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Life cycle assessment of yeast from spruce

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Summary

On behalf of Foods of Norway, a calculation for yeast has been carried out by NORSUS. The yeast production is based on the process developed in Foods of Norway. Beyond being a delivery to Foods of Norway, this work is also important for further work in the Livestock project where NORSUS is a partner. The project was carried out during 2020 and the study is based on data input from Borregaard and NORCE, who has been a subcontractor for Foods of Norway.

This report documents the life cycle assessment (LCA) of production of yeast based on BALI sugar from spruce. Environmental impact from the production of BALI (Borregaard Advanced Lignin) sugar is calculated from confidential data from Borregaard. The nitrogen source of yeast production can be either inorganic or organic. In this study, data for ammonia, waste and blood have been used. The data basis for the latter two is based on emissions from the chicken slaughter process where economic allocation has been applied. The prices are confidential and not stated in the report. There is a degree of uncertainty to these prices as they may change in a new market.

The results show that BALI sugar accounts for the largest share of the environmental impact for all impact categories, however sugar is also the raw material that makes up the majority in quantity. Ammonia and other raw materials accounts for smaller impacts. The impact from processing of yeast accounts for a small share of climate change, otherwise negligible.

If an organic N-source is used, chemicals and minerals are not required. When using offal and blood as N-sources, the environmental impacts for yeast are lower compared to yeast where the N-source comes from ammonia. The only exception is for land occupation, were the burden is slightly higher for yeast with offal N-source. How much lower depends on the value of the N-source (economic allocation).

A possible further development of the LCA may be inclusion of the benefit of using the biogenic CO_2 emitted from the fermentation process in other industrial purposes (i.e. greenhouse production). Then the environmental impact from the upstream value chain can be allocated between the product(s) and yeast. The environmental impact of yeast will then be reduced accordingly.

Contents

1 Introduction

On behalf of Foods of Norway, a center for research-based Innovation at the Norwegian University of Life Sciences, a calculation for yeast has been carried out by NORSUS. The yeast production is based on the process developed in Foods of Norway. The project was carried out during 2020 and the study is based on data input from Borregaard and NORCE, who has been a subcontractor for Foods of Norway.

Beyond being a delivery to Foods of Norway, this work is also important for further work in the Livestock[1] project where NORSUS is a partner. In the LIVESTOCK project, models will be developed to document sustainability of livestock production systems by using LCA/LCSA models and value chain economy.

Foods of Norway aims to contribute to growth and increased value creation in the Norwegian aquaculture and agriculture industries, by developing sustainable feed ingredients from natural bioresources that are not suitable for direct human consumption. Foods of Norway explore opportunities for using sustainable, new ingredients in feed for fish and farm animals. An example is the yeast production from wood, which are assessed in this report. By using sugar from spruce together with a nitrogen source, the yeast can be produced through a fermentation and drying process and be added to the feed concentrates as a protein source.

[1] 1 https://www.nmbu.no/prosjekter/node/41382

2 Method

2.1 Goal and scope

The goal and scope of the LCA is to document the methodology used and present the life cycle impacts of yeast based on sugar from the Borregaard BALI biorefinery process.

2.2 Functional unit and system boundaries

The functional unit is 1 kg of yeast with 92-94% dry matter content at factory gate.

The system boundaries are from cradle to the factory gate of the yeast production site. Emissions related to forestry work and transport from forest to the biorefinery is included. Infrastructure is included in the background processes upstream, but not in the foreground system. Biogenic carbon stored in the wood is not included in the climate change results,following the IPCC method with a timeframe of 100 years (IPCC 2013). This is because the stored carbon is emitted again when it is decomposed (included in feed or other products) or burned (wood products).

2.3 Allocation

In the first place, allocation should be avoided (ISO, 2006). If not possible, the inputs and outputs of the system shall be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them. The most suitable allocation procedure shall be used and documented.

The BALI process for sugar production from spruce has been modelled in two steps. In the first step, allocation based on dry mass was used for the two output streams lignosulfonate and intermediary product. In the second step, avoided burdens were subtracted from the system for the unhydrolysed residue going to incineration. It is assumed that the heat from combustion of unhydrolysed residue is replacing the energy mix being used for production of steam at the main Borregaard biorefinery in Sarpsborg. The output of the second step is hydrolysate with C6 (Hexose) and C5 (Pentose) sugars with minor content of lignin and others. The dry matter content of the hydrolysate is approximately 15.7%, and approximately 91% of this is sugar.

