# White Paper:

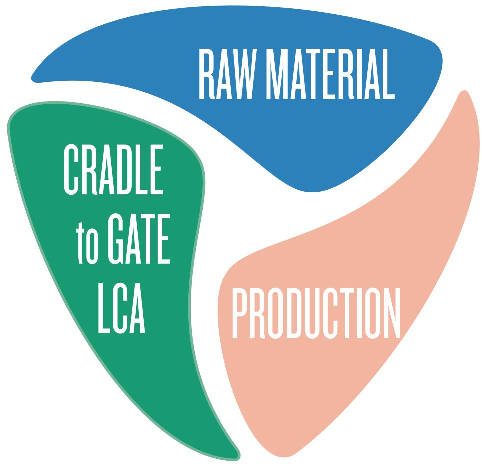
## BETAFIN® NATURAL BETAINE
## SUSTAINABLE AND SUBSTANTIATED

Danisco Animal Nutrition

# DuPont Industrial Biosciences commitment to sustainability

Consistently DuPont has proven to be a sustainability leader with our demonstrated performance in improving our value chain and reducing any negative impacts by harnessing opportunities to address global challenges in food, health, chemicals and energy. We have developed a differentiated business approach by managing the risks and building capacity in our supply chain, reducing our operational, environmental and social impacts and delivering sustainable product offerings to the market. With this approach sustainability challenges and concerns are seen as opportunities to advance impact reduction in our customers' processes and consumer applications.

Environmental and social impacts occur throughout a product's life cycle: from raw material acquisition to production (cradle to gate) or from raw material acquisition to use and end-of-life (cradle to grave). We have fine-tuned our approach to product development to include Life Cycle Assessment (LCA) and environmental footprinting. This will guide our efforts towards reducing our impact and to provide quantitative impact data to our customers, retailers and consumers.




Life Cycle Assessment is used at DuPont Industrial Biosciences as an analytical tool to quantify and interpret the flows to and from the environment (including emissions to air, water and land, as well as the consumption of energy and other material resources), over the entire life cycle of a product or service. An LCA provides a comprehensive view of the environmental aspects of the product or process throughout the product life cycle and a more accurate picture of the improvement potentials and the environmental trade-offs.



This paper documents the findings of a comparative LCA of betaine production by three alternative pathways: natural betaine from DuPont (Betafin® natural betaine) and two synthetic betaine products relevant in today's marketplace. This assessment has been conducted in line with the ISO 14040 – 14044 standards for comparative LCAs.

The assessment results demonstrate (see Section 2, Figures 4 and 5) that with regard to carbon footprint (contribution to global warming potential) Betafin® natural betaine production is 76-80% less impactful than the synthetic alternative pathways. Betafin® natural betaine outperforms the synthetic alternatives in 9 of the 13 total impact categories considered in the study, leading to a significantly less impactful and more sustainable product for our environment.

The naturally produced betaine for animal feed applications from DuPont offers unique benefits towards sustainability.

# 1. Assessing the sustainability of Betafin® natural betaine production alongside synthetic alternatives

An internal comparative LCA for three industry standard betaine manufacturing processes was conducted with Betafin® natural betaine, synthetic anhydrous betaine and synthetic betaine hydrochloride (HCl).

The LCA model is using comparative functional units equivalent to 1.0 kg crystalline anhydrous betaine (assuming 100% purity). All the products serve similar functions, however, due to differences in betaine quality and quantity between anhydrous betaine and betaine HCl the products under study are:

- 1.0 kg anhydrous betaine (for both Betafin® natural betaine and synthetic anhydrous betaine)
- 1.3 kg synthetic betaine HCl

The study has undergone an external critical review and has been determined to generally fulfil the requirements of the ISO 14040 and 14044 Standards.

