Perspective

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Organic food processing: a framework for concept, starting definitions and evaluation

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Abstract

In 2007 EU Regulation (EC) 834/2007 introduced principles and criteria for organic food processing. These regulations have been analysed and discussed in several scientific publications and research project reports. Recently, organic food quality was described by principles, aspects and criteria. These principles from organic agriculture were verified and adapted for organic food processing. Different levels for evaluation were suggested. In another document, underlying paradigms and consumer perception of organic food were reviewed against functional food, resulting in identifying integral product identity as the underlying paradigm and a holistic quality view connected to naturalness as consumers' perception of organic food quality. In a European study, the quality concept was applied to the organic food chain, resulting in a problem, namely that clear principles and related criteria were missing to evaluate processing methods. Therefore the goal of this paper is to describe and discuss the topic of organic food processing to make it operational. A conceptual background for organic food processing is given by verifying the underlying paradigms and principles of organic farming and organic food as well as on organic processing. The proposed definition connects organic processing to related systems such as minimal, sustainable and careful, gentle processing, and describes clear principles and related criteria. Based on food examples, such as milk with different heat treatments, the concept and definitions were verified. Organic processing can be defined by clear paradigms and principles and evaluated according criteria from a multidimensional approach. Further work has to be done on developing indicators and parameters for assessment of organic food quality.

Keywords: processing; organic; food; concept; definition; quality criteria

INTRODUCTION

In 2007, EU Regulation (EC) 834/2007 introduced principles and criteria for organic food processing which have been analysed and discussed in several scientific publications and reports on research project. In a recent paper by Kahl *et al.*[1] the quality of organic food was described by principles, aspects and criteria. The principles from organic agriculture were verified and adapted for organic food.[1] Different levels for evaluation were suggested. Underlying paradigms and consumer perception of organic food were compared with functional food, resulting in identifying an integral product identity as the underlying paradigm and a holistic quality view connected to naturalness as consumers' perception of organic food quality.[2] Although EU Regulation (EC) 834/2007 for organic production sets a legal frame and some general principles for organic food processing, clear operational principles and related criteria are still missing in order to evaluate processing methods.[3] Therefore the goal of this paper is to describe and discuss the topic of organic food processing in the context of food quality to make it operational. This is done by adapting the underlying paradigms and principles of organic agriculture and organic food to processing as part of the food chain, which becomes more and more important.[4] The focus is on concept development, better definitions and examples for verification.

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Because the concept of organic food processing is developed in the context of related approaches such as careful/gentle, minimal and sustainable processing, the results presented here are of general interest for agriculture and food scientists and technologists as well as stakeholders.

METHODOLOGICAL APPROACH

Experts from the international Food Quality and Health Association (FQH; www.fqhresearch.org) elaborated a framework for concept development, definition and evaluation of organic food processing. The work was carried out by 10–12 experts at three workshops in 2011 and 2012 (two meetings in Kassel, Germany, and one in Copenhagen, Denmark). This paper summarises the outcome of these meetings. Because the topics are of great relevance for the whole organic food sector, the first ideas of this paper were discussed at a workshop during the BIOFACH Expo 2012 among FQH members and other interested stakeholders. The feedback of this consultancy was translated into a first draft paper. A second consultancy round took place during BIOFACH Expo 2013, based on a second draft of the paper. The first draft of this paper was also presented and discussed at the IFOAM conference 2nd IFOAM EU Group Conference on organic food processing and environmental performance, 26–27 November 2012, in Frankfurt, Germany. This feedback was also implemented in the paper. Finally, the main topics of the paper were presented at the second International Conference on Organic Food Quality and Health in Warsaw in June 2013 and discussed among the scientists (www.fqh2013.org).

Because the topic is of high relevance for practice, stakeholders were further involved and the feedback was also integrated into the paper. The final text was sent to stakeholders from farming, processing, retailing, certification and research within the organic food and farming sector via the European Technology Platform TP Organics (www.tporganics.eu) June to July 2013. A qualitative survey was performed during BIOFACH Expo 2012 among organic stakeholders on their understanding of organic food processing related to concepts and criteria based on the EU Regulation for organic production. On the 15–18 February 2012, 200 organic exhibitors from 45 different countries around the world were involved in the survey, which was around 10% of the total exhibitors. Each of them received a questionnaire with the following questions: country of origin, years dealing with organic agriculture (<2/ 2–5/ 5–10/>10 years) and type of product dealing with vegetables + fruits, cereals, dairy products, meat, beverages, spices. Furthermore participants were asked whether they agree that 'careful processing' means 'minimal processing' or not; about the importance of process-related aspects (sustainability) and product-related quality aspects (taste, health) related to processing goals. Furthermore they had to respond whether they agree to restrict processing techniques and/or additives and whether they think organic integrity and vital qualities as mentioned in EC Regulation 834/2007 should be maintained in processing. For all these questions participants had five different possibilities to answer (strongly agree, agree, neutral, disagree, strongly disagree). Finally, the participants were asked whether the concept of naturalness would help to better understand careful processing.

All the descriptions and discussions in this paper are based on relevant scientific literature, including primary research and reviews, reports, books, dealing with organic food quality issues, IFOAM Principles and Standards,[5] EC Regulation 834/2007 and EC Regulation 889/2008, as well as personal consultancy with different stakeholders in the organic food sector. To illustrate the findings, three examples are given, which show the different intensity of processing from post-harvest treatments (apple) to preservation (milk) and finally forming a new product from different raw materials (bread).

CONCEPTUAL FRAMEWORK

The concept of organic food processing can be described in many different ways and from different perspectives. The authors focus on two aspects: (1) a summary of the historical development of organic food processing, and (2) a review of the underlying paradigms and principles in organic agriculture and organic food production together with a brief account of alternative food concepts.

According to the historical background, Schmid and Beck[4] gave an overview on how organic food processing was developed in terms of regulations and standards within the last few decades. Already in the 1970s private standards on organic food processing had been established, such as those of the Demeter association in Germany. Those standards made the responsibility of the manufacturer a central part of the concept. The first international standards were set in 1980 (first as recommendations) and 1982 (as standards) by the International Federation of Organic Agricultural Movements (IFOAM), which partly covered the processing sector and excluded technologies which might not fit with the general standards set. The standards followed a 'no-chemical' approach, which Kahl *et al.*[1] identified as a part of the organic food quality concept. Since the 1990s many national standards associations followed and developed product specific standards for processing of organic food. Based on terms such as 'natural', 'minimal' or 'sustainable' food production they followed a process-oriented approach rather than a product quality-oriented approach, taking environmental issues and animal welfare into account but mainly focussing on primary production.

