Sustaining progress in natural fibres

Natural fibre reinforcements and fillers are proving effective options for reducing the environmental impact of plastic products. Peter Mapleston looks at the latest developments

IMAGE: SHUTTERSTOCK

The availability and performance of fibres from all sorts of renewable resources continues to improve, helping compounders and processors that serve many markets to home in on targets for carbon footprint reduction, degradability, and overall sustainability. Much of this demand results from growing environmental concerns and increasingly restrictive regulatory requirements being imposed or threatened on the use of many plastics-based materials, particularly in the consumer goods sector.

Looking just to Europe, almost 150,000 tonnes of biocomposite granulates were produced across the continent last year, according to nova-Institute in Germany. It estimates that more than half of this volume contained cork, close to a third were wood-plastics composites, and near 10% used flax, hemp, or kenaf fibres. Some 4% of the compounds contained cellulose fibres (pulp or paper based) and the remainder were derived from a mix of sources comprising meadow grass, straw, nut shells, and other renewables. They are used for various reasons – not only for sustainability – with improved mechanical properties, aesthetics and weight reduction cited as prime goals.

Building materials company Alloc and research outfit **RISE PFI**, both based in Norway, earlier this year started a new project called "BioComp" with two industrial partners in the country. The project is centred on a new injection mouldable biocomposite system based on wood fibres (by-products of flooring production) and bioplastics, which are being implemented on a new compounding line that could eventually be used for commercial production. The BioComp initiative is a continuation of the FiberComp and ValBio3D projects previously discussed in Compounding World (see the May 2020 edition). Other partners in the BioComp project, which is partly funded by the Research Council of Norway, include **Norske Skog Saugbrugs** and Plasto.

"The bio and circular economy focuses on biobased materials, reduction of material consumption, increment of the product-lifetime and recycling of industrial side-streams, thus closing the loop of material utilisation," says Gary Chinga Carrasco, Lead Scientist in the Biocomposite area at RISE PFI. "This was one of the driving forces behind the project."

Chinga Carrasco says the project will develop new biocomposite products and covers the whole value chain from biocomposite production (the specialism of Norske Skog Saugbrugs), injection moulding (Plasto) and interior building materials (Alloc), all working in close collaboration with RISE PFI, which is responsible for biocomposite R&D.

Dag Molteberg is Senior Development Manager at Norske Skog Saugbrugs. He says the company's

Main image: A growing variety of natural fibres and fillers are being developed for production of reduced carbon footprint and lightweight polymer compounds

IMAGE: NORSKE SKOG SAUGBRUGS

Above: Norske Skog Saugbrugs is building a new plant for production of its Cebico wood fibre-based biocomposite pellets at its Halden site in Norway

main business is in the production of printing paper, but it also develops new green products based on its fibre resources and knowledge. "Saugbrugs has run several R&D activities related to biocomposites over the last ten years, but we are now taking this to an industrial and commercial level with the building of a new plant for production of biocomposite pellets."

The brand name chosen for the pellets is Cebico. They will be produced on the demonstration plant at the Norske Skog Saugbrugs plant at Halden in Norway, which will consist of a line for preparation of wood fibres, together with the compounding and pelletising line. Start-up capacity will be around 300 tonnes/yr. "The fibre source will be TMP (thermo mechanical pulp) spruce fibres, which we produce. Thermoplastics will be PE and PP, virgin and recycled. We will also investigate bio-based materials," Molteberg says.

Molteberg says the company sees large market opportunities within construction materials, consumer goods and packaging, among others. "We seek customers using conversion techniques like injection moulding, extrusion, hot pressing and 3-D printing."

Right: Aimplas is exploring the use of fillers derived from olive stones in the Oliplast project

Moulding expertise

Plasto Project Manager Runar Stenerud says its role in the project is to provide injection moulding expertise. The company operates highly automated injection moulding facilities that run 24/7 with unmanned production over night and during weekends. "Participation in BioComp project is important for us to further strengthen our value proposition," he says. "Solving complex problems in the most cost-effective and sustainable manner possible."

Alloc's goal is to ensure its interior building products meet the environmental expectations of its customers. "As a producer of interior building materials, Alloc has an environmental obligation to the market," says Leif Kåre Hindersland, Alloc's R&D Manager. "We need to make every effort to find better, lower-energy ways to produce, using sustainable and environmentally sound raw materials. We look at this project as a door-opener to a changing market with more and more demanding end users regarding the circular economy. There will also be an increased demand from governments around the globe that force every producer to go in the right direction."

