Specialty Food Ingredients – Environmental Impacts and Opportunities

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ABSTRACT

Specialty food ingredients (SFIs or just 'specialty ingredients') such as emulsifiers, food enzymes, hydrocolloids and cultures are typically applied in small amounts (<1% w/w of the final food product). Generally, little attention has been given to specialty ingredients in the LCA community (Foster et al 2006, BCFN 2011). DuPont Nutrition & Health (N&H) is a leading producer of specialty food ingredients worldwide. During the last five years, DuPont N&H has completed cradle-to-gate LCAs of a wide range of specialty ingredients, based on both attributional and consequential modeling. The average carbon footprint of DuPont N&H products is 3-4 kg CO_2e per kg (cradle-to-gate) but they only represent a small share of the final consumer products carbon footprint. More importantly, most solutions enable significant reductions of our customer's footprint by enabling replacement of animal derived raw materials (with e.g. soy protein), increasing processing efficiency or enabling reduced food waste in retail and households. DuPont N&H has identified more than 70 'sustainable solutions' and LCA screenings of 40 cases show that they can help customers reducing between 10 and 100 kg CO_2e per kg specialty ingredient applied.

Keywords: Specialty Food Ingredients, Life Cycle Assessment, Carbon Footprint, Food Waste, Sustainable Food

1. Introduction

A significant number of food companies apply life cycle assessment (LCA) to quantify the environmental burdens associated with their products. LCA studies have been published on a wide range of food, including dairy products, meat products, vegetables, fruits, bread, alcoholic and non-alcoholic beverages, confectionary etc. (Foster et al 2006, BCFN 2011). Few studies, however, are available on specialty ingredients such as:

- Emulsifiers (e.g. used to strengthen and soften the dough in bread)
- Food enzymes (e.g. bakery enzymes used to extend periods for which breads stay fresh)[1]
- Hydrocolloids (e.g. pectin used as gelling agent in jam and marmalade)
- Bacteria cultures (e.g. acidifying cultures applied in the production of yoghurt and fresh fermented milks)
- Antimicrobials and antioxidants (e.g. rosemary extract used to prevent pathogens and oxidation in meat)
- Reduced calorie sweeteners (e.g. xylitol used as sweetener in chewing gum).
- Soy protein (e.g. soy protein isolate used to replace animal protein in different food applications)

Apart from a few examples such as soy proteins and some sweeteners, specialty ingredients are typically used in small amounts (<1% w/w) to obtain certain functions such as extended shelf-life/freshness or improved taste, texture and mouth feel. In most existing LCAs of food products, impacts associated with SFIs are only modeled coarsely. But it is also important for food producers to understand the environmental impacts associated with SFIs, and more importantly to be aware of the opportunities they bring in terms of replacement of high impact raw materials, improvements in processing efficiency and not least reduction of food waste.

As a leading producer of SFIs, DuPont N&H decided three years ago to carry out cradle-to-gate LCAs on all main product categories. This paper shows examples of results from these studies as well as results from LCA screenings of the use stage. In the discussion part of the paper, attention will be given to methodological challenges.

[1] Several scientific LCA studies on enzymes including food enzymes are available in the literature (Jegannathan and Nielsen 2013).

2. Methods

In terms of cradle-to-gate LCA studies there has been completed six studies which have been third party reviewed in accordance with the ISO 14044 standard (two additional studies are in review). Our goal is that all our main product categories should be analyzed through 3rd party reviewed ISO 14044 compliant LCA studies by 2015. In addition, 40 LCA screenings of use stage impacts have been completed for a range of products and applications that we call sustainable solutions. The following sections address key methodological choices related to our cradle-to-gate LCAs as well as the LCA screenings of the use stage.

2.1. Goal and Scope

Our cradle to gate (or cradle-to-customer) LCAs include all life cycle stages from raw material acquisition to final dispatch of products to our customers and includes in many cases even outbound transport to the average customer. The functional unit can vary from study to study but reflects a reference flow of 1 kg specialty ingredient in all studies. Specialty ingredients are sold because of their function which is the reason why we often describe them as 'solutions' rather than 'products'. The functionality is therefore always described in detail, and relevant adjustments in the reference flow are made when comparisons are made between different SFIs.

