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Upcycling soybean by-products into protein-boosted ingredient

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A lab-scale study highlights the potential of a mushroom fermentation method to upcycle perishable okara into a nutritious and tasty food ingredient.

Scientists from Nanyang Technological University, Singapore ([NTU Singapore](#)) have demonstrated in a lab-scale study a fermentation method that could transform okara, a nutrient-rich soybean by-product from tofu and soymilk production, into a more flavourful and protein-rich food ingredient.

Okara is produced in large quantities by the soy food industry, but its high moisture content makes it highly perishable. Its high insoluble fibre content, coarse texture and relatively sour taste also limit its use in food. As a result, it is often discarded as food waste or used as low-value animal feed.

Reporting in the scientific journal [Food Chemistry: X](#), the NTU research team demonstrated that fermenting okara with oyster mushroom mycelium — the fine, rootlike network of a fungus — improves its nutritional and taste profiles. The proof-of-concept findings suggest that mushroom-based fermentation offers a promising approach to upcycle okara into a more palatable ingredient, which could help reduce food waste and support sustainable food production, subject to further process optimisation.

The NTU research team conducted the study in partnership with leading Japanese food manufacturing company Ichimasa Kamaboko.

The researchers used solid-state fermentation, a natural process where microorganisms grow directly on a moist solid material. They tested various formulations, including fresh and dried okara, as well as mixtures of okara combined with common mushroom-growing materials like wheat bran and sawdust.

They found that fermentation increased the nitrogen level of okara, one of the indicators of protein content. Lab analysis showed the protein content increased to between 27.7 and 30.2% by dry weight. Fermentation also increased glucose concentrations by 2.8 to 6.4 times from low initial baseline levels as the fungus converted complex carbohydrates into simpler sugars.

Lead investigator of the study Professor William Chen, Director of NTU's Food Science and Technology Programme, School of Chemistry, Chemical Engineering and Biotechnology (CCEB), said: "Our findings show that oyster mushroom mycelium can naturally improve okara by changing its composition and producing compounds that give it a savoury, umami taste. In addition, a separate study by my team also showed that oyster mushrooms grown on a substrate containing okara have enhanced nutritional value. Together, these findings create an opportunity to make better use of both okara and mushrooms as sustainable food sources in the future."

From sour to savoury

To evaluate sensory changes, the researchers analysed the fermented okara using an electronic ‘tongue’ — a device equipped with chemical sensors to measure different taste traits objectively. The test confirmed that fermentation reduced sourness while significantly enhancing umami (a popular, pleasant savoury taste) and overall taste richness.

However, NTU researchers noted some increases in bitterness and dryness in some fermented samples. These changes may be linked to changes in bitter-tasting amino acids and other compounds, some of which may also have potential health benefits.

The findings highlight the need to fine-tune the fermentation process to achieve a balanced, appealing overall flavour profile.

Sustainable use for okara

The study demonstrates the potential of oyster mushroom mycelium to convert an underutilised industrial residue into an ingredient with higher nutritional value and better taste.

First author Dr Malsha Samarasiri, research fellow at NTU’s School of CCEB, said: “Rather than treating okara solely as a waste stream, our research demonstrates that mushroom fermentation can create new, high-value opportunities to use this soybean by-product in food applications, contributing to a more circular and sustainable food system.”



Prof William Chen (left) and Dr Malsha Samarasiri with their fermented okara research, demonstrating improved nutrition and flavour through mushroom fermentation. Image credit: NTU Singapore

Looking ahead, the NTU research team will focus on evaluating operational energy requirements, verifying food safety, storage stability, aroma profiles and human 4 sensory evaluation, alongside optimising fermentation parameters and assessing financial viability for potential commercial scale-up.

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