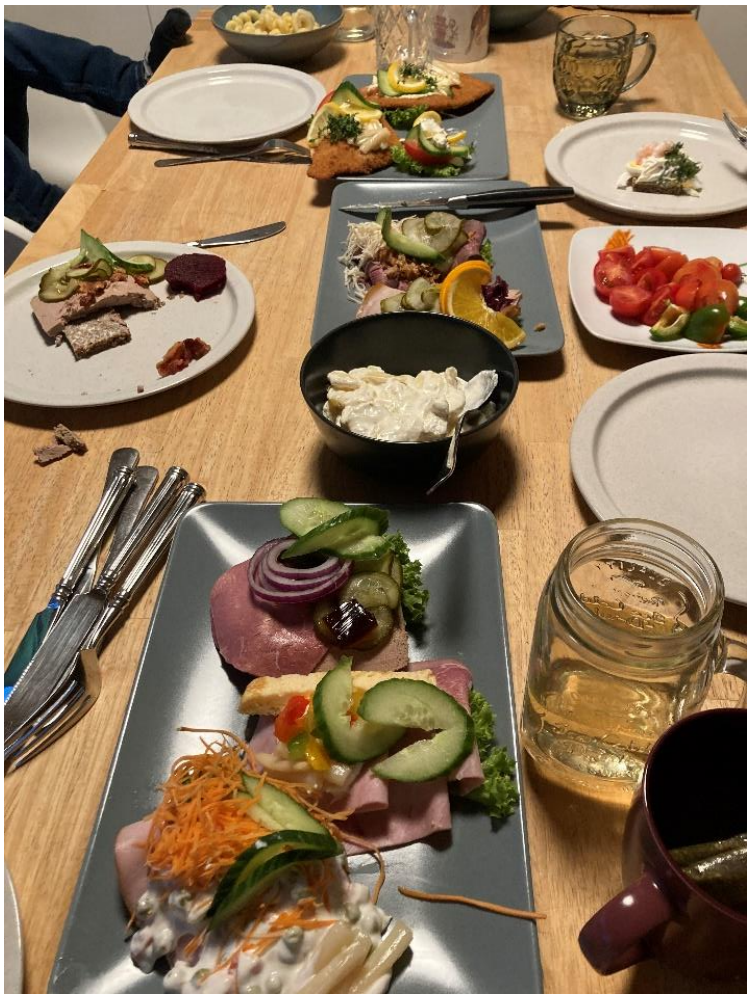
Functional Food

Child: I am so hungry and need to eat something now. Can food make me not only full, but also more healthy?



Is there any functional food on the table?

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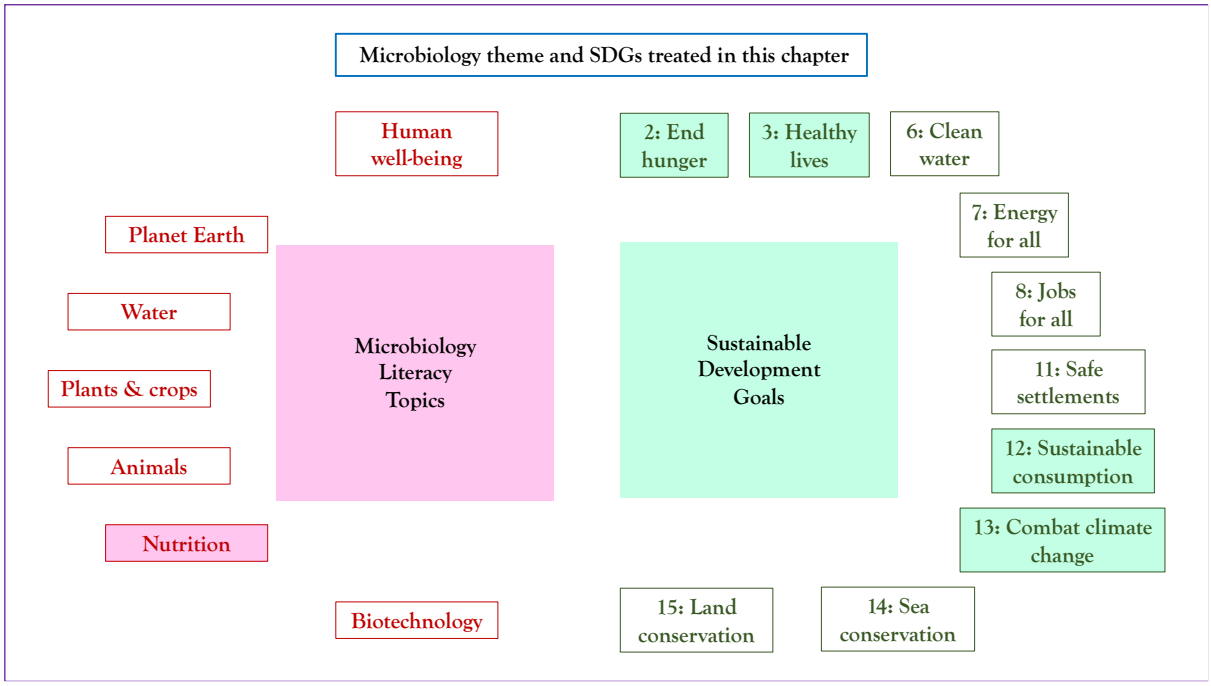
Functional Food