In 1991 the first EU regulation on organic food production was set up, – Regulation (EEC) 2092/91 – which was revised in 2007. In 2007 Council Regulation (EC) 834/2007 was published and in 2008 the implementation rules laid down in (EC) Regulation 889/2008 were published.

Council Regulation 834/2007 refers to terms such as 'natural' and 'minimal input'. The 'non-chemical' approach resulted in prohibition of chemical processing methods and restriction of additives. In parallel the Codex Alimentarius Guidelines on organic food production were established, which include basic principles of organic food processing.[6] EC Regulation 834/2007 defines organic food production in relation to 'the preference of certain consumers for products produced using natural substances and processes' in Section No. 1 and therefore processing methods should 'guarantee that the organic integrity and vital qualities of the product are maintained through all stages of the production chain' in Section No. 6:19. The specific principles which are applied to processing of organic food also exclude substances and processing technologies 'that might be misleading regarding the true nature of the product' in Section No. 6, c and the processing should be done 'with care'. This first overall definition of organic food processing can also be identified within the Codex Alimentarius Guidelines[6] as well as the revised IFOAM Standards.[5] Kahl *et al.*[1] discussed these terms within the organic food quality concept and gave starting definitions which may be also used within the food processing concept. In the past, quality concepts for food included nutrition as an important part of a lifestyle linked to personal values and a concept of health.[7] In Europe, especially from 1920 to 1950 (a period of industrialisation), a new, so-called 'Reform movement' tried to link nature and food to human health and life style. They all shared the antagonism to intervention that caused 'denaturing' of food such as artificial, synthetic fertilisers for farming or 'industrial' food processing changing the value of food for human health. Balfour claimed a memorable concept of health: 'health, whether of soil, plant, animal and man is one and indivisible'.[8] She called this the 'natural cycle'. According to her opinion the quality of soil should be transmitted to plants and then to animals or man directly. Recently, Levidow *et al.*[9] analysed the underlying paradigms of the European agricultural policy and differentiated between two different paradigms according to agriculture and food production. Kahl *et al.*[2] tested this in a comparison between organic food and functional food. The underlying paradigm of organic agriculture follows an agro-ecology approach, where processing plays a major part. Food production considers social and environmental issues in the evaluation of new processing methods. The food itself, as the central part in food processing is linked to a holistic view, which can be described as an integral product identity approach. This has enormous consequences for the organic food processing concept, which Schmid and Beck[4] mentioned in their description of the historical development of organic food processing. They referred to the 'road map' suggested by Gallmann[10] of further development of organic food processing: freshness, minimal processing and careful treatment. Nielsen[11] related organic food processing to minimal and careful processing, Kristensen and Beck[12] compared organic with sustainable processing and Beck[15] introduced the concept of 'appropriate technology' referring to Schumacher's concept of 'small is beautiful',[14] which connects food processing to decentralisation, simplicity, environment and social values. The concept of organic food processing includes most of these values as a mission for responsible manufacturers. The question is how to come from this paradigmatic level down to concrete principles and criteria for evaluation of processing methods. Kretzschmar and Schmid[3] showed that the principle of care might be an important tool for the practice in organic food processing but, in general, clear principles as well as related criteria are still missed. Beck[13] gave the first Code of Practice for Organic Food Processing, where requirements for daily practice were given, mainly based on the old EEC Regulation 2091/92 as well as IFOAM Basic Standards. Even here actual regulations on how to evaluate new processing technologies were not given. Beck *et al.*[15] analysed the current state of knowledge of processing and quality of organic food and concluded that an organic food quality concept is still not applied in practice taking underlying paradigms, principles and criteria for evaluation together. Beck *et al.*[16] presented guidelines for evaluating organic processing methods, which mainly refer to the EC regulation 834/2007. To summarise our findings on the organic processing concept, we refer to Schmid and Beck,[4] who maintain that organic processing methods should be 'suitable to guarantee genuineness, authenticity and conserve natural properties of the raw materials' and follow the three principles described by Gallmann,[10] which are freshness, minimal processing, and careful treatment. As Kahl *et al.*[1] found for describing the organic food quality concept, also here, we had the necessity to define terms, which are in use but not defined in a proper way such as 'careful' or 'natural'. Furthermore we recognised the need to clarify terms characterising organic processing where we did not know whether these terms would be exchangeable, such as 'organic', 'sustainable' and 'minimal'.

PROPOSED DEFINITIONS

Processing

Processing of food is defined in many different scientific books[17–19] and articles. We refer to these sources. Processing itself is the phase of transformation, of change of the food ingredients, by means of some active principles. Most reference literature categorises food processing according to these active or action principles. Active principles commonly found in the literature include the following: mechanical, chemical, physical, biochemical, biological, biotechnological, thermal cooking, preservation, cleaning, protection and any combination of these. The allocation of processing technologies to the categories or divisions varies across the literature and we could find no single over-arching division.

According to our research we can distinguish transformation of the substances in a production recipe into three major active principles. These are (1) physical, e.g. mechanical, thermal, electric, etc.; (2) chemical, e.g. oxidisation, polymerisation, etc.; and (3) biological, e.g. fermentation, biotechnological, genetic, etc. In order to sharpen the overall definition, we add some aspects, which may help to define organic food processing. Processing is a method including technology, additives, aids, a recipe and packaging. Organic food processing should therefore be defined and regulated on all these aspects.[4] These are all steps within the whole production chain and therefore need special requirements according to the raw material and should, as well, include packaging, storage and partly transport. Processing of food is always related to a goal of production. There are different goals such as preservation of the raw material, forming a new product from raw materials, etc. Here the overall goal is to increase the quality and safety of the product. Quality means product- and process-related criteria from a multi-dimensional approach.[1] Evaluation of processing methods or parts thereof should be done by comparison of at least two methods (comparison approach) and this comparison should be done on the same raw material and under the same goal of production.

Processing technology

According to standard scientific textbooks in the field of food science, food processing technologies are usually divided into three stages: pre-process, process and post-process. In the pre-processing phase, the food ingredients are prepared for processing; they may be extracted or treated in some way to make them ready for the processing phase. Post-processing encompasses any further treatment of the processed foods until they are ready for sale. As such, this may include coatings, dustings, enrobing and usually packaging, for example.

