FOOD METRES

Food Planning and Innovation for Sustainable Metropolitan Regions

D3.2

List of selected Indicators, Norm Values and Framework for Assessing Food Safety and Quality

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1. Introduction

Conventional food production operates in a global food supply network, which has been increasing exponentially since the 1960s. As ingredients are transported throughout the globe this leads to complicated networks (see Figure 1) (Ercsey-Ravasz et al., 2012).

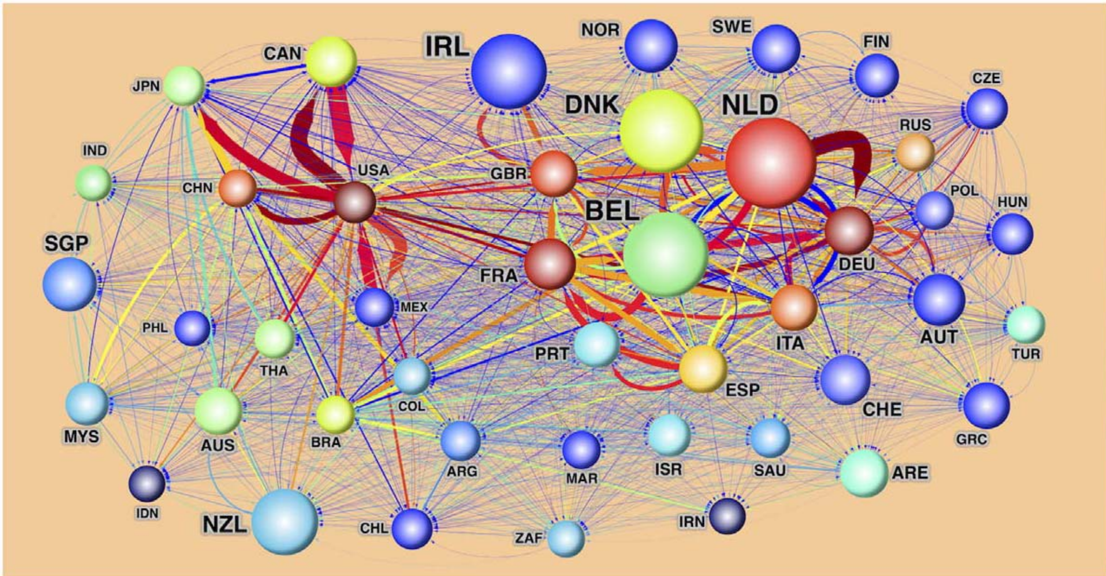

Figure 1. International trade activities in 2007 (Ercsey-Ravasz et al., 2012).

As consumers want a closer connection to the food they are consuming there is an increasing demand to shorten the food supply chains. Consumers perceive local products to have a higher quality, better taste, are fresh, reliable and the chain is transparent (Van der Jagt et al., 2014). The demand for local products has been rising over the years. As a result of this, the number of farmer markets in the USA has more than quadruplet since 1994 (www.ams.usda.gov). The increased demand has been reflected by the development of a high diversity of short food chain (SFC) types, which are either locally embedded, place-based alternatives, which focus on narrow consumer-producer-relations (e.g. urban agriculture or community-supported agriculture) or rather logistics and efficiency-oriented alternative (e.g. agro parcs). Particularly on the case study level, these innovations in agriculture are further investigated in in-depth studies within the six case studies regions of the FoodMetres project. The various SFC types have been previously described and classified in other FoodMetres tasks, including D2.1, D3.1 and D5.1. The SFC types may operate at different regional levels from short regional food chains (LAS) to long regional food chains (MAS) or global food chains (GAS). Definitions of LAS, MAS and GAS can be found in D3.1. It must be remarked that farms usually do not operate solely at the LAS, MAS or GAS level, but rather operate at different levels. For example, in the Netherlands local milk production is very limited and most of the milk is exported outside the Netherlands. Farms may thus operate both at the global and at the local scale.

The effects of shortening the food supply chain have been rarely studied (FASFC, 2012). On the one hand, food safety and quality in SFC are usually managed by one person, or a small team, who have a broad range of tasks. Their knowledge and actions are thus critical to control food safety and may become in conflict with their other daily activities. On the other hand, raw materials usually come from a local source with restricted processing or transactions, which may be less demanding to control. The short storage time may also have a positive effect on the quality and safety of the products provided that the products are properly stored (FASFC, 2014) .

In order to evaluate the effect of alternative food supply chain scenarios on food safety and quality, general indicators have been derived in task 4.1 of Foodmetres (see D.4.1). Food safety is assed using the occurrence/levels of pathogens and occurrence/levels of chemical hazards as indicators. For food quality the following general indicators were established (D4.1): nutritional value, freshness experience and shelf-life. These indicators were used as input in task 5.1. to include in the sustainability impact assessment (SIA). This SIA will allow to evaluate the effect of various innovative SFCs on the overall sustainability (including, social, economic and environmental indicators).

As currently information on food safety and quality of SFCs is limited and the indicators to assess these factors were broadly defined in D4.1 and D5.1, the aim of the current report is to establish specific indicators to obtain more in-depth knowledge on the effects of alternative scenarios on food safety and quality. A framework will be derived to assess food safety and quality based on specific indicators for the food commodities studied in the specific case studies. The focus of the research is on the European situation.

1.1. Food safety

Every food business operator (FBO) and thus also every farmer who puts food on the market is responsible for the safety of this product according to the General Food Law (Regulation (EC) No 178/2002). This means that food should comply with European Union (EU) regulations describing measures to be taken for minimising the level of food safety hazards in the product. An overview of available food safety legislation can be found at: http://europa.eu/legislation_summaries/food_safety/index_en.htm. Compliance with EU legislation should result in products with levels of food safety hazards below regulated limits. Depending on the food product, maximum limits are laid down for microbiological hazards (Regulation (EC) No 2073/2005). Limits for the chemical contaminants nitrate, mycotoxins, heavy metals, dioxins, PAHs and melamine are laid down in EU Regulation (EC) No 1881/2006 and maximum antibiotics residue limits are laid down in Regulation (EU) No 37/2010.

Levels of microbiological hazards in the final product can be minimised by applying hygiene measures during food production as are described in EU Regulations (EC) No 852/2004 and 853/2004. These regulations indicate that food production and processing should be based on HACCP (Hazard Analysis Critical Control Point) principles. HACCP consists of the following steps:

1. Conducting a Hazard Analysis: identifying which hazards may occur in the final product.
2. Identifying Critical Control Points: A critical control point (CCP) is a point, step or procedure at which control can be applied and a food safety hazard can be prevented, eliminated or reduced to accepTable levels. These CCPS will be identified within the food production system.
3. Establishing Critical Limits: A critical limit (CL) is the maximum and/or minimum value to which a parameter (such as pH or temperature) must be controlled at a CCP to obtain an accepTable level of the identified food safety hazard.
4. Monitoring CCPs: description of how the CCPs will be monitored in the food production system.
5. Establishing corrective actions: Actions are described that will be carried out in case a parameter in a CCP exceeds the CL.
6. Verification: determining whether the established HACCP system works properly.
7. Record keeping: documentation of the production process, HACCP plan, CCPs established, all monitoring results, and actions taken.

