From citrus waste to insect repellent.

GREEN TECHNOLOGIES TO RECOVER HIGH-VALUE PRODUCTS FROM CITRUS WASTE

A GREEN PECTIN PLAN FOR CITRUS PEELS

Production of citrus fruit crops worldwide exceeds 130 million tonnes per year, according to the World Citrus Organisation. More than a third of the world's output of citrus is processed, mostly into concentrated juice, and the fruit peels are mostly discarded. In line with a more circular agricultural approach to reduce waste, pectin – which has great value in food products – can be extracted from the citrus peel waste. A nagging issue, however, has been that most producers still use chemical methods to produce pectin. CSIR researchers believe they have found a solution.

Pectin. A scientific-sounding word that many people will say they have not encountered before. But it is as everyday as eating jam. The juices released when cooking fruit to make jam, and that eventually thickens the jam, is pectin. It is a polysaccharide found abundantly in the primary walls and the intercellular layers of plant cells. Citrus peel (lemon, grapefruit and orange) contains 30-35% pectin by mass of dried peel.

In addition to its uses in food products as the gelling agent in jams and jellies, it is also used in some liquid pharmaceutical preparations to add viscosity and stabilise emulsions and suspensions and it has potential health benefits, including a prebiotic effect and potential cardiovascular benefits by lowering low-density lipoprotein cholesterol. It even has potential to be used in edible packaging that can be tailored to deliver bioactives such as phytonutrients, vitamins or even pharmaceuticals directly to the gut.

CSIR principal researcher Dr Lucia Steenkamp says that while the demand for pectin continues to rise, most producers still use chemical methods to produce it. This is despite consumers increasingly demanding 'greener' products. In response, the CSIR has developed a green technology that can be easily adopted using the existing infrastructure in chemical plants.

"We applied an enzyme that is used commercially in the clarification of fruit juices. The CSIR developed a technology to produce low methoxy pectin using this enzyme. Low methoxy pectin has the added advantage that it does not require sugar for gelling. The normal high methoxy pectin obtained straight from the peels requires sugar for gelling. With low methoxy pectin, gelling is accomplished by adding calcium. This results in a product which can be safely used by people with diabetes and for weight loss products. The enzyme used for producing low methoxy pectin from high methoxy pectin can control the outcome of the final product more accurately, while chemical breakdown to low methoxy pectin usually can result in significantly different product qualities if not very well controlled.

"Significant improvements were made in the experimental development of methods, especially because no current commercial production facility makes use of an enzyme-catalysed conversion to the product. The technology resulted in a significant reduction of harsh chemicals such as sulphuric or hydrochloric acid," Steenkamp says.

CHOOSING ENZYMES OVER CHEMICALS TO PRODUCE INSECT REPELLENTS FROM CITRUS ESSENTIAL OILS

Citrus essential oils are derived from the peels of citrus fruits and are typically used in aromatherapy, household cleaning and skincare products. While lemon oils are often used in products to repel insects, the CSIR drew on its skills in biocatalysis to help a biotech enterprise to optimise a technology using orange oil to produce a new insect-repelling product, called Noot-a-bug.

Biocatalysis offers several advantages over traditional chemical catalysis, such as higher specificity, lower energy consumption, milder reaction conditions, less waste generation and better compatibility with renewable feedstocks – all aspects that are important in a circular economy.

"Biocatalysis is the ultimate green technology," says CSIR principal researcher Dr Lucia Steenkamp.

Optimisation of the bioconversion of citrus oil to nootkatone.

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"Through biocatalysis, we identify and optimise microorganisms and/or enzymes to accomplish specific reactions and produce certain desired molecules, instead of using classical chemical technologies. The technologies we develop do not require harsh chemicals or high temperatures; they consume little energy and normally generate little to no waste," she says.

The CSIR's experts in biocatalysis used an enzyme system to bioconvert compounds in the citrus oil into other more useful compounds with insect-repellent activities for small, medium and micro enterprise Applied Protein Biotechnologies (APBIO). The research team also developed a second product, nootkatone, for APBIO. This product is normally obtained commercially through the extraction of approximately 400 000 grapefruit to obtain 1 kg of nootkatone. Nootkatone is a sought-after natural organic compound in the flavours and fragrance sector and is also an insecticidal compound that repels and kills insects.

The CSIR technology uses a much cheaper compound found in orange oil, which is then bioconverted with an enzyme system to nootkatone at significant yields. The collaboration between the CSIR and APBIO resulted from the Industrial Biocatalysis Hub's mission to develop and localise technologies using biocatalysis. The hub is funded by the Technology Innovation Agency and the Department of Science and Innovation.

The scale-up of the technology resulted in the production of a market sample that exceeded agreed specifications, which led to APBIO signing a licence agreement with the CSIR. A complete dossier of the technology has been transferred to APBIO to enable the company to commercialise the technology and produce the two products of interest. APBIO has made good progress with the marketing of the products. The company is selling the Noot-a-bug oil to third parties who then include the oil as part of their own products. Some examples include the use of the product in an insect repellent product by Optimus Bio, marketed as Bug-away. The product was distributed as samples to delegates at the 2023 BioAfrica convention in Durban. Another example is Fever Tree, which now offers its lotion at most Clicks stores and will soon launch a normal cream (without sunblock). APBIO partnered with companies in Uganda and Tanzania that have tested Noot-a-bug in various formulations and found it superior to many others. They are now in the process of registering these in their respective countries. APBIO is exploring markets in China and Australia through a similar pathway.

The biggest success for APBIO to date was the work it did with African Applied Chemicals on nootkatone, which resulted in long-lasting insecticidal mosquito nets using a slow-release formula – and for which they are also pursuing World Health Organization (WHO) approval.

CSIR postdoctoral researcher Dr Moloko Mathipa Mdakane is one of a team that creates products from citrus waste using biocatalysis.

The price of pure nootkatone had proved prohibitely expensive for use in mosquito nets. APBIO participated in trials in Tanzania in which nets were used that contained APBIO's nootkatone formulations. If WHO approval is secured, APBIO may have to supply up to 60 tonnes per annum, slowly building up over the next 10 years.

WORKING WITH NATURE TO CREATE DISINFECTANTS FROM A CITRUS FRUIT EXTRACT

The CSIR has helped formulate a series of biocides for Biodx (Pty) Ltd, a company that has set out to reduce society's dependence on synthetic chemicals. The biocides are products formulated for surface disinfection for food contact and general surface disinfection.

Biodx (Pty) Ltd has spent 16 years researching and developing cutting-edge antimicrobial and antiviral technologies. The company drew on the technical skills of the CSIR and the Netherlands Organisation for Applied Scientific Research (TNO), and funding support from the South African Technology Innovation Agency and the South African Industrial Development Corporation to develop a new generation of disinfectants that no longer relied on synthetic chemical solutions.

CSIR principal researcher Dr Lucia Steenkamp says her team has assisted Biodx (Pty) Ltd with a product that is non-corrosive, Earth-friendly and rapidly kills many bacteria species and viruses. The company ran trials with large clients during Covid-19 and it was found to kill 99.9% of the virus in seconds on surfaces.

Biodx has sold tonne quantities of the products – first registered on 23 June 2021 as the only type 2 and 4 biocides from Africa in the European Union – to different local and international markets.

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