When producing 1 ton of yeast, 1.1 tonnes of CO_2 originating from sugar will be emitted. This is biological CO_2 and according to the IPCC, this should not be included in the climate change calculations (see section 2.2). However, this CO_2 can possibly be used for other industrial purposes. In this study, no value has been added to this CO_2 and the entire environmental impact from the fermentation process has been added to yeast. However, if it was assumed that this CO_2 was actually utilized as an input in another process (i.e. greenhouse production), some of the environmental impact can be allocated to products from this process. Thus, the environmental impact of yeast will be reduced accordingly.

2.4 Impact categories and characterisation methods

Choice of environmental impact categories were based on the product environmental footprint category rules PEFCR (FEFAC, 2018) for ‘Feed for food-producing animals’ developed for the European Commission

Joint Research Centre. The impact assessment method used is as implemented in the SimaPro LCA tool, based on EF (Environmental Footprint) method 3.0. This life cycle impact assessment method has a total of 28 indicators, however six of them have been identified as more relevant than the others when feed ingredients are concerned. This is described in chapter 8.1 in PEFCR (FEFAC 2018). Hence, these six indicators have been used in this report, and they are given together with their corresponding units and references in Table 2.1. In addition to the impact categories, an indicator on land occupation is given to sum up the number of square meters as a supplement to the land use impact category by LANCA.

Table 2.1 Environmental impact categories used in the LCA

Impact category	Indicator	Unit	LCIA method
Climate change	Radiative forcing as Global Warming Potential (GWP100)	kg CO_2 eq.	Baseline model of 100 years of the IPCC (based on IPCC 2013*)
Particulate matter	Impact on human health	disease inc.	PM method recommended by UNEP (UNEP 2016*)
Acidification	Accumulated Exceedance (AE)	mol H^+ eq.	Accumulated Exceedance (Seppälä et al. 2006 and Posch et al. 2008*)
Land use (as soil quality)	Soil quality index	Pt (dimensionless)	Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016*)
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq.	Accumulated Exceedance (Seppälä et al. 2006 and Posch et al. 2008*)
Water scarcity	User deprivation potential (deprivation-weighted water consumption)	m^3 depriv.	Available WAter REmaining (AWARE) as recommended by UNEP (2016) (Boulay et al. 2016/2018*).
-	Land occupation	m^2	Given as life cycle inventory results, without characterisation.

* LCIA (Life Cycle Impact Assessment) as implemented in the SimaPro LCA tool, in the EF 3.0 method (adapted) version 1.0

3 Inventory

3.1 Raw materials and energy

The data quality and representativity is considered good for most processes. Data related to raw materials and quantities are based on information from NORCE (NORCE, 2020). Specific data from Borregaard are used for BALI sugar. Ecoinvent data has been used as background data to have consistent datasets, except for of organic nitrogen sources, where the Agri-footprint database has been used. For chemicals, either European or global market processes have been used. As LCA tool, SimaPro Developer version 9.1.0.11 Multi user has been used together with the ecoinvent 3.6 allocation, cut-off by classification database.

For electricity and natural gas input, a market process for Norwegian electricity, high voltage, has been used.

Table 3.1 and

Table 3.2 show raw materials consumption and energy used in the yeast processing, respectively.

Table 3.1 Raw material for production of yeast (NORCE, Norwegian Research Centre 2020)

Raw material	kg/ton yeast (DM 92-94%)	LCI data
Sugar 50% solution state	3947.7	BALI sugar, as DM, 14.3% in hydrolysate, from BALI biorefinery hydrolysis process (modelled by NORSUS based on specific data from Borregaard)
Ammonia, 100% (N content 82%)*	137.9	Ammonia, liquid {RER}| ammonia production, steam reforming, liquid | Cut-off, U (ecoinvent)
Phosphoric acid, 75% solution state	50.0	Phosphoric acid, fertiliser grade, without water, in 70% solution state {GLO}| market for | Cut-off, U (ecoinvent)
CaCl2	7.5	Calcium chloride {RER}| market for calcium chloride | Cut-off, U (ecoinvent)
MgSO4	20.0	Magnesium sulphate {GLO}| market for | Cut-off, U (ecoinvent)
FeSO4	1.10	Iron sulphate {RER}| market for iron sulphate | Cut-off, U (ecoinvent)
KOH, 46% solution state	20.0	Potassium hydroxide {GLO}| market for | Cut-off, U (ecoinvent)
NaOH, 50% solution state	15.0	Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Cut-off, U (ecoinvent)
H2SO4, 96% solution state	13.0	Sulfuric acid {RER}| market for sulfuric acid | Cut-off, U (ecoinvent)
HNO3, 65% solution state	4.50	Nitric acid, without water, in 50% solution state {RER}| market for nitric acid, without water, in 50% solution state | Cut-off, U (modified ecoinvent-process)
Other, including selenium	0.500	Selenium {GLO}| market for | Cut-off, U (ecoinvent)

