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Life-Cycle-oriented Origin analysis – a method for calculating the geographical origin of products

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ABSTRACT

Knowledge of product origin is an important factor in purchasing decisions and consumers demand relevant information. However, at the moment, and especially for food products, such information is often fragmentary or incomplete and thus sometimes more confusing than clarifying. Analysis reveals that a method for calculating and communicating origin along the overall life cycle of a product is clearly lacking. The aim of the present paper is to present a method for assessing and providing information on product origin, taking food products as an example. The method proposed here is termed "Life-Cycle-oriented Origin analysis" (or in short LCOA). Life-Cycle-oriented Origin analysis is based on the life cycle assessment (LCA) approach, but it also incorporates information relating to the origin/location of raw materials, intermediary products, and processing. The present article outlines how the value of the referenced locations is assessed and how this may be used to depict the overall origin of a product. As consumers are particularly critical concerning questions of food origin, a pilot study on pre-packaged food is used here to illustrate how the concept of LCOA may be applied in practice. In principle, however, the concept may be applied to all types of consumer products. We suggest that Life-Cycle-oriented Origin analysis can be fruitfully employed in enhancing market communication and consumer research, and that it may also prove useful in matters concerning product (re-)design and optimization. Adoption of LCOA is likely to lead to improved supply chain communication for producers, and consumers may benefit by being able to assess, at a glance, the overall origin of a product.

1. Introduction

The proliferation of global trade has led to increasing spatial diversification with respect to product life cycles, i.e. the extraction, processing, production, packaging, storage and purchasing of many everyday products are now commonly dispersed across a very wide geographical area. Such spatial diversification is just as true for cars, electronic devices, machinery, and clothing, as it is for food. Regarding the latter, for example, for commodities purchased in a supermarket it is now proving difficult for both consumers and retailers to reconstruct production chains. Today's consumers have quickly become used to being offered food products from all over the world. At the same time, however, more and more consumers are demanding information on product origin, especially for food products. This has led to increasing discussion concerning the need for proper provision of transparent and reliable information on product origin. Most information on food product origin is provided as part of the procedures concerning foodstuff labelling. Within the EU, food labelling has to comply with EU labelling requirements. Producers and retailers also provide additional information on a voluntary basis. The EU labelling requirements are primarily designed to cover matters such as product safety and quality, the nature of ingredients, product shelf life and conditions of storage (Cheftel, 2005). As a consequence of the bovine spongiform encephalopathy (BSE) crisis a traceability reference code was introduced in 2000 ensuring that items of (unprocessed) beef could be traced back to the animal's 'country of origin', i.e. covering at least country of birth, country of fattening and country of slaughter. Although in principle full traceability is given, consumer research indicates that such origin information still only partly addresses consumer concerns (Verbeke and Ward, 2006). For meat products such as poultry, the sole requirement is that origin be defined in terms of 'of EU origin', or 'of non-EU origin'. For pork, at the moment, no origin information at all is required, although this will

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change soon as a result of new EU regulation covering the provision of food information to consumers (European Parliament and European Council, 2011). The new rules will apply to all EU member states from December 2014. From this point on, for example, origin labelling for meat will be mandatory for pig, sheep, goat and poultry meat, i.e. an indication of the country of origin or place of provenance must be provided. However, actual coverage and implementation is still likely to vary depending on which specific clauses the European Commission accepts in the two year period following adoption of Regulation 1169/2011. Existing regulations are also relevant. For example, according to Regulation 1182/2007 the consumer has to be informed about the country of origin of fruits and vegetables, although exemptions are made for bananas, potatoes, olives or coconuts and several other fruits. Generally, for processed foodstuffs, no declaration about the country of origin is necessary. For example, the manufacturer of strawberry jam is under no obligation to provide information on the location where the strawberries were harvested, nor must the producer of yogurt declare the origin of the milk used in yogurt production. Thus, at least as far as EU member states are concerned, we may conclude that information on food origin is fragmentary, intransparent and incomplete. In this regard, there is also little reason to assume that the situation is any better in non-EU countries.

The objective of this paper is to develop and test a new method for providing information on product origin. The case of food products is taken as an example as it is here that consumers tend to be most critical. The paper is organised as follows. Consumer expectations regarding food labelling, together with the shortcomings of current origin labelling systems, are discussed in the following section. The research design and the new Life-Cycle-oriented Origin analysis (LCOA) is presented in section 2, followed by a pilot study in section 3. Results are discussed in section 4 and conclusions are drawn in section 5.

1.1. Consumer demand for origin information

What essentially does the consumer expect from information concerning the origin of the food he or she purchases and is he or she satisfied with the information provisions sketched above? To answer this question, in 2012, the European Consumer Organisation, BEUC, commissioned a survey on origin labelling in the four EU Countries Austria, Poland, France, Sweden. The survey investigated consumer interest in origin labelling compared to other factors such as price, taste or brand (BEUC, 2013). The key findings are: A clear majority want to know the country of origin (50%–77% of respondents) or the region of origin (13%–36%). The use of the basic EU/non-EU distinction in labelling satisfies only a small number of respondents (4%–13%). Consumers place information on food origin in fifth or sixth place when ranking the relative importance of various purchasing criteria, i.e. origin is perceived as being less important than factors such as taste, price and use-by/best-before dates, but more important than brand and quality. Categories of food products for which information about origin is most important are meat (83%–93%) followed by fresh fruit and vegetables, fish, milk and dairy products (75%–90%). Information on the origin of processed fruit and vegetables is also considered desirable by a majority of respondents (62%–79%). The reasons stated by consumers for their interest in food origin relate to issues of food safety (51%–61%), quality (52%–57%) and, to a lesser extent, environmental (17%–50%) and ethical (40%–45%) concerns. As far as meat products are concerned, the results indicate that it is not always clear to consumers which part of the production process, i.e. birth, rearing, or slaughter, takes place in the indicated country, and that greater transparency as to what has occurred where will help avoid consumer confusion.

