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Review

New trends in technology and identity of traditional dairy and fermented meat production processes

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Interest in ecofood tourism is strictly related to the consumption of products associated with the geographical area visited. Local products are often requested by consumers living far from the production zones (e.g. in bistro restaurants that reproduce the atmosphere of typicality). This phenomenon, if on the one hand guaranteeing the continued popularity of certain traditional foods, highlights the inherent dangers that certain types of food pose. They could spread the risks to a much wider area that they might typically inhabit. The higher the demand for certain products, the more variations of the production processes of the traditional products there will be. This is particularly evident for fermented products that do not have trademark protection which allows products made with different technologies and/or raw materials to use the same designation. This paper reports the strengths and the weaknesses of traditional fermented food products, examining the concept of typicality, and evidencing the risks associated with consumption.

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Introduction

In the last few years, the demand for traditional food products has greatly increased and it poses a contradiction the consumer. Innovation in food production technologies has allowed the production of safer foods with a longer shelf life, and today the risk associated with food ingestion is considerably low. However, the new life-style trend known as 'green consumerism', with people demanding more foods that are organic and with reduced levels of chemical preservatives for food conservation (Leite, Montenegro, & de Oliveira, 2006), has led to a re-discovery of traditional food products (Settanni *et al*., 2012).

The food policies undertaken by many government institutions to protect small-scale producers, as well as those promoting nutrition guidelines, made consumers more sensitive to food culture. Products from traditional procedures became more attractive largely because consumers considered them more 'natural'. That perception gives the food an identity that, in turn, engenders a certain familiarity. All these aspects that help create a food's 'tradition' provide a perception of quality and legitimacy the consumers, even if they have never tasted it before.

When trying an unknown product, a consumer's behaviour may differ depending on the food's reputation. In general, people are suspicious of a new product obtained with innovative technologies or atypical raw materials. On the contrary, a traditional product associated with a given geographical area is perceived positively. In the latter case, consumers have somewhat of an idea of how the traditional food will taste and what its organoleptic characteristics will be, even what production peculiarities to expect, although they may have never encountered that product before. Intrinsically, consumers trust in the hygienic status of that product and take for granted its safety. When a food item causes food poisoning and/or diseases, there is enormous damage not only to consumers' health, but also to the food producer and the food's reputation. This subsequently affects the economic activities of that food market.

In several industrialized countries, food safety standards have recently been modernized. Government agencies involved in food regulation have developed and enforced standards that are more stringent, and have mandated more severe penalties for food manufacturers who do not comply with new regulations (Holmdel, 2011).

Since consumers have become more demanding and government requirements more rigorous in the last decades, food producers have faced conflicting challenges. Chemical additives have generally been used to combat specific microorganisms. However, for foods processed with no added synthetic preservatives, natural alternatives for the extension of shelf life of non-fermented foods include microbial inhibitors (e.g. bacteriocins and antifungal compounds) and vegetable by-products (e.g. essential oils and water extracts), and for fermented foods, pro-technological microorganisms that combat undesired (pathogenic/spoilage) agents. All these natural strategies may be used without compromising the naturalness of the traditional products, since they are generally recognized as safe (GRAS) (Settanni & Corsetti, 2008; Viuda-Martos, Ruiz-Navajas, Fernández-López, & Pérez- Álvarez, 2008).

For the above reasons, traditional food technologies are not immutable in principle (Cavazza, Franciosi, Settanni, Monfredini, & Poznanski, 2011). Several factors may have changed over time: raw material production and availability, environmental conditions, pre-harvest safety (for vegetables) and breeding (for animals), the origin and experience of the manufacturer, and as reported above, government regulations for hygienic safety. Even with all of these process changes, the final food product has remained essentially the same. Even so, these changes may affect the concept of food typicality: the expression of the characteristics of food's territory, history, and tradition (Iannarilli, 2002).

Based on the technology of transformation and the microbiology of processing and conservation, foods may be divided into two main groups: fermented and non-fermented products. In the former are included all foods obtained via the action of microorganisms that, during their growth, metabolize the macromolecules of raw materials, forming foods characterized by higher organoleptic and nutritional properties, and a more prolonged shelf life than starting materials. Fermenting microorganisms may still be alive at consumption. On the other hand, non-fermented foods are those in which the presence of microorganisms is generally undesired (Man & Jones, 2000).