Storyline

Eating food is important. We eat because we are hungry and need energy. Food is also an important part of our social life. Shopping for ingredients, cooking, sitting together and enjoying a good meal while eating and talking determines the quality of our life. We have several expectations of food: it should taste and smell good, it should fill our stomach, but it should also be healthy, or even make us healthier. Functional foods are a special group of food products which contain one or more 'additional' ingredients that can support our health. Such an ingredient could be a special compound, but also a living microbe! Fermented foods that contain microorganisms are closely linked to the concept of functional food, as microbes are able to produce an enormous variety of substances that could be beneficial.

The Microbiology and Societal Context

The microbiology: microorganisms in food; fermentation cultures; probiotics; adjunct cultures; bioprotection; microbial biotechnology. *And peripherally for completeness of the storyline:* food safety; food waste; animal feed. *Sustainability issues:* health, food and energy



Functional Food: the Microbiology

1. ***What are functional foods?*** Functional foods are considered to be foods that offer a benefit to health beyond their role in basic nutrition. The term functional food encompasses many and very diverse products. Foods are considered functional if they contain a special ingredient. Such an ingredient could be a chemical or biomolecule which would otherwise not or only be present in low concentrations, e.g. vitamin D in milk, folate in flour, or dietary fibres that work as ***prebiotics***. The special ingredient could also be a microorganism that has a selected activity. Worldwide, there is neither an official nor a uniform regulatory definition on what a functional food should be like or contain, and there is a lot of subjectivity in defining a functional food product (Dominguez Diaz et al., 2020). Nevertheless, fermented food products are often linked to the group of functional food.

2. ***Microbes in food – starter and adjunct cultures.*** Microbes in food can confer several functions, some of which can be beneficial and others which can be detrimental. Adverse microbes are pathogens and spoilage microorganisms which decrease food safety and quality. During food processing, multiple control steps are implemented to avoid having these microorganisms in the final product.

One way to inhibit spoilers and pathogens is food fermentation. Microbes naturally present on the raw material, or in defined (starter) cultures that are added at high concentrations, drive a fermentation to produce a ***fermented food***. The main purpose is that these fermentation cultures use the available sugars, grow, produce fermentation acids or alcohols, and lower the pH to generate an acidic environment. Such a process can be considered a form of ***biopreservation***, as it enhances shelf life and food safety. In comparison to the raw product, fermented food is often also more palatable and nutritious.

Food can also be used as a vehicle to incorporate additional 'adjunct' cultures into our diet. Adjunct cultures are microbes that are added because they have a specific function, e.g. they produce a specific compound or molecule to increase food safety. Concurrently, such a compound could be supportive for health and could be considered a functional food. Examples of adjunct cultures are ***bioprotective cultures*** and ***probiotics***. Bioprotective cultures are added because they produce compounds that inhibit spoilers and pathogens. Probiotics are a special type of microbe contributing to human health, but they have to be eaten alive.