Naturalness

This term seems rather difficult to define in the context of organic food processing. Kahl *et al.*[1] gave a definition in the context of organic food quality. The term 'true nature' seems to be relevant when 'natural' properties of the raw material are maintained through the processing process.[4] The understanding of naturalness depends on the focus.[20]

Minimal processing

Minimal processing of food is a clear concept which is described in literature and applied to various food products.[21] Minimal processing intends to limit the impact of processing on the nutritional and sensory qualities, while at the same time enhancing the shelf life of the fresh product. Minimal processing can be applied at various stages of the food supply chain, in storage, processing and packaging as the least possible treatment to achieve a purpose.[21] Nielsen[11] discussed this concept in the context of organic food processing, focusing on the fresh-like properties of the food. Minimal processing can also be defined as the mildest possible preservation adapted to a particular food.[22] A special concept is the minimal processed refrigeration of fruits and vegetables.[23,24] Several technologies were developed as minimal processing methods such as washing and drying,[25–28] sous-vide[29] or packaging.[30,31] Technologies developed and applied are high pressure processing for preservation[32,33] or pulsed electric fields as another non-thermal treatment.[25] Because minimal processing focuses on the fresh-like properties within post-harvest processes it is not exchangeable with organic food processing but can be part of the organic processing concept as discussed by Gallmann,[10] when preservation is the goal.

Sustainable processing

Kristensen and Beck[12] discussed sustainable processing in the context of organic food processing whereas Kahl *et al.*[1] discussed sustainability in the context of organic food quality. Sustainability, including all three pillars (environment, society, economy), seems to be a principle in organic food processing. Whether the convergence between 'sustainable' and 'organic' will lead to exchangeability of the two terms as describing a specific kind of processing, does not seem clear yet. Sustainable processing is still under development[34] and definite regulations are still missing.[35] Furthermore, process oriented criteria for evaluation according to the three sustainability dimensions are also not fully elaborated within the organic food production regulation and standard framework.

Careful processing

According to the Codex Alimentarius definition[6] as well as to the results from a Delphi survey among experts,[3] careful processing seemed to be synonomous/interchangeable with organic food processing, when the authors started the work. Nielsen[11] discussed this term in the context of organic food processing and concluded that a clear conceptual background is missing. He gave a broad definition, linking carefulness to three dimensions of product, environment and people. Careful processing refers to care taken with the raw materials used during the act of processing, in such a way that they maintain their integrity as far as possible, that all vital substances (all known nutrients) are protected and maintained where they are deemed beneficial to human health, and/or enhanced by the process, improved upon. Careful processing further refers to care taken with all other aspects, i.e. inputs and outputs of a given process. Careful processing will be undertaken in such a way that it cares for and takes care of people involved in the processing, as well as any biotic and abiotic factors both directly and also indirectly involved (impacted, implicated). Concepts such as 'cradle-to-grave' and more importantly 'cradle-to-cradle' are relevant to the design of careful processing and also to the design/management of their context. Careful processing is not exchangeable with organic processing. The principle of care seems to be an important principle within the organic processing concept.[10]

Based on these descriptions, starting definitions can be given for organic food processing. These are related to paradigms and principles. The principles are further differentiated in those, linked to ethical values and those related to more practical implications.

Starting definitions of organic food processing

- *Paradigm*: Ecology and integral product identity as described in Levidow *et al.*[9]
- *Principles related to ethical values*: Responsibility, integrity, care, health, sustainability, naturalness as described in Schmid and Beck[4] and given in IFOAM standards.[5]
- *Other principles*: Organic food processing takes raw material from nature (field, staple) rather than from synthetic origin (field-to-fork approach as defined in Codex Alimentarius, IFOAM standards and EC regulation). In developing processing methods a system approach is taken. For evaluation, a multi-dimensional model is applied[1] rather than reducing it to single indicators.[3] Minimal processing is applied to fresh food and appropriate methods are used for further processed food.[10]

EXPERT SURVEY

As already described in the methodological part, a survey has been conducted during BIOFACH Expo in February 2012. Sixty-three % of the exhibitors involved were from European countries, 22% from Asia, 10% from North and South America and 4% from Africa, which represents the distribution of all exhibitors quite well. The majority (50.5%) had dealt with organic produce for more than 10 years. Moreover around 90% of the exhibitors gave a positive vote to the goal of processing including process and product-related aspects. They were taking care of maintaining organic integrity and vital qualities of the food products. Even 88% agreed to restrict technologies in order to sharpen the profile of organic food processing. The study also indicated that the product-oriented quality aspect was slightly favoured compared to the process-related one, although the multi-dimensional approach, taking both aspects into account, was clearly visible. Also this survey underlined the need to define terms such as 'naturalness' and 'minimal' regarding organic food processing, as it was reported before[3] and discussed later on in this paper.

EXAMPLES FOR VERIFICATION

After analysis of the underlying paradigms and principles regarding an organic food processing concept, the authors started to make the concept operable through linking the defined principles to multi-dimensional quality approach including criteria, indicators and measurable parameters.[1] Whereas for processing of fresh apples preservation, the concept of minimal processing can be applied, for milk heating and bread making methods other aspects of the organic food processing concept have to be taken into account. Furthermore we realised that several criteria were not operable for measureable parameters (e.g. vital qualities) or no data existed in literature (e.g. sustainability) focusing on processing.

Fresh apple fruit chain

Several pre-harvest factors that differentiate between non-organic (including integrated production) and organic growing methods can affect the quality preservation of fresh apple fruits along the food chain. Differently from the non-organic (and integrated) cultivation systems, in the organic production the management of pests and diseases should be mainly based on preventive measures and on the use of substances allowed by the regulations as fungicides or insecticides.

Scab is the dominant disease for apples, caused by the ascomycete fungus *Venturia inaequalis*. The other main diseases are mildew, fireblight and collar rot. Therefore, selection of a variety with a low susceptibility to scab, Topaz for example, is the first preventive measure to be taken. Cultural practices (fertilisation, soil management, pruning), cutting out the infected parts of a tree, mulching the fallen leaves or taking them out from the orchard are also examples of preventive measures to be taken. Nevertheless, these preventive measures are appropriate and necessary, even if a possibly simplified programme of the permitted fungicide (sulfur, lime sulfur, copper) application is still necessary.[36–38]

After harvesting, the apples are transported in bins to the packing centre, where they are unloaded by submerging the bins in water, allowing the fruit to float through a canal to a further water tank in a process known as the pillow effect. This delicate method of moving the fruit can decrease bruising and abrasions. At this stage, the apples are washed in clean, temperature-controlled water. The clean apples are then sent on a conveyor belt to be graded. Before passing through the grading sorting mechanism, defective/damaged apples are usually picked manually at the quality inspection belt. Then the fruits are sorted and graded in an automatic machine. The size, colour and other parameters are defined in the control panel of the machine and produce is sorted–graded as per specified parameters. After this stage the apples are returned to a water tank to be washed, moved over soft brushes then rinsed. The apples are dried using high velocity air fans.

