

Supplementary file to manuscript:

**Dietary fiber as nutritional and sustainable
malt substitute for reducing glycemic load in
non-alcoholic beer**

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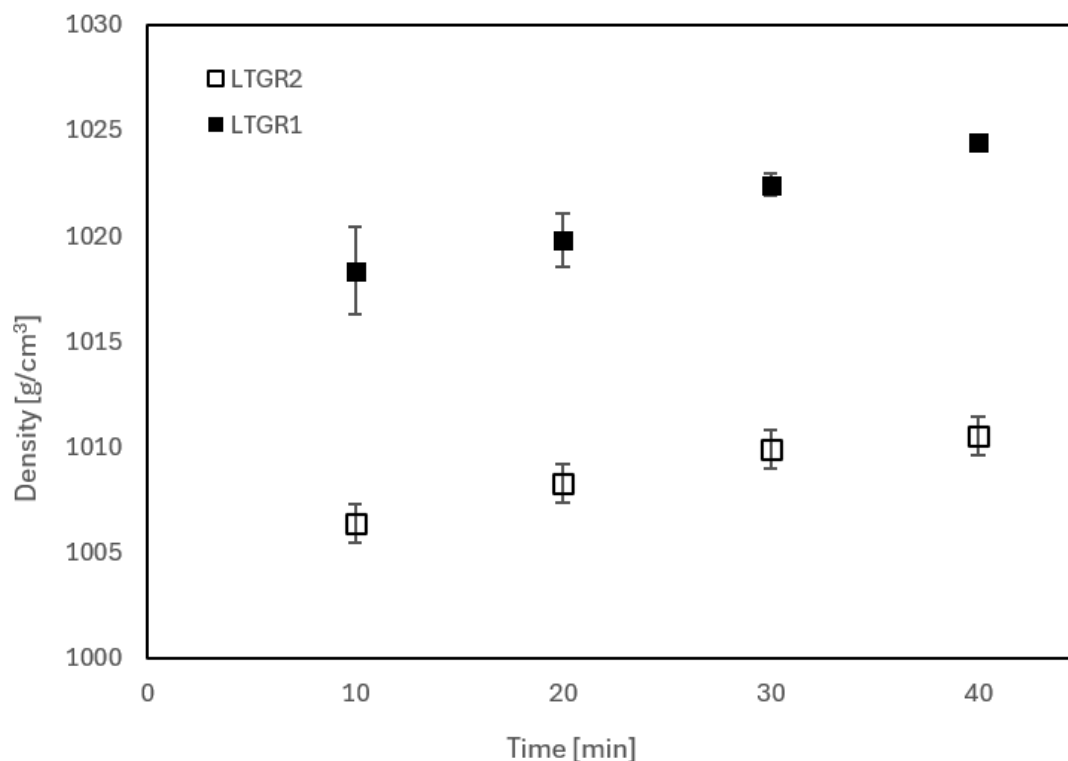
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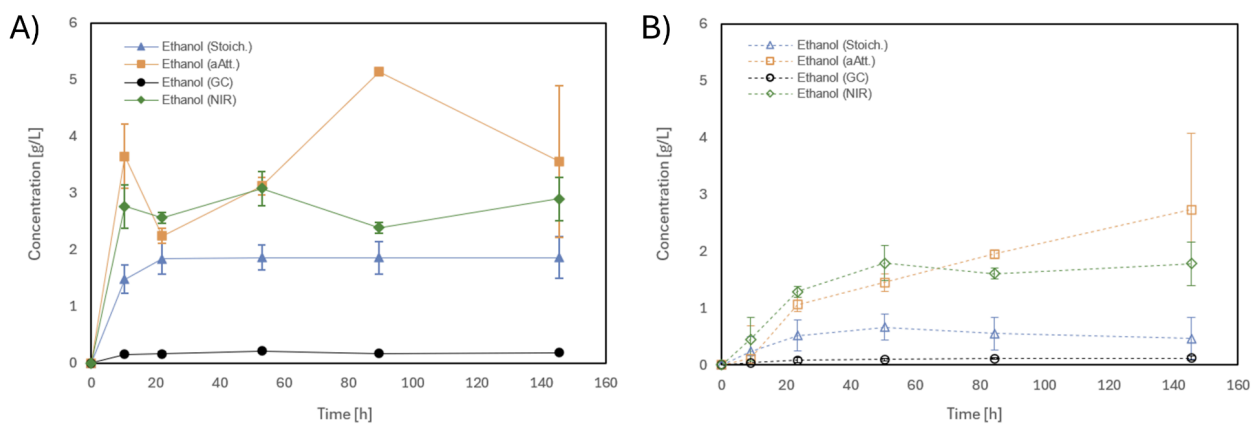
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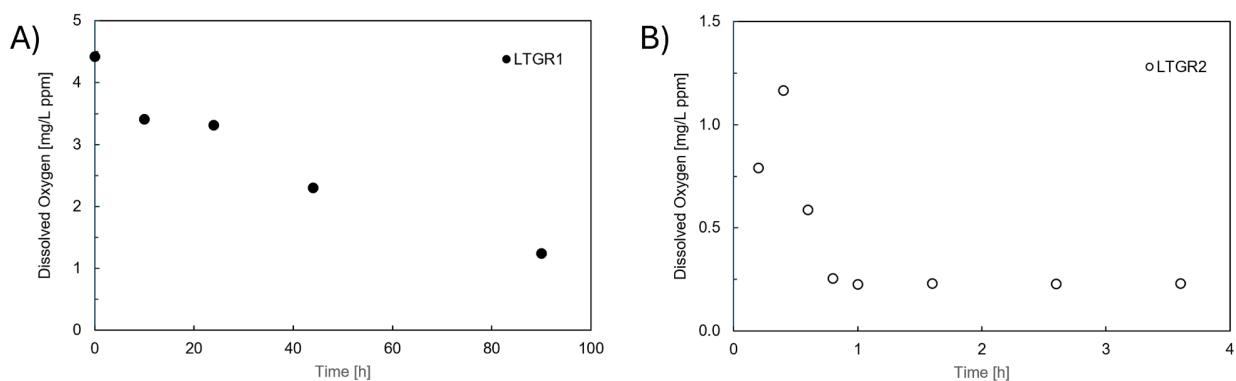
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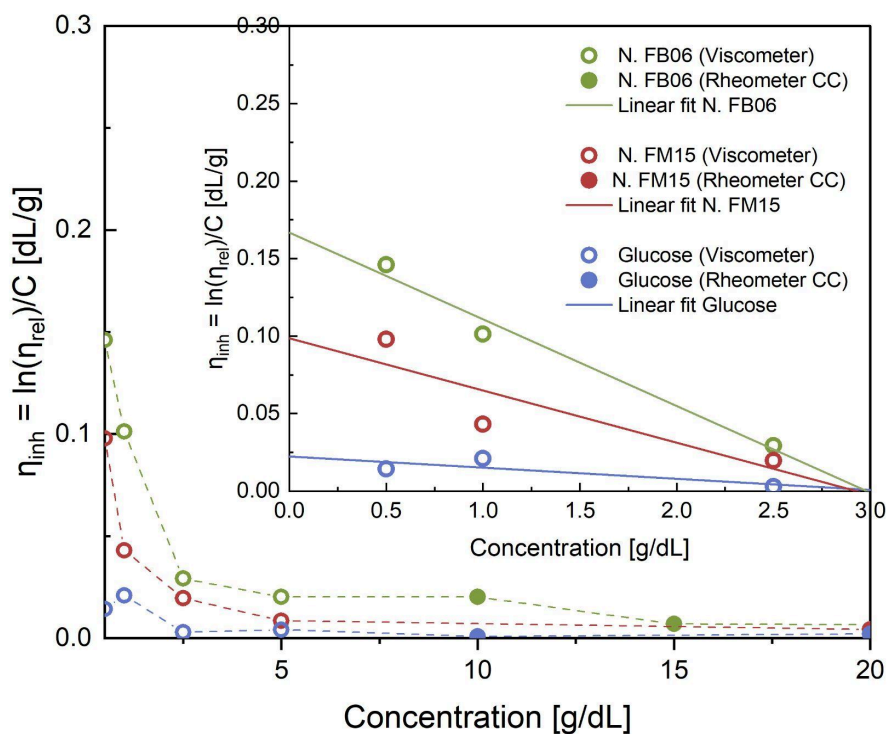
S.Fig.1: Wort density values as a function of mashing time for LTGR1 and LTGR2. For both LTGR1 (B1-3), and LTGR2 (B4.1-4.3), n=3 true replicates are displayed.



