Innovations in food preservation in pastoral zones

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Summary
Food preservation makes a significant contribution to food security and food safety in pastoral communities with limited access to external food sources. Raw materials are preserved by heating, drying, smoking, pickling, salting, curing or fermentation with microorganisms. This article describes preservation techniques in the pastoral context, targeting the major dietary components of milk, meat and cereals; related health risks; and potential innovations for food preservation. Sustainable elimination of pathogenic microorganisms, preventing re-contamination, sporulation and the growth of zoonotic and foodborne microorganisms, is necessary to enhance food safety and ensure food security by reducing post-harvest losses and food waste. However, modern preservation procedures are difficult to adapt to the lifestyles of pastoralists and so are rarely implemented or accepted. Innovations should therefore focus on improving existing accepted procedures by promoting synergistic combinations to compensate for the disadvantages of these traditional techniques and ensure the quality of the raw material right up until consumption. Drying and spontaneous fermentation are key preservation techniques among pastoralists that serve as opportunities for innovation and can be shared across pastoral communities. Further potential for innovation lies in the unique, largely uncharacterised, microflora biodiversity of fermented products. The characterisation, safety assessment and conservation of these microorganisms are needed to develop locally adapted starter cultures that retain or improve on the desired characteristics of the finished product. Careful sensitisation of stakeholders, the study of social acceptance and capacity-building at all levels are required to achieve the sustainable implementation of such innovations, which will contribute to enhanced food security and safety.

Keywords
Drying – Fermentation – Food safety – Food security – Hurdle principle – Lactic acid bacteria – Pastoralism – Starter culture.

Introduction

The pastoral system plays a vital role in food security and the food supply of a large part of the human population worldwide. Pastoralists and their livestock supply important nutrients, in terms of milk, meat and blood, to their own and external communities. Pastoralists have adapted their lifestyle to the climate and soil quality of semi-arid and arid land, employing extensive livestock keeping for meat and milk production. These pastoral or semi-mobile systems are estimated to keep 50–80% of their livestock on extensive grazing (1, 2, 3, 4). Approximately 80–90% of the milk volume is produced and marketed through informal channels of smallholder dairy units and pastoral communities. Livestock also serve a pivotal role in ensuring food security by acting as a cash reserve to purchase much-needed cereals and other foods during the dry season (5). Simultaneously, however, the system is also highly susceptible to food insecurity and poor food safety, due to climate variation, pasture availability, conflict, political instability and land privatisation (6, 7). Furthermore,

doi: 10.20506/rst.35.2.2527

quality controls and cold chains are rare, resulting in hygiene constraints and considerable losses, which account for approximately 20–30% of the production quantity of milk, meat and cereals (8, 9, 10, 11). Improving food preservation is thus a key aspect of enhancing food security by ensuring a higher conversion rate of the energy input of food production into a final food product, by reducing the energy which is lost through food loss, waste and spoilage.

Diet of pastoral communities and the need for food preservation

The diet of nomadic pastoralists is strongly based on animal products and cereals. Depending on geography, tribes and season, the pastoral diet consists of 12–89% meat and milk products, and the remaining quantity is usually obtained through cereals (5). Sorghum, millet and maize are among the main cereals consumed. They are prepared as porridge in varying forms, mixed with dried meat and milk. Dried fruits and vegetables, although less common, are added by pastoralists in Niger or Botswana when available and subsequently consumed or fermented as a whole (12, 13, 14).

Seasonal variations are frequent, affecting several components of the diet. Salt and sugar are especially limited during the rainy season, when markets may be held less frequently or further away and travelling is more difficult (14). Meat, blood or fat consumption is generally low but becomes more important during the dry season, whereas milk consumption is significantly higher in the rainy season and cereals provide the main source of energy (5, 13). Nutrients are restricted to these main sources, with milk and meat providing the major supply of protein, and energy is nearly 50% dependent on fat, comprising a high proportion of saturated fatty acids. The vitamin content of the pastoral diet is significantly lower than the recommended dietary allowances for vitamins B12, B6, C and folate (15), suggesting potential malnutrition due to an unvaried diet and strong seasonal fluctuations.

Pastoral dietary habits are, however, changing. The transition of nomadic pastoralists to sedentism, transhumance or agro-pastoralism is accompanied by a reduction in milk consumption in favour of cereals. Nevertheless, milk still provides a majority of micronutrients (vitamins A, B12 and C), even in these transformed populations, highlighting the importance of food products derived from animals and their appropriate preservation (16, 17).

