CHAPTER 18

Safety of Fermented Fruits and Vegetables

Eduardo Medina, Antonio de Castro, Concepción Romero, Eva María Ramírez, Manuel Brenes
Food Biotechnology Department, Instituto de la Grasa Seville, Spain

18.1 INTRODUCTION

Food fermentation is one of the oldest known uses of biotechnology. Fermented foods have evolved over the centuries worldwide according to local culture and artisanal practices. Indigenous fermented foods have been prepared and consumed for thousands of years and are strongly linked to culture and tradition, especially in rural households and village communities. Knowledge about traditional fermentation technologies has been handed down from parent to child for centuries. Fermentation not only preserves food but also enhances the sensory qualities of the final product. Traditionally, foods have been preserved through naturally occurring fermentation; however, modern large-scale production generally now uses of defined starter culture systems to ensure consistency and quality in the final product (Ross, Morgan, & Hill, 2002).

Many fruit and vegetable pickles are produced by lactic acid fermentation. Usually, pickles can be made by storing in a brine solution, dry salting, or fermenting without salt. The fermentation process involves the oxidation of carbohydrates to generate a range of products, which are principally organic acids, alcohol, and carbon dioxide. Such products have a preservative effect by limiting the growth of spoilage or pathogenic microbiota in the food. These include many organic acids such as lactic and acetic acids produced as end products, which provide an acidic environment unfavorable for the growth of many pathogenic and spoilage microorganisms.

It is only recently that consumer concern for food safety and a high demand for traditional food products has become an important challenge for the food industry. However, safety issues about hygienic conditions and prevalence of foodborne pathogens for a diversity of popular traditional fermented vegetable foods have been rather limited (Panagou, Nychas, & Sofos, 2013). Until recently, the production of these food commodities has presented heterogeneity due to the geographic area and local practice, resulting in a final product with diverse microbiologic, physicochemical and sensory qualities. This has drastically changed; production has shifted from artisanal practice to the industrial level under strict processing and hygienic conditions (Panagou et al., 2013).
These foods play an important role in the economy and food security of these producing countries. This review discusses the technologies of some popular traditional foods of vegetable origin around the world and discusses the potential microbiologic risks associated with their consumption and the food safety challenges that they raise.

18.2 TABLE OLIVES

Olive (Olea europaea L.) is a typical Mediterranean tree that has been grown in the region for millennia, and its fruit has been used in a variety of ways in the diet as table olives. The olive fruit is a drupe. It contains a bitter component (oleuropein) that makes it a fruit that cannot be consumed directly from the tree, but has to undergo a series of processes that differ considerably from region to region and that also depend on variety. According to the CODEX Standard for Table Olives (CODEX, 2013), table olives are classified into three types, depending on the degree of ripeness of the fresh fruit – green olives, turning color olives, and black olives. However, methods for processing are diverse. All aim to remove the glycoside oleuropein that makes olives unpalatable, even when fruits are fully ripened. In compliance with the Trade Standard Applying to Table Olives adopted by the International Olive Council (IOC, 2004), the following trade preparations can be found in the international market:

1. Treated olives. Bitterness is removed by alkaline treatment, and olives are immersed in brine in which complete or partial fermentation takes place. Treated olives can be preserved by the addition of acidifying agents.

2. Natural olives. Oleuropein is hydrolyzed by brining or successively rinsing in water. Olives are placed directly in brine, in which a complete or partial fermentation takes place. Addition of acidifying agents can be used for preservation.

3. Dehydrated and/or shriveled olives. Olives that have not undergone mild alkaline treatment, preserved in brine, or partially dehydrated in dry salt, treated by heating or some other process. Black olives in dry salt are a principal example of this.

4. Olives darkened by oxidation. Olives are preserved in brine, fermented or not, darkened by oxidation in an alkaline medium, and preserved in hermetically sealed containers subjected to heat sterilization; these should be of a uniform black color.

5. Specialties. Olives may be prepared by means of a distinct procedure or added to those mentioned. Such specialties retain the name “olive” as long as the fruit used complies with the general definition discussed earlier.