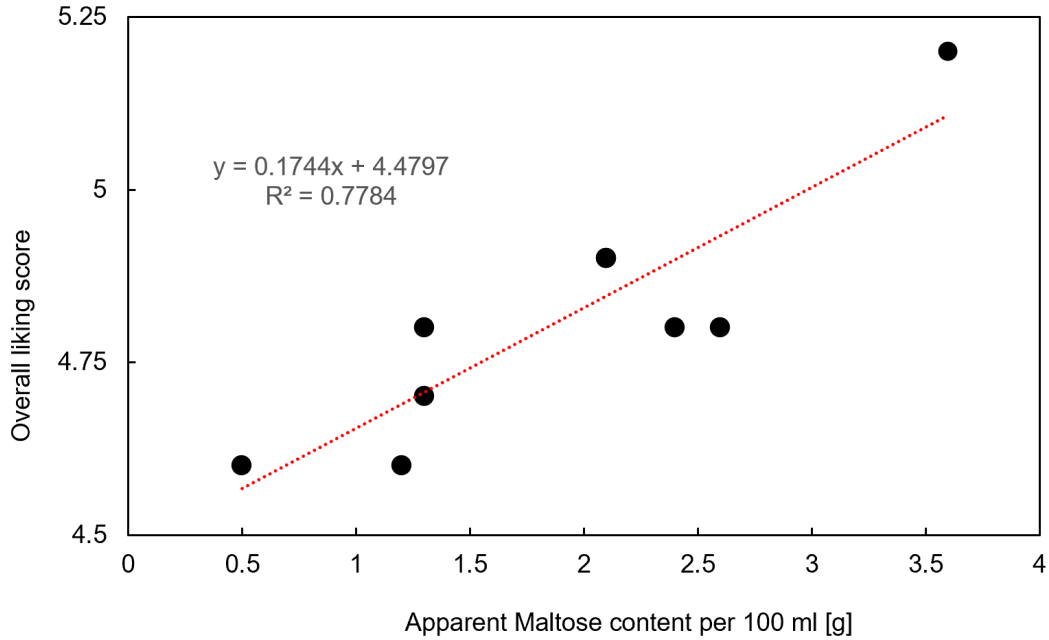
S.Fig.2: The ethanol concentration as a function of fermentation time for A) LTGR1 and B) LTGR2. NIR refers to NIR measurement, GC to gas chromatography measurement, Stoich. to the stoichiometric determination via glucose consumption and aAtt. to the determination via apparent attenuation. For both LTGR1 (B1-3), and LTGR2 (B4.1-4.3), n=3 true replicates are displayed.



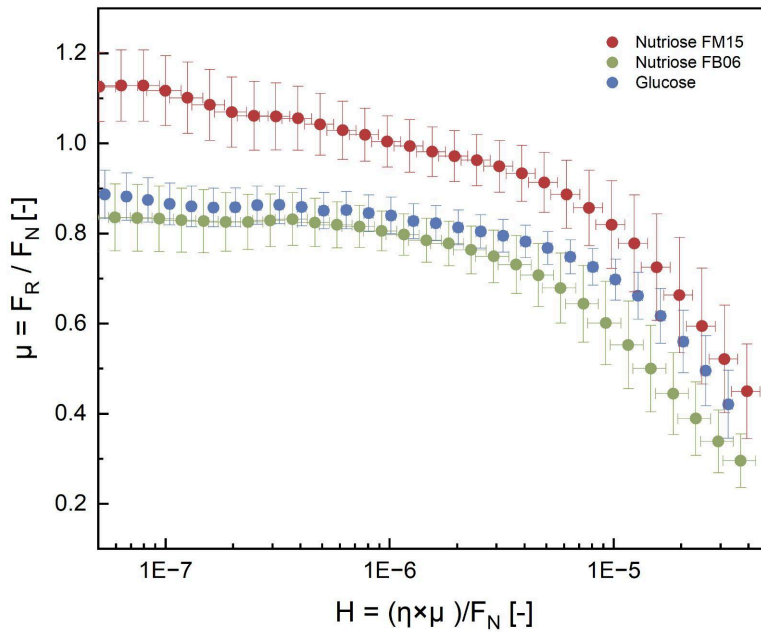
S.Fig.3: Dissolved Oxygen concentrations as a function of fermentation time for A) LTGR1 and B) LTGR2 with one single replicate.



