Life Cycle Network SYMPOSIUM, 26 March 2025, Imperial College London

Filling knowledge gaps with LCA: an example of progress and challenges

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*we wish to particularly acknowledge James for carrying out the majority of the LCA work described herein

Co-funded by the Horizon 2020 programme of the European Union

Understanding the long-term effects of switching over to sweeteners and sweetness enhancers (S&SE) in the context of public health and safety, obesity ***and sustainability***

Work Package 1
Innovation and Production

Develop and produce beverages and foods with novel sweeteners and blends for use in clinical trials to support sugar reduction strategies

Develop Sweetener Databases

Technological | Health Impact | Sweetness

Regulatory Framework Exploration

Facilitators and Barriers for Sweeteners

WP2 Summary
Short term impact on food behavior, physiology and health

Phase 1 (2020-2021)

Blend selection

Testing of 3 S&SE blends (**WP1**) in liquid matrix + 1 control beverage (sucrose)

Acute (1 d) effects of S&SE in liquids

Glycaemic and lipaemic response
Feeding behaviour
Subjective appetite, food preference, cravings, reward, 24h food intake.
Health effects
Rebound hunger, G.I. and metabolic side effects)

Phase 2 (2021-2022)

Blend testing

Testing of 2-3 S&SE blends (**Phase 1**) in 5 solid matrices + 1 control product per matrix

Acute & short-term (14 d) effect of S&SE in solids

Glycaemic and lipaemic response
Feeding behaviour (as for Phase 1 but 8h food intake)
Gut-brain & cephalic response biomarkers
Sub-studies Brain activity; Meal micro-structure; Health effects (incl. microbiota changes); Microbiological safety

Methodological platform (WP2/3)
Sweet receptor polymorphism prevalence (WP1)
Consumer perspectives/drivers (WP6)

Urine biomarker validation (WP4)

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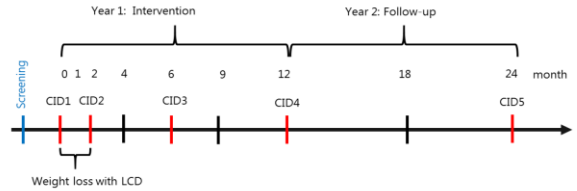
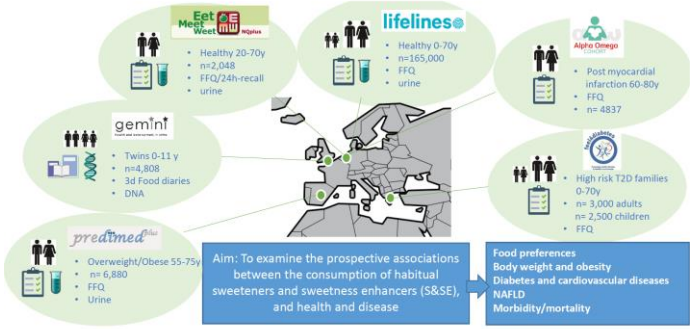
WP3
Long-term clinical trial



N=660 participants in total (330 adults & children) (n ~ 165/centre)
4 clinical trial centres:

- University of Copenhagen, DK (lead) – Anne Raben
- University of Harokopio, GR (co-lead) – Yannis Mannios
- University of Maastricht, NL – Ellen Blaak
- University of Navarra, ES – J. Alfredo Martinez

WP4. Population-based studies on sugar, sweeteners and health (lead: WU)



WP5 – Sustainability

Life Cycle Sustainability Assessment (LCSA) – ***integrated assessment*** combining environmental LCA, social LCA and Life Cycle Costing (LCC)

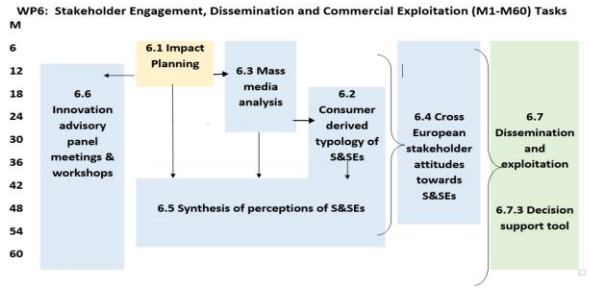
Sustainable Development

Life Cycle Sustainability Assessment

http://www.unep.org/publications/contents/pub_details_search.asp?ID=6236

and a 4th 'dimension' – Governance ?