The microflora of a typical fermented food defines the final characteristics of the resulting product, and often reflects the environment and systems of production. Several niche products are linked to certain production areas not only for the traditions that are handed down over time, but also and, most importantly, for the presence of microbial species and strains colonizing the processing environment and the equipment employed during processing (Settanni *et al.*, 2012) that contribute decisively to the identity of a given food.

In this paper, we have used the philosophy of traditional foods to valorise niche productions, defend small-scale producers, strengthen the link between food and places, and safeguard the territories and the biodiversity of autochthonous crops and livestock. The risks associated with traditional fermented food consumption have also been considered.

Tradition, typicality, innovation

In relation to food, the average consumer typically thinks about 'tradition' as an age-old process to obtain products that can still be appreciated in the present. When this process is performed in a specific geographical area, the resulting product is considered 'typical'. As an example, naturally fermented sausages represent traditional products. 'Suino Nero dei Nebrodi' sausages made using this technology (Sicily, Italy) represent typical products. These concepts determine a perceived quality and have a positive effect on consumer choice.

Since the 1980's, new production criteria have been needed to satisfy the increasing volumes of foods processed with high hygienic standards. In many cases, this trend involved drastic modifications to food processing that have deeply affected the relationship between production environment and product characteristics. The transition from artisanal or low-scale productions to those with a high degree of automation has influenced the entire agri-food chain (Wilkinson, 2004). The effects were different and variable depending on the product considered, but in majority of the cases, it impaired the characteristic territorial links that were more easily traceable for the artisanal productions.

On the other hand, the innovative production strategies have positively influenced the evolution of some high-value products, giving them an even higher value. Technological evolution has always accompanied the manufacturing of typical products, even those enjoying a 'recognition of quality' status [protected designation of origin (PDO), protected geographical indication (PGI), and traditional specialty guaranteed (TSG)], and recognition of 'geographical indications and traditional specialties' conferred by the European Community to promote and protect the names of quality agricultural products and foodstuffs (European Community, 2012). However, these products cannot remain unchanged within a changing ecological, technical, and social environment.

Modern day agriculture is different from that available 20 years ago; raw materials and final food products have also changed over time. Current tradition is based on past innovation, and current innovations may be considered as tradition in the future. The need to respond to the demands that come even from distant markets, economically relevant for the survival of certain traditional food items as well as their producers, often imposes the development of specific production criteria.

Recent processing innovations may have contributed to the increased value of many traditional food products, which not only provide energy and nutrition (McGuire & Beerman, 2011) but also possess other functions that are useful to the human body. However, they cannot cure human ailments and hence, must not be claimed to do so (McMahon & Reguly, 2010).

Food fermentations

By one biochemical definition, fermentation is an anaerobic process for deriving energy from the oxidation of organic compounds using an endogenous electron acceptor, which is usually an organic compound (Prescott, Harley, & Klein, 2005). Many microorganisms produce energy by means of this metabolic pathway. In food microbiology, the term fermentation is often used generically to refer to a process that is used for the transformation of raw materials into final products by the action of microorganisms or microbial enzymes. Fermentation helps in the production of safe and stable foods with a longer shelf life than its raw materials. These kinds of foods are more digestible and appealing than unprocessed substrates because they acquire new desired organoleptic characteristics. Fermented foods obtained both at artisanal and industrial levels are produced throughout the world. The most common products are alcoholic beverages, bread and baked goods, cheeses and fermented milks, table olives and other processed vegetables, and fermented meat and fish products (Wood, 1998).

Fermented foods are complex microbial ecosystems, mainly represented by lactic acid bacteria (LAB) and yeasts (and fungi in eastern Asian products), whose fermentation confers to the resulting products characteristic features, such as palatability, high sensory quality, structure and texture, stability, nutritional and healthful qualities, and when they are in a living form at the moment of consumption, potential probiotic properties.

