4

Table olive processing: general aspects

There are different processing procedures for the production of table olives, and in setting up a production facility there are a number of considerations that need to be taken into account. Key areas in the processing facility need to be separated, such as raw olive storage and grading areas, chemical storage (both for production and cleaning) and staff facilities. The materials to be used in the production of table olives must be of food grade quality and potable water must be used. The equipment must be made from food grade stainless steel, plastic or fibreglass and the facility must comply with statutory health and environmental regulations. The types of table olive processes used for black table olives, shrivelled black olives, turning colour olives, green-ripe olives, bruised olives and split olives are explained. The chapter also discusses secondary processing and the finished products. The authors have also examined the storage of raw olives prior to processing and have suggested a general protocol for the processing of table olives from receipt of the raw olives to the finished product. The environmental needs of the processing area are also considered with the types of processing to be undertaken. Records of all the processes used in the processing facility need to be kept so that any problems with the final product can be traced back to a specific point in the production line.

Introduction

Table olive processing involves the transformation of bitter inedible olives into an edible foodstuff. Processing methods also preserve the olives from natural deterioration so that they can be stored for significantly long periods and consumed as required. As well as being palatable, when processed the transformed olives must be safe to eat and have retained their nutritional qualities. Additional preservation techniques such as pasteurisation, heat sterilisation and preservatives are also used for some packaged olive products.

Processed table olives, a manufactured food, need to be produced by acceptable technologies under safe conditions for consumers and table olive operatives. The olives to be processed need to be grown, harvested, stored and transported by methods that minimise physical damage as well as prevent chemical and/or microbiological contamination.

Raw olives at all stages of maturation are bitter and mostly inedible and require processing before being suitable for consumption. As with other types of food processing, table olives should be processed under *Good Hygienic and Manufacturing Practices* using quality assured ingredients. Raw and processed olives must meet quality standards including varietal authenticity as well as physical, chemical and microbiological standards to ensure safe and nutritious products.

Table olive processing should be approached systematically. Processing facilities must be appropriate for the production and storage of table olive products and meet food, environmental, and occupational health and safety requirements. All processing must be undertaken in ways that minimise environmental impacts, such as fewer washing steps, and, where possible, reusing fermentation brines as packing solutions.

Requirements for the production of high quality table olives are:

- potable water (water that meets drinking standards);
- quality raw olives;
- food grade chemicals (salt, lye, food acids);
- food grade herbs, spices and condiments; and
- food grade cleaners and sanitisers.

All material used in table olive processing, such as water, salt, lye (caustic soda, sodium hydroxide), acetic acid, lactic acid, citric acid, hydrochloric acid, dextrose, sorbic acid, ferrous gluconate or lactate, herbs and spices, must meet food grade standards. Equally important in table olive processing is the water used for all operations in the plant, including washing and processing, as it can be a source of contaminants. Only potable water, which meets prescribed microbiological, chemical and physical standards set by national/regional authorities, must be used to reduce the risk of food poisoning and product spoilage.

Unlike olive oil production, where the technology is well defined and the processing automated, table olive production needs careful planning with regard to the size of the operation, the processing methods to be used and the products to be made. Safety issues are a high priority and if processing is not controlled effectively, spoilage of the olives and possibly food poisoning are both potential negative outcomes.

Table olive processing methods and varieties

During the planning phase, decisions need to be made regarding the types of olives to be produced and which varieties to use. Such information is given in Table 4.1. Even if other varieties are used, the processor must ensure that they have sufficient quantities of raw olives for commercial table olive production.

Table 4.1. Olive processing methods and suggested varieties

Processing method/style	Suggested varieties
Green	
Untreated in brine	*Conservolea*, *Chalchidikis*, *Manzanilla*, *Hojiblanca*, *Barouni*, *Picual*, *Verdale*
Spanish-style green (lye treated)	*Manzanilla*, *Hojiblanca*, *Sevillana*
Turning colour	
Ligurian olives	*Taggiasca* or *Frantoio*
Greek-style in brine	*Jumbo Kalamata*, *Verdale*
Black	
Naturally ripe in brine (untreated in brine)	*Conservolea*, *Frantoio*, *Leccino*, *Ascolana*, *Picual*
Kalamata-style	*Kalamata*, *Hojiblanca*, *Leccino*
Californian/Spanish-style (lye treated)	*Manzanilla*, *Californian Mission*, *Hojiblanca*
Salt-dried	*Thrubolea*, *Manzanilla*, *Frantoio*, *Kalamata*, *Leccino*
Heat-dried	*Manzanilla*, *UC13A6*, *Kalamata*, *Leccino*
Specialty products	
Marinated	Processed destoned green/black olives of any variety
Destoned – stuffed	*Manzanilla*, *Sevillana*
Pastes and tapenades	Destoned processed green or black olives of any variety