WP6: Stakeholder Engagement, Dissemination and Commercial Exploitation



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SWEET

Co-funded by the Horizon 2020 programme of the European Union

LCA/LCSA structure and Partners:
UNIS (Lead), BLONK (Co-lead), CARG, ONIRIS, EUROFIR

Environmental LCA on S&SEs in selected case-studies

Social LCA (sLCA)

Life Cycle Costing (LCC)

Life Cycle Sustainability Assessment (LCSA) - integration and extension
- Integrate aLCA, sLCA& LCC results under the UNEP LCSA framework
- Complementary sustainability perspectives e.g. UN-SDGs, value chain

Transfer LCA/LCSA inventory data and methods to external public users

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Sweetener life cycle - in brief

Production

Ingredients

Products

Retail

Consumption

Disposal

Environment

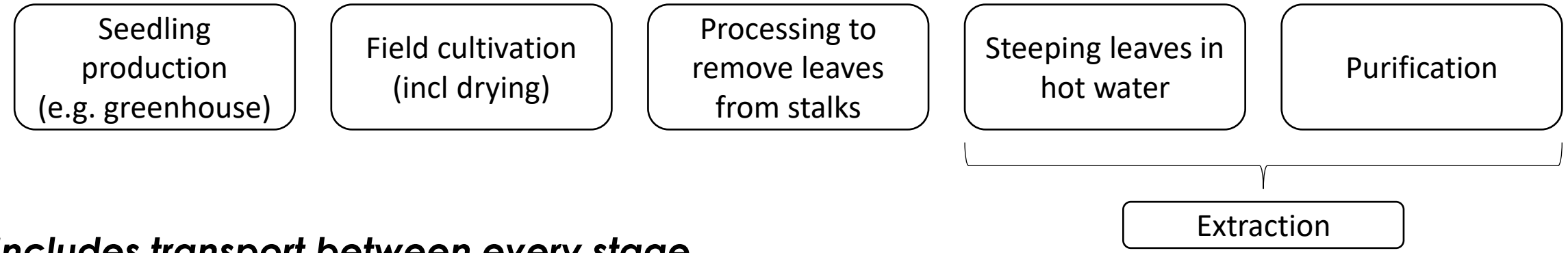
Society

Economy

Example - Steviol glycosides (EU prodⁿ)

Steviol glycosides production from leaf (life cycle)

Global production of steviol glycoside from leaf follows the same basic process:



Includes transport between every stage

Production from leaf in China is similar, but with different yields and energy sources.

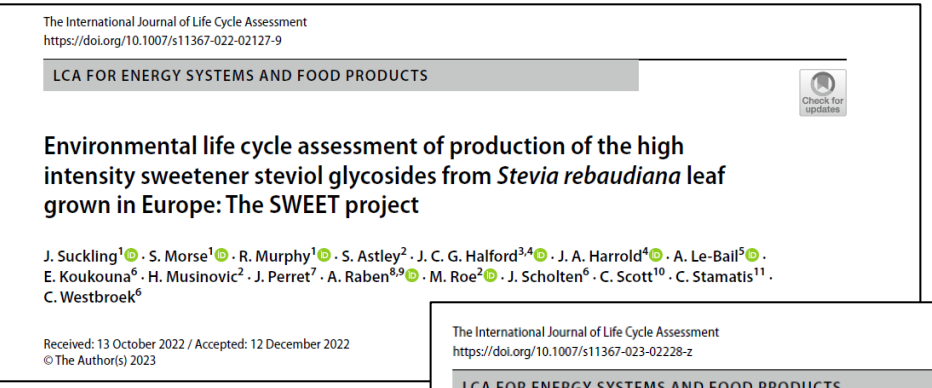
The sweeteners & sweetness enhancers

4 sweeteners & 1 sweetness enhancer have been assessed: *All now published and in the public domain*

Plant-based:
Stevia Rebaudioside A (Reb A)
Thaumatin

"Hybrid":
Sucralose

Artificial:
Aspartame
Neotame


The International Journal of Life Cycle Assessment
https://doi.org/10.1007/s11367-022-02127-9

LCA FOR ENERGY SYSTEMS AND FOOD PRODUCTS

Environmental life cycle assessment of production of the high intensity sweetener steviol glycosides from *Stevia rebaudiana* leaf grown in Europe: The SWEET project

J. Suckling[1] · S. Morse[1] · R. Murphy[1] · S. Astley[2] · J. C. G. Halford[3,4] · J. A. Harrold[4] · A. Le-Bail[5] · E. Koukouna[6] · H. Musinovic[2] · J. Perret[7] · A. Raben[8,9] · M. Roe[2] · J. Scholten[6] · C. Scott[10] · C. Stamatis[11] · C. Westbroek[6]

