WAGENINGEN
UNIVERSITY & RESEARCH

White Paper

Fermentation processes for natural food ingredients and products

# The fermentation approach of Wageningen University & Research

Consumers increasingly prefer food products made of naturally produced ingredients. This is leading companies to take another look at age-old fermentation processes for their clean-label promise and capacity for sustainable production. But what options does fermentation offer for the modulation of qualities such as taste, texture and nutrient content in food materials? What are the advantages in terms of sustainability? To what extent has the technology been proven and what are the major challenges?

> *"Fermentation is the perfect technological solution for more sustainable processes in the food industry."*
>
> Jeroen Hugenholtz, fermentation expert at Wageningen Food & Biobased Research

Wageningen Food & Biobased Research – one of the institutes within Wageningen University & Research (WUR) – has been using fermentation technology to investigate the production of natural food ingredients for decades. This research has proven that fermentation reduces the footprint of production processes and represents a crucial sustainable alternative for chemical synthesis. These are excellent reasons to share the accumulated knowledge by means of this whitepaper and to stimulate real-world application of this technology.

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# Opportunities and challenges

**What is fermentation?**
Fermentation is a food processing technology that utilises the growth and metabolic activity of micro-organisms for the stabilisation and transformation of food materials. While the technology was originally developed for the stabilisation of perishable agricultural produce, it has evolved beyond food preservation into a tool for creating desirable organoleptic, nutritional and functional attributes in food products.

Fermentation is also one of the key technologies being explored for the conversion of agrofood waste streams into high-value products such as food ingredients and nutraceuticals.

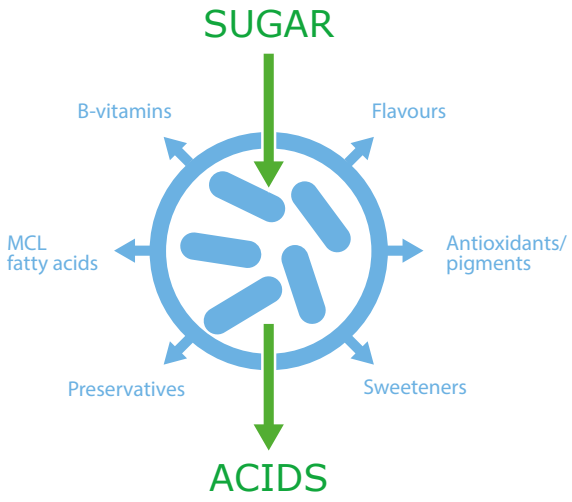


Figure 1: Conversion process

**Three different applications**
There are three ways to apply fermentation technology to introduce a given functionality in a food.

**Application 1: Agrofood waste streams**

Agrofood waste streams can be used as substrate for fermentation to produce the desired ingredients by selected micro-organisms. The purified ingredients are added to the final product as a food additive during the manufacturing process.

**Application 2: Foodstuffs**

Foodstuffs like tomato paste or dough can be fermented to develop a specific functionality. These intermediate products can be added to the final product during the manufacturing process without the need to isolate the specific active compound. This results in fermented foodstuffs which are label friendly.

**Application 3: Final products**

Fermentation can be executed in the final product to obtain the desired functionality.

Figure 2: Three different applications

**The major challenges**
There are also challenges in a fermentation process. For example: How do we design a process which results in the effective production of the desired functional components? The fermentation process must be carefully designed and monitored to achieve a final product or ingredient with reproducible composition. But how can such a process be made as cost effective as possible? The answer is to use cheap substrates, such as agrofood waste streams from primary production and retail, for functional fermentations. Regulatory matters related to the declaration and labelling of fermented foodstuffs also need to be addressed in cases when this leads to novel formulations.

*"We use our strong background in fermentation technology to assist companies in developing clean-label solutions."*

Joost Blankestijn, programme manager in Food Innovations for Responsible Choices at Wageningen Food & Biobased Research

Wageningen Food & Biobased Research is unique in its lab-to-pilot-scale approach to fermentation technology and ability to deploy and alter a wide variety of micro-organisms in order to find the most cost-effective route to a given fermentation process. These developments are based on a stepwise approach.

# WUR's fermentation approach

**1. Definition of biomaterials**
How should we select the most suitable substrate and fermentation conditions for optimal production of the desired functionality?

The first step is to translate the desired functionalities into a list of molecules or components that need to be produced by fermentation. Next, we need to determine which substrates will be used and which labelling requirements the client needs. Based on this information, Wageningen experts can propose a number of food-grade strains and fermentation conditions that deliver the desired functionality in the best possible way.