After these preliminary phases apple fruit can be covered with waxes. Apple fruit are naturally covered with a cuticle that forms a continuous layer on the skin surface which protects them against water loss, abrasions and infection by plant pathogens. The cuticle is composed of two main components: cutin and waxes. Waxes, responsible for the immersibility and permeability of the cuticle, are embedded within a matrix of cutin composed of covalently cross-linked hydroxy and hydroxyl-epoxy fatty acids. This composition differs among the apple cultivars and changes during fruit development.[39]

During the washing and cleaning operations part of this natural wax coating could be removed thus exposing apple fruit to water loss during handling and marketing. Preventing the loss of water in apples also helps to maintain quality (firmness and juiciness) particularly during long-term storage.

In the non-organic apple fruit industry, waxing of apple fruit with food grade waxes is common. Besides protecting against dehydration and shrivelling, the other reasons for waxing are aesthetic (appearance) and to slow the ripening process. Waxing of apples is carried out by applying a thin layer of wax on the surface by either dipping, brushing or spraying with wax. This coating is normally referred to as edible coating. The waxes for this scope come from animal or plant sources; the main waxes used on apples are carnauba wax, shellac wax and/or a combination of both. After applying wax, the fruits assume a glossy and firm appearance which is considered as an important quality indicator.

However, waxing apples can have some negative effects on the apple fruit: anaerobic respiration can occur in the fruits since the wax may act as oxygen barrier, thus causing the formation of off-flavours.[40] A number of alternative coatings of different origin and formulation have been proposed to extend the shelf life and keep the quality of apples during storage.[41–48] In the organic sector, although EU Regulation (EC) 889/2008 (Annex VIII Section B) and the USDA National Organic Program (2012) allow the use of some waxes, such as carnauba wax and bees wax, the practice of waxing apples is not commonly carried out by the organic-apple packers, mainly in Europe.

Apples are wax coated before market distribution primarily to improve their appearance. The other benefits of waxing (extension of shelf life, reduction of weight loss and respiration rate, retardation of ripening, and quality maintenance) can be achieved with appropriate storage techniques and conditions. Moreover, waxing can be used to disguise the quality of apples. Waxed apples may look glossy, firm and appealing, visually fresh, but they could be soggy and lacking the desirable crispy texture. According to these considerations, in the organic sector the practice of waxing seems not strictly necessary to allow the storage and quality of apples.

The following step in the fresh apple chain is storage. During apple storage, loss of quality can occur due to metabolic processes that continue after the fruit harvest, and to micro-organisms contaminating the fruits. The main metabolic process is respiration, which is catalysed by ethylene, and brings the fruit to ripening and senescence. Moreover, several micro-organisms (*Alternaria* spp., *Cylindrocarpon heteronema*, *Gloeosporium* spp., *Phomopsis mali*, *Venturia inaequalis*, *Botrytis cinerea*, *Penicillium expansum*, *Phytophthora cactorum*, *Sphaeropsis malorum*, *Trichotecium roseum*, *Rhizophus stolonifer*, *Monilinia fructigena*) are responsible for the decay of apple fruit in the post-harvest phase and can be a limiting factor for storage of apples.[49]

Several fungicides have been proposed and used to control the decay of apples caused by micro-organisms, or physiological disorders such as superficial scald during storage. Scald is manifested as browning of the skin as a result of damage to the hypodermal cells. It was shown that scald occurs through oxidation of α-farnesene, a naturally occurring volatile compound (terpene) in apples. For example, 1-methycyclopropene (1-MCP), a synthetic cyclopropene, has been shown to be effective in reducing the incidence ot superficial scald.[50] Diphenylamine (DPA) is an antioxidant widely used to control scald during apple storage. Moreover, 1-MCP can block ethylene receptors and prevent ethylene effects in plant tissues, including apples, for extended periods, thus contributing to maintaining apple quality during storage.[50] These substances are not permitted for the treatment of organic apples; however, due to the increasing consumer concerns, the use of chemicals even in the non-organic food chain is becoming limited. In 2009 the European Union decided to withdraw the authorisations for all the plant protection products containing DPA (Commission decision 2009/859/EC). In a recent paper it was demonstrated that apple storage facilities were contaminated with DPA, particularly the walls of the storage chambers where the DPA treatments had been carried out repeatedly. Although treatments with DPA had been suspended, the diffusion of this substance from the walls caused contamination of untreated apples at levels that easily exceeded the current maximum residue level of DPA in apples.[51] The need to substitute the post-harvest treatments with chemicals has represented a demand for improving and developing physical methods and new storage technologies.

For organically grown apples a hot water dipping of apples may be an alternative.[52] For example, treatments with water at a temperature around 50 °C for a short period of time (2–3 min at maximum) have been shown to be effective against *Gloeosporium*, *Monilia fructigena* and *Nectria galligena*.[53]

Apple storage can be carried out in refrigeration in air, under controlled atmosphere conditions, or ultra-low oxygen conditions. With refrigerated storage apple fruit can be stored for up to 5 months; in controlled atmosphere or ultra-low oxygen the storage can be prolonged even up to 1 year. Controlled atmosphere and ultra-low oxygen conditions can inhibit the action of ethylene, are effective in controlling micro-organisms, and also are able to reduce the incidence of scald.[49] Both these techniques can be used in the organic sector because the change of O_2, CO_2 and N_2 gas levels in the storage rooms are permissible by the organic regulation (EC Reg. No. 889/2008). Among physical approaches the dynamic controlled atmosphere storage technique has to be mentioned. It uses a fluorescence-based technology to monitor the responses of fruit to low oxygen and has been shown to be an effective alternative to DPA treatment for complete control of scald and apple quality preservation.[54,55] This technique involves the use of a non-destructive monitoring system of fruit chlorophyll fluorescence, which allows the detection of low-O_2 stress before development of associated disorders in apple fruit.[56] This system, by indicating when the fruit is under low-O_2 stress during storage, allows for the dynamic adaptation of the atmosphere composition in the controlled atmosphere room to an O_2 level lower than that set in ultra-low oxygen storage, but still tolerated by fruit; in this way it becomes possible to optimise the greatest benefits of ultra-low oxygen without producing detrimental effects due to anaerobic conditions.[57] Due to the prohibition of the use of chemicals for the control of scald, this technique achieved relevant success in the organic sector because it allowed for organic cultivation of apple varieties particularly susceptible to scald.

