Biorefinery facility to address waste challenges

The South African government has launched a R37.5-million biorefinery facility in Durban to enable extraction of maximum value from biomass resources. The facility, which is a first for South Africa, will support innovation in forestry, agro-processing and other biomass-based industries. *MechChem Africa* talks to the CSIR's Bruce Sithole, the chief scientist and manager of the facility.

Opened by the Minister of Science and Technology, Mmamoloko Kubayi-Ngubane, at the CSIR's Durban campus in March, the new Biorefinery Industry Development Facility (BIDF) is initially focused on the forestry sector, which is globally still experiencing financial difficulties. The CSIR's new BIDF aims to use biorefinery technology innovations to develop or extract high value chemicals and products from waste biomass and thus help prevent job losses in the sector and encourage sustainable growth.

"Refining waste biomaterials in South Africa's pulp and paper industry is practised on a very limited scale. Waste in the form of woodchips or sawdust from the wood, pulp and paper processing industries tends to end up in landfill sites, or is burnt, stockpiled or even disposed of by pumping it out to sea," says Sithole. "The potential to extract value from it is not realised, which means lost opportunities for the country's economy.

"When trees in South Africa's plantations are cut down to produce timber boards, paper or dissolving cellulose pulp, only about 47% of the value of the tree is utilised. The majority, therefore, is lost as waste. This includes the leaves, branches, bark, saw dust, process liquors, which are all useful resources for the chemical industry," he explains.

Sithole cites the three key ingredients and their approximate percentages that make waste wood and forestry products valuable: cellulose (38 to 50%); hemicellulose (23 to 32%); and lignin (15 to 25%). "The pulp and paper industries tend to be only interested in the cellulose and they only use the easily processed parts of the tree. Our mindset is to take everything that is classified as waste from the main stream forestry industries and to further process this waste into high-value chemicals and materials – this is what is called biorefinery processing," he tells *MechChem Africa*.

The CSIR's Biorefinery Industry Development Facility (BIDF) is looking at low quantities with high value, "which makes our biorefinery technologies ideal for uptake by local SMMEs," says chief scientist, Bruce Sithole.

"We begin downstream in the forests and saw mills where the waste is being generated. We recover the branches and bark along with any wood chips and sawdust. Then, using specialised chemical fractionation equipment and advanced analytical facilities, we use the different waste streams to extract a range of useful products," he continues.

Hemicellulose, for example, is present in the cell walls of all plant material. But unlike cellulose, it is a short chain and branched polymer. It consists of many natural sugar monomers known as polysaccharides. "So we are able to use solvent extraction processes to selectively extract specific sugars, such as Xylose, for example, that can be converted into Xylitol, a low calorific value 'artificial' sweetener widely used by diabetics and weight-watchers.

"Eucalyptus trees have a particularly high hemicellulose content, which creates good opportunities for the waste beneficiation process," Sithole says, adding that Xylitol is currently being imported into South Africa, which further enhances the localisation opportunity presented here.

Lignin, the third most abundant substance in natural wood, is another key area of research for the new BIDF. Lignin is the substance that makes newspaper go yellow over time, says Sithole. Lignin, particularly in its pure form, is a sustainable and renewable alternative ingredient for making thermoplastic materials, as well as phenolic and epoxy resins and isocyanates. Globally only 2.0 % is recovered for use to make products, one of the most notable being Arboform, a natural bioplastic developed in Europe.

"After extracting the hemicellulose and lignin, the fibrous cellulose material is almost all that remains. But there is also no need for this to go to landfill. We have developed proprietary procedures to convert this fibre into cellulose nano crystals," says Sithole. "With a tensile strength that exceeds that of stainless steel, this is a fantastic material that is now being used to produce super-high-performance and very lightweight composites – and the market price for crystalline nano fibre is now at about R12 000/kg.

"It is currently manufactured by reprocessing dissolving wood pulp, but the yield from wood to dissolving pulp is already only 35%, and from dissolving pulp to nano fibre, the yield is only 15%. So the current process yield is down to a little over 5.25 %," Sithole estimates, adding: "Our technology can produce crystalline nano fibre directly from sawdust without the need to first produce dissolving pump – with yields as high as 40%."

All in all, after having beneficiated each of the three major constituents of wood, very little waste remains, he notes. The facility can also extract pine oils from waste collected from pinewood forests and timber mills. "This can be used to make cleaning products, paint, plastics and even chewing gum.

"If you think about it, since all of our oil originally comes from biomass, most of which was once wood, almost every product currently derived from non-renewable oil-based resources can be produced directly from renewable plantations," argues Sithole.

Moving away from his forestry role, he goes on to describe another opportunity, the extraction of keratin from chicken feathers: "The local poultry industry currently produces 239-million tons of chicken feathers every year, which mostly go into landfill or are burned. But the chemistry of these feathers consists of up to 98% keratin, the same substance in fingernails and rhino horn," he explains.

Pure keratin is another high-value substance, widely used in the manufacture of cosmetics, shampoos and creams. Generally, it is difficult to produce high purity keratin, but we have developed solvent extraction-type processes that have proved very effective.

"Because we are using feathers that are contaminated with microbiological organisms, decontamination is the first proprietary procedure that we have developed. Then we pulverise, extract and purify the product into a creamy white gel that can be used as an input ingredient for numerous end product manufacturing processes, eg, shampoos," he informs *MechChem Africa*.

"As with feathers, keratin is a good insulator and it does not burn easily. Through polymerisation, therefore, it can also be used to make lightweight composites that are ideal for use as fire-resistant building insulation," Sithole adds.

The underpinning role of the CSIR and this facility are to make South Africa more competitive, create local jobs, enhance growth and to contribute towards economic transformation.

"Additionally, the country is running out of landfill space. This facility will help to solve that problem while creating high-value speciality chemicals and materials that can be used by local entrepreneurs to manufacture products that are currently imported.

"We are looking at low quantities with high value, which makes our biorefinery technologies ideal for uptake by local SMMEs. By looking at the full value chain, we can take beneficiation yields of our biomass industries from 47% all the way to beyond 90%.

"This is also important from a green perspective – the wood we use is all from plantation forests, so our input resource is not only currently a waste product, it is also a renewable resource.

"As a national facility, we are inviting SMMEs and industry to talk to us, to use the facility and to take these technologies further. We have also developed several financial models to help businesses to benefit from the facility's knowledge and processing technologies.

"Together, let's see what we can do to make a better South Africa," Sithole concludes. ❑

CSIR's BIDF facility

The BIDF facility is the third Industry Innovation Partnership Fund (IIPF) initiative to be launched by the Department of Science and Technology (DST) and its entity, the CSIR. The other two are the Biomanufacturing Industry Development Centre and the Nanomaterials Industrial Development Facility.

Speaking at the launch, Minister Kubayi-Ngubane said a ministerial review report highlighted low-levels of investments in research and development by the private sector as a key factor impeding economic growth. "A key recommendation of the report was for government to put in place effective measures and mechanisms to attract the private sector to invest in R&D and innovation," said the Minister.

The IIPF initiatives and the BIDF are key responses to those recommendations.

The BIDF is accessible to large industry and Small, Medium and Micro-sized Enterprises (SMMEs) for their research and development; analytical and pilot scale testing, evaluation, processing and development of technologies for processing biomass. Some of the equipment at the BIDF is unique in South Africa and the facility is home to highly skilled chemists, engineers and biologists who are well versed in technologies for beneficiation and valorisation of biomass.