Assessment Framework for the Evaluation of Organic Food Processing

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Content

1. Introduction

Processors having no experience in organic food processing may be not aware that organic principles are not only relevant in organic production but also apply for the processing of organic food. In contrast, if processors are thinking about investments in new processing technologies or are planning to process organic food and want to evaluate whether the new processing technology or their existing processing technologies comply with the organic principles, they are quickly struggling today to come to a meaningful result as the present regulatory framework does not provide conclusive guidance on organic food processing.

The organic regulation 834/2007 as well as the new organic regulation 2018/848 from 2021 on, only set a legal frame with general principles for organic food processing. Both regulations refer to terms such as "true nature", "restriction of the use…. to minimum extent" or "processing with care", meaning the exclusion of substances and processing methods that might be detrimental to the true nature of the product. However, these terms are not defined and partly unclear (Beck et al. 2012).

While most references to organic food processing remain vague two requirements given in the regulations are rather clear. The first is that for organic food processing biological, mechanical and physical methods should be preferred. The second states that food products need to be produced through processes that do not harm the environment, human health, plant health or animal health and welfare.

Concerning low-input food processing as stated by IFOAM Principles and Standards and EC Regulations, several perspectives have to be considered (Schmid et al. 2004). Low-input processing is associated with terms like minimal, sustainable, and careful processing. Taking all this into account a very broad perspective from the pre-processing state, the processing itself and various other stages of the food supply chain as storage and packaging must be included in assessing and evaluating new as well as existing technologies to be in line with organic food quality.

As Kahl et al. (2011) stated, IFOAM Principles and Standards and EC Regulations reflect the common understanding of organic food quality within the organic sector in Europe. Based on these and the outcomes of consultations with stakeholders in the organic sector, Kahl et al. (2011) identified five major underlying principles of organic food production and food quality: (1) naturalness, (2) health, (3) sustainability, (4) process and product orientation, and (5) system approach. In order to integrate these multi-dimensional principles into a conceptual framework allowing an evaluation of organic food quality Kahl et al. (2011, 2013) proposed to define organic food quality by process- and product-related aspects and criteria. Criteria are further described by indicators, which allow for an objective assessment.

Important aspects of organic food quality identified by Kahl et al (2011, 2013) and considered within this assessment framework are environmental, social, and economic sustainability describing process-related quality and nutritional and sensory quality describing product-related quality. The sustainability as well as the nutritional quality aspects cover health issues. If the three aspects, sustainability, nutritional and sensory quality, are then evaluated in a system approach four of the five above mentioned underlying principles of organic food quality are met. The remaining principle of naturalness affords a separate evaluation. However, due to the lack of a clear definition of naturalness this principle is the most difficult to evaluate.

Whilst there are first attempts and proposals how to define the word "naturalness", as e.g., maintaining natural properties of a raw material throughout processing, it remains still difficult to set uniform criteria for its evaluation within organic food processing. In consequence it remains a subjective and individual decision for each single processing technology how to define naturalness. Its definition will be influenced by an organization's understanding of the concept of naturalness.

It is important to mention that the aspects of organic food quality identified by Kahl et al (2011, 2013) and considered within this assessment framework are not final and all-inclusive. Within this assessment framework the mentioned aspects must be seen as a proposal for how to tackle the evaluation process. However, it is up to the users of this assessment framework to include other aspects considered to be important within a specific context.

The goal of this document is to provide guidance to processors, labelling organizations, and policy makers on how to assess and evaluate organic food processing being in line with organic principles. The document provides a detailed and step-by-step assessment framework for evaluating organic food processing and sets the minimum requirements to be met.

Since at this point there are no absolute measures available that define when a product is in line with the above-mentioned organic principles, the evaluation procedure proposed within this assessment framework is based on a benchmarking process. This means that the decision whether a product obtained with a new processing technology is line with organic principles is based on the comparison with the same or a similar product obtained with an established processing technology. And in case where no comparable processed product is available a new processed product needs to be compared with its raw materials or intermediate products.

This document was first elaborated by an expert working group within the CORE Organic Cofund project ProOrg and refined upon a consultation process within the whole project team and among stakeholders of the organic sector. The definitions used for organic food quality within the context of this framework were taken from the two conceptual papers of Kahl et al. (2011, 2013) and implemented in an applicable process to evaluate processing technologies to be in line with organic food quality. The evaluation process provided within the framework is generic and needs be tailored to a specific organic food product that shall be processed by specific technology within a specific company context.

2. Scope

This assessment framework represents a generic guideline and sets the minimal requirements on the assessment of processing technologies and the use of contentious substances in the context of organic food processing.

The main objective of the multi-dimensional assessment framework is to provide guidance on how to assess organic food quality as affected by processing technologies, processing methods, additives and processing aids used (incl. contentious substances). It further provides guidance on how to compare different alternatives of processing technologies and/or alternatives to contentious substances aiming at the same processing goal.

This assessment framework is targeted to operators in food processing in general and organic food processing specifically as well as to labelling organizations. Further, it may be also useful to legislative authorities.

NOTE: For convenience, the users of this assessment framework are in the following referred to by the general term "organizations".

This assessment framework can be applied throughout different food products, processing purposes, formulations/recipes, and processing technologies and where relevant also includes storage, transportation, and packaging.

This assessment framework can be applied to any type of processed food product and food processing technology, whether being in line with organic principles or not. Further, it can be applied in any food processing organization.

Although this assessment framework provides generic guidelines and suggests the requirements for evaluating organic food processing including a definition of the minimal requirements, it is not intended to promote uniformity of assessment across organizations as an assessment always needs to be tailored to the organization's internal and external context. The system boundary of the assessment will be defined case-specifically and will also need to consider the external and internal context of a specific organization and the level of uncertainty in available empiric data.

Even though the assessment framework provides an objective assessment procedure, the final evaluation whether a product obtained with a new processing technology is in line with organic principles is a value judgement. In fact, in the end it is a political decision to define what is in line with the organic principles. This decision must be taken by the different decision makers (i.e., EU commission, labelling organizations, organic sector as a whole) and cannot be provided by the assessment framework.

It is intended that this assessment framework helps to harmonize the evaluation procedure of organic food processing. It provides a common approach in support of the regulatory framework and the existing organic standards.

This assessment framework is not intended directly for the purpose of certification.

3. Terminology and definitions

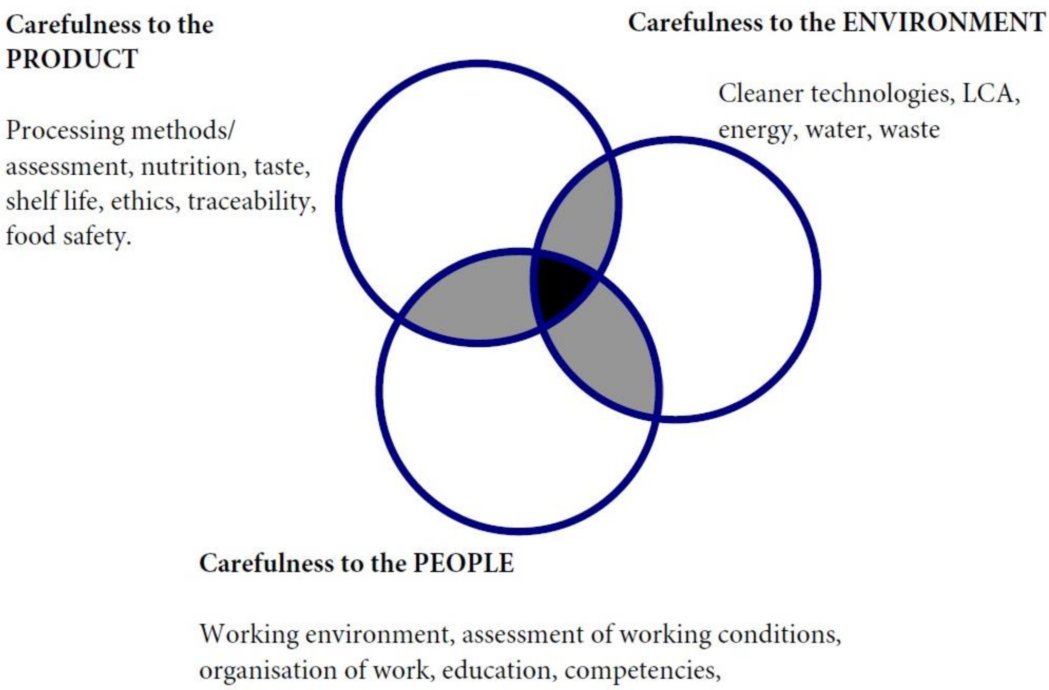
- Additives

  as defined by Article 3 (2) a) of regulation 1333/2008:

  "Food additive'' shall mean any substance not normally consumed as a food in itself and not normally used as a characteristic ingredient of food, whether or not it has nutritive value, the intentional addition of which to food for a technological purpose in the manufacture, processing, preparation, treatment, packaging, transport or storage of such food results, or may be reasonably expected to result in it or its by-products becoming directly or indirectly a component of such foods.

- Careful food processing

  There still is no common definition of "careful processing". The term "care" is also named as one of the IFOAM principles of organic agriculture (IFOAM-Organics International 2019) referring to the current and future wellbeing of people and the environment. It is, therefore, possible to broaden the understanding of careful processing to the sustainability approach, as e.g. illustrated by Schmid et al. (2004):



- Criterion/Criteria

  In the context of this framework a criterion describes organic food quality according to process- and product-related aspects (Kahl et al. 2011; Kahl et al. 2013). Criteria can be characterized and measured by indicators. An example of a process-related criterion is environmental sustainability of the production process, and an example of a product-related criterion is enjoyment.