Despite of the numerous processing methods of table olives used all over the world, only some of them undergo a fermentation step in the processing. The most important are described in the subsequent section.

18.2.1 Spanish-style green olives

The alkali treatment and brine cause the release of the fruit cell juices, forming a culture medium suitable for fermentation. There is a predominance of Lactobacillus pentosus,
which produces lactic acid from glucose (Sánchez, Rejano, Montaño, & de Castro, 2001). Lactobacilli and yeasts are the primary microorganisms responsible for and present during fermentation. At the end of the process, the pH value is around 4, and free acidity is above 0.6%. When properly fermented, olives have a long shelf life.

18.2.2 Natural olives
Fermentation of these olives takes a long time because, in fruits not treated with alkali, diffusion of soluble components through the epidermis is slow. A diverse microbiota grows in these brines (8–10% NaCl, w/v), although yeasts are the microorganisms always present throughout the process (García, Durán, & Garrido, 1985). The presence of LAB depends on the salt concentration and polyphenol content of the variety used.

18.2.3 Olives darkened by oxidation
Preservation is usually in brine, and a fermentative process comparable to that of natural black olives takes place. Yeasts continue to be the most important microorganisms in these solutions, although LAB can be found when acidified water is used instead of salt brine (De Castro, García, Romero, Brenes, & Garrido, 2007). A complete fermentation is not required. The essential operation is the oxidation that permits a complete blackening of the fruit skin and uniform coloration of the flesh. The final canned product has sensory qualities very different from those of fermented fruits obtained by other processes. The pH values are between 5.8 and 7.9, and the NaCl content is between 1% and 3% (w/v). Due to these chemical characteristics, which do not guarantee safety, olives darkened by oxidation have to be sterilized to prevent any possibility of foodborne pathogen growth.

18.3 CUCUMBERS
The origin of the cucumber (Cucumis sativus L.) has been attributed to Africa, China, India, or the Near East. Cucumbers are now grown throughout the world using fields or greenhouse culture. Cucumber fermentation and storage in bulk tanks is a method that allows the preservation of cucumber fruits for extended periods of time. Commercial cucumber fermentations are carried out in open tanks containing between 50% and 60% whole cucumbers and between 50% and 40% cover brine solution containing acetic acid, added as concentrated vinegar, and sodium chloride to achieve equilibrated concentrations of 25 mM acetic acid and 1.03 M sodium chloride (6% w/v), respectively. Sometimes calcium chloride is added to allow a crisp texture. Cucumbers are covered with wooden boards to prevent them from floating. The brine surface is exposed to UV light from the sun, which helps prevent yeast or mold growth.

Primary fermentation is carried out by LAB and yeast, and the rate of growth is dictated by the brine concentration (5–8% NaCl, w/v, initially) and temperature (Etchells & Jones, 1943). Fermentation by LAB is relatively rapid, and fermentable sugars are converted mostly to lactic acid, with little gas formation. The primary fermentation
occurs within 2–3 weeks reaching a final pH range between 3.1 and 3.5. The flavor of cucumber pickles varies widely, depending upon the spices and flavoring added to the numerous products. Proper levels of acid and salt in the finished product are essential and vary among the many products that are made, although the preservation of fermented pickles is ensured by pasteurization (Etchells & Jones, 1942).

### 18.4 Sauerkraut

Cultivars of cabbage (*Brassica oleracea*) originated in the Eastern Europe and Asia Minor. Fresh cabbage for sauerkraut is harvested mechanically or by hand and transported to the processor, where it is grade, cored, trimmed, shredded, and salted. Pederson and Albury (1969) defined the optimum conditions for fermentation of cabbage into sauerkraut with 2.0–2.2% of salt (w/v) and fermenting at a temperature of 18°C. Tanks are uniformly filled, heaped to extend slightly above the top of the tank, and loosely covered with plastic sheeting, which provides an anaerobic seal (Fleming, Kyung, & Breidt, 1995). The addition of salt to the shredded cabbage induces a high osmotic pressure, which leads to the extraction of juice from the fruit. This juice contains fermentable sugars. Microorganisms naturally present on the cabbage leaves will, in the absence of oxygen, use these sugars to produce lactic acid. *Leuconostoc mesenteroides* and *Lactobacillus plantarum* are the microorganisms that predominate in the fermentation.

