



Professor Bruce Sithole shows the Minister of Science and Technology, Ms Mmamoloko Kubayi-Ngubane, and other guests a handsheet, explaining some of the important characteristics required for a good quality paper

# The wonder of waste

Boosting industry competitiveness through biomass waste

Innovation is a wonderful thing. Who would have imagined a decade or so ago that chicken feathers, along with biomass waste, could be converted into high value chemicals and biomaterials?

Since its launch by the Minister of Science and Technology, Ms Mmamoloko Kubayi-Ngubane, on March 20th, the new Biorefinery Industry Development Facility (BIDF) at the Council for Scientific and Industrial Research (CSIR) in Durban has received a lot of media interest. And rightly so.

The R37.5 million biorefinery facility is a first for South Africa with the infrastructure and talent for the development and testing of biorefinery technologies. As a gap-bridger between research and industrialisation, it intends to support innovation in a range of industries, but its initial focus is the forest products sector.

Minister Kubayi-Ngubane said a ministerial review report highlighted several challenges that impeded the growth and strengthening of the country's national system of innovation, one of which was low levels of investments in research and development by the private sector.

"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.

She further stated that the Industry Innovation Partnership (IIP) was a response to those recommendations. Its key objectives were to leverage industry investment in research by stimulating increased co-funding and participation by industry players in projects to maintain and increase their export market share and mitigate under-spending in technology and innovation in identified niche or strategic sectors in the South African economy.

"Since 2008, as with most manufacturing sectors, the pulp and paper industry has taken a series of knocks," explains Sithole. "Biorefinery technologies have been identified as viable ways to revitalise the industry while addressing the issue of process waste."

The CSIR has earmarked technology innovations to help prevent job losses and enable growth in this sector, along with agro processing and other biomass-based industries.

## Four years and counting

Although the BIDF took four years from concept to completion, its journey effectively began in 2010 when Professor Bruce Sithole joined the CSIR and was tasked with setting up a biorefinery programme. He now heads up the ground-breaking facility.

"In 2011, the Forestry and Forest Products Research Centre (FFP) in Durban was repositioned into a biorefinery facility," notes Sithole. "Funding from industry, the CSIR and the Department of Science and Technology (DST) led to the creation of the BIDF."

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From left, Prabashni Lekha (senior researcher); Jerome Andrew (senior researcher); and Jonas Johakimu (senior engineer). Pic: CSIR

## Current R&D activities at the BIDF

Jonas Johakimu, a senior research engineer, is working on two projects: next-generation pulping technologies and the use of recycled fibres in packaging material manufacture.

Improving pulping efficiency to reduce energy and cooking chemicals is seen as an essential strategy for kraft pulp mills to reduce their operational costs, and wood chip activation projects have been identified as a priority for improving pulping efficiency in such mills. With data showing that significant savings can be achieved in kraft cooking liquor, energy and CaO in the lime kilns, the BIDF is developing wood chip activation technology that uses liquor generated in mills to avoid the problem of carbonate loading associated with using green liquor. This could be used to mitigate environmental and operational costs in kraft pulp mills.

The second project involves the integration of hemicelluloses and lignin sulphonate in the papermaking process.

Papers made from recycled fibres are usually characterised by inferior strength properties as recycled fibres contain a relatively higher amount of fines. These not only affect the strength properties, but also have a negative impact on the paper machine's process economics.

Furthermore, after repeated subjection to drying, recycled fibres have a tendency to be brittle and exhibit 'hornification', the stiffening of the polymer structure that takes place in lignocellulosic materials upon drying or water removal.

As a result, fibre refining results in damage rather than improving flexibility which is essential for fibre-to-fibre bonding, which in turn promotes strength development. To overcome this, mills use specialised chemicals such as dry strength additives and/or blend with virgin fibres.

The BIDF is investigating the adsorption of naturally based additives onto recycled fibres as alternative paper strength additives. Their use could lead to savings in process input costs.

"After we received the funding, we embarked on an information tour of stakeholders in South Africa and a common theme emerged that the industry is concerned with handling and disposal of wastes," recalls Sithole.

"The original plan was to refurbish the FFP building, but the costs were prohibitive. We decided instead to build a brand new facility adjacent to the Durban CSIR campus."

### Finding value and efficiency in waste

South Africa's pulp and paper industry makes use of its biorefinery capacity on a very limited scale. Sithole notes that biorefinery technologies seek to extract valuable materials and products from the waste material which can be used to enhance productivity and generate extra income for mills.

"Some mills spend R20 million per annum in management and disposal of their process waste. It is for this reason that our efforts are heavily focused on what to do with wastes that are in the form of bark, saw dust, chips, sludge, effluents and fly ash.

High-value speciality chemicals can be extracted from sawmill and timber processing waste, while mill sludge can be converted into nanocrystalline cellulose, biopolymers and biogas.

**TOP TO BOTTOM:** Students and staff at the BIDF; Professor Bruce Sithole heads up the new Biorefinery Industrial Development Facility at the CSIR in Durban.