RISE PFI has many years of experience in research and production of sustainable biocomposite materials based on several different polymers and tailor-made fibres and nanofibres, according to Chinga Carrasco. "We are pleased to be contributing to the industrial realisation of biocomposite products in Norway, with our extensive know-how and state-of-the-art equipment within the wood fibre processing, biocomposites and 3D printing areas."

Moving to southern Europe, Spanish research organisation **Aimplas** is looking at the use of the residues from olive cultivation in plastics. It is starting out from the premise that the main crops in the Mediterranean basin that generate lignocellulosic residues – potential raw material for composites and particleboards – can be woody crops such as olives, almonds, citrus fruits, and vines and cereals such as rice.

Global olive oil production has tripled over the past 60 years. For the 2019/20 growing season, global production amounted to 3.14m tonnes – close to 40% of it in Spain – according to data from the International Olive Council. It is an industry that creates considerable volumes of waste material – pruning of olive trees generates a large amount of biomass, which is made up of leaves (25% in dry weight) and branches. The olives themselves

IMAGE: AIMPLAS


IMAGE: APM

Right: Hemp-filled NAFIBoost concentrate pellets contain up to 60% hemp fibre in PE or PP

amount to 85% pulp and 15% stone (production of olive oil in Spain alone generates some 360,000 tonnes of olive stones annually).

All of these lignocellulosic residues of olive cultivation – leaves, branches, and stones – can be recovered to obtain composites, according to Aimplas. Together with Spanish olive oil producer Olivarera los Pedroches, it is working on a project in which the stones are recovered to develop novel bio-based, biodegradable, and compostable compounds.

"A new possibility for this by-product is the incorporation of olive stones as a reinforcing material in plastic materials providing a wood-like appearance, which can provide an alternative to plastic products in the packaging and household goods sector," Aimplas says. A new material, which has been named Oliplast, incorporates this filler/reinforcement derived from olive stones in a bioplastic matrix.

The process or preparing the olive stone fibres for incorporation into plastics compounds is not straightforward and requires various treatments. The stones must pass through a number of cleaning and grinding steps before separation into different fractions depending on the particle size obtained. These different particle sizes produce compounds with differing characteristics. Aimplas says that all products made with Oliplast can be treated as conventional organic waste and, in a particularly circular process, they could even be used to produce compost to fertilise the olive grove itself.

Growth continues at **APM** (Automotive Performance Materials), the hemp-filled compounds production joint venture between the automotive Tier One Faurecia and agricultural cooperative Interval. It says it will supply a newly developed grade, NAFILean Stiff, for use in the new Peugeot 308 model (other APM NAFI products were used on the previous model). Based on PP containing 20% hemp, the NAFIlead Stiff compound is said to be lighter than glass fibre reinforced PP but has a similar tensile modulus of 3.5GPa. It will be used to produce injection moulded structural instrument panel parts amounting to more than 5kg per vehicle.

Beyond automotive

APM is also pursuing applications outside automotive. The company now offers the NAFIBoost line of 60% hemp-filled concentrates, which are intended for mixing with PE or PP to obtain materials incorporating 10 to 20% hemp according to the end use requirements. It says this new strategy is expected to aid take-up of composite materials containing hemp. "APM's goal is also to limit the over-cost and make the technology affordable to

Naturally sparkling appliance design


IMAGE: UPM BIOCOMPOSITES

Left: The Mysoda range of domestic sparking drink machines are produced in a wood fibre filled PP compound from UPM Biocomposites

UPM Biocomposites worked with Finnish company Mysoda to create its line of domestic sparkling water machines. Launched last year, the appliances are made from UPM's Formi EcoAce biocomposite, which is manufactured from wood fibre and renewable mass balance PP produced from UPM BioVerno naphtha. All the raw materials are by-products of the wood and pulp industry.

The UPM Formi EcoAce compound is claimed to provide similar material properties to fossil-based alternatives and can be processed using industry-standard methods such as injection moulding and extrusion. The surface finish, however, provides a more wood-like appearance due to the fibre content.

The appliance was created for Mysoda by Helsinki, Finland-based Pentagon Design. "Striving for more sustainable solutions is a fundamental element of good design," says Creative Director Arni Aromaa. "For the design team it was natural to look for alternatives for fossil-based material in this home carbonation market, which is a sustainable solution in itself."