The cabbage is allowed to remain in the tanks until at least 1% lactic acid is formed (about 30 days minimum, depending upon the temperature) and can be stored beyond this time until needed for further processing. The sauerkraut may be packaged in can, glass, or plastic containers. When packaged in glass or plastic, the product is not heated. Instead, preservatives are added, and the product is held under refrigeration (Stamer & Stoyla, 1978). Canned sauerkraut is preserved by pasteurization without the addition of preservatives.

### 18.5 Fermented Onion (Sour Onion)

White, yellow storage, and sweet onions (*Allium cepa*) are typically used for lactic acid fermentation to produce sour onion. The sour onion has a tart acidic taste characteristic of sauerkraut, with onion flavor but without the pungency of raw onions (Robert & Kidd, 2005). Sour onions could be used in the same manner as sauerkraut as a condiment or side dish. The procedure for lactic acid fermentation of onions follows a similar process as for making sauerkraut from cabbage (Pederson & Albury, 1969). The onions are peeled of their dry outer skin, destemmed, and sliced. Salt is added to the slices with between 1.5% and 2.5% (w/w) onion. Also, sugar can be added in a range of 1–2% (w/w). Onions probably do not have the necessary LAB for fermentation, so they need the addition of a starter culture. An alternative method to promote fermentation is to add cabbage to the onions; the LAB in the cabbage ferment and grow and then carry
over to ferment the onions directly. The fermentation produces sour onion, with a pH between 3.25 and 3.35 and 1.2–1.5% (w/v) of lactic acid.

### 18.6 Fermented Carrots

Carrots (*Daucus carota*) can undergo lactic acid fermentation with good retention of color and texture and the salt-sour flavor typical of fermented vegetables (Niketic-Aleksic, Bourne, & Stamer, 1973). Carrots are peeled, washed with tap water, and cut into pieces. Treatment of vegetables with lye (1–2% NaOH, w/v) prior to placing them in brine may therefore be a useful alternative to pasteurization to achieve controlled fermentation (De Castro, Rejano, Sanchez, & Montano, 1995). After treatment, the alkaline solution is removed, and brine is added (5% NaCl, w/v). The brine is acidified with acetic acid to neutralize the NaOH absorbed by the carrots. After brine addition, and when the pH is around 5–7, a starter culture is inoculated. The fermentation of lye-treated carrots results in a greater use of the fermented material. Because not all sugars are consumed in the fermentation, long-term stability of the fermented carrots is not ensured, with a risk of secondary fermentation in the packed product. Appropriate preservation systems such as addition of preservatives or heat treatment (pasteurization) are frequently used in the packaging.

### 18.7 Caperberries

Caperberries are the product prepared from the fruits of the Mediterranean shrub *Capparis spinosa*. The production zone is limited to the Mediterranean basin. The usual commercial procedure for the processing of pickled caperberries consists of a first step of immersion in water for 4–7 days, during which there is a vigorous fermentation causing a color change of the fruit from green to yellowish (Sánchez, de Castro, & Rejano, 1992). The fruits are next placed in brine of 10–12% NaCl (w/v) and fermentation is finished. Caperberry fermentation is carried out almost exclusively by LAB. After a period of time, the salt concentration is raised to levels more than 10% (w/v) at equilibrium or the brine is changed for a fresh one to guarantee bulk storage until commercialization. Vinegar, spices, and aromatic products are usually added to the packing brine (Sánchez et al., 1992).