CCPs can be established following a decision tree (Figure 1).

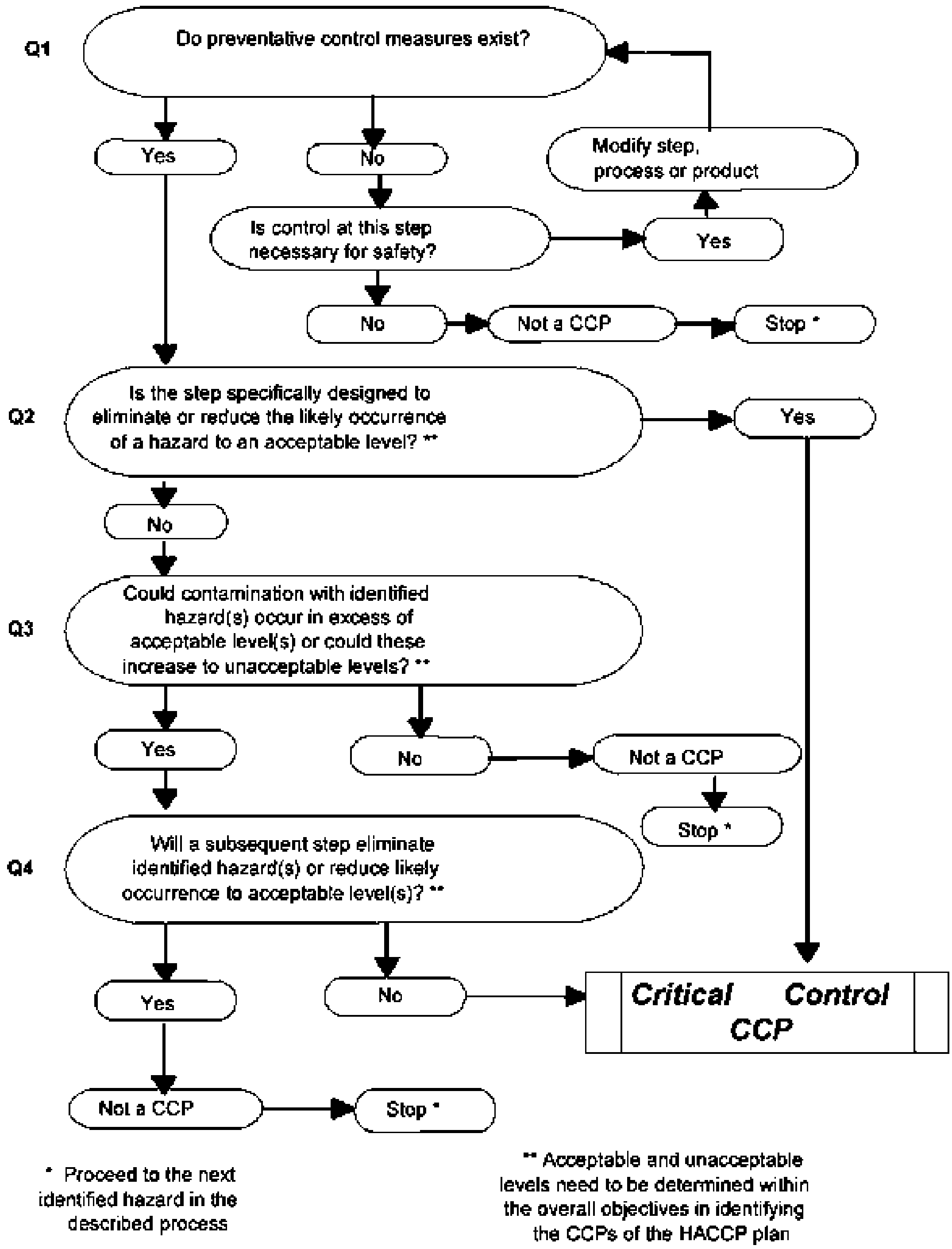

Figure 1. Decision tree to establish CCPs in a production line (FAO, 1997).

Large food producing companies work according to such HACCP systems. For SMEs, these HACCP systems are costly to establish and, furthermore, knowledge and expertise are usually lacking for establishing such systems. Therefore, hygiene codes have been established, which are practical guidelines for implementing HACCP in certain food production systems (FASFC, 2012). Both HACCP systems and hygiene codes focus on food processing after primary production.

Prerequisite for implementing such HACCP systems or hygiene codes is a proper design of the production processes and a hygienic working environment (Figure 2). Good Practices, like GMP (Good Manufacturing Practice) and GHP (Good Hygienic Practice) are guidelines established for this purpose. GMP is the most common good practice code (IFST, 2013). It consists of fundamental principles, procedures and means needed to design the basic environmental and operating conditions for food production (Van der Spiegel, 2004). Guidelines are prescribed on aspects like buildings and facilities, personnel, equipment, production and process control (ECFR, 2014). GHP is a good practice code specifically focused on hygiene. The guidelines of GHP describe hygienic aspects, like cleaning and disinfection, health and hygiene of personnel, pest control, and training.

At primary production, GAP (Good Agricultural Practice) is established, which is a good practice code developed for practices at farm level. At global level, Global GAP, also known as the Integrated Farm Assurance Standard (IFA), can be used, which consists of requirements on good agricultural practices demanded by European retailers (obligated and recommended). These requirements are mainly focused on food safety and traceability, but also on animal welfare, environment, and workers' health, safety and welfare. Global GAP includes Integrated Crop Management (ICM), Integrated Pest Control (IPC), Quality Management System (QMS), and HACCP (www.globalgap.org). Global GAP members can also initiate a local GAP standard or program. It is a stepwise approach that covers the minimum requirements for food safety and hygiene, containing control points and compliance criteria, a checklist, and general rules. The local GAP standard is available at two levels: the Foundation Level, which contains basic requirements for food safety and is especially established for producers who sell primarily at a local level. The Intermediate Level is a more expanded level incorporating stronger food safety criteria, which is accepted by selected national retailers. This is available for fruit & vegeTable, livestock and aquaculture producers (www.globalgap.org).

When both the basic requirements and a HACCP-plan or hygiene code are implemented, food safety is secured.