## 1.1 Functional unit and scope

The LCA focuses on the cradle to gate impacts associated with three alternative betaine production pathways that are relevant in today's marketplace:

- The Betafin® natural betaine production process involves betaine rich side-streams (betaine molasses and vinasses) from sugar beet plants which are used to produce anhydrous betaine at the Finnish production facility of DuPont.
- Chemical synthesis by the reaction of trimethylamine (TMA) with monochloroacetic acid (MCAA) involving an ion exchange process yielding anhydrous betaine (Chinese production).
- Chemical synthesis by the reactions of $Na_2CO_3$, MCAA, TMA and HCl, followed by crystallization into betaine HCl (Chinese production).

## 1.2 Excluded data and processes; other methodological issues

As is usual in an LCA, some aspects within the set boundaries are excluded due to redundancy or statistical insignificance. The scope and boundaries of this study excluded the impact of human activities, such as travel to and from work. It also excludes services such as marketing, accountancy, consultants, business travel and financial intermediations.

The Ecoinvent database (the main database used for this LCA) uses allocation between co-products, which does not comply with the preferred method for handling co-product allocation according to the ISO 14044 standard as well as the ILCD Handbook. However, it has been assumed that this does not have any significant impact on the result as the most important activities do not involve co-products.

## 1.3 What is "betaine"?

Betaine is naturally present within the cells of most microbial, animal and plant species, especially sugar beets (*Beta vulgaris*). The betaine concentration and bioavailability in plants and animals varies depending on the growing and osmotic stress conditions. Most of the commercially available natural betaine is extracted from sugar beet molasses which is a by-product of sugar beet processing. Betaine can also be chemically synthesized.

Betaine has numerous potential applications including industrial fermentation, food, sports nutrition, cosmetics, crop protection, de-icing for airport runways as well as animal nutrition. The present study focuses on the use of betaine as an animal feed additive.

Betaine has two roles in animal nutrition as:

- an osmoregulator it can protect cell enzyme systems and membranes from ionic inactivation during stress
- a methyl donor via transmethylation, it is more effective than other potential methyl group donors such as methionine and choline

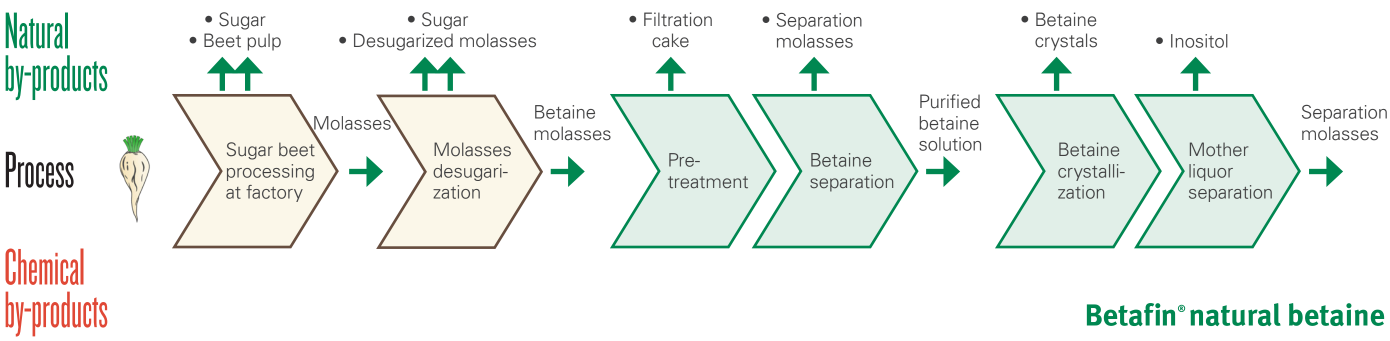
Betaine benefits parameters such as bodyweight gain, feed utilization, costs, carcass lean deposition and litter size with effects magnified at times of production stress (e.g. heat stress, coccidiosis challenge).

## 1.4 Production of Betafin® natural betaine

The Betafin® natural betaine production process is based on partnerships with sugar beet processors using proprietary molasses de-sugarization technology from DuPont and on the fact that sugar beet contains significant amounts of betaine. DuPont partners are able to increase their sugar yield by extracting more sugar out of their molasses and are able at the same time to recover a betaine rich fraction called betaine molasses. If not recovered this side-stream ends up as de-sugarised molasses.

