

Life Sciences und
Facility Management

From By-Product to Food Innovation:

Upcycling Side Streams into Novel Foods

Corinna Bolliger, Claudio Beretta, Matthias Stucki, Ivana Salvatore, Evelyn Kirchsteiger-Meier, Marie-Louise Cezanne, Liridon Rama, Maria Rudel, Robin Betschart ,Nadina Müller

Valorization of Swiss Agri-Food Side Streams (VALISS)

- **2.8 million tonnes food waste**

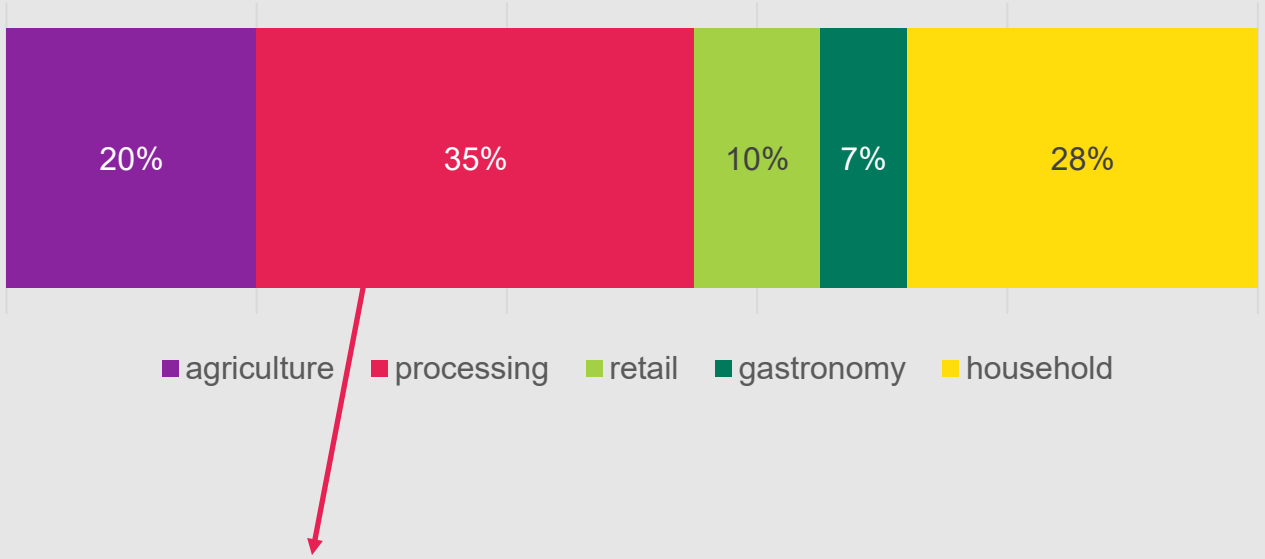
  per year in Switzerland

- **35% from food manufacturing**

  → large homogeneous side streams

Where does food waste occur?

Share of food waste mass along the Swiss food supply chain



VALISS Project: valorization of side streams

Beretta & Hellweg 2019

By-products

Novel Foods



Cocoa bean hulls



Chocolate with cocoa bean hulls





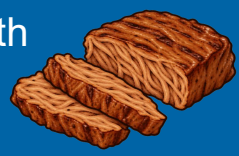
Barley Rootlets



Brewer Spent Grain



Meat alternative with brewery side streams





Spent Coffee Grounds



Coffee Silver Skin



Granola with coffee side streams



LCA Approach

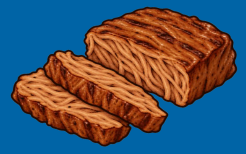
Problem of multi-functionality

a) Economic allocation

FU: 1kg of final product



chocolate



meat alternative



granola

b) System expansion with substitution:

FU: valorization or utilization of 1 kg of side stream



- Feed
  - Substitutes: mixture of ingredients providing same nutrients

- anaerobic digestion
  - electricity and heat → specific biogas yield
  - Substitutes: Swiss electricity mix and natural gas



- Incineration
  - electricity and heat → lower heating value.
  - Substitutes: Swiss electricity mix and natural gas