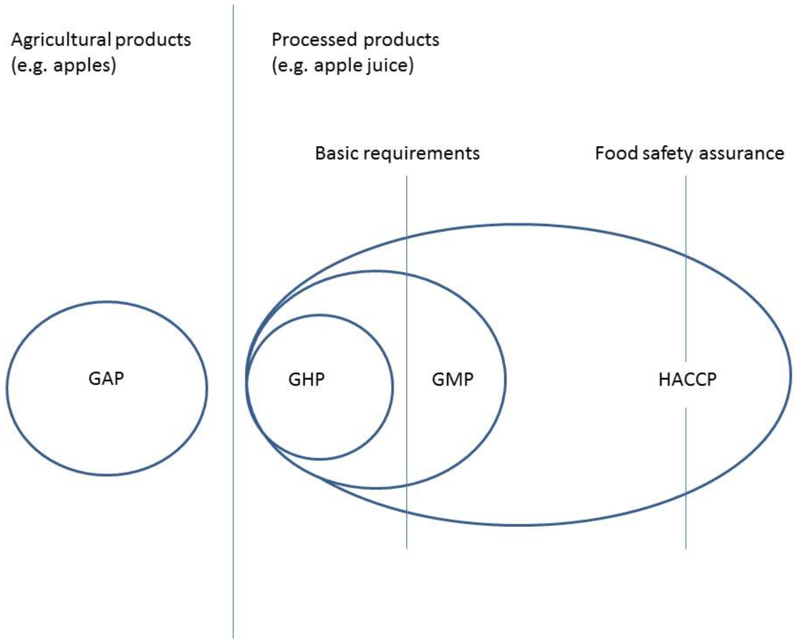

Figure 2. Food safety approach at primary production and processing of food products including basic requirements and food safety assurance.

1.2 Food quality

Food quality is distinguished into commercial and nutritional quality, referring to for example cleanliness, firmness, colour, size and shape, freshness, texture, aroma (commercial quality) and to essential nutrients (carbohydrates, amino and fatty acids) and biologically active compounds (vitamins, dietary fibre, flavonoids, carotenoids, phytosterols, phenolic acids and glucosinolates) as aspects for nutritional quality (Edwards-Jones et al., 2008).

The intrinsic characteristics of products are influenced by the ingredients, recipes used, the production process and storage conditions. For example, the ingredients of the feed influence the fat and protein levels of the milk produced by the cow (Kelly and Bach Larsen, 2010). Processing may affect the nutrient levels of the product. For example, quickly freezing a product (such as vegeTables) after harvest will help to preserve nutrients, whereas heating of produce may destroy nutrients present, but may on the other hand prolong the shelf-life of a product. Storage also influences nutritional levels: upon harvest, products contain certain levels of nutrients that will deteriorate over time under the influence of temperature and/or available oxygen. Temperature, light and humidity influence the deterioration of a product. Especially temperature can significantly affect the food quality (Manzini and Accorsi, 2013).

In general, the shorter the time between harvest and consumption, the higher the levels of nutrients, provided that the product is stored under appropriate conditions. The organizational structure is thus expected to affect the food quality resulting in differences in the quality of products produced within a LAS, MAS or GAS operational level.

Apart from nutritional values, organoleptic aspects (such as taste, colour, fragrance) also determine the quality of a food product (Noordhuizen and Metz, 2005). Storage conditions influence these aspects as prolonged storage at suboptimal temperature will allow spoilage bacteria to grow causing a deterioration of the quality of the product. Furthermore, products that contain fat are subject to oxidation, which causes a rancid taste. Oxidation is influenced by light and oxygen, and can thus be prevented by using appropriate packaging and storage (Manzini and Accorsi, 2013). Commercial quality is also influenced by the transport or harvesting equipment used. This is especially important for delicate products such as fruits and vegeTables or eggs (Manzini and Accorsi, 2013)

As organoleptic aspects are subjective, there are no general guidelines or limits available. However, the consumer appreciates a constant quality. Therefore, the producer usually aims at delivering a product within a specific range of organoleptic aspects and will thus specify company specific standards. A constant quality is achieved by controlling the production process such that the product produced is of consistent quality. Subjective assessments of quality are also particularly important in short and 'alternative' food chains, where consumers often associate certain product and chain characteristics with higher quality products and producers can generate 'attraction' to their products by emphasizing certain attributes (Ilbery and Kneafsey, 2000) . For example, chain transparency, through direct contact with food producers or through 'short' chains, can reassure consumers about the quality of their food, as can information about the production methods, place of origin and ethical dimensions. Some of these aspects can be certified, as in the EU's scheme to register and protect products of geographical origin, and current proposals to have schemes for island and mountain products ((EU) 1151/2012).

2. Framework for assessing food safety and quality

In order to establish an in-depth assessment of the food safety and quality of alternative SFCs, specific indicators need to be derived. These food safety and quality indicators will differ between different food commodities as well as the norm values for these indicators. Ideally, the food safety and quality of the commodities produced within the various alternative SFCs at local level (LAS)) are assessed by taking samples and analysing the set of indicators to establish whether they comply with the norm values. As this will not be feasible in practice, it was decided to derive a questionnaire that can be used to obtain a semi-quantitative assessment of food safety and quality of the various alternative SFCs at the local scale and compare the outcome with other organizational structures at the MAS and GAS level.

A framework was established to assess food safety and quality, which consists of the following steps:

1. Identification of indicators to assess food safety and quality based on literature review and expert opinion
2. Setting limits for the established list of indicators based on EU legislation or literature data
3. Determination of factors influencing food safety and food quality based on literature review and expert opinion
4. Based on steps 1-3, a questionnaire is derived that can be used to assess food safety and quality of food products produced within the various chain types and/or in the various case study regions.

The outcome of the framework is case specific as indicators, limits and influencing factors depend strongly on the commodities involved. In order to illustrate the framework, it will be applied to dairy products as these are produced in all case study regions.

In order to derive the most important indicators for dairy products, a systematic literature search was performed using the following databases: Scopus, Web of Science, CAB en Medline. Indicators were searched both for food safety and food quality using the following search strings:

Food safety:

TOPIC: specified food safety hazards, such as: *"food safety" or pathogen* or "chemic* pollut*" or "chemic* contamin*"*
AND TITLE: search terms related to the agricultural system, such as: *"*urban agric*" or production* or farm* or soil* or air* or organic* or convention**
AND TITLE: search terms defining the commodities in the case study under investigation: such as *milk* or cheese* or "ice cream*" or butter* or dairy*
AND TOPIC: *review* or survey*or overview**

Food quality:

TOPIC: specified food quality factors, such as: *nutri* or sensor* or shelf-life or vitamin* or mineral* or fresh**
AND TOPIC: search terms related to the agricultural system, such as: **urban agric*, crop*, primary production*, soil*, air**
AND TITLE: search terms defining the commodities in the case study under investigation: such as *milk* or cheese* or "ice cream*" or butter* or dairy*
AND TOPIC: *review* or survey*or overview**

Relevance of references was first determined based on the title of the reference. Abstracts of selected references were further evaluated for their relevance. Based on this selection, full papers were downloaded for further evaluation on relevance regarding the topic. Apart from these literature databases, the internet was used for additional information and reports from WUR were used.

Food safety and quality experts were asked to evaluate the established list of indicators and add or adapt indicators on this list. In total 18 experts provided input (9 scientists, 5 people from industry and 4 others (policy makers, NGOs)).

Once indicators were derived for the specific food commodities, limits were set for food safety and quality. These limits were based on legislation, or, if not available, on literature data. Subsequently, preventive measures were established based on literature and expert opinion.

3. Applying the framework to the dairy chain

In total 147 references were found on food safety and quality in the dairy chain. Based on title and abstract, 48 were regarded as relevant. Additional references were added due to snowballing citation or expert consultation. In total 35 references were used for establishing the framework in the dairy chain. The results of the literature study are described in paragraph 3.1 and 3.2 Paragraph 3.3 gives the questionnaire derived to assess the food safety and quality of the dairy chain.