- Food

  As defined in article 2 EU Reg. 178/2002.

- Food processing

  All post "primary production" processes like cleaning, preserving, mixing, transforming, packaging, labeling of foods targeted for human consumption.

  Consistent with the definition of the term 'preparation' in Art 2 (i) 834/2007, which "*means the operations of preserving and/or processing of organic products, including slaughter and cutting for livestock products, and also packaging, labelling and/or alterations made to the labelling concerning the organic production method;*".

  EU Reg. 178/2002 Art 3 17 defines 'primary production' as *"the production, rearing or growing of primary products including harvesting, milking and farmed animal production prior to slaughter. It also includes hunting and fishing and the harvesting of wild products;"*.

- Indicator

  Indicators are measurements used as representation of an associated (but non-measured or non-measurable) factor or quantity. Indicators in this context as proposed by Kahl et al. (2011) characterize a criterion (see above). Indicators are further determined through parameters and methods. An example of an indicator describing the criterion enjoyment are sensory attributes (e.g., appearance, texture, flavour, taste).

- In line with organic food quality

  "In line with organic food quality" means that a processed food product complies with organic food quality, which within this assessment framework is defined through aspects and criteria built upon the organic principles according to Kahl et al. (2011 and 2013) (see "Organic food quality"). Therefore, this term is interchangeable with the term "in line with organic principles" (see below).

- In line with organic principles

  "In line with organic principles" means that a processed food product complies with the organic principles as summarized in Kahl et al. (2011 and 2013). By that the respective food product also complies with organic food quality (see above).

- Minimal food processing

  Minimal food processing intends to use processing procedures that change the fresh-like quality of the food as little as possible and to limit the impact on the nutritional and sensory properties of the food, while at the same time endow the product with a shelf life sufficient for transport, storage and use/consumption (Ohlsson and Bengtsson 2002).

- Naturalness

  According to Verhoog et al. (Verhoog et al. 2007) naturalness can be understood from three different approaches. A no-chemicals approach especially in the farming context, an agro-ecological approach having in mind a more holistic and ecological way of thinking and an integrity approach respecting the integrity and characteristics of living organisms. Understanding naturalness on the processing level leads to maintaining natural properties of raw materials through the processing process and limiting the use of additives (Schmid et al. 2004; Kahl et al. 2013).

- Organic food processing

  Organic food processing refers to the processing of unprocessed organic products from "primary production" according to organic principles aiming at maintaining organic food quality (see below).

- Organic food quality

  In this assessment framework the definition of organic food quality is based on Kahl et al. (2011) and Kahl et al. (Kahl et al. 2013) and the organic regulation. Organic food quality is defined through process- and product related aspects. Process-related aspects can further be described by process-related criteria coming from the concept of sustainable food production, matching the impact of production processes on the environment (soil, water, atmosphere, plants, and animals) and society (social, economic, and cultural perspectives). Product-related aspects can be further described by product related criteria, as e.g., enjoyment (sensory attributes), vital quality, organic integrity, and true nature (maintaining typical characteristics of the raw material).

  Based on the above outlined theoretical background organic food quality covers sustainability aspects (at least covering environmental aspects and where relevant also economic and social aspects), nutritional quality aspects, sensory quality aspects and in a broader perspective also consumer perception aspects.

- Organic integrity

  Organic integrity means the inherent qualities of an organic product which are obtained through adherence to organic standards at the production level, and which must be maintained from production to preparation and distribution up to the point of final sale in accordance with organic standards, for the final product to be labeled or marketed as organic.

- Organic principles

  The International Federation of Organic Agricultural Movements (IFOAM) defines the organic principles as follows (IFOAM-Organics International 2019):

  - The Principle of Health - Organic agriculture should sustain and enhance the health of soil, plant, animal and human as one and indivisible.
  - The Principle of Ecology - Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them with the help of it.
  - The Principle of Fairness - Organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.
  - The Principle of Care - Organic agriculture should be managed in a precautionary and responsible manner to protect the health and wellbeing of current and future generations and the environment.

  The organic regulation 2018/848 sets specific principles for processed food:

  The production of processed organic food shall be based on the following specific principles:

  - (a) the production of organic food from organic agricultural ingredients;
  - (b) the restriction of the use of food additives, of non-organic ingredients with mainly technological and sensory functions, and of micronutrients and processing aids, so that they are used to a minimum extent and only in cases of essential technological need or for particular nutritional purposes;
  - (c) the exclusion of substances and processing methods that might be misleading as regards the true nature of the product;
  - (d) the processing of organic food with care, preferably through the use of biological, mechanical and physical methods;
  - (e) the exclusion of food containing, or consisting of, engineered nanomaterials.

- Parameter

  A measurable variable whose value determines the characteristics of an indicator. E.g., sensory profiles and its analyses can be the parameter and method to describe the indicator sensory attributes describing the criteria enjoyment.

- Processing

  As defined in article 2 EU Reg. 852/2004: "processing" means any action that substantially alters the initial product, including heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes.

- Processing aids

  As defined by Article 3 (2) b) of regulation 1333/2008:

  - (b) 'processing aid' shall mean any substance which:
    - (i) is not consumed as a food by itself;
    - (ii) is intentionally used in the processing of raw materials, foods or their ingredients, to fulfill a certain technological purpose during treatment or processing; and
    - (iii) may result in the unintentional but technically unavoidable presence in the final product of residues of the substance or its derivatives provided they do not present any health risk and do not have any technological effect on the final product.

- Processing technology

  Processing technology means the overall process of food processing including ingredients, additives and processing aids used, processing methods and packaging systems applied.

4. General principles of assessment process

For an assessment of organic food quality as affected by processing technologies (including ingredients, additives, and processing aids) to be effective, an organization should at all levels comply with the general principles below:

1. The assessment is based on the best available information.
2. The assessment is part of decision making.
3. Trade-offs between different aspects need to be made transparent.
4. The assessment is tailored to a specific case.
5. The assessment is dynamic, iterative, and responsive to change.
6. The assessment facilitates continual improvement of organic food processing.
7. The assessment is integrated in a company's management system.

5. Assessment Framework for Evaluation of Organic Food Quality

5.1 General

The assessment framework provides the foundations and arrangements to evaluate organic food quality of existing and new processed organic food products. The focus of the assessment is on changes in food technology including recipe, raw materials, additives, processing aids and the application of (new) processing methods. Furthermore, the evaluation – where relevant – may also include storage, transportation and packaging related to the food product of concern.

The framework ensures that the minimum required information about organic food processing is adequately generated and assessed. In order to come to a conclusion and support decision-making on a processed organic food product being in line with the organic food quality, the framework details the necessary benchmarking process that allows to compare the processed organic food product with existing alternatives. This section describes the necessary components of the framework for assessing and evaluating whether organic food processing meets organic food quality. Further, the section shows how the components of the assessment framework interrelate in an iterative manner (see Fig. 2).

5.2 Assessment process

Case definition

The assessment of organic food processing is always case-specific and, therefore, the assessment process needs to be tailored to the different parts making up a case (Fig. 1):

1. organisation's internal and external context;
2. processed food product;
3. recipe defining the processing purpose and processing steps;
4. processing technology used.

Aspects defining organic food quality to be integrated in the assessment

Based on the conceptual work of Kahl et al (2011; 2013) organic food quality is defined through specific aspects and criteria. For the assessment of organic food processing the following three aspects, which define organic food quality, are considered (see also Fig. 1):

1. Sustainability aspects, generally differentiating environmental, social, and economic sustainability. However, during the assessment process (see Chapter 5.3.2) the focus is on environmental and social sustainability only. Economic sustainability is integrated after the assessment as part of the overall evaluation of a case (see Chapter 5.3.3);

2. Nutritional quality aspects;
3. Sensory quality aspects.

In the context of organic food processing a pivotal underlying principle of organic food quality is naturalness (Kahl et al. 2011). Understanding naturalness on the processing level leads to the preservation of the natural properties of the raw materials through processing and limiting the use of additives. Even though organic food quality can be sufficiently defined by the three above mentioned aspects, naturalness should be addressed explicitly in the evaluation process as this is an explicit underlying principle of organic quality not covered by the three aspects directly (Kahl et al. 2011). Therefore, after a new technology is assessed along the three aspects (see Chapter 5.3.2) the result needs to be evaluated against naturalness. This is done towards the end of the whole evaluation during the evaluation step (see Chapter 5.3.3).