The main foodborne risks of the pastoral diet

Food safety in pastoral communities is largely affected by animal health, transportation, water quality, access to healthcare, access to hygiene information, recontamination, storage, and temperature constraints (18, 19, 20, 21, 22, 23). This means that zoonotic foodborne infections and intoxication related to microorganisms are one of the main health risks, besides pesticides and other toxic chemical pollutants (24).

Microorganisms in food can be categorised into those that enable fermentation or cause spoilage and those that are pathogenic (25). Fermentative microorganisms, mainly lactic acid bacteria, are beneficial in contributing to the fermentation process and generally safe for human consumption. Spoilage microorganisms cause product deterioration with undesirable 'off' flavours, aromas or textures, and may or may not be detrimental to health. Zoonotic and foodborne pathogenic microorganisms are the main health risk for humans and animals. Zoonotic infections are infectious diseases that can be transmitted between animals and humans. They represent a major public health risk, especially via animal- and plant-derived food which has been contaminated with animal microbiota. Animal microbiota of the skin, saliva, mammary glands, faeces, meat and reproductive tract are the corresponding reservoirs for these bacteria, which include the following zoonotic and foodborne pathogens: *Staphylococcus aureus, Clostridium perfringens, Clostridium botulinum, Bacillus anthracis, Bacillus cereus, Brucella* spp., *Listeria monocytogenes, Mycobacterium bovis, Salmonella*, Shiga-toxin-producing *Escherichia coli* (STEC, including enterohaemorrhagic *E. coli* or EHEC), and possibly *Streptococcus agalactiae* (18, 24, 26, 27, 28).

Zoonotic and foodborne microorganisms are responsible for severe, life-threatening, febrile, enteric and parasitic diseases. They need to be differentiated by their effect – infection versus intoxication – and the required infectious dose. Highly infectious agents, such as *M. bovis*, STEC, *Shigella* spp., *Salmonella* spp., *Campylobacter* spp., *Brucella* spp. and *Coxiella burnetti*, require as little as a single cell to a few hundred cells to cause disease (29, 30, 31, 32, 33), which makes animal contact and the consumption of raw dairy and meat products a key risk factor (34, 35). On the other hand, classical foodborne pathogens causing food poisoning, such as *S. aureus* (when related to enterotoxin production) or *B. cereus*, need to multiply and produce toxins in food before becoming harmful to humans (36, 37, 38). Heat stability among many of these foodborne microorganisms and their toxins is a main contributor to the spread of foodborne diseases (36, 38). Furthermore, mycotoxins produced by fungi, such as aflatoxins or ochratoxins, are extremely heat stable. Moreover, they are persistent toxins that cannot be removed from food products and can also translocate from animal feed to meat and milk. They possess chronic and cumulative toxicity that accumulates in the liver or fatty tissue of humans and animals, leading to a long-term enhanced risk of cancer (39, 40).

Disabling or limiting the growth of microorganisms at the earliest stage is the key approach to reducing toxin concentration and enhancing food safety (41). Highly infectious pathogens must be eliminated through some method. Therefore, combined preservation techniques, such as heat followed by fermentation or drying, are needed to combat these two groups of pathogens, in addition to mass vaccination of livestock, diagnostic tests and slaughter strategies.

Food preservation – techniques, mechanisms and limitations

Food preservation procedures

The aim of food preservation is to prolong shelf life by delaying chemical or biological spoilage processes. The shared goal of all processes is to modify the food environment in a way that inhibits or reduces pests (insects, rodents and birds), microorganism growth and chemical reactions of food components to reduce post-harvest losses and extend shelf life (42). Traditionally, preservation is achieved through physical, chemical and biological means, such as heating, salting, sugaring, curing, drying, smoking, pickling, cooling, freezing or fermenting with microorganisms (43, 44).

Basic mechanisms for preservation

The main mechanisms of preservation procedures, as described in this section, are related to water activity (a_w), acidity, redox potential, temperature and atmosphere composition. A_w determines the amount of water available for microorganism growth and chemical or enzymatic reactions. A_w reduction is achieved by drying, especially in arid and semi-arid regions, where sun and climate conditions are optimal. Most bacteria relevant to food require an a_w of >0.95–0.97 (44, 45). Lower values of 0.91–0.95 and even 0.80–0.87 are tolerated by foodborne pathogens such as *L. monocytogenes* and *S. aureus*, respectively. Halophilic bacteria, xerophilic moulds and osmophilic yeasts predominate in the a_w range of 0.61–0.80. There is no microbial growth observed below $a_w < 0.61$ (45).

