Solid-state fermentation by *Yarrowia lipolytica* improves the nutritional value of fruit peels

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Abstract

The awareness and concern about dietary choices have been growing among consumers, leading to a surge in demand for information regarding food quality, sustainability, and safety [1,2]. The search for healthier diet habits has instigated the exponential growth of the organic food industry [3]. Therefore, fermentation emerged as a promising strategy to improve the nutritional profile of food products (such as protein content and lowering of reducing sugar content), presenting a valuable alternative that can be incorporated into dietary regimens.

This study evaluated the upgrade of the nutritional value of orange (OP) and banana (BP) peels through solid-state fermentation (SSF) using *Yarrowia lipolytica*. In 2019, this yeast and its metabolites were Generally Recognized as Safe (GRAS) by the Food and Drug Administration, and the European Food Safety Authority approved its biomass as a novel food [4,5]. The OP and BP are a good source of nutrients, rich in carbohydrates (36.7 % and 17.8 %), lipids (4.4 % and 8.3 %)and fiber (13.6 % and 23.1 %), respectively. The content of reducing sugars was 13.2 mg/g for OP and 9.6 mg/g for BP. Furthermore, the peels are a great source of minerals, including calcium (OP - 28.5 mg/100g; BP- 7.3 mg/100g), potassium (OP- 14.6 mg/100g; BP- 45.1 mg/100g) and phosphate (OP - 2.6 mg/100g; BP- 2.7 mg/100g). However, these food by-products are poor in protein, corresponding to 8 % in OP and 13 % in BP.

Fruit peels (5 g dry mass) were fermented at 27 °C for 2 days with various supplements: NH_4Cl, $(NH_4)_2SO_4$, corn steep liquor (CSL), and soybean molasses (SM). The highest yeast biomass in the fermented OP (0,2 ± 0.03 g/g) was obtained in conditions of 2 % NH_4Cl and 40 % SM supplementation, whereas in BP (0,28 ± 0.07 g/g) was attained in conditions of 2 % $(NH_4)_2SO_4$ and 40 % SM supplementation. A significant reduction in the reducing sugar content was observed in OP (63 %) and BP (89 %), demonstrating that yeast assimilated the soluble sugars to grow.

Following optimization of the conditions for each fruit peel, the scale-up was performed using 10 g of dry peels in 500 mL Erlenmeyer flasks and trays for 4 days. BP fermentation in trays led to a 21 % increase in biomass concentration and similar biomass concentration for OP was attained. Protein content increased by 54% and 53% in fermented OP and BP in flask experiments. In tray experiments, a 65% and 59% enhancement in protein was obtained in fermented OP and BP respectively. The lipid content of fermented BP increased by 29% in flasks and 64% in trays. By contrast, no improvement in lipids content was obtained after SSF of OP. The carbohydrate concentration remained similar after BP fermentation (about 20%), but OP fermentation reduced carbohydrate content by 34% in flasks and 18% in trays.

This study demonstrates the potential of SSF by *Y. lipolytica* to upgrade the nutritional value of OP, particularly the total protein content. These substrates offer a cost-effective solution due to their abundance, low cost, and high nutritional content. Accordingly, fermenting fruit peels is a step forward for food and industrial biotechnology since it has the potential to produce innovative products with nutritional value while also having a favorable environmental impact through the valorization of undervalued food-grade by-products.

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