### 18.8 Pickled Garlic

Garlic (*Allium sativum* L.) has been used through the ages as an ingredient in the preparation of condiments, sauces, and seasonings. A heat treatment of blanching is essential for the preparation of pickled garlic to prevent enzymatic activity that would produce a pungent flavor and other unwanted effects during storage (Rejano, Sanchez, de Castro, & Montano, 1997). After cracking the bulbs to separate the cloves and washing with tap water, the garlic is covered with brine (8% NaCl, w/v) and inoculated with a starter culture. Garlic fermentation improves flavor, enriches with desirable metabolites produced
by microorganisms, and enhances safety. The controlled fermentation using a starter culture of *Lactobacillus plantarum* was studied by De Castro, Montaño, Sanchez, and Rejano, 1998. The starter culture grew abundantly in the case of blanched garlic, producing mainly lactic acid and reaching a pH of 3.8 after 7 days, but its growth was inhibited in unblanched garlic. The presence of residual fermentable matter in the fermented garlic justifies the use of a preservation method, such as pasteurization, to ensure the microbiologic stability of the packed product.

### 18.9 Potential Hazards Associated with Traditional Fermented Vegetables: Public Health Risks

Potential hazards in fermented vegetable food can be classified as physical, chemical, or biologic hazards. Physical hazards include the presence of foreign matter in processed foods, such as metal, glass, or plastic objects, particulate matters in brines, and stones in pitted olives. Like foreign matter, the entry of a chemical may be inadvertent, accidental, or deliberate. Chemical contaminants can cause immediate toxic effects. If cleaning agents or sanitizers are used incorrectly in the processing plant, they could be considered as potential contaminant. Other chemical contaminants of interest are allergens, especially when equipment is shared with other types of food. Use of pesticides in the growing area can create a potential hazard if they persist in the final product. Food preservatives such as benzoates are normally added to fermented vegetables. Furthermore, benzoic acid in the presence of ascorbic acid, another food preservative, may decarboxylate to benzene, which is classified as carcinogenic in humans (IARC, 1987). Benzene was found in canned and jarred carrot samples (Lachenmeier, Steinbrenner, Löbell-Behrends, Reusch, & Kuballa, 2010) and, in cucumbers and caperberries, but only when packed in plastic pouches after prolonged storage at room temperature (Casado et al., 2011).

Biologic hazards can occur during fermentation as a result of microbial metabolism, like biogenic amines in sauerkraut fermentation. The use of starter cultures can also contribute to the suppression of microorganisms, forming biogenic amines (Halász, Baráth, & Holzapfel, 1999). In addition, mycotoxins represent a major issue regarding the safety of traditional vegetable products. Contamination of table olives with various mycotoxins is well documented, and Greek-style black olives are the most likely to be contaminated (Gourama & Bullerman, 1988).

Control of microbiologic quality is of major importance in the prevention of foodborne illness and is very relevant in fermented vegetables. The origin of the microbiota in fermented foods is diverse – fruits, water, brine, pipes, containers, equipment in general, and atmosphere. The raw material generally contains an extensive microbiota, which could potentially grow and compete for nutrients. Some traditional technologies aim to upset the ecologic parameters of the raw material so as to select for specific beneficial groups of microorganisms and inactivate as many of the microorganisms initially present in the food as possible. This allows for the lowest development of microbiologic changes during storage.
LAB represent only a small proportion of the initial microbiota in the raw fruit, and this group is responsible for lactic fermentation of the product. LAB have sufficient acidity to produce a low pH in pickles, and then the resulting product may be considered reasonably safe. In fermented pickled vegetable products, pH, acidity, and reduced water activity ($a_w$) (high salt content) are the main parameters that inhibit undesirable microorganisms to safeguard the health of consumers. Also, other agents that contribute as antimicrobial factors, such as the type of organic acid (acetic or lactic acid), production of carbon dioxide, ethanol, and bacteriocins, as well as lowering of the redox potential and nutrient depletion, should be considered (Adams & Nicolaides, 1997).