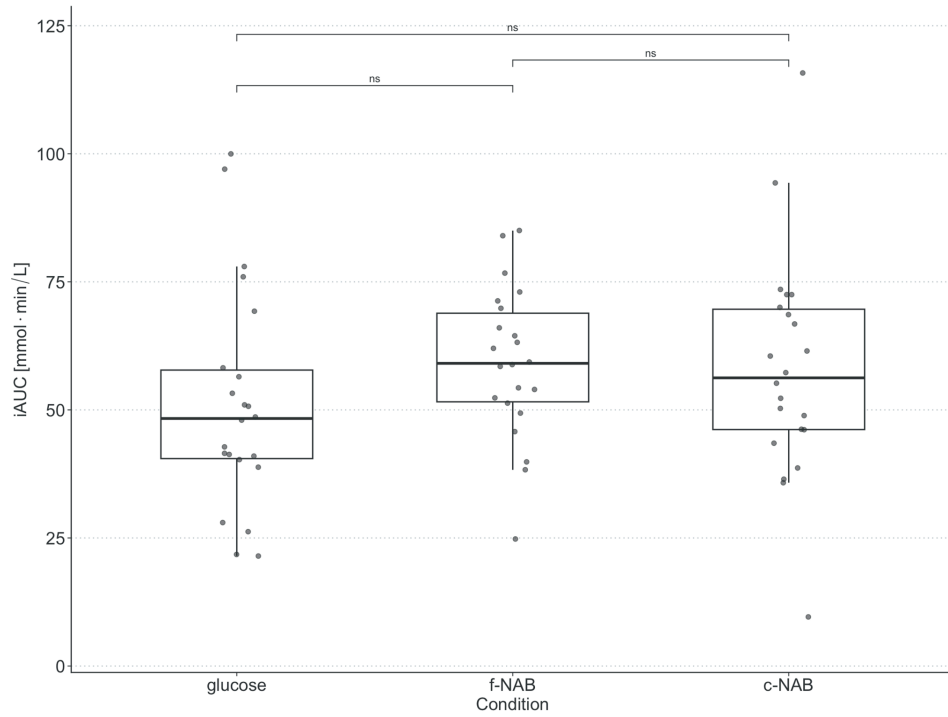
S.Fig.4: Inherent viscosity as a function of concentration for glucose, Nutriose FM15 and Nutriose FB06 (Kraemer plot). Open symbols represent Ubbelode capillary viscometer measurements (n = 3 replicates), whereas closed symbols represent rheometer measurements obtained using a CC geometry (n = 2 independent replicates). The y-axis intercept of the linear fit corresponds to the intrinsic viscosity.



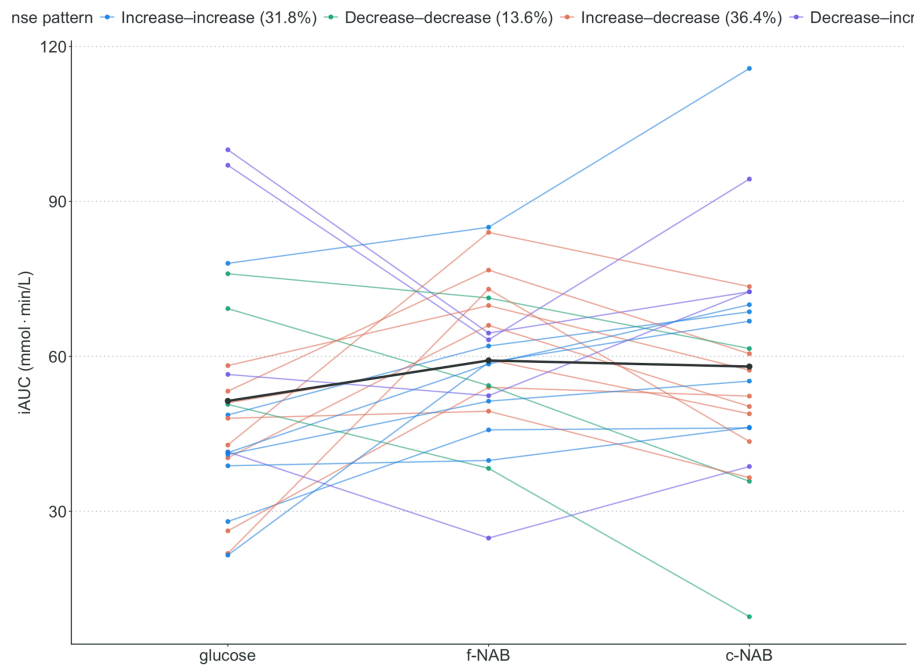
S.Fig.5: Linear dependency of overall liking score and apparent maltose concentration of NAB and AFB. The red line is a regression line of the data points. The overall liking score ranges from 1 to 6 with 1 being very poor liking and 6 being high liking. The data of the taste evaluation is collected from: Alkoholfreie Biere im Test: Kein Bier fällt durch. Retrieved August 22, 2024, from <https://www.srf.ch/sendungen/kassensturz-espresso/tests/bierdegustation-alkoholfreie-biere-im-test-kein-bier-faellt-durch>.



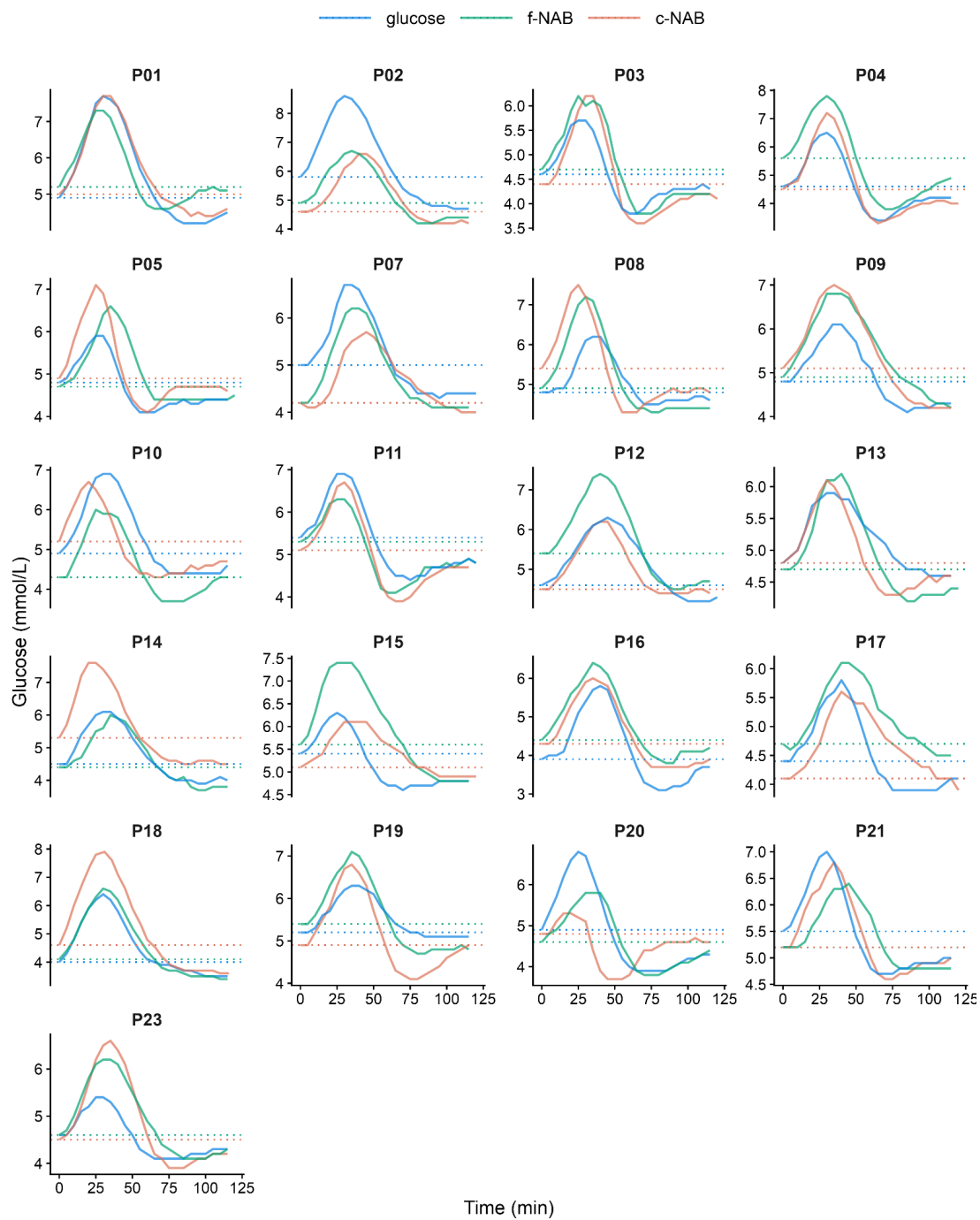
S.Fig.6: Friction coefficient as a function of the Hersey number for glucose, Nutriose FM15 and Nutriose FB06.



