Morro Materials: The Next Generation of High-Performance, Natural, Non-Chemically Modified, Biodegradable Polymer-based Materials

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1. Executive Summary

Plastic is an important material that provides product protection, performance in use, and convenience for consumers, forming an integral part of our daily lives. Yet, the negative environmental impacts resulting from our reliance on plastic are increasingly clear. At least 8 million metric tonnes of macroplastic waste reaches our oceans every year, where it can slowly degrade into harmful microplastics (Jambeck et al., 2015). An additional 1.5 million metric tonnes of primary microplastics also reach our oceans annually, originating from products containing intentionally added microplastics (IUCN, 2017).

Xampla's ambition is to provide customers with the benefits of plastic, but without the negative environmental impacts. We have developed alternative high-performance plant-based materials that meet the requirements of specific commercial applications, including those in which plastic is practically impossible to recycle or could leak into the environment. Through our consumer brand Morro, we aim to continue delivering products to consumers with biodegradable materials that the consumer can trust.

Bio-based plastics remove primary production reliance on non-renewable fossil fuel sources, but only about one quarter of the commercially available bio-based plastics are biodegradable (Nova Institute, 2019). Furthermore, many biodegradable polymers (such as polylactic acid, PLA) only break down in industrial-composting conditions (temperatures > 58°C for 180 days; ISO 17088). When industrially compostable polymers like PLA reach the environment, they are still at risk of breaking down to release potentially harmful microplastics. Certain biodegradable polymers can also release potentially harmful chemical additives during their breakdown process.

Consequently, scientists across the world continue to search for new natural polymer-based materials that can offer the performance (low cost, manufacturable, lightweight, water resistant, durable) and consumer convenience of plastics in use, but with improved end-of-life properties (safely biodegrading in controlled environments or if accidentally released to the environment within weeks). This search for biodegradable plastic-free alternatives has become even more critical in the face of the expanding body of regulations around plastics and microplastics production, use, and disposal in the UK and Europe, with key legislation including the EU Single-Use Plastics Directive 2019/904, national plastic packaging taxes, the European Chemicals Agency's proposal on restricting intentionally added microplastics, and national extended producer responsibility schemes. Importantly, only non-chemically modified natural materials sit outside the scope of the single-use plastics regulations; thus, current category-leading alternative 'bio-based' polymer materials including PLA and polyhydroxyalkanoates (PHAs) do not provide plastic-free solutions.

Originally spun out from the University of Cambridge and now with a team of 43 industry-leading professionals based in the Cambridge Science Park Bioinnovation Centre, Xampla's mission is to replace the world's most polluting plastics for good. Our core focus is on developing sustainable and plastic-free solutions for plastic use cases where reducing, reusing, and recycling are not viable alternatives. These applications include replacing single-use plastics, intentionally added microplastics, water-soluble polymers (WSPs), and polymers in liquid formulations (PLFs) with natural, non-chemically modified, biodegradable natural polymer-based alternatives (Morro materials).

In this white paper, we describe Xampla's range of high-performance plant-based Morro materials and explain how our platform technology is differentiated within the expanding field of natural and biodegradable materials. Morro materials are produced from abundant plant-based feedstocks, through a scalable, reproducible manufacturing process that relies on molecular self-assembly to produce non-chemically modified yet high-performance materials with tightly controlled properties. Our core technology lies in protein self-assembly, but we also deploy biomimetic processes to manipulate other complex natural polymers without relying on chemical modification; delivering high-performance plastic-free solutions.

In use, Morro materials offer a unique combination of strength (even comparable to some petroleum-based polymers such as low-density polyethylene) and barrier properties (with oxygen barrier properties comparable to polyvinyl chloride), while at end of life Morro materials will completely biodegrade in soil, freshwater and marine environments. We supply Morro materials as resins, which are compatible with existing synthetic polymer resin conversion facilities, and can be processed into a range of high-performance structured materials including flexible films (Morro Soluble Film and Morro Edible Film), coatings (Morro Coating), and microcapsules (Morro Micro and Morro Nutri), meeting high-volume commercial application requirements and addressing the global plastics crisis.

