Life cycle inventories of brewer's grain, DDGS and milk replacer

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Preface

This report presents the life cycle inventory of Brewer's grain, DDGS and milk replacer. The current report serves as an extended appendix to Schmidt and Dalgaard (2012) and Dalgaard and Schmidt (2012).

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1 Introduction

This report describes the inventory data used for the modelling of four new feedstuffs in the Arla farm model. These new feedstuffs are malt sprouts (by-product of malt production), brewer's grain (by-product from beer brewing), dried distillers grain with solubles, DDGS (by-product of bio-ethanol production), and milk replacer.

The modelling principles follow Schmidt and Dalgaard (2012), and the background data link to the inventory in Dalgaard and Schmidt (2012).

2 The food industry system

This chapter serves as an extension to chapter 5 in Dalgaard and Schmidt (2012).

2.1 Inventory of malting and brewing system (brewer's grain)

The Danish name of brewer's grain is 'mask'. Brewer's grain is a by-product from beer production and is used as cattle feed. Beer production can be split into the following processes:

1. Barley cultivation. Data are already available for Denmark and Sweden in Dalgaard and Schmidt (2012).
2. Malting. Barley grains are made to germinate by soaking in water, and are then halted from germinating further by drying with hot air. Malt is the determining product, whereas barley sharps and malt sprouts are dependant by-products. Data are obtained from Kløverpris et al. (2009). Data are from a Danish malt house and are assumed to be representative for both Danish and Swedish malt production.
3. Brewing. Beer is produced from malt and the brewing process can be divided into several steps: Milling, mashing, filtration and boiling. For simplicity, these different activities are aggregated into one single activity here. Data are based on Kløverpris et al. (2009) and are assumed to be representative for both Danish and Swedish beer brewing. The functional unit in the study of Kløverpris et al. (2009, page 4) is seven tons of wort extract after boiling. Based on data from Kløverpris et al. (2009) it has been calculated that 1 kg wort extract equals 1.45 kg beer (4.6% alcohol). Beer is the determining product and brewer's grain is the dependant product.

The inventories of malting and brewing are presented in **Table 2.1**. The only differences between the Danish and Swedish versions of the inventories are:

- The barley input to the malt houses are from Denmark and Sweden respectively.
- The electricity used at the malt houses and breweries are from Denmark and Sweden respectively.
- The price data applied for economic allocation (switch 2, 3 and 4) are from Denmark and Sweden respectively.

By-products from the malt house include both barley sharps and malt sprouts (Kløverpris et al. 2009), but these are aggregated in one single category and calculated as malt sprouts. 22% of the malt sprouts are barley sharps. The water input to the brewery is based on the data from Kløverpris et al. (2009), but also water for diluting the wort from 6.6% alcohol to 4.6% alcohol is added. It is assumed the density of beer is 1 kg/litre.

Table 2.1: LCI of malting and brewing meal activities.

Exchanges	Activity: Country: Unit:	Malt house DK/SE	Brewery DK/SE	Utilisation of malt sprouts GLO	Utilisation of brewer's grain GLO
Output of products					
Determining product:					
Malt	kg	0.820			
Beer (4.6% alc)	kg		6.72		
Malt sprouts for treatment	kg			1	
Brewer's grain for treatment	kg				1
By-product:					
Malt sprouts for treatment	kg	0.0461			
Brewer's grain for treatment	kg		0.800		
Feed energy	MJ net energy			6.91	1.86
Feed protein	kg			0.275	0.0583
Input of products/material for treatment					
Barley	kg	1			
Malt	kg		1		
Water	kg	1.67	6.83		
Natural gas, burned	MJ	1.67	0.267		
Electricity	kWh	0.00869	0.00650		
Steel	kg		0.000014		
Lactic acids	kg		0.00300		
Enzymes	kg		0.00050		
Sugar mill, capital goods	kg	0.820	0.672		
Sugar mill, services	kg	0.820	0.672		

The LCI data on barley used at the malt house are from Dalgaard and Schmidt (2012) and are not updated to year 2012. It is assumed only Danish barley is used at the Danish malt house and only Swedish barley at the Swedish malt house.

According to Kløverpris et al. (2009, Table 5) 0.24 MJ steam is used per kg malt during the brewing. This is converted to natural gas by assuming an efficiency of 90%.

At the brewery 0.014 gram steel is used per kg malt processed (Kløverpris et al. (2009). The steel is already covered by 'Sugar mill, capital goods' and is therefore not presented in **Table 2.1**.