There are two approaches to achieve the desired functionality in this phase. One is to use the agrofood stream as the starting point and add value to it. In this case, the end functionality will often be undefined and there will be a broad screening of functionalities. The other approach is to define a very specific functionality and narrow down the specific micro-organism to be used.

**2. Quick assessment of required functionality**
How should we monitor fermentation to see whether it is successful and whether the required functional molecules have been produced?

Wageningen Food & Biobased Research has a wide variety of screening tools to assist in finding the fastest route to a given functionality. For example:
- Various high-throughput approaches can help monitor growth (fermentation) for a large number of combinations in substrate/microorganism/fermentation conditions. This includes direct measurement of pH changes in turbid foodstuffs as well as molecular tools for measuring growth in various micro-organisms.
- Flavour and off-flavour expertise technology provides the necessary tools for the development of natural flavours via fermentation. This expertise effectively connects instrumental flavour analysis to consumer sensory techniques.
- A novel functional in vitro screening assay can assess whether ferments activate sweet taste receptors.
- An extensive food-physics toolbox, including pressure-sensing multi-channel pipet-robots, can assist in the search for texturising agents.

**3. Application of ferments**
How should we apply ferments or fermented foodstuffs in real food?

New food product development is a risky undertaking with as many as half of new food products reckoned to fail. The application phase of the WUR's fermentation approach is therefore a crucial step. In the end, a given ferment or fermented foodstuff needs to be applied in real food. Obviously, the realised functionality must be present in the final food product and remain stable during its entire shelf life. We can use the available pilot facilities to produce a wide range of products and assess the robustness of the produced components. Last but not least, we can assist companies in this phase to define their labelling strategy.

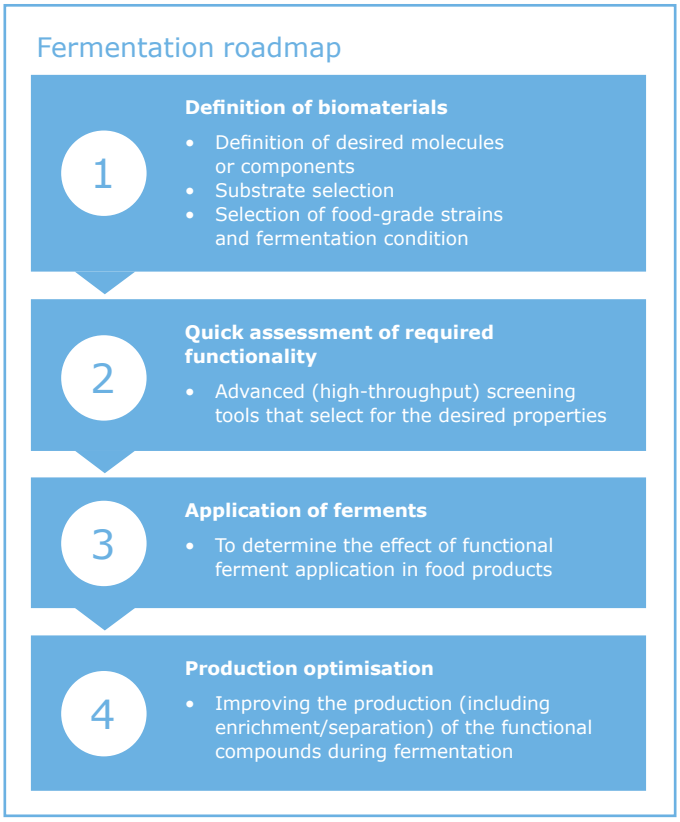

Figure 3: The stepwise fermentation approach

**4. Production optimisation**
How can we improve the production of functional compounds during fermentation?

In some cases, the activity/strength of a given functionality needs to be increased. To reach maximum production levels, we use our metabolic knowledge of a broad range of micro-organisms to:
- adapt the selected micro-organism to the preferred substrate,
- combine different substrates to allow better growth of the selected micro-organism,
- continuously remove an inhibitory product during fermentation or change the physical parameters of fermentation such as pH, temperature or gas atmosphere.

Applying this knowledge enables us to help you develop more powerful ferments and reduce the costs involved in improving certain functionalities in food.

# Examples of successful fermentation processes

The Wageningen experts have already successfully developed various fermentation processes for novel food ingredients and end products. Here are a few examples.