Betaine molasses from partners is transported to DuPont's production plant in Finland where betaine is extracted using filtration, separation and crystallization methods. At the same time another valuable sugar beet by-product, inositol, is recovered, crystallized and sold for nutrition applications. Any remaining material is collected and evaporated for separation molasses which is sold for cattle feed applications. Figure 1 shows a simplified process flow diagram of the Betafin® natural betaine production process. Consistent with consequential LCA methodology, this study seeks to model only those activities that are actually affected as a "consequence" of the change in production (increase in production of betaine), and exclude those that are constrained (and thus do not respond to a change in production).

**Figure 1: Natural betaine process flow**



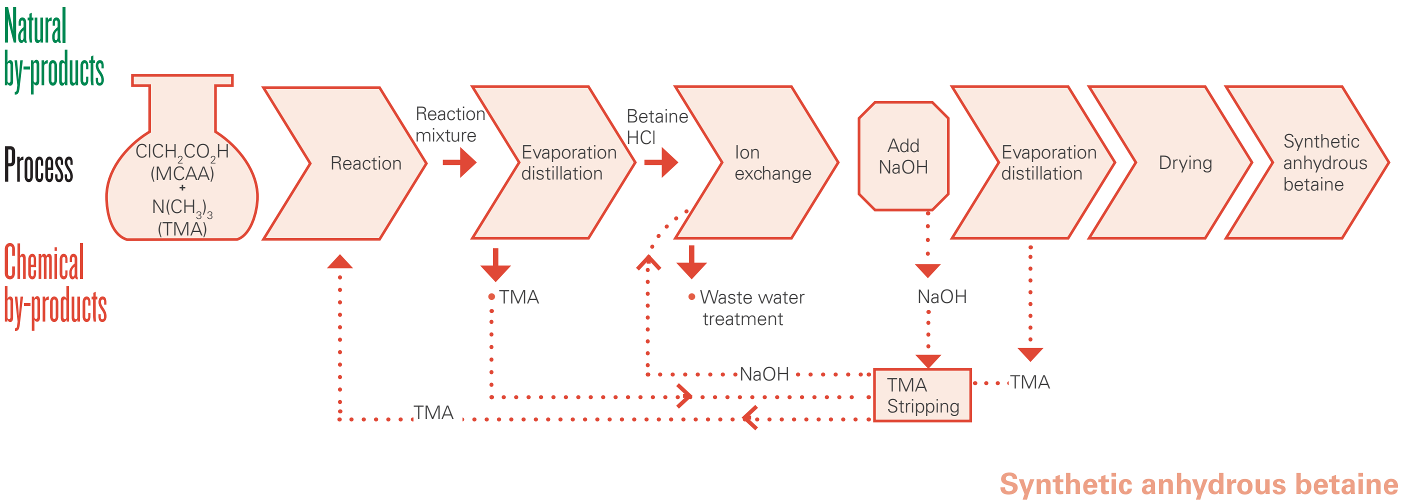
### 1.5 Production of synthetic anhydrous betaine

Chemical synthesis routes to produce betaine or betaine hydrochloride are based on a well known reaction of TMA with MCAA. The primary raw materials are produced as follows:

- TMA is produced by the reaction of ammonia and methanol employing a catalyst. This reaction co-produces the other methylamines, monomethylamine and dimethylamine.
- MCAA is mainly produced by the chlorination of acetic acid.

For synthetic anhydrous betaine, TMA and MCAA are allowed to react in aqueous solution in a batch reactor to form betaine HCl. The reaction mixture containing mainly betaine HCl and residual TMA is led to evaporation for removing the free TMA. Then the remaining solution is put through a strong anion exchange resin, where NaOH is used to separate betaine HCl into betaine and NaCl fractions. The purified betaine solution is evaporated and totally dried to yield crystalline anhydrous betaine. Figure 2 shows a simplified process flow diagram for chemical synthesis of anhydrous betaine.