*) N content is calculated from molecular weight, inflow of N in ammonia is 113,6 kg/ton yeast

Table 3.2 Energy and water for production of yeast

Energy	Per ton yeast (DM 92-94%)	LCI data
Electricity, process [kWh]	1000	Electricity, high voltage {NO}| market for | Cut-off, U (ecoinvent)
Electricity, cooling pump [kWh]	100	Electricity, high voltage {NO}| market for | Cut-off, U (ecoinvent)
Natural gas for drier [kWh]	194	Heat, central or small-scale, natural gas {RER}| market group for | Cut-off, U (ecoinvent)
Natural gas for steam [kWh]	109	Heat, central or small-scale, natural gas {RER}| market group for | Cut-off, U (ecoinvent)
Water [m^3]	3,31	Water, unspecified natural origin, NO

In addition, tap water is used for processing and sea water for cooling.

The production of sugar is based on data from the Borregaard BALI process. Data for steam is based on the specific energy mix at the main Borregaard biorefinery. The detailed data for production of sugar are kept confidential.

The production of yeast gives an emission of 1.1 tonnes CO_2/tonnes of yeast that originates from sugar. This CO_2 is biological and is not included in the climate change calculation according to the IPCC, see section 2.2. This CO_2 can possibly be used for other industrial purposes.

Wastewater will consist of steam from drying and cooling water. If a spray dryer is chosen, there will be fine protein particles not captured by the filter. It is assumed that a biological treatment plant is established that captures nitrogen and phosphor. LCI data used is "Wastewater, average {Europe without Switzerland}| market for wastewater, average | Cut-off, U".

3.2 Alternative nitrogen source

There are several possible sources of nitrogen (N) and a combination of two different sources may be appropriate. Inorganic nitrogen can provide a considerable amount of nitrogen when combined with an organic nitrogen source to give sufficient amounts of microbial biomass (Lapeña et al., 2020). In this study, ammonia (NH_3) is used as inorganic N-source, as given in table 3.1. The results are compared with two organic N-sources, offal or blood respectively. If an organic N-source is used, chemicals and minerals are not required.

The environmental impact will depend on the animal species and the value of the products and by-products. In this study, chicken offal and blood is used. Economic allocation is used between chicken products, offal and blood as these have different use. The valuation of these products is of great importance for the analysis. The difference between offal and blood in this analysis is therefore based on the value of each outflow from the slaughter process.

Table 3.3 shows which SimaPro processes that are used for organic N. The allocation factor in these processes has been modified, based on Norwegian economic values from Norilia. In a future market, prices may change and thus also the share from the value chain for chicken that will be allocated to offal and blood, respectively. However, the economic value of offal and blood is difficult to estimate in a new market and as a result of that, also the environmental impact may change.

The amount of offal or blood used in the yeast fermentation process is calculated from the N-content in ammonia, which is 113,6 kg N/ton yeast produced (see Table 3.3). if offal is used, hydrolysate is first made by adding equal parts offal and water and in addition enzymes.

Table 3.3 Alternative organic nitrogen source used for production of yeast

	Kg N/ton yeast (DM 92-94%)	LCI data
Offal [1]	113,6	Chicken co-product, feed grade, at slaughterhouse/NL Economic (modified allocation factors, Agri-footprint)
Blood[1]	113,6	Chicken co-product, other, at slaughterhouse/NL Economic (modified allocation factors, Agri-footprint)

1) N content 11 g/liter

4 Results

Table 4.1 show the environmental impacts for yeast as 92-94% dry matter for following different N-sources: Ammonia, offal and blood. The input flow of the N-source is based on the same N-content (see also Table 3.1 and Table 3.3).

Table 4.1 Environmental impacts for 1 kg of yeast
(parentheses show the percentage compared to yeast N-source NH_3)

Impact category	Unit / kg yeast (DM 92-94%)	Yeast N-source NH_3	Yeast N-source offal		Yeast N-source blood	
Climate change	kg CO_2 eq	1,25	0,92	*(73 %)*	0,90	*(72 %)*
Particulate matter	disease inc.	1,42E-07	1,22E-07	*(85 %)*	1,19E-07	*(83 %)*
Acidification	mol H+ eq	0,021	0,019	*(90 %)*	0,019	*(88 %)*
Land use (as soil quality)	Pt	244	241	*(99 %)*	240	*(99 %)*
Eutrophication, terrestrial	mol N eq	0,033	0,032	*(96 %)*	0,030	*(91 %)*
Water scarcity	m^3 depriv.	2,70	2,14	*(79 %)*	2,06	*(76 %)*
Land occupation	m^2	0,35	0,36	*(103 %)*	0,34	*(100 %)*