Good Manufacturing Practice (GMP) and table olives

Processors need to develop procedures that ensure the olives to be processed are of the correct variety, at the same maturation state, not damaged or defective and of a size relevant to market standards. When packed for sale, olives should be of uniform size, except for specialty mixes where several varieties are used. Sizing and grading is undertaken manually or by machines. The Codex Alimentarius (1987)/IOOC (2004) Table Olive Standards have listed specific size ranges (see Table 4.2) for processed table olives. Exporters will also need to check with individual countries for any local requirements.

Table 4.2. Summary of the size scale for grading table olives as set by the Codex Alimentarius (1987)/IOOC (2004) Table Olive Standards

Size range olives/kilogram	Interval within a size range
60/70–111/120	10
121/140–181/200	20
201/230–381/410	30
Above 411	50

Processing olives should be commenced as soon as possible, preferably within one to two days after harvesting. Olives must be washed in potable water prior to entering the processing line. Process control (microbiological, chemical and physical) is essential during table olive production. Procedures must be developed and documented according to Hazard Analysis Critical Control Point (HACCP). Product profiles must also be developed for each olive type being produced, for example *Kalamata*, Greek-style black or green, Spanish-style green, Californian black, Ligurian, Thrumbes or dried. All inputs, such as olives, water, herbs and spices, chemicals and cleaning agents, must have product profiles and be under inventory control. A system allowing for product recall, an essential element in food production, must also be in place.

Water requirements for table olive production

Water is required for all washing procedures as well as preparing brine and lye solutions. As water can contain a number of contaminants (physical, chemical or microbiological), all water used for table olive processing must meet drinking water standards (potable water). The general characteristics of potable water are:

- physical: there should be minimal particulate matter;
- chemical: salts, iron, heavy metals and organic chemicals must be within health and safety limits; and
- microbiological: no harmful organisms are present.

Scheme water (water from state or municipal authorities) is generally of potable water quality and so can be used as is. However, this water source should be tested at the point of entry into the processing plant and thereafter should be tested annually. Groundwater and tank water can contain a number of contaminants, so water from these sources should be tested and treated before use. Groundwater, tank water and water from dams, lakes and rivers can typically have one or more of the following types of contaminants:

- physical: particulate matter, mineral, organic matter;
- chemical: herbicides, pesticides, industrial chemicals, naturally occurring salts and metals; and
- microbiological: microorganisms of faecal and/or plant origins.

Water of unknown quality needs testing by an accredited laboratory and must be treated before use. If contaminated with microorganisms the water must be sanitised, for example by UV irradiation, in the following cases: (1) if coliform/thermotolerant coliform organisms are present, or (2) if there are no coliforms/thermotolerant coliform organisms present but the Heterotrophic Plate Count is >500 CFU/ml.

Typical results of tank water analyses presented in Table 4.3 indicate that both tanks tested had higher than normal Heterotrophic Plate Counts and coliforms. The Heterotrophic Plate Counts, although high, are typical of rainwater tank water. The coliform count is unacceptably high. Successfully sanitised water should have a Heterotrophic Plate Count of 500 CFU/ml or less.

Table 4.3. Typical microbiological analyses of untreated rainwater tank water undertaken by the authors
CFU/ml, colony forming units per millilitre.

Parameter	*Results*		
	Potable water	*Tank water 1*	*Tank water 2*
Appearance	Clear, colourless	Clear, pale, straw coloured	Clear, colourless with debris
Heterotrophic plate count			
At 21°C CFU/ml	<500	>1000	>1000
At 31°C CFU/ml	<500	>1000	>1000
Coliforms CFU/100 mL	0	23	33
Thermotolerant coliforms/100 mL	0	<2	<2

UV light disinfection of water. Equipment for UV light irradiation of water is easy to install and the process is effective against most microorganisms. Filters should be fitted before the UV system for the removal of particulate and organic matter by filtration and/or reverse osmosis. This is critical to effective UV disinfection. Using reverse osmosis is expensive and the system requires regular maintenance, so its use in table olive processing is optional. Variable flow rates can also reduce the effectiveness of the process.