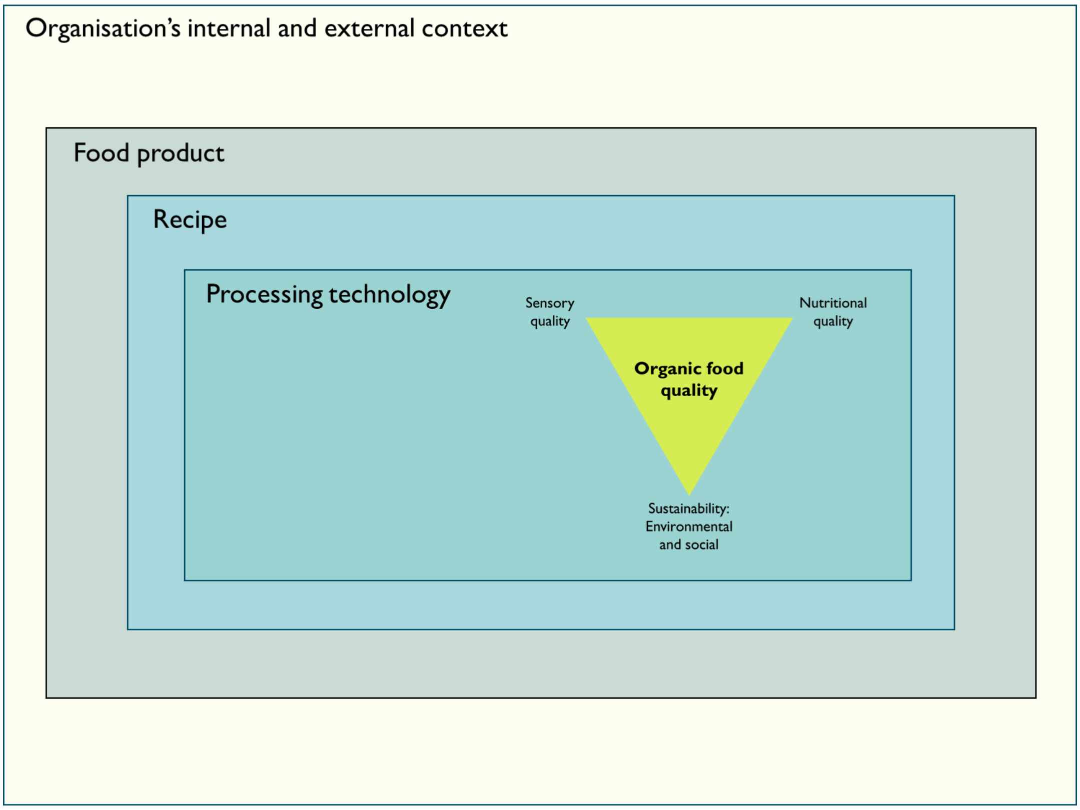


Figure 1. Parts making up a case: If a processor (organisation) wants to evaluate organic food quality it usually starts with a specific food product, which is defined through a recipe. The recipe further defines the processing technology. All these parts of a case are relevant for tailoring the assessment.

When evaluating organic food quality for a specific case of organic food processing it needs to be analysed how and to what extend the above listed aspects are affected through processing in order to tailor the assessment to the case (see assessment steps, Chapter 5.3).

Besides environmental and social sustainability, as well as nutritional and sensory quality, the overall evaluation of organic food quality also requires accounting for consumer perception and economic sustainability. However, in contrast to the former aspects consumer perception and economic sustainability are not at the core of organic food quality as they do not evolve intrinsically from organic processing but are determined primarily by external factors, i.e. the consumers and the markets. Therefore, they are not included within the assessment process of the processing technology (Chapter 5.3.2) but considered after the assessment for the overall evaluation of organic food quality (see Chapter 5.3.3).

Criteria

Within the "sustainability" aspect criteria need to be identified separately for environmental and social issues as well as later for economic issues during the overall evaluation. Examples of criteria covering environmental issues are resource use, environmental pollution, or toxicity. Examples of criteria covering social issues are child labour and working conditions during the agricultural production of raw materials as well as working conditions during processing. Economic sustainability in the context of a food processor is primarily restricted to criteria related to business-management issues.

For the aspects "nutritional quality" and "sensory quality" criteria are identified based on the common definition of nutritional and sensory quality respectively. Examples of criteria within the nutritional quality aspect are presence of nutrients or nutrient density or nutritional value. Criteria within the sensory quality aspect cover for example enjoyment. The criteria within the nutritional and sensory quality aspects potentially indicate the distinction between the raw material and the processed product in its main nutritional and sensory characteristic. Therefore, criteria within these two aspects may be suited as a proxy to analyse whether the principle of naturalness is still met in the context of a processed organic product.

Indicators and parameters

Once the relevant set of criteria for each aspect of a specific case is determined, indicators for each criterion and measurable parameters for each indicator need to be defined. A criterion may include several indicators (e.g., the criterion "Toxicity" includes indicators "Human toxicity", "Terrestrial eco-toxicity", "Freshwater eco-toxicity" and "Marine eco-toxicity", see Annex I, Tab. A1). Depending on the case, not all indicators of a criterion may be relevant.

Further, depending on the processing technology and the product being evaluated, the indicators need to be adjusted. For example, the indicator "protein denaturation" to evaluate the criterion “nutritional value” can be useful for milk and milk products. In addition, it also provides information on “naturalness”. However, protein denaturation would not be relevant in the context of fruit juices.

Table 1 lists examples for indicators and parameters for the criterion “nutritional value” within the nutritional quality aspect. In Table A1 (Annex I) for each aspect of organic food quality examples of criteria and the corresponding indicators and parameters are specified. It is important to note that when two or more processing technologies to process an organic product are compared the same indicators and parameters must be used.

Table 1. Examples of indicators and parameters for the criterion “nutritional value”.

Indicators	**Parameters**
Protein Fat, saturated and unsaturated fatty acids Carbohydrates / sugars Salt Vitamins Minerals and trace elements Fiber Antioxidants / phytochemicals Quality-reducing substances (contaminants, microbiological load)	Content in g or mg/100 g food product (depending on substance in mg/ppm…./100 g)
Protein denaturation	β-lactoglobulin in ml/l milk

5.3 Steps of the assessment process for evaluating organic food quality

The core assessment process for evaluating organic food quality consists of the parts “Establishing the context”, “Assessment” and “Evaluation” (Fig. 2). It is an iterative process that needs to be responsive to changes in the processing of an organic food product (i.e., changes in recipe). Therefore, a periodic monitoring of the parts of the core assessment process should take place, which can be integrated in an organisation’s existing management processes.

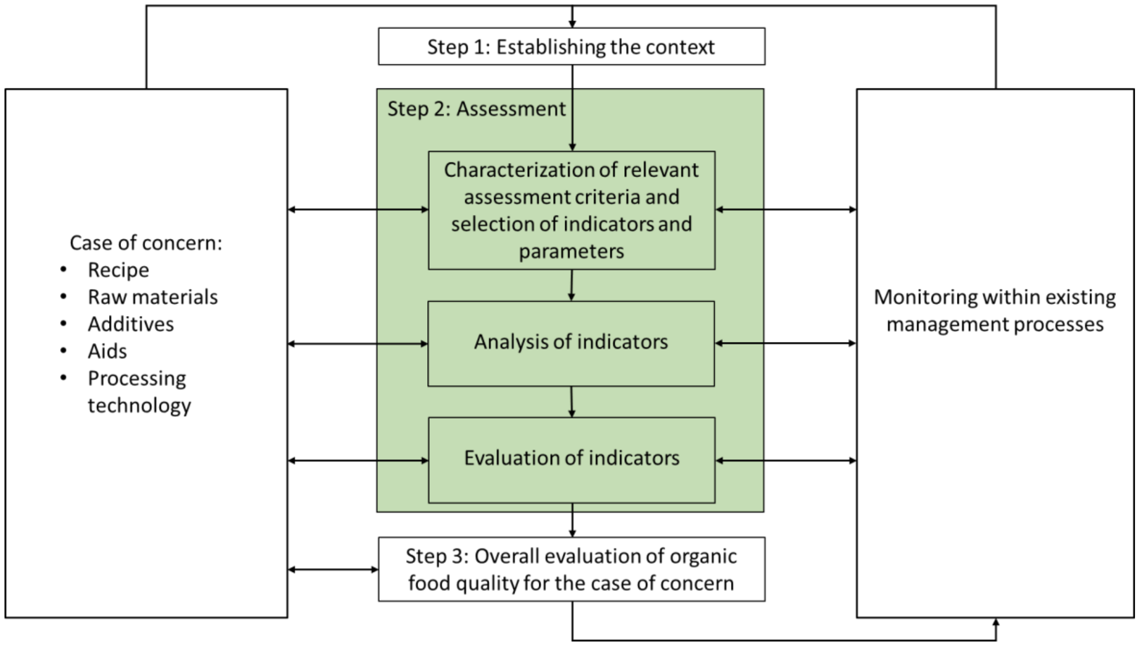


Figure 2. Assessment process of food processing for evaluating organic food quality.

5.3.1 Step 1. Establishing the context

Establishing the context involves the acquisition of a profound system understanding of the case for which organic food processing needs to be assessed. Here the importance of the different aspects within the case is identified and the system boundaries for the assessment are defined. Overall, this step is the basis for the tailored assessment.

Substep 1.1: System understanding of the case of concern

The individual processing steps involved in a case including all inputs (raw materials, intermediate products, and energy) and outputs (intermediate and/or final products) need to be listed and the different processing steps need to be made explicit (Fig. 3) including the identification of the reference raw materials involved, which are relevant for the "naturalness" check. Further it needs also to be checked if the case of concern is in line with the organic regulation. Typically, the information necessary to describe the case of concern needs to be provided by the respective experts. Information compiled within Substep 1.1 is the prerequisite for establishing the context across Sep 1.

Substep 1.2: Preliminary criteria relevance check

In a preliminary relevance identification process, it is (qualitatively) assessed how and to what extent criteria within the different aspects of organic food quality (sustainability, nutritional quality, sensory quality) are affected within each processing step but also during raw material production outside the organization. The purpose of this is to identify potentially relevant elements in the organic food processing of a specific case that may need to be assessed further in detail and to identify the questions to be answered in the following steps in order to evaluate organic food quality. This preliminary criteria relevance check sets the basis for the selection of criteria, indicators, and parameters in Step 2. In case an analysis of naturalness is intended, already at this stage the indicators within the nutritional and sensory quality aspect, which have been identified as potentially relevant, should be checked for their suitability to analyse the naturalness of the processed organic product.