Definitions

Probiotics: 'Live microorganisms that, when administered in adequate amounts, confer a health benefit on the host' (isappscience.org)

Prebiotics: 'A substrate that is selectively utilized by host microorganisms conferring a health benefit' (isappscience.org)

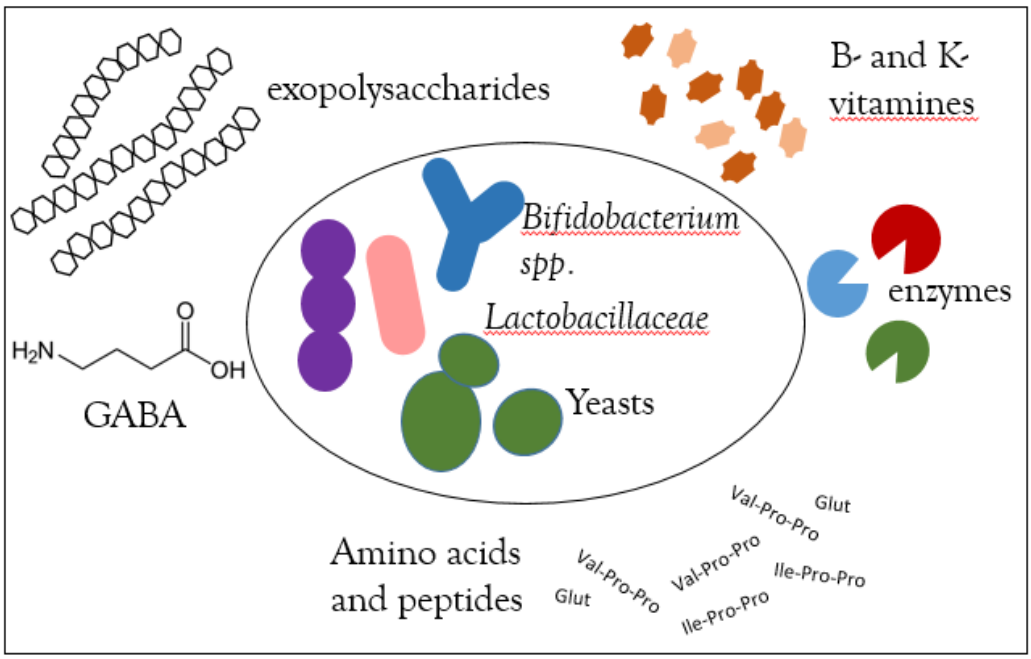
Fermented food: Food produced with the aid of growing microbes (natural or added starter cultures) or by the activity of microbial enzymes

3. ***Functional foods that involve microbes.*** Microbes associated with food are diverse and include bacteria (e.g. lactic acid bacteria, which all have in common the production of lactic acid as a main fermentation metabolite, or *Bifidobacterium* spp., which are often added as probiotics), yeast (*e.g. Saccharomyces cerevisiae)* and fungi.

There are several ways how microbes or a microbial activity can contribute to the production of a functional food, which cannot always be strictly separated.

a. Food can act as carrier
b. Food can be produced through the activity of a specific microbe
c. A microbe can be added to produce a specific compound
d. A compound produced by a microbe can be purified and added to the food

An example of (a) is any yoghurt that contains a probiotic such as the *Bifidobacterium* strain BB12, while the fermented dairy drink Yakult is an example of (b). The use of some members of the species *Bacillus subtilis* (*B. subtilis* Natto) to increase the concentration of Vitamin K2 of fermented soybeans, and the addition of *Propionibacterium freudenreichii to* sourdough to yield higher concentrations of vitamin B12, are examples of (b) and (c). These microbes also produce B12 and K2 when grown in a cultivation medium, so vitamins could be produced independently of food, purified, and then added to the food product (d). However, such a scenario would be associated with higher costs, and vitamins are considered to be feed additives subject to higher levels of regulatory oversight.



Examples of functional compounds produced by food microbes.

Other compounds that microbes can produce in a food product include small molecules, amino acids and peptides, exopolysaccharides, and conjugated fatty acids. The role of these compounds is very different. Some examples:

- The small molecule gamma-amino butyric acid (GABA) is considered a neurotransmitter, diuretic and tranquilizer and is produced by several lactic acid bacteria.
- Functional microbes can help to improve flavor through the production of specific peptides with kokumi (=flavor enhancing) ability, while accumulation of the amino acid glutamate can reduce the need for added salt.

- Microbial enzymes can support the formation of sweetness in the product, reducing the need to add sugars to the product.
- Alternatively, the formation of sugar alcohols can compensate for sweetness of sugar-reduced cakes.
- Starter cultures that form exopolysaccharides enhance the proportion of non-digestible, dietary fibres. Such dietary fibres can act as prebiotics, i.e. selectively enhance the abundance of microbes that contribute to health.