1.2. Shortcomings of product labelling concerning origin

Thus, while information on origin is clearly of interest to the buyer, there appears to be a clear gap between the perceived and the true product origin. Zühlsdorf and Spiller (2012), for example, refer to pre-packaged *Long Grain Rice from Northern Germany* in order to illustrate the difficulties consumers have in assessing misleading product claims concerning the origin of food. In this case, it is largely unclear how the terms ‘local’, ‘regional’ or ‘region’ are to be defined and there is too much room left for (mis)interpretation. An online analysis of voluntary labelling schemes[1] undertaken by the present authors reveals that the thresholds required for official designation as “local” or “regional” vary between 51% and 100% of product weight. The recent German initiative *regionalfenster* is trying to overcome such a low level of regulatory consistency by means of origin-related product labelling. Here, the region of origin of the raw materials has to be specified in terms of a rural district, a federal state, or an area defined in terms of a specified geographical radius. The *regionalfenster* foresees, that the first main ingredient and the value enhancing components at 100% originate from the region named and are also processed there. If the first main ingredient shares less than 50% to the overall product weight, then the other ingredients have to originate from the named region until an overall ‘regional’ share of 51% is reached. A declaration concerning the origin of seeds, feedstuff and young animals is optional (www.regionalfenster.de). As the initiative only started in 2014, it is too early to use as a guide to experience. The two EU schemes and their related logos *Protected designation of origin* (PDO) and *Protected geographical indication* (PGI) are intended to help promote and protect the standing of regional foods. While the PDO logo certifies that a product is prepared, processed and produced within a specific region, the PGI logo is less stringent. PGI labelling simply indicates that at least one of the stages of preparation, processing or production has to take place in the designated region. This is often cause for misinterpretation by consumers. As an example Zühlsdorf and Spiller (2012) name the PGI labelled “Black forest” ham.[2] While this is smoked in the Black Forest area, the necessary pigs are imported from abroad. When consumers were presented with this knowledge, 47% felt deceived. Misinterpretation of these labelling schemes goes hand in hand with a low level of consumer awareness and lacking knowledge about the existence and meaning of PDO and PGI labels impede successful information. To sum up, voluntary labelling schemes concerning product origin emphasise the local or regional share contained within a product. This is also true for more stringent schemes such as the *regionalfenster* or the EU PGI logo. Labelling and product claims can easily be misinterpreted since several relevant process steps, ingredients, or raw materials needed in a product's life cycle may be completely ignored. Such schemes thus tend to place excessive weight on local or regional activities. In the next section we look at how a more systematic consideration of product life cycle may be employed in dealing with “origin”.

1.3. Origin information in LCA and EPD

LCA is used to estimate the existing and potential environmental impact of a product, a process or a service. This is done by compiling an inventory of related energy and material inputs and

[1] The following web pages were accessed: www.bewusstkaufen.at and www.labelonline.de, for German speaking countries; www.standardsmap.org and www.ecolabelindex.com for international references.

[2] The Black Forest is a densely wooded area in the southwest of the German province Baden-Württemberg.

environmental releases, evaluating their environmental impacts and then interpreting the results. LCA methodology is laid down by ISO 14040:2006 and ISO 14044:2006 and further described in guidelines (US EPA, 2006; EC, 2010) while environmental product declaration (EPD) and product category rules (PCRs) comply to ISO 14025:2006.

Under LCA, product origin is relevant when specifying the geographical location of a process, with an emphasis being placed on market delimitation. The market related data considered relevant for designating geographical scope are related to production mix, market supply mix and market consumption mix. For example, if an energy-using consumer product in France were part of the relevant data set under consideration, the corresponding French electricity market consumption mix, conditions of product use in France, and French recycling rates would all have to be considered. Here, geographical scope is defined solely in terms of the representativeness of the data used with respect to the goal of the study (EC, 2010). Considering LCA case studies concerning food and feed products we find that product origin is defined mainly with respect to the above market criteria (Roy et al., 2009; Ruviaro et al., 2012; Webb et al., 2013; Knight et al., 2010). However, adopting a broader view, it becomes clear that references to geographical location should also incorporate the related journey distances in order that all subsequent payloads may also be assessed. Apart from activities occurring locally, regional and/or national activities also play a role in LCA studies (e.g. UK meat imports from Brazil). The proliferation of qualitative environmental product claims such as “green” or “environmental friendly” has increased the need for more transparent and quantitative product information (Ingwersen and Stevenson, 2012). Environmental product declaration (EPD), also referred to as a type III environmental declaration,[3] is a standardized and LCA-based tool which is used to communicate the environmental performance of a product (Del Borghi, 2013). EPD programs were first launched in Europe, but are now also in place in East Asia or North America (Subramanian et al., 2012). EPDs systematically apply product category rules (PCRs) such that a meaningful cross-product comparison of LCA studies may be undertaken. PCRs define the boundaries of the life-cycle stages of products in a given category. A product category is used to designate a group of products that fullfill equivalent functions. Ingwersen and Stevenson (2012) identified at least 300 PCRs in various official programs, ranging from staple food products to advanced electronics. An analysis of food product EPDs in terms of dairy and meat products (based on data provided by an international program operator, see www.environdec.com), reveals that information on product origin is normally provided with respect to the final product or – in a qualitative manner – with respect to the related preceding stages of production. However, the EPDs neither quantify the geographical information with respect to production processes and essential inputs, nor do they relate the origin of locations of production steps to a functional unit (i.e. the product).

2. Materials and methods

In the previous sections we analysed how information on the geographical origin of a product is taken into account in terms of various product claims, labelling schemes, LCAs and EPDs. The analysis revealed that both product and labelling schemes may result in misinterpretation as they do not rely on a life cycle perspective and thus may fail to take account of relevant process steps, ingredients or raw materials. Additionally, since labelling schemes tend to emphasise the local or regional content of the product, a biased picture of the product's overall origin may emerge. LCAs, in contrast, are designed to take perfect account of the overall life cycle of a product. The main difficulty remaining, is that neither the itemization of the different production step locations, nor the analysis of the interconnections between origin information and processes are taken into consideration in LCA or EPD methodologies. These findings, together with earlier preliminary work (Klade and Seebacher, 2012) concerning the objective evaluation of origin-based information on foods, served as inspiration for the formulation of the following research questions:

1. How may the geographical origin of a product be quantified such that all life cycle-relevant ingredients and/or processing procedures are accounted for appropriately and scientifically?
2. How can this method be applied to the gathering and processing of market information?