3.1 Food safety indicators

Microbiological hazards

There is an increasing demand for locally produced dairy products, which in many countries has led to the start of small scale dairy farms. These farms are more likely to have the cows close to the dairy facilities, use private wells for water supply and use raw milk for cheese production (Rosengren et al., 2010). Dairy cattle are, however, a reservoir of pathogens such as *Salmonella*, *Campylobacter* and *Escherichia coli*. In organic farming, cows are allowed to graze outdoors which may lead to an increase of zoonotic diseases, such as *Campylobacter, Toxoplasma* (Kijlstra and Eijck, 2006) or *Listeria monocytogenes*, which is a ubiquous pathogen that survives in plants and soil (Kousta et al., 2010). Raw milk can become contaminated with pathogenic bacteria through the farm environment by contamination of the exterior of the teats (Te Giffel and Wells-Bennik, 2010). During milking, the milk can become contaminated through contact with contaminated faeces (Griffiths, 2010; Oliver et al., 2005). Another source of contamination is through mastitis, as an udder infection is primarily caused by a *Staphylococcus aureus* infection (Kousta et al., 2010). And the third route of contamination is through the milking installation. When cleaning and disinfection of the equipment is not performed properly, bacteria may adhere to surfaces or may be present in milk residues causing grow and subsequent contamination of the next milking batch (Te Giffel and Wells-Bennik, 2010).

Pasteurized milk may become contaminated through cross-contamination via the environment (Oliver et al., 2005). The following Figure indicates the various sources of contamination of dairy products that may occur at a dairy farm. Not all practices indicated in the Figure will be applicable for all countries. Especially important is the use of manure as a fertilizer or contaminated water to irrigate field crops (Oliver et al., 2005).

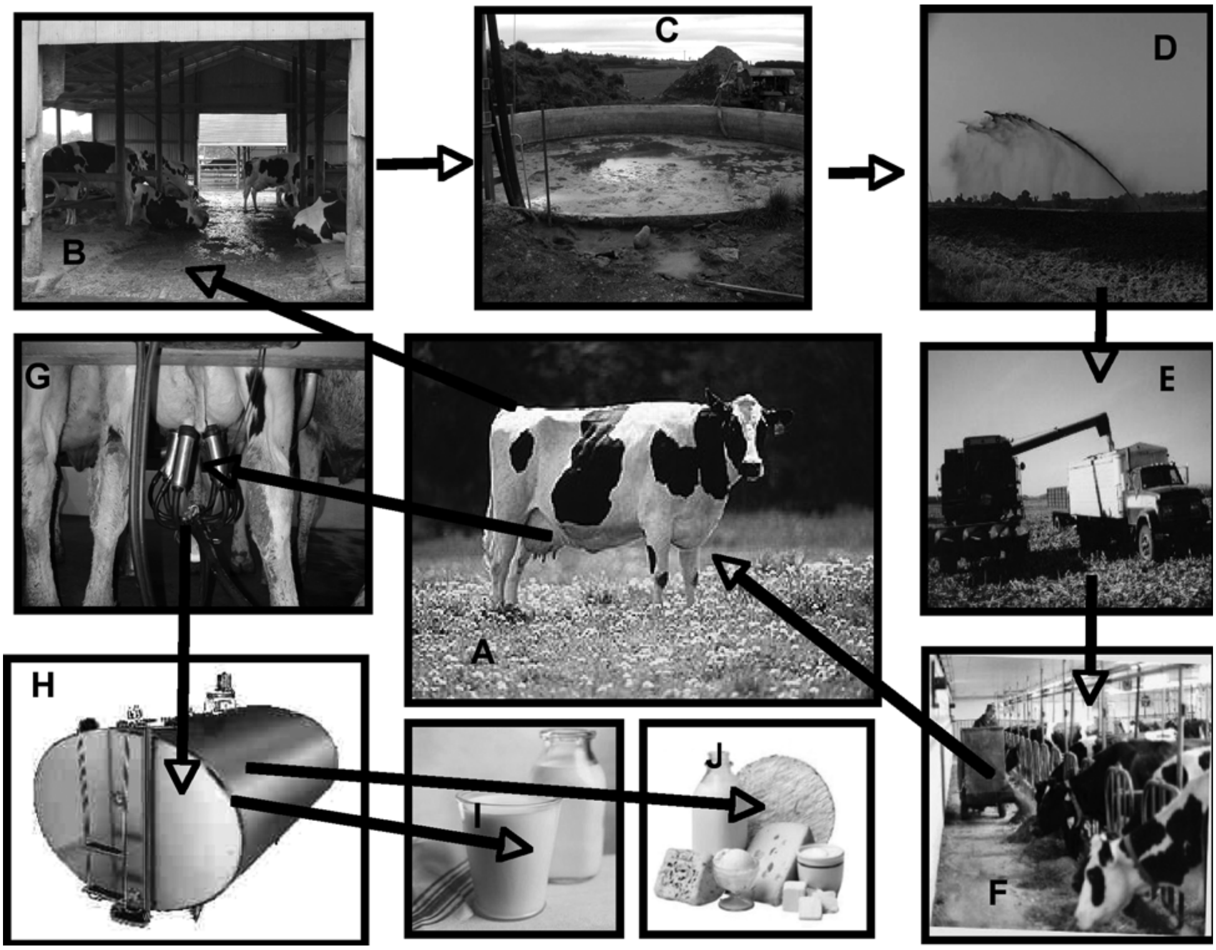

Figure 3. Cycling of foodborne and veterinary pathogens in the dairy farm environment and their transfer to milk. (**A**) Amplification of the pathogen in the cow. (**B**) Dissemination in the immediate environment of the cow via faeces. (**C**) Accumulation of faeces on the dairy. (**D**) Spreading cow manure onto croplands. (**E**) Crops become contaminated with pathogens. (**F**) Contaminated feed consumed by cows. (**G**) Milk can become contaminated with pathogens during milking. (**H**) Pathogens enter bulk tank milk. (**I,J**) Unpasteurized milk, cheese, and other dairy products made from unpasteurized milk consumed by humans (Oliver et al., 2005).

As a result of these various contamination sources, dairy products may become contaminated with foodborne pathogens, which may cause foodborne illnesses upon consumption. A recent review by the US Centers for Disease Control and Prevention (CDC) indicates that dairy products are second in causing foodborne illnesses (after leafy green vegeTables) and are the leading cause of hospitalizations linked to foodborne illnesses (Painter et al., 2013). Various types of cheese have occasionally been implicated in foodborne outbreaks associated with severe symptoms and a high fatality rate. Pathogenic microorganisms associated with these diseases were *S. aureus*, *L. monocytogenes*, *E. coli* O157:H7 and *Salmonella* spp (Kousta et al., 2010).

