D4.5 - Safety and sustainability assessment of processes and materials II

Aim: make good decisions early on

Safe-and-Sustainable-by-Design (SSbD) plays a crucial role in the development of new materials by integrating safety and sustainability from the outset. This holistic approach considers human health, environmental impact, and socio-economic factors throughout the material's life cycle. SSbD ensures product safety for end-users, minimizes occupational hazards during production, and reduces environmental toxicity, emphasizing biodegradability and recyclability at the end-of-life (EoL) stage.

This report presents the final safety and sustainability results of foams developed in the **BreadCell** project. Through virtual and in-person meetings, on-site partner visits, and desk research, a comprehensive safety assessment strategy was conceptualized, identifying potential risks. The evaluation covered production and post-processing exposure routes, cytotoxicity, and biodegradability. Additionally, safety strategies and end-of-life considerations were developed. The sustainability assessment of BreadCell technology encompasses the three pillars—economic, environmental, and social—while aligning with the United Nations Sustainable Development Goals (UN SDGs).

BreadCell Safe-and-Sustainable-by-Design concept

1. Safety assessment of processes and materials II
- 1.1 Hazard assessment of chemicals and materials
- 1.2 Human health and safety aspects in lab-scale
- 1.3 Human health and environmental aspects in the final application

2. Sustainability assessment of processes and materials II
- 2.1 Environmental sustainability assessment
- 2.2 Socio-economic sustainability

This assessment is divided into two key components: the safety assessment, which focuses on identifying and mitigating potential risks to human health and the environment associated with manufacturing processes and material as well as foam properties; and the sustainability assessment, which evaluates the economic, environmental, and social dimensions of **BreadCell** materials and foam production. The aim is to enable timely decisions that comply to regulatory standards and minimize adverse effects on human health and the environment.

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Safety assessment of processes and materials II

1.1 Hazard assessment of chemicals & materials

No hazards have been classified for cellulose pulps, viscosifiers, foaming agents and the BreadCell additives like surfactants. Therefore, cytotoxicity screening tests were focused on the foaming agents and foams of different characteristics developed in the project.

1.2 Human health and safety aspects at lab-scale

The dose response assay was used to quantify IC_{50} values. The BreadCell foams **are not toxic** compared to reference materials that are considered as safe used in food contact material.

Non-cytotoxic materials*

1.3 Human health and environmental aspects in the use cases

A tailored safety testing strategy focused on cytotoxicity, bacterial mutagenicity and irritation tests:

In vitro **cyto-toxicity**	***In vitro*** **skin irritation**	***In vitro*** **ocular irritation**	**Bacterial mutagenicity**

**in vitro under testing conditions - max concentration of 50 mg/ml*

BreadCell foam is

…non skin irritant!
…non ocular irritant!
…non mutagenic!
…less toxic than EPS and PU foams and other commercially available samples!

Biodegradability testing

BreadCell foams fulfil the criteria of biodegradability under controlled composting conditions using the biodegradability testing apparatus.

EN 13432:2001 and IS/ISO 14855-1

BIODEGRADABLE

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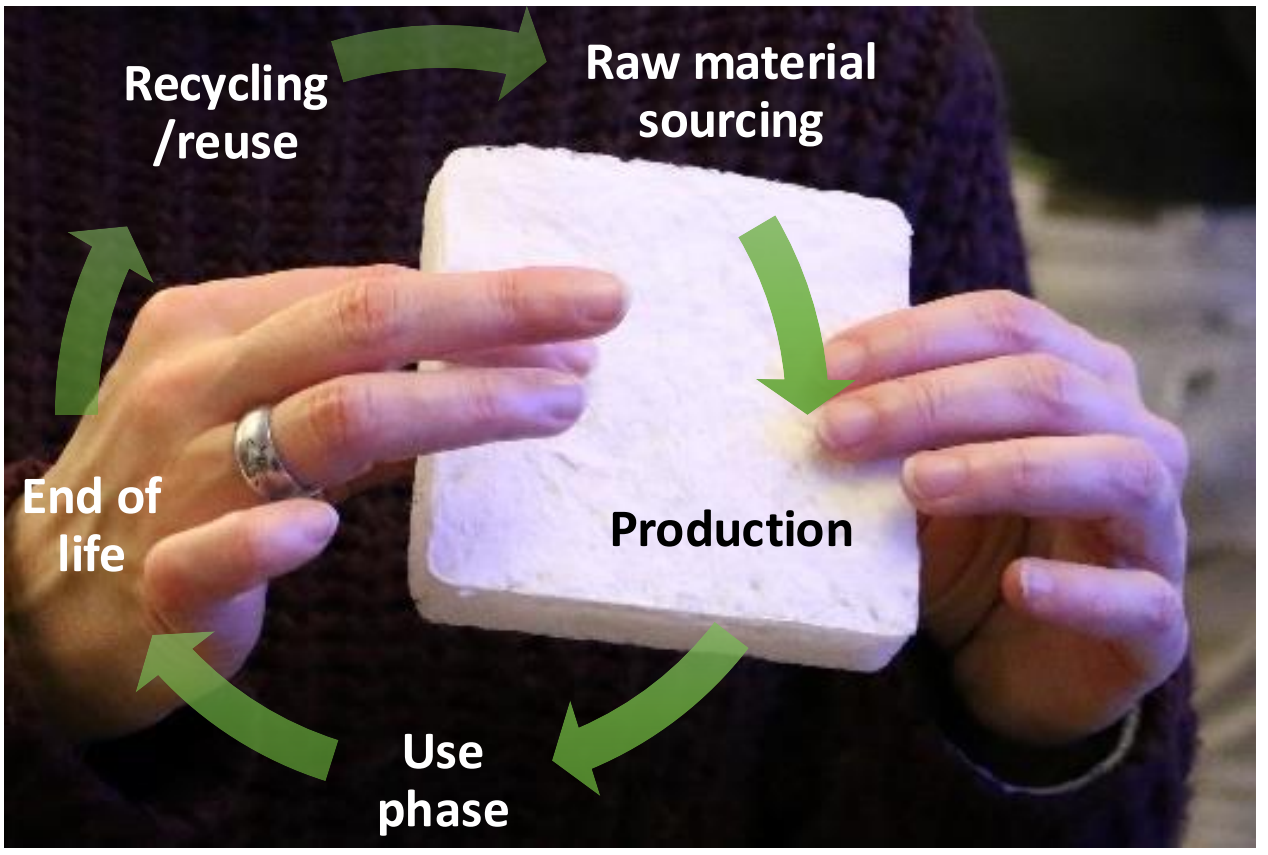
Sustainability assessment of processes and materials II