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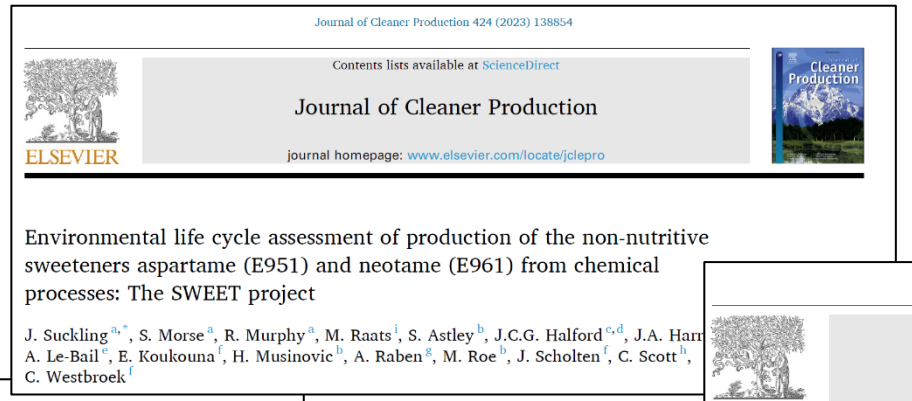
LCA FOR ENERGY SYSTEMS AND FOOD PRODUCTS

Environmental life cycle assessment of production of the non-nutritive sweetener sucralose (E955) derived from cane sugar produced in the United States of America: The SWEET project

E. Blenkley[1] · J. Suckling[1] · S. Morse[1] · R. Murphy[1] · M. Raats[10] · S. Astley[2] · J. C. G. Halford[3,4] · J. A. Harrold[4] · A. Le-Bail[5] · E. Koukouna[6] · H. Musinovic[2] · A. Raben[7,8] · M. Roe[2] · J. Scholten[6] · C. Scott[9] · C. Westbroek[6]


Journal of Cleaner Production 424 (2023) 138854

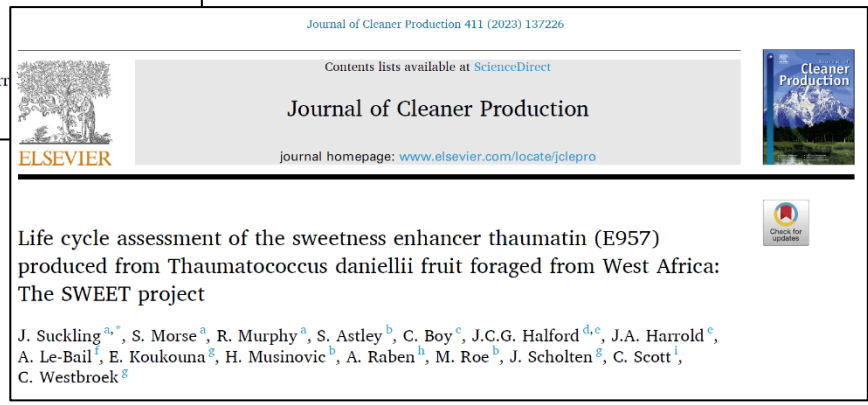
Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Environmental life cycle assessment of production of the non-nutritive sweeteners aspartame (E951) and neotame (E961) from chemical processes: The SWEET project

J. Suckling[a,*], S. Morse[a], R. Murphy[a], M. Raats[i], S. Astley[b], J.C.G. Halford[c,d], J.A. Harr
A. Le-Bail[e], E. Koukouna[f], H. Musinovic[b], A. Raben[g], M. Roe[b], J. Scholten[f], C. Scott[h],
C. Westbroek[f]


Journal of Cleaner Production 411 (2023) 137226

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Life cycle assessment of the sweetness enhancer thaumatin (E957) produced from Thaumatococcus daniellii fruit foraged from West Africa: The SWEET project

J. Suckling[a,*], S. Morse[a], R. Murphy[a], S. Astley[b], C. Boy[c], J.C.G. Halford[d,e], J.A. Harrold[e], A. Le-Bail[f], E. Koukouna[g], H. Musinovic[b], A. Raben[h], M. Roe[b], J. Scholten[g], C. Scott[i], C. Westbroek[g]

