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## Introduction

Changing from a linear food system to a circular food economy is one of the most powerful things we can do to address climate change and food insecurity.

Beer is a traditional product, with traditional mechanisms to utilize its waste such as brewer's spent grain being used as livestock feed. However, livestock are also major sources of greenhouse gas emissions. As a result, we should consider other approaches for upcycling brewery waste into new foods.

## Waste Streams in Beer

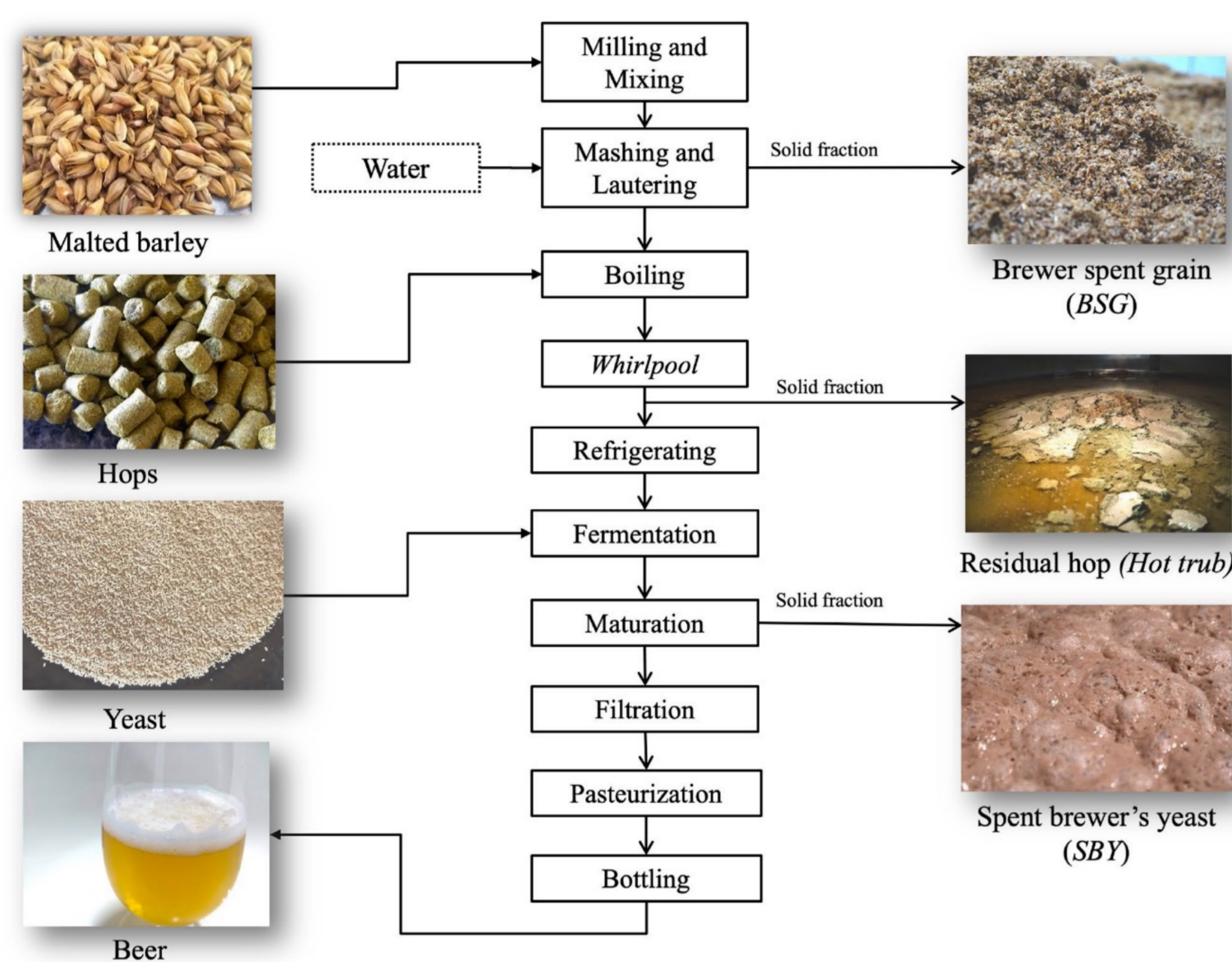


Figure 2. Inputs and waste streams in beer, reproduced from Marston *et al.* 2020