## *Natural flavours*

How do we produce natural and intense flavours? Fermented foods are generally recognised and appreciated for their specific flavour, which is a smooth combination of the original components present in the foodstuff and the unique components produced by microbial conversion. This natural process to produce desired aroma components is utilized by the microbial experts in Wageningen and offered to food and ingredient companies for the production of natural flavours. We offer fermentation processes for a wide variety of flavour components, ranging from very specific single components such as valencene and notekatone to more complicated compound flavour blocks such as cheesy, creamy, hearty and sweet-and-sour.

## *Stable side streams: extended storage of fresh crops*

How can we best extend the shelf life of perishable vegetable and fruit crops and residues? We are working on a range of approaches. Our current focus is on the rapid fermentation of the waste stream/surplus produced by the growing of local crops. In order to avoid spoilage due to fungi and other causes, and to allow a wider time window for processing. Typically, we use lactic acid bacteria, selected for rapid fermentation of specific waste products. This produces specific antimicrobial compounds that suppress the rotting process and produce minimal off-flavours during the fermentation process. Such an approach enables us to offer the vegetable/fruit-growing industry the possibility to process and make use of the large proportion (30% or more in the Netherlands and much higher in most tropical countries) of their produce that is currently lost.

## *Sugar reduction*

How can we reduce calories in high-sugar foodstuffs without losing the desired sweetness? Fermentation, almost by definition, is the ideal natural process for this. We have developed a range of fermentation processes that result in complete or almost complete removal of high-calorie sugars and their replacement with low-calorie sweeteners. This is achieved by optimising the conversion of sugars into the low-calorie sweetener erythritol or by converting the available food protein into sweet peptides.

## *Shelf-stable non-alcoholic beverages*

The development of non-alcoholic versions of traditionally alcoholic beverages is challenging because the removal of alcohol leads to the loss of a certain mouthfeel and preservative function, especially when certain flavours/fruit extracts are added. The traditional role of fermentation in prolonging the shelf life of alcoholic drinks needs to be replaced with other solutions. We can provide a range of fermentation approaches for the production of both natural and non-alcoholic preservatives and components, such as polyols and various polysaccharides that reproduce an alcoholic mouthfeel in non-alcoholic beverages.

## *Vitamin enrichment of vegetables*

Consumers are eating less meat, eggs and dairy products, which can lead to deficiency in vitamins B12 and D. We found a solution in certain microbes, which are the main and sometimes only source of essential vitamins for humans. Microbial activity in the human gastrointestinal tract provides vitamin K for humans, while the vitamin B12 in dairy results from microbial production in the rumen of cows. We have studied these vitamin-producing bacteria and developed fermentation processes leading to vitamin-enriched fermented fruits, vegetables, juices and pastes. A specific example of such an approach is the fermentation of lupin, which is transformed into a tasty, protein-containing, vitamin-enriched alternative to meat when fermented with a mixture of selected fungi and the multivitamin-producing *Propionibacterium freudenreichii*.

# Getting to work

Hopefully this whitepaper has given you a greater insight into possible fermentation approaches and inspired you to consider the technology as a solution for your food-related business in the future. We would like to share more of our knowledge and experiences, and invite companies already considering the use of fermentation for new products or processes to reach out to us.

**What can we do for you?**
We can offer food manufacturers and ingredient suppliers natural ingredients and clean-label solutions based on fermentation. This can help you improve the flavour, preservation, texture, nutrition and calorie limitation of your food products – and in many cases a combination of these benefits. And it can help make your production process more sustainable.

We can provide effective support to you via projects large and small, ranging from a one-to-three-month feasibility project to the comprehensive development of new products and production processes over several years.

**Our expertise**
- Unique lab-to-pilot-scale approach to fermentation technology. In our dedicated fermenter labs, we can scale up fermentation processes to 2, 100 and even 1000 litres.
- Quick assessment tools to screen efficiently for a desired functionality.
- Extensive knowledge of underused food materials and residual streams that can be converted into the desired end products with fermentation technology.
- CRISPR/CAS and metabolic modelling expertise for work with various micro-organisms, ranging from yeasts and fungi to anaerobic bacteria and algae, enabling the most cost-effective fermentation process for a given product.

*The benefits*
- Fermentation technology provides a solution to 'label-friendly' alternatives to the chemical-sounding ingredients that are being increasingly scrutinised by consumers.
- Fermentation is a sustainable method for the production of food ingredients and reduces the carbon footprint of production processes.
- Using our knowledge of cost-effective side streams, we can design fermentation processes that add value to existing streams.

## More information?

*Interested in possibly giving fermentation a try?*

Get in touch with Joost Blankestijn to discuss the various options for collaboration.

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*Looking for more information on the fermentation process itself?*

Contact Jeroen Hugenholtz.

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