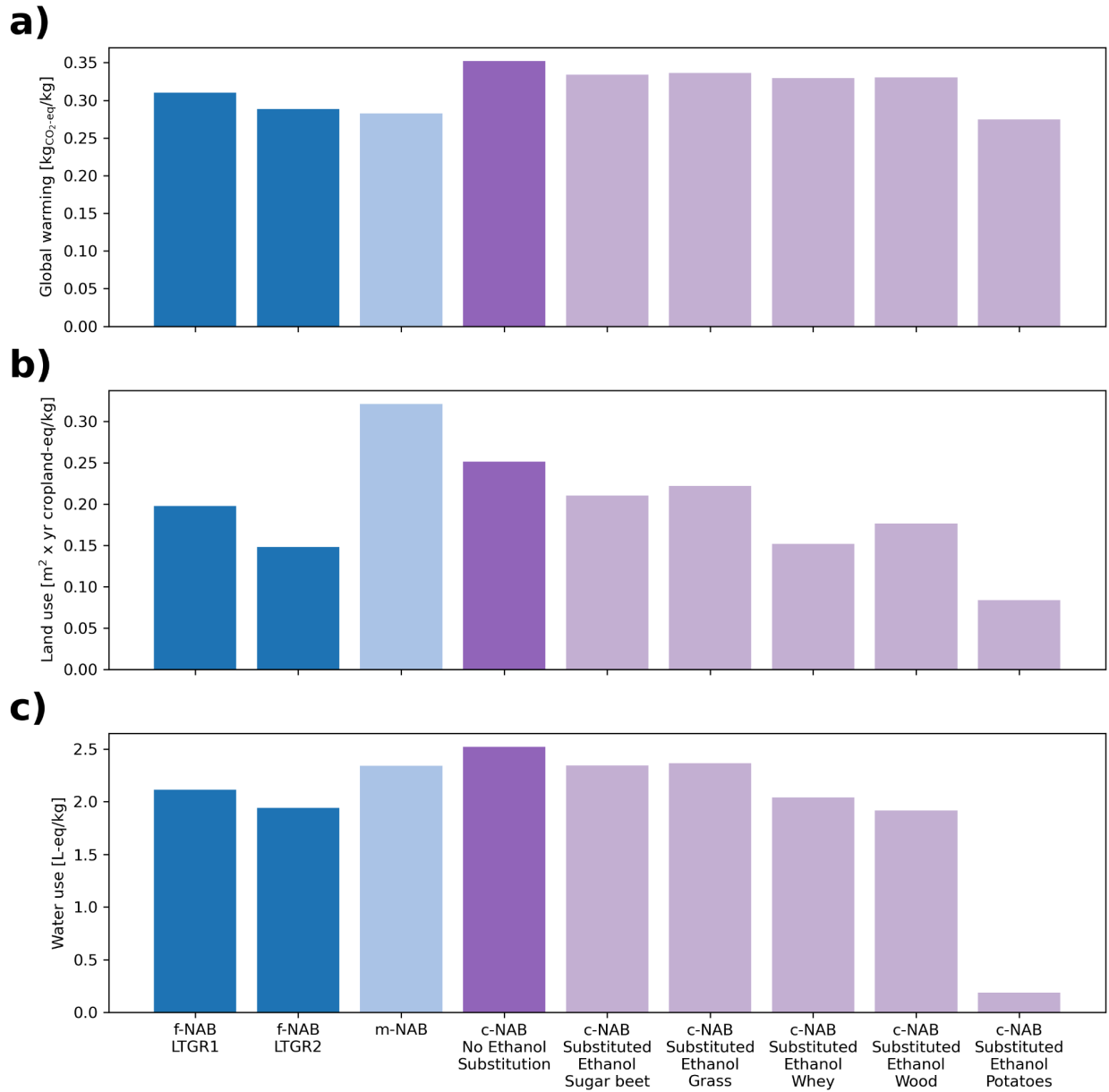
S.Fig.7: Box-and-whisker plots of the calculated iAUC across beverage interventions. Horizontal box lines show the 25th (lower line), 50th (bold line), and 75th (top line) percentile and the whiskers the respective 5th and 95th percentile.



