Biogas or feed – different pathways for selected food industry residues from a greenhouse gas perspective

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ABSTRACT

In this paper, GHG emissions of biogas systems based on food industries residues are analysed according to the method described in the ISO-standard for life cycle assessment. Furthermore, two perspectives are included, one where the residues are not utilised for other purposes today and one where the residues are utilised as animal feed, here presented as systems expansion. The results show that all residues studied are well suited for biogas production if there is no demand for them as animal feed today. Otherwise, it is often more efficient to grow dedicated biogas crops directly.

Keywords: biogas, food industry residues, feed, LCA

1. Introduction

Production of food results in various kinds of food industry residues that can be utilized in different ways depending on their individual features and demand from other market sectors. Often, such residues are used as feed but in some regions this demand decreases due to changes in livestock production. Also, there is a growing market for biofuels where such feedstock could be utilized as well. Recently, the use of industrial residues for the production of biogas as transportation fuel has also attracted a great deal of interest since such production does not compete directly with the use of agricultural land. However, only a limited number of studies quantifying greenhouse gas (GHG) emissions from such biogas systems have been performed. For comparison, the environmental performance of other biofuels such as ethanol and biodiesel as well as biogas from waste and dedicated energy crops has been investigated in several studies (see e.g. Börjesson and Tufvesson, 2011, JRC, 2007, Kendell and Chang, 2009 and Reijnders and Huijbregts, 2008). Also, if the demand for feed remains and such feedstock are used for biogas production, they must be replaced by other animal feed. This may shift the environmental burden from one system to another and needs to be included in a system analysis.

In this paper, which is mainly based on the findings presented in Tufvesson et al. (2013), GHG emissions from different biogas system, where biogas is utilized as a vehicle fuel produced from industrial residues, are analyzed and compared from a life-cycle perspective including different utilization pathways for the residues. Residues included are distiller's waste, rapeseed cake, whey permeate, fodder milk and bakery residues. Also, calculated GHG emissions from biogas systems based on food industry residues are compared to corresponding emissions from biogas systems based on dedicated energy crops.

2. Methods

The analysis is based on the principles described in the ISO standard 140 44 (ISO, 2006). The functional unit is 1 MJ of upgraded and compressed biogas at the biogas plant. Included life cycle emissions of GHG are carbon dioxide (CO_2) of fossil origin, methane (CH_4) and nitrous oxide (N_2O). Characterization factors are set to 1, 25 and 298 g CO_2-ekq./g CO_2 respectively (IPCC, 2006a).

Data is presented for two scenarios; no allocation and system expansion. In the scenario with no allocation all feedstock are considered as residues and no emissions are allocated to them before entering the biogas system. In addition to the upgraded and compressed biogas, all biogas systems also generate digestate which is applied to arable land as a fertilizer. Thus, GHG emissions could be allocated between biogas and digestate. However, this digestate has no clearly defined value today and due to its low dry matter content, it is not considered to have a heating value either. Thus, all GHG are allocated to the biogas produced (Tufvesson et al., 2013). When system expansion is applied, food industry residues are assumed to be replaced with soymeal and barley as animal feed. Also, in the case with system expansion, the digestate is assumed to replace mineral fertilizer.

Inventory data for biogas production and upgrading are collected to represent average new technology that is commercially available today. Inventory data for generation of electricity used in the biogas system, production of mineral fertilizers and animal feed has been chosen to represent average products used in Sweden today.

2.2. Investigated substrates

The substrates investigated in this paper have different features which affect the production of biogas and digestate as well as the amount of mineral fertilizers and animal feed that can be replaced. Also, the same kind of food industry residue could have different features depending on the original raw material and how it has been processed. The features assumed in this study are presented in Table 1. Further background on assumptions made can be found in Tufvesson et al. (2013).

Table 1. Features of analyzed substrates (Tufvesson et al., 2013).

