

What a

WASTE



Developments in waste valorization technologies have the potential to converge innovations on zero-waste and protein security to ensure a sustainable protein future.

David W. Smith digs up a number of innovators who truly believe there's brass in muck



The eureka moment for David Whitewood occurred in a field of broccoli where he was discussing the power of AI to solve farmers' problems. As far as the eye could see, Whitewood, the CEO & Founder of UK agtech startup Upp, was surrounded by discarded broccoli leaves and stems. Around four-fifths of this nutritious plant go to waste.

"It's the 21st century and the state of the art for broccoli harvesting is a gang of men with sharp knives," Whitewood says. "I asked the farmer when they would finish harvesting the crop that we were standing in. And he said, 'They have!'"

At the time, just before Covid-19, sustainability was on Whitewood's mind. Greggs' vegan sausage rolls were selling out and oat milk was trendy. "I remembered the old adage, 'Where there's muck there's brass,'" he says. A bit of research revealed the broccoli sidestream contained 30% protein and was packed with vitamins, iron, phosphorous and zinc.

Whitewood's ambition was to extract the extra edible part of the plant that was routinely rejected. The unused parts tossed away would be straightforward to extract. The waste broccoli, he figured, could be used to create a dried protein

for a range of products, including sports drinks, baked goods and ready meals. There was a catch though: the cost of recovering it from the field made it unviable.

Robo crops

Whitewood wasn't the first person to think of the idea – others before him had tried and failed to resolve the technical challenges. "My idea was, if we automate harvesting, could we harvest the whole plant? Could we take the high-value heads for market and then upcycle the waste?"

Whitewood worked with the University of Lincoln's agri-robotics team to develop AI and computer vision to recognize ripe broccoli heads, even when partially occluded with leaves. Robotic solutions were too slow to handle the large bulk of a broccoli crop, which weighs 80 metric tons per hectare, and were far too expensive in any case. Forced to innovate, lead engineer Martin Stace invented an automated system that could selectively harvest at speeds of 3km/h.

"That's fast enough to replace seven harvest laborers with sharp knives and it can work at night," reports Whitehead. "The heads are separated from the rest of the plant and

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Upp's ongoing journey from innovative idea to start-up with developed technology and investors is a microcosm of what's happening in the food waste industry

"OUR PATENTED TECHNOLOGY CAN SEPARATE FIBER FROM PROTEIN, POLYPHENOLS AND STARCH, ALLOWING FOR A CLEANER INGREDIENT WITH LESS FLAVOR AND COLOR, AND BETTER TEXTURE"

Illinois-based AgriFiber Solutions produces soluble corn and oat fiber ingredients using upcycled food waste ingredients. The fiber is added to plant-based cheeses and milks to improve textures and taste. Prototypes have been created, including cream cheese bites and spiced chocolate coffee beverages.

Rodger Jonas, CCO, says many protein ingredients for plant-based foods struggle with solubility, color and texture. "Our technology can separate fiber from protein, polyphenols and starch, allowing for a cleaner ingredient with less flavor and color, and better texture. We're now building plants to make protein and fiber ingredients."

As food produced using food waste becomes more accepted, Jonas

believes it will be a commercial boon for the upcycling industry. "There's general recognition in the market that reduction of food waste is a goal that can separate two products in competition. If a product is upcycled – or using upcycled ingredients – then it can make the difference in choice for the consumer's purchase."

But Jonas advises companies to avoid trying to match the precise flavors and textures of meats, poultry and seafood. "Producers should be getting used to developing unique eating experiences. The resultant food products would create a following and niche that would create steady business. This would end the need to blend proteins due to off flavors and textures," he says.

the sidestream is bailed and sent for upcycling. We're also developing a containerized field factory unit to reduce the crop bulk into fractions for further processing."

Commercial opportunities in waste

Upcycling waste for proteins is not solely about sustainability. Making more of what we grow makes commercial sense, Whitewood reckons. "Processing the 'tailings' of gold mines for precious metals can be lucrative as well as kinder to the environment. Plant-based foods suffer from input costs and the farmer has already paid to grow and harvest the crop. Depending on the cost to recover and process, upcycled ingredients can be very competitive," he says.

(Right) Brewing beer creates a byproduct called brewer's spent grain, so AB InBev created EverGrain to unlock every grain of potential in its barley

Despite the inspiring example of a food waste company like Upp, it remains challenging for innovative start-ups to commercialize ideas. Todd Blase, Business Development Manager Protein & Dairy at the Swedish company Alfa Laval – which provides technology for upcycling food waste – likens the nascent sector to craft brewing and the cannabidiol (CBD) cottage industry a few years ago. "Every week there were new start-ups wanting to process hemp and recover CBD," he says. "But most were making small quantities. The hardest thing to achieve was to scale the business up and it's just as true for food waste start-ups. The big buyers such as Coca-Cola or Starbucks just won't be interested if you can't give them consistent product by the semi-load. They just couldn't add it to their ingredients."