2.2. Life Cycle Inventory (LCI)

In DuPont N&H consequential and attributional life cycle inventory modeling are seen as complementary rather than competing which will be explained later. Both approaches are therefore included in our detailed third party reviewed LCA studies as well as LCA screenings of the use stage.

In consequential modeling co-product allocation is consistently avoided by system expansion (substitution) and constrained processes are excluded from the analyzed product system. As an example, this means that hydropower would not be included in the grid mix for electricity in a country where all hydropower is fully utilized (e.g. Norway). Modeling of indirect land use change (ILUC) is only included in sensitivity scenarios.

Attributional modeling represents an approach where co-product allocation is typically handled with allocation, and where no distinctions are made between constrained and unconstrained processes (Sonnemann and Vigon 2011 p74). In DuPont N&H economical allocation is generally used for handling of co-product allocation in our attributional models, which is consistent with the ecoinvent V3 default allocation model (Weidema et al 2013).

Background processes have generally been modeled based on data from the ecoinvent V2.2 database (in all studies completed before 2014), but other data have been used when these have been deemed to represent a higher level of data quality. This includes, for example, data on country-specific marginal and average electricity which has been modeled separately in collaboration with 2.-0 LCA consultants (Schmidt et al. 2011). Ongoing studies are based on Ecoinvent 3 which allows for more consistent modeling, where either economical allocation or system expansion is used in all background processes.

2.3. Life Cycle Impact Assessment (LCIA)

The Recipe midpoint model has been used as the default method for impact assessment (in all studies completed before 2014) but other LCIA methods, including end-point methods, have been applied for sensitivity studies. Ongoing LCAs applies the ILCD LCIA method available in SimaPro 8 which is applied as it is recommended by the European Product Environmental Footprint (PEF) Guide and is a result of a consensus project aimed at establishing current best practice for LCIA (European Commission 2012).

2.4. Use stage modeling

In most cases, one type of specialty ingredient can typically be used in many different food products where it can have various functions. Furthermore, specialty ingredients are often used in various combinations and in different parts of the world. Needless to say, it is complex to model the use stage without focusing on concrete cases. The use stage has therefore been modeled separately and at screening level, focusing on specific applications in different parts of the world. Three scenarios are calculated for each solutions which represent attributional modeling, consequential modeling (incl ILUC) and consequential modeling (excl ILUC) which is chosen as our default model. The advantage of the different models is that it allows us to adapt to specific customer preferences. In terms of LCIA the screenings only address the carbon footprint based on characterization factors in the ILCD LCIA method in Simapro 8.

Conceptually, it is possible to distinguish three types of SFIs based on their functions: Specialty ingredients that mainly are applied to enable a substitution of raw materials (or modify recipes), ingredients that mainly aim at increasing processing efficiency and finally ingredients that serves to prolong the freshness or shelf-life of food products, see Figure 1.