Since the combination of LCA with EPD is largely taken for granted when attempting to make the environmental impact of products comparable and communicable, the objective of our work can also be extended to include the following research question:

3. How may the LCA methodology and EPD standard be used to develop a method suitable for providing information on product origin?

2.1. Life-Cycle-oriented Origin analysis (LCOA)

This section presents a comprehensive and transparent method for depicting and communicating information on the overall geographical origin of a product. We refer to this method as ‘Life-Cycle-oriented Origin analysis’ (LCOA). In short, LCOA inventorizes the raw materials, semi-products, product ingredients and processes occurring throughout the product's life cycle, and references them in terms of where they are generated, transferred or processed. Thus, LCOA facilitates the quantification of the overall origin (i.e. the “geographical footprint”) of a product. LCOA adopts the terminology and procedures found in LCA as much as possible since the latter method provides the most feasible basis for generating and processing quality-assured data throughout the life cycle. Fig. 1 illustrates the essential steps of LCOA. Apart from step 7, all steps, with appropriate adaptations being made to step 5, follow the LCA framework. The successive steps entailed in LCOA are elaborated below.

2.1.1. Goal, scope and functional unit

Before starting an LCOA the product should be classified using a product classification system (e.g. UNSD, 2013). It should be specified whether the study is used for business-to-consumer (marketing, labelling) or for business-to-business communication (e.g. supporting re-design along the supply chain) to better envision the needs of the addressees. As a result such a specification may facilitate the choice of the appropriate allocation procedure. Generally the functional unit is one unit of product including its packaging. In case of food and agricultural products both LCA studies and product category rules (PCRs) typically recommend 1 kg net weight of packaged product (Ruviario et al., 2012; Meissner Schau and Magerholm Fet, 2008; e.g. PCR, 2013). In the pilot application outlined in chapter 3 we classified our product as *meat of poultry, fresh or chilled* according to UN CPC class 2112 and

[3] Type III environmental declarations are declarations “providing quantified environmental data (based on an ISO 14040 LCA) using pre-defined parameters, and, where relevant, additional environmental information (ISO 2006c).”

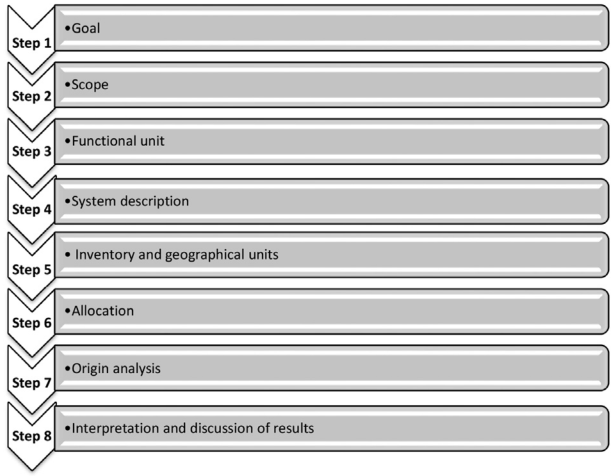

Fig. 1. Successive steps in Life-Cycle-oriented Origin analysis.

defined the functional unit as 1 kg of packaged product. The goal was determined as follows: to analyse the overall origin of the packaged product and contrast it with the outcomes of a consumer survey. It was not intended to use the results for or business to business communication or comparative assertion ("origin claim").

2.1.2. LCOA inventory

This section deals with procedural instructions for the compilation of an LCOA inventory.

Specify and check the overall procedure by adopting PCRs: We generally recommend to adopt appropriate PCRs to justify or confirm choices made in respect to functional unit, system boundaries, allocation-, cut-off- and data quality rules. A helpful overview of operators providing PCRs is given for instance by Hunsager et al. (2014). For our pilot application we consulted two PCRs provided by the international EPD® System IES (available on www.environdec.com).

Identify co-products and fix type of allocation: If a process provides more than one product, i.e. delivers more than one good, it is called multi-functional. In case of our pilot application we identified relevant co-products and therefore had to apply an allocation procedure. According to LCA and EPD methodology the existence of co-products affords that all inputs (and outputs) must be portioned between the product being assessed and the co-products. The ISO 14044:2006 presents a decision hierarchy to this: (1) subdivision, (2) system expansion, (3) allocation based on physical relationship (e.g. mass allocation), (4) allocation based on other relationship (e.g. economic allocation) (EC, 2010). From that it may be concluded that subdivision and mass allocation are preferential. As mentioned above we consulted PCR *meat in general* and PCR *poultry meat* from the IES to solve the allocation problem for our pilot application. While PCR *meat in general* prioritises partitioning which reflects the underlying physical relationships, PCR *poultry meat* explicitly recommends economic allocation (PCR, 2013; PCR, 2015). We decided to avoid economic allocation in favour of mass allocation since the outcome is handed over to consumers. The rationale for the decision was that consumer information by means of food labelling is based on weight. We however want to emphazise that – depending on the purpose of the LCOA – it may be more feasible to apply economical allocation.

Identify relevant processes: All processes which generate or alterate relevant raw materials, semiproducts, the final product as such and ingredients (e.g. spices) have to be identified. For our pilot application concerning poultry meat we identified the processes feedstuff production, feedstuff formulation, rearing, slaughtering and packaging as relevant. Since LCOA follows a cradle-to-gate approach and ends with the final (packaged) product, distribution, retail, use and end-of-life processes are not regarded.

Address each process separately: This rule is essential to avoid loss of spatial information. For example, let us assume that two feed components are cultivated in area A, transferred to area B, mixed there and then re-imported to A. In such a case the two feed components 'belong' both to area A and to B – once to the place were cultivation takes place and once to the location where 'mixing' proceeds.

Assign mass or monetary values to the identified processes: All processes have to be assigned with the associated mass respectively economic value depending on the type of allocation chosen. In our pilot application the process 'slaughterhouse' generates a mass of 3.04 kg which have to be partitioned between the product and co-product (Fig. 4). As far as possible these values should rely on primary data provided by the contract supplier.

Disregard auxiliary materials: Solvents to extract, detergents or water to clean etc. are disregarded as they do not add to the final product or intermediates. The goal of the LCOA is to analyse the geographical footprint/composition of the final product, therefore auxiliary materials are not relevant.