Lactic acids and enzymes are inputs, which not formerly are used in the modelling by Schmidt and Dalgaard (2012). Since the used amounts of lactic acid and enzymes are very small compared to the flows of raw materials and products, it has been assumed that the life cycle emissions from these inputs can be represented by average chemicals described in Dalgaard and Schmidt (2012)

Feed protein and feed energy content of the by-products are calculated from feed characteristic data on malt sprouts and brewer's grain from Møller et al. (2005). Data are presented in appendix B. By-products from the malt house include both barley sharps and malt sprouts Kløverpris et al. (2009), but are aggregated in one single category and calculated as malt sprouts. 22% of the malt sprouts are barley sharps.

Capital goods and services per kg malt are represented by the use of capital goods and services in the sugar industry per kg of sugar.

The prices used for economic allocation are from FAOSTAT (2014) and are presented in Appendix C. The price of 'Brewing or distilling dregs and waste' which represent brewer's grain in the modelling was unrealistic high for the Swedish data. Therefore, the Danish price on brewer's grain was also used for modelling Swedish brewer's grain. The Danish price on brewer's grain was comparable with prices on brewer's grain in England (DairyCo, 2014).

2.2 Inventory of bioethanol production (DDGS)

The Danish name of dried distillers grain with solubles is 'bærme' (Møller et al., 2005) and in this text the abbreviation DDGS is used. DDGS is a by-product from bioethanol production. The LCI presented in **Table 2.2** is based on Schmidt and Brandão (2003) who used data originally published data by Jensen et al. (2007). The reference flow unit presented by Schmidt and Brandão (2013, page 52) is one MJ bioethanol. To enable calculating allocation factors the reference flow was converted to 0.0370 kg bioethanol using the lower heating value of bioethanol from Renewable Energy Directive (2009).

Table 2.2: LCI of bioethanol production

	Activity:	Bioethanol production	Utilisation of distillers grains
Exchanges	Country: Unit:	DK/SE	GLO
Output of products			
Determining product:			
Bioethanol	kg	0.283	
Distillers grains for treatment	kg		1
By-product:			
Distillers grains for treatment	kg	0.373	
Feed energy	MJ net energy		7.60
Feed protein	kg		0.288
Input of products/material for treatment			
Wheat	kg	1	
Enzymes	kg	0.00869	
Sulphuric acid (94%)	kg	0.00686	
Phosphorous acid (74%)	kg	0.00126	
Sodium hydroxide (49%)	kg	0.000542	
Ammonia water (25%)	kg	0.000878	
Urea (45%)	kg	0.000763	
Calcium chloride (68%)	kg	0.000273	
Electricity	kWh	0.137	
Natural gas, burned	MJ	3.47	
Sugar mill, capital goods	kg	0.283	
Sugar mill, services	kg	0.283	

The LCI applied for wheat is from Dalgaard and Schmidt (2012), and it is assumed Danish wheat is used for bioethanol produced in Denmark, and that Swedish wheat is used for bioethanol produced in Sweden. Enzymes, sulphuric acid, phosphoric acid, sodium hydroxide, ammonia water and calcium chloride are not formerly are used in the modelling by Schmidt and Dalgaard (2012). Since the used amounts of these chemical are very small compared to the flows of raw materials and products, it has been assumed that the life cycle emissions from these inputs can be represented by average chemicals described in Dalgaard and Schmidt (2012)

As for the malt house, capital goods and services are represented by the sugar industry.

The prices used for economic allocation are from USDA (2014) and are presented in Appendix C.

2.3 Inventory of milk replacer for calves

The main ingredient in milk replacer for calves is milk powder (Vitfoss, 2014). Milk powder production for human consumption is considered to be a good representative for milk powder used in milk replacers for calves and therefore data from www.lcafood.dk (Nielsen et al., 2005) have been used as a starting point for the modelling. Milk powder production includes the following steps: 1) fresh milk is received from farms 2) the milk is pasteurised 3) the pasteurised milk is concentrated by evaporation, 4) concentrated milk is dried in fluid bed, 5) the dry milk is packed and stored at in a slightly heated storage room prior to distribution.

The inventory presented in **Table 2.3** is based on Ramirez et al. (2006) and Nielsen et al. (2005) and used for the modelling of milk replacer for calves. It is assumed Danish milk is used for milk replacer consumed in Denmark, and Swedish milk is used for milk replacer consumed in Sweden. The amount of milk used per kg milk powder is calculated from the dry matter content of milk (10%) and milk powder (96%) (Ramirez et al. 2006). MJ natural gas used is calculated by multiplying the mass of evaporated waters with the energy required for evaporation assuming a 90% fuel energy to effective energy efficiency(Ramirez et al., 2006). Electricity and water use is from Nielsen et al. (2005). As for the malt house, capital goods and services are represented by the sugar industry.

