European Commission

ENVIRONMENTAL FACTSHEET: ***ACETIC ACID***

PRODUCT INFORMATION

Acetic acid (CH_3COOH) is a carboxylic acid with applications in both chemical and food industries. It is largely used as feedstock for the production of vinyl acetate (a monomer used in the manufacture of the polymer polyvinyl acetate) and other esters (commonly used in inks and paintings), and as a solvent in different chemical reactions and purification processes.

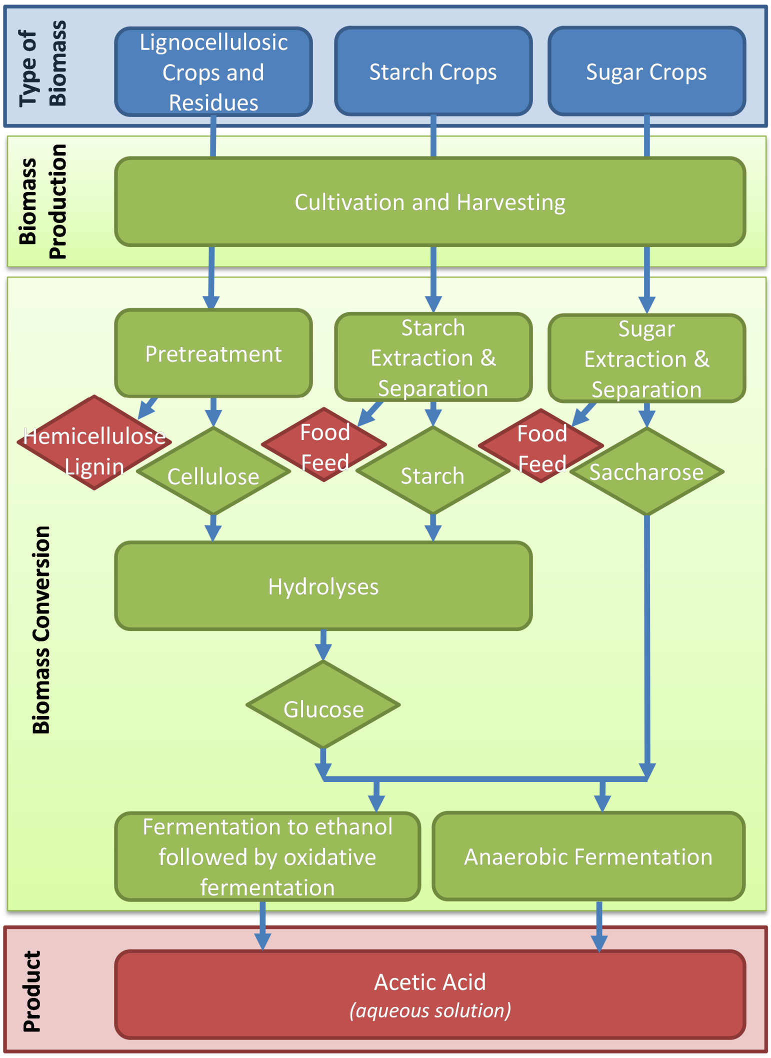

Figure 1. *Acetic acid production chains*

Worldwide, acetic acid is mainly produced from fossil-based feedstocks through carbonylation of methanol. It can also be commercially produced by fermentation (bio-based pathway) of sugars for ethanol, mostly for food purposes, e.g. for the production of vinegars (aqueous solutions of acetic acid, up to 15%). Acetic acid can be produced by two fermentation processes: i) oxidative (aerobic) fermentation of ethanol and ii) anaerobic fermentation of sugars.

Oxidative fermentation requires a first step of sugar fermentation to ethanol (by yeasts) followed by ethanol fermentation to acetic acid accomplished by bacteria of the genus *Acetobacter*, performed under oxygen supply.

Anaerobic fermentation is performed without oxygen using anaerobic bacteria (such as *Clostridium thermoaceticum*) able to directly convert sugars to acetic acid. The bio-based pathways present low productivities due to the inhibition of bacteria at low pHs. Therefore, research is focused on improving acetic acid productivity by developing bacterial strains with improved pH tolerance. Due to the low concentrations of acetic acid in the final fermentation broth, its separation/purification is also a challenge since the conventional separation methods (such as distillation) are not economically sound at these low concentrations.

Processes such as electrodialysis, pervaporation and solvent extraction (liquid-liquid extraction) have been proposed to remove acetic acid from the fermentation broths.

The maturity of various acetic acid production technologies is summarised in Figure 2. The use of lignocellulosic materials appears as the least advanced production system. On the contrary, the use of sugars from starch or sugar crops is commercially available for the production of acetic acid aqueous solutions.