Figure 4.1 shows the relative contributions from raw materials and process emissions. It is seen that the BALI sugar accounts for the largest share of the environmental impact for all impact categories, i.e. climate change (63%), water scarcity (77%) and particulate matter (82%), however, it is also the raw material that makes up the majority in quantity. Ammonia accounts for 21% of climate change, 12% of water scarcity and 8% of particulate matter. For the other impact categories, ammonia has a relatively small contribution. Other raw materials have small contributions, the largest are water scarcity (10%), particulate matter (9%) and acidification (9%). The impact from processing of yeast accounts for a small share of climate change (8%), otherwise negligible.

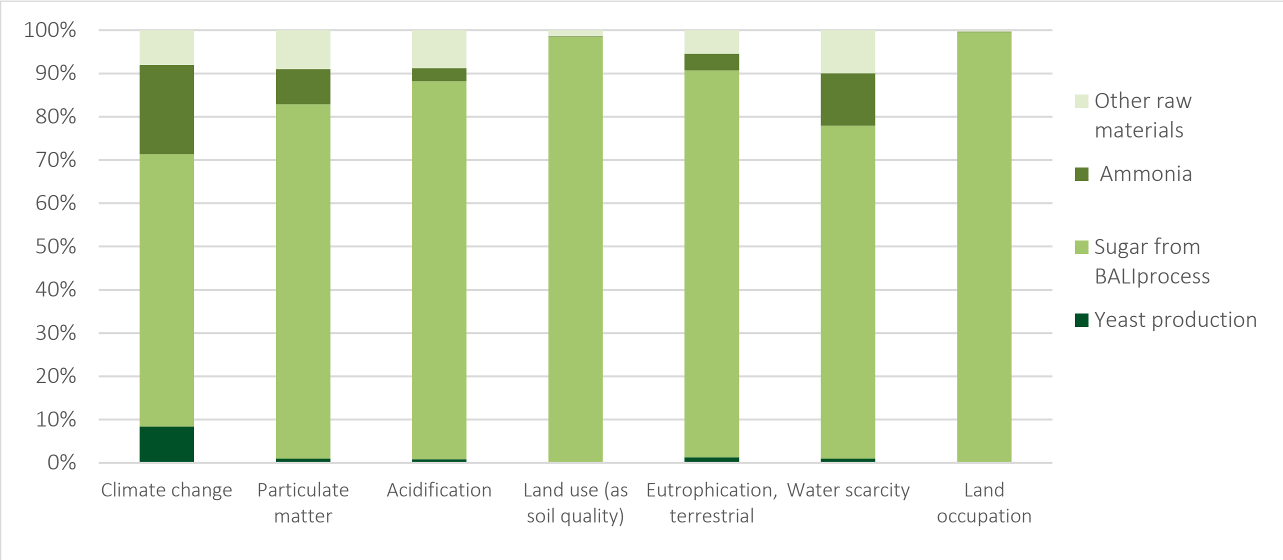

Figure 4.1 Environmental impact results for 1 kg of yeast (N-source ammonia)

5 Conclusion

This report documents the production of yeast based on BALI sugar from spruce. Environmental impact from the production of BALI sugar is calculated from confidential data from Borregaard. The nitrogen source of yeast production can be either inorganic or organic. In this study, data for ammonia, offal and blood have been used. The data basis for the latter two is based on emissions from the chicken slaughter process where economic allocation has been applied. The prices are confidential and not stated in the report. There is a degree of uncertainty to these prices as they may change in a new market.

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If an organic N-source is used, chemicals and minerals are not required. When using offal and blood as N-sources with economic allocation factor, the environmental impacts are lower compared to yeast where the N-source comes from ammonia. The only exception is for land occupation, were the burden is slightly higher for yeast, N-source offal. How much lower depends on the value of the N-source (economic allocation).

A possible further development of the LCA may be inclusion of the benefit of using the biogenic CO_2 emitted from the fermentation process in other industrial purposes (i.e. greenhouse production). Then the environmental impact from the upstream value chain can be allocated between the product(s) and yeast. The environmental impact of yeast will then be reduced accordingly.

As a part of the project LIVESTOCK, further work is to include the LCA of yeast as a module in an LCA of pigs fed with yeast-based feed compared to traditional soy feed.

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