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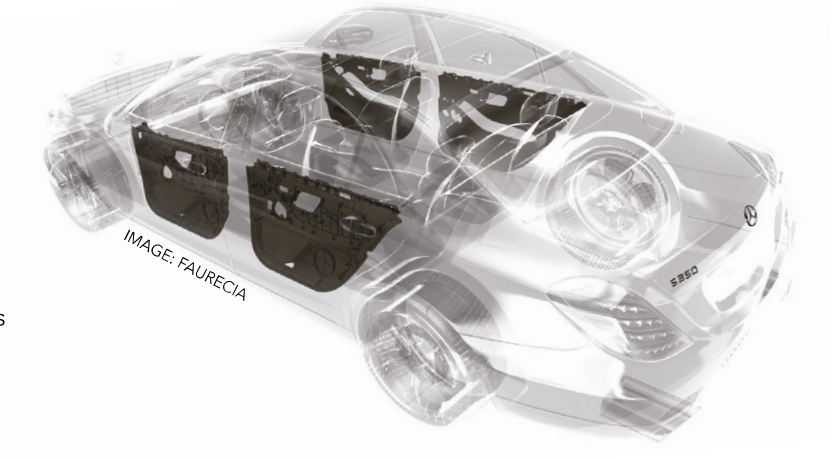
new areas," says Jean-Marie Bourgeois-Jacquet, in sales & business development at the venture.

Faurecia, meanwhile, says innovation in sustainable materials is taking place across all of its business groups. The company says its aim is to reduce the CO_2 footprint of materials used for interior applications by 87% by 2030. Faurecia Interiors introduced its first NAFILean hemp-based products in 2008 and the company says it is building on this to develop other interiors products that have reduced CO_2 emissions.

"A number of plants are suitable for use as bio-composites in plastic products – linen and bamboo, for example," says Laurence Dufrancatel, who is Innovation Materials Manager and part of the Sustainable and Smart Product Line cteam member at Faurecia Interiors. "For use in automotive interiors parts, hemp meets OEMs' performance and safety requirements."

The NAFILean range has grown from one product to four today, with a next generation grade said to be in the development pipeline. "Each of these improves on the 'parent product' by lowering CO_2 emissions, reducing weight, or opening possibilities for more uses. The original NAFILean products are on average 25% lighter than their conventional counterparts and save around 28% in CO_2 emissions," says Dufrancatel.

"NAFILean Stiff and NAFILite develop on the existing range, offering more uses," he says. "NAFILean Stiff makes for a tougher part that can be used in different settings while still saving 52% of CO_2 emissions. And NAFILite has a microcell structure with 29% reduction in weight and 43% in CO_2 emissions before its use phase. NAFILean R, which uses a 100% recycled plastic matrix, saves



Above: NAFILean components are used on 17 production vehicles, including the Mercedes S Class

108% of associated CO_2 emissions."

Faurecia is now producing NAFILean products for 17 vehicle models and the products can be found in around 13m cars. The next generation of NAFILean will be a high performance version – NAFILean Perf. It will offer even higher reductions in weight and CO_2 emissions at 41% and 58% respectively, according to Dufrancatel.

Current NAFILean products are manufactured by injection moulding but Dufrancatel says Faurecia is now developing its NFPP family, which comprises a new range of interior component options for compression moulding technology. The first generation of this series is said to be already in serial production. "Compression presents opportunities to develop natural fibre composites using other plants such as flax and kenaf and expand the uses of our solutions in visible parts, for example," he says.

Agricultural sourcing

Hungarian compounder **Inno-Comp** has been involved in research sponsored by the European Union and the Hungarian government on the development of what it says is a new biocomposite product family. "On a degradable PLA or non-degradable, mainly PP, polymer basis, our compounds are manufactured from natural materials that originate from domestic agriculture. But they are not intended to be reused there, for example grind of apricot shells, walnut shells, almond shells, and hemp fibre," says Sales Engineer Balázs Kugler.

"Blending PLA with hemp fibres improves the quality of the produced material in multiple ways: apart from its natural appearance, its physical properties and compostability are also much more

IMAGE: INNO-COMP/VILHEMP

Above: Vilhemp is using hemp reinforced PLA compounds from Inno-Comp to produce compostable cutlery

IMAGE: FRAUNHOFER WKI

Above: Fraunhofer Institute researchers have produced a range of flame-retardant bio-filaments for 3D printing

improved compared to the plain PLA," says Kugler.

Inno-Comp is working with start-up end-product manufacturer **Vilhemp** and an undisclosed global wholesale company. Vilhemp is using the PLA-based compound for the production of cutlery that can be composted after use. Under industrial conditions, visible decomposition begins after 28 days.

The materials are being produced on a production line based on a Theysohn TSK032HV/46D type two-screw extruder equipped with an Econ underwater pelletising system. It was installed and commissioned in July last year. "This tailor-made machine was configured in a way to be suitable for producing high quality specialities such as natural-filler filled biocomposites and flame retarded compounds," Kugler says.