In a similar way, acidity is a key parameter determining the growth of microorganisms in food. The critical boundary is pH 4.5, below which *C. botulinum* is no longer able to grow. At lower pH values, acid-tolerant bacteria, such as lactic acid bacteria and acetic acid bacteria, are still able to multiply, whereas at pH 2 or lower, yeasts and moulds predominate (44). Acidity is also coupled with atmosphere composition and redox potential. The optimal redox potential ranges from less than -250 megavolts (mV), for strict anaerobic microorganisms, to +500 mV, for aerobic microorganisms. These parameters and their interactions determine the susceptibility of food products to spoilage microorganisms and pathogens (46).

Limitations of preservation

Preservation also has limitations. Low-quality raw materials cannot be turned into high-quality products, since they retain heat-resistant toxins. Measures to inactivate all microorganisms in heavily contaminated food, without detrimentally affecting the food itself, lead to residual surviving populations of microorganisms, accompanied by the activation of bacterial sporulation and the possibility of recontamination.

Producers and consumers are often unaware of these risks (20, 47, 48). Therefore, raising general awareness of hygiene, quality control of raw materials and the selection of appropriate preservation 'hurdles', i.e. obstacles that the pathogen or spoilage organism must overcome to remain active in the food, are of vital importance to help ensure food safety and security.

Dairy, meat, cereal and vegetable preservation techniques for pastoral zones

General aspects of food preservation

The environment dictates food availability and the pastoral diet; and these, in combination with foodborne zoonotic diseases, determine the preservation techniques required. Milk, meat and cereals are the main food products that require preservation from key pathogenic microorganisms. These foods have completely different physical properties, such as a_w and acidity. This renders them susceptible to different spoilage organisms and foodborne pathogens, and so – in industrialised manufacturing – they must be processed by specific preservation technologies. In the pastoral context, however, the available resources and technologies are minimal, which restricts preservation to generally simple techniques in accordance with regional and climatic factors and cultural roots. These simple universal techniques are drying, salting, heating, smoking and fermenting (Fig. 1).

Preservation of animal products

Animal products such as milk and meat, as well as blood, are major dietary components for most pastoralists. However, they represent a high risk of zoonotic and foodborne infections. This is related to their high a_w and pH values, nutrient-rich composition and potential direct contamination with animal microbiota from skin, saliva, mammary glands and faeces.

Slaughtering animals is rare among many pastoral communities and meat is often sourced from natural or accidental deaths, or animals that are intentionally slaughtered for occasional ceremonies (49). The rare decision to slaughter livestock is based largely on economics: milk – in contrast to meat – provides a more subsistent system and sustains more people per unit of land than other arid land production systems (50). However, animals also produce a large quantity of meat and other by-products, highlighting the importance of preserving all such raw materials, including blood and fat, which are highly nutritious and rarely wasted by pastoralists.

Meat, blood and fat

Meat requires fast consumption or preservation as spoilage occurs quickly. Therefore, meat is conserved via drying, salting, curing, smoking, fermenting, cooling, cooking, pressing, oil application, and combinations of the above (49, 51, 52, 53). Drying meat, with or without the combination of salting or curing, occurs throughout the world, providing pastirma in Turkey, pemmican in North America and biltong in South Africa (54). Biltong, for example, is prepared in a simple process from long, thin strips of meat, which are