Furthermore, consumption of raw milk poses a health risk as pathogenic bacteria are frequently found at levels that may cause human health problems (De Reu et al., 2004; Jayarao et al., 2006; Kousta et al., 2010; Leedom, 2006; Ljupco et al., 2012; Murphy et al., 2005; Oliver et al., 2005; Rosengren et al., 2010). A recent research could not confirm the alluded beneficial health effects of raw milk and, therefore, it is advised to heat the milk prior to consumption (Claeys et al., 2013). There is, however, a growing group of consumers who prefer to drink raw milk because of its better taste and/or assumed health effects (Enticott, 2003). Therefore, there are initiatives to use mild preservation techniques that are also applied for the production of fruit juices, which will keep the organoleptic properties of the raw milk and at the same time provide a safe product for consumption (http://www.boerderij.nl/Rundveehouderij/Nieuws/2013/11/Top-wil-rauwe-melk-in-supermarkt-1408596W/).

In order to prevent contamination at farm level, dairy products should be produced as hygienically as possible. At farm level, In general, pathogen contamination can be reduced by using water from a suiTable source (poTable quality or from a deep well), protecting milk storage tanks to prevent access from vermin and proper sanitation of milking and milk storage equipment. Storage temperature and time in the bulk tank influence possible bacterial growth (Griffiths, 2010). Furthermore, a mastitis control program is essential (Kousta et al., 2010; Pellegrino and Donnelly, 2004). Neave et al. (1969) established a 5-point mastitis control plan consisting of: 1. the identification and treatment of clinical cases, 2. routine antibiotic dry cow therapy for every cow at drying-off, 3. post-milking teat disinfection, 4. culling of persistently infected cows and 5. regular maintenance of the milking machine (Bradley et al., 2012). Most important is the identification and treatment of clinical cases as well as separating the milk from sick cows. Although routine antibiotics use is not allowed in organic farms, cows with mastitis may be treated with conventional treatments (maximum of two treatments per cow per year) (Kijlstra and Eijck, 2006). Due to increased concerns about the development of antibiotic resistance, antibiotics use at conventional farms is also diminished. This means, for example, that cows are no longer routinely treated with antibiotics during the dry-off period and that other control measures are implemented to achieve an effective dry cow management (Barlow, 2011). The efficacy of homeopathic treatments has not been proven and should thus not be recommended (Kijlstra and Eijck, 2006; Ruegg, 2009).

Intermittent milking during the dry-off period is used in controlling mastitis, which seems to be effective (Ruegg, 2009).

For processing, HACCP has been developed in order to meet the food safety standards indicated in directive No 92/46/EC that contains regulations for the hygienic production and sale of raw milk, heat-treated milk and milk-based products (Pellegrino and Donnelly, 2004). The following CCPs have been established for the production of pasteurized milk:

1. Reception of raw milk (Ali and Fischer, 2002; Azar and Rofehgari-Nejad, 2009; El-Hofi et al., 2010). The milk should be stored at the farm in bulk tanks that are well maintained. The temperature of milk at the time of pick up should not exceed 5°C (Ali and Fischer, 2002).
2. Storage of raw milk at the plant. The milk should be stored for a maximum of 72h and below 5 °C (Ali and Fischer, 2002; Azar and Rofehgari-Nejad, 2009).
3. Pasteurization. Milk is usually heated to 72 °C for 15s (Ali and Fischer, 2002; Azar and Rofehgari-Nejad, 2009; El-Hofi et al., 2010).

As indicated in the introduction, prerequisite for a HACCP plan is the application of GMP, including GHP (personal hygiene, training, cleaning and disinfection of equipment etc.) both for the production of raw milk and for the further processing steps.

Chemical hazards

Apart from microbiological hazards, chemical hazards may also occur in milk. Antibiotics use (e.g. during the dry-off period) may result in the presence of antibiotic residues in the milk when milk is delivered within the waiting period (Ali and Fischer, 2002; Noordhuizen and Metz, 2005; Sandhu, 2007; Silanikove et al., 2010). Antibiotics have prescribed waiting periods, meaning that farmers need to wait a certain period of time after treatment before they can sell the products to the consumer (directive No 2001/82/EC). These waiting periods have been established to prevent the occurrence of antibiotic residues in dairy products above the maximum residue limits as laid down in EU regulation (EU) No 37/2010.

Other chemical hazards that may be present in the product are mainly related to contaminated feed including, for example, aflatoxins, pesticides, heavy metals and dioxins. Aflatoxins may be produced by *Aspergillus* spp., under conducive conditions of crop growth, transport and storage. Dairy cows may be exposed to aflatoxins due to contaminated feed, such as maize. In the cow's body, aflatoxin B1 may be converted in the milk, resulting in the presence of aflatoxin M1 in the milk, which is harmful to human health (Van der Spiegel et al., 2013). Prevention of the presence of aflatoxins in feed ingredients should start with proper farm management during crop growth. However, given the influences of the climate, a complete reduction is not achievable. Transport and storage of feed should be clean and dry (low water activity and proper temperature) such to prevent (further) growth of *Aspergillus* spp. and subsequent toxin production. Furthermore, a continuous monitoring program is needed to prevent cows being fed with contaminated feed (Burgess, 2010).

Sometimes pesticides are found in milk due to the use of contaminated feed. Particularly organochlorides have been found in the past such as DDT and HCH and cyclodines like aldrin, dieldrin etc. These pesticides have been extensively used, especially in tropic areas and as they are very persistent, they may still be found in the environment. Crops grown in these areas may thus become contaminated and consequently pesticide residues are transferred to milk (Nag, 2010b). Other polar pesticides that are frequently used in crop production such as glyphosate and chlormequat may also end up in milk. However, within Europe, pesticides are seldom found above MRLs.

Feed may also be contaminated with dioxins, polychlorinated biphenyls (PCBs) and heavy metals (Nag, 2010a). The dioxin scandal in Germany in 2010 showed that contaminated feed can have large consequences on livestock production (BBC, 2011). Dioxins and heavy metals may also contaminate the milk via the farm environment (through the soil, air or water). The use of sewage sludge has been related to contamination with these chemical contaminants (Nag, 2010a; Silanikove et al., 2010). Previous research has shown that when cows are grazing on contaminated land, chemical contaminants may be transferred to the cow and end up in the milk (Franz et al., 2008; Van Asselt et al., 2013). Heavy metals may persist in the cow for several weeks after the exposure has stopped. In general, low concentrations of heavy metals are found in milk as transfer of these compounds from feed to milk is low. However, in case cows are grazing on contaminated land, levels in milk may become much higher (Nag, 2010b)

Overview

An overview of all relevant food safety hazards for dairy products, as well as their limits and preventive measures are indicated in the following Table.