Disregard wastes and emissions: Although LCOA follows the structure of a classical LCA and adheres to existing EPD programs, it is targeted to provide origin information. Therefore all types of emissions and wastes are disregarded.

Disregard energy, transportation and infrastructure: The method focuses on origin information about upstream products and the final product itself and does neither investigate the depletion of raw materials or energy nor environmental effects caused by transport or infrastructure. Therefore we disregard energy, transportation and infrastructure and classify them as auxiliary materials which do not add to the origin of the product.

Specify cut-off value: In analogy to LCA the cut-off value determines the maximum of the relevant processes that can be disregarded in the subsequent origin analysis. In our pilot application we stipulated that a minimum of 99% of the processes have to be regarded, therefore the cut off value amounts to a maximum of 1% expressed in terms of mass or monetary value.

Define appropriate scales for the geographical unit areas

LCOA asks for a spatial specification of each relevant process along the supply chain. In meat production the processes of slaughtering or packaging normally take place in a distinct company site, whereas other processes such as broiling or feed cultivation may be dispersed over different sites, either within a certain region or world-wide. Therefore the data about the origin of raw materials, semiproducts and the spatial localization of processes may vary in resolution and scale. We decided to scale the spatial information by means of administrative entities as they are properly defined. In LCOA spatial information expressed as an administrative entity is referred to as *geographical unit*. The degree of resolution depends on the objective of the study. The smallest spatial units are villages or municipalities, followed by districts and provinces. Such a small-scale resolution will be most effective in pointing out the local or regional aspects of a product.

Table 1 and Fig. 2 exemplify how processes can be depicted in different spatial resolutions by means of a scaling of interconnected geographical units.

In the example of Table 1 the cultivation of feed component 1 (process P1) takes place in the districts A and B which are both part of province C in state D which again is member state of the EU. So each of the geographical units A & B, C, D or EU may specify process P1. If the goal of the LCOA study is to work out the regional aspect of the product then the units *district A & B* or *province C* would be a more appropriate choice than D or EU.

Table 1
Scaling geographical units.

Process	Description	Mass or monteary value (kg or €)	SCALING GEOGRAPHICAL UNITS MORE LOCAL → MORE GLOBAL District	Province	State	
P1	Cultivating feed component 1	M 1	A & B	C	D	EU
P2	Cultivating feed component 2	M2	A	C	D	EU
P3	Mixing feed components 1 + 2	M1 + M2			E	EU
P4	Seeds for feed component 1, 2	M3				China (Global)

In the course of process *mixing feed components 1 + 2* both components are transported to state E, mixed there and then are re-imported to D. So this process has to be addressed separately whereby the sum ‘M1 + M2’ have to be allocated to state E.

Seeds for the cultivation of feed components 1 and 2 are imported from China. If the study focus on regionality within e.g. the EU, origins outside Europe such as *China* may be subsumed with the unit *Global* as well. We recommend to hold the unit *Global* ready for cases where an assignment to distinct nations makes little sense. And finally, if the spatial location of a process cannot be identified it has to be designated as *unknown*.

2.1.3. Origin analysis

Origin analysis uses the compiled data of the LCOA inventory to calculate the overall origin of the product. Table 2a shows a spread sheet used for the calculation of origin. Each process contributes a distinct mass or monetary value which has to be allocated to a geographical unit. The sum of the values allocated to a geographical unit constitute it's share to the overall origin. A subsequent division gives the aliquot share expressed as percentage of the overall origin of the product. The methodology enables different aggregation levels in respect of the geographical units. As can be seen in Table 2a the allocation of data entries accentuate the regionality of the product by choosing A, B instead of C, D or EU which could be also possible according to Table 1.

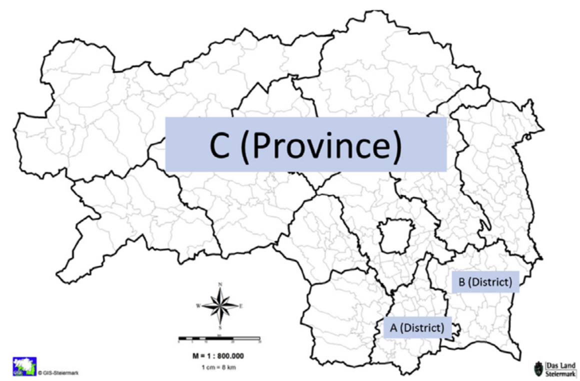

Fig. 2. Scaling geographical units.

3. Results

3.1. Pilot application with packaged chicken breast — product specification

LCOA methodology was first tested on a pilot application during an internship semester held in 2013 at the Institute of Systems Sciences, Innovation and Sustainability Research at Graz University. The project entailed the close cooperation of students in the bachelor's program in environmental systems sciences. The chosen product was purchased in a supermarket in Styria in spring 2013, and is referred to here as “*Chicken breast for retailer S*”.[4]

The goal of the study was to analyse the overall origin of the packaged product and to contrast the results with a consumer survey. It was not intended to use the results for comparative assertion (“origin claim”) or business to business communication, therefore mass allocation was chosen. The product was classified using the UN CPC hierarchy as *meat of poultry, fresh or chilled*. It was decided that cultivation of feed components as well as the provision of seeds for feed cultivation are relevant processes. Fertilizers for cultivation are categorized as auxiliary materials and therefore left out of scope.

The product was photographed and the photos were used for a consumer survey. Fig. 3 shows that the packaging carries the EU organic products label and the AMA Biogütezeichen (a similar Austrian-based seal of quality). Additional information is given on the packaging: *produced in Austria* (hergestellt in Österreich) plus the name and address of the farmer concerned. According to information given by the Austrian Ministry of Agriculture, Forestry, Environment and Water Management,[5] the claim *produced in Austria* relates to the place where the raw materials for the product are generated. In our case, the producer of “*Chicken breast for retailer S*” was found to be the company Herbert Lugitsch GmbH located in the Austrian province Styria. The description of the pilot application below follows the theoretical scheme given in Fig. 1. The goal of the pilot application is to investigate the geographical origin of the packaged product “*Chicken breast for retailer S*”. Product life cycle information was provided by the producer Herbert Lugitsch GmbH. All life cycle stages, from raw material production to packaging, were included in the analysis. Processes such as retailing, consumption and disposal are ignored, as are questions concerning energy input and transportation. The functional unit chosen was 1 kg of the packaged, ready for use, product (net weight).