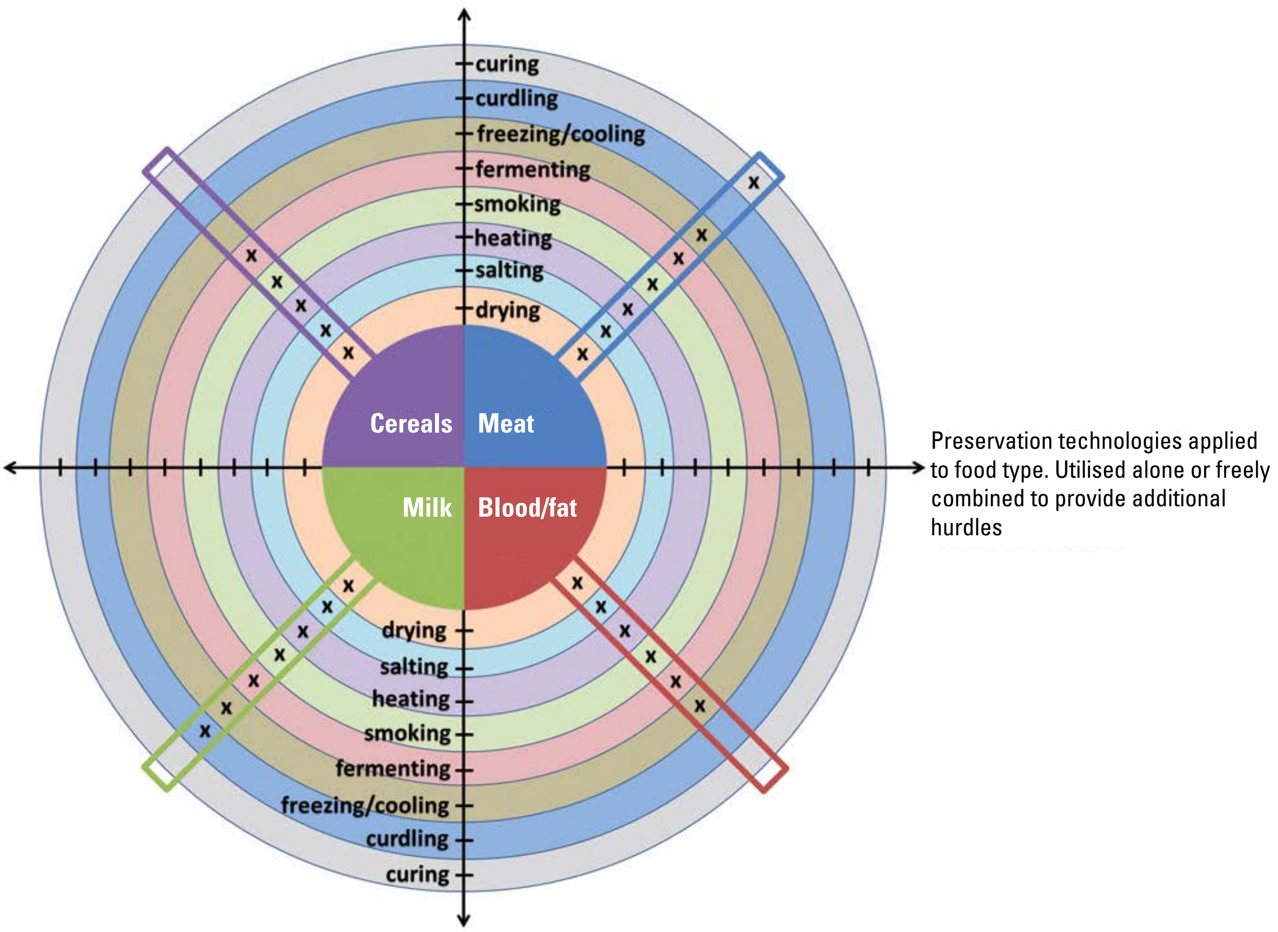

Fig. 1

Principal preservation technologies used by pastoralist communities and the four basic food groups of their diets

These technologies are used alone or freely combined by pastoralists, depending on the product recipe. Each additional technology adds an extra hurdle to enhance food preservation, and the intensity of the treatment determines the preservative effect (e.g. longer drying periods lead to lower water activity). Drying mainly comprises direct sun and air exposure, whereas freezing and cooling processes are limited to pastoralists in cold climatic zones and seasons slightly salted and then air dried for 10–14 days (55). This simple procedure is readily applied and modified by pastoralists worldwide to obtain other products, such as borcha (Mongolia); shamoot (Sudan); ndariko (a Fulani and Hausa speciality); kilishi, by previous roasting of the meat (Nigeria and sub-Saharan Africa); and, with additional curing, kaddid (in Morocco and Tunisia). These techniques use traditional livestock animals as meat sources, in addition to deer, reindeer, antelope, whale, walrus and fish (52, 56, 57, 58, 59). Fish, particularly in northern Europe and Central Asia, is often slightly smoked as well, to repel insects (57). Its simplicity and effectiveness, paired with the dry climatic conditions of many pastoral zones, make drying an ideal preservation technique, and probably the most widespread.