Technology Readiness Levels

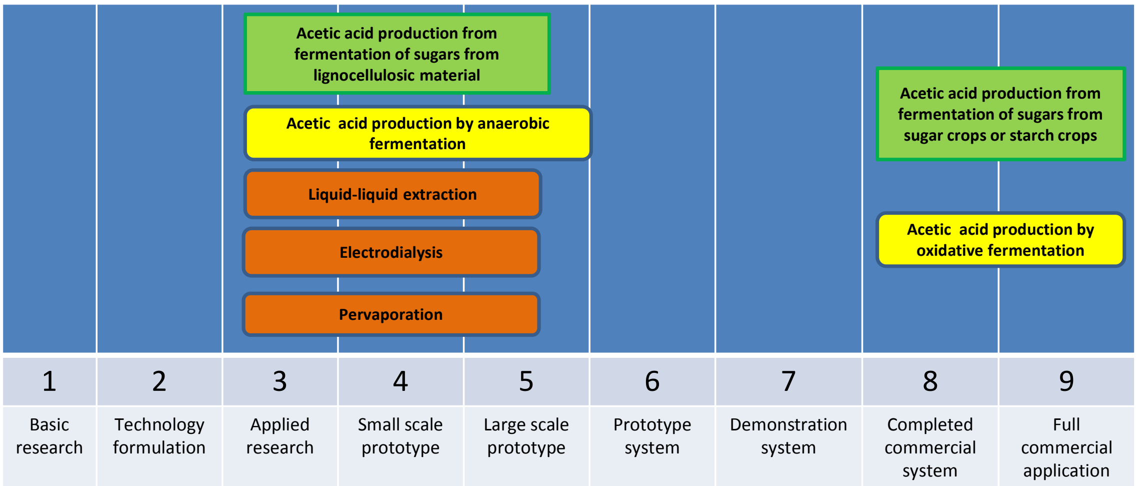

Figure 2. *Technology readiness levels for acetic acid production*

SWOT (Strengths, Weaknesses, Opportunities, Threats)

S1. Acetic acid has a wide variety of applications in food and chemical industries.	**W1.** The bio-based pathway presents low productivities. **W2.** Separation of acetic acid from the fermentation broth is difficult.
O1. The development of new separation technologies may increase the production efficiency. **O2.** The development of bacterial strains with higher pH tolerance may improve acetic acid yields.	**T1.** Biomass availability, competition with food, feed and energy.

ENVIRONMENTAL DATA AND INFORMATION

The environmental performance of acetic acid is summarised in Table 1 based on the available relevant LCA data for acetic acid production through anaerobic fermentation using different raw materials (corn, sugar cane and corn stover) and purification methods such as liquid-liquid extraction, distillation and electrodialysis.
Most of the values refer to the cradle-to-gate (see Figure 3) LCA approach. Climate change results are also found for cradle-to-grave systems considering incineration without energy recovery as end-of-life scenario for acetic acid [1]. The BREW project [1] considers the use phase negligible in the cradle–to-grave calculations.
For this product, the available results were found for climate change, land use, primary energy and non-renewable energy. No results were found for the remaining impact categories described in the environmental sustainability assessment methodology that was developed in the context of this project (see explanatory document).

System boundaries of the environmental assessment

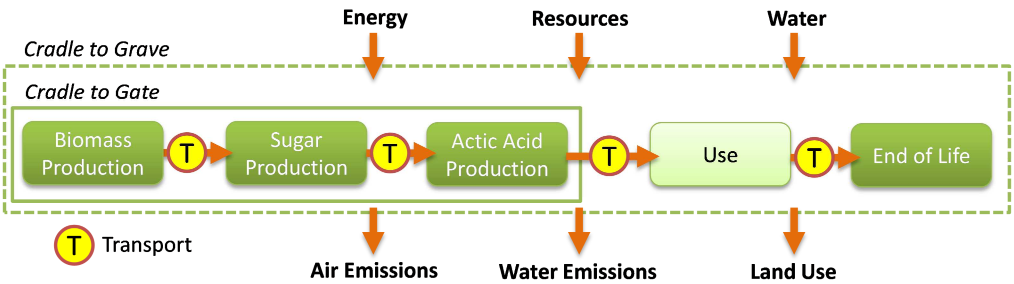

Figure 3. *LCA system boundaries for acetic acid production and end-of-life*

1. Cradle to gate: includes resources extraction (energy, materials and water), transport and the production steps until the gate of the acetic acid factory. **2. Cradle to grave:** additionally to the cradle to gate activities, this system includes transport and distribution of the product, use of acetic acid and its end-of-life.