Substep 1.3: System boundary setting for the evaluation of organic food quality for the case of concern

When it is clear for the case of concern where and to what extent (qualitatively) in the whole production process the different criteria are affected and the questions to be answered by the assessment are clearly defined, the system boundaries to be considered throughout the further assessment steps can be drawn. In case previously identified elements (Substep 1.2) lie outside of the drawn system boundary this needs to be made transparent and justified.

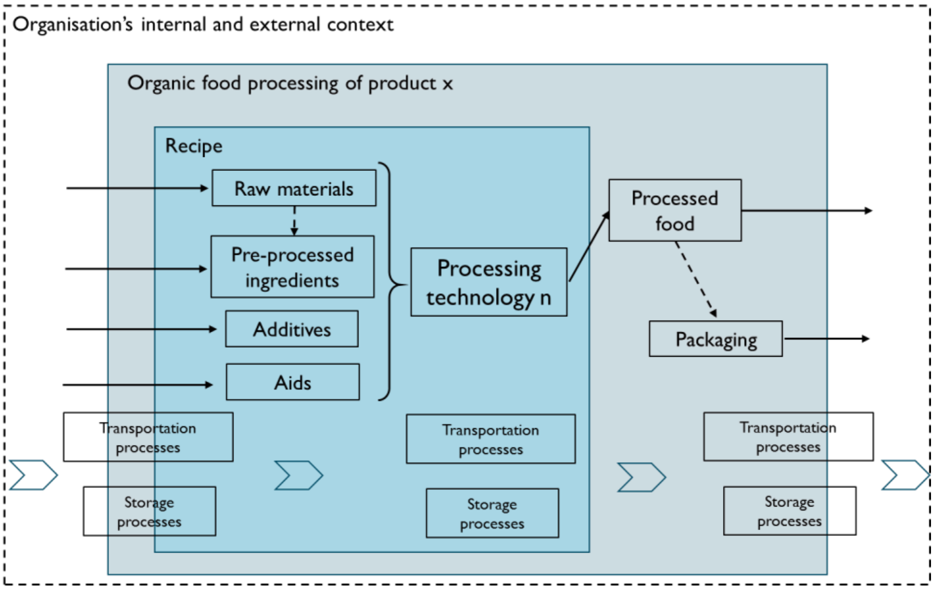


Figure 3. Food processing elements: System understanding as prerequisite for system boundary setting.

5.3.2 Step 2. Assessment

Substep 2.1: Detailed characterization of criteria and selection of indicators and parameters relevant for the case of concern

First, the criteria identified to be potentially relevant within the chosen system boundary for the case of concern from Step 1 are characterized in detail in order to confirm or reject their relevance in the given case. Further, if with the ongoing examination of the case additional criteria become apparent that were not identified within Step 1, they are included within this substep.

Second, for the relevant criteria suitable indicators are identified. As a criterion may cover several different issues or may be described from different angels, several indicators per criterion may exist (e.g., within the aspect environmental sustainability the criterion “Toxicity” covers human toxicity and eco-toxicity with separate indicators for each, see Tab. A1 in Annex I). Therefore, in this substep it needs to be decided which indicators and associated parameters to include to sufficiently describe the relevant criteria within each aspect. When selecting the indicators for criteria within the nutritional and sensory quality aspects attention should be given to indicators that also describe characteristics that are suited as proxy to describe naturalness when the processed food is compared with its raw materials. Table A1 in Annex I provides a list of indicators and parameters for different criteria within each aspect. However, the table is not exhaustive and may need to be adapted and/or completed for a specific case.

Substep 2.2: Analysis of the relevant indicators

Once the relevant indicators and the corresponding parameters have been chosen, indicators are quantified individually. Preferably, indicators allow for a quantitative assessment using measurable parameters. However, within an aspect there may be criteria that can only be qualitatively assessed (e.g., within the aspect social sustainability the criterion “Job satisfaction” of the manufacturers of an organic food product). In this case, a semi-quantitative approach should be taken by scoring the possible qualitative answers of an indicator on a quantitative scale.

Substep 2.3: Evaluation of indicators analysed by comparison with alternative processing and with raw materials

Upon quantification of the indicators for each criterion the individual indicator values need to be benchmarked in order to evaluate whether organic food processing is in line with organic food quality for the criteria of concern. However, absolute benchmarks usually do not exist. Therefore, benchmarking requires an analogous assessment of the same or a similar food product obtained by one or several existing (organic) processing technologies using the same criteria, indicators, and parameters as for the food product obtained by the new processing technology. If no comparable processed food product exists, the new case is compared with its raw materials or intermediate products.

Benchmarking the case with its raw materials using the indicators within the nutritional and sensory quality aspects may also be used as a proxy to evaluate naturalness.

The benchmarking allows to evaluate for which indicators the new or further developed technology is superior to existing technologies. The evaluation of each individual indicator from Substep 2.3 is the basis for the overall evaluation in Step 3.

5.3.3 Step 3. Overall evaluation of organic food quality

Once the individual criteria are assessed for a specific product, they must be weighted for the overall evaluation on organic food quality. Based on this overall evaluation a decision can be taken.

In contrast to the characterisation and analysis of criteria, which is an objective process (i.e., Step 2) the weighting used to calculate the overall score is a subjective process. One needs to be aware that using different weighting factors may change the overall result and in consequence the decision taken. Therefore, it is important that the applied weighting scheme is made transparent and justified.

In the evaluation process presented here weighting is necessary on three different levels, which are of different importance within the whole evaluation process:

1. Weighting of indicators if two or more are used within a criterion.
2. Weighting of the different criteria within an aspect.
3. Weighting of the three aspects describing organic food quality.

The weighting of indicators and criteria is less problematic, as it is context specific and can usually be carried out within an organisation in an internal process or by involving a narrow circle of stakeholders of an organisation's external context. In contrast, the weighting of the aspects describing organic food quality is something that should be based on a broad consensus of a wide range of stakeholders within the organic sector. The weighting of the aspects is not something that should be adapted to a specific context as this would weaken the concept of organic food quality. Methodologically, a broad stakeholder process for the weighting of the aspects could be supported by a multi-criteria decision analysis – MCDA (Department for Communities and Local Government 2009).

Substep 3.1: Weighting of indicators and aggregating to criterion level

If a criterion is described by more than one indicator, first, weighting of the individual indicators within this criterion is necessary to express how strong each indicator contributes to the value of the respective criterion. A proposal for a weighting scheme for those criteria described by more than one indicator is given within the case example in Annex II.

Second, as different indicators are usually measured on different scales and expressed by different units the indicator values need to be standardized to normalized dimensionless scores e.g., between 0 and 100. The benchmark of each indicator derived in Step 2 can be taken to set the upper limit of the score range. For practical reasons the scores from 0 to 100 can be transferred to a rating scale of e.g., in its simplest form a three-point scale from -1 to +1 with 0 representing the benchmark (e.g., existing organic processing technology). This way it becomes comprehensible when an indicator value of the new processing technology is superior or worse compared to the existing technology. Though, it is necessary to make transparent, how the score values distribute over the scale range. A detailed procedure on how to standardize indicator values is described in the case example in Annex II.

Once indicator values are standardized, criteria characterized by more than one indicator are quantified by multiplying the weighting factor of each indicator with the indicator score / scale value and then summing the weighted scores of the indicators.

Substep 3.2: Weighting of the different criteria and aggregating the criteria scores to aspect score

As different criteria do not necessarily contribute to the same extent to an aspect and, in a wider sense, to the goals of organic food quality, criteria must be weighted before the aspect score can be calculated that results from all its criteria scores (in the case example in Annex II equal weighting for the different criteria within the respective aspects was assumed). The score of an aspect is derived by multiplying the weighting factor of each criterion with the criteria score and then summing the weighted criteria scores.

Furthermore, criteria within the nutritional and sensory quality aspects are additionally aggregated to a separate score of the respective aspect to be used as a proxy for naturalness. This is done by multiplying the weighting factor of those criteria expressing characteristics of naturalness within each aspect with the respective criteria score and then summing the weighted criteria scores.

Substep 3.3: Weighting of aspects and aggregating aspect scores to overall score for organic food quality and to naturalness score

Ideally, the weighting of the sustainability, nutritional and sensory quality aspects is based on a broad consensus among the stakeholders of the organic sector. Such a consensus can then be used throughout all evaluations of processing technologies and food products. A consensus on the weighting factors for the aspects can be obtained through a stakeholder process.

Once a consensus exists, it is recommended to use these proposed weighting factors for the three aspects. If different weighting factors are used in an evaluation this should be made transparent and justified.

The overall score of a case is derived by multiplying the weighting factors of each aspect with the aspect score and then summing the weighted aspect scores.

For the overall score used as proxy for naturalness the scores for the nutritional and sensory quality aspects are multiplied with the respective weighting factors of these two aspects and then summed.

Substep 3.4: Benchmarking the overall score for organic food quality and the naturalness score

The overall score of a product obtained by a new processing technology needs to be compared with the overall score of the same or a similar product obtained by existing processing technologies. The difference in scores between the products obtained by new and existing processing technology needs to be benchmarked with the maximum difference set for organic food quality. Such a maximum difference in scores needs to be set by a broad consensus among the stakeholders of the organic sector and needs to be re-evaluated periodically.

The separate overall score describing naturalness needs to be compared with the respective score of the raw materials. Analogously, the difference in the naturalness scores between new processing technology and raw materials needs to be benchmarked with the maximum difference set for naturalness. Also, this maximum difference in scores needs to be set by a broad consensus among the stakeholders of the organic sector and needs to be re-evaluated periodically.