## What is Koji?

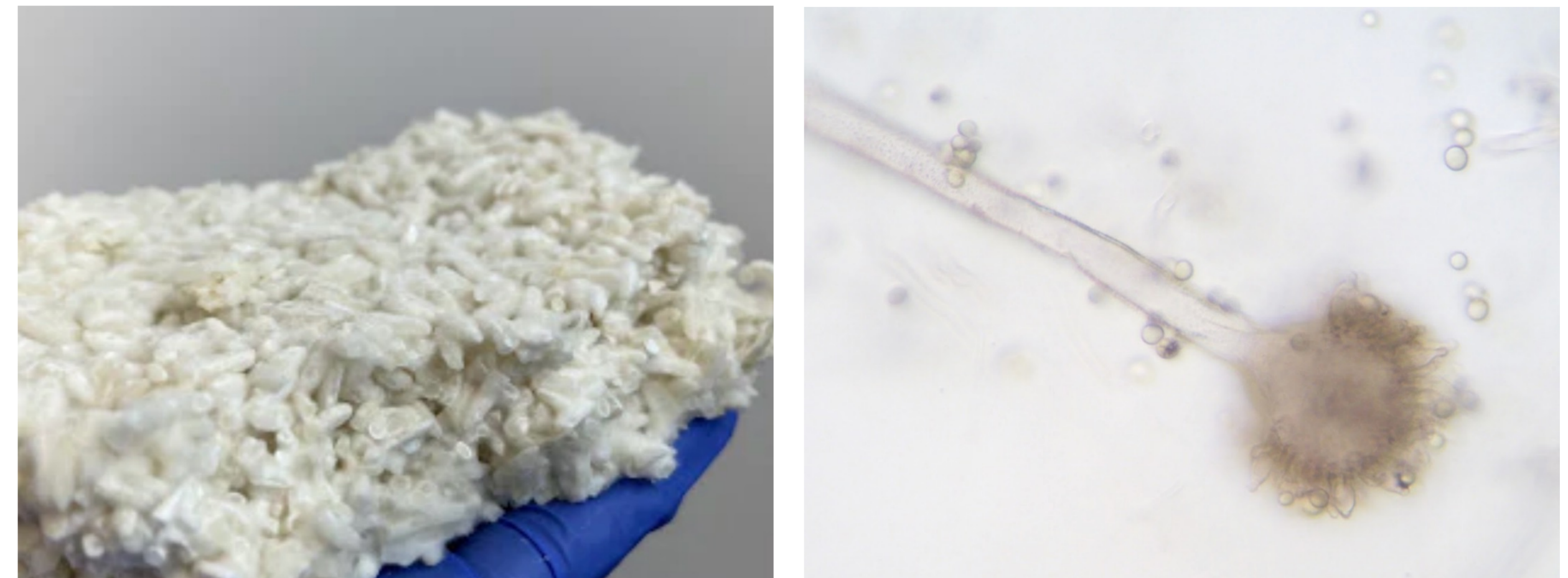


Figure 1. Images of Koji (clockwise from top left) Koji mycelium grown on rice. Koji conidiophore (spore-bearing structure) under the microscope at 400x.

- *Aspergillus oryzae* filamentous fungus.
- Specific strains domesticated by humans – similar to yeast.
- Used in both mycelium and sporulated formats.
- Can be used dry or fresh, as spores or as pre grown koji.
- High levels of enzyme production: amylases, proteases, and more
- Used traditionally in Asia to produce soy sauce (shoyu), miso, sake, amazake, and more.
- Can grow on solid substrates such as cooked grains.
- Can grow koji biomass on rice, legumes, brewer's spent grain.

## Methods & Results



Figure 3. Overview of process for producing spent grain shoyu by inoculating spent grain and soybeans with koji.