Environmental assessment: settings & impacts

Table 1. LCA results for one kg of acetic acid in a cradle to gate system

Raw material input (feedstock)	Corn		Sugar cane		Corn stover	
LCA boundaries	Cradle to gate	Cradle to grave	Cradle to gate	Cradle to grave	Cradle to gate	Cradle to grave
Allocation/substitution	A($-m), S	A($-m), S	A($-m), S	A($-m), S	A($-m), S	A($-m), S
Geographical coverage	EU	EU	Brazil	Brazil	EU	EU
References	[1]	[1]	[1]	[1]	[1]	[1]
Impact categories from Environmental Sustainability Assessment methodology						
Climate change ($kgCO_2eq$)	(0.7-6.6)	(2.1-8.1)***1***	(-0.1-4.7)***2***	(1.1-6.2)***1***	(0.0-5.5)***3***	(1.5-7.0) ***1***
Additional impact categories						
(Land use) (m^2)	(1.4-2.6)	N.A.	(1.5-2.6)	N.A.	(0.6-1.1)***4***	N.A.
Primary energy (MJ)	(63.4-180.7)	N.A.	(69.6-191.9)	N.A.	(64.9-183.5)	N.A.
Non-renewable energy (MJ)	(43.7-144.9)	N.A.	(22.5-106.3)***2***	N.A.	(31.9-123.4)***3***	N.A.

Notes: N.A. not available. A=Allocation ($-economic; E-energy; m-mass). S=Substitution. SE=System expansion.

The normalisations presented in Figures 4 were performed using the normalisation factors provided in the JRC methodology [2] and the ReCiPe normalisation factors (see explanatory document).

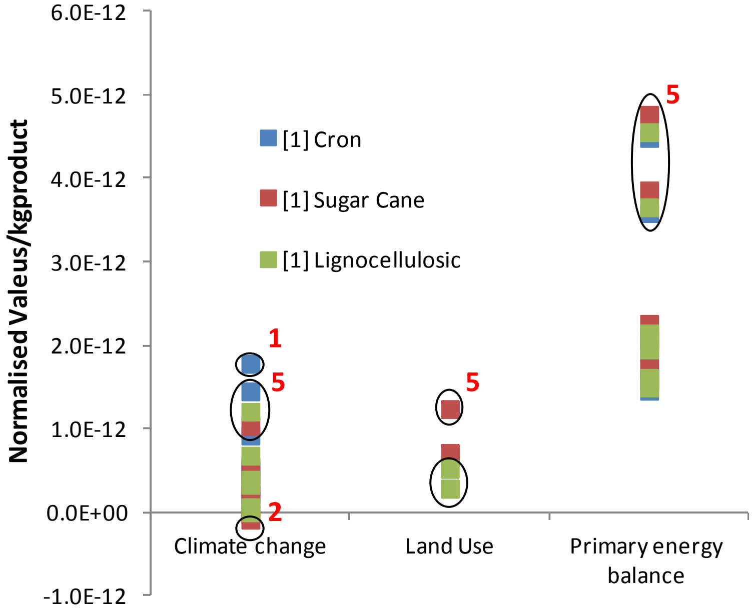

Figure 4. *Environmental performance expressed as normalised impact categories*

Comments and interpretation of environmental performance (Table 1 and Figure 4):

1. The highest values found for climate change were reported from studies that consider cradle to grave boundaries. It can be therefore concluded that the use and the end-of-life phases are environmentally significant;
2. The lowest values found for climate change and non-renewable energy demand were obtained for the production of acetic acid from sugar cane, owing to the high productivity yields of sugar and the credits assigned to the process [1] for the energy surplus, generated from bagasse burn;
3. Reference [1] considers burning of lignin-rich waste [obtained in the pretreatment (hydrolyses) (see bioalcohols via fermentation factsheet) of corn stover] to produce power and heat. This results in decreased impacts in non-renewable energy demand and climate change categories;
4. The land requirements for acetic acid production from corn stover are lower compared to those from corn and sugar cane. This is due to the fact that economic allocation is applied [1], which assigns a lower economic value to corn stover than to corn kernels;
5. The highest values found for all the reported impacts correspond to cases where batch anaerobic fermentation is considered for the production of acetic acid, in contrast with the use of continuous fermentation. This indicates that the use of continuous operation systems is likely to decrease the environmental impact of acetic acid production.

REFERENCES / FURTHER INFORMATION

[1] BREW Project - Medium and long-term opportunities and risks of the biotechnological production of bulk chemicals from renewable resources. http://brew.geo.uu.nl/

[2] EC – JRC, 2014. Normalisation method and data for environmental footprints – Draft v. Sept2014.

FP7 Project REFERENCES in CORDIS www.cordis.europa.eu
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