Apple is a major source of phenol compounds. In particular, flavonoids are important constituents located mainly in cortex and in skin; the majority of the antioxidant activity originates from flavonoids, although other phenolic compounds contribute.[58] Additionally, phenolic compounds determine sensory characteristics of colour and taste. The content of flavonoids in apples has been shown to be specific for particular tissues and genetically, developmentally and environmentally regulated in a very complex way.

Storage, particularly long-term storage, can modify the phenolic composition of apple. However, the trend observed for these changes is not uniform, ranging from a decrease of the phenol content to no change, or to an increase.[59–62] In general, differences may be due to different cultivars and differences in ripening.[63] Moreover, a different pattern between the different phenolic compounds has been described.[59]

One drawback of both controlled atmosphere storage with ultra-low oxygen concentration and exposure to 1-MCP is the potential suppression of production of volatile compounds contributing to apple flavour.[64,65] Both technologies inhibit ethylene action thus decreasing the biosynthesis of volatile compounds.[65] Instead, the dynamic controlled atmosphere technique has been shown able to preserve organic apple aroma compounds during long-term storage better than ultra-low oxygen in combination with 1-MCP treatment, and hot water treatment did not produce marked changes in volatile composition after four months of refrigerated storage.[66]

The environmental impacts of apple production strongly depend on growing method and location.[67] Some research demonstrated that organic farming practice can be associated with lower nitrogenous losses from the soil,[67] a lower energy requirement and global warming potential.[68] However, it is to emphasise that the basis for the calculation of the environmental impacts, i.e. on an area basis (hectacre) or on actual throughput (kilograms or tons), can have a substantial effect on the results due to the difference in yields between non-organic, integrated and organic growing methods. The productivity of an organic apple orchard is typically lower than that of a non-organic or integrated managed orchard; however, the yield differences are contextual and depend on several factors (soil characteristics, variety, pest management, harvest year, etc.).[69–72] The primary energy requirement of apple cultivation can have a different relevance on the energy requirements of the life cycle according to the length of the supply chain. Some studies on LCA applied to apple production demonstrated that when a long-distance transport scenario is considered, the energy requirement of the apple transport stage can reach 60–70% of the total energy requirements and Green-House-Gases (GHG) emissions.[67,68]

Milk heat treatments and their impact on milk quality

In order to illustrate how the various processing methods affect the quality of a final processed food product, milk was selected as the model product. The available publications comparing different processing methods used to prolong milk's shelf life [e.g. pasteurisation, ultra-heat-treated (UHT) methods, sterilisation] were analysed. Among the analysed publications only the authors of two studies mentioned the source of the raw material and carried out all compared processing methods on the same raw material.[73,74] The authors of all the other publications analysed not only did not provide the information about the origin of the raw material (in some cases milk samples originated from the market), but also the tested processing steps were done under different conditions of temperature, time, pressure, etc. in different studies and because of this their results could not be used for the purposes of this article.

Many studies comparing the effect of different processing methods on the quality of milk, regardless of the origin of the raw milk and of the different conditions of tested processing methods are summarised by Camprodon.[75] The results of this study show the general trend in quality caused by thermisation, microfiltration, pasteurisation, sterilisation and UHT methods in comparison to the quality of the raw milk samples.

The aim here is to illustrate an operable approach for evaluating organic processing technologies. The following developmental steps were taken.

A spider-web graph is a graphical form often used to present the results of a sensory analysis. It provides the possibility of easy comparison and interpretation of results obtained for even a very wide range of tested products. This graphical form can become a simple tool for the selection of processing methods that would be optimal for all actors involved in the food chain. To properly present comparisons of studies we selected the studies by Morales *et al.*[73] and Śmietana *et al.*[74] from many publications analysed which compared different processing methods of milk.

In these two publications the impact of different milk processing methods on various quality parameters were compared and the research was based on one known source of raw milk. But the results of these two studies are presented in different ways. The parameters measured by Morales *et al.*[73] are presented in a spider-web graph and the results presented by Śmietana *et al.*[74] in a table. On the one hand we did not want to compare on one graph the results of the raw material from two different sources; on the other hand both authors used different parameters (such as temperature) when carrying out the processing methods of raw milk. Furthermore, the results obtained by Śmietana *et al.*[74] were presented in a table, because the number of quality parameters studied was too small to be presented in a spider-web graph which looks best when comparing more than five parameters (e.g. a spider-web graph with four parameters has the shape of a square).

To create a spider-web graph, first of all a scale from 0 to 100 was set, where 0 means low-quality milk and 100 is high-quality milk presented on the basis of the parameter tested. The scale 0–100 was set to be able to present the results for diverse parameters in one spider-web graph, and to standardise the expression of results of the various quality parameters, which are usually expressed in different units. The adopted scale will be called an 'index', and the process to unify the results expressed in different units to absolute values will be called indexing.

Indexing has been carried out in different ways, depending on whether or not the substance, which is a milk quality parameter, is a desirable or an undesirable substance in the milk of high quality. It was necessary in order to avoid a situation in which the highest value of an undesirable substance would be 100, which would mean that milk containing a high level of an undesirable substance would be characterised by the highest quality.

If any substance should be present in the milk, which means that this substance is desirable, its value measured in the raw milk was adopted as 100 on the absolute values scale (on the index). Then for the purposes of creating the index all values of the substance measured in milk processed by various methods were calculated by the proportion.

If the presence of the substance is undesirable in milk, the value of this substance measured in the sterilised milk (a) was adopted as index = 0, due to the knowledge that sterilisation is a method which is the most invasive and extremely reduces the quality of the milk. Then 100 was divided by the value of the substance measured in sterilised milk (*a*). This result was multiplied by the values obtained for the further tested processing methods (b_{1-n}, where *b* is the value of the substance measured in other milk than sterilised and $1 - n$ is the number of tested processing methods) and subtracted from 100. The indexing method specified here can be presented in the form of the following formula: $100 - [(100 : a) \times b_{1-n}]$. In this way the obtained values of quality parameters were plotted on the axes of the spider-web graph, representing equivalents of the measured parameters. Figure 1 shows the spider web of different milk quality parameters of different heat treatments of the samples referring to Morales *et al.*[73]

In Table 1 the microbiological quality is presented, which was examined by Śmietana *et al.*[74] for different processing methods. The data presented in the table are original data (without converting to the form of the above mentioned index).