“We are developing technologies for extracting valuable compounds from sawdust and have created a novel low-cost method for production of cellulose nanocrystals from wood biomass.” The latter is probably one of the biggest opportunities as cellulose nanocrystals can find application in strong composite materials that can replace plastics.

The facility is also concentrating on next-generation pulping technologies, the conversion of wood extracts into high value products and the beneficiation of green liquor dregs.

### A feather in the cap of innovation

Another avenue that pricked the interest of those in attendance is the beneficiation potential of chicken feathers in high-value products.

While small quantities of waste chicken feathers are processed into feed for livestock, the majority is traditionally incinerated or landfilled. “The keratin can be successfully extracted from the poultry by-product to be used in high-value applications, such as nanostructured materials for biomedical applications,” explained Sithole.

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**TOP:** Bruce Sithole, Jane Molony, Minister Mmamoloko Kubayi-Ngubane and Nelson Sefara from Sappi Tech Centre. **ABOVE:** Samples of the types of biomass waste that the CSIR is exploring as raw material.



**ABOVE:** Pule Seemela, a technician in the BDF, operating a flow-through digester.

## Converting hydrophilic extracts into xylitol

Paul Kekana, a PhD student, is looking into the beneficiation of sawdust via chemical fractionation to collect hydrophilic extractives.

Sawdust has previously been used in the pulp production process as an admixture for hardwood pulp to increase its strength. The downside is the large stockpiling of sawdust waste on site due to lack of disposal options. This can pose health risks to employees and local residents, as well as an environmental hazard.

This project aims to investigate and modify existing technologies or develop new ones to fractionate the wood biomass into its individual components such as lignin, cellulose, hemicellulose and extractives via chemical means. Various acids such as sulphuric, formic and acetic acids can be used as catalysts in the hydrolysis of the hemicellulosic fraction; the remaining cellulose and lignin fractions being largely unaltered. These chemical components will then be used as a valuable raw material resource for beneficiation into a range of biochemicals and biomaterials such as xylitol and bioplastics.

## Talking talent

Not only is some of the equipment unique in South Africa, the facility is home to highly-skilled chemists, engineers and biologists who are well-versed in technologies for beneficiation and valorisation of biomass. The BIDF currently employs has 10 CSIR staff and a complement of 20 MSc and PhD graduate students and post-doctoral fellows.

Significant investments are being made to develop the human capital required to support the sector. The CSIR has partnered with the University of KwaZulu-Natal to develop the required skills and expertise that will galvanise a local biorefinery technology sector.

Sithole adds, “The BIDF is accessible to large industry and SMMEs for their research and development, analytical and pilot scale testing, evaluation, processing and development of technologies for processing biomass.

## Collaboration is critical

Paper Manufacturers Association of South Africa (PAMSA) executive director Jane Molony highlighted the importance of advocacy, public-private partnerships and sector innovation funding. “Collaboration is critical. If our mills didn’t have this waste, this facility would not have been developed. We need each other.”

Through PAMSA’s investment in its Masters and PhD students, its Process Research Unit is also looking at patenting a catalyst to improve the caloric value of bio-oil up to the same level as regular fuel. “This couldn’t have been done without the funding and support of the DST,” Molony added. Thanks to PAMSA’s strong advocacy efforts, National Treasury now also recognises carbon sequestration by plantation trees in the carbon tax equation. “Carbon is stored in paper, and even though we don’t produce it in volumes from previous years, we still use it, and we can discover new ways to use wood and process waste – again, by working together.”

“Even as an energy- and water-efficient industry, we need to work together to find innovative ways to remain sustainable and survive when our primary product is in less demand. Thank you for believing in our sector and investing in it. It is exactly what we need, especially with paper machine closures taking place. We need these value-added products – it is the best way to remain sustainable.”

CSIR CEO Dr Thulani Dlamini said making South Africa more competitive was at the heart of the institute. “Our mandate requires us to use science and technology to contribute to scientific and industrial development, which will improve the competitiveness of the South African industry and also create new industries.”

“The CSIR is using innovation to contribute to economic growth and thus assisting in the fight against poverty, inequality and unemployment,” said Dr Dlamini. ■

**RIGHT:** Chicken feathers hold a beneficiation potential for high-value products. “The keratin can be successfully extracted from the poultry by-product to be used in high-value applications, such as nanostructured materials for biomedical applications,” explained Bruce Sithole.

## Can green liquor dregs be used to neutralise acid mine drainage?

PhD student Keolebogile Sebogodi is exploring the beneficiation of green liquor dregs through the treatment of acid mine drainage (AMD). A major waste stream of kraft pulp mills, green liquor dregs are landfilled which is an increasingly unsustainable process due to shortage of landfill space, high cost of transportation, and impending waste regulations.

AMD is often mitigated by neutralisation using caustic soda, an increasingly expensive chemical. Sebogodi is looking into the feasibility of using alkaline green liquor dregs to replace caustic in neutralisation of AMD.

**FROM LEFT:** PhD student Mduduzi Khumalo with Elsie Sibande (technician) and Keolebogile Sebogodi (PhD student). Pic: CSIR