- Composting
  - Substitute: based on the equivalent NPK content of mineral fertiliser



Chocolate with cocoa bean hulls

a) Economic allocation

- 1.1% cocoa bean hulls (CBH)
- 98.9% cocoa bean

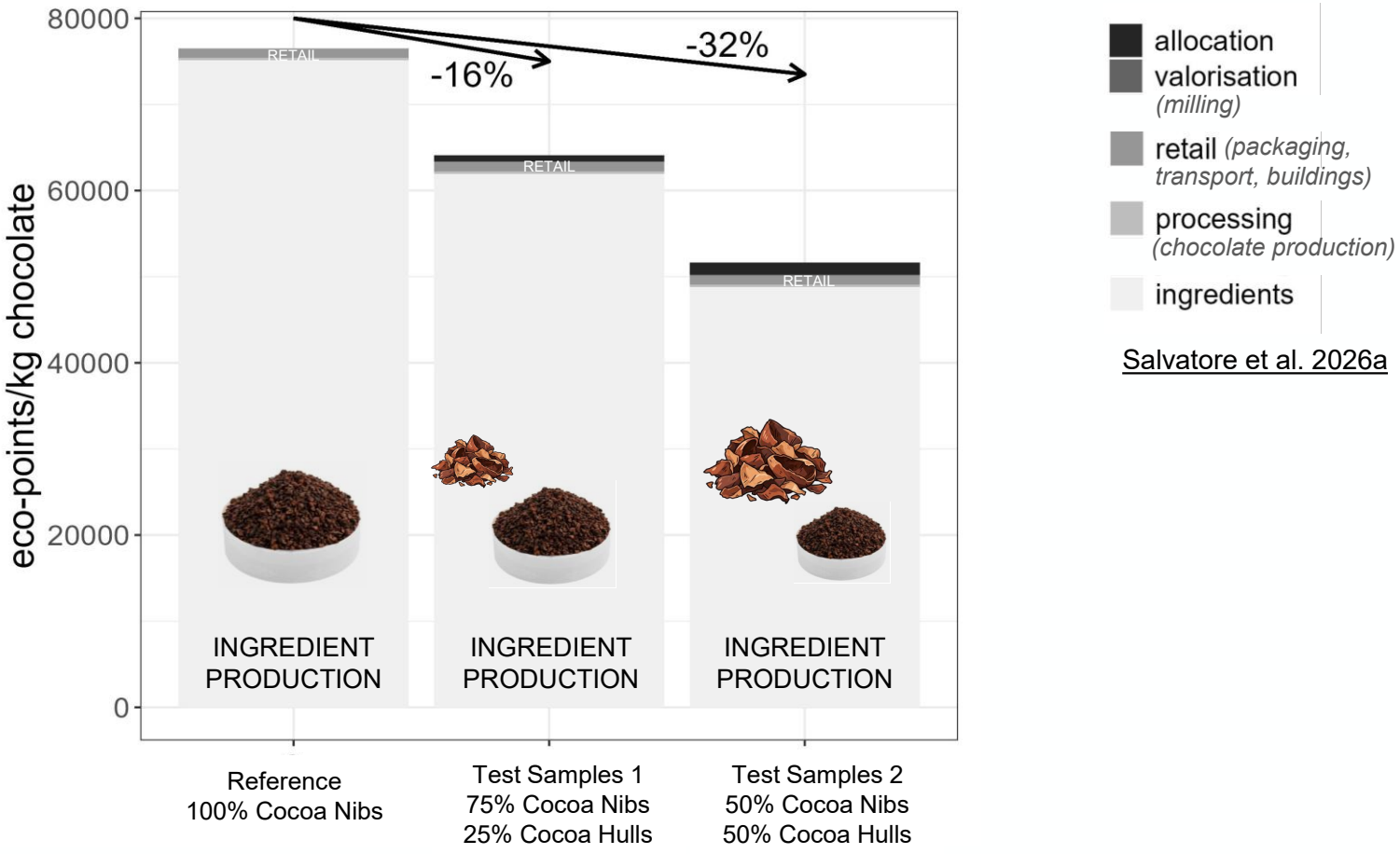


Recipes

- Reference scenario dark chocolate: 100% cocoa nibs
- Option 1: 25% of cocoa nibs replaced by CBH
- Option 2: 50% of cocoa nibs replaced by CBH