Food preservation benefits from synergistic effects and additional 'hurdles' produced by combining preservation techniques. Drying, for example, is enhanced by being carried out more than once, or being paired with heating, encapsulation (such as in clay meatballs, described below), fermentation or the addition of preservatives, such as curing agents. The Turkish dry meat called pastirma is produced by repeated curing, drying and pressing, while jirge is a fermented meat product from the Hausa community in West Africa (59, 60). The simple cooking of meat pulp, which is then formed into balls and sun dried, is practised by Tswana agro-pastoralists in the Kalahari area of Botswana (12). Clay meatballs represent a variation of this and are traditionally produced in West Africa from meat wrapped in leaves and then encased in clay, before being heated in the fire to form a solid casing for preservation (61). Fruit-paste extract from the fruit of the *Ziziphus abbysinica* shrub is used by pastoralists of West Pokot, Kenya, to preserve meat (51). Pastoralists in northern and Central Asia, including the Himalayas, have developed a large variety of sausage meats and fat and blood products of yak and beef origin that rely on a combination of boiling and freezing, smoking, drying or fermentation for preservation (57, 62). Meat fermentation is widely practised by pastoralists in the Northern Hemisphere. Meat and/or fat from fish and mammals is stuffed into casings of intestines, stomach or skin, or into tubs and sacks, buried in pits, and allowed to ferment, which often leads to a strongly rancid flavour (57). Through these techniques and their various combinations, pastoralists are able to adequately preserve large quantities of meat from a carcass to ensure food security and reduce food waste. In times of emergency, such as drought, reducing numbers of livestock and the adequate long-term preservation of even larger quantities of meat must be undertaken so as not to waste these highly valuable food resources. For such long-term storage, drying – the most widespread technique – is recommended, preferably preceded by at least two of the following processes: heating, salting, smoking and fermenting. Applying sequential hurdles in this way should ensure adequate preservation.

Milk

Milk, in contrast to meat, is obtained daily from dairy animals. Spoilage is rapid, especially at high temperatures and under poor hygiene conditions. The high energy and nutrient content of milk provides an ideal substrate for microorganism growth (25). Therefore, preservation is a must. Owing to climatic conditions, only pastoralists in Central Asia and the Northern Hemisphere – Europe and America – rely on freezing or cooling milk products for winter storage (57). Traditionally, and more commonly, milk is preserved via spontaneous fermentation or backslopping, a process which adds a small amount of a previously fermented batch to the fresh milk (63). This process is further enhanced by combination with drying and even smoking for long-term storage. This leads to a huge variety of dried, smoked and fermented dairy products in northern Europe, Central Asia, Siberia, Mongolia, Tibet and Africa, from cows, camels, goats, sheep, mares or yaks, such as airag, koumiss, fènè, gariss, biruni, rob or suusac, to name only a few examples (64, 65, 66, 67, 68, 69).

Fermentation is applied to milk, meat and cereal products worldwide. As a result of its wide distribution, long tradition and widespread acceptance (63), fermentation possesses great potential to enhance food safety and security as the basis for future innovations (70). However, fermentation does not inhibit acid-tolerant microorganisms such as STEC. Furthermore, these organisms require only low infectious doses to cause disease. A heat-preservation step is thus highly recommended. The combination of heat treatment followed by fermentation establishes an effective hurdle system which uses existing preservation techniques synergistically (42).

However, heat treatment often runs counter to cultural beliefs, which means that stakeholders must be persuaded to use it and socially acceptable interventions must be developed (23, 70). Heat treatment also inactivates most of the fermentative autochthonous microflora, thus reducing the capacity for spontaneous fermentation. This is why fermentation procedures after heat treatment require activation through added bacteria (backslopping) or, ideally, through a starter culture. This opens up a large field of potential innovation and the possibility of discovering previously neglected or undescribed functional microflora.

For long-term storage, raw and fermented milk products are regularly further processed by extended continuous fermentation over several years (69), or by boiling, curdling, drying, freezing or smoking, or combinations thereof (57). In Central and northern Asia and Siberia, in particular, the practice of drying milk products for long-term storage is common. Whey is drained from the yoghurt, which is then sun dried into balls to form qurut. Sometimes the yoghurt is boiled first, so that it curdles, and is then dried into cheese, called bïslag. This process can also be followed by smoking. In this way, special types of cheese, formed into so-called cakes and worm shapes, are produced. Nomadic pastoralists, such as the Mongols, Kazakhs and Turks, for example, often exchanged information on preservation practices, resulting in a large variety of products based on the same fundamental principles of drying (57).