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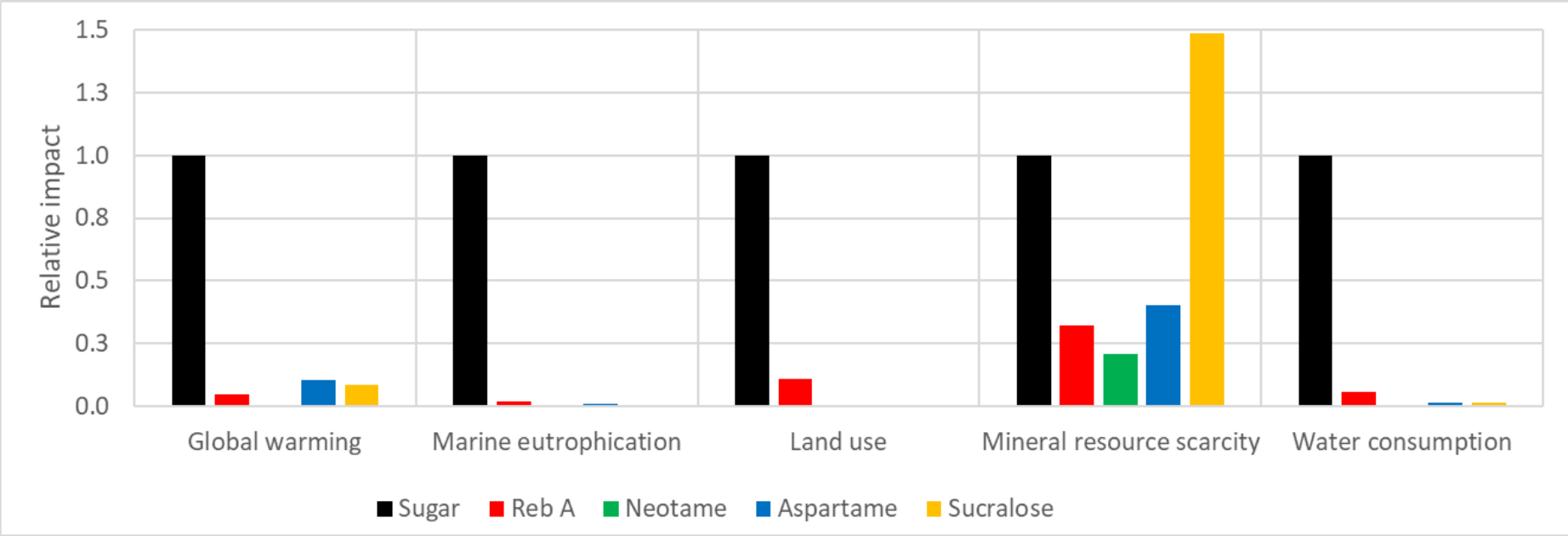
Environmental impact

Impact of sweeteners compared to sugar in terms of sweetness equivalence.
Impact data is normalised to 1 kg sugar.

Sweeteners have lower environmental impact across nearly all categories



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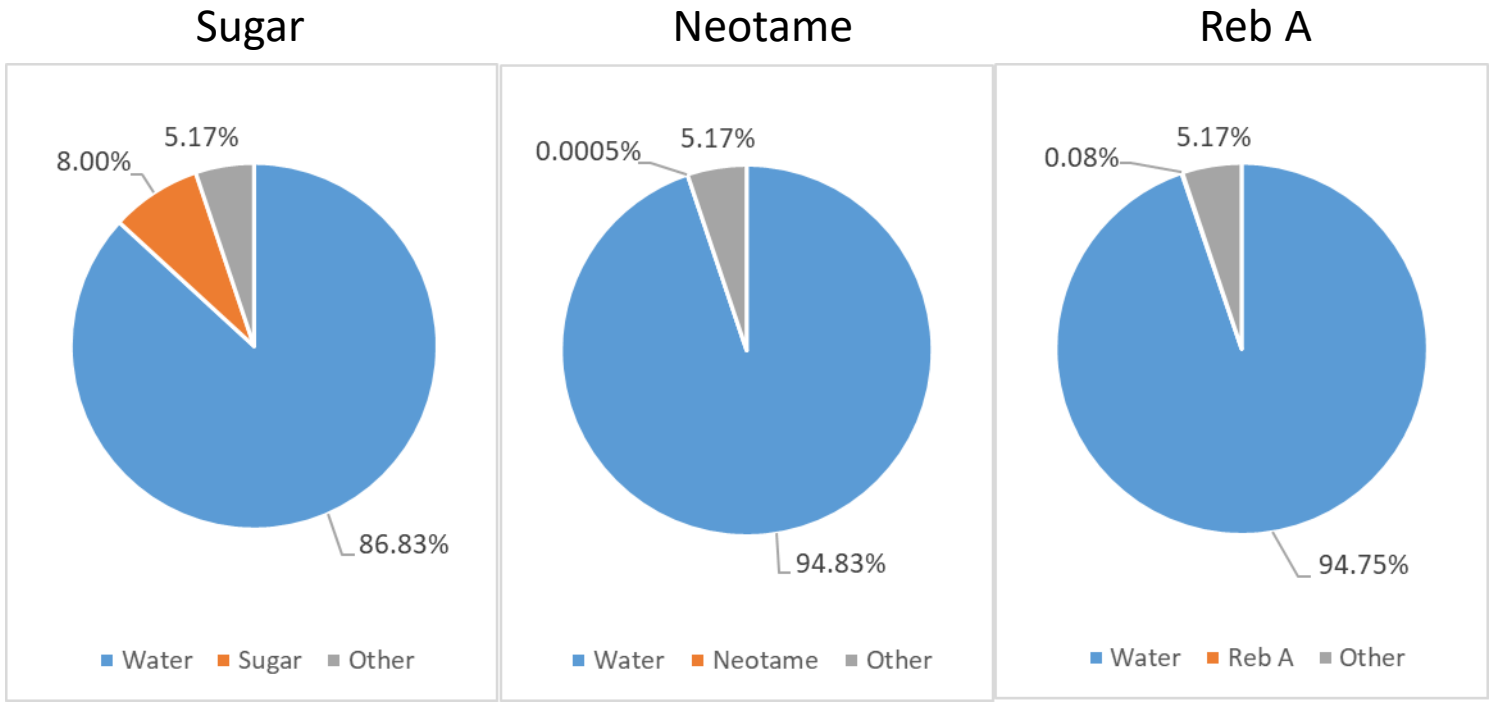
Drinks: Formulation