Applying a spider-web graph allows presentation of the results of many different quality parameters in an easy and clear way, which should be taken into account when assessing different processing methods to be in coherence with the broad concept of food quality with different categories (nutritional quality, commercial quality, environmental impact, etc.).[1] Comparing different processing methods by values obtained for the different quality parameters enables the possibility to classify which of these treatments is most optimal from different points of view and achieves the goals of sustainable development and of providing health promoting food.

Environmental impacts of milk production (life-cycle assessment)

Environmental impacts of food products occur across the entire food chain, from production of inputs for different steps, through farming, industry and retail to households.[76] Life cycle assessment (LCA) is an international standardised quantitative environmental assessment tool, considering a product's life cycle with all used resources and environmental impacts in each step from production to waste management.

Most of the studies assessing environmental impacts of milk production are limited to farm gate. There are significantly fewer studies about the environmental impacts of dairy processing on environment.[77] A clear finding from previous milk LCAs[78,79] is that milk production in dairy farming is responsible for most of the environmental impacts during the milk product's life cycle, other stages such as processing, packaging and transport usually have considerably less impact. A review of 60 studies[80] concludes that, for the milk production, 85% of the greenhouse gases and 40% of the energy consumption are linked to the dairy farm.

However, previous LCAs mostly consider traditional milk pasteurisation and there is a serious deficit of scientific studies where environmental impacts of different milk processing technologies are actually compared.

Hospido *et al.*[81] made an LCA of processed milk, based on dairy data where pasteurisation, UHT and sterilisation were all used. It was found that relative contribution of dairy to total environmental impacts was more than 50% in several impact categories (Fig. 2).

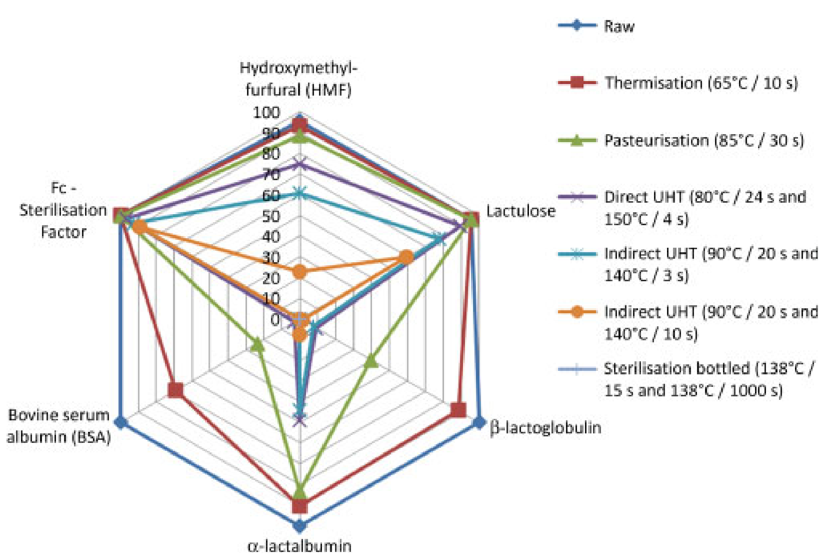

Figure 1. Spider-web of selected milk quality parameters responding to different heat treatments of the samples (own calculation, data from Morales *et al.*[73]).

Table 1. Selected milk safety parameters responding to different milk treatments

Parameter	Raw milk	Pasteurised milk (72 °C, 15–20 s)	Microfiltrated (1.4 µm ceramic membrane) and pasteurised milk (65 °C, 15–20 s)	Sterilisation UHT
Total bacterial count directly after treatment (cfu mL^{-1})	290 000	850	<10	<1
Number of psychrotrophs directly after treatment – TBC (cfu mL^{-1})	110 000	<10	<1	<1
Number of heat resistant microorganisms after treatment (cfu mL^{-1})	10 000	600	<10	<1
Number of anaerobic spores after treatment (cfu mL^{-1})	4 000	30	<10	<10
Total bacterial count after 9 days of storage (cfu mL^{-1})	ND	600 000	<10	<10
Number of psychrotrophs after 9 days of storage(cfu mL^{-1})	ND	520	<1	<1
Number of heat resistant microorganisms after 9 days of storage (cfu mL^{-1})	ND	270	<10	<1
Number of anaerobic spores after 9 days of storage (cfu mL^{-1})	ND	4 000	<1	<10

Reproduced from Smietana *et al.*[74]
ND, not detected.

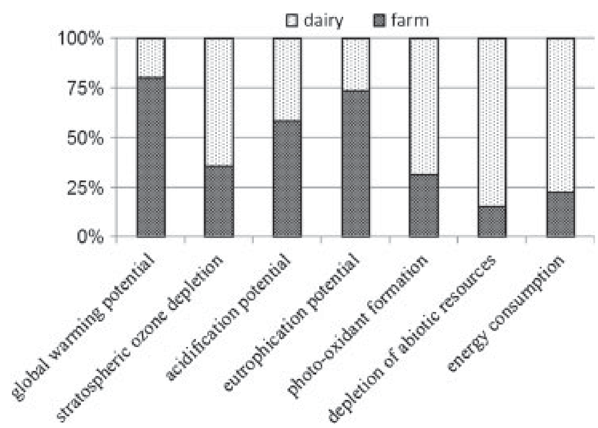

Figure 2. Relative contribution of farm and dairy to total environmental impact categories producing 1 L of packaged liquid milk.[81]

Hospido *et al.*[81] pointed out that photo-oxidant formation, depletion of abiotic resources and stratospheric ozone depletion were not significant impacts in this study. Nevertheless it illustrates the contribution of farm and dairy to total environmental impacts in numerous categories. According to Hospido *et al.*[81] total energy consumption to produce 1 L of packaged milk is 6.21 MJ (1.39 MJ at farm level and 4.82 MJ at dairy factory); it vividly illustrates the energy consumption of the milk processing industry.

González-García *et al.*[82] also found that the relative contribution of dairy factory to total environmental impacts of producing packaged UHT milk to be 50% or more in several impact categories: abiotic depletion, ozone layer depletion, human toxicity, fresh water aquatic ecotoxicity, marine aquatic ecotoxicity, photo-oxidants formation and cumulative energy demand. Farm contribution was higher (more than 50%) in acidification, eutrophication, global warming and terrestrial ecotoxicity.

Hospido *et al.*[81] pointed out that most of the environmental impacts in dairy are caused by packaging (tetra-brik manufacture). González-García *et al.*[82] also found that on-site emissions derived from dairy factory together with the packages and energy requirements production have significant impact.