Milk is also preserved by transformation into butter. In the Sudan, this is carried out by fermentation to ease the extraction of a butter called samin, for long-term storage (69). Stored butter can develop rancidity, due to oxidative reactions, but is nonetheless appreciated by several pastoral communities, such as those in Ethiopia and Central Asia. This demonstrates that all components of milk are used for consumption and preservation, leading to very different products of varying organoleptic properties, which are deeply rooted in their respective cultures.

Preserving cereals, vegetables, fruits and plant-based materials

Cereals are mostly affected by pests and fungi, due to their low a_w values. Fungal contamination begins during cropping and initial drying, and so thorough control is required along the supply chain and in storage facilities. Drying is the main approach for raw cereal grains, supported by the addition of ash, minerals or activated charcoal to absorb moisture and oxygen (71). Further procedures include physical barriers, pesticides or insecticides against rodents and insects. However, the application of toxins must be carried out very carefully to avoid toxicity to humans and livestock (71). Once rehydrated and cooked, for example as a porridge, the high carbohydrate content of cereals makes them susceptible to bacterial contamination and the germination of spores. Additional preservation mechanisms, such as cooling, drying, salting, pickling or traditional fermentation, are thus required to ensure food safety and the shelf life of the cooked product (12, 72, 73).

Vegetables and fruits are not regular dietary components of pastoralists. Nevertheless, when and where they are available, they are usually preserved by drying, as in the northern regions of Togo, Benin and Mali (74). Yams, an important dietary component of people in West Africa, are prone to large post-harvest losses. Only the production of sundried yam chips was found to be practicable and feasible for rural farming and these can be stored for up to one year (75). Improved methods for sun drying are also being developed for mangoes, which can serve as a stable vitamin A source, especially in rural areas of West Africa (76). Fermentation processes for the traditional preparation of attiéké, a dish made from cassava, are also being improved for lower aflatoxin levels or detoxification from cyanogenic glucosides (77). The nutritional value and ease of preparation and storage of these types of food should be promoted, through trade and information-sharing among rural farmers, agro-pastoralists, nomadic pastoralists and the growing community of sedentarising pastoralists.

Opportunities and risks for development and innovation: uniqueness and biodiversity of traditional fermentation

Pastoral communities still live simple lives without easy access to modern food-processing technology. Therefore, any intervention, innovation or new approach must take the simplicity and deep cultural roots of the pastoralist way of life into consideration. The introduction of salted, smoked camel meat into Ethiopia and sundried mangoes into West Africa to supply vitamin A are recent examples where local acceptance of these innovations was achieved (76, 78).

However, changing lifestyles and markets have to be considered when developing interventions in order to reach larger communities. There are an estimated 20 million pastoralists and 240 million agro-pastoralists in sub-Saharan Africa alone, with a further 20 million pastoral households throughout the rest of the world, highlighting the economic potential of these communities (79). There is also a growing urban population derived from pastoralism through sedentarisation (80). Since herds are still kept in remote areas, the distances between producers and these newly urbanised consumers have increased, affecting transportation routes and leading to the need to improve food preservation and minimise spoilage, waste and health risks. Innovations in food preservation would ensure that the extensive livestock production systems of pastoralists, suitable for semi-arid and arid environments, can be continued and that market channels remain accessible. This would support the lifestyle and livelihoods of pastoralists and possibly counteract the move towards intensive farming systems, which are undoubtedly less sustainable in semi-arid and arid climates.

The large diversity of traditional fermented products of plant, dairy and meat origin provides an untapped resource of microorganisms to enhance preservation techniques (73, 81), improve nutritional and functional properties (such as iron and zinc availability and vitamin content), and contribute to the detoxification of cyanogenic glucosides or mitigate the risk of aflatoxin (82, 83). Novel genera, species, variants and strains are frequently detected from fermented plant, milk, meat and seafood products worldwide, especially in Asia and Africa (66, 84, 85, 86, 87, 88). The vast majority of fermented products are still not analysed for microbial composition. However, the newer and more accessible DNA sequencing-based technologies linked with functional analyses will assist in unravelling these new species. Metagenomics provides further insight into whole microbiota and the search for novel functional strains with specific properties (89). Nonetheless, careful selection of target regions and bioinformatics tools is needed to accurately differentiate between species (90). In the past, many identification approaches have relied on techniques targeting species known from well-characterised Western products. In addition, classical methodologies may not always discriminate accurately to the degree demanded by the latest advances in taxonomy. A recent example relates to a novel, dairy-adapted variant of *Streptococcus infantarius* subsp. *infantarius* (*Sii*), which is predominant in African fermented milk products (18, 66). *Sii* was first mistakenly identified as *S. thermophilus*, as this was the anticipated species, using an assay targeting the *lacZ* gene (85). Using appropriately adapted tools, several reservoirs of this African *Sii* variant were subsequently detected across sub-Saharan Africa (65, 91). They predominated in traditional fermented dairy products and probably play a pivotal role during product formation – which is in contrast to their expected role as a member of the gastro-intestinal, commensal and opportunistic pathogenic complex of *S. bovis*/*S. equinus* (92).