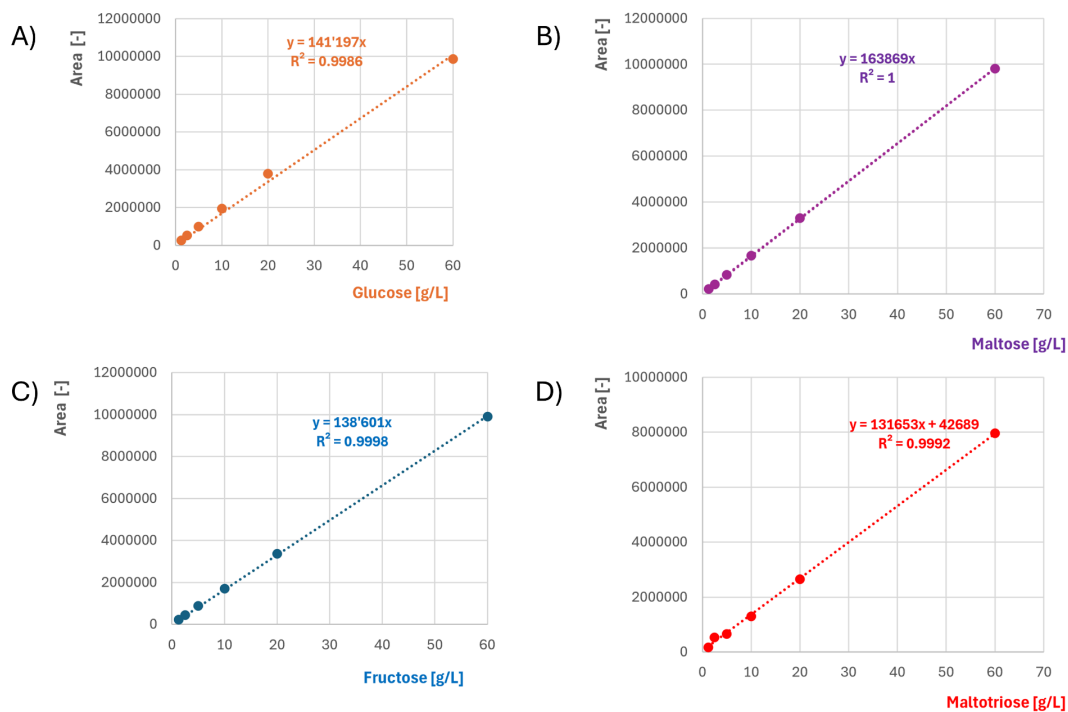
S.Fig.8: Spaghetti plot with individual iAUC trajectories based on relative mean iAUC values moving from glucose to f-NAB to c-NAB. The bold black line indicates the mean iAUC value for each intervention.



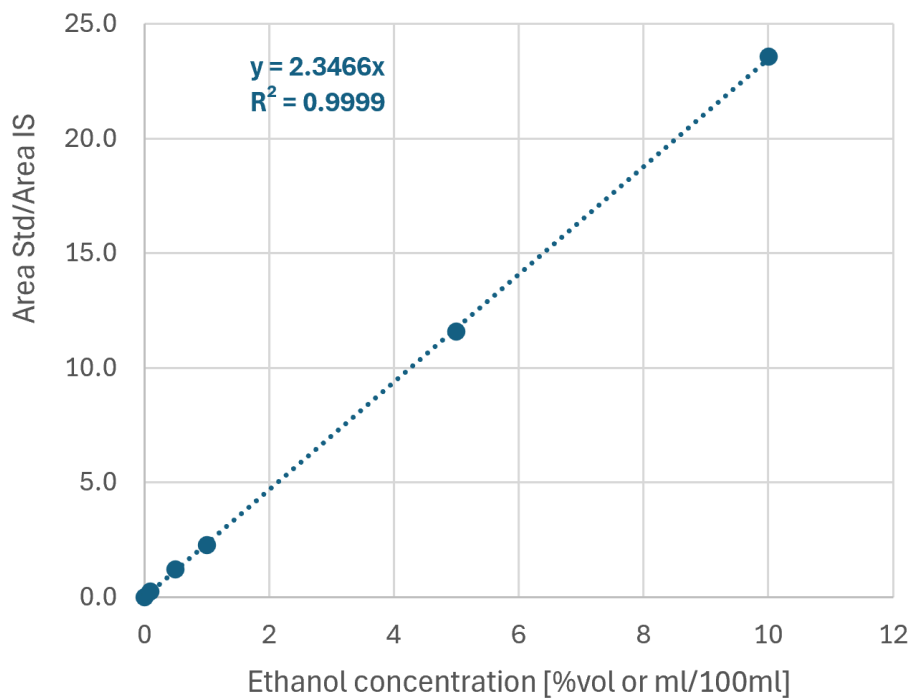
S.Fig.9: Individual glucose curves after the intake of glucose, c-NAB and f-NAB of each participant of the intervention study.



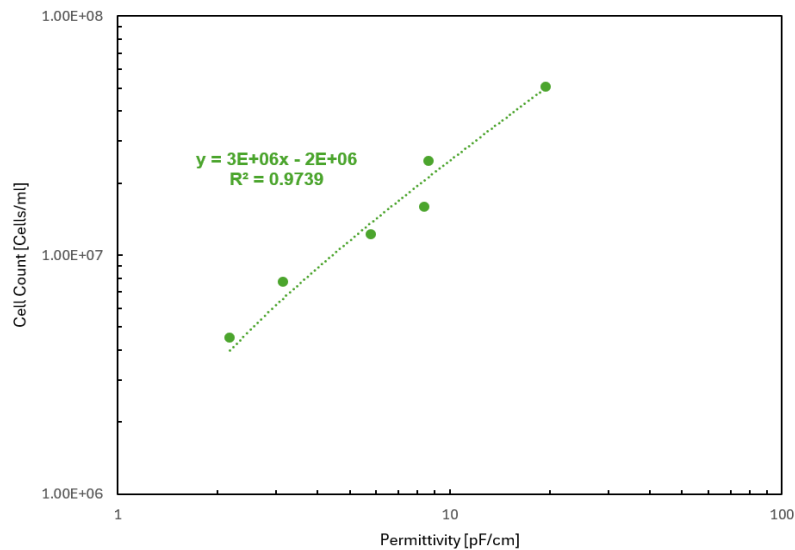
S.Fig.10: Comparison of environmental impacts of NABs with substitution of ethanol. Environmental impacts for (a) global warming, (b) land use, and (c) water use of 1 kg non-alcoholic beer with high malt content (m-NAB), fiber-rich non-alcoholic beer as used for sensory testing (f-NAB LTGR1), fiber-rich non-alcoholic beer as used for measuring glycaemic load (f-NAB LTGR2) (all three produced with maltose-negative yeast to inhibit ethanol formation), and non-alcoholic beer produced by conventional brewing with subsequent alcohol removal by nanofiltration and distillation (c-NAB). Additionally, the impacts of c-NAB are shown under the assumption that the removed ethanol is reused in alcoholic beverages where it substitutes food-grade ethanol from primary production methods.