Chocolate with cocoa bean hulls



Salvatore et al. 2026a

Chocolate with cocoa bean hulls



b) System expansion with substitution

Alternative scenarios

- Mulching
  - NPK fertiliser with equivalent NPK content
- Incineration
  - Swiss average electricity mix
  - Energy from natural gas
- Feed
  - Mixture of wheat bran, oat husk, sunflower cake and alfalfa cubes



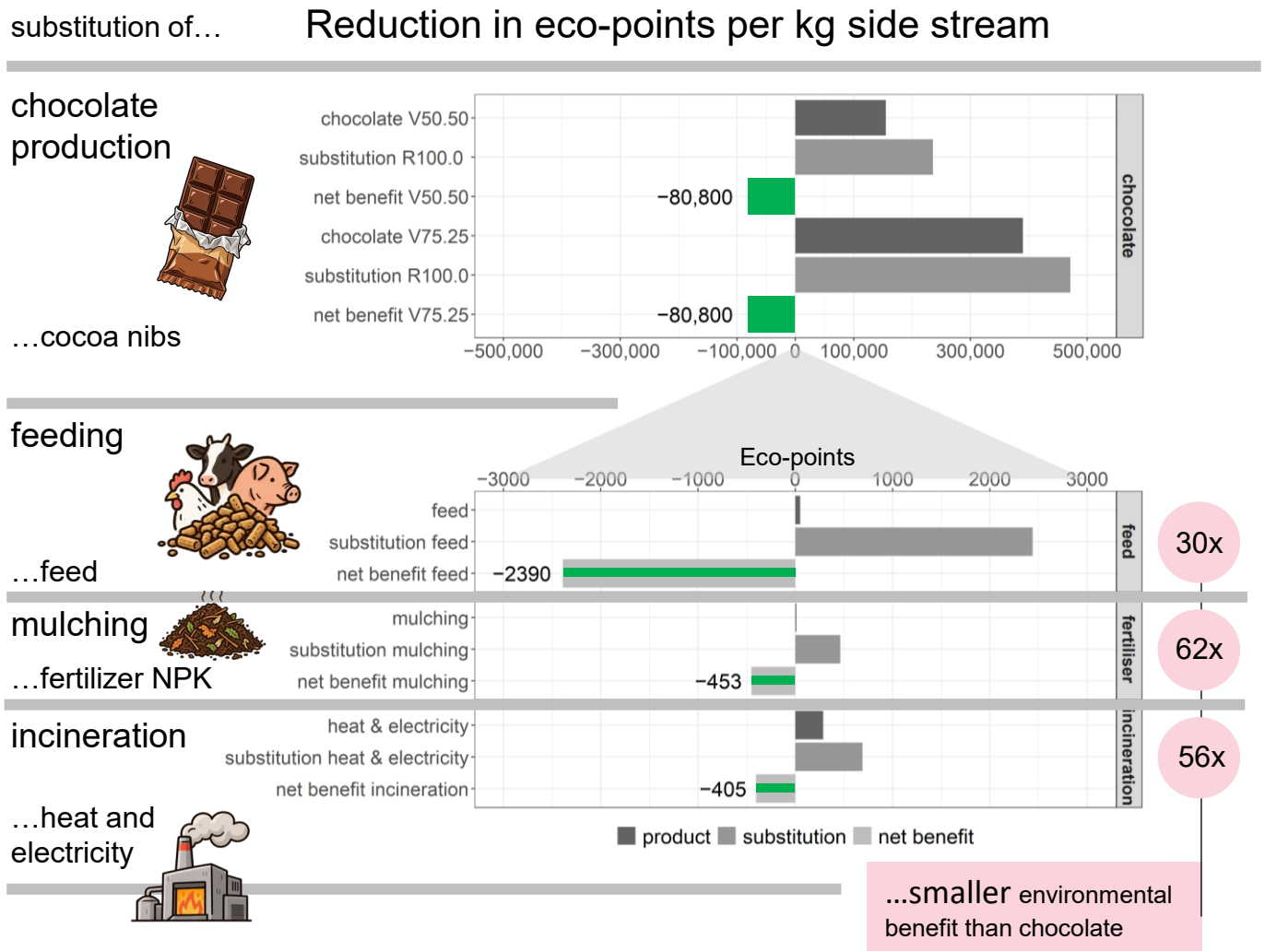






Salvatore et al. 2026a

Comparison of different valorization scenarios of cocoa bean hulls

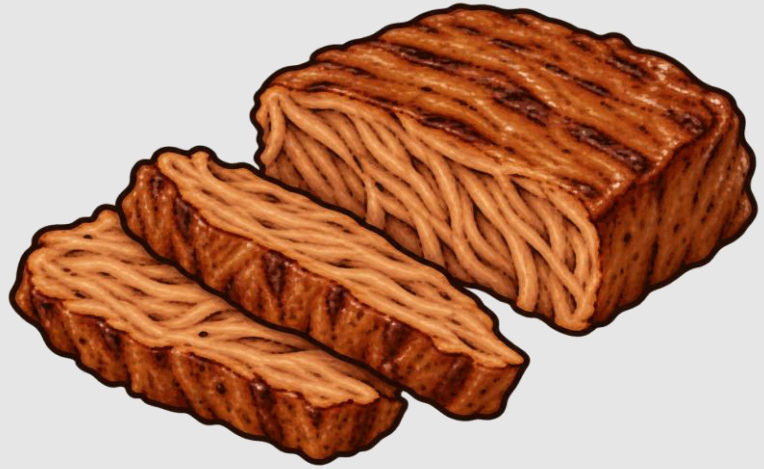


Salvatore et al. 2026a

8

High-moisture meat alternative (HMMA) with barley rootlets and spent grain

a) **Economic allocation**
   - 0.22% to Brewer Spent Grain
   - 0.02% to Barley Rootlets
   - 99.76% to Beer