Particular attention should be given to the occurrence of Clostridium botulinum and its toxin, because this is considered as one of the most important safety issues in fermented vegetables. C. botulinum is extremely common in soil and waters and is a spore former. The toxin is only produced when the bacteria are in a vegetative form. In acidic food, pH is considered a critical factor. In addition, botulism toxin formation is unlikely at pH $< 4.8$ and $a_w < 0.94$ (Odlaug & Pflug, 1979; Briozzo, de Lagarde, Chirife, & Parada, 1986). Fermented vegetables at a pH higher than 4.6 are considered to be low acid and, if packed in sealed containers in the absence of oxygen and not refrigerated, can host C. botulinum. This organism, generally in the spore form, germinates into the vegetative form, in which cells produce toxins as they multiply.

### 18.10 EPIDEMIOLOGIC DATA

Most fermented vegetables are considered as ready to eat (RTE) products that are usually consumed without cooking, thus making contamination with pathogens a potential public health concern. Fermented or acidified vegetable foods, such as table olives, pickles, or sauerkraut have a long history of microbial safety. However, traditional fermentation undertaken by the indigenous microbiota is normally an uncontrolled process, which can result in inconsistent final products that may harbor undesirable microorganisms. Street markets were the origin of many of the samples in which food pathogens were found, whereas undesirable microorganisms were not found in most industrially packed samples.

The presence of numerous genera of spoilage bacteria, including Salmonella and Shigella spp., Aeromonas hydrophila, Yersinia enterocolitica, Staphylococcus aureus, Campylobacter, Listeria monocytogenes, Escherichia coli O157:H7, and other pathogenic strains have been recognized for many years on vegetables that are used in RTE and processed foods (Beuchat, 1996). Staphylococci grow well at salt concentrations between 7% and 10% and at a low pH of 4.2, and other pathogens such as E. coli O157:H7, L. monocytogenes, and Salmonella spp. have been shown to develop resistance under stressful conditions, including low pH (Gahan, O’Driscoll, & Hill, 1996; Lee, 2004).
The presence of pathogenic bacteria in brine of table olives has been reported. For example, *L. monocytogenes* (Caggia, Randazzo, Salvo, Romeo, & Giudici, 2004), *S. aureus* (Asehraou, Faid, & Jana, 1992; Pereira, Pereira, Bento, & Estevinho, 2008; Romeo, Piscopo, Mincione, & Poiana, 2012), and coliforms (Asehraou et al., 1992; Franzetti, Scarpetlini, Vecchio, & Planeta, 2011; Pereira et al., 2008; Romeo et al., 2012), *Y. enterocolitica* and *E. coli* (Lucena-Padrós, Caballero-Guerrero, Maldonado-Barragán, & Ruiz-Barba, 2014), have been found in table olives from several countries. Furthermore, botulism outbreaks due to *C. botulinum* have been associated with table olives, and recalls of the suspected products have also been reported (Fenicia, Ferrini, Aureli, & Padovan, 1992; Cawthorne et al., 2005; Kailis & Harris, 2007). Although different pathogenic microorganisms have been isolated from fermented vegetables, there are very few reports about illness outbreaks caused by the consumption of this type of food. In the case of table olives, the only important incidents have been related to the presence of botulinum neurotoxins. The most severe outbreaks took place in the United States in 1919–1920, the so-called ripe olive scare (Horowitz, 2011). However, the products implicated, which resulted in around 27 fatalities, were not actually fermented products but were olives darkened by oxidation that were improperly sterilized. Other botulism outbreaks caused by black olives, with no deaths, were attributed to incorrect storage at ambient temperature once 5-kg cans were opened (Fenicia et al., 1992). There have been seven other episodes of botulism intoxication from 1990 until the present, with around 40 human cases and one death, in Finland (Jalava et al., 2011). The causes of all these outbreaks were incorrect manufacturing (*pH* values above acceptable limits, inaccurate heat treatment) or incorrect handling practices. It should be emphasized that artisanal products were often the origin of these outbreaks, whereas industrial producers of fermented vegetables have an excellent safety and wholesomeness record. Apart from pathogenic microorganisms, unauthorized or too high a content of different substances have been detected in fermented vegetables and notified to the Rapid Alert System for Food and Feed by countries of the European Union. Unauthorized colors, too high a content of erucic acid, sulfite, benzoic acid, and others are the most common nonconformities. Nevertheless, to the best of our knowledge, no illness has been documented with these by consuming fermented vegetables.