If there is no same or similar product obtained by an existing processing technology to compare a new product it is still possible to compare with the overall score of the raw material(s).

Substep 3.5: Including further aspects for decision making

Beyond the scoring of organic food quality, there are further aspects that may need to be integrated into the final decision-making process. Especially, consumer perception plays an important role for the success on the market of a new processing technology. It needs to be clarified if consumers will have a specific perception towards the case of concern and if so if this is positive or negative in order to judge the market opportunity. Consumer perception also relates to economic sustainability of a new food product, which needs to be evaluated within the final decision-making process.

Substep 3.6: Decision on the case of concern to be in line with organic food quality

If all the above points are sufficiently elucidated the final decision on the case of concern to be in line with organic food quality can be taken.

6. Recording the assessment process

Assessment activities for organic food processing should be traceable. In the evaluation process, records provide the foundation for improvement in methods and tools, as well as in the overall process.

Decisions concerning the creation of records should take into account the following:

- the organization's needs for continuous learning;
- benefits of re-using information for future evaluation purposes;
- costs and efforts involved in creating and maintaining records;
- legal, regulatory and operational needs for records;
- method of access, ease of retrievability and storage media;
- retention period; and
- sensitivity of information.

7. How to deal with data uncertainty?

Assessments do not represent accurate science and are always characterized by uncertainties on different levels, e.g., due to missing data, poor data quality, and/or limited transferability of available data to a specific case. Generally, the availability of sufficient reliable information to make robust evaluations is a challenge in almost any assessment leading to some level of uncertainty in the assessment result. As it is impossible to define a minimal level of certainty to be achieved in assessments in general to guaranty reliable results, the level of quality of an assessment result depends on many factors that may differ from case to case.

As the main purpose of the assessment process outlined in the Assessment Framework is to provide decision support on organic food quality, a certain range of uncertainty is tolerable. In the end it is a question on how to deal with uncertainty in the assessment to still allow for a reliable assessment result. Therefore, dealing with uncertainty in data quality is an integral part of assessments and the evaluations drawn up on them. It is important to understand what the implications of poor data availability and quality are for the assessment result.

For people dealing with assessments the first time, it is not easy to understand and anticipate the implications of data uncertainty on the assessment result. However, the necessary understanding will mostly grow by experience. Therefore, for all those that are not familiar with assessments and want to apply the procedure described in this Assessment Framework, it is recommended to consult assessment experts the first few times carrying out the assessment.

Sometimes it is possible to base parts of an assessment on a single or a few studies only, which is problematic because the few studies are not necessarily representative for a specific case. While of course it is risky to consider results from a limited number of studies only, it is, therefore, important to consider uncertainty in the underlying data in the assessment result and make transparent that the evaluation is based on a limited data base. Contrasting the assessment-based evaluation with an additional expert judgement is always recommended.

Further, data uncertainty is best being tackled in an uncertainty analysis by expressing parameter values as a range reflecting the variability in the underlying data. Even though the variability is often not known, different ranges of ±20, 30 or even 50% of an uncertain parameter value can be assumed and the assessment result generated. Considering these value ranges in the assessment will show at what level of uncertainty the assessment result will lead to a different conclusion. It is then up to expert judgment to evaluate whether an assumed uncertainty level is still acceptable in the context of a given evaluation. A general rule of thumb is the higher the uncertainty level leading to an opposite assessment result the more robust the assessment even under limited data availability and/or quality.

Even though assessments based on limited data availability and/or quality lead to results that need to be treated with caution, one needs to be aware of the alternative. Assessments support decision making. If decisions are made without considering the underlying criteria and cause-effect-relationships, they are often arbitrary. Therefore, an evaluation based on a structured assessment process as outlined in this Assessment Framework is still the better choice to support decision making even in situations of poor data quality than relying decisions on gut feeling. In that sense the proposed assessment process harmonises the evaluation process, supports transparency, and enhances system understanding.

8. References

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Annex I – Examples of criteria, indicators and parameters

Table AI-1. Criteria and Indicators for the different aspects of organic food quality.

Aspect	Criterion	Indicator	Parameter[1]	Remarks
Sustainability[1] - environmental	Energy use: Reduction of non-renewable energy sources	Non-renewable energy demand	MJ/unit	
	Water use: Reduction of fresh water resources	Fresh water use	m^3/unit	
	Land use: Reduction in land use and land degradation	Land use (total)	$m^2 * a^{-1}$/unit	Relevant only if agricultural production is within system boundaries.
		Industrial land use	$m^2 * a^{-1}$/unit	
		Arable land use	$m^2 * a^{-1}$/unit	Relevant only if agricultural production is within system boundaries.
		Permanent grassland use	$m^2 * a^{-1}$/unit	Relevant only if agricultural production is within system boundaries.
		Erosion	kg * a^{-1}/unit	Relevant only if agricultural production is within system boundaries.

[1] For more information on sustainability indicators specifically in food and agricultural systems see: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiatO-0mof0AhV_i_0HHXhVBRgQFnoECAYQAQ&url=http%3A%2F%2Fwww.fao.org%2F3%2Fi4113e%2Fi4113e.pdf&usg=AOvVaw2_5bQpW-YhB3QSy-GPFozz

Aspect	Criterion	Indicator	Parameter[1]	Remarks
Sustainability - environmental	Land use change	Deforestation	m^2/unit	Relevant only if agricultural production is within system boundaries.
		Agricultural to industrial	m^2/unit	
		(semi-)Natural to industrial	m^2/unit	Forests or other (semi-)natural habitats. Relevant only if agricultural production is within system boundaries.
		Permanent grassland to cropland	m^2/unit	Relevant only if agricultural production is within system boundaries.
		Peat soil to cropland	m^2/unit	Relevant only if agricultural production is within system boundaries.
	Biodiversity	Species loss potential	SLP/unit	Relevant only if agricultural production is within system boundaries.
		Landscape intactness	m_2 SNH * km^2/unit	Relevant only if agricultural production is within system boundaries.

Aspect	Criterion	Indicator	Parameter[1]	Remarks
Sustainability - environmental	Mineral use	P use	kg/unit	Relevant only if agricultural production is within system boundaries.
		K use	kg/unit	Relevant only if agricultural production is within system boundaries.
	Marine resource use	By-catch	kg/unit	Relevant only if fishery is within system boundaries.
		Disturbance of marine environment	m^2/unit	Relevant only if fishery is within system boundaries.
	Atmospheric resource use/pollution	Ozone depletion	kg CFC-11-eq./unit	
		Photochemical ozone formation	kg NMVOC-eq./unit	
	Atmospheric resource use/pollution	Particulate matter	kg PM2.5-eq./unit	Mostly relevant if agricultural production is within system boundaries.
	Climate change	Global warming potential	kg CO_2-eq./unit	

Aspect	Criterion	Indicator	Parameter[1]	Remarks
Sustainability - environmental	Toxicity	Human toxicity, non-cancer effects	cases/unit	Mostly relevant if agricultural production is within system boundaries.
		Human toxicity, cancer effects	cases/unit	Mostly relevant if agricultural production is within system boundaries.
		Freshwater eco-toxicity	PAF.m3.day/unit	Mostly relevant if agricultural production is within system boundaries.
		Marine eco-toxicity	kg 1,4-DB-eq./unit	Mostly relevant if agricultural production is within system boundaries.
		Terrestrial eco-toxicity	kg 1,4-DB-eq./unit	Mostly relevant if agricultural production is within system boundaries.
	Eutrophication	Terrestrial eutrophication	molc N-eq./unit	Relevant only if agricultural production is within system boundaries.
		Freshwater eutrophication	kg P-eq./unit	Relevant only if agricultural production is within system boundaries.
		Marine eutrophication	kg N-eq./unit	Relevant only if agricultural production is within system boundaries.

Aspect	Criterion	Indicator	Parameter[1]	Remarks
Sustainability - environmental	Other environmental impacts	Acidification	molc H+-eq./unit	Relevant only if agricultural production is within system boundaries.
		Ionizing radiation	kBq U235-eq./unit	
Sustainability - social	Fair trading practices	Fair pricing and transparent contracts		Qualitative assessment through interviews
		Rights of suppliers		Qualitative assessment through interviews
	Decent livelihood	Quality of life		Qualitative assessment through interviews
		Wage level	% of employees paid a living wage	
		Capacity development		Qualitative assessment through interviews
		Fair access to means of production		Qualitative assessment through interviews

Aspect	Criterion	Indicator	Parameter[1]	Remarks
Sustainability - social	Labour rights	Employment relations		Qualitative assessment through interviews
		Forced labour		Qualitative assessment through interviews
		Child labour		Qualitative assessment through interviews
		Freedom of association and right to bargaining		Qualitative assessment through interviews
	Equity	Non discrimination		Qualitative assessment through interviews
		Gender equality		Qualitative assessment through interviews
		Support to vulnerable people		Qualitative assessment through interviews

Aspect	Criterion	Indicator	Parameter[1]	Remarks
Sustainability - social	Human safety and health	Workplace safety and health provisions		Qualitative assessment through interviews
		Health coverage and access to medical care		Qualitative assessment through interviews
		Public health: Measures to avoid pollution and contamination		Qualitative assessment through interviews
	Cultural diversity	Indigenous knowledge		Qualitative assessment through interviews
		Food sovereignty		Qualitative assessment through interviews

Aspect	Criterion	Indicator	Parameter[1]	Remarks
Nutritional quality	Concentration of macronutrients	Carbohydrates [2]	g/100g	
		Fiber	g/100g	
		Proteins	g/100g	
		Fats, saturated and unsaturated fatty acids	g/100g	
	Concentration of micronutrients	Minerals	g or mg/100g	
		Vitamins	µg or mg/100g	
		Trace elements	µg or mg/100g	
	Concentration of phytochemicals	Total flavonoids	mg/100g	
		Polyphenols	mg/100g	

[2] Depending on the technology or product under assessment, a more detailed look for the subgroups of all nutrients like carbohydrates, proteins, fat, fibers, vitamins and minerals is recommended.