Substrate	**DM[a]**	**Plant available nutrients (% of DM)**			**Methane yield**	**Corresponding feed (kg DM/kg DM substrate)**	
	(%)	**N**	**P**	**K**	**Nm^3/tonne DM**	**soy meal**	**barley**
Distiller's waste	8,0	4.0	0.9	1.1	302	0.4	0.6
Rapeseed cake	91	5.0	1.2	0.7	422	0.7	0.3
Whey permeate	5,0	0.5	0.8	2.5	309	0	1.1
Fodder milk	9,0	3.9	0.8	1.0	472	0.4	1.5
Bakery residues	61	3.7	0.2	0.4	304	0	1.0

[a] Dry matter

2.3. Analyzed biogas systems

It is assumed that all food industry residues are transported by truck to a centralized co-digestion plant where biogas is produced, upgraded and compressed. Corresponding to the system boundaries applied by Börjesson *et al.* (2010) further transportation of compressed biogas is not included. The transportation distance is set to 10 km for liquid substrates and 30 km for rape seed cake and bakery residues and the energy input for transportation is set to 1,1 MJ/tonne*km (Börjesson and Berglund, 2006).

Electricity consumption at the biogas plant is set to 30.2 MJ/tonne of substrate in addition to the electricity used for upgrading and compression which is set to 1.6 and 1.3 MJ/Nm^3 of biogas respectively. Emissions are based on average Swedish power production and corresponds to 11 g CO_2-eqv./MJ. Also, it is assumed that the biogas plant use 93.6 MJ of biogas to produce process heat (Lantz et al., 2009; Tufvesson et al., 2013).

The methane leakage is set to 1.5% of the biogas produced including biogas production, upgrading and digestate storage at the plant representing a modern biogas plant. For comparison, the average methane losses from Swedish co-digestion plants and upgrading plants were 1.8% and 1.4% respectively in 2012 (Avfall Sverige, 2012). However, there are also biogas plants with state of the art technology where methane losses could be 0.5% or lower.

The digestate produced is transported 10 km by truck, stored in covered concrete tanks and spread on arable land by tractor. Based on IPCC (2006b) it is assumed that there will be no direct emissions of N_2O from the digestate storages. Emissions of NH_3 from the storage tanks are set to 1 % of the total amount of nitrogen in the digestate which also cause indirect emission of N_2O (IPC, 2006b). The amount of indirect N_2O is calculated based on equation 1.

$$N_2O = N*EF*(44/28) \qquad \text{Eq. 1}$$

N_2O = indirect emissions of nitrous oxide
N = emissions of nitrogen as NH_3-N (kg N)
EF = emission factor, which is here set to 0.01 kg N_2O-N/kg NH_3-N

In the system expansion, indirect emissions of N_2O from spreading of the digestate are included as well. These emissions are calculated according to Equation 1 assuming that 5 % of the total amount of ammonium nitrogen in the digestate is lost at NH_3.This assumption requires good spreading techniques as well as appropriate weather conditions (Tufvesson et al., 2013).

The amount of mineral fertilizers that could be replaced by digestate is presented in Table 1. Based on the market situation in Sweden, it is assumed that 30% of the mineral nitrogen is produced with catalytic N_2O reduction resulting in average emissions of 6.7 kg CO_2-eqv./kg N. For P and K, emissions are set to 3.2 and 0.5 g CO_2-eqv./kg respectively (Tufvesson et al., 2013).

In addition to the nutrients presented in Table 1, digestate also contains carbon compounds of which some will form stable humus in the soil. In this analysis it is assumed that 40% of the dry matter in the digestate is carbon and 10% of this carbon is conservatively estimated to form long-term stable soil organic matter. A more comprehensive background for this assumption is presented in Tufvesson et al. (2013).

The assumed amount of crops needed to replace the various substrates as animal feed is presented in Table 1. GHG emissions from production of soybean meal and barley are set to 980 and 450 g CO_2-eqv./kg DM respectively (Flysjö et al., 2008). Emissions are calculated assuming average cultivation conditions, including direct land-use change, but not any indirect land-use change.

3. Results

In Figure 1 the contribution to global warming potential is shown for the biogas systems analyzed. The results vary considerably between the case with no allocation and the case with system expansion. However, for all the systems studied the contribution to global warming was lower than for petrol and diesel. In Table 2 it is clearly seen that the parameters that contribute most to the global warming potential are the replacement of mineral fertilizers and animal feed in the system expansion.

In figure 2, GHG emissions from biogas systems based on food industry residues, including system expansion, are compared to biogas systems based on cultivated crops, dedicated for biogas production. Although all biogas systems reduce GHG emissions compared to petrol and diesel, it is clear that the reduction is higher when dedicated energy crops are utilized.