Results of recent milk studies show that the contribution to total environmental impacts of milk production from the dairy industry are also important in addition to impacts from farming systems. Energy use and other impacts are smaller for raw milk due to the absence of processing but in the case of broadening the limits of the studied system, product losses due to shorter shelf-life may be higher in retail and consumption steps which lead to increased environmental impacts. Processed milk needs additional energy in dairy but its shelf-life is significantly longer, therefore losses are decreased and UHT milk needs less energy for storage, which may reduce total environmental impacts.

There is a serious lack of studies about environmental impacts of different milk processing technologies through the milk life cycle. In order to find processing methods which are careful in both environmental and milk quality point of view, there is a strong need for LCA studies considering milk life cycle from farm to consumption and waste management, comparing different processing alternatives and consumption chains to see their full impacts. Also economic and social impacts of different scenarios should be assessed to discuss the sustainability within the food chain.

Levels of evaluation: criteria/indicator/method (parameter)

For determining/evaluating organic food quality different quality levels or steps should be considered, which are shown in Table 2. When trying to connect the level where the expectations of the consumers and the regulations are formulated with the results from laboratory measurements, an additional level is needed between the two.[1] For example, when there is a connection between a physiological process and the laboratory results they can be used as biomarkers to follow the influence of processes on, for example, human health. In this case the physiological process is

Table 2. Milk quality related criteria, indicators and parameters regarding the organic quality model

Quality level	Perception/perspective	Example
Criterion	Regulation /consumer level	Enjoyment/pleasure
Indicator	Specialist/practitioner level	Sensory properties
Parameter/method	Method/lab level	Simple description

Source: own representation based on Kahl *et al.*[1]

the indicator and health is the criterion. In the case of criteria from the perspective of regulation, such as 'organic integrity', which is formulated in Regulation (EC) No. 834/2007, there is no direct connection to a laboratory result. When using the level description of Kahl *et al.*,[1] the regulations and consumer expectations are called criteria, while the laboratory results are called parameters. The connecting level in between could be called 'indicators'. These indicators can be identified as coming from the practitioners, who are working on a daily basis within the processing in question.

In this part of the study we focused on new product related criteria for organic food. These are criteria for organic food quality which have to be considered additionally when compared to non-organic food. Some of them come from Regulation (EC) No. 834/2007. Food quality criteria and principles specific to organic food have been analysed.[15]

Vital qualities, organic integrity and true nature are identified as new product related criteria relevant for organic food processing. They are formulated in Regulation (EC) No. 834/2007 for organic food processing. However, no requirements have been set up for achieving these criteria. Furthermore, neither definitions nor instruments such as parameters or indicators to measure them have been determined.

When taking the example of organic milk processing the same problem appears: apart from the overall prohibition of using genetic engineering and ionising radiation, no other processing technology or requirements for gentle processing have been evaluated in Regulation (EC) 834/2007. Basic milk processes such as homogenisation, pasteurisation, UHT and sterilisation are permitted without any limitation.

So, on the one hand within EU Regulation (EC) 834/2007 a type of food processing (here, dairy) in terms of criteria (regulation–consumer expectation level) is stipulated which is gentle, does not mislead regarding to the true nature of the product and which guarantees that the organic integrity and vital qualities of the product are maintained; but on the other hand there are no measuring instruments, definitions and requirements in the EC regulation nor can they be found in the scientific literature.

In organic standard-setting associations, however, there are different rules/limitations for processing of dairy products. When looking at Table 3 some processing methods/technologies are excluded in the regulations of, for example, Demeter or Bio Suisse for the processing of milk (e.g. sterilisation). Bio Suisse and Bioland defined a limitation on the parameter-level for the UHT technology: UHT technology is allowed only if the β-lactoglobulin content of the milk after processing is 500 mg L^{-1} (see Table 3).

The reasons for the restriction of processing methods/technologies can be found at the criteria level/consumer expectation level. Associations such as Demeter or Bio Suisse explain that the processing should be done with care and gently to the quality of the product. Demeter pointed out that the quality of the raw material should be kept or developed further through the whole processing steps.

So within the product-group specific standards of some organic associations there are the first attempts to make the criteria concretely useful and include them within the different milk processing steps. But there are still definitions, parameters/methods and especially indicators (practitioners level) missing in order to measure them and make them applicable for organic processors.

Bread making

In the following example, the production of bread is presented. To obtain assessment indicators regarding processing with care in organic agriculture, two extreme bread production methods are contrasted: (1) traditionally produced bread with minimal input, and (2) bread from a large bakery that fully exploits the possibilities of the EU Regulations for organic farming (EC) 834/2007 and EC2007; [(EC) 889/2008EC2008a)]. In order to clarify the difference to the conventional method, a third production method of commonly produced bread from a large bakery is described (Table 4).

The farming system was not considered because there are no differentiating criteria between organic minimum and organic maximum. This is also true for drying the kernels. The EU regulations for organic farming only require that the variety has to be Genetically Modified Organisms (GMO)-free and that reproduction of the variety takes place under organic conditions. However, in the organic farming movement, there is intense discussion regarding acceptable breeding techniques.[83] There is a group of cultivators who breed exclusively for organic farming. Several private standards prohibit certain breeding techniques (e.g. hybridisation). Long transportation distances, including from outside Europe, also occur in organically cultivated grain. On the other hand, some bakeries advertise working with regionally produced raw materials. Associated with transportation are notable environmental impacts (e.g. energy use, global warming potential).[84] A large variety of milling types exists. Barrel mills process the grain in 10–12 stages. In contrast there is one-stage milling which utilises high speed, high acceleration, and high shear forces. Milling types are the hammer mill, impact mill, and pin mill. Possible indicators to measure milling intensity are thermo-sensitive enzymes and the destruction of starch. The decision is between slow baking and fast (direct) baking. Kneading does not distinguish between these two processes but, rather, the fermentation time. For fermentation, slow baking may need up to 16 h. It can be carried out with or without cooling. Examples of slowly baked bread are a French baguette or an Italian ciabatta.[85] Slow-baked loaves are made from flour, water, salt and yeast. From the long fermentation, the quantity of yeast can be small (0.1–0.5%). From the long rising process (fermentation), the bread can develop a good flavour. Moreover, the browning and cut resistance, compared to direct baking loaves, is improved. For fermentation, fast baking needs about 1 h. Due to the shorter fermentation, the amount of yeast must be considerably higher as compared to slow baking (2–5%). In organic maximum, the addition of other substances is allowed: ascorbic acid to stabilise the flour and improve the gluten properties, lecithin as an emulsifier, baking margarine to improve the dough properties, and a number of enzymes. Commonly used enzymes are xylanases, glucose oxidases, peroxidases, amylases, proteases, peptidases and lipases. They improve dough development, impede drying out of the dough, improve fermentation stability and tolerance, increase the volume, and improve the colour, taste and shelf life.[86] Five to 20 enzymes are used in conventional bread.[87] The extent of their use by organic bakeries is unknown. Enzymes are defined as processing aids and measurements therefore are generally not declared (EC 889/2008). The enzymes for organic products are not allowed to be developed from genetic modification. Some standards from private organic associations prohibit the use of isolated enzymes (e.g. Bioland, Demeter). In slow baking, fermentation is not interrupted; however, organic maximum allows fermentation to be interrupted through the use of a shock freezer.

