The agrifood and agri-processing sectors produce an abundance of waste material and fibrous residues that are being used as a new source of raw materials for fibres, plastics and chemicals.

Food waste and fashion

Where some see only waste, others see new resources. Of the many sustainability measures that textile companies can implement, one of the most challenging is to turn food and agricultural waste into high-performance materials. Enterprising companies, from start-ups to established firms, have now set their eyes on this new source of ingredients for the textile industry.

The companies working in this field are joining a small selection of textile firms that have already walked this path. Taiwanese company Singtex turns used coffee grounds into different additives that it uses to make its S.Café fabrics and thermal insulations. US-based 37.5, formerly known as Cocona, sources the activated carbon it integrates into its fibres from coconut shells, another food industry leftover. The scale of the food-processing industry suggests that there might be many more unused materials that could be converted into useful ingredients for the textile industry.

Orange Fiber, a fibre made from citrus waste in Sicily, is one of these and featured in a capsule collection created by Salvatore Ferragamo for summer 2017. The young textile company manufactured its first 10,000 metres of fabric for the luxury Italian fashion company. Founded by Adriana Santanocito and Enrica Arena in 2014, the award-winning start-up has roots in Catania, Sicily, although its operational headquarters are now in the Trento region of northern Italy. The fabric used by Ferragamo is made in 67% Orange Fiber and 33% silk. The yarn was spun in Spain and woven in Italy's silk centre near Como.



German performance sportswear brand Vaude has backed the PFC-free laminate of its Strone cycling jacket with a layer of printed S-Café made from used coffee grounds first introduced by Taiwan-based Singtex in 2010.

Vaude

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Orange Fiber converts citrus waste into a fibre that is similar to acetate. The company estimates that the Italian juice-making industry produces more than one million tonnes of residues per year.

Italian fashion house Salvatore Ferragamo created a capsule collection for Summer '17 using a fabric made from Orange Fiber and silk.

Salvatore Ferragamo / Orange Fiber

"Orange Fiber is made from leftovers from the juice-making process. The waste is broken down to extract the cellulose, which is converted into a fibre that is similar to acetate," Enrica Arena tells *WSA*. The cellulose extracted from orange peel undergoes an acetylation process, but for dyeing and printing, Ms Arena says the fibre is closer to a viscose than an acetate. Finished products will carry a label indicating "modified cellulose".

The young company has patented its process, which it claims is made using clean production methods. "Citrus pulp contains a lot of oil which means we do not need any petrochemical oils," says Ms Arena. "The pulp is a waste material that juice makers must dispose of, they are not used as food for consumption, and the trees are not cut down." The founders are already launching a life cycle assessment (LCA) to see how their manufacturing process can be further improved.

In 2015 Orange Fiber won a Global Change Award, an innovation challenge created by the H&M Foundation, which provided the young team with €150,000, adding to the €300,000 raised from a mix of public and private organisations, including the European Regional Development Fund and the Trento region. In 2017, it received new funding from FTL Venture Inc, a venture capital fund headed by fashion and digital entrepreneur and investor Miroslava Duma, who seeks to support eco-projects in the fashion industry. Ms Duma has joined the company's advisory board.

Seed-funding and the citrus connection

Poly6 Technologies, a start-up based in Boston, also sees in citrus waste a source of new ingredients to make bioplastics and textiles. Founded by MIT post-doctoral fellow Keith Hearon and Matthew Stellmaker, who studied at the Georgia Tech School of Architecture, the company has already developed its first Citrene bioplastic. The primary markets that Poly6 is targeting are 3D printing and inkjet additives. "We are hopeful of using Citrene in textile applications in the next 12 to 18 months," Mr Stellmaker says.

Yet another project to develop materials from food-crop waste, US and Canada-based Agraloop is focusing on finding end-uses for the tonnes of residue not used by growers of hemp and flax as well as, banana, pineapple and sugar cane. On average, only 37% of the food crops is used for food, the remaining 67% is left, and often incinerated. According to the company, they believe that flax and hemp seed oil crops generate almost 730,000 hectares of residues every year. They also claim that the five crops combined are said to generate 244 million tonnes of fibrous waste. Agraloop intends to put

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EarthColors by Archroma are available in a range of five different shades that "are typical colours you would expect from nature," says marketing manager Nuria Estape.

Archroma

these resources to better use as a textile fibre. It also plans to use them as biofuels and to develop biochemicals, industrial raw materials and agricultural inputs.