Drink formulation by fraction

The difference is really between:

i) Sugar

ii) Sweetener + some more water



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Drinks: Impact

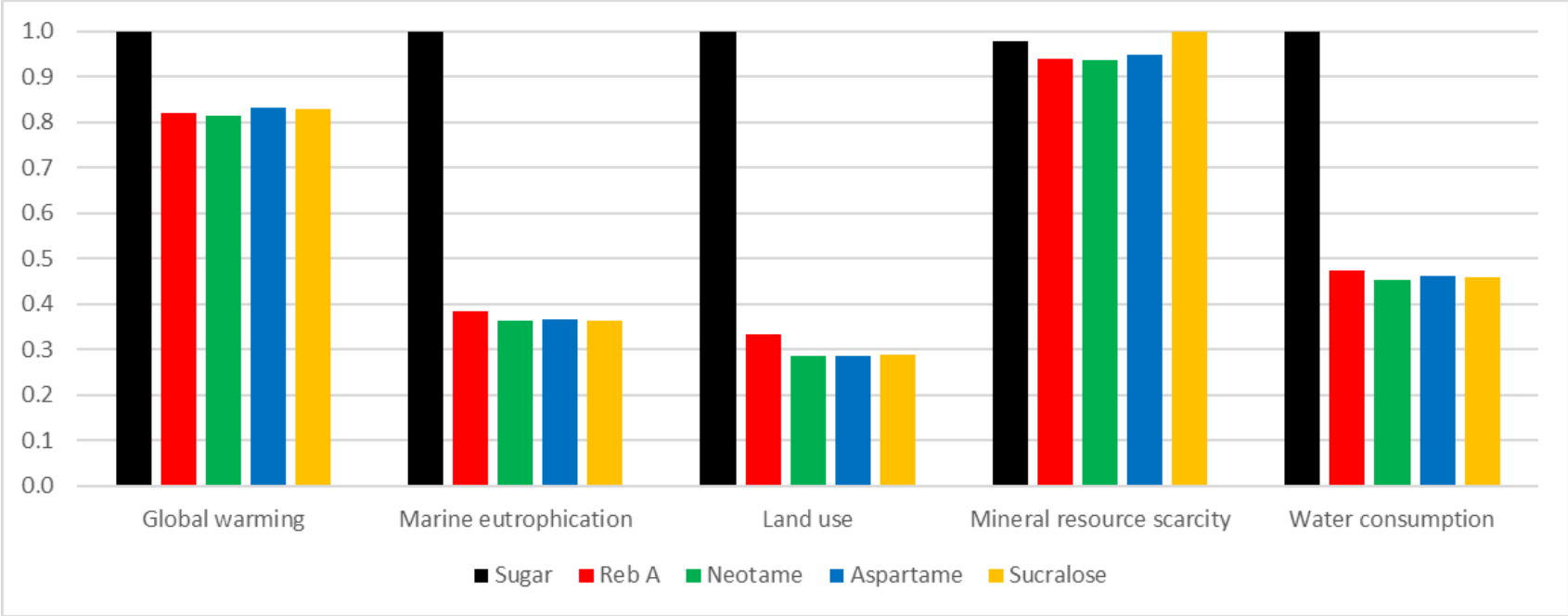
Environmental impact is <u>reduced</u> when sugar is replaced

This is observed across all impact categories.