The main challenges of incorporating such novel species, variants and strains are associated with safety. Food safety standards in Europe and the Western Hemisphere are based on safe history of use, sometimes complemented by strain-specific analysis of the absence of genetically acquired properties, such as antibiotic resistance, based mainly on data from the developed world (93, 94). Such documentation is unfortunately not available for pastoral areas, except for the knowledge that these fermentation procedures are among the traditional practices of the community, i.e. 'tried and tested'. However, proof of innocuity for human consumption is a major prerequisite before any advance can be incorporated into food production (94). Such proof is laborious and costly to achieve, requiring both international collaboration for the latest methodologies and expertise and local research partners for cultural connections to stakeholders. Informal market chains and small-scale producers are key stakeholders for implementation as they handle the majority of trade from pastoralists. Private–public partnerships, especially at ground level, are important to gain the cooperation of these stakeholders through sensitisation, and capacity-building is needed at all levels to establish long-term sustainability of the relationship and implementation of socially acceptable interventions. This must be accompanied by social evaluation of accepted interventions by social scientists and teaching of hygiene principles, combined with an awareness of the quality of raw materials, sources of contamination and animal health.

One principal challenge lies in obtaining adequate research funds to assess the safety of these unfamiliar microorganisms and demonstrate their benefits for the livelihoods of pastoral communities through product innovation, since already-approved Western starter cultures are readily available. However, replacing indigenous strains or species changes the properties of the product and will probably result in low acceptance and compliance, while risking the loss of valuable products and biodiversity.

Conclusion

Pastoralists have a long tradition of food conservation, since it is a necessary part of their lifestyle. Food security and food safety are major factors for survival. Traditional preservation procedures are highly adapted to the lifestyle and resources available.

However, changing lifestyles, markets, climate extremes and growing populations require process modifications to satisfy the demand for quantity, quality and safety. Generally, food preservation method interventions should target simple, traditional, locally rooted and accepted methodologies. Techniques should be combined to compensate for the disadvantages of any single procedure, thus establishing more 'hurdles' for the pathogen and enhancing food safety. Fermentation practices harbour enormous biodiversity potential and opportunities for innovation that should be mined by international public–private partnerships, under a framework of access and benefit-sharing, with reference to the Nagoya Protocol to the Convention on Biological Diversity and the principles laid out by the Swiss Commission for Research Partnerships with Developing Countries (KFPE principles) (95). Early involvement of stakeholders, from pastoralists to informal markets, interdisciplinary researchers, government and industries, are key factors in success and sustainability. Past research has demonstrated that many surprises can occur when analysing foreign ecosystems, highlighting the need for a robust and critical dissection of results, so that novel aspects that might be beneficial for future innovations in food preservation are not overlooked.

Acknowledgements

The authors acknowledge the significant contribution of Dr Zakaria Farah, who established the research programme into camel milk and food processing in developing countries at ETH Zurich, has initiated many international collaborations between ETH Zurich and research institutions in developing countries, and raised awareness for the importance of these topics in the development framework.

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Les innovations en matière de conservation des aliments dans les zones pastorales