Agraloop takes the fibrous cellulosic raw material from flax and hemp crops to make its "first-generation yarn" that could be ready for commercialisation in 2018. Agraloop has patented what it is calling an "orbital" composite yarn construction, a three-component yarn blending staple fibres and filament yarns, with a filament core, a staple sheath and a filament wrap yarn. It could contain up to 55% Agraloop fibre and be blended with cotton, cellulosic or synthetic yarns. The production plant, which the young company is currently scaling up, would furthermore require no external source of energy as it would be powered by waste used as biofuel.

The process Agraloop has developed has two main stages: an on-farm process decorticates the fibrous waste material that is then transferred to a wet-spinning facility. "Our initial scale-up will take place in Canada and the north of the US," says Isaac Nichelson, one of the three co-founders. "Utilising state-of-the-art composite yarn construction we are able to apply Agraloop fibres to finer-count yarns and technical fabrics for high-performance sportswear knits and wovens."

The company says it is already in discussions with private and public sector organisations in several tropical regions for a future global roll out. "This is primarily to access the massive volumes of sugar cane and banana residues in Mexico, Central America and south-east Asia, as well as exploring ways of maximising value for communities around organic cotton residues in India," he says. The three co-founders, Mr Nichelson, Yitzac Goldstein and Geof Kime, have a long history of working in sustainable fashion. Mr Kime was the first legal hemp farmer in Canada following legalisation in 1997. The company currently plans to initiate early-stage commercial activity within six months of completing its seed-funding round this summer.

Seeking to create a sustainable hoodie, New Zealand-based sportswear brand Kathmandu chose a fleece fabric made in traceable cotton and Repreve, a recycled polyester made by Unifi, and dyed it with Archroma's EarthColors in three different shades.

Kathmandu



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Seafood fount

The Umorfil Beauty Fiber developed by Camangi in Taiwan currently contains collagen peptides embedded in viscose or polyester yarns that are derived from the fish-scale waste of tilapia fisheries. "If the fishing industry disposes of the unwanted fish scales on land, it causes land acidification," says marketing director Janis Lee. After this first successful project, the company is now looking into the possibility of finding useful ingredients in oyster shells for its textiles. "Taiwan has set up oyster farms to remove heavy metals from polluted water streams. An oyster is a wonderful organism that can purify 50 gallons (190 litres) of water per day, but it is then no longer suitable for consumption," she says. The company believes it may be able to extract zinc and copper ions from the diligent shellfish and use these as an additive for a new type of Umorfil fibre.

Spices and herbs

Kathmandu and Patagonia are the first companies to make commercial ranges using Archroma's patent-pending EarthColors dyestuffs. These are extracted from a number of different agricultural waste products, including almond shells, rosemary and orange rinds. The sulphur biosynthetic dyestuffs are derived from renewable resources but perform like synthetic dyes, according to the company. In development for the past five years, the project has now reached industrial scale. Not only does it put waste products to good use, but it can also be considered an industrial variation of a locavore. "The raw materials are sourced within 500 km of the plant in Barcelona," says Nuria Estape, marketing manager for Archroma's brand and performance textile specialties business.

EarthColors are currently available in a range of five shades, derived from six raw materials, in brown, reddish and greenish tones. "These are typical colours you would expect from nature," says Ms Estape. "They are not seasonal, but rather basic shades that are particularly suited to slow fashion." Inspired by the concept, US organisation Cotton Inc reached out to Archroma to find a second use for its cotton farming residues. "The capsule that protects the cotton flower produces the same shade as almond shells or rosemary leaves," she says of the dyestuff developed within that framework and which was presented at Première Vision last year. Archroma exhibited at the 2017 OutDoor exhibition in Friedrichshafen and presented fabrics made in Flocus kapok fibre and dyed with EarthColors.

"There is huge interest for materials made from natural and renewable resources, but there are also many questions with regards to performance and availability. Our EarthColors biosynthetic dyes address these two issues," says Ms Estape. "It is very challenging, but it is important, for our future, to use what nature offers." The company's research and development teams are pursuing their research, looking to expand the number of shades and to develop biosourced dyestuffs that can be used on synthetic fibres. Other sources of chemicals for the textile industry could also be discovered.

Finding uses for agricultural and food waste is one of the many challenges that lie on the path to a circular economy. These projects are all the more promising that they have the potential to provide farmers with an additional source of income and the textile industry with a new source of raw materials.

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