Aspect	Criterion	Indicator	Parameter[1]	Remarks
Nutritional quality	Antioxidant evaluation	Antioxidant activity	µM Trolox/L	
	Microbiological quality	Microbial load	Log CFU/g or ml	
		Toxic organisms[3]		
	Other nutritional compounds	pH	pH	
		Total soluble solids	Brix	Useful in the context of juice.
	Inner quality	Vital quality	E.g., Cu chloride crystallization	
		Holistic quality	Fluorescence excitation spectroscopy	

[3] The type of relevant microorganism depends on the technology or product under assessment.

Aspect	Criterion	Indicator	Parameter[1]	Remarks
Nutritional quality	Presence of contaminants	Constituents of toxic relevance	For example: - Phytase	
		Process contaminants	For example: – Acrylamide	
		Outside contaminants	For example: – Biocide – Environmental contaminates	

Aspect	**Criterion**	**Indicator**	**Parameter**[1]	**Remarks**
Sensory quality	Enjoyment	Taste	Sensory profile analysis	
		Odour	Sensory profile analysis	
		Aroma profile	Sensory profile analysis	Gas chromatography (GC), high performance liquid chromatography (HPLC)
		Colour intensity	chroma index	
		Texture and haptics	Sensory profile analysis	

[1] The parameter unit may vary as it depends on the assessment method used.

Annex II – Case example

Please note:
The following case example is for illustrating purposes only. It does not represent an in-depth assessment of the chosen case.

Evaluation of high-pressure pasteurization in organic apple juice production

Introduction

The processing of organic apple juice through high-pressure pasteurization (HPP) is used as case to illustrate the application of the Assessment Framework for the Evaluation of Organic Food Processing by following the step-by-step procedure described therein. To evaluate whether HPP used as processing technology to produce organic apple juice is in line with organic food quality, thermal pasteurisation (TP) of apple juice is used as benchmark within Step 2 of the assessment process.

To specifically evaluate the naturalness of the juice pasteurised by HPP a comparison with the raw material (i.e., raw apple or untreated pure apple juice) is needed. These comparisons allow to evaluate whether high pressure pasteurisation is superior to existing technologies for the indicators considered while still fulfilling the requirements for naturalness.

The purpose of the example is to illustrate the mode of operation of the assessment process from Step 1 to 3, up to Substep 3.3 as described in the Assessment Framework for the Evaluation of Organic Food Processing. As Substeps 3.4 to 3.6 are important for the overall decision but not part of the assessment process they were excluded in this example. Further, as for this case example many assumptions were taken arbitrarily (e.g., regarding the different weighting factors) the result cannot be taken for a real evaluation of HPP treated organic juice.

Step 1. Establishing the context

Substep 1.1 System understanding

Two processing technologies are compared to produce organic apple juice:

1. High pressure pasteurisation (HPP) at a pressure of 400 MPa as the new processing technology to be evaluated in the context of organic food quality.

2. Thermal pasteurisation at 82-90 °C for 15-150 seconds on a plate heat exchanger as the benchmark representing the existing technology to produce organic apple juice.

The technical frame in this case is rather simple: The pressing of the pure apple juice and the packaging (bottling) are assumed to be the same for both pasteurisation processing technologies (Figure AII-1). In terms of ingredients used or processing aids there are no differences between the two technologies in question.

Regarding the packaging solution different scenarios are possible. For example, the juice pasteurised by HPP could be packed in aseptic packaging. In this case the technical frame should include the process from pasteurisation to packaging.

As reference raw material to evaluate naturalness either are raw, unprocessed apples or untreated pure apple juice could be used. As literature values for the relevant indicators were found for untreated apple juice this was taken as reference to check for naturalness.

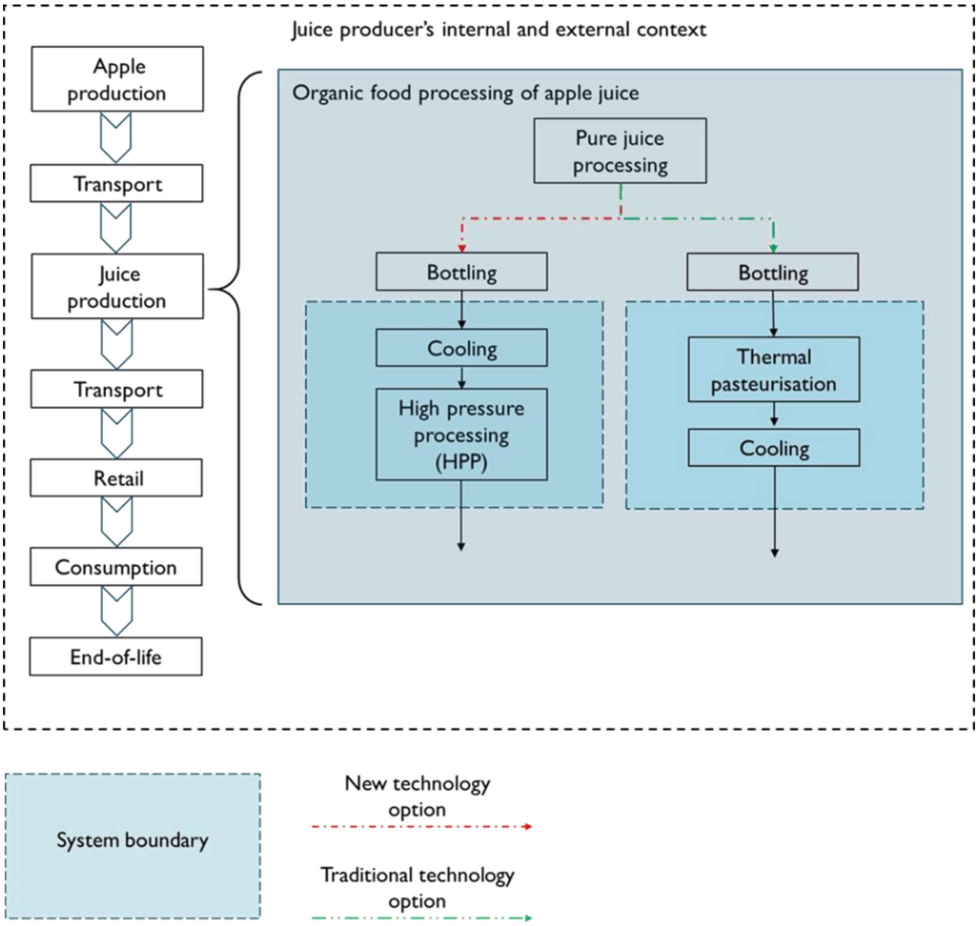

Figure AII-1. System boundaries of the case and the benchmark.

Substep 1.2: Preliminary criteria relevance check

Regarding environmental sustainability it can be expected that HPP has an influence on the criterion "energy use" within the pasteurisation process and, therefore, also on the criterion "climate change". Regarding social sustainability, respective criteria may be neglected as social aspects in the agricultural production of the raw material (apples) are of minor relevance and the new pasteurisation technology is not expected to have a major influence on the working conditions.

Regarding the aspect of nutritional quality changes can be expected for the criteria "concentration of micronutrients", "concentration of phytochemicals", as well as for "other nutritional compounds".

Regarding the aspect of sensory quality changes can be expected for the criterion "enjoyment".

Regarding the analysis of naturalness all indicators considered within the nutritional and sensory quality aspect are potentially suited to compare the processed juice with untreated pure juice.

Substep 1.3: System boundary setting

Based on the system understanding described above the system boundaries are set around the high-pressure pasteurisation technology, which is compared and benchmarked with thermal pasteurisation (Figure AII-1). Pure juice processing is the same for both pasteurisation technologies, therefore, in this case it is outside the system boundaries. Juice will be packed in bottles before the pasteurisation process. Therefore, it is not necessary to evaluate packaging. If for the thermal pasteurisation the packaging process was after the thermal treatment than packaging would need to be evaluate as well because it would be a different process.

Step 2. Assessment

Substep 2.1 Detailed characterisation of relevant criteria and selection of indicators and parameters for the relevant criteria

Regarding the sustainability aspect, for the environmental dimension a life cycle assessment (LCA) study comparing different pasteurisation technologies revealed that HPP and thermal pasteurisation contribute most to energy use, climate change and water use (Pardo & Zufia, 2012)[4]. Energy use and climate change were already identified within Substep 1.2 and water use was identified as additional criteria within this substep. Therefore, these three criteria are selected as the most relevant ones for the assessment of the sustainability aspect. Indicators selected to describe the criteria were chosen from the list in Annex I and are shown in Figure AII-2.

Based on a study on nutritional and sensory quality concentration of micronutrients, concentration of phytochemicals, other nutritional compounds and enjoyment were identified as relevant criteria in the context of apple juice (Wibowo et.al., 2019)[5]. All these criteria within the nutritional and sensory quality aspects are also relevant for the analysis of naturalness.