2. The opportunity and challenge of natural and biodegradable polymer-based materials

The production, use, and disposal of plastics and intentionally added microplastics in the UK and Europe is facing an increasingly stringent regulatory environment, with the introduction of market restrictions on certain single-use plastic items specified under the EU Single-Use Plastics Directive 2019/904 and certain intentionally added microplastics specified under the European Chemicals Agency's (ECHA) proposal to restrict intentionally added microplastics. In addition, plastic packaging is increasingly subject to national plastics packaging taxes and Extended Producer Responsibility (EPR) for packaging regulations.

Importantly, the EU Single-Use Plastics Directive defines plastic as both traditional petroleum-derived plastics and natural polymer-based materials that have been chemically modified, as well as including polymers that are biodegradable or compostable. Thus, current category-leading alternative bio-based materials including polylactic acid (PLA) and polyhydroxyalkanoates (PHAs), which are classified as chemically modified, do not provide a "plastic-free" alternative, despite industry campaigning against this position. Furthermore, there is no de minimis threshold for the plastic content within a single-use plastic item. Thus, for example, single-use plastic-coated paperboard packaging used for food containers and beverage cups sits within the regulatory framework of the single-use plastics regulations in some jurisdictions, according to Directive (EU) 2019/904.

The ECHA proposal to restrict intentionally added microplastics ban is designed to avoid the environmental release of over 90% of the 42,000 metric tonnes of intentionally added microplastics released into the environment in the EU each year, with market restrictions expected for products with widely available alternatives and extended transition periods for products that currently lack widely available alternatives.

These restrictions on the use of single-use plastics and intentionally added microplastics have been designed specifically to focus on plastic use cases where reducing, reusing, and recycling are not viable alternatives.

Within this context, the global bioplastics market is expected to grow from $11.6BN (2022) at a CAGR of 18.8% to reach $44.7BN in 2030 (Grand View Research, 2022). There remains a well-recognised need to transition away from the linear plastics economy (take-make-dispose) towards a circular economy that maximises value and minimises waste (Ellen MacArthur Foundation, 2017).

At the same time, the UK has an ambition to become a world leader in sustainable packaging and over 40 companies (responsible for over 80% of plastic packaging sold through UK supermarkets) have committed to ambitious 2025 targets as signatories of the UK Plastics Pact (WRAP, 2019).

Challenge

Scientists in fast-moving consumer goods companies have been searching for years for natural and biodegradable materials to replace conventional fossil fuel-derived polymers used across many products including single-use plastics and intentionally added microplastics. They have already tested and tried multiple pre-commercial and commercial solutions. However, their search for an ideal natural and biodegradable material to replace conventional fossil fuel-derived polymer-based materials has remained limited by four key factors:

1. **Poorer performance.**

Ultimately, readily biodegradable and home-compostable natural polymer-based materials (typically based on polysaccharides, such as thermoplastic starch) have not yet been shown to deliver the required mechanical performance in use. Other, less readily biodegradable materials (such as polylactic acid) offer improved mechanical properties, but will only biodegrade under industrial-composting conditions (temperatures of > 58°C for 180 days; ISO 17088; Narancic et al., 2018) and risk releasing potentially harmful microplastics if they break down in the environment.

2. **Reliance on chemical modification to improve performance.**

Recognising the limited performance of many natural polymer-based materials, chemical modifications are frequently implemented to improve material performance. For example, the performance of polysaccharide-based materials such as starch or seaweed can be improved by the addition of cross-linkers, plasticisers, and/or reinforcers. However, chemical modification often has a detrimental impact on end-of-life performance, reducing material biodegradability. Furthermore, natural polymer-based materials that have been chemically modified still sit within the scope of single-use plastics regulations; for example, current category-leading alternative bio-based material PLA.

3. **Manufacturability challenges including higher price and lack of scalable production and drop-in manufacturing processes.**

Natural and biodegradable polymers are typically at least 2-3 times more expensive to produce than petroleum-based polymers, which limits their ability to replace fossil fuel-derived polymers in mass market applications. Next-generation materials such as polymers produced by microorganisms or genetically modified bacteria (silk polypeptides, PHAs) offer promising performance, but are challenging to manufacture at scale and would be more expensive. In addition, natural and biodegradable materials are often incompatible with existing synthetic polymer conversion processes; yet, drop-in solutions are critical to adoption at scale by converters, which have significant investment in current assets.