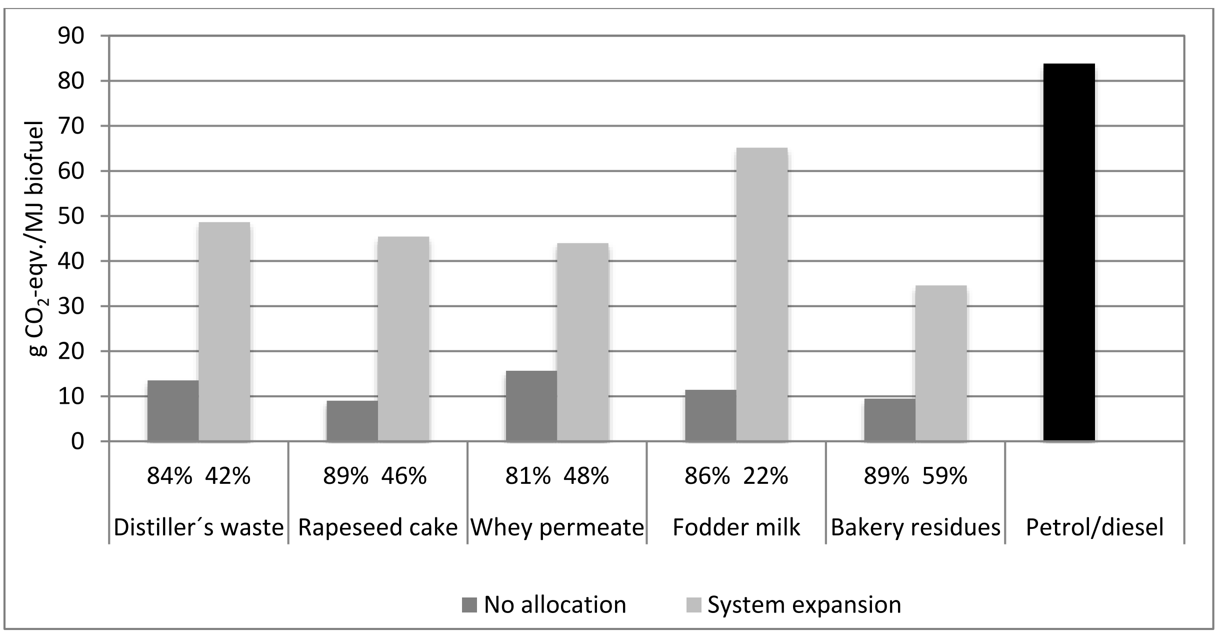

Figure 1. Contribution to global warming potential from biogas based on industrial residues (taken from Tufvesson et al., 2013). The reference for petrol and diesel is set to 83,8 g CO_2-eqv./MJ (European Commission, 2009).

Table 2. The total contribution and most important parameters contributing to global warming potential when no allocation and system expansion is applied (taken from Tufvesson et al., 2013).

Substrate	Global warming potential (g CO_2-eqv./MJ biogas)							
	Transport[a]	Process energy	Methane leakage	Digestate[a]	Total no allocation	Mineral fertilizer	Animal feed	Total system expansion
Distiller's waste	1.1	1.5	7.5	3.5	13.6	-23	58	49
Rapeseed cake	0.2	0.9	7.5	0.4	9.0	-19	55	45
Whey permeate	1.5	1.4	7.5	4.9	15.3	-8	38	44
Fodder milk	0.6	1.1	7.5	2.0	11.2	-12	66	65
Bakery residues	0.4	1.0	7.5	0.7	9.6	-21	46	35