The main fermentation methods used in food production are depicted in Fig. 1. Fermentation is one of the oldest known food preservation techniques. Fermentation is a key method for the extension of shelf life of foods, in addition to drying and salting. Fermentation enables food availability and safety in times of seasonal scarcity or famine. In developing countries, particularly in areas where refrigeration, canning and freezing facilities are either inaccessible or unavailable, fermentation is still widely utilized as a means of food preservation (Settanni & Moschetti, 2010).

Historically, fermented foods have been consumed by mankind since ancient times: fermented cereals, in the form of sourdough bread, were already part of the European diet 5000 years ago (Währen, 1985); a frieze depicting dairy productions is evidence that dairy technology was known in Ancient Sumeria around 3000 B.C. (Salvadori Del Prato, 1998); beer is one of the oldest beverages humans have produced, dating back to at least 5000 B.C., and recorded in the written history of Ancient Egypt and Mesopotamia; archaeological evidence has revealed that the world's oldest known winery was active in Armenia in 4100 B.C. (Keys, 2003); sausages were already popular among the ancient Greeks and Romans (Trojan & Piotrowski, 2000). Hence, fermented foods represent traditional biotechnologies employing GRAS microorganisms. These agents have been used for food production and ingested by humans for millennia, and hence, their presence in foods has the approval of various international control institutions. The term GRAS stems from a general recognition of safety based on experience from common use in food by a significant number of people before 1958 (Federal Food, Drug, and Cosmetic Act., 1958).

Local raw materials

In the concept of typicality and identity, the use of local raw materials plays a defining role in the perception of quality by consumers. This can be challenging because the raw materials may be available only for a limited time but the demand may be spread throughout the year. In this situation, a product may still remain 'typical' after traditionally processing the raw material, no matter what its origin (e.g. cheeses made with reconstituted milk).

For fermented foods, environmentally indigenous microorganisms that are considered autochthonous (Dubos, Schaedler, Costello, & Hoet, 1965) are often associated with a given area and should be reported as a typical food ingredient. These microorganisms are often responsible for the expression of typical flavour and are part of the tradition associated to a given food product (Piraino, Zotta, Ricciardi, & Parente, 2005; Schuller, Alves, Dequin, & Casal, 2005).

For traditional fermented food production, the fermenting microorganisms are of paramount importance. They represent the direct link between the food and the historical and social conditions characteristic of a given area. Since the microbiota of the typical fermented foods determine their final characteristics, they act as the producer's 'co-workers' and are part of the production traditions established over time. The roles of microbiota have been investigated, understood, and employed to drive several processes (Wood, 1998), but many others still need to be studied and, so far, represent a kind of 'secret' that the microorganisms use for transforming raw materials into final products.

The process of selecting microorganisms to be employed as autochthonous starter (in all fermented foods) or secondary (mainly in cheese-making) cultures is essentially based on the characterization of the pure microorganisms isolated from the same foods during or at the end of fermentation (Garabal, 2007). The various cultures are not only investigated for the development of organoleptic characteristics (structure, colour, odour, and aroma) and stability of the final products, but, depending on the species, also for their absence of toxicity and resistance to antibiotics (Settanni *et al*., 2014). Unfortunately, some LAB transferred to humans by fermented foods are involved in the dissemination of antibiotic-resistant strains in the environment. Among these, enterococci have garnered a lot of attention (Giraffa, 2002).

Foulquié Moreno, Sarantinopoulos, Tsakalidou, and De Vuyst (2006) reviewed the roles of enterococci in food fermentation and suggested that their presence in some foods, especially cheeses and sausages, although often related to direct faecal contamination, is desirable, since they strongly contribute to the generation of characteristic aromatic profiles. In studies involving cheeses, several strains originating from raw milk were linked to the cheese's typicality. However, some enterococci, including those commonly associated with food fermentation (e.g.