4. **Limited number of materials that go beyond biodegradability to "do no harm" in the environment.**

According to a recent study (Narancic et al., 2018) and published examination of TÜV AUSTRIA's database (Ghosh and Jones, 2021), only two tested natural polymers to date have been proven to biodegrade under all standard tests of environmental conditions (i.e., spanning soil, freshwater, and marine): polyhydroxybutyrate (PHB) and thermoplastic starch (TPS). However, both PHB and TPS suffer from poor mechanical performance (they are highly brittle), which limits their commercial application. Incomplete biodegradation of PHB could also be potentially harmful to aquatic organisms (González-Pleiter et al., 2019).

Xampla

Inspired by nature, Xampla has developed the next generation of high-performance, natural, non-chemically modified, and biodegradable polymer-based materials, called Morro. The unique structure of our non-chemically modified Morro materials has enabled us to overcome the poor performance challenge associated with existing natural and biodegradable materials, which have often relied on chemical modification to improve performance. At the same time, our reliance on abundant plant-based feedstocks combined with a scalable production process and drop-in conversion processes means that we have been able to overcome the production challenges associated with next-generation natural and biodegradable materials. Crucially, since Morro materials offer high-performance and are non-chemically modified, they deliver a truly plastic-free alternative.

Nature's solution: Self-assembly

Molecular self-assembly - the spontaneous organisation of molecules without external control - is ubiquitous in nature and centrally important in life, responsible for forming complex cellular structures including lipid membranes and folded proteins. Self-assembly is driven by non-covalent rather than covalent interactions between molecules, delivering functional properties without relying on chemical modification. Optimised by evolution, self-assembly processes are low energy, low cost, and inherently scalable.

A reminder on covalent and non-covalent chemical bonding	
Covalent bond: When two atoms share one or more electron pairs. Covalent bonds are the strongest types of bonds and define molecular structure. Typical carbon-carbon bond strength: 346 kJ/mol.	**Non-covalent bond:** Does not involve electron sharing. Instead, non-covalent bonds are formed by a range of different interactions either between molecules or within a molecule. Non-covalent bonds are much weaker than covalent bonds (typical bond strengths < 20 kJ/mol). Despite their individually weak bond strengths, non-covalent bonds play an extremely important role in molecular self-assembly and are responsible for the three-dimensional structure of proteins. Some important non-covalent bonds are hydrogen bonds, ionic bonds, dipole-dipole interactions, van der Waals forces, and hydrophobic interactions.

Our solution: Structured plant-based materials

Xampla leverages biomimetic processes such as self-assembly techniques and has created a new class of high-performance structured plant-based Morro materials that are suitable for replacing single-use plastics, intentionally added microplastics, water-soluble polymers (WSPs), and polymers in liquid formulations (PLFs) in multiple commercial applications. Crucially, as we rely on self-assembly rather than chemical cross-linking to deliver material performance, our all-natural, non-chemically modified, plant-based materials sit outside the scope of single-use plastics regulations and will biodegrade at end-of-life, whether in home compost, soil, freshwater, or marine environments, with no risk of breaking down into harmful by-products. To deliver performance at scale, we have developed natural, non-chemically modified polymer-based resins that provide drop-in solutions to existing synthetic polymer manufacturing supply chains. Morro materials can be manufactured from a range of feedstocks, including non-food-grade raw materials in the case of non-food-grade material applications. Through precisely controlling the self-assembly process, Morro materials can be used to produce soluble and edible films, coatings, and microcapsules from a range of abundant plant-based feedstocks.

Potential impact of our solution

Morro materials are high-performance, natural, non-chemically modified, biodegradable, and can be produced at scale and are compatible for existing conversion facilities, suitable for high-volume commercial applications. Replacing petroleum-based materials such as single-use plastics, intentionally added microplastics, WSPs, and PLFs with Morro materials will:

- Reduce environmental pollution from plastics/microplastics
- Reduce reliance on non-renewable fossil fuel sources
- Support manufacturers across multiple industries to continue to deliver high-performance materials to their customers, while meeting their sustainability goals and regulatory requirements