3.1.1. System description

Most of the information and data presented below was gathered during two meetings with the company CEO. The company imports parent chickens from Germany and transfers them to 3 organic parents farms, all of them located in Styria. The eggs from the parent farms are then transferred to a hatchery located in Styria. The hatchery output is spread across 17 broiler farms located in Burgenland, Lower Austria, Carinthia and Styria. The chickens start with a weight of 0.040 kg–0.045 kg and reach an average weight of

[4] The retailer “S” — SPAR — is a supermarket chain in Austria.

[5] http://www.lebensministerium.at/lebensmittel/biolebensmittel/Bio_Kontrolle.html (accessed 14.08.2013).

Table 2a
Spread sheet for calculating the overall origin of a product.

Process	Mass or monetary value (kg or €)	Geographical unit				
		A	A&B	E	Global	Unknown
P1	M1		M1			
P2	M2	M2				
P3	(M1 + M2)			M1 + M2		
P4	M3				M3	
Share on origin (kg or €)	ΣM = M1 + M2 + (M1 + M2) + M3	M2	M1	M1 + M2	M3	
Share on origin (%)	100	(M2/ΣM)*100	(M1/ΣM)*100	((M1 + M2)/ΣM))*100	(M3/ΣM)*100	0

2 kg. Fattening requires 4.9 kg of feedstuff. The feed for fattening consist of 12 components, 10 of which originate in Austria, 1 in Sweden, and 1 imported from Germany, but which may be considered to be of global origin. The seeds for feedstock production are from Austria. The feed components are cultivated in Burgenland and Lower Austria and processed in a feed mill in Burgenland. After fattening, the chickens are transferred to a slaughterhouse in Styria by lorry using containers. The chickens are stunned with carbondioxide and stabbed in the throat. Feathers, intestines, heads and feet are removed. For processing the carcass is cut up into breast, legs, wings etc. The pieces are packaged under protective gas atmosphere using stretch film, labelled and delivered to retailers. The mass lost as a result of slaughtering amounts to between 33% and 35%. Chicken breast averages 32.9% of carcass weight (commonly varying between 31.8% and 33.3%). So one third of the carcass is processed into chicken breast, while the rest is processed into purchasable co-products. No further loss in terms of waste is assumed. The packaging material originates from Austria, Germany and Italy.

3.1.2. LCOA inventory with geographical units

The masses converted during the life cycle are presented in Fig. 3, and the corresponding geographical locations, in Fig. 4.

As can be seen, 3.04 kg of carcass is needed to gain 1 kg of chicken breast. Thus, assuming a weight loss of 33% at slaughtering, 4.54 kg of fattened animal is needed. Since fattening a chicken to a weight of 2 kg requires 4.9 kg of feedstuff, feedstuff demand is calculated to be 11.125 kg. Chick input of 0.043 kg is required for a fattened chicken of 2 kg. Thus, an average weight of 0.0976 kg for the hatchling is used in the calculation. The average weight of a hatching egg is 0.052 kg. Since only 65% of the hatching eggs develop into chickens, 0.180 kg of hatching eggs is needed to produce 0.0976 kg of chickens. For the hatchery, as such, no feed input is needed. With regard to the parent farm, a breeder hen produces 200 hatching eggs (i.e. 130 chickens) over its lifetime. For that it needs 52 kg of feed. This quantity includes a 10% share for the chock. Accordingly, 0.40 kg of feed is needed for one chicken, which is equivalent to 0.90 kg feed for 0.0976 kg of chicken. In estimating the demand for chickens from the parent farms, we assume that a breeder hen produces 130 chickens over its lifetime. 2.24 parent chickens are needed for chicken breast, so the corresponding figure for the breeder is 0.017 chickens with a weight of 0.00074 kg. The process "chicken from first hatchery" was left out in the further analysis since the estimated quantity is below the cut-off value of 1% of the overall mass. The packaging material for the product amounts to 0.02 kg. For the process "seeds for feed-broiling" no data was available from the producer, so mass was estimated using secondary data from the literature. Relevant data were found in Eriksson et al. (2005), Iriarte et al. (2010), Nguyen et al. (2012) and Webb et al. (2013). This was supplemented by internet research (Table 2b). The ratio used in calculations relating to "seeds for feed (breeding)" is the same ratio as that used in the process "seeds for feed (broiling)", i.e. 1.5%, giving 0.012 kg of seeds for 0.90 kg of feedstuff. Due to the fact that the product is labelled as organic chemical fertilizers and pesticides do not have to be considered (see Fig. 5).

According to Fig. 3, in addition to the 1 kg of product investigated here, a further 2.04 kg of co-products are produced. An analysis of the relevant upstream mass values was made. The results are shown in Table 3.

Fig. 3. Front (right) and back (left) images of "*Chicken breast for retailer S*".