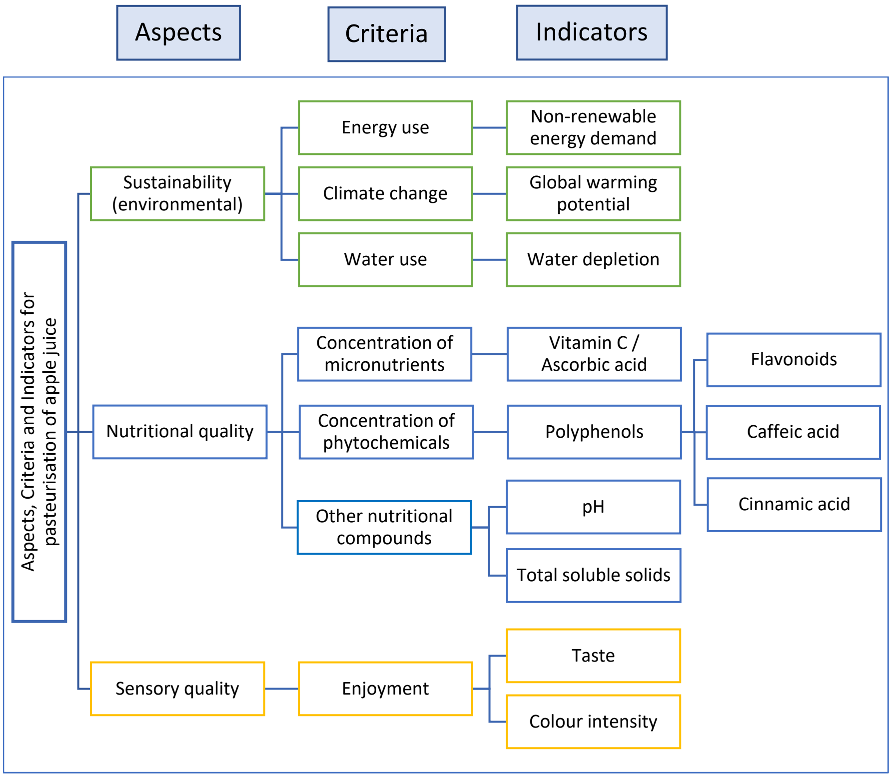

Figure AII-2. Overview of relevant criteria and possible indicators describing them for the three aspects defining organic food quality of pasteurized apple juice.

[4] Pardo, Guillermo; Zufía, Jaime (2012): Life cycle assessment of food-preservation technologies. Journal of Cleaner Production 28, 198–207.
[5] Wibowo, S.; Essel, E.A.; de Man, S. ; Bernaert, N.; van Droogenbroeck, B.; Grauwet, T. et al. (2019): Comparing the impact of high pressure, pulsed electric field and thermal pasteurization on quality attributes of cloudy apple juice using targeted and untargeted analyses. In Innovative Food Science & Emerging Technologies 54, p. 64–77.

Substep 2.2 Analysis of the relevant indicators

The study of Pardo & Zufia (2012) was carried out on a ready-to-eat meal containing fish and vegetables and not on juice. Nevertheless, from the study it was possible just to extract the parameter values to quantify the chosen indicators for the three criteria caused by the pasteurisation step only for HPP as well as for thermal pasteurisation (columns "HPP absolute value" and "TP absolute value) in Table AII-1). These values were transferred one to one to the case analysed under the assumption that the relative difference between the two pasteurisation processes is the same regardless of the food pasteurised.

The study of Wibowo et al. (2019) analysed nutritional and sensory quality of apple juice. Therefore, the study represented the case assessed. Parameter values to quantify the indicators describing nutritional and sensory quality criteria were taken one to one from Wibowo et al. (2019) (Table AII-1). The indicator "Taste" was characterised semi-quantitatively on a scale of 1 (very bad taste) to 9 (very good taste).

Table AII-1. Characterisation and analysis of relevant criteria within the three aspects for HPP and thermal pasteurisation (TP).

Aspect	Critera	Indicator	Parameter	HPP absolute value	TP absolute value
Sustainability - environmental	Energy use	Non-renewable energy demand	MJ/kg	0.088	0.185
	Climate change	Global warming potential	kg CO_2eq/kg	0.087	0.234
	Water use	Water depletion	l/kg	1.575	2.904
Nutrition quality	Concentration of micronutrients	Vitamin C	mg/100 g	9.700	1.400
	Concentration of phytochemicals	Polyphenols	mg/100 g	3.250	1.690
	Other nutritional compounds	pH	pH	3.4	3.8
		total soluble solids	Brix	13.0	12.9
Sensory quality	Enjoyment	Taste	dimensonless	7.3	6.5
		Colour intensity	chroma	34.91	32.80

Substep 2.3 Evaluation of indicators analysed by comparison with alternative processing and raw materials

Based on the parameter values compiled for HPP and thermal pasteurisation (Table AII-1), the normalisation was carried out taking thermal pasteurisation (benchmark) as the 100% basis. Therefore, the normalised value for thermal pasteurisation is set to 100

(Table AII-2). The normalised value for HPP (Table AII-2) was carried out according to the following formula:

$$HPP_{normalised\ value} = \frac{TP_{normalised\ value}}{TP_{absolute\ value}} \times HPP_{absolute\ value}$$

Table AII-2. Normalisation and rating of absolute parameter values.

Aspect	Critera	Indicator	Parameter	HPP absolute value	TP absolute value	HPP normalised value	TP normalised value	Rating	Remarks
Sustainability - environmental	Energy use	Non-renewable energy demand	MJ/kg	0.088	0.185	48	100	+1	
	Climate change	Global warming potential	kg CO_2eq/kg	0.087	0.234	37	100	+1	
	Water use	Water depletion	l/kg	1.575	2.904	54	100	+1	
Nutrition quality	Concentration of micronutrients	Vitamin C	mg/100 g	9.700	1.400	693	100	+1	
	Concentration of phytochemicals	Polyphenols	mg/100 g	3.250	1.690	192	100	+1	HPP: 75% loss / TP: 87% loss
	Other nutritional compounds	pH	pH	3.4	3.8	89	100	-1	
		total soluble solids	Brix	13.0	12.9	101	100	0	
Sensory quality	Enjoyment	Taste	dimensonless	7.3	6.5	112	100	+1	scale 1=very bad 9=very good
		Colour intensity	chroma	34.91	32.80	106	100	0	chroma/saturation index

In cases where an absolute parameter value of the benchmark is negative, and the corresponding absolute value of the case is positive than the following formula needs to be applied to calculate the normalised value for the respective parameter value of the case:

$$C_{nv} = \frac{(C_{av} - B_{av})}{|B_{av}|} \times B_{nv} + B_{nv}$$

B_{av} absolute parameter value of benchmark
B_{nv} normalised parameter value of benchmark (=100)
C_{av} absolute parameter value of case
C_{nv} normalised parameter value of case

In cases where an absolute parameter value of the case is negative, and the corresponding absolute value of the benchmark is positive than the following formula needs to be applied to calculate the normalised value for the respective parameter value of the case:

$$C_{nv} = \frac{B_{nv}}{(B_{av} - C_{av})} \div |C_{av}|$$

B_{av} absolute parameter value of benchmark
B_{nv} normalised parameter value of benchmark (=100)
C_{av} absolute parameter value of case
C_{nv} normalised parameter value of case

Finally, in cases where an absolute parameter value of the benchmark equals zero, the corresponding normalised value for the case is not defined. In such a situation, the parameter value of the case is automatically rated as better when parameter values greater than zero represent the better case and vice versa rated as worse when parameter values greater than zero represent the worse case (see below).

The rating of the normalised parameter values (Table AII-2) was carried out on a three-point scale. They were transferred based on the ranges indicated in Table AII-3 to rating scores from -1 to 1. A deviation of ±10% between the normalized values was still considered as no difference. A negative rating score represented characteristics that were worse for the respective indicator of the new technology compared to the existing technology, positive values indicate that a characteristic was better in the product processed with the new technology compared to the product processed with the existing technology. Because for environmental sustainability the lower the score range the better for the environment and for nutritional and sensory quality the higher the score range the better for these two aspects, this needs to be accounted for when attributing score ranges to the rating scale (Table AII-3).

Table AII-3. Transfer of normalized values to rated scale.

	Sustainability - environmental	**Nutritional / sensory quality**
Rating score	**Range of $HPP_{normalized\ value}$**	**Range of $HPP_{normalized\ value}$**
+1 = better	<90	>110
0 = same	>90; <110	>90; <110
-1 = worse	>110	<90

For the three indicators considered within environmental sustainability always HPP showed the lower impact compared to thermal pasteurisation (Table AII-2). Among the indicators analysed within the nutritional and sensory quality aspects only pH was less favourable for the juice processed with HPP than with thermal pasteurisation, all other indicators performed the same or better in juice treated with HPP (Table AII-2).

For the analysis of naturalness, the indicator values for HPP describing the criteria within the nutritional and sensory aspects were compared to the respective values of untreated pure juice (UPJ) (Table AII-4). Parameter values for UPJ were taken from

Wibowo et al. (2019)[6]. As in the comparison of HPP treated juice with juice processed by thermal pasteurisation, normalized scores were transferred to a three-point scale ranging from -1 to 1. According to this rating there is no difference in total soluble solids and colour intensity in the HPP treated juice compared to untreated pure juice (Table AII-4). For all other indicators used to analyse naturalness HPP treated juice performed worse than untreated juice.

Table AII-4. Naturalness check of HPP with untreated pure juice (UPJ).