3. Morro: Xampla's High-Performance Plant-based Materials

Our core platform technology is based on 15+ years of fundamental protein self-assembly research led by Professor Tuomas Knowles, a global leader in protein biophysics and Professor of Physical Chemistry and Biophysics at the University of Cambridge. Xampla's family of intellectual property rights protects our core process, which enables scalable, reliable, and reproducible production of flexible films, coatings, and microcapsules from a range of abundant plant-based raw materials. For edible applications, we use widely available high-purity food-grade raw materials, while for non-food-grade applications, we are also exploring the potential of plant-based waste agricultural biomass sources such as leguminous crop residues. Our production process relies on biomimetic processes such as self-assembly; thus, only requiring mild processing conditions. Importantly, since we rely on self-assembly, we do not need to add any chemical modifiers such as cross-linkers, meaning that while our materials have remarkably high strength, they are also readily biodegradable (even home-compostable), and will safely break down in the environment. Since they are non-chemically modified, our materials should sit outside the scope of single-use plastics regulations.

While our core technology lies in protein self-assembly, we are also deploying biomimetic processes to manipulate other complex natural polymers without chemically modifying them and are developing a range of natural, non-chemically modified, and biodegradable polymer-based materials designed to meet specific target application requirements. Here, we describe our structured plant protein-based materials in more detail.

Protein self-assembly

Proteins are the building blocks of life. Their unique ability to spontaneously self-assemble into complex structures plays a vital role in most biological processes. Protein self-assembly into β-sheet rich structures is responsible for the remarkable physical properties of silk, which has been described as the "ultimate biomaterial", combining tensile strength with extensibility, and extreme toughness (Rising and Johansson, 2015). However, silk-based materials lack commercial-scale production processes, which makes them unsuitable for high-volume applications such as replacing highly polluting plastics used in single-use applications.

Structured plant-based materials

We have developed novel approaches to produce a range of structured materials from plant proteins, including pea protein. The original piece of scientific work that allowed us to first understand how we can structure our materials using biomimetic processes is described in our *Nature Communications* article (Kamada et al., 2021).

This production process delivers self-assembled films with superior mechanical properties than plant protein-based films generated through conventional methods, and even comparable to films of some synthetic polymers such as low-density polyethylene. The β-sheet rich structure that we obtained in our film is characteristic of silk materials and was the first time that such high amounts of organised intermolecular β-sheet structures have been reported in plant protein-based materials (Kamada et al., 2021). The organised intermolecular β-sheet structure confers not just mechanical strength, but also excellent oxygen barrier properties (comparable to polyvinyl chloride). At the same time, since the proteins are stabilised through intermolecular bonding rather than chemically cross-linked, Morro materials readily biodegrade, even when released into the environment.

Polyamides: Remarkably strong and elastic materials		
Silk: Primary structure consists of a non-repetitive globular N-terminal domain, followed by a linear repetitive sequence of amino acids (predominantly alanine and glycine), followed by a non-repetitive globular C-terminal domain (Rising and Johansson, 2015). Silk proteins self-assemble into β-sheet crystals. Described as the "ultimate biomaterial", silk combines high tensile strength with extensibility, and extreme toughness (Rising and Johansson, 2015).	**Nylon:** First petrochemical-based fabric, invented in 1934. Nylon offers many of silk's properties (high strength, flexibility) but can be manufactured at scale. However, virgin nylon is produced from non-renewable fossil fuels in an energy-intensive process. Nylon is neither biodegradable nor widely recycled, meaning it typically ends up as landfill waste or is incinerated. In the oceans, nylon breaks down to produce harmful microplastics.	**Morro materials:** Combine the structural properties of silk (β-sheet structures) with the scalable manufacturing capability of nylon. At the same time, unlike nylon, our all-natural, non-chemically modified, biodegradable polymer-based material is produced from abundant and renewable raw materials, using a mild and non-polluting process. At end-of-life, Morro materials safely and readily biodegrade, even in case of accidental release into the environment.

By varying the processing conditions, our novel approach enables scalable, reliable, and reproducible production of a range of plant-based materials with highly controlled properties. In addition to their excellent physical properties, Morro materials are:

(i) Produced from abundant, renewable, and natural plant-based feedstocks. Ensuring security of supply when integrated into high-volume supply chains, relying on non-food-grade raw materials in the case of non-food-grade material applications.

(ii) Non-chemically modified. Delivering high-performance plastic-free solutions for brands and consumers, outside the scope of single-use plastics regulations and plastic packaging taxes in the EU or the UK.