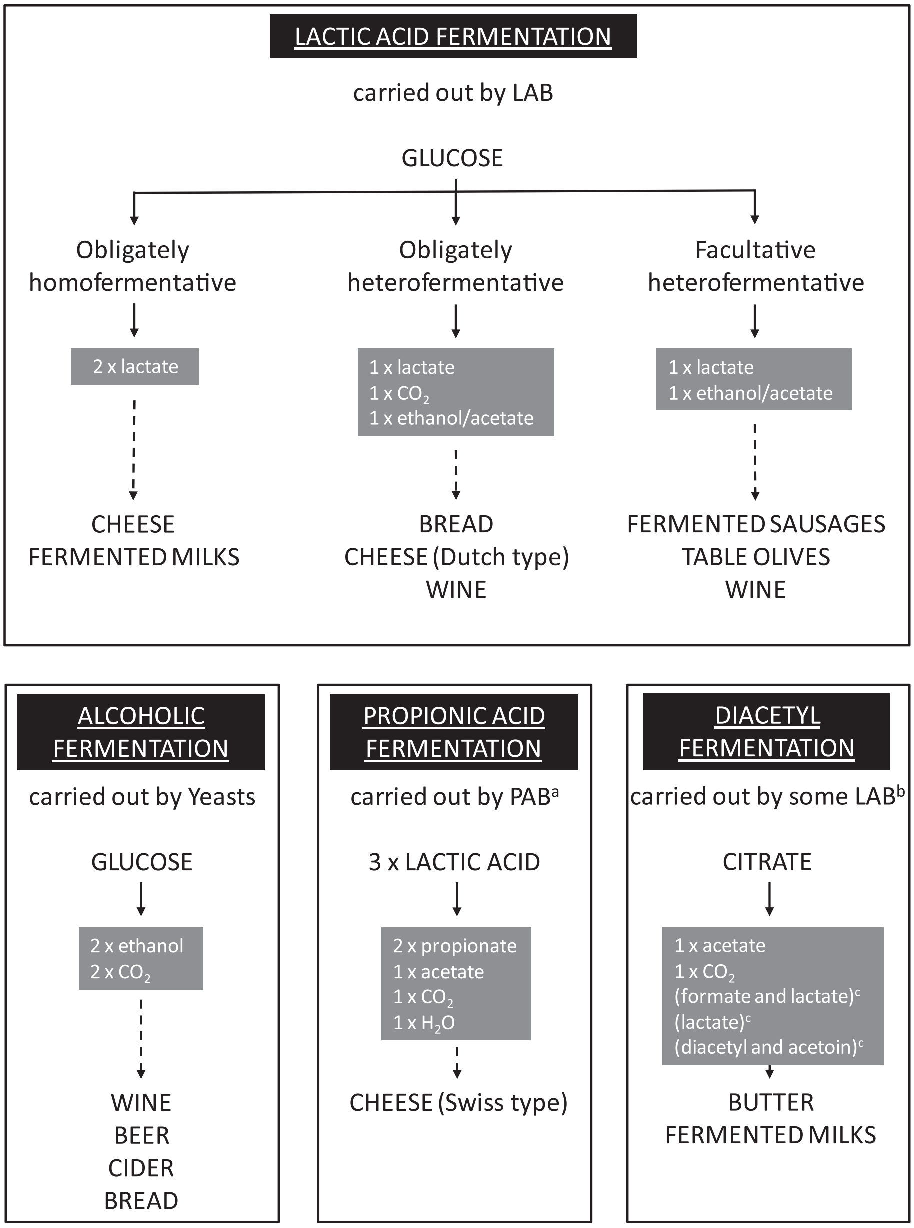

Fig. 1. Main food fermentations. Superscript letters: [a], propionic acid bacteria; [b], mainly performed by *Lactococcus lactis* subsp. *lactis* biovar *diacetylactis* and *Leuconostoc mesenteroides*; [c], the products between brackets are different depending on the microorganism and the conditions of fermentation.

Enterococcus faecalis and *Enterococcus faecium*) have been associated with community-acquired and nosocomial infections (Franz, Holzapfel, & Stiles, 1999). Thus, once proven their safety, the use in certain food productions, mainly long-term ripened cheeses, preserves typicality.

Safeguard of tradition and risk of standardization

In order to maximize the performance of the autochthonous strains selected during fermentation, a revision or an adaptation of the traditional production protocols could be necessary. These modifications must be respectful of the essential and distinctive aspects of the product tradition. Reference to the production area assumes cultural significance and, especially, an assurance of respect of the production rules by producers. This also provides transparency and guarantees the real origin of the product and on the process production.