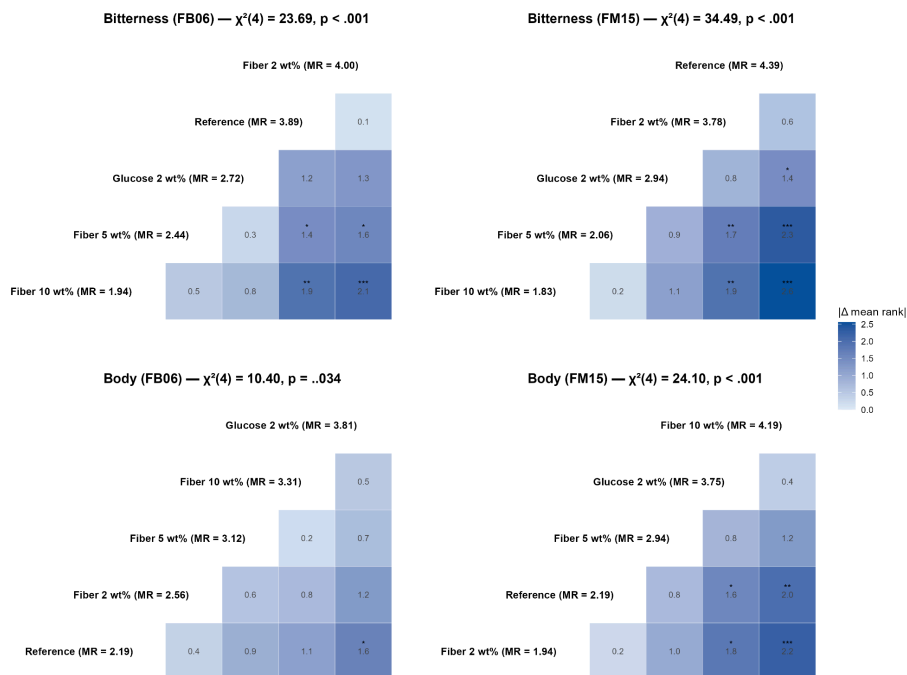
S.Fig.11: HPLC-RID calibration curves of A) glucose, B) maltose, C) fructose and D) maltotriose.



S.Fig.12: GC-FID calibration curve of ethanol.



S.Fig.13: Calibration curve of the measured permittivity data points with the total cell count. The total cell count was obtained with the haemocytometer.



S.Fig.14: Sensory differences in bitterness and body between fiber-enriched NAB (f-NAB) formulations and glucose-free and glucose-containing sample. Heatmaps show pairwise absolute differences in mean ranks (Δ mean rank) for bitterness and body obtained from ranking series with FB06 and FM15. Higher ranks indicate higher perceived bitterness or body. Products are ordered according to their mean rank within each ranking series. Diagonal tiles report the mean rank (MR) of each product. Friedman test statistics are reported in the panel titles. Asterisks denote significant pairwise differences according to the Nemenyi post hoc test (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Table S.1: Total digestible carbohydrate content, sugar profile, dietary fiber content and composition of samples used for intervention study. * denotes residual extract with FB06 contribution

	Wort LTGR1	Wort LTGR2	Ratio (LTGR2/LTGR1)
Glucose [g/l]	3.779 ± 0.137	1.436 ± 0.431	0.380
Maltose [g/l]	11.584 ± 2.004	3.704 ± 1.279	0.320
Maltotriose [g/L]	0.931 ± 0.127	0.291 ± 0.103	0.312
Density [g/cm ³]	1.0226 ± 0.002	1.01234 ± 0.001	0.545*

LCA results for all Recipe 2016 midpoint (H) indicators

Table S.2: Environmental impacts of c-NAB Environmental impacts for all Recipe 2016 midpoint (H) impact categories for the production of non-alcoholic beer by conventional brewing with subsequent alcohol removal via nanofiltration and distillation (c-NAB). The values from climate change (CC), land use (LU), and water use (WU) were used to produce Figure 7 in the main manuscript. Abbreviations: TA - Terrestrial acidification; CC - Climate change; FE - Freshwater ecotoxicity; ME - Marine ecotoxicity; TE - Terrestrial ecotoxicity; FRS - Fossil resource scarcity; FEU - Freshwater eutrophication; MEU - Marine Eutrophication; HTc - Human Toxicity: carcinogenic; HTnc - Human Toxicity: non-carcinogenic; IR - Ionising Radiation; LU - Land use; MRS - Material resource scarcity; OD - Ozone Depletion; PMF - Particulate Matter Formation; POFhh - Photochemical Oxidation Formation: human health; POFte - Photochemical Oxidation Formation: terrestrial ecosystems; WU - water use.

	Hop cultivat ion	Hop extracti on from pellets	Hop pelletin g	Barley cultivat ion	Malting	Yeast product ion	Isoamy l acetate product ion	Brewin g	Nanofil tration & Distillat ion
TA [kg SO ₂ -eq]	3.8E-06	2.4E-08	1.1E-07	9.6E-04	1.4E-05	1.0E-05	1.2E-07	2.3E-04	5.7E-05
CC[kg CO ₂ -eq]	9.0E-04	2.8E-05	1.7E-05	8.7E-02	2.4E-02	9.1E-04	3.3E-05	1.5E-01	9.1E-02
FE [kg 1,4-DC B-eq]	5.0E-05	1.0E-06	8.0E-06	3.9E-03	1.9E-04	1.5E-04	3.0E-06	8.5E-03	1.3E-03
ME [kg 1,4-DC B-eq]	6.4E-05	2.0E-06	1.0E-05	5.3E-03	2.6E-04	2.0E-04	4.0E-06	1.1E-02	1.7E-03
TE [kg 1,4-DC	2.8E-03	2.7E-05	1.7E-04	2.8E-01	5.5E-03	6.1E-03	1.0E-04	2.9E-01	3.2E-02

B-eq]										
FRS [kg oil-eq]	2.5E-04	1.0E-05	3.0E-06	1.9E-02	8.8E-03	2.6E-04	1.3E-05	4.8E-02	3.3E-02	
FEU [kg P-eq]	2.0E-07	1.5E-09	8.3E-09	2.0E-05	5.7E-07	2.9E-07	7.5E-09	2.2E-05	2.6E-06	
MEU [kg P-eq]	9.9E-08	5.4E-10	1.7E-09	5.2E-04	3.6E-07	5.6E-07	9.8E-10	9.7E-06	1.4E-06	
HTc [kg 1,4-DC B-eq]	1.6E-04	2.0E-06	6.0E-06	1.6E-02	1.5E-03	1.6E-04	5.0E-06	1.9E-02	5.7E-03	
HTnc [kg 1,4-DC B-eq]	1.1E-03	1.5E-05	9.1E-05	1.4E-01	3.1E-03	2.8E-03	4.5E-05	1.3E-01	1.8E-02	
IR [kBq Co-60-e q]	3.5E-05	6.0E-06	3.1E-05	2.0E-03	4.9E-04	2.2E-04	1.0E-05	2.5E-02	4.5E-03	
LU [m ² x yr croplan d-eq]	2.3E-05	4.2E-07	2.4E-06	2.5E-01	5.7E-05	2.9E-04	1.2E-06	1.6E-03	4.0E-04	
MRS [kg CU-eq]	2.8E-05	3.8E-07	6.8E-07	2.6E-03	2.7E-04	8.8E-03	5.6E-07	8.7E-03	1.1E-03	
OD [kg CFC-11 -eq]	1.5E-09	6.3E-12	5.6E-11	1.1E-06	3.5E-09	2.6E-09	9.4E-12	7.1E-08	1.5E-08	
PMF [kg PM2.5- eq]	2.2E-06	9.2E-09	3.2E-08	2.0E-04	5.4E-06	2.6E-06	4.5E-08	8.5E-05	2.2E-05	
POFhh [kg NOx-eq]	2.0E-06	2.9E-08	3.8E-08	4.2E-04	2.3E-05	2.0E-06	6.6E-08	1.9E-04	8.7E-05	
POFte [kg NOx-eq]	2.1E-06	3.2E-08	4.0E-08	4.3E-04	2.5E-05	2.0E-06	7.3E-08	2.0E-04	9.7E-05	