(iii) Supplied as a drop-in resin, compatible with existing plastics manufacturing supply chains. Suitable for processing into a range of structured materials including films, coatings, and microcapsules.

(iv) When required, produced from food-grade raw materials with food-safe processing routes. Creating new market opportunities in edible applications including films, coatings, and microcapsules.

(v) Biodegradable in home-composting conditions, as well as in marine, soil, and freshwater environments according to industry standards. Morro materials are non-chemically modified and exceed the performance requirements of existing biodegradability standards, which assess biodegradability in terms of carbon dioxide release but do not consider ecotoxicity or the release of potentially harmful breakdown products. Morro materials break down safely in the environment, without releasing any ecotoxic or harmful components either during partial or complete biodegradation.

Biodegradability

Although there is a plethora of alternative materials referred to as "biodegradable", there are ongoing concerns regarding the real-world environmental fate of so-called "biodegradable" materials. Unfortunately, materials are frequently described as biodegradable, without any reference to the conditions and timeframe required for biodegradation. Many biodegradable polymers including PLA will only biodegrade under industrial-composting conditions. When industrially compostable polymers reach the environment, they still risk breaking down to release potentially harmful microplastics. Indeed, only two tested natural polymers have been proven to date to biodegrade under all standard tests of environmental conditions (Narancic et al., 2018; Ghosh and Jones, 2021): PHB and TPS. However, both suffer from poor mechanical performance, which limits their commercial application.

Biodegradability test conditions are also unrepresentative of real-world conditions. In a recent UK-wide study, researchers found that the majority (60%) of commercially available packaging labelled home-compostable did not fully disintegrate in home-compost bins, with fragments instead persisting and contaminating soils (Purkiss et al., 2022).

Finally, standards solely focused on measuring biodegradability in terms of carbon dioxide release do not consider ecotoxicity or the release of potentially harmful fragments during partial or complete biodegradation. For example, PHB may release nano-scale residues during incomplete biodegradation that could potentially be toxic to aquatic organisms, causing significantly reduced cell growth (González-Pleiter et al., 2019).

Morro materials are an all-natural, non-chemically modified, and biodegradable polymer-based alternative to plastic. We believe that Morro materials are the third class of materials proven to biodegrade under all standard tests of environmental conditions (i.e., spanning soil, freshwater, and marine), and the first to combine biodegradability with excellent mechanical performance and no risk of harm in the environment.

What does biodegradable mean?
• **Industrially compostable (ISO 17088; EN 13432):** Material will biodegrade under industrial-composting facilities (less than 10% of original material remains after industrial-composting at temperatures above 58°C for 180 days). • **TUV AUSTRIA OK Compost HOME:** Material will biodegrade under home-composting conditions (less than 10% of original material remains after home-composting at ambient temperature - between 20 and 30°C - for 365 days).

• **TUV AUSTRIA OK biodegradable MARINE/SOIL/WATER:** Material will biodegrade under ambient conditions in marine/soil/freshwater environments (less than 10% of original material remains after testing at a temperature of between 20 and 25°C for 56 days)

4. Product case studies

(i) Water-soluble films

Xampla has developed a natural, non-chemically modified, biodegradable polymer-based alternative to conventional WSPs such as polyvinyl alcohol (PVOH), which delivers the convenience of traditional wrappers used in home care and cleaning applications such as dishwasher tablet pouches, laundry detergent pods, and water-soluble cleaning sachets, but addresses key brand and consumer concerns about potential harm to the environment at end of life.

Morro Soluble Film has been designed to dissolve rapidly in the presence of water and detergents to release its constituent ingredients, which are all-natural, plant-based, and safe for the environment and humans. Independent test results have confirmed rapid and complete biodegradation of Morro Soluble Film in soil, freshwater, and marine environments.

We have developed scalable film production and sachet conversion (thermal welding and flow-wrapping) processes that enable downstream integration of our material within existing manufacturing supply chains. We have conducted consumer trials with key brand partners, which have found that our material matches or exceeds performance expectations in use as a dishwasher tablet wrapper. Unlike conventional WSPs such as PVOH, which dissolve in water, we can tailor the solubility profile of our films. This enables us to improve film stability in highly humid or freezing conditions and could unlock the use of plastic-free secondary packaging.

