



#### Coordination

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#### Keywords

Bioeconomy  
Bread waste  
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Valorisation

#### INRAE divisions

[ACT](#)  
[MICA](#)  
[TRANSFORM](#)

#### Some publications

Lucas, T., Thiriet, P., Redlingshöfer, B., Aissani, L. (2024). Valorisation des rebuts et invendus de pain – Exemple d'instrument d'une circularité territoriale existante mais fragile. CIEC, Montpellier.

# INRAE

## Bioeconomy for urban areas



CARIBOU

## Circularity of the bakery production



Supporting the development of circularity in the bread-making industry from the socio-economic, organisational and technological points of view, using bakery waste and unsold bread

In France, unsold and rejected bread represents around 500,000 and 270,000 t in industrial processing and distribution respectively, and is mainly produced in urban and peri-urban areas. The CARIBOU exploratory project looked at the management and recovery of bread rejects and unsold bread (URB) at the production and distribution stages. To support the development of RIP value chains, CARIBOU brought together environmental assessors, technologists and human and social scientists from three INRAE divisions.

## Progress and results

CARIBOU aimed to better characterize the flows of these URBs, their management and recovery channels, their dependence on context (producer typology and territory characteristics), and their compliance with regulations (AGEC law, GAROT law). It also aimed to explore valorization by fermentation in liquid and solid media, by fungal or mixed processes.

1. An analysis of the literature over the period 2016-2022 showed that, for this bioresource, the articles cover all conceivable valuations listed in the regulatory hierarchy. A formalisation of the scientific literature review on URB valuation over the period 2016-2023 was newly submitted to the *Journal of Industrial Ecology*. This work quantitatively confirmed that the research effort, while focused on all valorization routes for this substrate, was unbalanced in relation to the hierarchy recommended by the regulations (quantified on the basis of the proportion of articles per valorization type over the period). CARIBOU provided an opportunity to reflect on the criteria that should guide the decision-maker's choice of recovery route. Compared with the previous period, the research effort was clearly in line with the original intention of the product studied (prevention and recycling for human consumption). This last result was a determining factor in the direction taken for the ANR AAPG 2023 ( $\mu$ Cosmos) submission. Finally, CARIBOU pointed out that the prevention stage could conceal part of the impact (cases where the URB producer does not dispose of it and mobilises actions lower down the hierarchy on site) and that the yield of the recovery operation was too often overlooked in the research published to date (biorefineries in particular). This reflection has guided the positioning of Task 2 of the Project, with, for example, the exploration of RIP fermentation without sterilisation or inoculation.

2. CARIBOU has also explored fungal or mixed (yeast/bacteria) recovery methods, with a focus on process simplicity (without sterilisation and/or extraction). The literature review highlighted the fact that most of the routes described in the literature are implemented using pure strains, which more often than not require the medium to be sterilised and an often complex final purification stage to extract the molecule of interest. All of these constraints have a negative impact on the economics of these processes, and very few cases of the production of molecules of interest on an industrial scale have been described. The energy required to sterilise URBs, the complexity of the technologies used and the management of residues linked to the low mass yield of production limit the environmental benefits of using URBs to produce molecules of interest. The first trials carried out at OPAALE-PANDOR research units showed that whatever the type of bread (wholemeal bread, white flour baguette or long-life sandwich bread) and the storage conditions, butyric fermentation dominated in 7 out of 9 configurations. In the other two cases, fermentation tended towards malolactic fermentation. The secondary molecules produced were acetic and succinic acids. Butyric acid has recognised anti-inflammatory properties, and a great deal of work is underway to assess the health benefits of adding this acid. Three strains from the collection of the Centre International des Ressources Microbiennes -Banque de Ressources Fongiques de Marseille were targeted, among species known to be edible (*Agaricus bisporus*, *Lentinula edodes* and *Pleurotus ostreatus*). Based on macroscopic observations of the cultures (colonisation rate and density), the *Pleurotus ostreatus* strain, BRFM 1326 was selected. The amino acid profile and compositional analyses of total dietary fibre in the bread sample colonised by the fungus compared with the control bread showed a nutritional benefit provided by the fungal culture. In particular, the quantity of insoluble dietary fibre and resistant starch more than doubled.
3. The flows of URBs, by way of local recovery, and their determinants were studied by means of surveys of bakery actors (artisanal bakeries (AB), industrial or semi-industrial bakeries) or distribution (supermarkets and hypermarkets) and charities in Rennes Métropole (RM) and la Plaine Commune (PC) in the Paris region.
  - Access to medium and large-scale retailers proved difficult. A total of around twenty surveys were carried out in the two areas, most of them with floor managers. It was found that supermarkets first seek to prevent losses (batch promotions because of financial management at department level), then request bio-waste collection (AGEC law for large producers). The results for retailers are similar in both areas.
  - Unsurprisingly, mini-markets, which are often not covered by the regulations (obligation to sort bio-waste, food donation agreement), almost always dispose of their waste in household waste (tomorrow in a bio-waste collection scheme).
  - In the light of initial surveys of charities, and particularly in la Plaine Commune, bread does not seem to be a key food product for food aid, which explains why it is a minor source of value in supermarkets. Bread made from white flour is not taken up by food aid ('duck bread' because it is just good to give to ducks), which echoes the selection of special breads by those involved in food recycling, whether in microbreweries (cereal bread) or biscuit factories (organic sector). This implies that (i) these two uses should not be dissociated, as they may be in 'competition' for the same material, (ii) white bread could be used in a low-value sector (animal feed or biorefinery?) without competing for the resource with human food, and (iii) white bread could be used in a low-value sector (animal feed or biorefinery?) without competing for the resource with human food.
  - The semi-industrial or industrial Bakery, Viennoiserie and Pâtisserie (BVP) production (4 surveys in Rennes Métropole) mainly recycles for food aid and

animal feed; bio-waste collection is used as an alternative. These players are all interested in food recycling (whether in a closed loop or not), but have not taken the plunge (at the test stage at most). The difference with supermarkets for food aid can be explained by the nature of the gap (production gap available from the morning of the production day versus end-of-day surplus available the following day).

- A territorial metabolism has been sketched out in Rennes Métropole for small-scale bakeries. Subject to confirmation, a significant flow linked to prevention (~20% in total) was revealed by this analysis and the portfolio of recovery seems different in rural areas (few visits by associations for food aid and more 'bartering'). It is planned to complete this work as part of the ANR 'μCOSMOS' project.

## Project members

INRAE division	Units	Expertise and contributions
<b>ACT</b>	UMR SADAPT	Territorial ecology, estimates of flows from surveys and database analysis, interdisciplinary analysis of <u>territorial</u> metabolism
<b>MICA</b>	UMR BBF	Microbial enzymology applied to recovering agro-industrial waste
<b>TRANSFORM</b>	UR OPAALE	Process engineering, environmental assessment, life cycle analysis