### 18.11 Contemporary Studies and Trends

Acidified vegetable products can be heat-processed to ensure shelf stability and safety. The times and temperatures needed for that purpose have been reported (Breidt, 2006), and a 5-log reduction standard has been adapted by the US Food and Drug Administration (FDA) (Breidt, Hayes, Osborne, & McFeeters, 2005; Breidt, Sandeep, & Arritt, 2010). Cucumber brines were used to represent vegetable fermentation because table olives, cabbage, and other vegetables may have inhibitory compounds that could affect

---

**References**


---
microbial survival. These studies revealed that *E. coli* O157:H7 could survive in cucumber fermentation brines and requires between 3 and 24 days to achieve the 5-log reduction. Among other factors, brine pH and acidity, temperature, and redox potential were established as the main characteristics affecting the death rate in cucumber brines (Breidt, Hayes, & McFeeters, 2007). These data may be used to aid manufacturers of fermented vegetable products to determine safe production practices based on fermentation pH and temperature.

The same problem is present for other fermented or acidified vegetable products. For example, survival of *E. coli* O157:H7 and *L. monocytogenes* during kimchi fermentation has been addressed (Cho, Lee, & Choi, 2011). Moreover, survival of *L. monocytogenes* and *Salmonella typhimurium* in spontaneous cauliflower fermentation has been demonstrated (Paramithiotis, Doulgeraki, Tsilikidis, Nychas, & Drosinos, 2012), and these authors have raised the need for safety reassessment of fermented vegetables. Sauerkraut was inoculated with a cocktail of *E. coli* O157:H7 and *L. monocytogenes* and monitored during the fermentation. (Niksic et al., 2005). *E. coli* and *L. monocytogenes* persisted in the brines for most of the fermentation, although at the end of the fermentation, neither pathogen had detectable population.

Recently, Grounta, Nychas, and Panagou (2013) investigated the survival of foodborne pathogens inoculated on natural black table olives during aerobic storage without brine. They demonstrated that natural black olives are not a favorable environment to support the growth of the investigated pathogens, and the population of all pathogens had a rapid decline within the first 2 days of storage, depending on the case. Medina, Brenes, Romero, Ramirez, and de Castro (2013) investigated the fate of *E. coli, Salmonella enterica, L. monocytogenes,* and *S. aureus* when they were inoculated into different industrial olive brines, and their survival was correlated with the presence of phenolic and oleosidic substances. The time needed to reduce the inoculated pathogen populations by 5 log oscillated between less than 5 min and up to 17 days in the least deleterious conditions. It has been recently that some phenolic and oleosidic substances present in olive brines possess significant bactericidal activity against food and plant pathogens (Brenes et al., 2011; Medina, Brenes, García, Romero, & de Castro, 2009).

According to these studies, even though the brine environment and fermented vegetables do not seem to support the growth of pathogens, findings have shown the survival of some pathogenic strains and thus probable transmission of the pathogen through the packaging and retailing or direct retailing in bulk.

**18.12 REGULATORY STATUS**

Fermented vegetables are a food; hence, their manufacture, distribution, storage, and consumption are governed by food, health, and safety regulations. Among the most typical fermented vegetables, green olives, cucumbers, and caperberries are usually packaged
and preserved by their own physicochemical characteristics (relatively high values of acidity and salt), although a preservation method such as pasteurization is frequently used to guarantee the best preservation when certain levels of acidity and salt are desirable. If the fermentation process is successful, the final product is microbiologically stable and safe and can be stored without the need of thermal treatment or the use of preservatives for a long period of time (Breidt, 2006).