**Figure 2: Synthetic anhydrous betaine process flow**



## 1.6 Production of synthetic betaine HCl

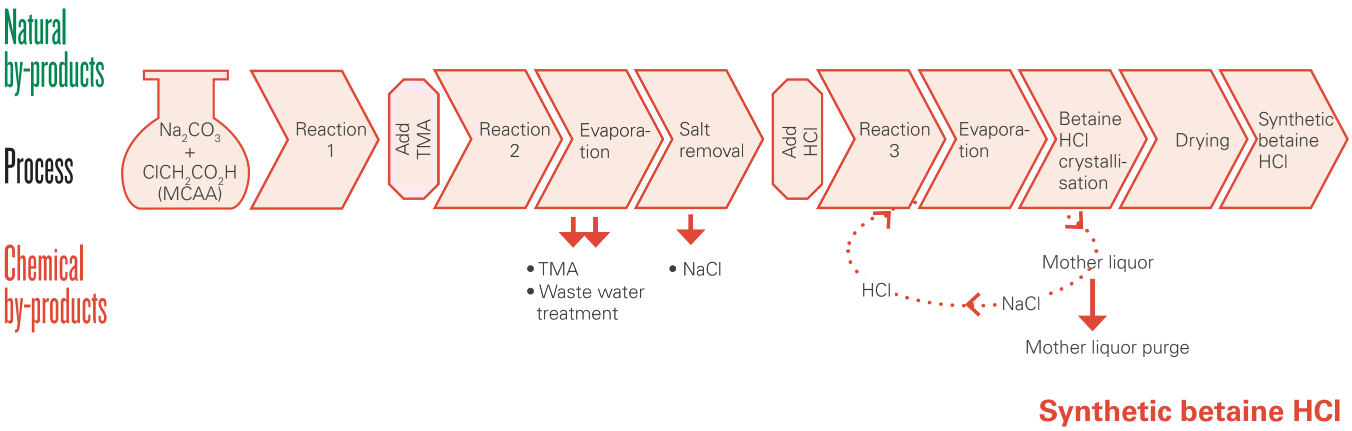
Data for the production of synthetic betaine HCl produced in China was obtained from conversations with an industry expert (Zhuoyao, 2012), as well as theoretical reaction conversions and assumptions in material balance by DuPont staff scientists/ engineers (Kuusisto *et al*, 2012). Again, a market based approach is taken for the production of synthetic betaine HCl and marginal electricity is applied.

Synthetic betaine HCl is produced in three sequential reactions:

1. Sodium carbonate ($Na_2CO_3$) and MCAA react in an aqueous solution producing sodium chloroacetate.
2. Sodium chloroacetate reacts with TMA, generating a solution of betaine and NaCl.
   Prior to the third reaction the solution is concentrated by evaporation and salt removal.
3. Betaine reacts with HCl to form betaine HCl.
   After evaporation betaine HCl crystallizes out of the mother liquor and is centrifuged and dried.
   The mother liquor continues to circulate increasing the crystal yield.
   Finally NaCl and the mother liquid purge enter the waste treatment along with the waste stream from the first evaporation step.

Figure 3 shows a simplified process flow diagram for the synthetic betaine HCl process.

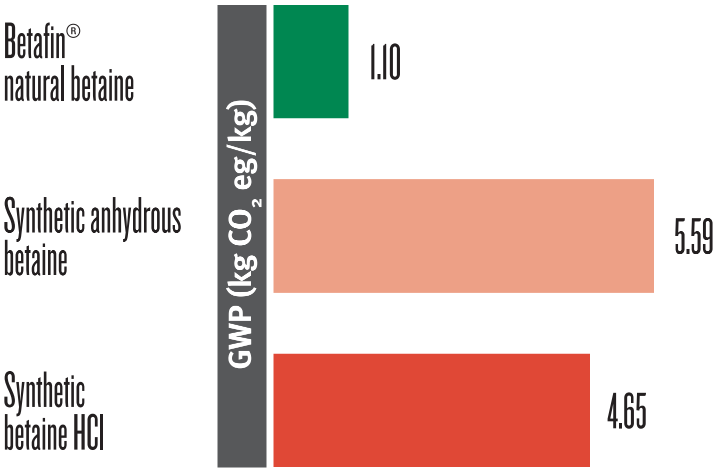
**Figure 3: Synthetic betaine HCl**



## 2. Results

The LCA clearly indicates that Betafin® natural betaine has a particularly low global warming potential (carbon footprint) relative to the synthetic alternatives available on the market. The results suggest that the carbon footprint of Betafin® natural betaine is 76-80% lower than the synthetic alternative pathways (see Figure 4).