Electrical compounds

At the **Fraunhofer Institute** for Wood Research (WKI), a team headed by Dr Arne Schirp working together with various partners has embarked on a new project called BioFla, which is looking into how bioplastics and biocomposites can be produced for electronics and logistics applications. The aim is to develop flame retardant products using halogen-free systems while also providing the necessary resistance to heat and impacts.

"The biomaterials currently available on the market do not fully satisfy these requirements," says Schirp. "We are developing materials which have the necessary properties, and which can be processed by means of injection moulding and FDM additive manufacturing. Products such as light switches, sockets, motion detectors, cable ducts or charging stations for electric vehicles could soon be produced from biomaterials."

As a first step, Fraunhofer WKI is working in collaboration with the Fraunhofer Institute for Applied Polymer Research IAP on the development of a halogen-free bio-flame retardant based on organophosphoric acid ester. In a second step, this will be reactively bound to polylactide (PLA). The binding of the reactive flame retardants and the partial crosslinking of the PLA is achieved through electron irradiation.

Compounds will contain wood fibres and impact modifiers. Schirp says that research indicates that, possibly contrary to expectation, the wood fibres have a positive effect on heat resistance and flame retardancy. "Thermoplastics have a relatively high heat of combustion and burn without charring. By adding wood, charring is induced. Replacing a certain percentage of the thermoplastic with wood particles changes the fire behaviour by decreasing the heat of combustion of the volatiles. In addition, residue formation is increased due to the wood particles," he explains.

Parallel to the developments with self-synthesised flame retardants, the team is also using commercially available flame retardants. Other thermoplastics, both bio and non-biobased, are also being examined.

All the compounds are processed by means of

Below: Testing the tracking resistance of a PLA biopolymer compound formulated for electrical applications at Fraunhofer WKI

IMAGE: FRAUNHOFER WKI/HAGER ELECTRO

injection moulding and FDM filament-type additive manufacturing to form test specimens for subsequent testing. The materials are evaluated for their UL94 fire performance rating, heat resistance, glow-wire test, tracking resistance, tensile strength and modulus of elasticity, impact resistance, water absorption and swelling.

"During the first year of the project, it was possible to develop PLA-based formulations, extrude them into filaments and print them, thereby achieving the UL94 V-0 classification at a test-specimen thickness of 1.6 mm," says Schirp. "Flame-retardant PLA as well as a flame-retardant wood fibre-reinforced PLA/PBS blend successfully withstood the glow-wire test at 960° C. With regard to tracking resistance, the flame-retardant, wood fibre-reinforced PLA/PBS blend achieved at least 175V; in one test, 200 V and 250 V were also achieved."

In the second year of the project, research will involve investigations with PHB and PET, as well as the new bio-flame retardant. In addition, and in cooperation with project partners from industry, the formulations will be compounded on a larger scale and processed for applications in electrical engineering and electronics (E&E) and logistics.

Cellulose research

Natural fibre interest does not stop at Europe's borders. In North America, **Performance BioFilaments**, a Canadian producer of nanofibrillated cellulose, recently completed an investigation in collaboration with the National Research Council of Canada's Automotive and Surface Transportation Center to determine and evaluate material prop-

IMAGE: FORTUM

Above: The Prima chair, widely used throughout Finland's schools, is now available in a compound based on cellulose reinforced recycled PP

Back to school for Prima

A collaboration between Finnish furniture company Isku and Fortum (probably best known as a clean power generation company but which has also developed plastics based on post-consumer recyclates) has led to the introduction of a new version of Isku's Prima school chair. Used in schools around the world since the 1990s, this new version of the classic design is made from recycled plastics, mostly consumer packaging collected from Finnish households, reinforced with cellulose fibre.

"Fortum Circo PP FC recycled plastic is a new type of material specifically developed to meet the requirements of a highly durable product," says Mikko Koivuniemi, Fortum's Product Line Manager, Plastic Recycling.

The compound was developed in collaboration with a third Finnish company Elastopoli, which has been working on development of natural fibre reinforced composites for 14 years, and is based on a patented process technology. "The material has qualities on par with virgin plastic, but its environmental impacts are significantly smaller," says Koivuniemi.