Example data:
- Global warming potential

Sugar drink:
0.61 $kgCO_2$-eq/kg

Non-sugar drink:
~ 0.51 $kgCO_2$-eq/kg



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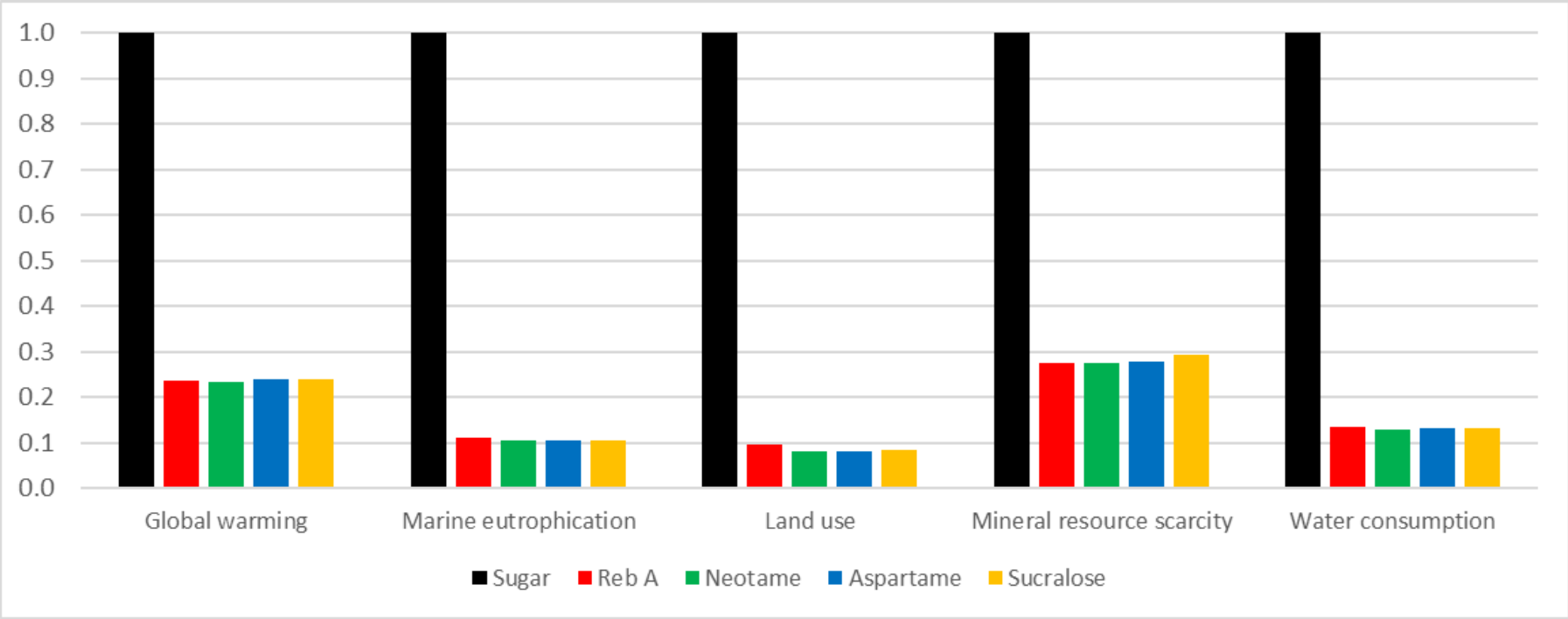
Drinks: Impact

Environmental impact is <u>reduced</u> when sugar is replaced – this is even more so on a calorie density basis (12.7 vs 44.2 kcal/100g for sweetener or sugar drink)



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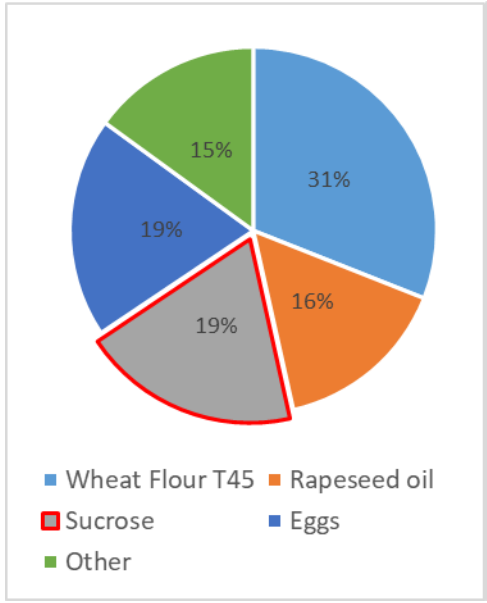
Biscuits: Formulation