Table 1. Indicators with their limits for food safety and factors influencing the indicators for the production of cheese, cream, butter and milk of dairy cows at the farm

Indicator	**Limit**	**Factors influencing indicator levels**
S. aureus	-Toxins absent in 25 g (limit for cheese)[1] -maximum 2 out of 5 samples between 10^4 and 10^5 cfu/g (process criterion for cheese from raw milk), between 100 and 1000 cfu/g (cheese from pasteurised milk), between 10 and 100 (fresh cheese)[1] and between 500 and 2000 cfu/g (raw milk)[2]	Raw milk -mastitis control plan -proper storage at farm (max 1 day ≤ 8 °C/ 2 days ≤ 6 °C) Processing -GMP/GHP -proper pasteurization
E. coli	Maximum 2 out of 5 samples between 100 and 1000 cfu/g (process criterion for cheese)[1]	Raw milk -GHP -maintenance of equipment -proper storage at farm (max 1 day ≤ 8 °C/ 2 days ≤ 6 °C) Processing -GMP/GHP -pasteurization
Salmonella spp	Absent in 25 g (limit for cheese, butter and cream from raw milk and for ice cream)[1]	Raw milk -GHP - maintenance of equipment -proper storage at farm (max 1 day ≤ 8 °C/ 2 days ≤ 6 °C) Processing -GMP/GHP -pasteurization
L. monocytogenes	< 100 cfu/g (ready-to-eat products)[1]	Raw milk -GHP - maintenance of equipment -proper storage at farm (max 1 day ≤ 8 °C/ 2 days ≤ 6 °C) Processing -GMP/GHP -pasteurization

Aflatoxin M1	0.05 µg/kg raw milk[3]	Raw milk -feed control -dry storage of feed
Antibiotic residues	Maximum Residue Limits (MRL) as indicated in (EU) 37/2010 depending on antibiotics administered. For tetracycline, the MRL is 100 µg/kg milk	Raw milk -compliance to waiting periods
Pesticides	MRLs as indicated in (EU) 396/2005	Raw milk -feed control
Dioxins/PCBs	Dioxins: 2.5 pg/g fat milk and milk products; dioxins + dioxin-like PCBs: 5.5 pg/g fat milk and milk products[3]	Raw milk -feed control -no use of sewage sludge
Heavy metals	0.02 mg Pb/kg milk[3]	Raw milk -feed control -no use of sewage sludge

[1]From regulation (EU) No 2073/2005
[2]From directive (EC) 92/46
[3]From regulation (EU) No 1881/2006

3.2 Food quality indicators

Food quality implies the technical features of a product (such as protein or fat content) as well as consumer perception about the product (taste, flavour etc.) (Noordhuizen and Metz, 2005). Milk is composed of lactose, fat, proteins and salts. Lactose content is important for further processing of milk in products such as yoghurt as this sugar is fermented by lactic acid bacteria (Kelly and Bach Larsen, 2010). Levels of lactose are fairly constant in milk, but may drop in case of mastitis (Geary et al., 2014). A high level of protein and fat is not only important for milk, but will also result in a higher cheese yield (Pandey and Voskuil, 2011). Protein levels are not much influenced by feeding factors, although an increased milk yield (by increasing energy supply) will increase protein content as well. A high fat intake reduces the protein content, which may complicate the possibilities to meet specified fat and content levels in the milk (Harstad and Steinshamn, 2010). Within the EU, farmers are paid based on the protein and fat content of their milk (Burgess, 2010).

Milk contains several fatty acids; their chemical properties largely influence both the nutritional value and its technological properties. One of these fatty acids, conjugated linoleic acid (CLA) is assumed to be beneficial for human health (Kelly and Bach Larsen, 2010). CLA levels increase when cows are grazing on the pasture compared to feeding with silage (Harstad and Steinshamn, 2010). In spring, levels of CLA in milk are higher than in summer as young plants contain higher levels of unsaturated fatty acids than plants in the generative stage (Harstad and Steinshamn, 2010). In general, the composition of the milk is largely influenced by the feed as well as by genetic features and thus the breed of the cow (Kelly and Bach Larsen, 2010).

Milk quality is also influenced by the vitamin and mineral levels. Milk is a good source of vitamins B1, B2, B12 as well as the fat-soluble vitamins A, D and E. The latter vitamins also act as antioxidants and may thus effect the shelf-life of the milk. Milk also contains a range of minerals: macro elements (such as calcium and phosphor) as well as trace elements (such as iron, cupper, selenium). Calcium, however, is one of the major minerals in milk and its concentration is mainly influenced by the protein level in the milk. Dairy products have a major contribution to the daily calcium intake in Western European diets (Gaucheron, 2013). Both vitamin and mineral levels in the milk are influenced by the feed composition and can be enhanced using supplements in the feed (Harstad and Steinshamn, 2010).

The composition and quality of the milk are negatively influenced when the cow is suffering from mastitis or other infections. As a defence mechanism, the number of somatic cells will increase during infection. Therefore, somatic cell count (SCC) is a measure for the quality of the milk (Burgess, 2010). Total viable count (TVC) is another quality parameter, which gives an indication for the hygiene level at the farm. For TVC, directive No 92/46/EC indicates a maximum level of 100,000 cfu/g. However, this high level is only reached when the milking practice is poor, farm equipment is inadequately cleaned, milk is improperly cooled or herd health is poor. Using GHP at farm level may provide bacterial levels ≤ 10,000 cfu/g (Burgess, 2010). Apart from SSC and TVC, antibiotic residues in the milk may influence the milk quality. Residues not only affect the safety of the milk, but may also influence processing of the milk in case lactic acid bacteria are used as a starter for the production of yoghurt or cheese. Dairy processors may give fines when somatic cell counts (SSC), antibiotic levels or total viable count (TVC) are above specified limits (Burgess, 2010).

Apart from the nutritional quality, the commercial quality is also influenced by the feed composition. For example, when a cow is grazing on a meadow with wild flora such as garlic or onions, this will influence the organoleptic characteristics of the milk. As indicated earlier, levels for these characteristics are not available but will be producer specific. The implementation of a sensory screening program will provide a constant quality product (Burgess, 2010).

Table 2. Indicators with their desirable levels for food quality in cow milk and factors influencing these indicators

Indicator	Desirable levels	Factors influencing indicator levels
Fat content (%)	4.09±0.46[1]	- feed composition - cow breed (genetics) - cow health (regular checks)
Protein content (%)	3.42±0.35[1]	- feed composition - cow breed (genetics) - cow health (regular checks)
Lactose	4.5-5%[2]	- mastitis control plan
CLA		-feed composition (grazing)
Vitamin A and E		-feed composition (grazing or grass silage; use of supplements)
Minerals (selenium, iodine)		-feed composition (feed with natural high mineral content; use of supplements)
SCC (cfu/g raw milk)	≤400000[3]	- mastitis control plan
TVC (cfu/g raw milk)	≤100000[3]	- proper cleaning, proper cooling - mastitis control plan - minimise time between milking and processing
Antibiotic residues	Maximum Residue Limits (MRL) as indicated in (EU) 37/2010 depending on antibiotics administered. For tetracycline, the MRL is 100 µg/kg milk	- correct use of antibiotics (including compliance to waiting periods) -discarding milk of antibiotic treated cows (milked last and equipment cleaned afterwards)
Freezing point	≤-0.535[4]	- emptying milk tank after cleaning
Acidity (%)	0.16-0.17[4]	
Flavour	No bitterness No rancidity	- feed composition (odours from silage, molasses, wild flora (garlic)) - SSC -residues of cleaning agents and disinfectants
Taste	Specified by producer	-feed composition -sensory screening program
Colour	Specified by producer	-feed composition -sensory screening program

[1]From Barlowska, 2011
[2](Kelly and Bach Larsen, 2010)
[3] From EU directive (EC) 92/46
[4]From Ali&Fischer, 2002

3.3 Questionnaire for the assessment of food safety and quality of dairy milk

The safety and quality of dairy products may be assessed by measuring the indicators given in Tables 1 and 2 and determining whether or not their values comply with the specified limits or desirable levels. As this will be too costly to perform for all indicators and for a range of dairy products, a questionnaire was derived that can be used to obtain a semi-quantitative assessment of the safety and quality of dairy milk and cheese. The questionnaire was based on the factors mentioned in Tables 1 and 2 that have an influence on the level of the indicators. The focus of the questionnaire was on the production of dairy milk or cheese. However, most of the questions are also relevant for other dairy products.