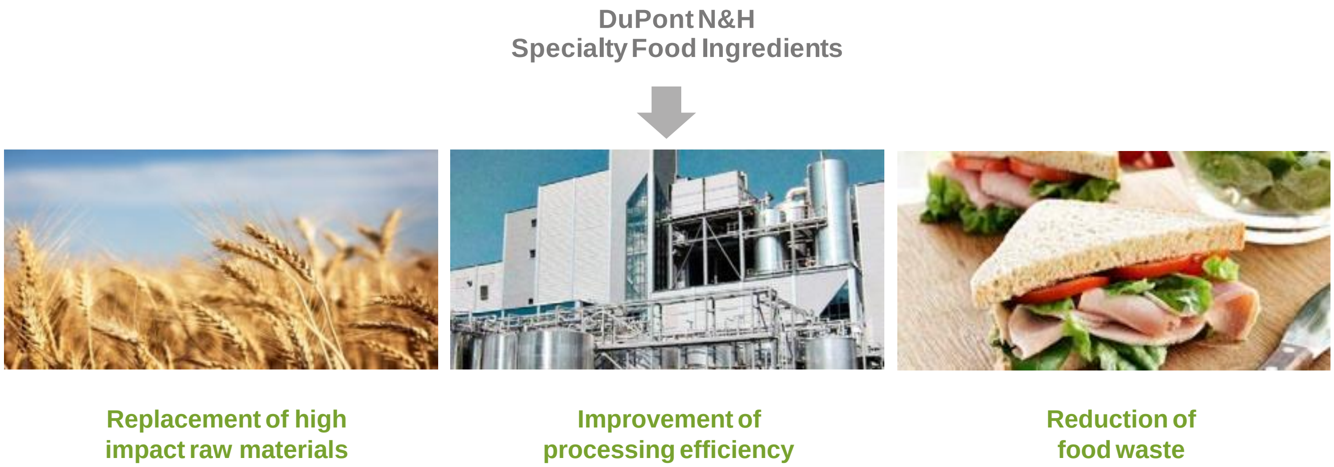

Figure 1. Conceptual model of interaction between SFIs (top center) and the food value chain with raw material providers (left), food producers (center) and finally end-consumers (right).

As illustrated the distinguishing feature between the three groups of SFIs depend on which part of the food value chain they mainly address:

- Upstream SFIs: Some SFIs address upstream impacts by enabling modifications in raw material composition e.g. by replacing animal protein and fat with vegetable protein and fat (Figure 1 left). This application can be divided in two sub-categories: direct upstream where the SFI itself constitutes the replacement (e.g. soy protein that replaces milk protein) and indirect upstream where the SFI has an indirect role allowing the replacement to take place (e.g. hydrocolloids that facilitate a reduction of animal fat or a replacement with vegetable fat in dairy, while maintaining similar taste and texture).
- Processing SFIs: Another group of SFIs addresses the food processing directly – e.g. by allowing for larger throughput and/or increased efficiency (Figure 1 center).
- Downstream SFIs: These are SFIs that address the food products' freshness and their taste and texture as perceived by the end customers in a typical use scenario (Figure 1 right). This application has the potential to reduce food waste significantly, especially for categories of food products where the dominating reason for food waste is that it has passed a date label, has gone moldy or rotten, looked, smelt or tasted bad.

All three functions have a significant potential to promote sustainability in the food value chain – especially upstream and downstream SFIs that address the most important hot-spots of average food products (raw materials and food waste). A large generic group of SFIs such as food enzymes or hydrocolloids can have several of the above mentioned functionalities, while more specific products typically have a more narrow functionality related to one of the functions.

3. Results

3.1. Example of comparative LCA on Xylitol/Xivia®

One of the first LCAs completed by DuPont N&H was a comparative LCA on the sweetener xylitol, which was reviewed by a third party panel in 2011. Two production methods were compared – one based on a side stream from the pulp and paper industry (the wood based concept used by DuPont), and one based on corn cobs (used by most of our competitors). The study was completed by Earthshift consultants and applies attributional modeling but with the use of system expansion (substitution) for energy and waste related foreground processes. In this particular study, Impact 2002+ has been used for life cycle impact assessment (LCIA). A significant difference was anticipated, but it was a surprise to most that the wood based technology actually generated 85-99% lower impacts across all investigated impact categories (see Figure 2).