Fractional replacement biscuit dough and fruit filling

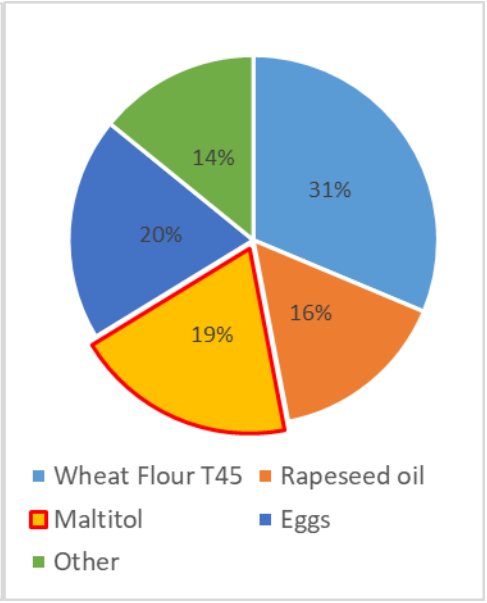
Sweeteners are added to fruit filling only

Dough (25g)

Sugar

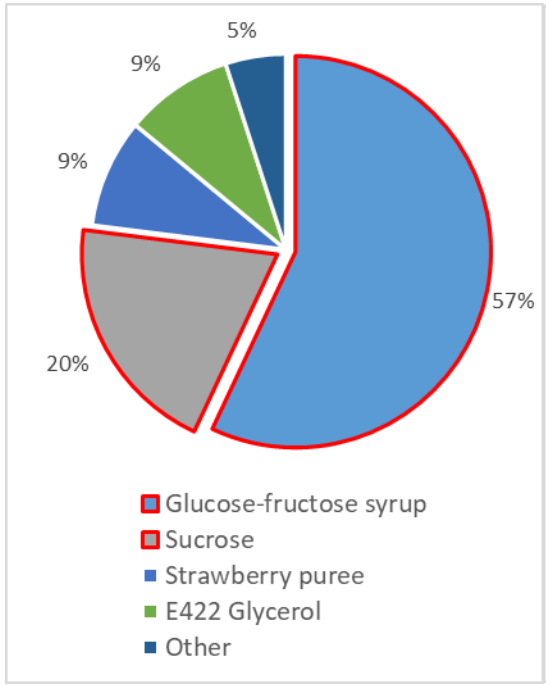


Sweetener

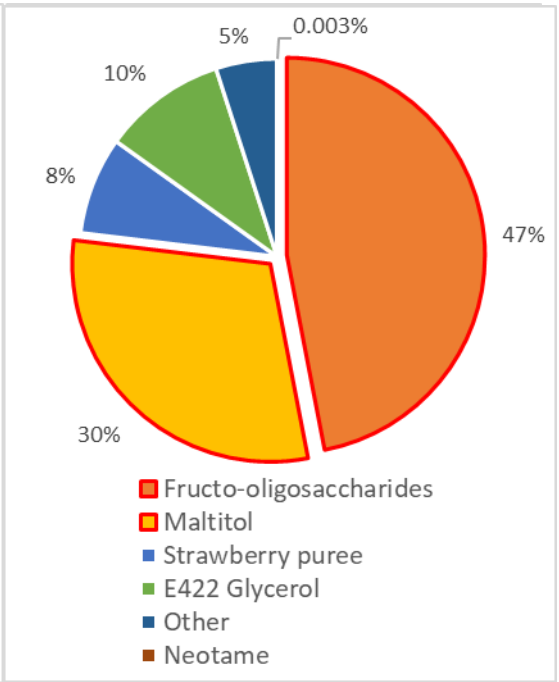


Fruit filling (5g)