**Figure 4: Net comparison of Global Warming Potential (GWP) of betaine products**



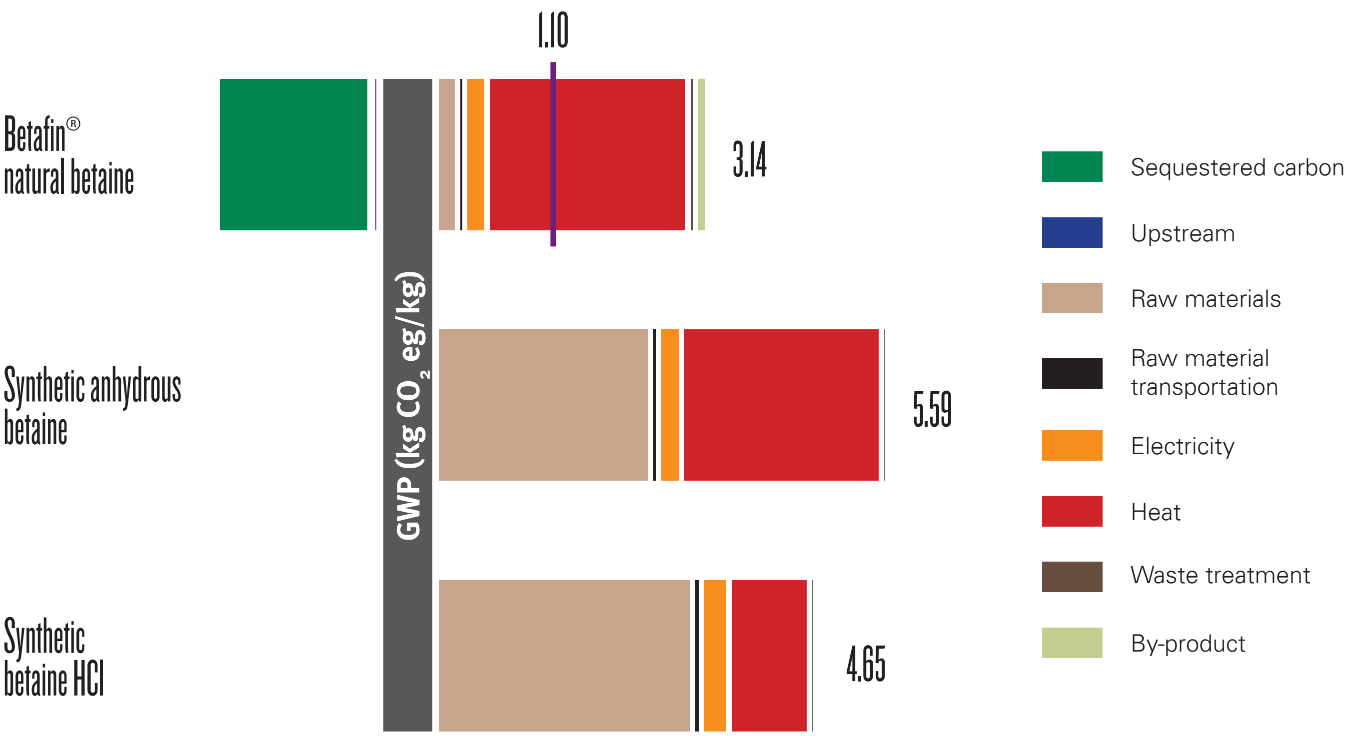

Furthermore, out of the 13 additional impact categories that were considered in the study, Betafin® natural betaine out performs the synthetic alternatives in 9 categories, leading to a significantly less impactful and more sustainable product (Table 1 below and Appendix 1 for product impact categories description).