4. ***Functional foods not only for humans?*** Functional food is not only of interest for human nutrition, but could also be beneficial for companion (cats, dogs) and farmed animals (pigs, cows, chicken, fish, maybe even insects?) as functional feed. The purpose of functional feed differs between these two groups. Functional feed for companion animals aims to improve general well-being and prolong life; an example of functional food is pet chow with added dietary fibres/prebiotics or probiotic microbes. For farmed animals, the purpose of functional feed is driven primarily by economic considerations: animals should grow bigger, faster, produce more milk, meat or protein, and be less sick.

On the other hand, functional feed might also contribute to achieving the sustainable development goals of the UN, for example through the reduction of methane via nutritional changes, which is a major greenhouse gas produced by ruminants such as cows, sheep and goats.

5. ***The next generation – which other functional foods could there be?*** Food has been used as vehicle for classical probiotics (*Bifidobacterium* spp, *Lactobacillaceae*) for decades. One development will be to use other microbes, e.g. to improve gastrointestinal health with gut microbes that have a specific function. Again, food could be used to maintain these microbes, but this is technologically more difficult, and will keep biotechnologists busy during the next years. Many gut microbes are more demanding than the probiotics that have been used so far, and most importantly, they do not like to be exposed to oxygen. Nevertheless, first attempts were successful to integrate the gut microbe *Akkermansia muciniphila* in chocolate, in which it survived for several weeks. Other examples will likely follow in the future!

Relevance for Sustainable Development Goals and Grand Challenges

- **Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.** Use microbes to produce biopreserved food for enhanced food safety and prolonged shelf life.
- **Goal 3. Ensure healthy lives and promote well-being for all ages.** Reduce salt and sugar content, increase dietary fibre content of food to address obesity and other health issues related to a Western diet
- **Goal 12. Consume and produce responsibly, reduce food waste.** Use microbes to produce biopreserved food for enhance food safety and prolonged shelf life.
- **Goal 13. Climate action.** Maybe this is relevant more for functional feed than food, but functional food either involving microbes or feed ingredients could contribute to reducing climate changes through a reduction methane.

Pupil Participation

1. **Class discussion: Which functional food do you eat?**
    a. Which functional foods do you know?
    b. What do you eat every day?
    c. Do you eat any functional foods?

2. **Class exercise: Design the next generation of functional food!**
    a. which functional foods will be needed in the future?
    b. Could functional food be a vehicle of selected medication or vaccines?
    c. Does such functional food maybe already exist?

(Form groups and develop novel functional food. Prepare models, and present to others in the class.)

The Evidence Base, Further Reading and Teaching Aids

Dominguez Diaz et al. 2020. An international regulatory review of food health-related claims in functional food products labeling. J Funct Foods 68, 103896
Marcial-Coba et al. 2019. Dark chocolate as a stable carrier of microencapsulated *Akkermansia muciniphila* and *Lactobacillus casei*. FEMS Microbiol Lett 266, fny290
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Sato et al. 2001. Production of menaquinone (vitamin K2)-7 by *Bacillus subtilis*. J Biosci Bioeng 91, 16.
Xie et al. 2018. In situ fortification of vitamin B12 in wheat flour and wheat bran by fermentation with *Propionibacterium freudenreichii*. J Cereal Sci 81, 133.
Zhao et al., 2015. Effect of glutamate accumulation during sourdough fermentation with *Lactobacillus reuteri* on the taste of bread and sodium-reduced bread. Cereal Chem 92, 224
https://isappscience.org/a-roundup-of-the-isapp-consensus-definitions-probiotics-prebiotics-synbiotics-postbiotics-and-fermented-foods/

Glossary

Biopreservation: The use of microbes or microbially produced compounds to extend shelf life and enhance food safety. A fermented food is biopreserved.

Bioprotective cultures: Microbes that are added to food (or feed) because they can enhance shelf life and food safety through a special activity

Fermented food: Food produced with the aid of growing microbes (natural or added starter cultures) or by the activity of microbial enzymes changing the properties of the raw material (for example cereals, milk, fruits and vegetables) through the break down of sugars and the formation of organic acids or ethanol.

Probiotics: 'Live microorganisms that, when administered in adequate amounts, confer a health benefit on the host' (isappscience.org)

Prebiotics: 'A substrate that is selectively utilized by host microorganisms conferring a health benefit' (isappscience.org)