Recipes

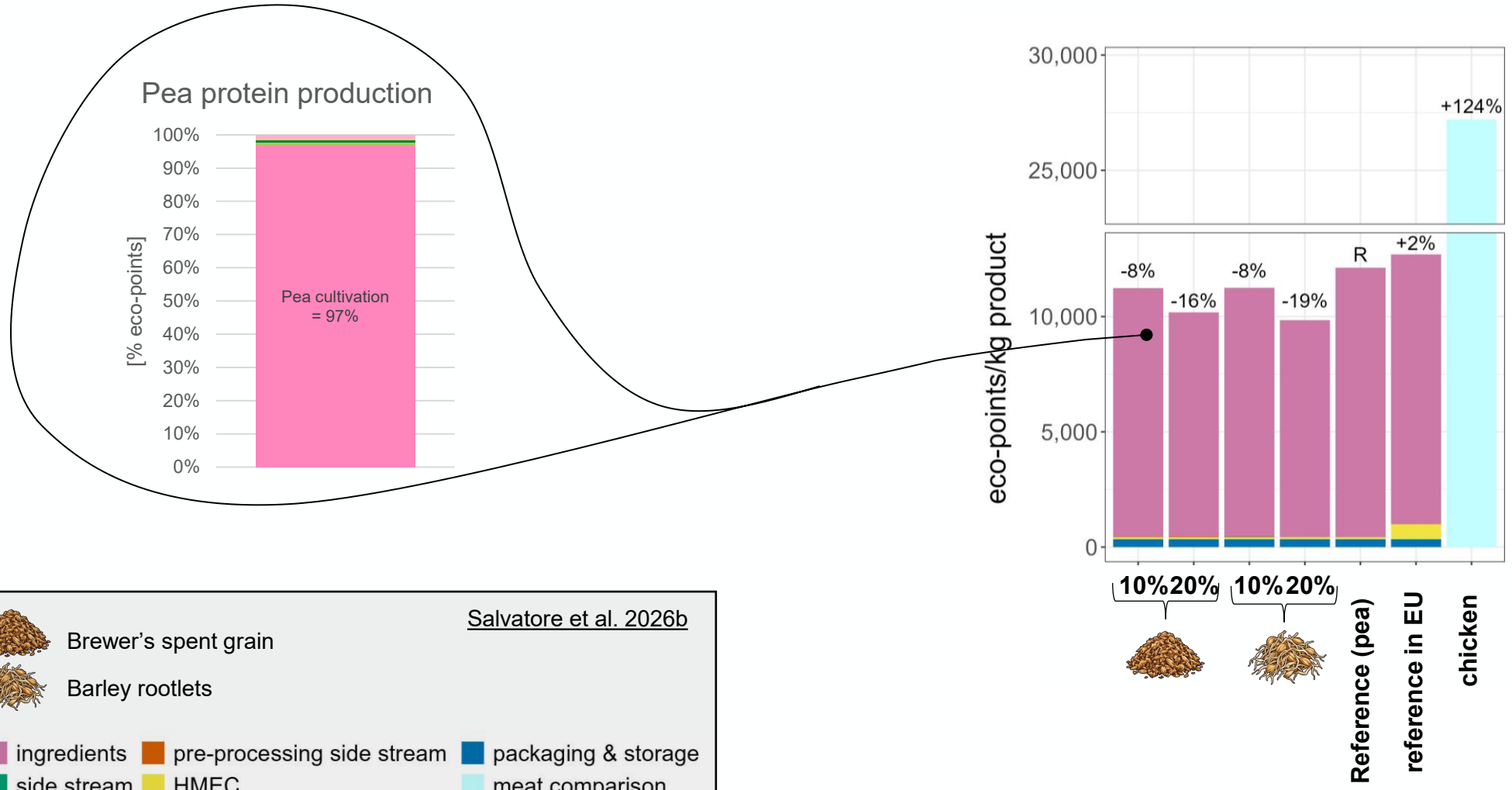


- Reference product: HHMA with pea protein
- Option 1: 10% of pea protein replaced by Brewer Spent Grain
- Option 2: 20% of pea protein replaced by Brewer Spent Grain



- Option 3: 10% of pea protein replaced by Barley Rootlets
- Option 4: 20% of pea protein replaced by Barley Rootlets

High moisture meat alternatives with beer side streams



Granola with coffee grounds and coffee silverskin

a) **Economic allocation**
   - spent coffee grounds (SCG):
     - 0.2% spent coffee grounds
     - 99.8% coffee beverage
   - coffee silverskin (CSS):
     - 0.0004% silverskin
     - 99.9996% to coffee bean

Scenarios:
- Reference granola 1
  - Recipe 1: 14.4% of ingredients are replaced by wet SCG
- Reference granola 2
  - Recipe 2: 11.5% of ingredients are replaced by dried CSS
  - Recipe 3: each 5.7% of ingredients are replaced by CSS and SCG