**Table 1: Product impact categories**

| | Units | Betafin® natural betaine | Synthetic anhydrous betaine | Synthetic betaine HCl |
|---|---|---|---|---|
| **Product impact categories** | **kg** | **1.0** | **1.0** | **1.3** |
| Fossil depletion | kg oil equivalent | **1.07E+00** | 2.52E+00 | 2.57E+00 |
| Metal depletion | kg Fe equivalent | **5.07E-02** | 2.86E-01 | 3.61E-01 |
| Water depletion | $m_3$ | 2.03E-02 | 3.06E-02 | 1.77E-02 |
| Urban land occupation | $m_2a$ | 3.54E-02 | 3.13E-02 | 2.77E-02 |
| Agricultural land occupation | $m_2a$ | 2.97E+00 | 1.12E-01 | 9.37E-02 |
| Marine eutrophication | kg N equivalent | **2.55E-03** | 4.15E-03 | 6.45E-03 |
| Freshwater eutrophication | kg P equivalent | **7.12E-04** | 1.55E-03 | 8.42E-04 |
| Terrestrial acidification | kg $SO_2$ equivalent | **6.31E-03** | 2.81E-02 | 2.13E-02 |
| Ionizing radiation | kg U235 equivalent | 3.80E-01 | 4.10E-01 | 1.28E-01 |
| Particulate matter formation | kg PM10 equivalent | **1.74E-03** | 8.79E-03 | 6.70E-03 |
| Photochemical oxidant formation | kg NMVOC | **4.78E-03** | 1.73E-02 | 1.48E-02 |
| Ozone depletion | kg CFC-11 equivalent | **9.34E-08** | 1.52E-06 | 1.80E-06 |
| Climate change | kg $CO_2$ equivalent | **1.1** | 5.59 | 4.65 |

Natural betaine's high impact for water depletion, urban land occupation and agricultural land occupation can all be attributed to the relationship with animal feed markets and the feed energy and feed protein crops. Therefore this has an impact on other crops used for animal energy and protein supply. As an animal feed additive, betaine benefits parameters such as bodyweight gain, feed utilization, carcass lean deposition and litter size with effects magnified at times of production stress. By improving performance in these areas, a diet containing betaine can produce more meat (end product) from a given amount of feed, benefiting the overall sustainability profile of meat.

**Figure 5: Comparison of contributions to the Global Warming Potential (GWP) of all three betaine products**




The comparative results in Figure 5 above show the resources used for each product assessed in the LCA. Betafin® natural betaine has a lower overall carbon footprint than the synthetic alternatives at approximately 3.14 (kg$CO_2$ eg/kg). However, due to the sequestered carbons and the use of an up stream co-product in the Betafin® production process this further reduces its carbon footprint to the line indicated at 1.10 (kg$CO_2$ eg/kg).

# 3. What does this mean?

Production of food products including growth of crops, transportation, processing, use and disposal account for approximately one third of total man-made greenhouse gas emissions. Meat production typically has a high carbon footprint, with red meats higher than white meats due to methane emissions by ruminants.

Animals raised on low carbon farms achieve optimized performance targets, high breeding outputs, increased available metabolisable energy (ME) using co-products and early final target weights. Feed additives improve Feed Conversion Ratios (FCRs) and reduce the need for maintenance energy helping achieve consistent production performances. Therefore, using a feed additive that is more sustainable will further reduce the carbon foot print of a farm.

The near future will see the proliferation of food companies publishing the carbon footprint of their products and using this information on their packaging. Some companies have already started to publish data.

# 4. The future?

The world faces unprecedented challenges. In the next 40 years, the world's population is projected to grow to 9 billion people. Pressure to supply protein sources to the world will lead to increased deforestation, an influx to large conurbations and the climate will change as a result of global warming.