WU 9.7E-03 3.2E-04 1.8E-03 6.0E-01 3.5E-02 4.5E-02 7.3E-04 1.5E+00 2.8E-01
[m³-eq]

Table S.3: Environmental impacts of m-NAB Environmental impacts for all Recipe 2016 midpoint (H) impact categories for the production of non-alcoholic beer by brewing with maltose-negative yeast and higher sugar contents from malt (m-NAB). The values from climate change (CC), land use (LU), and water use (WU) were used to produce Figure 7 in the main manuscript. Abbreviations: TA - Terrestrial acidification; CC - Climate change; FE - Freshwater ecotoxicity; ME - Marine ecotoxicity; TE - Terrestrial ecotoxicity; FRS - Fossil resource scarcity; FEU - Freshwater eutrophication; MEU - Marine Eutrophication; HTc - Human Toxicity: carcinogenic; HTnc - Human Toxicity: non-carcinogenic; IR - Ionising Radiation; LU - Land use; MRS - Material resource scarcity; OD - Ozone Depletion; PMF - Particulate Matter Formation; POFhh - Photochemical Oxidation Formation: human health; POFte - Photochemical Oxidation Formation: terrestrial ecosystems; WU - water use.

	Hop cultivation	Hop pelleting	Hop extraction from pellets	Barley cultivation	Malting	Yeast production	Brewing
TA [kg SO ₂ -eq]	2.9E-06	1.9E-08	8.8E-08	1.2E-03	1.8E-05	5.9E-06	2.2E-04
CC[kg CO ₂ -eq]	6.9E-04	2.2E-05	1.3E-05	1.1E-01	3.1E-02	5.3E-04	1.4E-01
FE [kg 1,4-DCB-e q]	3.9E-05	1.0E-06	6.0E-06	5.1E-03	2.4E-04	8.9E-05	7.9E-03
ME [kg 1,4-DCB-e q]	4.9E-05	1.0E-06	7.0E-06	6.8E-03	3.3E-04	1.1E-04	1.0E-02
TE [kg 1,4-DCB-e q]	2.2E-03	2.0E-05	1.3E-04	3.6E-01	7.1E-03	3.6E-03	2.3E-01
FRS [kg oil-eq]	1.9E-04	8.0E-06	2.0E-06	2.4E-02	1.1E-02	1.5E-04	4.6E-02
FEU [kg P-eq]	1.6E-07	1.2E-09	6.4E-09	2.5E-05	7.3E-07	1.7E-07	2.0E-05
MEU [kg P-eq]	7.6E-08	4.2E-10	1.3E-09	6.7E-04	4.7E-07	3.3E-07	8.5E-06
HTc [kg 1,4-DCB-e q]	1.2E-04	2.0E-06	5.0E-06	2.0E-02	1.9E-03	9.4E-05	1.8E-02

HTnc [kg 1,4-DCB-e q]	8.1E-04	1.1E-05	7.0E-05	1.8E-01	4.0E-03	1.6E-03	1.2E-01
IR [kBq Co-60-eq]	2.7E-05	4.0E-06	2.4E-05	2.6E-03	6.3E-04	1.3E-04	2.4E-02
LU [m ² x yr cropland- eq]	1.7E-05	3.2E-07	1.9E-06	3.2E-01	7.4E-05	1.7E-04	1.2E-03
MRS [kg CU-eq]	2.2E-05	2.9E-07	5.3E-07	3.3E-03	3.5E-04	5.1E-03	8.6E-03
OD [kg CFC-11-eq]	1.2E-09	4.8E-12	4.3E-11	1.4E-06	4.5E-09	1.5E-09	6.8E-08
PMF [kg PM2.5-eq]	1.7E-06	7.1E-09	2.4E-08	2.6E-04	6.9E-06	1.5E-06	7.8E-05
POFhh [kg NOx-eq]	1.6E-06	2.2E-08	2.9E-08	5.4E-04	2.9E-05	1.1E-06	1.8E-04
POFte [kg NOx-eq]	1.6E-06	2.4E-08	3.0E-08	5.6E-04	3.2E-05	1.2E-06	1.9E-04
WU [m ³ -eq]	7.5E-03	2.5E-04	1.4E-03	7.7E-01	4.5E-02	2.6E-02	1.5E+00

Table S.4: Environmental impacts of f-NAB LTGR1 Environmental impacts for all Recipe 2016 midpoint (H) impact categories for the production of non-alcoholic beer by brewing with maltose-negative yeast added dietary fibers as used for sensory testing (f-NAB LTGR1). The values from climate change (CC), land use (LU), and water use (WU) were used to produce Figure 7 in the main manuscript. Abbreviations: TA - Terrestrial acidification; CC - Climate change; FE - Freshwater ecotoxicity; ME - Marine ecotoxicity; TE - Terrestrial ecotoxicity; FRS - Fossil resource scarcity; FEU - Freshwater eutrophication; MEU - Marine Eutrophication; HTc - Human Toxicity: carcinogenic; HTnc - Human Toxicity: non-carcinogenic; IR - Ionising Radiation; LU - Land use; MRS - Material resource scarcity; OD - Ozone Depletion; PMF - Particulate Matter Formation; POFhh - Photochemical Oxidation Formation: human health; POFte - Photochemical Oxidation Formation: terrestrial ecosystems; WU - water use.