Granola with coffee side stream

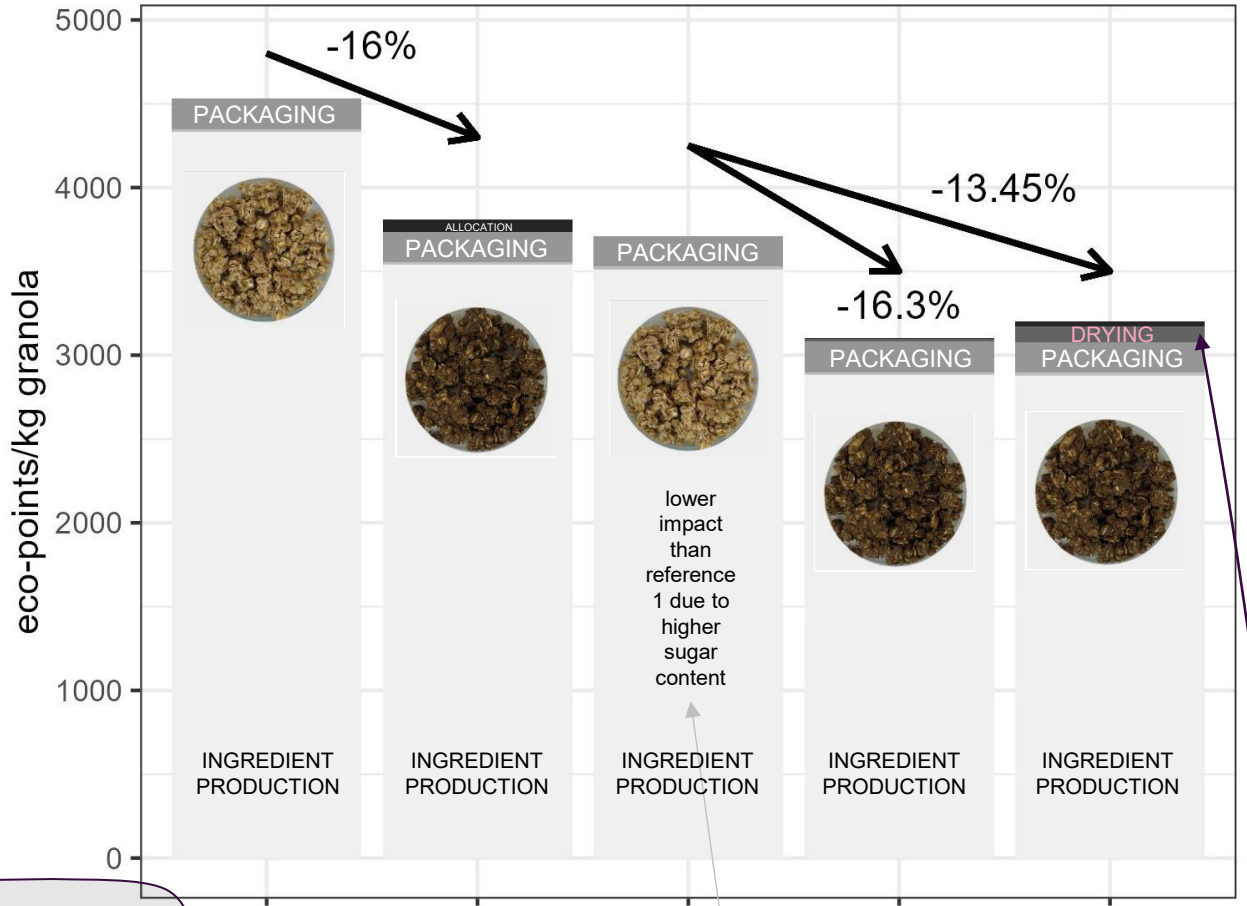
allocation
valorization of side streams
production - packaging
production - processing
production - ingredients

Spent Coffee Ground

Coffee Silver Skin

Eco-Points in this project are calculated with the Ecological Scarcity Method

Salvatore et al. 2026c



reference granola recipe:
- ca. 60% oat flakes
- sugar, sunflower oil, chopped almonds, puffed soybeans, white flour

reference 1 (18% sugar)

14.4% **(wet)**

reference 2 (29% sugar)