(ii) Edible films

Morro Edible Film is a natural, non-chemically modified plant polymer-based film designed to replace single-use plastic sachets used in food and beverage packaging. When manufactured in a food-grade facility following a food-grade manufacturing process and using food-grade ingredients, Morro Edible Film unlocks innovative product formats such as zero-waste, edible, and cookable packaging applications.

We have launched our hot water-soluble, edible, cookable film as a stock cube wrapper to replace single-use plastic sachets with Gousto, the UK market leader in recipe boxes. Morro Edible Film is compatible with standard soluble film (solvent casting equipment) and sachet conversion (thermal welding) processes, suitable for integration within existing sachet manufacturing supply chains. To date, we have manufactured kilometres of Morro film using standard production processes.

In initial at-home consumer trials led by Gousto, our dissolvable stock cube sachets received 90% positive feedback, with end users reporting that the sachet had no impact on the dish (i.e., no differences in taste, smell, texture, or appearance). There is considerable consumer excitement at the novelty of the format and with Gousto currently selling around 25 million stock cube wrappers each year, this format change could enable Gousto to avoid the production and disposal of 17 tonnes of hard-to-recycle plastic annually.

(iii) Coatings

Morro Coating is a natural, non-chemically modified polymer-based alternative to plastic functional and barrier coatings for paperboard packaging, which combines performance in use with biodegradability at end-of-life (whether in home-composting, soil, freshwater, or marine environments), and - unlike traditional plastic coatings - does not contaminate paperboard recycling streams. Crucially, unlike alternative natural polymer-based coatings such as PLA, Morro Coating - since it is 100% manufactured from natural, non-chemically modified polymers - is clearly outside the scope of the European Single-Use Plastics Directive and plastic packaging taxes in the EU and UK.

We have successfully demonstrated the performance of Morro Coating as part of a plastic-free coating system for paperboard materials, coating on industrial-scale equipment, delivering a drop-in solution for conversion into high-volume coatings.

(iv) Microcapsules

Microencapsulation is the process of surrounding tiny particles or droplets with a protective coating, typically a polymeric shell. Morro Nutri delivers natural, edible, and plant polymer-based microcapsules to protect sensitive vitamins and nutrients in liquids from UV light, low pH, or high temperatures (e.g., experienced during product pasteurisation). Our plant protein-based microcapsule shell eliminates the need for opaque or obscured packaging, unlocking new packaging formats and designs for manufacturers, enabling fortified drinks to be shipped in more readily recyclable transparent plastic bottles.

We have developed Vitamin D2 microcapsules with global drinks manufacturer Britvic. Vitamin D2 has exploded in popularity over the past few years, with growing evidence of its role in healthy immune system function. However, vitamin D2 is highly sensitive to UV light, low pH, and heat. In the absence of high-performance plant-based solutions, soft drinks manufacturers have had to rely on opaque or obscured packaging to protect vulnerable vitamins from UV light, while many have avoided adding vitamin D2 because of the high cost of over-dosing to overcome poor stability.

We have scaled-up the production of Morro Nutri to commercial scale using standard large-scale processes such as spray drying.

5. What to look for in a biodegradable material

For manufacturers facing increasing restrictions on single-use plastics and intentionally added microplastics in the UK and the EU, and looking to transition away from plastic to sustainable and plastic-free alternatives, Morro materials have the potential to offer all the attributes of an ideal natural and biodegradable material:

- **Natural feedstock,** produced from abundant plant-based raw materials, potentially even from waste agricultural biomass sources.
- **Scalable manufacturing process,** which can be used to produce a range of high-performance structured materials including flexible films, coatings, and microcapsules.
- **Excellent performance in use,** with high strength and excellent oxygen-barrier properties that can even match that of some petroleum-based polymers.
- **Drop-in solution for existing conversion facilities,** enabling replacement of plastic in high-volume applications.
- **Safe for human consumption,** as well as vegan, creating new market opportunities in edible applications such as microencapsulation of unstable micronutrients or edible film to replace single-use plastic sachets.
- **Rapid biodegradation** in industrial- and home-composting conditions, as well as in soil, freshwater, and marine environments according to industry standards, with no risk of harm even in the case of partial biodegradation.
- **Plastic-free,** designed to sit outside the scope of single-use plastics regulations and should not be liable for plastic packaging taxes in the EU or the UK, since Morro materials are manufactured from non-chemically modified polymers.