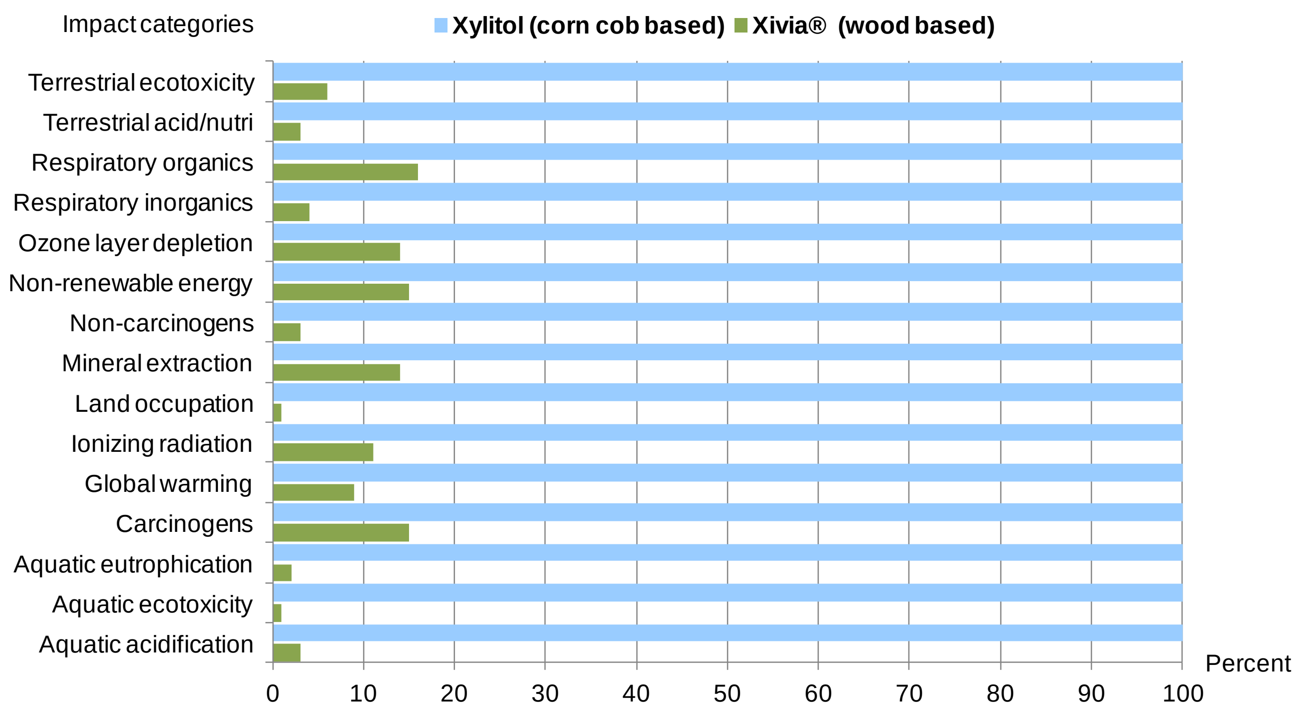

Figure 2. Characterized results from comparative LCA (based on Impact 2002+) of corn cob based xylitol and DuPont's wood based xylitol (Xivia®) based on Dahliwal, Hamilton and Laurin (2010).

In terms of global warming potential the wood based technology contributed 3.6 kg CO_2e per kg Xivia® (cradle-to-gate) while the corn cob based technology contributed 38.6 kg CO_2e per kg xylitol from cradle-to-gate (Dahliwal, Hamilton and Laurin 2010). Results also published in Danisco (2011) and Dahliwal and Thrane (2011).

3.2. Carbon footprint and hot-spots for different groups of SFIs

Based on findings from LCA studies of SFIs as well as DuPont's Corporate Footprint based on WRI & WBCSD (2004 and 2010), it can be concluded that average carbon footprint of DuPont N&H's specialty ingredients is in the range of 3 to 4 kg CO_2e per kg from cradle-to-gate, excluding ILUC. The main contribution comes from raw materials (53%), while processing represents 35% of the cradle-to-customer footprint. Inbound and outbound transport both represents 6% respectively (Thrane 2011, Dalgaard et al. 2013).

With a typical application level of less than 1% w/w of the customer's final product, this suggests that specialty ingredients in most cases have a modest contribution to a food product's total footprint. There are cases, however, where SFIs are used in larger amounts such as for soy proteins, and in the case of Xivia® in chewing gum applications.