11.5% **(dry)**

5.7 % **(dry)** **5.7 %** **(dried)**

…of the granola reference recipe substituted by…

Granola with coffee grounds and coffee silver skin

b) System expansion with substitution

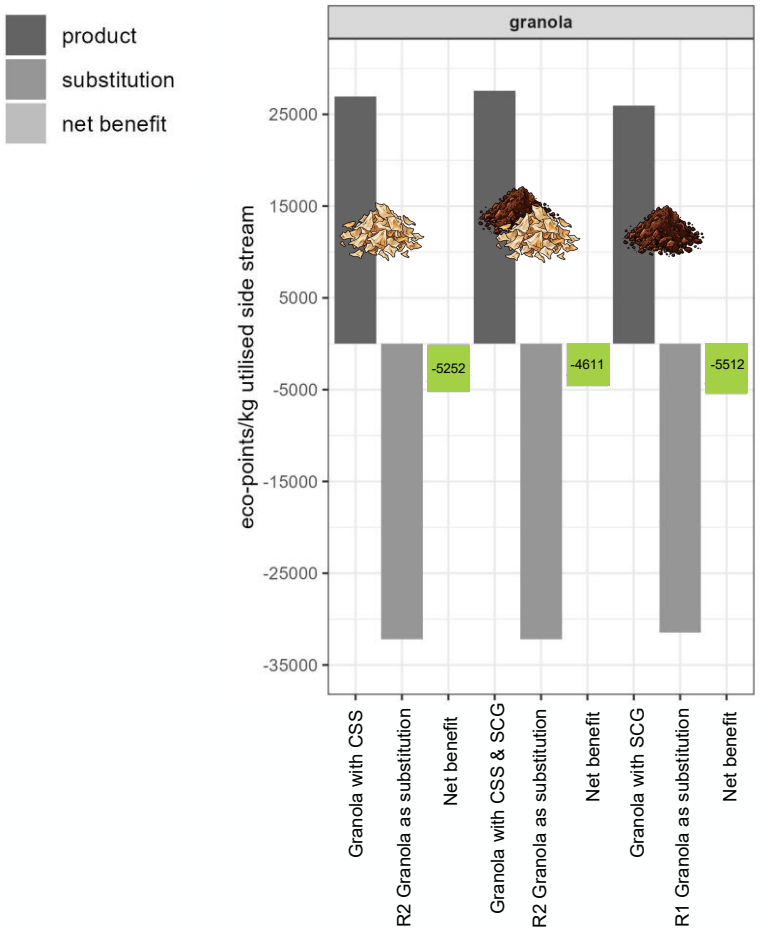
Alternative scenarios

- Mulching
  - NPK fertiliser with equivalent NPK content
- Anaerobic digestion
  - Swiss average electricity mix
  - Energy from natural gas