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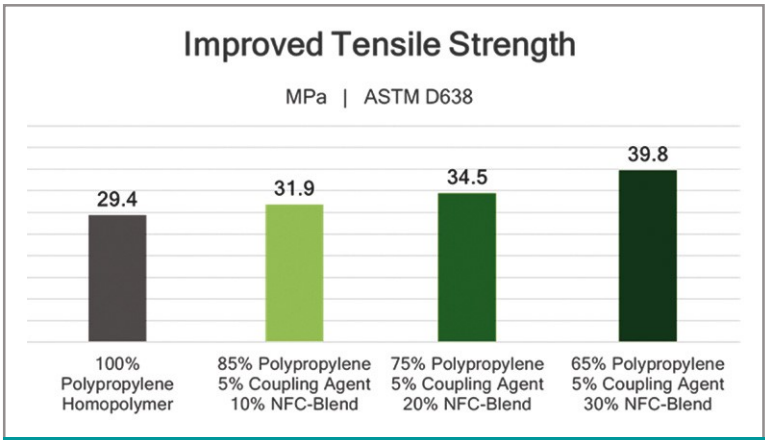

Figure 1: Measured tensile strength of PP compounds containing different levels of nanofibrillated cellulose (NFC)
Source: Performance BioFilaments

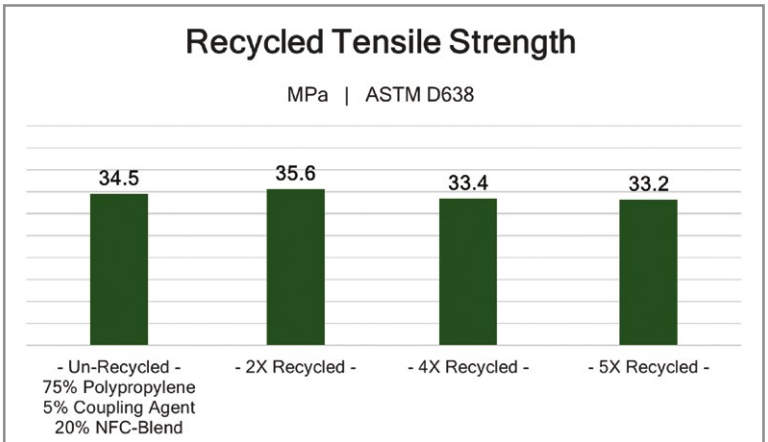

Figure 2: Measured tensile strength value for a PP compound containing 20 wt% NFC reinforcement after multiple recycling passes
Source: Performance BioFilaments

erty gains and recyclability of natural fibre reinforced thermoplastics.

Geoff Fisher, Director of Business Development at Performance BioFilaments, says the investigation involved compounding of nanofibrillated cellulose (NFC) derived from wood fibres via mechanical refining into diverse polymers, including PP and PLA, and testing these compounds for gains in strength (Figure 1). The compounds were then put through multiple re-grind/extrude cycles to see how those gains obtained from the fibres persisted after being recycled.

Tests showed that NFC cellulose can deliver increases of more than 30% in tensile strength and more than 75% in tensile modulus with loadings of up to 30 wt% in PP and PLA. Interestingly, it was found that these properties changed little after being recycled five times (tensile strength results are presented in Figure 2).

Meanwhile, Georgia, US-based **Attis Innovations** recently entered the plastics market with a portfolio of biobased fillers as well as polymeric materials and resin extenders. Targeted feedstocks under consideration include black liquor, woody biomass, crop stover, nut hulls and shells, grasses, and numerous other renewables.

Attis formed a strategic partnership three years ago with Alpharetta, US -based **Genarex**, which extracts otherwise low-value materials from corn ethanol by-products and uses them as bio-additives in plastics. It says it now has the ability to service customers with "a versatile array of materials" which bring value and cost savings to a variety of applications.

"Attis Innovations' primary product for the plastics space is a unique, melt-flowable lignin, a bio-additive that brings unparalleled cost savings and performance to common resin systems," says Bob Montgomery, VP Product Development at the company.

Bio-based fillers

Attis also markets a suite of bio-fillers called Bylox through its strategic partnership with Genarex. These fillers are said to differ greatly from existing bio-filler options in that the material is primarily protein-based, which Montgomery claims gives it superior ductility and particle size.

"Bylox LT has shown great success with many film applications, including agricultural mulch film and yard and pet waste bags," he says. "Bylox HT is a more thermally stable product that is capable of processing in conjunction with higher temperature products without creating anisotropic shrinkage issues or significant loss of mechanical properties. Bylox Clean is an outstanding product with lower base colour and odour, and in addition to working in films has shown the ability to substitute some plasticiser used in the production of flexible PVC for a significant cost reduction."

In a separate development, Montgomery says Attis Innovations is also currently pursuing the development of a fully bio-based, 100% lignin-borne carbon fibre product.

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