Table 2.3: LCI of milk powder production. Based on Ramirez et al. (2006) and Nielsen et al. (2005)

	Activity:	**Milk powder production**
	Country:	DK/SE
Exchanges	**Unit:**	
Output of products		
Determining product:		
Milk powder	kg	0.104
Input of products/material for treatment		
Milk from farm	kg	1
Electricity	kWh	0.037
Natural gas, burned	MJ	4.18
Water	kg	0.490
Sugar mill, capital goods	kg	0.104
Sugar mill, services	kg	0.104

There exist many different kinds of milk replacers and they are based on different feedstocks: Milk powder, soybean protein, whey, wheat starch, palm oil, soy oil, coconut oil etc. They also differ widely in price and efficiency in terms of their ability to enhance growth of calves. Milk replacers based on 50-60% skimmed milk are the most commonly used type on Danish milking farms (Vitfoss, 2014). The data on milk replacer ingredients presented in **Table 2.4** are considered to be a good representative for milk replacers sold on the Danish market (Vitfoss, 2014). The exact content of ingredients is considered as confidential information by Vitfoss (2014) and therefor presented as ranges in **Table 2.4**. The main ingredient in milk replacer is milk powder, which constitutes 75-85% of the milk replacer. Vegetable oil is a mix of different kinds of vegetable oils, where palm oil is the most dominating.

Table 2.4: List of ingredients and characteristics of milk replacer. Source: Vitfoss (2014)

Milk replacer	Units	
Ingredients		
Powder of skimmed milk	%	50-55
Powder of whole milk	%	25-30
Whey powder	%	1-2
Wheat starch (highly refined)	%	< 1
Vegetable oil	%	10-20
Minerals, vitamins	%	4
Feed properties		
Raw protein	%	21
Raw fat	%	17
Ash	%	6.5

Data presented in **Table 2.5** are used for the modelling of milk replacer. Powders of skimmed milk, whole milk and whey (**Table 2.4**) are modelled as milk powder (**Table 2.3**). Palm oil is modelled according to Dalgaard and Schmidt (2012, p 84), and wheat starch and minerals (**Table 2.4**) are modelled as 'Other chemicals (Dalgaard and Schmidt 2012, p 12).

Table 2.5: LCI of milk replacer.

	Activity:	Milk replacer production	
	Country:	DK/SE	GLO
Exchanges	Unit:		
Output of product			
Milk replacer	kg	1.268	
Input of products			
Milk powder	kg	1.000	
Palm oil	kg	0.209	
Other chemicals	MJ	0.0588	

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Appendix 1: Feed and crop properties

This appendix serves as an extension to appendix B in Dalgaard and Schmidt (2012).

Appendix table 1: Feed characteristics. Feed code refers to the feed code (Danish: Foderkode) in Møller et al. (2005).

Feed:		Brewer's grain (fresh)	Malt sprouts	Distillsrs grain
	Feed code: Unit	266	265	262
Input parameters				
Dry matter content	kg DM/kg	0.245	0.950	0.900
Raw protein	kg/kg DM	0.238	0.289	0.320
Raw fat	kg/kg DM	0.010	0.028	0.070
Carbohydrate	kg/kg DM	0.612	0.619	0.554
Ash	kg/kg DM	0.05	0.064	0.056
Digestible energy	MJ/kg DM	14.1	13.6	14.9
Feed energy content	SFU/kg DM	0.97	0.93	1.08
Calculated parameters				
Gross energy	MJ/kg DM	20.7	19.4	20.1
Digestible energy *	MJ/MJ	0.681	0.700	0.726
Feed energy (net energy)	MJ/kg DM	7.59	7.22	8.45

*expressed as a percentage of gross energy

Appendix 2: Prices

This appendix serves an extension to appendix C.3 in Dalgaard and Schmidt (2012).

Appendix table 2: Prices

Food industry system. Data are from 2012.				
Prices	**Unit**	**DK**	**SE**	**Data source**
Malt	EUR/kg	0.358	0.393	Export price: 'Malt, not roasted' and 'Malt, roasted'. UNSD (2014), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 08/07-2014). Data for Sweden are from 2011 due to data lack.
Malt sprouts	EUR/kg	0.054	0.251	Export price: 'Brewing or distilling dregs and waste'. UNSD (2014), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 08/07-2014). Data for Sweden are from 2011 due to data lack.
Beer	EUR/kg	0.807	0.775	Export price: 'Beer made from malt'. UNSD (2012), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 08/07-2014). Data for Sweden are from 2011 due to data lack.
Brewer's grain	EUR/kg	0.054	0.054	Export price: 'Brewing or distilling dregs and waste'. UNSD (2014), Commodity Trade Statistics Database. United Nations Statistics Division. http://data.un.org/Browse.aspx?d=ComTrade (Accessed 08/07-2014). Data are Danish.
Bioethanol	EUR/kg	0.352	0.352	United States Department of Agriculture (2014). Downloaded from http://www.ams.usda.gov/. (Accessed 9/08-2014). Data represent the market in United States the first week of 2012, and are used for both Denmark and Sweden.
DDGS (90% dry matter)	EUR/kg	0.157	0.157	