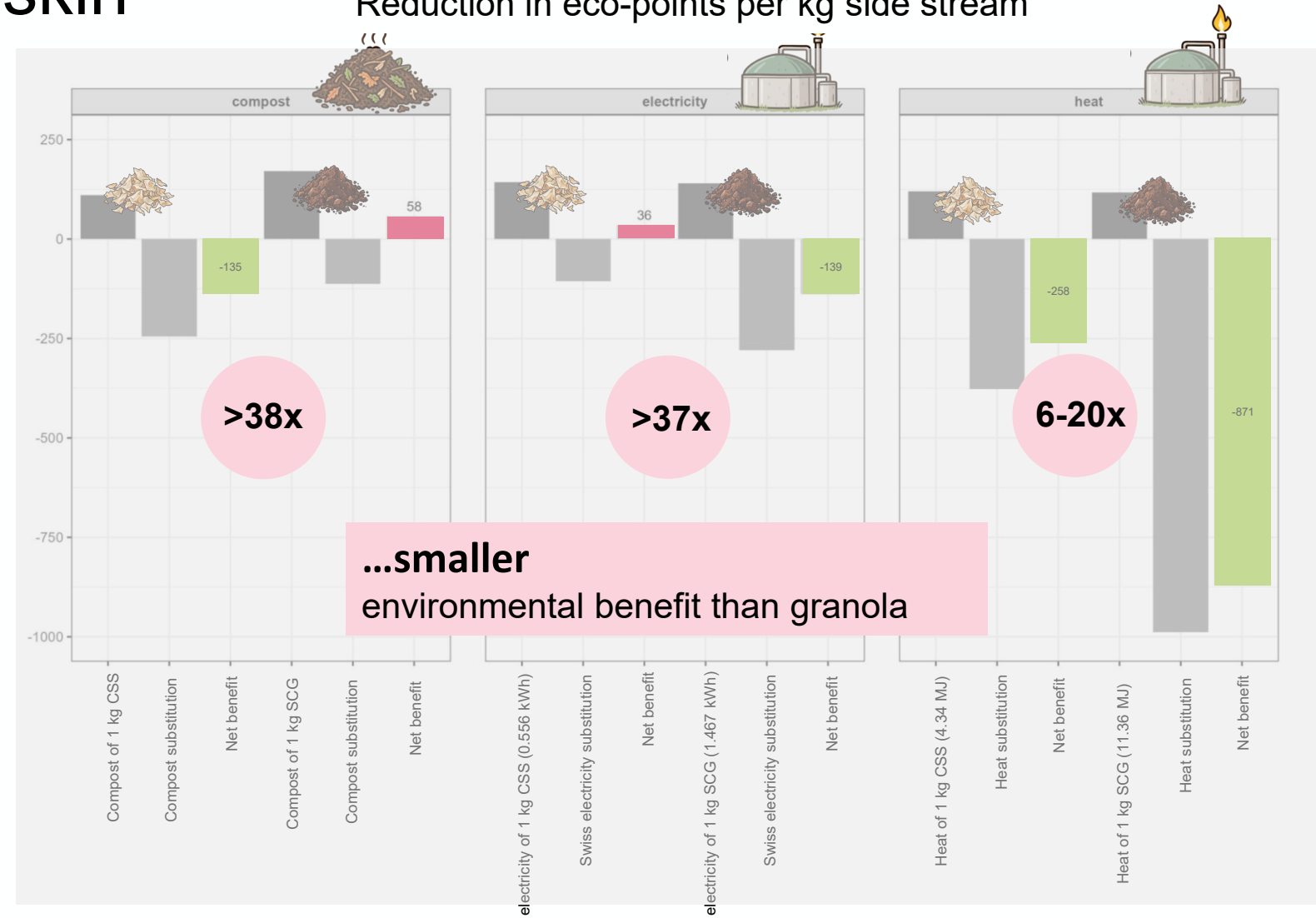


Salvatore et al. 2026c

Comparison of different valorization scenarios of spent coffee ground & coffee silver skin



Reduction in eco-points per kg side stream



Conclusion – VALISS

CHOCOLATE

16 - 32%

Reduction in eco-points

Cocoa bean hulls

MEAT ALTERNATIVE

8 - 19%

Reduction in eco-points

Brewer’s spent grain + barley rootlets

GRANOLA

14 - 16%

Reduction in eco-points

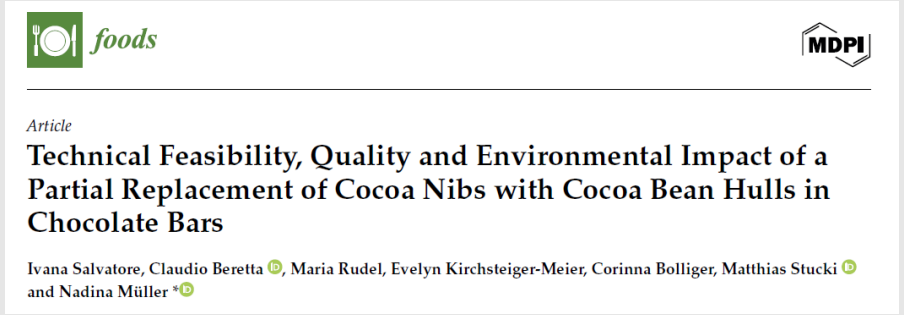
Coffee silverskin + spent coffee grounds

Valorising sidestreams in human food products offers substantial environmental benefits → dependent on formulation and substitution assumptions.

Valorization of Swiss Agri-Food Side Streams (VALISS)

Project Team

- Institute of Food and Beverage Innovation
  - Ivana Salvatore
  - Claudio Beretta
  - Evelyn Kirchsteiger-Meier
  - Marie-Louise Cezanne
  - Nadina Müller
- Institute of Natural Resource Sciences
  - Corinna Bolliger
  - Matthias Stucki
- Institute of Computational Life Sciences
  - Liridon Rama
- Others
  - Maria Rudel
  - Robin Betschart (student)


foods

MDPI

Article

Technical Feasibility, Quality and Environmental Impact of a Partial Replacement of Cocoa Nibs with Cocoa Bean Hulls in Chocolate Bars

Ivana Salvatore, Claudio Beretta, Maria Rudel, Evelyn Kirchsteiger-Meier, Corinna Bolliger, Matthias Stucki and Nadina Müller *


foods

MDPI

Article

Upcycling Brewer's Spent Grain and Barley Rootlets by Partial Substitution of Pea Protein Isolate in Extruded High Moisture Meat Analogues

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