2.1 Environmental sustainability assessment

Life cycle assessment (LCA) approach

Utilize life cycle thinking at low technical readiness level to understand comprehensive impacts



Raw material sourcing: The transition to biobased foams supports sustainability by reducing reliance on non-renewable resources. Promoting sustainable forestry practices is crucial.

Production: Pulping and bleaching phases are associated with emissions. The CO2 emissions from the fermentation process only make a small contribution to the overall footprint.

Use phase: Energy consumption, emissions, and resource use can affect a product's environmental impact, along with impacts on human health and ecosystems.

End of life: No major foreseen challenges in disposal and recycling; Biodegradable and can be recycled as paper. However, specific routes are very use case specific.

Greenhouse gas emissions: BreadCell foams show **lower environmental impact** than petroleum-based alternatives (EPS/PU), but industrial-scale assessments are needed to develop sustainability further.

Eutrophication: Wastewater from pulp production can increase eutrophication impacts. Emphasis is on the importance of supply chain transparency.

Acidification, ozone depletion, ozone formation: Bio-based products perform similarly to fossil-based counterparts with only minor differences observed.

Interpretation and suggestions

Adopt **sustainable sourcing strategies** to combat forest degradation and protecting biodiversity

Emphasize **durability** in product design to **reduce waste**

Implement end-of-life approaches that **enhance recyclability and biodegradability** and take the use cases into consideration

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Sustainability assessment of processes and materials II

2.2. Socio-economic sustainability

The sustainability of bio-based foams within the broader spectrum of bio-based products of the bioeconomy depends on their environmental, economic, and social impacts that intersect with United Nation's SDGs. Progress towards the SDGs in general has been slow, and **it is urgent to address critical challenges such as urban sustainability, fossil fuel subsidies, material consumption disparities, and climate change**. The role of bio-based products, including bio-foams, is pivotal in mitigating these challenges and advancing towards a fairer and greener world.

BreadCell can make a difference – Social impact and relation to UN SDGs

In 2015, the United Nations General Assembly developed 17 sustainable development goals (SDG), which are described as "*shared blueprint for peace and prosperity for people and the planet, now and into the future*".
https://www.un.org/sustainabledevelopment

SDG	Impact of bio-based products
SDG 3: Good health and well-being	Reduced pollution, health hazards minimized
SDG 7: Affordable and clean energy	Reduced fossil fuel reliance
SDG 8: Decent work and economic growth	Economic opportunities, rural job creation
SDG 9: Industry, innovation, and infrastructure	Techno-economic viability, innovation
SDG 11: Sustainable cities and communities	Enhanced urban waste management, rural development
SDG 12: Responsible consumption and production	Biodegradability, compostability, circular economy
SDG 13: Climate action	Greenhouse gas reduction, climate mitigation.
SDG 14: Life below water	Aquatic pollution reduction, particularly microplastics, possible negative impact of pre-treatment of pulp
SDG 15: Life on land	Sustainable forest management

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BreadCell foam components materials are **non hazardous**

BreadCell foams are

non-toxic, non-irritant and non-mutagenic

BreadCell foams can be **dispersed** back in water and components can be **reused**

BreadCell foams are **biodegradable**

BreadCell foams have a **low environmental footprint**

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