Investor interest

Upp is in the enviable position of being a standalone company with £500,000 (US\$612,000) pre-seed investment from sustainability investor Elbow Beach Capital, as well as grant funding of around £1 million (US\$1.24 million) and further investor interest for a £3 million (US\$3.7 million) seed round this year. Whitewood believes investors have good reason to look closely at the food waste sector.

To date, though, venture capitalists have preferred to pump a lot of investment into fermented and cultured proteins, but the timelines to get to market at scale are long and expensive and may not deliver the returns they desire. "Most fermented and cultured protein start-ups simply won't make it," Whitewood says. "And I also see large checks being written for alternative proteins from crops such as grass and duckweed. These need to overcome novel food approvals and be integrated into farming production systems. We don't need novel food approval – after all it's just broccoli!"

Upp will begin farm testing and producing ingredients on a small scale in September, and Whitewood says three major food brands are working with the company with a view to using the powder as an ingredient. Initially, commercial use is likely to be in Spain and the UK, but he intends to pitch to California's broccoli growers afterward.

For emerging food waste companies, it's often a good idea to partner with established companies. Alfa Laval, an industrial giant with subsidiaries in 100 countries, provides technology to help with upcycling to EverGrain, a subsidiary of the US brewer Anheuser-Busch. EverGrain has innovated a process to extract a protein isolate, which it calls EverPro,



"Depending on the incremental cost to recover and process, upcycled ingredients are potentially very competitive"

DAVID WHITEWOOD
CEO & FOUNDER, UPP





from spent grain in the beer-brewing process. EverPro has a neutral taste and high nutritional value, making it suitable to add to sports drinks, smoothies, or energy bars.

EverGrain uses Alfa Laval's separation and fluid handling technology at its facility in St Louis, Missouri, where production began last June. "Brewing material is ideal for upcycling. It's been created for human consumption so it's not downgraded material and there's lots of information available about how to develop it. The other type of brewing for alcohol is ethanol plants and they're already a big contributor to high-protein animal feed," Blase says.

Alfa Laval has been involved in food waste research with various partners for years, the main market being pet food. "Some food waste sources are being used as food for black fly larvae, but with increasing sanitary focus on pet food, processes are transcending to human consumption. It's still an exhaustive and expensive process – it takes years to make sure an ingredient is fit for human consumption."

Could waste solve global hunger?

Researchers from King's College London (KCL) recently made the claim that converting food waste into protein using sustainable technologies could wipe out malnutrition worldwide, making the food waste economy worth hundreds of billions of dollars. The research, published in *Green Chemistry*, said the number of people suffering from malnutrition is set to rise from 841 million to 909 million by 2030, yet 1.3 billion tons of wasted food and 11.1 billion tons of crop residues, such as wheat straw, are produced annually.

"Our research suggests that beyond any individual technology, it's important to synergistically integrate technologies and optimize the protein recovery from diverse waste streams," believes Dr Miao Guo, a Lecturer in Engineering and co-author of the study.

The KCL research found fermentation was one of the most critical technologies for upcycling food waste. Arable farming produces eight billion tons of carbohydrate waste every year, but if it were fermented to make mycoprotein, it would supply the same amount of protein as five billion cows – three times the global population today, the report claimed.

The fermentation process is already used to make the kitchen staple, Quorn, a partner in the research. The authors said by applying mycoprotein technologies to agricultural crop residues alone, 562 megatons of protein could be



"Chefs are developing recipes with us and numerous restaurants are eager to try out our products on their menus"

KOEN WENTINK
CEO, NOA BIOSCIENCES

produced annually. Major barriers to be surmounted, though, include public suspicion of waste-to-protein processes and regulatory divergence from country to country.

Microbial alternative proteins

Fermentation is widely used in the alt-protein sector, but the process is more environmental when raw materials from food waste are used. This is the philosophy driving Swedish start-up Cirkulär. "If we produce raw material with the sole purpose of using it in a fermentation process, we're losing a lot of potential," feels Eric Öste, Founder. "Microbial proteins using fermentation should feed off by-products and waste as raw material to be truly sustainable."

Cirkulär has a commercial contract with a paper mill in Sweden and Öste says the company will commercialize its feed protein production in small volumes this year and scale up in 2024. "We expect to be fully operational in a couple of years, enabling production of a minimum of 15,000-20,000 tons of feed protein a year," he reports.

Like so many start-ups in the sector, however, Cirkulär needs investors to finance its commercial plant. "We've got a lot of expertise and we see surging interest in the valorization >

(Above) NoA Biosciences is transforming woody biomass into fungal protein products. Containing 0% fat and a variety of vitamins and polyphenols offering health benefits, the ingredient is intended for use in cooking to replace traditional proteins (Top Left) If consumers were to replace just one fifth of their red meat consumption with microbial proteins derived from fungi or algae, deforestation could be reduced by 56% come 2050

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