[a] Transport of substrate
[a] Storage, transport and spreading of digestate

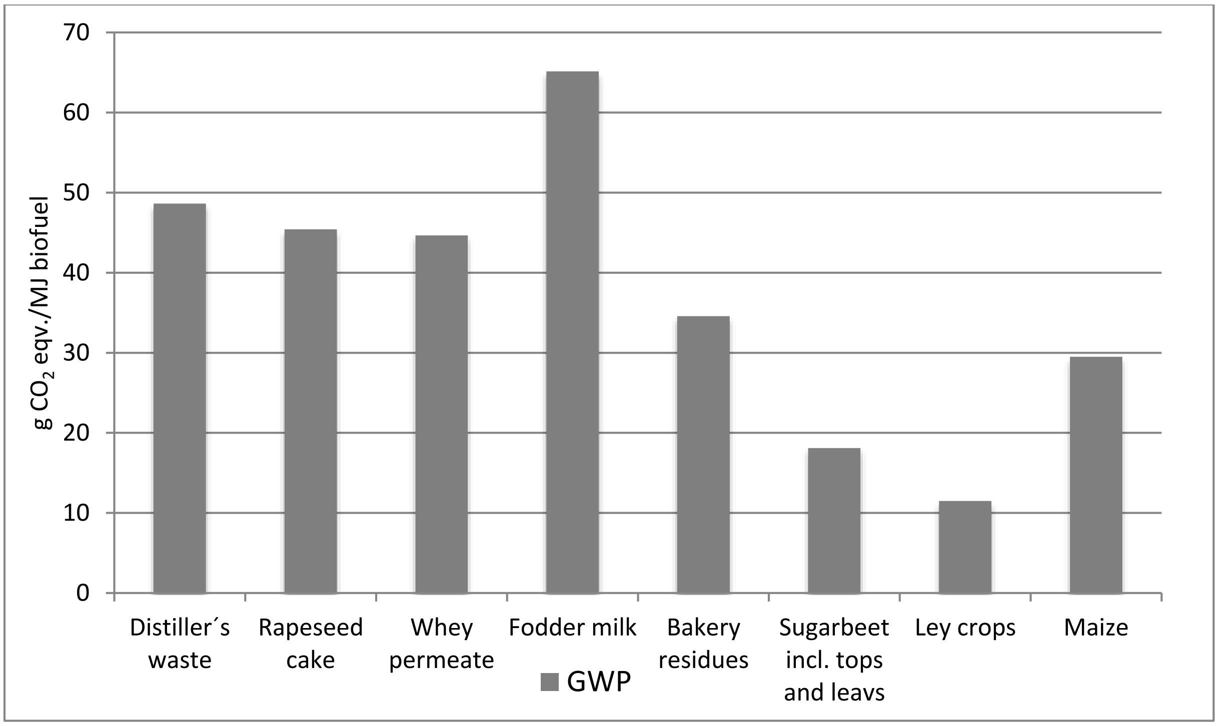

Figure 2. Contribution to global warming potential when system expansion is applied for biogas from industrial residues and dedicated crops (unfertilized grassland as reference land-use) taken from Börjesson et al., (2010).

4. Discussion

Many kinds of food industry residues are well suited for biogas production since they contain organic matter that could relatively easy be degraded in an anaerobic process. The residues are also concentrated to few industrial sites and could easily be transported to a biogas plant in the vicinity of the site or on the site. When the biogas produced is utilized to replace fossil fuels, all analyzed biogas systems also reduce GHG emissions compared to petrol and diesel. This approach is also encouraged by the debate on iLUC factors and the promotion of using residues and waste for biofuel production which e.g. is the case in the EU's Renewable Energy Directive (European Commission, 2009). However, this is a simplified view based on a limited systems perspective since it does not include the potential alternative utilization of the residues. If there is a demand for the residues as feed, their utilization as biogas feedstock will be compensated for by, e.g. new feed crop production. According to the ISO-standard of LCA (ISO, 2006), system expansion should also be applied when possible to cover all relevant indirect effects influencing the result.

As presented in this study, the utilization of food industry residues as feed, if there is such a market, will thus result in the highest reduction of GHG. Food industries considering the best way how to handle their organic residues from a greenhouse gas perspective should thus closely evaluate the possibility to utilize such residues as feed. However, if there is no such market, biogas production is a suitable alternative.

5. Conclusion

Food industry residues analysed in this paper are well suited for biogas production and the reduction of greenhouse gas emissions will be substantial compared with fossil vehicle fuels. One important prerequisite is, however, that the industrial residues cannot be utilized as animal feed. Otherwise, the benefits will be significantly reduced due to additional production of feed crops. If so, it could be more efficient to grow dedicated biogas crops and continue to utilize the industrial residues as animal feed.

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