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Effects of climate change on food safety hazards in the dairy production chain

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ABSTRACT

The aim of this study is to analyse the effect of climate change on emerging food safety hazards in the dairy production chain. For this purpose, a holistic approach was used to select critical factors from inside and outside the production chain that are affected by climatic factors. An expert judgement study was conducted to identify and to rank the most important critical factors with relation to emerging food safety hazards in the Dutch dairy production chain. Results included major critical factors affecting the occurrence of food safety hazards when the climate will change in variable and extreme weather conditions, e.g. an increasing temperature and excessive rainfall. The experts mentioned feed-related issues (raw materials, pasture, silage, storage, and manufacturing of compound feed) and animal health as the most important critical factors that affect the occurrence of food safety hazards due to climate change. Feed manufacturing and animal health need to be closely monitored in order to anticipate on climate change effects. The results of the present study can be used as basic elements of an Emerging Risk Detection Support System (ERDSS), a system for stakeholders from industry and government to identify and control emerging hazards in the dairy production chain.

1. Introduction

Food safety incidents often originate in the early stages of food production chains (Jooste & Anelich, 2008). For instance, during the past five decades a number of dioxin-related incidents have occurred in the feed and food chain, the main source being the use of contaminated feed ingredients (Huwe & Smith, 2005; Lascano Alcoser, Velthuis, Hoogenboom, & Van der Fels-Klerx, 2011). In 1998, milk in the Netherlands and Germany was contaminated by dioxin due to contaminated citrus pulp (imported from Brazil) as a feed ingredient for ruminant feed (Hoogenboom et al., 2004). In 2004, milk of dairy farms in the Netherlands was contaminated by dioxins in potato peels, an industry by-product, used as animal feed. The peels were contaminated with dioxin-containing kaolinic clay used for sorting-out the poor quality potatoes (Hoogenboom et al., 2010). Another example of food safety incidents is aflatoxin-related. In 2003, milk in Italy was contaminated with aflatoxin M1 at levels above the legislative limit due to contaminated maize destined for animal feed (Giorni, Magan, Pietri, Bertuzzi, & Battilani, 2007). Subsequently, in 2004, aflatoxin M1 in milk and aflatoxin B1 in feed in Italy were found to be higher than the maximum norm again (Decastelli et al., 2007).

For the dairy production chain this implies that food safety hazards have to be strictly controlled at all stages of the chain but particularly at the stages of the feed manufacturer and the dairy farm. Feed for cows consists of compound feed, pasture, and/or silage. Ingredients for compound feed bought by the feed manufacturer can originate from all over the world. Food safety hazards with relation to compound feed include the potential presence of pesticide residues, PCBs, dioxins, aflatoxins, and radionuclides (Nag, 2010a, 2010b). Pasture and silage are often home-grown at the dairy farm. Food safety hazards that often occur in pasture and silage include dioxins and mycotoxins (Nag, 2010a, 2010b). Additionally, concentrates and by-products are usually bought by dairy farmers, which may contain unknown hazards. Moreover, cows can be treated with antibiotics that are transferred into milk (Nag, 2010a, 2010b). Contaminants in raw milk may be zoonoses, *Salmonella*, *Staphylococcus aureus*, and *Escherichia coli* (Stessl & Hein, 2010).

Not all hazardous contaminants in the dairy production chain will have consequences for human health. Contaminants in feed, water, and soil can be filtered out or partly broken down before transfer to meat or milk from the cow and, therefore, do not reach final food products (Kan & Meijer, 2007). Only those toxic contaminants that are transferred into milk and/or meat products may have consequences for human health.

Climate change will affect the occurrence of food safety hazards in the dairy production chain. The Fourth Report by the UN International Panel on Climate Change (IPCC) has projected the consequences of climate change including temperature, precipitation, CO_2 levels and weather extremes (Bernstein et al., 2007). The expected impact of these changes on agricultural systems, in particularly on food safety, has been depicted by several authors (Miraglia et al., 2009; Paterson

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& Lima, 2010; Tirado, Clarke, Jaykus, McQuatters-Gollop, & Frank, 2010; Tubiello et al., 2008). Higher temperatures, elevated CO_2 concentrations, precipitation changes and extremes will result in increased pest and weeds pressure and increased vulnerability of organic carbon pools. This will affect not only food production systems concerning food security but also food safety. The specific consequences of climate change effects vary for the different regions in the world (Paterson & Lima, 2011; Tubiello et al., 2008). Global warming may affect dairy cattle by increased incidents of animal diseases (Stem, Mertz, Stryker, & Huppi, 1988) and increased thermal stress of cattle, which both will directly affect milk production (Klinedinst, Wilhite, Hahn, & Hubbard, 1993). Elevated temperatures and extreme weather events, such as droughts and floods, may also indirectly influence milk production and its quality as a consequence of shifts in the availability and quality of feed and water. In fact, the presence of mycotoxin producing fungi on maize and wheat is very much depending on environmental conditions and it is expected, for example, that aflatoxin producing species belonging to *Aspergillus* section will become more prevalent with the forecasted climate change (Bunyavanich, Landrigan, McMichael, & Epstein, 2003; Paterson & Lima, 2010; Paterson & Lima, 2011). This imposes a threat to human health since this toxin is transferred to milk when lactating dairy cattle are fed with aflatoxin B1 contaminated feedstuffs (Prandini et al., 2009). Monitoring and early signalling of food safety hazards are thus very important to prevent from human health effects.