The questionnaire can be send to farmers participating in the various case study regions. The answers are classified in red, orange and green as indicated in Appendix 1. The outcome of the questionnaire will thus give an indication on the safety and quality level of the farmers involved. When farmers in different chain types are participating, the overall level of food safety and quality between farmers operating in various chain types at LAS, MAS or GAS level can be compared as well as differences between case study regions.

Table 3. Questionnaire for the assessment of food safety and quality of dairy milk

Nr	Question	Answer
Production of raw milk		
1	To what extent is the meadow safe for grazing?	☐ No sewage sludge is applied ☐ The history of the meadow is known (no indications of possible contamination of dioxins, heavy metals or other organic pollutants) ☐ A safe fertilizer is used (not based on chicken manure and not containing chemical contaminants)
2	How do you keep the sTable and sleeping boxes clean and dry?	☐ STable and sleeping boxes are cleaned daily or every two days and fresh straw is used ☐ STable and sleeping boxes are cleaned regularly (....x/week) and fresh straw is used ☐ STable and sleeping boxes are cleaned and fresh straw is used when necessary
3	Which of the following characteristics are applicable regarding the feed you use?	☐ Feed is stored under proper storage conditions (clean and dry) ☐ Concentrate is obtained from a certified company (such as GMP+) ☐ Roughage is obtained from well-maintained silage (preventing fungal infections)
4	Which water is used for the cows?	☐ Drinking water or water from deep and covered wells (> 25 m) ☐ Treated rain water, shallow surface water, water from rivers, canals etc. is used (using UV-light or chemical treatment; if filtration is used, the water should be tested regularly on faecal bacteria) ☐ Untreated rain water, shallow surface water, water from rivers, canals etc. is used ☐ Effluent is used
5	Do you have a pest control plan?	☐ Yes, I have a plan established by a certified company for pest control

		☐ No, I check for presence of pests myself and take actions when necessary ☐ No, I don't need a pest control plan
6	How do you prevent mastitis?	☐ The milking machine is regularly maintained ☐ Teats are cleaned with water or dry towel prior to milking ☐ Teats are disinfected after milking using spraying or dipping ☐ Sick cows are identified and treated ☐ Persistently infected cows are segregated or culled ☐ Effective dry cow management is applied
7	How long do you wait to use the milk after a cow has been treated with antibiotics?	☐ Depending on instructions from the vet ☐ I use a standard waiting period of ....days ☐ I wait till the cow has recovered and then start using the milk again ☐ I use the milk directly at the start of the antibiotics treatment
8	Which measures do you take regarding personal hygiene?	☐ Workers, visitors and subcontractors are wearing protective clothing ☐ Boots are cleaned prior to milking ☐ Hands are washed prior to milking and after visiting the toilet ☐ No smoking, drinking and eating in the milking parlour ☐ Wounds are covered ☐ Employees report illnesses
9	How often are these measures checked?	☐ Measures are checked daily and actions are taken when measures are not applied ☐ Measures are checked regularly and actions are taken when measures are not applied ☐ Measures are explained when introducing new employees
10	How often do you remove waste (faeces) from the milking area?	☐ After every milking round ☐ Regularly: ....x/week ☐ When necessary
11	How do you clean the milking	☐ The milking installation is cleaned with hot water (of drinking water

	equipment and environment?	quality) and detergent/disinfection agent after every milking round ☐ After cleaning the milking installation is properly drained ☐ The milking environment is regularly cleaned (....x/week)
12	Do you have a tracking en tracing system?	☐ Yes, I have a structured system in which I record all data per batch (feeding regime, date of production, batch number, diseases, safety and quality characteristics of the milk etc.) necessary to track and trace the product and its safety and quality ☐ Yes, I have a structured system in which I record only production data per batch (feeding regime, date of production, batch number) necessary to track and trace the product ☐ No, I do not have a tracking and tracing system
Processing of milk (e.g. pasteurised milk, cheese)		
13	Are you working according to a HACCP system of hygiene code?	☐ Yes, I have identified potential food safety hazards or used the safety hazards identified in a hygiene code ☐ Yes, I use registration forms for monitoring data (e.g. time, temperature) ☐ Yes, I take actions in case of exceeding the limits ☐ No, I work according to my own system
14	Do you regularly check the quality and safety of the raw milk?	☐ Total Viable Count is checked (....X/month) and Somatic Cell Count is checked (....X/month) ☐ The milk is periodically checked for pathogens ☐ If in doubt, antibiotics are checked ☐ Fat and protein content, freezing point and acidity are checked for every batch
15	How do you store the raw milk prior to processing?	☐ Maximum storage time:.......hour ☐ Maximum storage temperature: ....°C
16	Do you heat the milk prior to processing?	☐ Yes ☐ No

17	If so, what is the time and temperature of this heating step and which method is used?	Time and temperature: ☐ Time:.......sec ☐ Temperature:............ °C Method: ☐ Batch pasteurisation ☐ Flash pasteurisation
18	Which measures do you take regarding personal hygiene?	☐ Workers, visitors and subcontractors are wearing protective clothing ☐ Boots are cleaned prior to processing the milk into dairy products ☐ Hands are washed prior to processing of the milk and after visiting the toilet ☐ No smoking, drinking or eating in the production area ☐ Wounds are covered ☐ Employees report illnesses
19	How often are these measures checked?	☐ Measures are checked daily and actions are taken when measures are not applied ☐ Measures are checked regularly and actions are taken when measures are not applied ☐ Measures are explained when introducing new employees
20	How do you check the quality of the final products?	☐ By observing the flavour of products for every batch ☐ By observing the taste of products for every batch ☐ By observing the appearance (colour, texture etc)of products for every batch ☐ Different, namely.....

4. Conclusions

A framework has been derived to establish a list of indicators and norm values to assess the food safety and quality of products within alternative SFC. For demonstration purposes, the framework was applied to the dairy chain. The same procedure could be applied to derive a list of indicators and norm values for other food production chains as well.

As it will be too costly to assess the levels of indicators quantitatively, a questionnaire was derived for a semi-quantitative assessment of food safety and quality. The questionnaire can be applied within the case studies and the outcome can be used to compare food safety and quality between various alternative SFC as established in D5.1. This will give an indication of the performance of farmers operating in the various chain types at LAS, MAS and/or GAS level. Application of the questionnaire will give more detailed information on the food safety and quality performance than based on the generally derived indicators used in the impact assessment of D5.1. As such, the outcome of the questionnaires can be used as extension of the sustainability impact assessment as performed in D5.1 and the results can be visualised in D5.3.