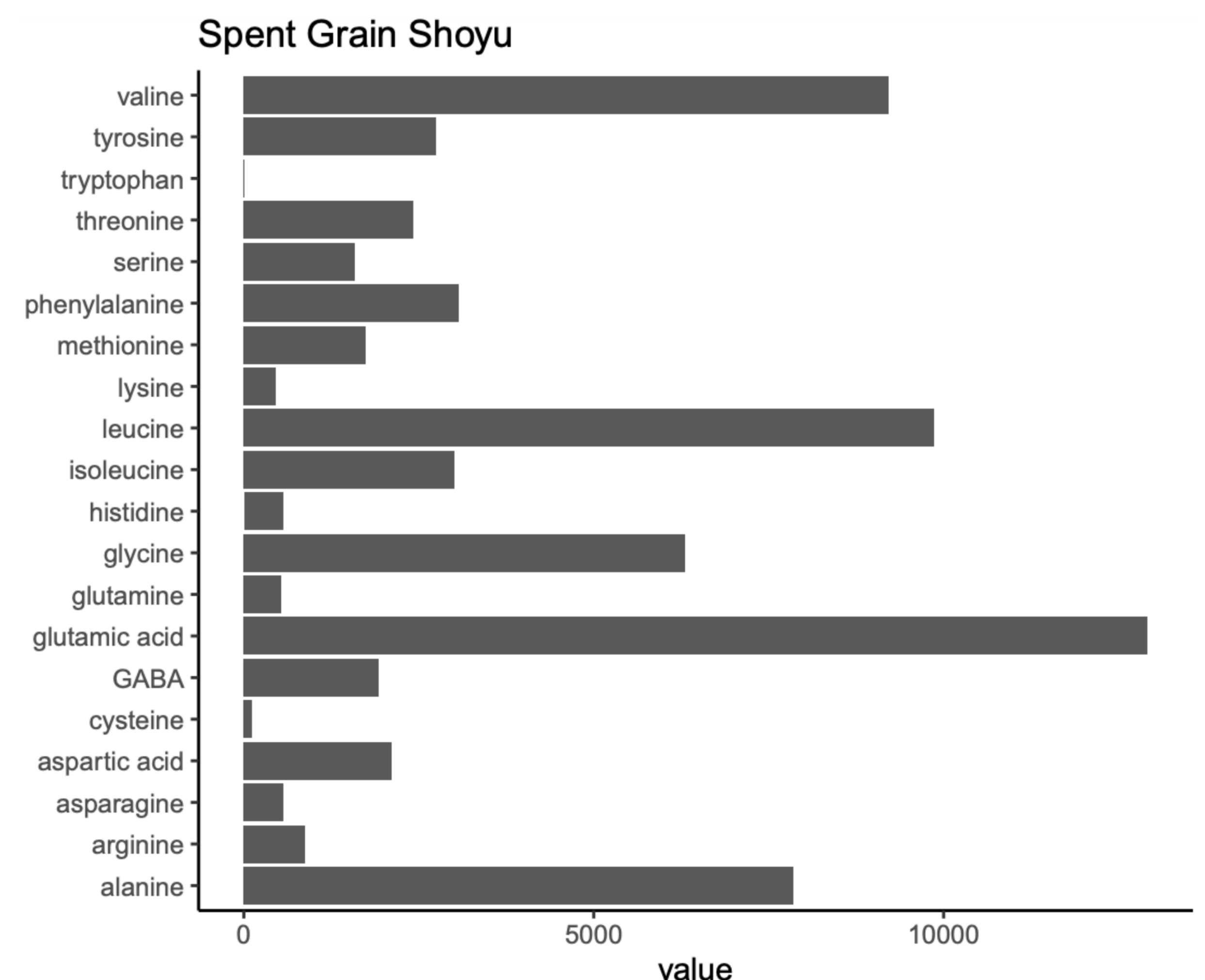


Figure 4. Measurement of amino acid concentration of finished Spent Grain Shoyu using HPLC.

### Spent Grain Shoyu (soy sauce from spent grain)

- Very high in glutamic acid. ~12,000 ppm = ~1.2% .
- Comparable glutamic acid content to commercial soy sauces.
- Also high in essential amino acids leucine and valine.
- Essential amino acids are not synthesized by the human body - they must be obtained from diet.
- Spent Grain Shoyu could be produced as an upcycled consumer packaged good or as a seasoning in brewpubs/taprooms