Outbreaks of disease caused by vegetative cells of acid-resistant food pathogens in some acid foods have caused concern about the safety of acidified vegetable products by the FDA and acidified vegetable industry. The FDA issued regulations governing the safe manufacture of acidified vegetables that were promulgated in 1979 (21 CFR part 114). The purpose of regulating these products, which have an excellent safety record, was to prevent botulism due to improper acidification. The final pH value for acidified foods must be at or below 4.6 for all ingredients. It has been shown that spore outgrowth and toxin production by \textit{C. botulinum} will not occur if the pH is maintained below 4.6 (Breidt & Caldwell, 2011). Bacterial pathogens have been reported on fresh cucumbers and other vegetables used for commercial fermentation. The FDA currently has a 5-log reduction standard for \textit{E. coli} O157:H7 and other vegetative pathogens in acidified pickle products.

No official microbiologic criteria for table olives are available. The minimum requirements for these characteristics should comply with the trade standards for table olives in international trade established by the International Olive Council (IOC, 2004) and the standards of the Codex Alimentarius provided by the FAO and the WHO (CODEX, 2013). Heat treatment is only mandatory for ripe olives, which need to be sterilized because their pH values are around 5.5–6.5, far above the safety limit for preventing the growth of \textit{C. botulinum}. Although olives preserved by salt and acidification or natural fermentation are usually free of \textit{C. botulinum} and its toxin, only if the pH is constantly monitored and maintained below 4.6.

Although there are no specific microbiologic limits for fermented fruits and vegetables, all these products are RTE foods, and therefore European Commission (EC) Regulation No. 2073/2005 on microbiologic criteria for foodstuffs is applicable to countries in the European Union. According to this regulation, amended by Regulation No. 1441/2007, the only microorganism that has to be considered in every RTE food not intended for infants or special medical purposes is \textit{L. monocytogenes}, with a limit of 100 CFU/g of product, a criterion to be maintained during the whole shelf life. This regulation makes also a distinction between foods that are able or unable to support the growth of \textit{L. monocytogenes}. Products with pH $\leq$ 4.4 or $a_w \leq 0.92$ are considered to belong to the second category, as well as products with a pH $\leq$ 5.0 and $a_w \leq 0.94$. Fermented fruit and vegetables usually have $a_w$ values higher than 0.94, and therefore it is of paramount importance to guarantee that the pH of the fermented vegetables is always maintained below 4.4 during shelf life, not only to prevent the growth of \textit{L. monocytogenes} but also to prevent the growth of other foodborne pathogens.
Apart from microbiologic criteria, fermented fruits and vegetables should comply with the maximum residue levels of any pesticide or other contaminants. For example, the CODEX Standard for Pickled Cucumbers (CODEX, 1981) states the limits of tin and lead, and the CODEX Standard for Pickled Fruits and Vegetables (Codex, 2007) alludes to pesticide residues. The objective of processors should be to achieve zero risk for foodborne illness and injury. This can only be achieved if processors follow practices that ensure that vegetables selected for processing are produced by good agricultural practices (GAP), processed by the principles of good manufacturing practices (GMP), and produced at premises with equipment and by personnel that can meet good hygienic practices (GHP). All these prerequisites should be considered under the umbrella of food safety management systems, which include not only the hazard analysis and critical control point (HACCP) system, but also other tools to prevent intentional adulterations, such as CARVER (criticality, accessibility, recuperability, vulnerability, effect, and recognizability), TACCP (threat assessment and critical control points), and VACCP (vulnerability analysis and critical control points), which are mandatory in some countries.

18.13 CONCLUSIONS

Fermented vegetable products have common characteristics of high acidity and low pH that usually make them safe and microbiologically stable all along their shelf life. However, survival of certain acid-resistant pathogenic bacteria can occur when they are not properly processed or handled. Different additives such as acidifiers (e.g., acetic, lactic, malic, citric, and other acids), preservatives (e.g., sorbates, benzoates, sulfites, in some cases), and others can be added to pickled products to enhance their safety and keeping quality. Nevertheless, the most extended practice is the heat treatment, pasteurization. Heat treatment deactivates vegetative bacteria forms of possible pathogens, preventing their growth in this environment. Fermented fruits and vegetables maintain an exceptional record of wholesomeness that together with their valuable nutritional and organoleptic attributes, make them foodstuffs from the past and toward the future.

REFERENCES