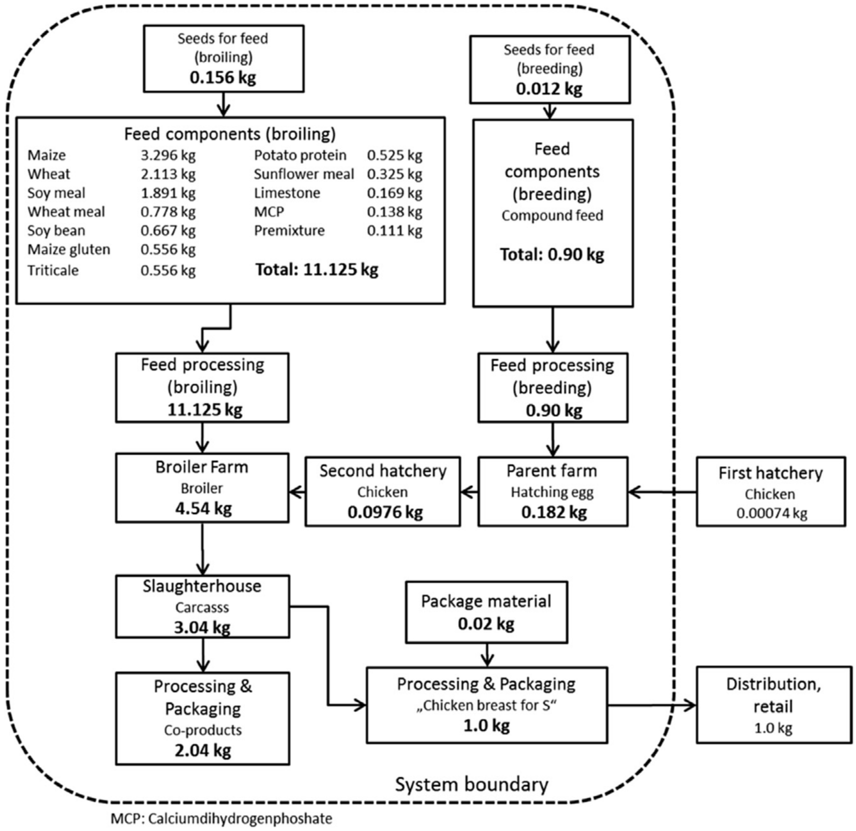

Fig. 4. Inventory of relevant processes and mass values.

3.1.3. *Origin analysis*

Various political entities, starting with districts, and then moving on to larger units, were employed in assigning suitable process values to geographical units (see Table 4).

4. Discussion

Table 5 provides the results of the pilot application in detail. The presentation covers 11 processes (rows) and 11 geographical units (columns). The geographical units are sorted according to administrative hierarchy, starting with districts (left), moving on to provinces, and then to countries (right). There are two (Austrian) districts, three (Austrian) provinces, two aggregations of (Austrian) provinces and two countries. According the geographical units *global* and *unknown* are *provided (*for definition see chapter 2.1.3).

Tables 5–7 present the overall origin of the product *chicken breast for retailer S* in three variations based on the same information. Table 5 provides the results of the Origin analysis in full detail and emphasises the local or regional aspects of the product. Aggregation in Table 6 integrates districts and provinces and

Table 2b
Mass estimates for seeds needed for feedstuff cultivation for broiling.

No	Feed component	kg	Seeds/yield•ha (kg/kg)	Source	kg seeds/kg FU
1	Maize	3.296	20/7630	Nguyen et al. (2012)	0.009
2	Wheat	2.113	140/6010	Nguyen et al. (2012)	0.049
3	Soy meal	1.891	50/1760	Eriksson et al. (2005)	0.054
4	Wheat meal	0.778	(based on wheat)	Nguyen et al. (2012)	0.018
5	Soy bean	0.667	53/2708	Nguyen et al. (2012)	0.014[a]
			50/2200	Eriksson et al. (2005)	
6	Maize gluten	0.556	27% yield from maize milling[b]	Yield: Nguyen et al. (2012)	0.0004
7	Triticale	0.556	80/4400[c]	–	0.010
8	Potato protein	0.525	2500[d]/42,000 (protein content: 2%[e])	Yield: Webb et al. (2013)	0.0006
9	Sunflower meal	0.325	5/2100	Nguyen et al. (2012)	0.0005[a]
			2.7/2200	Iriarte et al. (2010)	
10	Limestone	0.169	Inorganic	–	–
11	Calcium dihydrogenphosphate	0.138	Inorganic	–	–
12	Premixture	0.111	Inorganic & synthetic	–	–
Total		11.125			0.156

[a] Mean value.
[b] Calculated according to: http://www.distillersgrains.org/files/grains/K.Davis–Dry&WetMillProcessing.pdf.
[c] Calculated according to: http://www.ksre.ksu.edu/bookstore/pubs/MF2227.pdf.
[d] http://de.scribd.com/doc/25269110/Potato-Production.
[e] http://en.wikipedia.org/wiki/Potato.

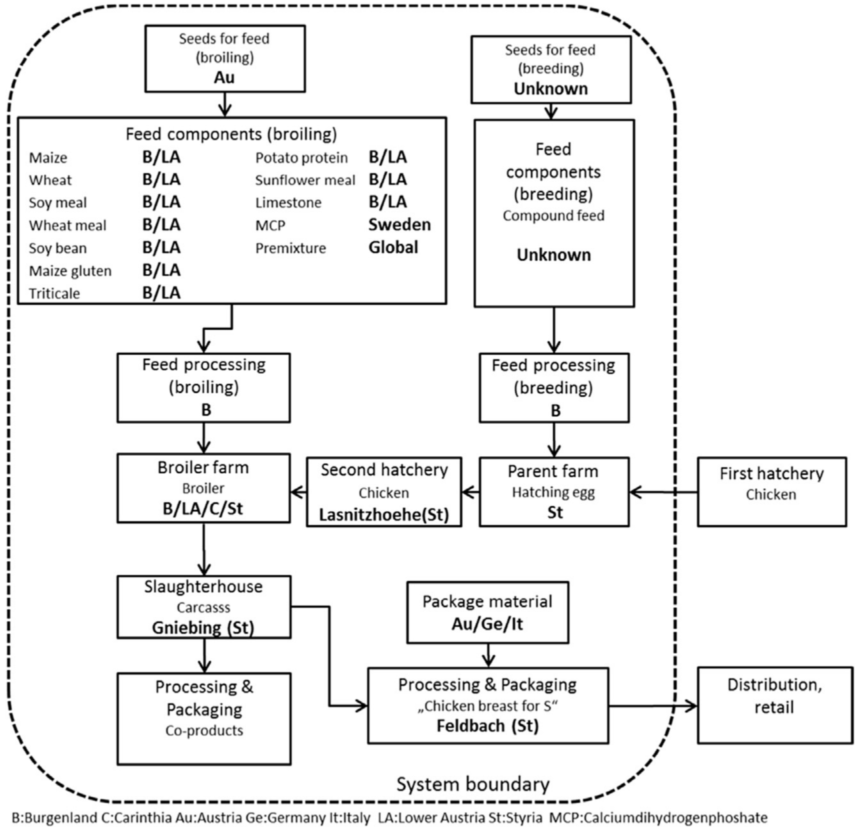

Fig. 5. Inventory with geographical units.

presents the results at national level. But not only geographical units but also processes may be further aggregated as shown in Table 7. Therein initial processes 1 to 6 are aggregated to *Feedstuff*, processes 7 to 9 to *Born + Reared*, process 10 to *Slaughtered* and process 11 *Processed + Packaged*.