Emulsifiers: For average emulsifiers, the raw materials (mainly vegetable oils) constitute about 80% of the cradle-to-gate footprint, and the average emulsifier has a carbon footprint of 3-5 kg CO2e per kg product from cradle-to-gate (Muñoz 2014). Both attributional and consequential modeling has been applied, but the results are within the range mentioned above in both LCI models.

Food enzymes: LCA of enzymes have been conducted for several years in DuPont Industrial Biosciences. In terms of carbon footprint, the most important life cycle stage for food enzymes are processing (fermentation, formulation and recovery) followed by raw materials use in the fermentation process. The carbon footprint ranges between 1 and 10 kg CO_2e per kg enzyme from cradle-to-gate mainly depending on the type and quantity of raw materials, the fermentation time and the concentration (Dettore 2014). Again both consequential and attributional modeling has been used and both approaches are represented within the indicated carbon footprint range.

Hydrocolloids: In terms of carbon footprint, the processing stage is important for most hydrocolloids. Processing aids also have a noteworthy contribution to the footprint, but it should be stressed that hydrocolloids are a very diverse group of ingredients with large variations in hot-spots and impacts. The typical carbon footprint ranges from 1-12 kg CO_2e per kg hydrocolloid from cradle-to-gate. This range covers many different hydrocolloids of which most have been analyzed through screening level LCAs apart from a third party reviewed LCA of pectin published in 2011 (Thrane 2011). Consequential modeling has been applied in combination with attribution modeling in the third party reviewed LCA which showed only a minor difference in impacts.

Cultures: Similar to most hydrocolloids, the processing stage represents an important contribution to the carbon footprint for cultures – mainly due to the energy use. Two types of direct inoculation cultures exist: Frozen cultures and freeze dried cultures, which are concentrated and therefore more efficient. Adjusted for functionality, the cradle-to-gate footprint for both types of cultures are in the range between 8 and 12 kg CO2e per kg. Cultures are added at rather small dosages in yoghurt and cheese; between 0.5 and 2 kg frozen cultures per 10,000 liters of milk. As for most SFIs their contribution to the final products footprint is therefore small. In a cradle-to-customer perspective, the carbon footprint for outbound transport can be important, especially for frozen cultures. The reason is that frozen cultures have to be stored at minus 50°C to 60°C and frequently require air transport – especially for transcontinental shipments. In cases where outbound transport involves airfreight, freeze dried cultures are likely to offer a low carbon footprint alternative to frozen cultures. Both consequential and attributional modeling has been applied and again no significant differences in impacts have been identified apart from what is covered by the suggested interval (Thrane 2012, Thrane 2013a, Thrane 2013b).

Reduced calorie sweeteners: For this category, only Xivia® has been analyzed and the study shows that the raw material- and processing stage represent the largest carbon footprint (due to energy use). The carbon footprint of Xivia® is within the same range as our average product, 3-4 kg CO2e per kg (Dahliwal, Hamilton and Laurin 2010). But as Xivia® is the only sweetener type that has been analyzed, it is not possible to conclude that this product is representative for the other products in this category.

Protein solutions: For soy protein concentrate (min 65% protein per dry matter) and soy protein isolate (min 90% protein per dry matter) the main contribution comes from the processing stage due to energy use. A detailed LCA is being completed but final results are not yet available. Preliminary results indicate that the carbon footprint is around 2-4 kg CO_2e per kg protein product. Consequential modeling suggests a lower impact compared to attributional modeling.

Apart from the product groups mentioned above, DuPont N&H also produces antimicrobials and antioxidants (covering products such as Natamax®, Nisaplin® and GUARDIAN® Rosemary Extract) as well as a range of other products that could be termed 'other' which include fibers, rare sugars, soy lecithin etc. Considering the large number of ingredients and applications, the scope has been limited to cover the above mentioned groups in the present article.

3.3. LCA screenings of avoided burdens (use stage impacts)

As mentioned, the use stage has also been modeled by LCA screenings focusing on the carbon footprint. So far, more than 70 solutions have been identified and 40 of these have been quantified by LCA screenings. In a typical case, 1 kg specialty ingredient contributes to avoiding 10-100 kg CO_2e (net) compared to a situation where the ingredient is not used. All LCA screenings have been made according to both attributional and consequential modeling, but the results presented in the following are only based on consequential modeling, which in most cases represent a more conservative estimate of potential savings.