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Résumé

Dans les communautés pastorales, dont l'accès aux sources d'approvisionnement alimentaire extérieures est limité, la conservation des denrées alimentaires joue un grand rôle pour assurer la sécurité alimentaire et l'innocuité des aliments. Les méthodes permettant de conserver les aliments crus sont le traitement thermique, la déshydratation et le séchage, le fumage ou fumaison, le saumurage, le salage et la fermentation. Les auteurs décrivent les techniques de conservation pratiquées par les sociétés pastorales, axées sur les composantes les plus importantes du régime alimentaire des populations concernées, à savoir le lait, la viande et les céréales, ainsi que les risques sanitaires qui leur sont associés et les innovations potentielles dans ce domaine. Afin de minimiser les pertes post-récolte et le gaspillage alimentaire et d'améliorer ainsi l'innocuité des aliments et la sécurité alimentaire, il est indispensable d'éliminer durablement les agents pathogènes, d'empêcher la survenue de nouvelles contaminations et d'éviter les risques de sporulation et de croissance de micro-organismes zoonotiques ou d'origine alimentaire. Cependant, les procédures modernes de conservation sont difficiles à concilier avec le mode de vie des pasteurs, ce qui explique qu'elles soient mal acceptées et rarement mises en pratique. Les efforts d'innovation devront donc porter en priorité sur l'amélioration des procédures actuellement acceptées et encourager le recours simultané à plusieurs méthodes afin de créer une synergie qui permette d'atténuer les inconvénients des techniques traditionnelles tout en garantissant la qualité des aliments crus jusqu'au moment de leur consommation. La déshydratation et la fermentation spontanée, deux méthodes majeures de conservation dans les communautés pastorales, offrent un potentiel d'innovation qui peut être largement diffusé parmi ces communautés. La biodiversité exceptionnelle de la microflore présente dans les produits fermentés doit encore faire l'objet d'une caractérisation exhaustive afin d'exploiter le potentiel d'innovation qui lui est associé. Pour qu'un levain naturel constitué de flore bactérienne puisse être élaboré localement en perpétuant, voire en améliorant les caractéristiques souhaitées du produit final, il faut préalablement caractériser ces micro-organismes, évaluer leur innocuité et les conserver. La mise en œuvre durable de ces innovations requiert une sensibilisation minutieuse des parties prenantes, l'analyse de leur acceptabilité par la société et le renforcement des capacités à tous les niveaux, ce qui contribuera à améliorer la sécurité alimentaire et l'innocuité des aliments.

Mots-clés

Bactérie acido-lactique – Déshydratation – Fermentation – Innocuité des aliments – Levain – Pastoralisme – Sécurité alimentaire – Technique de conservation basée sur une combinaison de facteurs.

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Innovaciones en la conservación de los alimentos en zonas de pastoreo

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Resumen

En las comunidades pastorales, que tienen escaso acceso a fuentes alimentarias externas, la conservación de los alimentos contribuye en gran medida a la seguridad y la higiene alimentarias. Para conservar un alimento crudo es posible cocinarlo, secarlo, ahumarlo, encurtirlo, salarlo, curarlo o hacerlo fermentar con microorganismos. Tras describir las técnicas de conservación utilizadas en medios pastorales, prestando especial atención a los componentes básicos del régimen alimentario (esto es, leche, carne y cereales), los autores exponen los riesgos sanitarios conexos y las posibles innovaciones en la materia. Para mejorar la inocuidad de los alimentos y garantizar la seguridad alimentaria es indispensable librarlos duraderamente de microorganismos patógenos, lo que evita la contaminación reiterativa e impide la esporulación y el crecimiento de microorganismos zoonóticos y de transmisión alimentaria, cosa que a su vez reduce el volumen de pérdidas tras la cosecha y el de alimentos echados a perder. Sin embargo, resulta difícil adaptar los modernos procedimientos de conservación a los modos de vida de las sociedades pastorales, lo que hace que rara vez sean implantados o aceptados. Por ello las innovaciones deben ir dirigidas ante todo a mejorar los procedimientos ya existentes y aceptados promoviendo combinaciones sinérgicas para compensar las desventajas de esas técnicas tradicionales y garantizar la calidad de los alimentos crudos hasta el momento en que sean consumidos. El secado y la fermentación espontánea, que son técnicas fundamentales de conservación entre los pastores, ofrecen oportunidades de innovación que las diversas comunidades pastorales pueden compartir. Otro posible yacimiento de innovación reside en la singular biodiversidad de la microflora de los productos fermentados, que en gran parte aún no está caracterizada. La caracterización de estos microorganismos, la evaluación de su inocuidad y su conservación son otros tantos procesos necesarios para obtener cultivos iniciadores adaptados al contexto local que retengan o mejoren las características deseadas del producto final. Para posibilitar una aplicación duradera de tales innovaciones, que contribuirán a lograr mayores cotas de seguridad e higiene alimentarias, es preciso sensibilizar cuidadosamente a los interesados, estudiar la aceptación social de los procedimientos en cuestión e impartir formación a todos los niveles.

Palabras clave

Bacteria acidolácticas – Cultivo iniciador – Fermentación – Inocuidad de los alimentos – Pastoreo – Principio de las barreras – Secado – Seguridad alimentaria.

■

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