Fermented foods produced at industrial levels in different places are characterized by unchanging organoleptic features. Hence, the active microorganisms must possess repeatable and reproducible technological performances to obtain product standardization. On the contrary, local fermented foods are produced at artisanal levels with autochthonous microorganisms that are adapted to the production area (environment), the local raw materials (substrates) and the traditional protocol (technology). These microorganisms may not reproduce their performances in different conditions.

Fermented food products obtained without a definite production protocol may be produced with technologies, raw materials, equipment and microorganisms different from those used traditionally. The raw materials may be subjected, if possible, to thermal decontaminating treatments and the equipment historically used for making food are replaced by tools made with materials that can be easily sanitized. These modifications of the production procedures make the inoculation of starter cultures necessary. When the starter culture is composed of a limited number of strains, and is applied to different productions, a flattening of the taste of the final products may occur, with the risk that the final products may no longer be distinguishable by production technology and/or geographical origin. This phenomenon is particularly evident when the raw material contains the microorganisms responsible for typicality (e.g. raw milk) and the equipment used for transformation are made with material (e.g. wood) that can help the formation of microbial biofilms strongly contributing to the food's typicality (Didienne *et al*., 2013; Licitra *et al*., 2007; Lortal *et al*., 2012).

In the dairy field, many cheeses represent niche products manufactured in small-size farms with raw milk from cows of indigenous breeds that are fed mainly on poor quality natural pasture. This is the case of Caciocavallo Palermitano cheese, manufactured within the Palermo province (Sicily, Italy) with milk from the autochthonous species 'Cinisara'. Traditional cheese making is carried out using wooden dairy equipment without the addition of starter LAB. Recently, some variations in the production system have been registered by some dairy factories, especially those that use a high volume of milk to be processed into cheese. The milk is pasteurized in stainless steel containers and commercial starters are added into the milk before coagulation (Fig. 2). This results in the production of cheeses designed as 'Caciocavallo Palermitano' that are substantially different (Settanni, Di Grigoli, Tornambé, Gambino, & Bonanno, 2010). A study conducted on the microbiological characterization of both traditional and innovative technologies applied to obtain this cheese revealed that, following the traditional protocol, a clear dominance of the *Streptococcus thermophilus* strains was observed when the entire manufacturing process was performed in wooden vats, highlighting the influence of