Direct upstream SFIs: One example of direct raw material replacement is the use of Xivia® instead of corn cob based xylitol in chewing gum. The net avoided impact per kg applied Xivia® is the difference in impact between one kg corn cob based xylitol and one kg Xivia®, which amounts to 35 kg CO_2e. LCA screenings shows that the carbon footprint is reduced by 42-85% per kg chewing gum when switching from corn cob based xylitol to Xivia®. The large interval represents differences in xylitol content in the final recipe with all ingredients including gum base. The modeled xylitol content ranges from 5% to 55% (Dalgaard et al. 2013a). Another example could be the use of soy protein to replace milk or meat protein in different applications such as dairy products, sausages and burgers. Updated third party reviewed LCA results of soy protein isolate are not yet available, but our LCA screenings suggest that 1 kg isolated soy protein contributes to reducing 10 kg CO_2e (net) in application where it replace milk protein[2] and even more when replacing meat protein. An example of a beef burger, where the beef content is partly replaced with textured soy concentrate, shows that the carbon footprint of the beef can be reduced with as much as 35% (Dalgaard et al. 2013 a and b).

Indirect upstream SFIs: An example where the specialty ingredient has an indirect effect on raw materials could be a pectin based ingredient solution, such as GRINDSTED® SB555, that makes it possible to replace milk protein with vegetable protein in yoghurt, without compromising organoleptic properties. An LCA screening shows that 1 kg GRINDSTED® SB555 contributes to reducing 12 kg CO_2e per kg (net) in a specific application where it allows for using vegetable protein instead of milk protein in yoghurt. The solution allows the footprint of the final yoghurt to be reduced with 18%. Other solutions exist which enable replacement of meat protein in sausages, burgers etc. (Dalgaard et al. 2013b). Another example of indirect upstream substitution could be the enzyme Alphalase® AP4 applied in beer production. This solution makes it possible to brew a good quality beer where 60% of the malt is replaced with barley. LCA screenings show that 1 kg Alphalase® AP4 contributes to reducing 100 kg CO_2e (net) in this application and the footprint of the final beer is reduced by 12% (Dalgaard et al. 2013a).

Processing SFIs: An example of processing SFIs is FoodPro® Cleanline - an enzyme solution which can significantly reduce the impacts of ultra high temperature processing of milk in dairies (UHT). This solution prevents fouling in the UHT processing systems, leading to higher capacity while reducing the need for cleaning cycles that otherwise would require significant amounts of water, energy and cleaning chemicals. An LCA screening shows that 1 kg FoodPro® Cleanline contributes to reducing 35 kg CO_2e per kg (net) when applied in UHT processing. In a large scale dairy with 6 UHT lines, this translates in to annual net savings of 322 tons CO_2e (Dalgaard et al. 2013b).

Downstream SFIs: Finally an example of a solution that addresses downstream food waste is the use of emulsifier and enzyme blends in bakery products. Food waste is a major issue, and bakery products are one of the worst culprits for avoidable food waste. Approximately 30% of bakery goods like bread, cakes and cookies are wasted in the households and according to WRAP about 90% of this waste occurs because the products are not perceived as fresh (Gustavsson et al. 2011, Quested and Johnson 2009). DuPont has developed enzyme solutions that apart from providing the usual bread softness and crumb elasticity, also keep the bread moist longer. The enzymes are sold under the Powerfresh® brand name and are often used in combination with emulsifiers. An LCA screening has been completed for a use of 50% higher dosage of Powerfresh® (increase from 20 gram to 30 gram enzyme dosage per 100 kg flour) in toast bread in North America, enabling the bread to stay fresh for 21 days compared to 14 days with the lower dosage. Based on a model of the relationship between freshness and bread waste, calibrated with data from Quested (2013), it is estimated that the bread waste in retail and households is reduced by 30%. The LCA screening shows that the carbon footprint is reduced with 12% per kg bread consumed in this case – and several thousand kg CO_2e is avoided per kg extra enzyme that is applied. This example involves our newest and most sophisticated enzymes, but even standard enzymes (and emulsifiers) can make a huge difference in markets where enzymes are more rarely used, such as parts of Eastern Europe and Russia.