Sugar



Neotame



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Biscuits: Impact

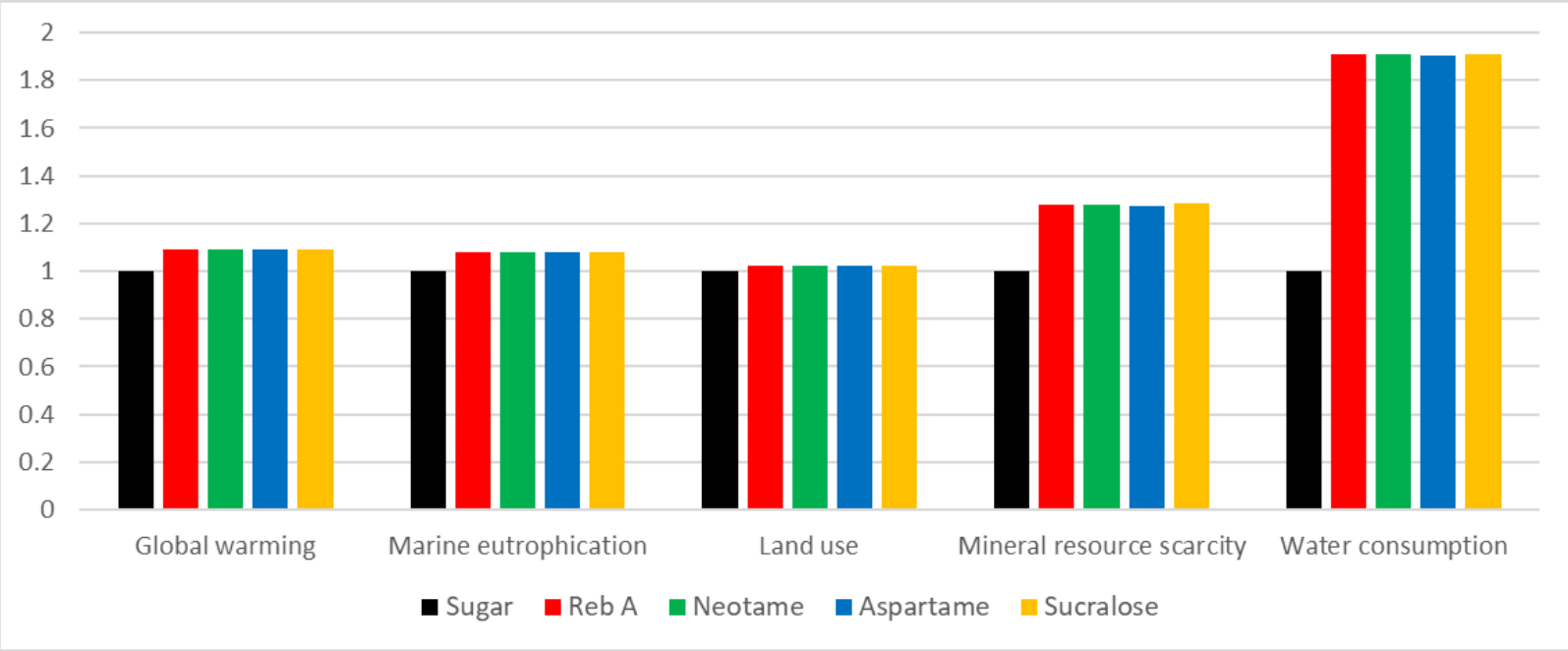
Environmental impact <u>increased</u> when sugar is replaced.
Increase is because the impact of sugar is less than that of maltitol

This is observed across all impact categories.

Example data:
- Global warming potential

Sugar biscuit:
2.72 $kgCO_2$-eq/kg

Non-sugar biscuit:
~ 2.97 $kgCO_2$-eq/kg



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The Bulking agents: another knowledge gap solved

Process simulation modelling used to generate detailed LCI data for sorbitol and maltitol

Now recently published in JCP 2025

Journal of Cleaner Production 494 (2025) 144985

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Environmental life cycle assessment of producing sorbitol and maltitol from wheat starch using process simulation: The SWEET project

J. Suckling [a,h,*], G. Brussino [b], E. Koukouna [b], N. Misailidis [c], A. Koulouris [i], D. Petrides [c], S. Morse [a,h], M. Raats [d,h], J. Scholten [b], C. Westbroek [b], J.C.G. Halford [e,f], J.A. Harrold [f], A. Raben [g], R. Murphy [a,h]

[a] Centre for Environment and Sustainability, University of Surrey, Guildford, UK
[b] Blonk Consultants, Gouda, the Netherlands
[c] Intelligen Inc., Freehold, NJ, 07728, USA
[d] School of Psychology, University of Surrey, Guildford, UK
[e] School of Psychology, University of Leeds, Leeds, UK

Achievements and 'misses'

- **Novel LCI data and LCA outcomes on S&SEs in drinks, yoghurts and bakery goods**
- **Recognition of the 'formulation' role – significance of bulking agents**
- **Extension of the findings to the 'whole diet' level – in progress**
- **Extension of the results to the public health / societal level** X

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Consumption

1) Need to put foodstuffs in context of a whole diet setting.

Work is currently on-going with Blonk partner using Optimeal.

2) WHO report of health effects of sweeteners.

Findings do not appear to be significant/consistent across all health effects.

From the Life Cycle Sustainability Assessment perspective, it is not possible to draw definitive conclusions.

Reference: RIOS-LEYVRAZ, M. & MONTEZ, J. 2022. Health effects of the use of non-sugar sweeteners: a systematic review and meta-analysis. Geneva, Switzerland: World Health Organization. ISBN: 978-92-4-004642-9. URL: https://www.who.int/publications/i/item/9789240046429

Take-aways from SWEET's sustainability work

When sugar is replaced….. BOTH the sweetness and the bulk, technical function must be replaced

Reformulation to replace technical functions **is a more important driver of environmental impact change than the specific sweetener used.**

For water-based drink – environmental impact is reduced
For solid foods - environmental impact can be increased

The Functional Unit for the LCA is important (mass, serving, caloric, etc….)

Dietary level modelling - shortly

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Thanks to the partners

and more info at https://sweetproject.eu/

Co-funded by the Horizon 2020 programme of the European Union