6. Conclusion

Pressure on manufacturers to transition to natural, biodegradable, and plastic-free alternatives that continue to deliver performance in use has never been greater. Inspired by nature, Xampla has developed a next-generation high-performance, natural, non-chemically modified, and biodegradable polymer-based material produced from widely available plant-based feedstocks.

Morro materials are the first natural, non-chemically modified, and biodegradable polymer-based materials that can deliver the required material properties in use, while readily and safely breaking down when released into the environment, with no risk of harm.

Morro materials are supplied as resins suitable for processing in existing plastics conversion facilities to produce a wide range of structured materials, including Morro Soluble Film, Morro Edible Film, Morro Coating, and Morro Nutri. This makes Morro materials an ideal choice for eliminating the most polluting plastics including single-use plastics, intentionally added microplastics, WSPs, and PLFs in multiple high-volume commercial applications, ranging from homecare to food and beverages.

Our next-generation natural, non-chemically modified, and biodegradable plant-based Morro materials can play a leading role in the global transition to a bio-based and circular economy, addressing six UN Sustainable Development Goals: 8 (Decent work and economic growth); 9 (Industry, innovation, and infrastructure); 12 (Responsible consumption and production); 13 (Climate action); 14 (Life below water); and, 15 (Life on land).

To find out more about Xampla and Morro materials, request commercial samples, and discuss development needs, please contact our CTO Dr Marc Rodríguez Garcia at marc@xampla.com.

We are always interested in exploring new applications where our next-generation natural, non-chemically modified, and biodegradable polymer-based Morro materials can add value, so please talk to us about how we can help you to meet your specific requirements.

You can also find out more about our technology on our website (www.xampla.com), or follow us on LinkedIn (https://www.linkedin.com/company/xampla/) and Twitter (@XamplaUK).

7. About Xampla

Xampla is a world-leading company in the development of natural polymers for commercial applications. Our mission is to eliminate the world's most polluting plastics for good, from everyday single-use plastics such as sachets and flexible packaging films to "hidden" plastics such as intentionally added microplastics in personal care and home care products.

Xampla originally spun-out of the University of Cambridge to commercialise Professor Tuomas Knowles' world-leading and patented protein material research. CTO Marc Rodríguez Garcia, Senior Scientist Ayaka Kamada and Aviad Levin (Research Fellow) developed the processes and applications that are the basis of Xampla's defensible technology, working with Professor Knowles before co-founding Xampla. To demonstrate the commercial potential of our natural, non-chemically modified, and biodegradable polymer-based alternative Morro materials, we have developed multiple differentiated launch products including Morro Soluble Film, Morro Edible Film, Morro Coating, and Morro Nutri.

Xampla's Technical Adviser and cofounder Professor Tuomas Knowles is a global leader in protein biophysics, with 200+ peer-reviewed journal articles cited over 17,000 times. He is a named inventor on 14 patents and was named UK Academic Entrepreneur of the Year by Business Weekly. His research focuses on understanding and controlling the fundamental mechanisms of protein self-assembly processes, creating new types of functional materials. In his role as Professor of Physical Chemistry and Biophysics at the University of Cambridge, he leads a biophysics and biophysical chemistry research team of nearly 40 people. An experienced start-up founder, Professor Tuomas Knowles has cofounded four additional University of Cambridge spin-outs from his world-leading protein research: Wren Therapeutics (since renamed WaveBreak), Fluidic Analytics, Transition Bio and Ride Therapeutics.

Xampla is a Certified B Corporation™, which demonstrates that we balance profit and purpose through applying the highest standards of social and environmental performance, public transparency, and legal accountability. We are also accredited to ISO 9001 for our quality management system and ISO 14001 for our environmental management system.

Building on our patented platform technology, all-natural, non-chemically modified, biodegradable polymer-based Morro materials are set to eliminate the most polluting plastics including single-use plastics, intentionally added microplastics, WSPs, and PLFs across multiple global markets, while also supporting the creation of entirely new global markets.