Aspect	Critera	Indicator	Parameter	HPP absolute value	UPJ absoulte vlaue	HPP normalised value	UPJ normalised value	Rating	Remarks
Nutrition quality	Concentration of micronutrients	Vitamin C	mg/100 g	9.700	13.000	75	100	-1	
	Concentration of phytochemicals	Polyphenols	mg/100 g	3.250	13.000	25	100	-1	
	Other nutritional compounds	pH	pH	3.4	4.0	85	100	-1	
		Total soluble solids	Brix	13.0	13.0	100	100	0	
Sensory quality	Enjoyment	Taste	dimensonless	7.3	9.0	81	100	-1	scale 1=very bad 9=very good
		Colour intensity	chroma	34.91	32.37	108	100	0	chroma/saturation index

To classify the results of the naturalness check of HPP treated with untreated juice the analogous analysis was carried out for juice processed by thermal pasteurization (Table AII-5). In addition to total soluble solids and colour intensity also pH turned out to be the same for juice processed with thermal pasteurisation compared to untreated natural juice. All other indicators performed the same as in the naturalness check of HPP treated juice (Table AII-4).

Table AII-5. Naturalness check of thermal pasteurisation (TP) with untreated pure juice (UPJ).

Aspect	Critera	Indicator	Parameter	TP absolute value	UPJ absoulte vlaue	TP normalised value	UPJ normalised value	Rating	Remarks
Nutrition quality	Concentration of micronutrients	Vitamin C	mg/100 g	1.400	13.000	11	100	-1	
	Concentration of phytochemicals	Polyphenols	mg/100 g	1.690	13.000	13	100	-1	
	Other nutritional compounds	pH	pH	3.8	4.0	95	100	0	
		Total soluble solids	Brix	12.9	13.0	99	100	0	
Sensory quality	Enjoyment	Taste	dimensonless	6.5	9.0	72	100	-1	scale 1=very bad 9=very good
		Colour intensity	chroma	32.80	32.37	101	100	0	chroma/saturation index

[6] Wibowo, S.; Essel, E.A.; de Man, S. ; Bernaert, N.; van Droogenbroeck, B.; Grauwet, T. et al. (2019): Comparing the impact of high pressure, pulsed electric field and thermal pasteurization on quality attributes of cloudy apple juice using targeted and untargeted analyses. In Innovative Food Science & Emerging Technologies 54, p. 64–77.

Step 3 Overall evaluation of organic food quality

Substep 3.1 Weighting of indicators and aggregating to criterion level

For all criteria described by one indicator only the weighting factor for the indicator is 100%. However, within the nutritional quality aspect the criterion “Other nutritional compounds” and within the sensory quality aspect the criterion “Enjoyment” are described by two indicators each (Table AII-1). For the simplicity of this illustrative example each indicator within these two criteria was weighted with 50% (Table AII-6). The same weighting factors were used for the naturalness check (Table AII-7 and AII-8).

Substep 3.2 Weighting of criteria and aggregating to aspect level

As this example serves illustrative purposes only it was assumed that all criteria within an aspect have equal weights (Table AII-6). The rating score for each aspect was obtained by multiplying the rating score of each criterion with the criteria weighting factor and then summing the products (weighted mean, Table AII-6). For the naturalness check the same criteria weighting factors were used and the rating score for nutritional and sensory quality was calculated accordingly (Table AII-7 and AII-8).

Substep 3.3. Weighting of aspects and aggregating aspect scores to overall score for organic food quality and to naturalness score

Again, for simplicity it was assumed within this example that all aspects are equally important to describe organic food quality and, therefore, the same weighting factor was given to each aspect for the aggregation to the overall score (Table AII-6). The overall score was obtained by multiplying the rating score of each aspect by the aspect weighting factor and summing the products. Under all assumptions taken within this example, the overall score for organic food quality reached 0.67 (Table AII-6).

Table AII-6. Comparison of HPP treated apple juice with apple juice treated by thermal pasteurisation to evaluate organic food quality.

Aspect	Aspect weighting factor	Aspect rating	Criteria	Criteria weighting factor	Indicator	Indicator weighting factor	Rating Criteria
Enviromental sustainability	33%	1.000	Energy use	33%	Non-renewable energy demand	100%	+1
			Climate change	33%	Global warming potential	100%	+1
			Water use	33%	Water depletion	100%	+1
						Aspect rating	1.000
Nutrition quality	33%	0.500	Concentration of micronutrients	33%	Vitamin C	100%	+1
			Concentration of phytochemicals	33%	Polyphenols	100%	+1
			Other nutritional compounds	33%	pH	50%	-1
					Total soluble solids	50%	0
						Aspect rating	0.500
Sensory quality	33%	0.500	Enjoyment	100%	Taste	50%	+1
					Colour intensity	50%	0
						Aspect rating	0.500
Overall rating		0.67					

For calculating the score for naturalness, which is based on the nutritional and sensory quality aspect only, it was assumed that the two aspects contribute equally to naturalness resulting in a weighting factor of 50% in this case (Table AII-7 and AII-8). The overall rating was calculated in the same manner as for the score for organic food quality (see above). When checking for naturalness of HPP treated juice compared to untreated apple juice an overall score of -0.67 was obtained under all assumptions taken within this example (Table AII-7).

Table AII-7. Naturalness for HPP treated apple juice (comparison of HPP treated apple juice to untreated apple juice).

Aspect	Aspect weighting factor	Aspect rating	Criteria	Criteria weighting factor	Indicator	Indicator weighting factor	Rating Criteria
Nutrition quality	50%	-0.833	Concentration of micronutrients	33%	Vitamin C	100%	-1
			Concentration of phytochemicals	33%	Polyphenols	100%	-1
			Other nutritional compounds	33%	pH	50%	-1
					Total soluble solids	50%	0
						Aspect rating	-0.833
Sensory quality	50%	-0.500	Enjoyment	100%	Taste	50%	-1
					Colour intensity	50%	0
						Aspect rating	-0.500
Overall rating		-0.67					

For the further evaluation of the score obtained for naturalness in the comparison of HPP treated juice with untreated pure juice this was compared to the score for naturalness of juice processed with the existing technology (i.e., thermal pasteurisation). As can be seen from Table AII-8, the overall score for naturalness of juice processed by thermal pasteurisation resulted in -0.58, which is 14% better than the naturalness score of HPP treated juice compared to untreated pure juice.

Table AII-8. Naturalness for apple juice treated by thermal pasteurisation (comparison of apple juice treated by thermal pasteurisation to untreated apple juice).

Aspect	*Aspect weighting factor*	*Aspect rating*	*Criteria*	*Criteria weighting factor*	*Indicator*	*Indicator weighting factor*	*Rating Criteria*
Nutrition quality	*50%*	**-0.666**	*Concentration of micronutrients*	*33%*	*Vitamin C*	*100%*	-1
			Concentration of phytochemicals	*33%*	*Polyphenols*	*100%*	-1
			Other nutritional compounds	*33%*	*pH*	*50%*	0
					total soluble solids	*50%*	0
						Aspect rating	**-0.666**
Sensory quality	*50%*	**-0.500**	*Enjoyment*	*100%*	*Taste*	*50%*	-1
					Colour intensity	*50%*	0
						Aspect rating	**-0.500**
Overall rating		***-0.58***					

Substep 3.4 Benchmarking the overall score for organic food quality and the naturalness score

The way the rating scale and weighting was defined within this example the overall score of organic food quality for HPP treated juice may range from -1 to +1. An overall score of -1 would be reached if HPP treated juice performed worse than thermal treated juice for all indicators considered. In contrast, an overall score of +1 would be reached if HPP treated juice performed better than thermal treated juice for all indicators considered. If no differences between HPP and thermal treated juice for the indicators considered were found, the overall score would result in zero. Therefore, with a positive value of 0.67 in the overall score (Table AII-6), organic food quality for the HPP treated juice seems to be considerably better than for thermal treated juice.

In contrast, the characteristics of naturalness of HPP treated juice were 0.67 score points worse (Table AII-7) than in the raw material (i.e., untreated pure juice). Also, the characteristics of naturalness of juice processed with thermal pasteurisation was worse than for untreaded pure juice. However, with -0.58 score points (Table AII-8) characteristics of naturalness of thermal treated juice was slightly better than of HPP treated juice.

Considering only the results from the comparison between HPP and thermal treated juice (Table AII-6) one could conclude that organic food quality is higher for the HPP treated juice. However, when also considering the characteristics of naturalness, the picture is not clear. Since the difference in characteristics of naturalness between the two treatments is 9 score points only, one could argue that this difference is tolerable and, therefore, organic food quality of HPP treated juice outperforms the quality of thermal treated juice.

However, a final conclusion whether the better performance of HPP treated juice in the overall score is sufficient to fulfil the requirements for organic food quality and whether the deviance in naturalness characteristics compared to the raw material can be tolerated both scores need to be compared with a generally validated benchmark. This means that first it needs to be defined what the minimum value for the overall score of organic food quality for the HPP treated juice should be compared to the overall score of organic food quality for the juice processed with thermal pasteurisation. Second, it needs to be defined a how much lower score for the characteristics of naturalness in the HPP treated juice compared to untreated juice is still tolerable to be in line with the organic principle of naturalness.

Such generally validated benchmarks should be based on a broad consensus among the stakeholders within the organic sector. Ideally, consensus is obtained through a structured stakeholder process. In addition, for a final conclusion on the case also consumer acceptance and economic sustainability would need to be considered. However, as the purpose of this example was to illustrate the assessment process, the additional substeps according to the Assessment Framework are not elaborated further here.