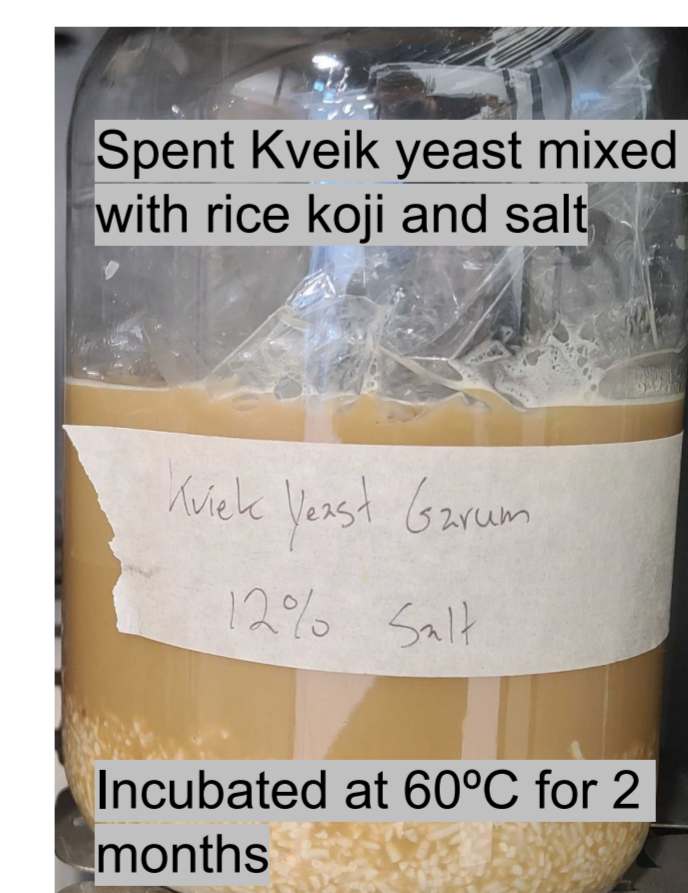
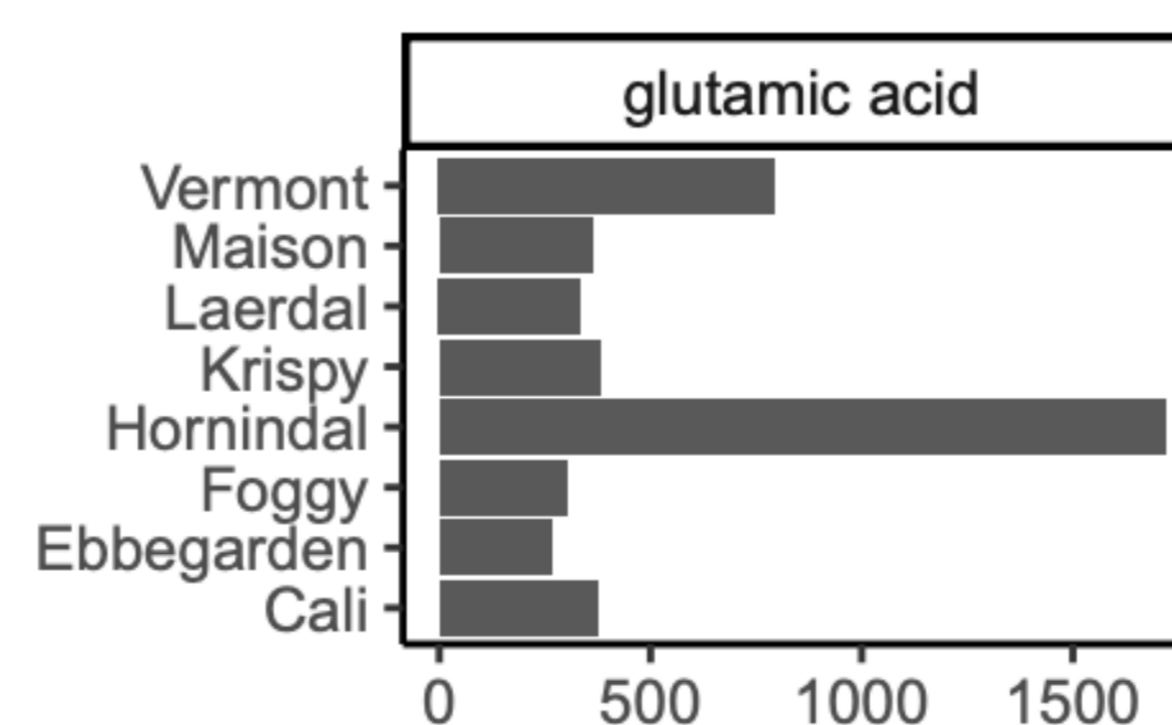


Figure 5. Measurement of amino acid concentration of yeast slurry and an overview of the Yeast Garum production process.

### Yeast Garum (amino sauce similar to fish sauce or Marmite)

- Hornindal Kveik yeast slurry was found to be a good source of umami-tasting glutamic acid.
- Glutamic acid content increased to ~1% (10,000 ppm) after fermentation.
- Strong cheesy, umami flavour.
- Potential vegan and lower carbon replacement for fish sauce, Parmesan cheese.



Scan QR Code for additional Koji fermentation resources

## References

- Marson, G. V., de Castro, R. J. S., Belleville, M. P., & Hubinger, M. D. (2020). Spent brewer's yeast as a source of high added value molecules: a systematic review on its characteristics, processing and potential applications. *World Journal of Microbiology and Biotechnology*, 36(7), 1–22. <https://doi.org/10.1007/s11274-020-02866-7>
- Zilber, D., Redzepi, R. *The Noma Guide To Fermentation* (Book)
- Umansky, J. *Koji Alchemy* (Book)