All processes allocated to the geographical unit ‘Unknown’ can be interpreted as an essential knowledge deficit from the viewpoint of the study. In our study the processes *seeds for feed (breeding)* and *feed components for breeding* are allocated to that unit.

The convenience of the geographical unit ‘Global’ is exemplified by means of raw materials *Premixture* and *Packaging material*: *Premixture* is a mixture of components derived from different countries all over the world. The relatively small share of 0.5% and the fact that its origin is principally known led us to the decision to

Table 3
Mass allocation.

Process	Type	Mass (kg)	Allocated to co-product (2.04 kg)	Allocated to “chicken breast” (1.0 kg)
Seeds for feed (broiling)	Various	0.156	0.105	0.051
Seeds for feed (breeding)	Not specified	0.012	0.008	0.004
Feed components (broiling)	Maize	3.296	2.208	1.088
	Wheat	2.113	1.416	0.697
	Soy meal	1.891	1.267	0.624
	Wheat meal	0.778	0.521	0.257
	Soy bean	0.667	0.447	0.22
	Maize gluten	0.556	0.373	0.183
	Triticale	0.556	0.373	0.183
	Potato protein	0.525	0.352	0.173
	Sunflower meal	0.325	0.218	0.107
	Limestone	0.169	0.113	0.056
	Calcium dihydrogenphosphate (MCP)	0.138	0.092	0.046
	Premixture	0.111	0.074	0.037
Feed components (breeding)	not specified	0.90	0.60	0.29
Feed processing (broiling)	Feed mixture	11.125	7.454	3.671
Feed processing (breeding)	Feed mixture	0.90	0.60	0.29
Parent farm	Hatching egg	0.182	0.122	0.06
Second hatchery	Chick	0.0976	0.065	0.032
Broiler farm	Broiler	4.54	3.05	1.5
Slaughterhouse	Carcass	3.04	2.04	1.0
Processing and packaging	Package material	0.02	–	0.02
	Chicken breast	1.0	–	1.0

Table 4
Geographical locations and units.

Process	Type	Mass	Geographical unit	Geographical unit
Seeds for feed (broiling)	Various	0.051	Austria	Austria
Seeds for feed (breeding)	Various	0.004	Unknown	Unknown
Feed components (broiling)	Maize	3.532	Burgenland/Lower Austria	Burgenland/Lower Austria
	Wheat			
	Soy meal			
	Wheat meal			
	Soy bean			
	Maize gluten			
	Triticale			
	Potato protein			
	Sunflower meal			
	Limestone	0.056	Lower Austria	Lower Austria
	Ca-dihydrogenphosphate	0.046	Sweden	Sweden
	Premixture	0.037	Global (Germany)	Global
Feed components (breeding)	Various	0.29	Unknown	Unknown
Feed processing (broiling)	Feed mixture	3.671	Burgenland	Burgenland
Feed processing (breeding)	Feed mixture	0.29	Burgenland	Burgenland
Parent farm	Hatching egg	0.06	Styria	Styria
Second hatchery	Chick	0.032	Lasnitzhoehe	District "Graz Surrounding"
Broiler farms[a]	Broiler	1.5	Burgenland/Lower Austria/Carinthia/Styria	Burgenland/Lower Austria/Carinthia/Styria
Slaughterhouse	Carcass	1.0	Gniebing	District "Southeast Styria"
Processing and packaging	Package material	0.02	Austria/Germany/Italy	Global
	Chicken breast	1.0	Feldbach	District "Southeast Styria"

[a] According to the company (Herbert Lugitsch GmbH) the product as such originates from 17 broiler farms located in Burgenland, Lower Austria, Carinthia or Styria.

allocate it to 'Global'. For *Packaging material* the origin is also known, but again it was decided to allocate the process to "global" to avoid defining a complex geographical unit consisting of three European countries.

Table 8 provides an evaluation of the data quality of our case study together with a proposal for (further) LCOA studies on food products. Thereby indicative threshold values given in the ILCD Handbook (EC, 2010) and PCR documents are considered as for example the ratio between specific (primary) and generic data.

For our case study most of the information and data presented was gathered during two meetings with the company CEO, therefore they can be classified as specific. Only for the calculation of the mass value for process *seeds for feed (broiling)* generic data from literature have been used. As Table 5 shows generic data share 0.4% of the overall origin. Equally allocation to 'unknown' accounts for 2.5% of the overall origin. To check data reliability we used two LCA studies (Nguyen et al., 2012; Bengtsson and Seddon, 2013) and found no suspicious deviations. However, we assume that such a procedure is only acceptable if the product and the supply chain is straightforward. Generally uncertainty of results arise from choices and assumptions made during the modelling of the inventory (system boundaries, allocation rules). This should be addressed by a sensitivity check according to ISO 14044:2006.

5. Conclusions

The pilot application presented in the previous section shows that LCOA may offer a useful approach, at least in principle, to

Table 5
Detailed results of LCOA for "Chicken breast for retailer S".

No	Process	Mass (kg)	Southeast Styria	Graz surrounding	Styria	Burgenland	Lower Austria	Burgenland/lower Austria	Burgenland/lower Austria/Styria	Austria	Sweden	Global	Unknown
			District	District	Province	Province	Province	Aggregation of provinces	Aggregation of provinces	Country	Country	–	–
1	Seeds for feed (broiling)	0.051								0.051			
2	Seeds for feed (breeding)	0.004											0.004
3	Feed components (broiling)	3.671					0.056	3.532			0.046	0.037	
4	Feed components (breeding)	0.29											0.29
5	Feed processing (broiling)	3.671				3.671							
6	Feed processing (breeding)	0.29				0.29							
7	Parent farm	0.059			0.06								
8	Second hatchery	0.032		0.032									
9	Broiler farm	1.5							1.5				
10	Slaughterhouse	1.0	1.0										
11	Processing and packaging	1.02	1.0									0.02	
Geographical unit's share of origin (kg)		11.588	2.0	0.032	0.06	3.961	0.056	3.532	1.5	0.051	0.046	0.057	0.294
Geographical unit's share of origin (%)		100	17.3	0.3	0.5	34.2	0.5	30.5	12.9	0.4	0.4	0.5	2.5

Table 6
First Aggregation with geographical units equal or lager than countries.