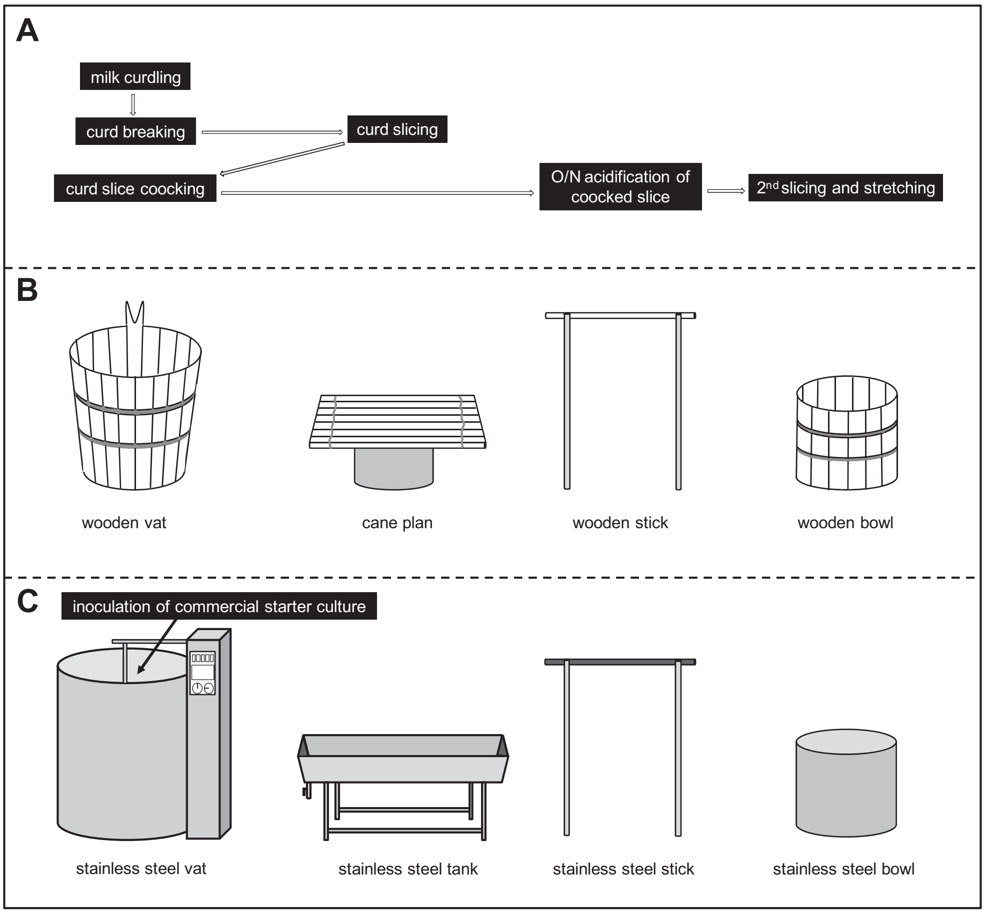

Fig. 2. Schematic representation of Caciocavallo Palermitano cheese production. A, cheese making; B, traditional equipment; C, stainless steel equipment used for the innovative process.

traditional equipment in the typicality of the product. On the contrary, the production carried out in stainless steel equipment mainly contained the commercial starter strain (Settanni *et al*., 2012). This example shows that a mild change could be represented by the selection of autochthonous strains isolated during traditional cheese making and added to the raw milk to be transformed using stainless steel equipment (works in progress) in order to maintain a certain typicality of the production as well as high hygienic standards. In fact, when the transformation process is uncontrolled several problems may occur. Nonpasteurized dairy products are numerically most involved in diseases outbreaks than those made with pasteurized milk (Langer *et al*., 2012).

Effect of the transformation environment

The autochthonous microorganisms are necessary to define the 'territoriality' of several fermented foods. Pure microbial starter cultures became available to processors in the 1940's and 1950's, but their use in the meat industry has been widespread since the 1980's (Doyle & Meng, 2006). Today, the use of starter cultures to manufacture fermented meat products is common to many countries, but several traditional methods of making sausages still survive. Despite the benefits in terms of hygienic safety due to the commercial starters, their application might cause the loss of specific traditional characteristics of the final products and acceptance by consumers.

Several improvements in the production of fermented meat have been put into practice recently, but it remains a very traditional process in areas where typicality of products and a long history of making them are seen as a source of local pride and a way to preserve local customs. In this contest, the spontaneous fermentation represents the oldest process to produce sausages. Methods of production that rely on spontaneous fermentation have been used the longest, but it may be that the environment in which the sausages are made have a bigger impact in transforming the meat and other ingredients into the finished product than the actual microorganisms that are found on them. Francesca, Sannino, Moschetti, and Settanni (2013) performed a microbiological characterization of traditional fermented meat products from the Sicilian pigs of the species 'Suino Nero dei Nebrodi', reared in a restricted area of the Nebrodi Mountains (Sicily, Italy), and are eventually made into sausages and salami without the addition of commercial starter LAB. This work demonstrated that, although no commercial starter was used during the mixing of ingredients, the fermentation process was dominated by two types of bacteria that helped in food production and gave it its typicality: *Lactobacillus sakei* and *E. faecalis*. These strains were found on the surface of factory equipment even before contact with the meat mixture. The surfaces analysed were not made of wood. The meat mixture was prepared in plastic tanks, and the mouth of the mincing machine was made of stainless steel. However, they still retained the LAB strains that allowed the factory to make their traditional meat products. The findings highlight the direct influence the production environment can have on the final characteristics of the finished product.

Hygienic safety of traditional foods

The raw materials and the bacteria found in them do not just lend fermented foods their typicality: it also affects the food's safety. Although the microbiota that cause the production of organic acids, carbon dioxide, ethanol, hydrogen peroxide and diacetyl, antifungal compounds, bacteriocins, and antibiotics during the fermentation process helps protect these kinds of foods (Settanni & Corsetti, 2008), they are not necessarily enough to guarantee that there will not be unwanted microorganisms in the final mixture.