A new exiting product range with a significant potential for food waste reduction is protective cultures such as HOLDBAC® cultures used for spoilage and pathogen prevention in dairy and meat applications. LCA screen-

[2] In this example the milk protein is modeled based on the LCAfood database where the process "Milk powder, no quotas' has been modified and updated based on LCI data on milk from Schmidt and Dalgaard (2012) & Dalgaard and Schmidt (2012) using the consequential mode. If attributional modeling had been used instead the avoided burden would have been 15 kg CO2e per kg soy protein that replaces milk protein (Dalgaard et al. 2013 b).

ings of protective cultures applied to fresh cheese shows that the carbon footprint can be reduced with nearly 5% per kg consumed cheese – and 220 kg CO_2e is avoided per kg HOLDBAC® cultures applied (Dalgaard et al. 2013b).

4. Discussion

4.1. Difference between attributional and consequential modeling

In LCAs of specialty ingredients, the difference between attributional and consequential modeling is often modest. But there are situations where the differences actually matter. These can be situations where a part of the product system that is constrained, is left out in the consequential model. An illustrative example is SFIs that enable a partial replacement of milk fat with palm oil in cream cheese. This results in a significant improvement when attributional modeling is applied, but has no effect when consequential modeling is used. The latter presumes, according to the consequential model we have used, that milk fat is a dependent co-product constrained by the main product milk. Hence, instead of influencing the production of milk, a change in demand for milk fat would affect the marginal oil on the world market (namely palm oil). In terms of modeling, this implies that we replace palm oil with palm oil – hence no effect.

4.2. Consequential modeling (pros and cons)

The advantage of consequential modeling is arguably that it better reflects the functioning of the market and attempts to model consequences of concrete decisions or choices in a concrete market context. From a consumer perspective, it could be the environmental impacts of buying product A versus not buying it – or buying product A instead of product B. Both situations imply changes – which is exactly what consequential LCA attempts to model. A hot-spot assessment is not necessarily about changes – but as soon as it is used to guide decisions or to make strategic choices it does concern changes. Consequential modeling is tailor-made to decision support and is better able to address the bigger picture including the direct and indirect market effects.

Consequential modeling avoids co-product allocation – often by system expansion. This leaves less room for arbitrary choices of allocation methods, but on the other hand consequential modeling opens up for different choices and assumption related to identification of marginal products and other market aspects. It could be argued that consequential modeling, by including markets aspects, requires too much from the LCA practitioner and makes LCA a too broad research discipline. Some would probably argue that 'the best is the enemy of the good' in this context. Ultimately one of the fundamental challenges of consequential LCA is that it can be hard to comprehend, not least for non-experts. As an example it can be difficult to communicate that an LCA of soy oil based emulsifier does not include soy oil in the inventory, because it is constrained by the demand for soy meal. The consumer, customer or other stakeholder might get confused – and skeptical when they are told that palm oil is included instead because this is the marginal oil on the world market. But this is rather a communication issue than it is a real disadvantage of consequential LCA. Another challenge is that it, by putting attention to the marginal, could lead to a missed opportunity to collaborate with the suppliers of soy oil to reduce upstream impacts. This does not have to be the case, but could be the outcome when results are interpreted by non experts.