How we address the demand for food availability, energy efficiency, reduced $CO_2$ emissions and better health and nutrition will be critical to the future of our industry, the world population and the planet. Using products such as Betafin® natural betaine can be a step towards limiting this impact.

150,000

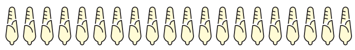
**The world's population will grow by 150,000 people daily for the next 40 years.**

# 5. People, planet and profit

We address sustainability challenges by our innovation, how we source our raw materials and produce our products.

For DuPont Industrial Biosciences, sustainability is about finding innovative solutions to help customers make products that provide lasting benefits to the society we live in, today and tomorrow.

70%



**To feed them, we'll need 70% more safe, nutritious food**

# 6. Additional product benefits

Betafin® natural betaine is extracted from sustainable sugar beet molasses and vinasses (fermented molasses) using a patented chromatographic separation process.

Betaine has two important functions in animal nutrition as an osmolyte and as a methyl donor via transmethylation. Through its osmolyte and methyl donor functions Betafin® natural betaine offers many benefits in animal production:

- maintain gut integrity at time of production stress
- improve productive performance
- reduce feed costs

Betafin® natural betaine benefits at the feed mill:

- a natural product – not chemically synthesized
- consistent, guaranteed high levels of pure betaine
- very low chloride content benefits osmolytic function
- heat stability to 200°C
- non-hazardous, safe in use
- non-corrosive for equipment
- non-aggressive in vitamin and mineral premix
- multi-species applications

# 7. Regulatory status

Local regulations should be consulted regarding the use of this product, as legislation regarding its use may vary from country to country. Advice regarding the legal status of this product may be obtained on request.

# 8. A more sustainable solution for customers

Overall, this study demonstrates a significantly lower environmental impact for the production of Betafin® natural betaine relative to synthetic betaines considered in this study.

# 9. Becoming first choice

Dupont Industrial Biosciences is the world's leading producer of animal feed additives and among the strongest players in biotechnology. We have a heritage built on quality, trust, integrity and sound science.

We will seize opportunities to partner with our customers and create sustainable solutions that meet their market needs. Our goal is to become a preferred supplier and partner – our customers' first choice.

We have a reputation for regulatory and animal nutrition application knowledge.

We form strategic partnerships with customers to meet the needs of the global food industry.

We are in close co-operation with the scientific community and actively publish the findings of our research and development work.

We collaborate closely with our customers all over the world. We have laboratories in many countries, so we can develop and test specific products tailored to fit local markets.

We offer a unique all-in-one approach; from concepts and claims to application technology and marketing partnerships.

# Appendix 1

| Product impact categories | Definition |
|---|---|
| Fossil depletion | Resource depletion potential of organic substances found underground in deposits formed in a previous geologic period which can be used as a source of energy such as coal or petroleum |
| Metal depletion | Resource depletion potential of natural metals found in the ground such as iron, copper, silver etc. |
| Water depletion | Resource depletion potential of water |
| Urban land occupation | Occupation of land that is built-up such as factories or housing |
| Agricultural land occupation | Occupation of land that is agricultural |
| Marine eutrophication | Increase of nutrient levels in marine habitats such as run off |
| Freshwater eutrophication | Increase of nutrient levels in fresh water such as run off |
| Terrestrial acidification | Emissions of nitrogen and sulphur in the atmosphere that cause acidification to ecosystems |
| Ionizing radiation | Radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from the orbit of an atom, causing the atom to become charged or ionized |
| Particulate matter formation | The formation of air pollution from solid particles and liquid droplets. Pollutants can vary in size and can be composed of many materials and chemicals |
| Photochemical oxidant formation | A chemical reaction that takes place between nitrogen oxides and volatile organic compounds exposed to UV radiation e.g. smog |
| Ozone depletion | A reduction in total volume of the earth's stratosphere (ozone layer) and a decrease in the earth's stratospheric ozone around the polar regions |
| Climate change | A change in global or regional climate patterns largely attributed to atmospheric carbon dioxide produced by the use of fossil fuels |



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