Table 3. Comparison of different organic standards/regulations regarding milk treatments and regulated processing methods

Type of preservation	Temperature and time	Pressure conditions	Technology	Restrictions by EC regulations	Naturland	Bioland	Bio Suisse	Gäa	Demeter
Pasteurisation	72–76 °C, 15–30 s	—	Batch heater, heat exchanger	v	v	v	v (positive analysis of peroxidase) multiple pasteurisation processes not allowed	v	v
High-temperature pasteurisation	85–127 °C, 8–15 s or 0.7–1 s (steam injecting)	—	Steam injecting	v	v	v	x	v	x
UHT generally	133–150 °C, 1–4 s	—	—	v	v	v allowed only when accompanied by β-lactoglobulin analysis with a value above 500 mg L^{-1}		x	x
UHT direct	approx. 150 °C, 2 s	—	Steam injecting/steam infusion	v	v	v allowed only when accompanied by β-lactoglobulin analysis with a value above 500 mg L^{-1}		x	x
UHT direct	approx. 135–150 °C, 3–4 s	400 kPa	Water steam injecting					x	x
UHT indirect	approx. 138 °C, 15 s	—	UHT heat exchanger	v	v	x allowed only when accompanied by β-lactoglobulin analysis with a value above 500 mg L^{-1} (at present no technology available)		x	x
UHT indirect	approx. 137 °C, 4 s, longer preheating time	—	Plate heat exchanger						
Sterilisation (in the package)	≥ 121 °C (to 125 °C) minimum 3 min	—	Steam autoclave (continuous or discontinuous)	v	x	x	x	x	x
Sterilisation	≥ 100–120 °C, 10–45 min	—	Autoclave (continuous or discontinuous)	v	x	x	x	x	x

v ℑ allowed (green), with conditions (yellow).
x ℑ not allowed (red).
Source: own representation based on Camprodon[75], Strahm[89], 2009 and the regulations of the organic associations Bioland, Bio Suisse, Naturland, Demeter Germany, Demeter International, Gäa.

Table 4. Possible differentiating factors of organic wheat bread production

Possible differentiating criteria	Organic minimum	Organic maximum	Conventional industrial bakery
Variety	Adapted to organic farming/traditional breeding techniques	Typical for conventional agriculture/manipulative breeding techniques	Typical for conventional agriculture/manipulative breeding techniques
Transport/origin of the wheat	From the region/country	Imported from abroad (another continent)	Imported from abroad (another continent)
Milling	Milling in stages	One stage mill	Barrel mill
Baking process	Slow baking	Fast baking	Fast baking
Recipe	Flour, water, salt, yeast (0.1–0.5%)	Flour, water, salt, yeast (2–5%), ascorbic acid, lecithin, baking margarine, enzymes (no GMO)	Flour, water, salt, yeast (2–5%), ascorbic acid, lecithin, baking margarine, enzymes (GMO), L-cysteine (E920), DATEM (E472e)
Interruption of fermentation	No	Yes (shock freezer)	Yes (shock freezer)

Thus, the dough pieces can be preserved for months. Production and sale can then be separated by greater spatial and temporal differences. Finishing the loaves can take place directly in retail outlets. Interrupting baking by shock freezing affects the gluten quality; therefore, the use of enzymes is necessary to achieve a satisfactory baking outcome.[86] It is assumed that shock freezing is associated with high energy use.[84] Regulation (EC) No. 834/2007 for organic food processing prohibits the usage of GMOs (varieties, enzymes) and the usage of less-controversial additives in organic bread. With regard to the use of enzymes and processing methods, there are no restrictions. Therefore, the difference between organic bread fully exploiting the possibilities of the EC regulations for organic food processing compared to conventionally produced bread is less than that of organic bread produced with minimal inputs. The practicability of slow baking is demonstrated by the association 'slow baking e.V.' (www.slowbaking.de) in which several hundred bakeries are members, producing exclusively slow-baked bread.[88]

CONCLUSIONS

Organic food processing is related to clear paradigms and principles. For evaluation a multi-dimensional approach is needed, making it operational. Gaps are identified such as missing operational criteria and parameters. Further research work has to be done on developing and defining indicators and parameters for multi-dimensional evaluation for different product groups. Together with the relevant stakeholders there has to be a balance of the different criteria in order to choose innovative technologies in organic food processing.

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APPENDIX

The following list gives details of guidelines, standards and regulations according organic food processing.

Bio Suisse Schweiz 2011. Weisungen zu . den Richtlinien – Lizenznehmer und Hofverarbeiter. Margarethenstr. 87, CH-4053 Basel

Bioland Deutschland 2009: Bioland-Richtlinien für die Verarbeitung- Milch, Milcherzeugnisse, Butter, Käse, Speiseeis – Mainz

Demeter Deutschland 2010: Richtlinien Verarbeitung. Demeter e.V. Brandschneise 1, D-64295 Darmstadt

Demeter-International e.V. 2012: processing standards for the use of demeter, biodynamic® and related trademarks

Gäa, 2010 Deutschland: Gäa-Richtlinien Verarbeitung, Stand 11/2010 (Gäa e.V. – Vereinigung ökologischer Landbau)

Naturland Deutschland 2010: Naturland Verband für ökologischen Landbau e.V. Naturland Richtlinien Verarbeitung

USDA National Organic Program 2012: Organic regulations, title 7 – Agriculture; http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=e036a628ce0eacec20f168e0432d2dda&rgn=div8&view=text&node=7:3.1.1.9.32.7.354.6&idno=7. [Accessed on 22 October 2012]

Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91. *Official Journal of the European Union*, **L189** (20.7.2007):1–23 (2007).

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For further reading see: http://vlex.com/vid/organic-labelling-42671438#ixzz1DFmWwO6T

