglycerol ester based on fatty acids of vegetable origin. It minimises the pigment loading in masterbatches to obtain true colours and can also be combined with renewable waxes to boost colour strength.

Furthermore, the dispersion aid has shown a perfect fit in fibre composites, where it can enable considerably higher fibre contents. For example, by adding 2.5 weight percent of **Einar® 103** in HDPE composites with agave fibres, the fibre concentration could be increased from 20 to 50 weight percent without compromising processability.

With the efficiency of Einar® 101, it is possible to increase the pigment concentrations in a masterbatch, providing additional cost benefits.

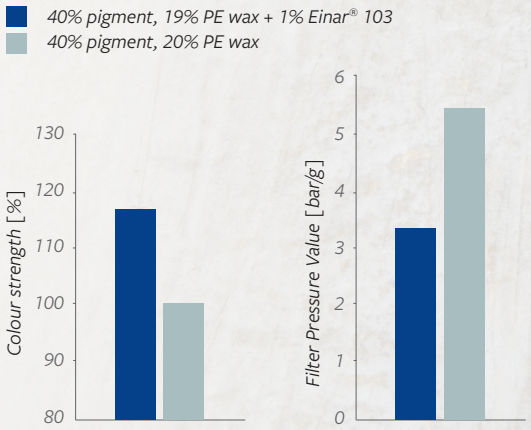
Dispersion with Einar® 103

Pigment Blue 15:3 in LLDPE measured with a 20 µm filter



Boost your PE wax with Einar® 103

40% Pigment Blue 15:3 in LLDPE measured with a 20 µm filter



The foundations of Palsgaard's polymer additives

The modern food emulsifier was invented by the founder of Palsgaard, Einar Viggo Schou (1866 – 1925), in 1917 at the Palsgaard Estate in Juelsminde, Denmark. The estate is also the home of the Schou Foundation which steers the businesses of Palsgaard and its Nexus R&D resource. The plant-based 'Palsgaard Emulsion Oil' started a new era in food manufacturing, where emulsifiers had traditionally been derived from lecithin in eggs or milk proteins mixed with other substances. As applications extended into non-food industries, so did dedicated customer support. Palsgaard has a history of sharing its knowledge and expertise with processors and manufacturers since 1925. Innovations in plant-based additives are driven on two levels, by an advanced Polymer Application Centre and by the fundamental R&D of Nexus.

The Nexus of innovation

Beyond supporting Palsgaard's plant-based additives business, the company's independently operated Nexus R&D resource ensures that it will be able to meet the growing needs of the plastics industry for more natural, bio-based product ingredients in the long term.

More than simply adjusting the formulation of existing Einar® products, Nexus develops new plant-based and food-grade additives from scratch. Research activities even extend to investigations in completely new raw materials and technologies, such as algae and natural nanoparticles, seeking answers to where all the carbon we need will come from once fossil sources run dry.

Nexus comprises several teams of highly motivated scientists and engineers, who use their broad expertise and advanced laboratory facilities to serve Palsgaard with innovation, quality control, and physical and chemical analyses. Manufacturers and processors in the plastics industry who partner with Palsgaard also gain access to the wealth of Nexus's knowledge.

Polymer Innovation Centre

The Polymer Innovation Centre is Palsgaard's state-of-the art resource for product development and customer project support. The Centre is fully equipped for meticulous testing and validation to make the transition of sustainable plant-based technology into successful additive solutions as flawless as possible.

For instance, static decay time and surface resistivity of application samples are evaluated at ambient as well as low humidity, where the ability to dissipate charges is reduced. Resistance to hot and cold fogging are tested in a 60°C water bath and a 5°C cooling cabinet, respectively. Plastics processing capabilities, including injection moulding, blow moulding and calendaring equipment, are available for mould release and pigment dispersion trials as well as investigating the impact of additive loading on melt flow, mechanical properties and surface quality.

The Centre also supports customers by running comparative trials with Einar® vs. competitive additives. It offers realistic industrial pilot testing of new or modified polymer formulations, which can significantly facilitate the proper upscaling and time-tomarket of innovative, sustainable applications with plant-based additives. Experienced technical teams are skilled in dealing with the requirements of many different geographies, and work hard to solve unique challenges.

About the author

Christina Normann Christensen was Product & Application Manager for polymer additives at Palsgaard.

At the company's Polymer Application Centre in Juelsminde, Denmark, she was responsible for planning, coordinating, managing and implementing the development of Einar® plant-based additives and customer projects for non-food applications.

Christina Normann Christensen has a Master of Science from Aarhus University in Chemical Engineering with specialisation in polymers and plastic engineering.

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