Hop cultivati on	Hop pelleting	Hop extractio n from	Barley cultivati on	Malting	Yeast producti on	Dextrine producti on	Brewing
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	pellets							
TA [kg SO ₂ -eq]	2.9E-06	1.9E-08	8.8E-08	6.7E-04	9.8E-06	5.9E-06	1.8E-04	2.2E-04
CC[kg CO ₂ -eq]	6.9E-04	2.2E-05	1.3E-05	6.0E-02	1.7E-02	5.3E-04	9.3E-02	1.4E-01
FE [kg 1,4-DCB-eq]	3.9E-05	1.0E-06	6.0E-06	2.7E-03	1.3E-04	8.9E-05	1.8E-03	7.9E-03
ME [kg 1,4-DCB-eq]	4.9E-05	1.0E-06	7.0E-06	3.7E-03	1.8E-04	1.1E-04	1.7E-03	1.0E-02
TE [kg 1,4-DCB-eq]	2.2E-03	2.0E-05	1.3E-04	1.9E-01	3.8E-03	3.6E-03	4.2E-02	2.3E-01
FRS [kg oil-eq]	1.9E-04	8.0E-06	2.0E-06	1.3E-02	6.1E-03	1.5E-04	3.1E-02	4.6E-02
FEU [kg P-eq]	1.6E-07	1.2E-09	6.4E-09	1.4E-05	3.9E-07	1.7E-07	1.2E-05	2.0E-05
MEU [kg P-eq]	7.6E-08	4.2E-10	1.3E-09	3.6E-04	2.5E-07	3.3E-07	3.2E-05	9.7E-06
HTc [kg 1,4-DCB-eq]	1.2E-04	2.0E-06	5.0E-06	1.1E-02	1.1E-03	9.4E-05	5.8E-03	1.8E-02
HTnc [kg 1,4-DCB-eq]	8.1E-04	1.1E-05	7.0E-05	9.6E-02	2.2E-03	1.6E-03	4.5E-02	1.2E-01
IR [kBq Co-60-eq]	2.7E-05	4.0E-06	2.4E-05	1.4E-03	3.4E-04	1.3E-04	1.6E-03	2.4E-02
LU [m ² x yr cropland-eq]	1.7E-05	3.2E-07	1.9E-06	1.7E-01	4.0E-05	1.7E-04	2.2E-02	1.8E-03
MRS [kg CU-eq]	2.2E-05	2.9E-07	5.3E-07	1.8E-03	1.9E-04	5.1E-03	9.9E-04	8.6E-03
OD [kg CFC-11-eq]	1.2E-09	4.8E-12	4.3E-11	7.4E-07	2.5E-09	1.5E-09	1.6E-07	7.1E-08

PMF [kg PM2.5-e q]	1.7E-06	7.1E-09	2.4E-08	1.4E-04	3.8E-06	1.5E-06	4.3E-05	7.9E-05
POFhh [kg NOx-eq]	1.6E-06	2.2E-08	2.9E-08	2.9E-04	1.6E-05	1.1E-06	1.1E-04	1.8E-04
POFte [kg NOx-eq]	1.6E-06	2.4E-08	3.0E-08	3.0E-04	1.8E-05	1.2E-06	1.2E-04	1.9E-04
WU [m ³ -eq]	7.5E-03	2.5E-04	1.4E-03	4.2E-01	2.5E-02	2.6E-02	1.5E-01	1.5E+00

Table S.5: Environmental impacts of f-NAB LTGR2 Environmental impacts for all Recipe 2016 midpoint (H) impact categories for the production of non-alcoholic beer by brewing with maltose-negative yeast added dietary fibers as used for measuring the glycaemic load (f-NAB LTGR2). The values from climate change (CC), land use (LU), and water use (WU) were used to produce Figure 7 in the main manuscript. Abbreviations: TA - Terrestrial acidification; CC - Climate change; FE - Freshwater ecotoxicity; ME - Marine ecotoxicity; TE - Terrestrial ecotoxicity; FRS - Fossil resource scarcity; FEU - Freshwater eutrophication; MEU - Marine Eutrophication; HTc - Human Toxicity: carcinogenic; HTnc - Human Toxicity: non-carcinogenic; IR - Ionising Radiation; LU - Land use; MRS - Material resource scarcity; OD - Ozone Depletion; PMF - Particulate Matter Formation; POFhh - Photochemical Oxidation Formation: human health; POFte - Photochemical Oxidation Formation: terrestrial ecosystems; WU - water use.

	Hop cultivat ion	Hop pelletin g	Hop extracti on from pellets	Barley cultivat ion	Malting	Wheat flakes	Yeast product ion	Dextrin e product ion	Brewing
TA [kg SO ₂ -eq]	2.9E-06	1.9E-08	8.8E-08	3.8E-04	5.6E-06	1.3E-04	5.9E-06	1.8E-04	2.2E-04
CC[kg CO ₂ -eq]	6.9E-04	2.2E-05	1.3E-05	3.4E-02	9.5E-03	1.1E-02	5.3E-04	9.3E-02	1.4E-01
FE [kg 1,4-DC B-eq]	3.9E-05	1.0E-06	6.0E-06	1.6E-03	7.5E-05	7.6E-04	8.9E-05	1.8E-03	7.9E-03
ME [kg 1,4-DC B-eq]	4.9E-05	1.0E-06	7.0E-06	2.1E-03	1.0E-04	4.4E-04	1.1E-04	1.7E-03	1.0E-02
TE [kg 1,4-DC B-eq]	2.2E-03	2.0E-05	1.3E-04	1.1E-01	2.2E-03	2.3E-02	3.6E-03	4.2E-02	2.3E-01
FRS [kg]	1.9E-04	8.0E-06	2.0E-06	7.5E-03	3.5E-03	1.1E-03	1.5E-04	3.1E-02	4.6E-02

oil-eq]									
FEU [kg P-eq]	1.6E-07	1.2E-09	6.4E-09	7.8E-06	2.2E-07	8.4E-06	1.7E-07	1.2E-05	2.0E-05
MEU [kg P-eq]	7.6E-08	4.2E-10	1.3E-09	2.1E-04	1.4E-07	4.6E-05	3.3E-07	3.2E-05	9.7E-06
HTc [kg 1,4-DC B-eq]	1.2E-04	2.0E-06	5.0E-06	6.2E-03	6.0E-04	5.2E-04	9.4E-05	5.8E-03	1.8E-02
HTnc [kg 1,4-DC B-eq]	8.1E-04	1.1E-05	7.0E-05	5.4E-02	1.2E-03	7.1E-02	1.6E-03	4.5E-02	1.2E-01
IR [kBq Co-60-e q]	2.7E-05	4.0E-06	2.4E-05	8.1E-04	2.0E-04	1.9E-04	1.3E-04	1.6E-03	2.4E-02
LU [m² x yr croplan d-eq]	1.7E-05	3.2E-07	1.9E-06	9.9E-02	2.3E-05	2.5E-02	1.7E-04	2.2E-02	1.8E-03
MRS [kg CU-eq]	2.2E-05	2.9E-07	5.3E-07	1.0E-03	1.1E-04	1.1E-04	5.1E-03	9.9E-04	8.6E-03
OD [kg CFC-11- eq]	1.2E-09	4.8E-12	4.3E-11	4.2E-07	1.4E-09	1.8E-07	1.5E-09	1.6E-07	7.1E-08
PMF [kg PM2.5- eq]	1.7E-06	7.1E-09	2.4E-08	8.1E-05	2.1E-06	2.0E-05	1.5E-06	4.3E-05	7.9E-05
POFhh [kg NOx-eq]	1.6E-06	2.2E-08	2.9E-08	1.7E-04	9.0E-06	3.6E-05	1.1E-06	1.1E-04	1.8E-04
POFte [kg NOx-eq]	1.6E-06	2.4E-08	3.0E-08	1.7E-04	1.0E-05	3.7E-05	1.2E-06	1.2E-04	1.9E-04
WU [m³-eq]	7.5E-03	2.5E-04	1.4E-03	2.4E-01	1.4E-02	1.6E-02	2.6E-02	1.5E-01	1.5E+00