

**Date of poster presentation: 11 April 2022**

## **Microbiome research and innovation needs a systems approach**

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Microbiomes (microbial communities and their “theatre of activity”) occur everywhere in natural and cultivated ecosystems, such as soils, plants, animals, and our bodies. Microbiome activities are essential for many environmental processes and can provide solutions for circular economy concepts. In addition, microbiomes can contribute to sustainable solutions to many important societal challenges, such as zero hunger, reversing the loss of biodiversity and climate mitigation. Microbiome research is a booming field with numerous publications published every year. Here, we will present the current state of the microbiome research field and propose routes on how the huge potential of microbiome research can drive bio-innovations.

The rapidly developing microbiome research landscape was studied by a global mapping of microbiome research projects and bibliometric analysis of microbiome publications. Both methods revealed that microbiome research is performed in many different science fields, and similar concepts within and across fields are studied. However, microbiomes are mostly investigated in one ecosystem at-a-time. Several reasons for this fragmentation have been identified, such as the majority of projects have a budget of <250 kEuro, often supporting one early career scientist and many past projects focussed on describing microorganisms within the studied ecosystem.

We conclude that the transition to a systems approach in microbiome research is needed to leverage microbiome functions fully. This involves understanding how microbiome modulation affects the ecosystem studied as well as the connected ecosystems. Furthermore, it creates an understanding of how the modulation of microbiomes results in the desirable functions needed as a basis for the transition towards a sustainable and circular bioeconomy.

In addition, we recommend that microbiome research should be addressed explicitly in research and innovation strategies and boosted through dedicated research calls. New regulatory frameworks need to include guidelines and clear procedures for the registration of microbiome-based solutions. Moreover, the potential of microbiomes has to be communicated to a wide range of actors and the general public.

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*Keywords: microbiome, systems approach, food system, research landscape*