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Appendix 1. Assessment of the outcome of the questionnaire established in Table 3.

Nr	Question	Answer	Assessment
Production of raw milk			
1	To what extent is the meadow safe for grazing?	☐ No sewage sludge is applied ☐ The history of the meadow is known (no indications of possible contamination of dioxins, heavy metals or other organic pollutants) ☐ A safe fertilizer is used (not based on chicken manure and not containing chemical contaminants)	All three boxes are ticked Two boxes are ticked No or one box is ticked
2	How do you keep the sTable and sleeping boxes clean and dry?	☐ STable and sleeping boxes are cleaned daily or every two days and fresh straw is used ☐ STable and sleeping boxes are cleaned regularly (....x/week) and fresh straw is used ☐ STable and sleeping boxes are cleaned and fresh straw is used when necessary	First answer is ticked Second answer is ticked Third answer is ticked
3	Which of the following characteristics are applicable regarding the feed you use?	☐ Feed is stored clean and dry ☐ Concentrate is obtained from a certified company (such as GMP+) ☐ Roughage is obtained from well-maintained silage (preventing fungal infections)	All three boxes are ticked Box 2 and 3 are ticked (safe feed, but unsafe storage) No box is ticked

4	Which water is used for the cows?	☐ Drinking water or water from deep and covered wells (> 25 m) ☐ Treated rain water, shallow surface water, water from rivers, canals etc. is used (using UV-light or chemical treatment; if filtration is used, the water should be tested regularly on faecal bacteria) ☐ Untreated rain water, shallow surface water, water from rivers, canals etc. is used ☐ Effluent is used	First answer is ticked Second answer is ticked Third answer is ticked
5	Do you have a pest control plan?	☐ Yes, I have a plan established by a certified company for pest control ☐ No, I check for presence of pests myself and take actions when necessary ☐ No, I don't need a pest control plan	First answer is ticked Second answer is ticked Third answer is ticked
6	How do you prevent mastitis?	☐ The milking machine is regularly maintained (preventive measure) ☐ Teats are cleaned with water or dry towel prior to milking (preventive measure) ☐ Teats are disinfected after milking using spraying or dipping (preventive measure) ☐ Sick cows are identified and treated (corrective measure) ☐ Persistently infected cows are segregated or culled (corrective measure) ☐ Effective dry cow management is applied (corrective measure)	All 5 boxes are ticked ≥1 preventive (box 1, 2 or 3) and ≥1 corrective (box 4, 5 or 6) measure is ticked All other options

7	How long do you wait to use the milk after a cow has been treated with antibiotics?	☐ Depending on instructions from the vet ☐ I use a standard waiting period of ....days ☐ I wait till the cow has recovered and then start using the milk again ☐ I use the milk directly at the start of the antibiotics treatment	First answer is ticked Second answer is ticked Third or fourth answer is ticked
8	Which measures do you take regarding personal hygiene?	☐ Workers, visitors and subcontractors are wearing protective clothing ☐ Boots are cleaned prior to milking ☐ Hands are washed prior to milking and after visiting the toilet ☐ No smoking, drinking and eating in the milking parlour ☐ Wounds are covered ☐ Employees report illnesses	All 6 boxes are ticked ≥3 boxes are ticked <3 boxes are ticked
9	How often are these measures checked?	☐ Measures are checked daily and actions are taken when measures are not applied ☐ Measures are checked regularly and actions are taken when measures are not applied ☐ Measures are explained when introducing new employees	First answer is ticked Second answer is ticked Third answer is ticked
10	How often do you remove waste (faeces) from the milking area?	☐ After every milking round ☐ Regularly: ....x/week ☐ When necessary	First answer is ticked Second answer is ticked Third answer is ticked

11	How do you clean the milking equipment and environment?	☐ The milking installation is cleaned with hot water (of drinking water quality) and detergent/disinfection agent after every milking round ☐ After cleaning the milking installation is properly drained ☐ The milking environment is regularly cleaned (....x/week)	All 3 boxes are ticked Box 1 and 3 are ticked No or 1 box is ticked
12	Do you have a tracking en tracing system?	☐ Yes, I have a structured system in which I record all data per batch (feeding regime, date of production, batch number, diseases, safety and quality characteristics of the milk etc.) necessary to track and trace the product and its safety and quality ☐ Yes, I have a structured system in which I record only production data per batch (feeding regime, date of production, batch number) necessary to track and trace the product ☐ No, I do not have a tracking and tracing system	First answer is ticked Second answer is ticked Third answer is ticked
Processing of milk (e.g. pasteurised milk, cheese)			
13	Are you working according to a HACCP system of hygiene code?	☐ Yes, I have identified potential food safety hazards or used the safety hazards identified in a hygiene code ☐ Yes, I use registration forms for monitoring data (e.g. time, temperature) ☐ Yes, I take actions in case of exceeding the limits ☐ No, I work according to my own system	Box 1,2 and 3 are ticked Box 2 and 3 are ticked Box 4 is ticked
14	Do you regularly check the quality and safety of the raw milk?	☐ Total Viable Count is checked (....X/month) and Somatic Cell Count is checked (....X/month) ☐ The milk is periodically checked for pathogens ☐ If in doubt, antibiotics are checked	All 4 boxes are ticked Box 1 is ticked

		☐ Fat and protein content, freezing point and acidity are checked for every batch	All other options
15	How do you store the raw milk prior to processing?	☐ Maximum storage time:.......hour ☐ Maximum storage temperature: ....°C	Max storage < 72h, max T < 5 °C Depending on time-temperature combination Max storage >72h, max T >5 °C
16	Do you heat the milk prior to processing?	☐ Yes ☐ No	Yes No
17	If so, what is the time and temperature of this heating step and which method is used?	Time and temperature: ☐ Time:.......sec ☐ Temperature:........... °C Method: ☐ Batch pasteurisation ☐ Flash pasteurisation	>30 minutes at 63°C (batch) or >15 sec at 72 °C (flash) Depending on time-temperature combination <30 minutes at 63 °C (batch) or < 15 sec at 72 °C (flash)

18	Which measures do you take regarding personal hygiene?	☐ Workers, visitors and subcontractors are wearing protective clothing ☐ Boots are cleaned prior to processing the milk into dairy products ☐ Hands are washed prior to processing of the milk and after visiting the toilet ☐ No smoking, drinking or eating in the production area ☐ Wounds are covered ☐ Employees report illnesses	All 6 boxes are ticked Box 2,3 and 6 are ticked All other options
19	How often are these measures checked?	☐ Measures are checked daily and actions are taken when measures are not applied ☐ Measures are checked regularly and actions are taken when measures are not applied ☐ Measures are explained when introducing new employees	First answer is ticked Second answer is ticked Third answer is ticked
20	How do you check the quality of the final products?	☐ By observing the flavour of products for every batch ☐ By observing the taste of products for every batch ☐ By observing the appearance (colour, texture etc.) of products for every batch ☐ Different, namely.....	All 3 boxes are ticked 2 boxes are ticked 1 or no boxes are ticked