No	Process	Mass (kg)	Austria	Sweden	Global	Unknown
			Country	Country	–	–
1	Seeds for feed (broiling)	0.051	0.051			
2	Seeds for feed (breeding)	0.004	–			0.004
3	Feed components (broiling)	3.671	3.588	0.046	0.037	
4	Feed components (breeding)	0.29	–			0.29
5	Feed processing (broiling)	3.671	3.671			
6	Feed processing (breeding)	0.29	0.29			
7	Parent farm	0.06	0.06			
8	Second hatchery	0.032	0.032			
9	Broiler farm	1.5	1.5			
10	Slaughterhouse	1.0	1.0			
11	Processing and packaging	1.02	1.0		0.020	
Geographical unit's share of origin (kg)		11.588	11.189	0.046	0.057	0.294
Geographical unit's share of origin (%)		100	96.6	0.4	0.5	2.5

Table 7
Second aggregation with processes condensed to life cycle stages.

Chicken breast for retailer S				
Life cycle stage	Mass	Origin Austria	Origin Non-Austria	Origin Unknown
Feedstuff	7.977 kg	95%	1%	4%
Born + reared	1.591 kg	100%	–	–
Slaughtered	1.0 kg	100%	–	–
Processed + packaged	1.02 kg	98%	2%	–
Overall life cycle	11.588 kg	>96%	<1%	<3%

quantifying the geographical origin of a product. While LCOA follows the structure of a classical LCA and adheres to existing EPD programs, it is adjusted to provide origin and not environmental information. It has not yet been codified in the form of official standards or regulation, however the definitional clarity of the steps needed to undertake LCOA is assumed to be high enough to achieve an adequate level of objectivity and validity. This becomes particularly apparent when compared to the shortcomings found in existing food labelling systems (see section 1.2).

5.1. Limitations and further need for clarification

It is well known that many product life cycles and supply chains are often highly complex and diverse. In such cases the work involved in implementing LCOA, for example, with respect to gathering appropriate data, may often be perceived as being not worth the effort. During the course of the above pilot application we were pleasantly surprised concerning the willingness of the company to provide information. However, this may not be enough as the availability of relevant life cycle information in terms of primary data is absolutely essential. Our case study demonstrates the applicability of LCOA for food products. Beyond that we postulate, that LCOA is equally applicable to many other product groups and we propose similar case studies on e.g. textiles or electronic equipment. The investigated case study applies to a simple type of (food) product which is barely processed. The method as such is not limited to product simplicity although applicability of course depends on data availability and an indentification of all relevant processes. Failing to get a reasonable result would not depend on the method as such but on process complexity and/or data gaps. Where mass- or economic values, processes or spatial locations cannot be sufficiently identified or assigned the share of 'Unknown' may be to high to proceed with the analysis.

LCOA is not meant to be an immediate substitute for food labelling systems concerning origin. The most fundamental difference is that in case of a labelling scheme a product has to fulfil certain criteria or pass distinct thresholds values to receive a labelling while in case of LCOA there are no criteria or thresholds predefined for that. In other words: The output of an LCOA could be applied to approve or designate a 'certain' origin, but an LCOA is both more flexible and holistic than a labelling scheme. LCOA studies are suitable to complement LCA studies on food products (e.g. Høgaas Eide, 2002; Tugnoli et al., 2008; Del Borghi et al., 2014) since the scope of LCA is environmental performance but not origin. When used for product comparisons, EPDs or comparative assertions LCOA has to adhere to product category rules, especially if the study is used for communication purposes. To avoid misinterpretation flow charts should clearly designate the processes within the system boundaries as well as a discussion and interpretation of the results should be given.

5.2. Potential fields of application

With the limitation that Life-Cycle-oriented Origin analysis so far lacks codification as an official standard or regulation, we assume that the method can be fruitfully employed for an unbiased analysis of origin along the supply chain (in-house, B2B). Additionally the information gathered can be further used to enhance market communication about the origin of a product (B2C). And it may also prove useful for the redesign and optimization of a product. We believe that a reasonable consumer segment is more and more requesting regional products at least in terms of food so suppliers may be interested to sort out components originating far

Table 8
Proposal for data quality.

	Pilot application "chicken breast"	LCOA of food products	Value given from LCA/EPD manuals	Reference
Overall data completeness	Unknown: 2.5 Known: 97.5	Unknown (very good): ≤5%[a] Unknown (acceptable): ≤25%[a]	"Very good": 95% Acceptable: 75%	ILCD handbook (EC,2010)
Specific (primary) versus generic data	Specific: 99,6 Generic:0,4	Specific: ≥90% Generic: ≤10%	Specific: ≥90% Generic: ≤10%	PCR (2015)

[a] If used for market communication (B2C).

beyond. This argument is not compromised by the fact that supply chains are more and more globally interconnected. In our study only 2.5% of the overall origin had to be classified as 'Unknown'. Thus, the outcome of our LCOA study may be stated as follows: with respect to the product's life cycle more than 97% of the origin is known while the share of unknown origin is less than 3%. When results can be stated in this way, they are likely to be useful for producers (and others) who wish to engage in a more sophisticated or systematic form of supply chain and/or product origin analysis.

There are several shortcomings in existing labelling schemes when it comes to their ability to communicate overall (food) product origin to the consumer. This is true both for voluntary schemes, and for official origin labelling schemes. LCOA may be either integrated into an existing labelling scheme or – as indicated in Table 7 – may be used independently and left to speak for itself. Since LCA and EPD methodologies largely ignore product origin information, LCOA could be used to supplement EPDs. The LCOA approach is widely in line with the basic requirements demanded of such methods and also makes use of existing PCRs. However, this does not rule out the need for further testing in order to find out in which particular areas LCOA may best be applied.

Another potential field of application we see is consumer research. So for instance the outcomes of a product LCOA can be compared with corresponding consumer expectations. Such a comparison would reveal if there is a discrepancy between the product origin, as calculated by LCOA, and the product origin, as perceived by consumers.

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