To stay up to date with developments, please join our mailing list by sending an email to hello@xampla.com

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Highlighted Team Members

 Alexandra French, CEO	Alexandra is an experienced chemist who joined Xampla to lead the company through the next phase of growth. She has 25 years' experience working at specialty chemicals company, Johnson Matthey, where she held a variety of senior leadership, commercial, operation, and technical roles. She has a degree in Natural Sciences from the University of Cambridge.
 Dr Marc Rodríguez Garcia, CTO and Co-Founder	Marc is an experienced biochemist with expertise in the application of natural biopolymers in structured materials including films, coatings, and microcapsules. Prior to co-founding Xampla, he was a Postdoctoral Research Associate in the Knowles Lab (Cambridge), where he developed the core basis of Xampla's IP portfolio. He completed his PhD at the University of Glasgow.
 Dan Hawksley, CFO	Dan Hawksley is the CFO at Xampla. Originally a chemist, Dan retrained as an accountant with Deloitte before moving on to work for a variety of high-growth technology focused companies including venture capital firm, Amadeus Capital Partners and systematic hedge fund, Cantab Capital Partners. Dan brings a wealth and diversity of experience to Xampla to help it scale-up operations and achieve commercial success.
 Dr Scott Thompson, Head of R&D	Scott has 10 years' industry experience leading teams developing and industrialising polymer-based materials, including translating conceptual and demonstrator polymers from academic settings to functioning and scalable technology, while capturing new IP. He is a technical expert in resin development and characterisation and has a PhD in Polymer Chemistry from the University of Cambridge.
 Dr Sabina Burmester, Head of Engineering	Sabina has nearly 30 years' experience developing and scaling up the manufacture of innovative materials. She has led engineering teams at Johnson Matthey and Unilever developing new process technologies and ensuring successful technology transfer and implementation into pilot- and factory-scale facilities. She has a PhD from the University of Cambridge.

 Stanley Mitchell MBA, Head of Business Development	Stanley brings a wealth of experience in working with multinationals to deploy cutting-edge technologies across a diverse range of sectors including FMCGs. This work includes developing innovation strategies focused on biomaterials for P&G, PepsiCo, and Kraft. He has an MBioChem from the University of Oxford and an MBA from Quantic School of Business and Technology.
 Lynette Holland, Principal Scientist; Product Lead for Microcapsules	Lynette is an R&D and innovation expert with a 25- year track record of success in FMCGs. She is highly accomplished at new product development, with >10 products commercialised and nearly 40 patents and scientific publications. She worked at P&G for >20 years and has developed microencapsulation delivery systems in laundry, personal care, and fragrances.
 Katrina Curl, Head of Marketing and Communications	Katrina Curl brings a wealth of industry experience across tech, FMCG and retail. She has delivered successful and award-winning marketing campaigns for some of the world's largest brands including Unilever, Canon and Britvic and now leads across all of Xampla's marketing and communication strategies
 Hugo Barroux, Product Development Manager; Product Lead for Films and Coatings	Hugo specialises in developing new materials and technologies for packaging. He joined Xampla from Unilever, where he worked as a Material Packaging Technologist in the Foods and Refreshments Category. He has also worked at L'Oréal's Packaging Center of Expertise, and has an engineering degree from the Université De Technologie de Troyes.
 Dr Ayaka Kamada, Research Scientist	Ayaka joined Xampla on a prestigious Marie Sklodowska-Curie Postdoctoral Fellowship working with Professor Tuomas Knowles. She completed her PhD in protein material development in the Knowles lab, making significant contributions to Xampla's IP portfolio, including publishing self-assembly of plant proteins into films in *Nature Communications* (Kamada et al., 2021). She has a Masters in Bioengineering specialising in biomaterials from the University of Tokyo.

 Dr James Taylor, Innovation Manager	Dr James Taylor is a physical organic chemist and specialises in microencapsulation. Prior to joining Xampla, he was a Postdoctoral Researcher at Radboud University (Nijmegen) and at the University of Glasgow, where he also completed his PhD in Chemistry studying the design, synthesis, and analysis of self-replicating molecules using various NMR techniques.
 Professor Tuomas Knowles, Scientific Advisor	Tuomas is a world leader in protein biophysics and as Professor of Physical Chemistry and Biophysics, leads a research team of nearly 40 people. He is an experienced start-up founder, who has cofounded two additional University of Cambridge spin-outs based on his world-leading protein research: Wren Therapeutics (now WaveBreak) and Fluidic Analytics. He was named UK Academic Entrepreneur of the Year by Business Weekly.

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