There are various warning systems for notification on the occurrence of a hazard (Van Asselt, Meuwissen, Van Asseldonk, Teeuw, & Van der Fels-Klerx, 2010). Examples are the EU Rapid Alert System on Food and Feed (RASFF), the WHO-Global Outbreak Alert and Response, and the Global Public Health Intelligence Network (GPHIN) in Canada. Such warning systems address known, well characterised food and feed safety hazards (Marvin et al., 2009). However, a more pro-active system is necessary to identify new food safety hazards or reintroduced known hazards with an unexpected new or increased significant exposure and/or susceptibility (Kandhai, Booij, & Van der Fels-Klerx, 2011; Marvin et al., 2009).

Such a proactive system for early identification of emerging hazards may be based on a holistic approach considering a wide range of disciplines and expertise (Kandhai et al., 2011; Marvin et al., 2009). The holistic approach assumes emerging hazards leading to food safety risks may result from factors inside as well as outside the food production chain (Marvin et al., 2009; Van Asselt et al., 2010). Climate change may be one of the factors from outside the production chain (Van Asselt et al., 2010; Van der Fels-Klerx, Kandhai, & Booij, 2008). Several studies have identified critical factors to be used in an emerging risk identification system from a retrospective approach. Within these studies, food incidents from the past were analysed in order to select the most important critical factors (Hagenaars et al., 2006; Kleter, Groot, Poelman, Kok, & Marvin, 2009; Van der Roest et al., 2007). However, these studies are restricted since they may be case-sensitive and it is unclear whether these findings are also applicable to dynamic production chains (Van Asselt et al., 2010).

Critical factors can be made measurable by the establishment of indicators functioning as signals when an emerging hazard occurs. Several previous studies have identified such critical factors and related indicators for food production (Schelvis-Smit, Poelman, & Schneider, 2008; Valeeva, Meuwissen, Oude Lansink, & Huirne, 2005; Van Asselt et al., 2010). However, their validity for the dairy production chain and the possible influencing effect by climate change are still unknown.

Data for the identification of emerging hazards are scarce. The use of expert judgement has shown to be successful in other studies dealing with uncertainties and scarce or unavailable data in food safety matters (Hagemann & Scholderer, 2009; Huwe & Smith, 2005; Kandhai et al., 2011; Van Asselt et al., 2010; Van der Fels-Klerx, Horst, & Dijkhuizen, 2000; Webster, Jardine, Cash, & McMullen, 2010).

The aim of this study is to analyse the effect of climate change on emerging food safety hazards in the dairy production chain. For this purpose, the holistic approach was used to select critical factors from inside and outside the production chain that are affected by climatic factors. Expert judgement was used to identify and relatively weigh the major factors affecting the occurrence of food safety hazards when climate will change.

2. Material and methods

Critical factors for identifying emerging food safety hazards may cover a large number of factors from inside and outside the dairy production chain. Therefore, an expert judgement study was used to select and weigh major factors from a pool of pre-selected factors with a broad scope.

2.1. Sample

2.1.1. Experts

Twelve preselected experts from the Netherlands were approached to participate in the expert judgement study. The experts were selected based on their knowledge and experience on dairy feed manufacturing and/or on the dairy farm since these stages were considered most relevant with respect to climate change including dairy and feed scientists, and experts from dairy and feed sector organisations, dairy and feed processing companies, an entrepreneurial and employers' organisation, and a dairy inspection agency. These experts represented the interests of various actors in the Dutch dairy production chain. The Dutch dairy situation is different from other dairy production chains (e.g. those in South and East-European countries) due to the co-operative structure of the chain, relative short distances between actors, the smaller number and larger size of companies, and mainly non-mixed dairy farms. This may influence the perception of the actors. Therefore, the characteristics of the Dutch dairy production chain are described below.

2.1.2. Dutch dairy production chain

Milk production in the Netherlands is one of the highest in Europe and amounts 11 billion kg annually. The milk is processed into cheese, butter, milk powder, fresh dairy products and specialties, involving 300 wholesalers and 6800 outlets. Similar to other EU countries the Netherlands encounters a decreasing trend in number of dairy cows which is accompanied with a declining number of farmers and an increased level of farm technology and milk yield (Demeter, Meuwissen, Oude Lansink, & Van Arendonk, 2009).

In 2008 about 20,700 dairy farms harboured 1.4 million dairy cows with an average farm size of 70 cattle. About 44% of these farms have 70 cows or more, 43% have 30–69 cows and 13% of the farms are small with 1–29 dairy cows. Only a small fraction of the milk produced in the Netherlands (e.g. 1%) is coming from organic managed farms, which is considerably lower than some surrounding countries, e.g. 9% observed in Denmark (PZ, 2008b).

The Dutch dairy sector is dominated by a co-operative structure with one dominant player which processes about 80% of all milk delivered to factories. In addition to high milk production the Netherlands is also one of the highest dairy product importing countries in the EU. The import in 2007 represented a value of 2.3 billion euro (PZ, 2008a). About 52% of the milk is used for cheese manufacturing which contributes to about half of the chain total export value (Demeter et al., 2009; PZ, 2008b). The dairy production chain can be divided into four different stages, being; feed production, dairy farm, milk processing, and retail sector (Valeeva et al., 2005), and transportation of ingredients and produces between the stages.