Integrated biorefinery development for the extraction of value-added components from orange peel waste streams

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Fruit waste from catering and, in particular, waste from citrus processing are of particular interest due to their high content of valuable bioactive compounds and their wide range of potential uses in various sectors of the food, cosmetics and pharmaceutical industries. When citrus fruits are juiced, about 50% of the weight of the processed fruit is generated as waste, in the form of peels, seeds, pulp and rag that could be recycled through biorefining to produce value-added compounds such as d-limonene, pectin, free sugars and fermentable sugars from the polysaccharide content. Under this context, the main objective of this study is the development of an integrated biorefinery for the conversion of orange peel residues into value-added products and a sugar-rich hydrolysate for the production of microbial oil using the oleaginous yeast strains *Lipomyses starkeyi* DSM 70296 and *Cryptococus curvatus* ATCC 20509.

The main components of orange peel residues are free sugars (30.3%, db), glucan (23.1%, db) and pectin (20.5%, db). The hemicellulose fraction (3.6% db) contains mainly arabinan (1.75%, db) and galactan (1.80%, db). The lignin content was low (5.2%, db) and the essential oils were up to 2.1%.

The essential oils were first extracted from the orange peel residues by hydrodistillation, resulting in 0.98% (w/w) extract. Subsequently, the free sugars were extracted using water at 40ºC for 2 h, resulting in a recovery yield of 97.1%. The remaining residues of orange peels were treated with an aqueous ethanol solution of 70% (v/v) in order to extract the phenolic compounds. At a solid to liquid ratio of 1:10 (w/v), a total phenolic content of 842 mg gallic acid equivalents/100 g orange peel residue was obtained. The pectin-rich extract was obtained from the remaining orange peel residues. Pectin extraction was performed by HCl treatment at 90ºC and pH 1.6, followed by treatment with the same volume of absolute ethanol, resulting in a pectin yield of 80.8%. The remaining carbohydrate-rich residues were subjected to enzymatic hydrolysis using commercial enzymes at 50ºC under agitation for the production of a sugar-rich hydrolysate.

The oleaginous yeast strains *L. starkeyi* and *C. curvatus* were evaluated for microbial oil production in fed-batch bioreactor fermentations carried out using mixtures of free sugars and hydrolysates from orange peel waste. The oleaginous yeast strain *C. curvatus* resulted in the production of 70.5 g/L dry cell weight (DCW) after 88 h with a lipid content of 60.6% w/w. In the case of *L. starkeyi* a higher DCW (107.8 g/L) was obtained after 190 h, with a lipid content of 51% w/w. The microbial lipids produced by *C. curvatus* and *L. starkeyi* contained mainly oleic acid (C18:1), followed by palmitic acid (C16:0), linoleic acid (C18:2) and stearic acid (C18:0).

The development of an integrated biorefinery approach based on orange peel residues for the recovery of essential oils, free sugars, phenolic compounds and pectin-rich extracts, followed by enzymatic hydrolysis of the carbohydrate content, is a promising way to ensure sustainable utilisation of orange peel residues, while the recovery of value-added compounds will provide additional revenue for the biotechnological production of microbial oil.

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