Cheese can be classified into six types based on raw materials and microbial inocula (Mucchetti & Neviani, 2006): 1) pasteurised milk and selected starters; 2) pasteurised milk and natural starters; 3) thermal-treated milk and natural starters; 4) raw milk and selected starters; 5), raw milk and natural starters and; 6) raw milk without starters. From a hygiene perspective, the last category is the one that deserves major attention, because final products can be contaminated by pathogenic microorganisms because of their presence in raw milk and survival during the cheese making process (Donnelly, 2004).

Long-ripened cheeses are generally considered safe, even though they are obtained from raw milk. The June 2001 revision (European Community, 2001) of Directive 92/46/EEC, which lays out regulations for the microbiological criteria for food consumed by the European economic community and the Commission Regulation EC 2073/2005 (Commission Regulation, 2005) have established that cheeses made from either raw milk or milk subjected to thermal treatments need to be evaluated for the presence of four main pathogens: *Listeria monocytogenes*, *Salmonella*, *Staphylococcus aureus*, and *Escherichia coli*. However, since all of the microbial groups present in milk are trapped in the fat-protein matrix (Franciosi, Settanni, Cologna, Cavazza, & Poznanski, 2011), other pathogens may be transferred to the cheese.

Member states may be authorized to grant individual or general amendments to the rules of the above directive for cheese that is produced with an aging period of at least 60 days because 'the microbiological limits for raw milk may be changed if the finished product meets the requirements for *S. aureus*' (Dixon, 2000). That said, ripening cheese for longer than two months does not necessarily mean that cheese consumers are in the clear. Todaro *et al.* (2011) conducted a study on the microbiological characterization of several PDO Pecorino Siciliano cheeses, which fall into the sixth category listed above, i.e. made from raw milk without starters. The cheeses that were analysed were all ripened for five months, but were made in different dairy factories, using milk from different farms, subjected to different salting techniques, and all had different final weights. Each showed the presence of spoilage from pseudomonads and pathogens that were mainly from the *Enterobacteriaceae* family. These pathogens were present in worrisome concentrations, comparable with the levels of LAB. Among the pathogenic species, *Citrobacter freundii*, *Enterobacter*, *E. coli*, *Klebsiella oxytoca*, *Serratia grimesii*, and *Stenotrophomonas maltophilia* were identified and some of them are emerging as important nosocomial pathogens. The authors suggested converting the production process for PDO Pecorino Siciliano cheese from that involving raw milk without starters (category 6) to that involving raw milk and natural starters (category 5), and adding autochthonous LAB as starter bacteria in order to improve the hygienic conditions of this cheese without spoiling its typicality. Other Italian consortia producing PDO raw ewes' milk cheese (e.g. Pecorino Romano and Pecorino Toscano) adopted this strategy to ensure the hygienic safety of the final products.

Following that strategy, Settanni *et al*. (2013) used different *Lactococcus lactis* strains previously isolated from PDO cheese to improve their final quality. After five months of ripening the cheeses manufactured with the autochthonous strains as starters, there were no detectable levels of pseudomonads or members of *Enterobacteriaceae*.

Conclusions

Traditional food production processes are an integral part of regional culture. The consumption of typical foods strengthens connections with the places of their origin, helping preserve their way of life and their future development. For fermented foods in particular, a change in production technology is sometimes necessary in order to ensure consumers' safety and to foster the perception that the foods are natural. However, the changes must be respectful of tradition in order to avoid an irreversible rejection by consumers. Since trust is earned over time and generations, one wrong act can affect the entire system of production for a given food. The autochthonous microbiota, considered as local raw material/ingredient, may play a major role in the determination of territorial specificity because they could make the food safer to eat and also, in many ways, help to preserve the identity of the typical, traditional foods. Fermented foods made from raw milk or meat must be manufactured with the addition of autochthonous microorganisms not only for the preservation of food typicality, but also for avoiding risks to consumers' health.

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