4.3. Attributional modeling (pros and cons)

Attributional modeling is often described as a more normative approach with fewer considerations about the functioning of the market. Instead it follows traditional supply chain logic and it better reflects how current supply chains are physical connected. The fewer number of variables related to the market, also reduce to option for modeling related differences when comparing results from LCA studies. Attributional modeling is arguably easier understand, and from a supply chain logic, it makes intuitively more sense that soy beans are included in an LCA of soy oil, instead of the marginal vegetable oil (palm oil) as suggested in consequential modeling. It can be argued that, attributional modeling better reflects the way many consumers and NGOs attribute a responsibility on the suppliers in the actual supply chain. An example is when stakeholders avoid agricultural products than are produced in regions where deforestation is taking place – by sourcing from other regions may just reflect a shift of burdens via indirect land use changes, and eventually the effect on deforestation may be the same.

The main disadvantage of the attributional approach is that it includes constrained suppliers, i.e. the results of an LCA include emissions from suppliers that will not change their production as a consequence of a change in the demand for the studied product. Further, the attributional approach often involves different allocation methods for multiple product output activities. Apart from making studies more difficult to compare, this approach ignores the real effects of by-products and the allocated processes fail in some cases to maintain basic balances such as mass balance, carbon balance, energy balance etc.

It is out of scope in the present article to make a more elaborate description of pros and cons, but it should be clear that depending on the purpose of the LCA, both approaches have advantages and disadvantages and that it can be fruitful to provide both perspectives in LCA studies.

4.4. Other aspects of Sustainability

The present article has focused on environmental impacts, mainly the carbon footprint. But there are obviously many other elements of sustainability such as food security, health and nutrition aspects.

Several initiatives are taking place to broaden aspects of sustainability within our own supply chain. Emulsifiers and hydrocolloids can enable reductions of salt and fat (including trans-fat) in food products. Reduced calorie sweeteners can obviously reduce sugar levels, and products such as Litesse® can increase fiber contents of foods. Other examples are probiotic cultures, which can promote a healthy bacteria flora in the digestive system. Social sustainability aspects related to food are however complex to describe and include in a short article about SFIs, and it is highly context and culture dependent. In Mexico for example, milk competes on price with soda. This means that solutions to make milk more affordable is likely to have a positive effect on both food security and health – despite reducing the amount of milk solids on a per liter basis. The theme about what defines a sustainable and healthy diet has recently been described in a discussion paper by Garnett (2014).

5. Conclusion

DuPont N&H continuously seeks to reduce the environmental impacts from all life cycle stages including raw materials, transport, processing and use. It should be recognized, however, that environmental burdens associated with SFIs typically are small or insignificant in the final consumer products. This is due to the small amounts used (typically < 1% w/w) and the relative modest carbon footprint of 3-4 kg CO_2e per kg average SFI. The latter is close to the footprint of the products in which they are typically used.

More importantly, SFIs can make a significant difference in terms of reducing the footprint of the food products in which they are used. SFIs have the largest potential to leverage sustainability in the use stage where they can affect all stages of the customer’s value chain. Three groups of SFIs can be distinguished depending on how they influence the customers’ value chains:

- SFIs that influence the first stage of the customers value chain (raw materials) – e.g. by allowing replacement of animal based with vegetable based protein or fat.
- SFIs that contributes to improve customers manufacturing efficiency.
- SFIs that mainly address the last stages of the customer’s value chain, by enabling food products to stay fresh longer and thereby reducing food waste.

Food enzymes are an example of specialty ingredients that can address raw material substitution, processing efficiency and downstream food waste. Other groups of SFIs are typically less comprehensive in their functionality, but they can have the same potential to reduce impacts such as isolated soy protein replacing animal protein.

DuPont N&H has identified 70 solutions that allow for carbon footprint reductions in the customers value chain. LCA screenings of 40 solutions reveal that these solutions allow for reductions between 10 and 100 kg CO_2e per kg SFI applied. But there are also examples where 1 kg specialty ingredient can lead to reductions of more than 1000 kg CO_2e by reducing food waste.

Detailed third party reviewed LCAs have been applied for cradle-to-gate LCAs, while the use stage has been modeled through screening level LCA. Both attributional and consequential modeling is applied in all studies and generally results vary little. There are cases, however, where significant differences emerge, especially for dairy products. While these differences may appear inconvenient they show that methodological uncertainty can be significant in certain cases.

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