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A mushroom-powered boost for soybean byproducts

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Prof William Chen (left) and Dr. Malsha Samarasiri with their fermented okara research, demonstrating improved nutrition and flavor through mushroom fermentation. Credit: Nanyang Technological University

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 byproduct from tofu and soymilk production, into a more flavorful 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 fiber 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.

In a [paper](#) published in the journal *Food Chemistry: X*, the NTU research team demonstrated that fermenting okara with oyster mushroom mycelium—the fine, rootlike network of a fungus—substantially 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 optimization.

Would you try this umami-flavoured fermented soybean product? Credit: NTUsg

Fermentation boosts protein content and flavor compounds

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

The researchers used solid-state fermentation, a natural process in which 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.

Fresh okara supported dense growth of the oyster mushroom mycelium, which fully covered the material over an 11-day laboratory incubation period. As the fungus grew, its natural enzymes broke down the complex plant fibers of okara into simpler, more digestible nutrients, releasing beneficial sugars and amino acids (the building blocks of protein).

The researchers 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 Program, School of Chemistry, Chemical Engineering and Biotechnology (CCEB), said, "Okara is a soybean byproduct that is rich in nutrients, but its high fiber content, short shelf life and less appealing flavor have long limited its use in food products for people.

"Our findings show that oyster mushroom mycelium can naturally improve okara by changing its composition and producing compounds that give it a savory, 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."

"This proof-of-concept approach offers a promising way to turn okara into more valuable food ingredients instead of discarding it, though further research is needed to evaluate pretreatment requirements, energy efficiency, scale-up feasibility and production economics alongside food

safety and consumer acceptance," added Chen, who is also director of the Future Ready Food Safety Hub @ NTU (FRESH@NTU).

From sour to savory

To evaluate sensory changes, the researchers analyzed 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 savory taste) and overall taste richness.

The fermented material contained 2.2 to 6.6 times more free amino acids, compared to unfermented okara, which naturally contains low baseline levels. Among these, glutamic acid and aspartic acid—the principal amino acids responsible for umami flavor—increased by up to 4.1 times.

Fresh okara recorded the highest concentration of these savory amino acids among all tested media.

Fermentation also boosted 5'-nucleotides, another class of natural flavor enhancers that work together with amino acids to intensify umami, by 3.2 to 6.3 times.

Succinic acid, an organic acid known for its savory profile, became the predominant organic acid after the fermentation process, increasing by up to 14.9 times in certain formulations. Conversely, citric acid, which causes sourness, generally decreased following fermentation.

Together, these natural chemical shifts explain the stronger umami flavor and reduced sourness recorded by the electronic tongue.

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 flavor profile.

A more sustainable use for okara

The study demonstrates the potential of oyster mushroom mycelium to convert an underutilized 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 byproduct in food applications, contributing to a more circular and sustainable food system."