Water source → Filtration/reverse osmosis → UV sanitiser → Storage tank → End use

End uses of treated water relevant to table olive processing include: washing water for olives, preparing lye solutions and fermentation brines, and for packing solutions. An alternative to UV sanitising of water is to use a continuous heat exchange pasteuriser where incoming water is treated at 72°C for 15 seconds. Other disinfection methods for water are available but some that use chemical sanitisers are less suitable as they may interfere with table olive processing, particularly where naturally processed olives by fermentation are being made. Where treated water is retained in water storage tanks, such tanks should be covered and the water utilised as quickly as possible. Tanks not being used should be emptied, cleaned and kept clean and dry.

Planning table olive processing facilities

Table olive activities can be divided into four broad categories: producing raw olives (see Chapter 3), primary processing of raw olives, secondary processing of primary processed olives, and packing and marketing olive products.

The Australian table olive industry is in a position to implement the latest practices in table olive processing. Much of the recent international research effort has been directed to the chemical, microbiological and organoleptic control of table olive production. Emphasis is placed on the prevention of spoilage due to poor quality fruit, contaminated inputs (such as water), lack of documented procedures, use of unhygienic premises and equipment, and unhygienic staff practices as well as poor packaging and storage of final products.

Processing facilities require careful planning with respect to processing methods and capacity. As indicated earlier, facilities and processing procedures must meet occupational health, safety and environmental standards. All equipment must be constructed so that it can be easily cleaned and sanitised. Processing equipment should be constructed from food grade material, such as plastic, fibreglass or stainless steel, and be suitable for the function required. Processing tanks and containers vary in size, with some exceeding 15 tonnes. Boutique table olive processors often use plastic barrels to process olives. Larger scale enterprises use processing tanks of substantial sizes (see Figs 4.1, 4.3 and 4.4).

Excluding the cost of buildings and land, a small table olive processing plant with a capacity of up to 20 tonnes of olives can cost as little as A$50 000–A$100 000 to establish. Large-scale facilities of 500 tonnes or more will cost between one and two million dollars (Australian) depending on the level of sophistication. Ancillary equipment and facilities for large-scale processing such as waste disposal, pumps, sorting tables, graders, destoners, bottling lines and a testing laboratory can account for at least a further A$300 000. Australian developed machines for slicing and destoning olives are expected to cost approximately A$30 000–A$40 000. The cost of similar machinery imported from overseas is of the same order. When purchasing equipment, processors should ensure that efficient backup for repairs and maintenance is available.

Key considerations for establishing a table olive processing facility include the following:

- understand the industry, products and markets;
- decide on the size of operation: boutique, small, or large scale;
- determine the environmental issues, such as disposal of washing water, brines and lye solutions;
- determine sources of quality fresh olives: from your own olive crop or olives sourced from others;
- consider how olives will be delivered to the processor. Use quality systems;
- establish sources for acquiring quality water and food grade ingredients. Use recognised suppliers;
- plan functional and hygienic processing plants. Check building, food, and environmental codes;
- employ trained operatives: formally or in-house trained;
- establish documented processing procedures with controls. Implement HACCP;
- adhere to occupational health and safety requirements. Check appropriate codes;
- establish procedures to maintain product profiles. Implement laboratory testing; and
- establish product recall procedures. Check the FSANZ or other statutory food codes.

Functional table olive processing facility

Processing facilities must be appropriate for the production and storage of table olive products. They must meet statutory food regulations and good manufacturing practice as well as occupational health and safety and environmental requirements. The plant design should ensure that all operations can be undertaken effectively without the risk of contamination or cross contamination. All areas and equipment must be kept clean, hygienic and free from insects, rodents and other pests. One such processing plant is depicted in Fig. 4.1.

Figure 4.1 Small-scale Australian table olive processing enterprise at Casino, NSW. (Photo: Newton and Merryl Ellaby.)

Pest control. Pests, such as rodents and insects (especially cockroaches), can carry pathogens like *E. coli* and *Salmonella*. Doors and windows should be placed so they prevent the entry of animals, birds and insects. Keeping areas clean and tidy and removing unwanted gear that could harbour vermin are important strategies. Where infestations are present, baits and traps should be used rather than pesticides, which could increase the risk of contamination.

Plate 1. *Kalamata (Kalamon)* variety at different maturation stages: green-ripe, turning colour and naturally black-ripe olives. Note natural bloom on the black olives.

Plate 2. *Arbequina* olives.

Plate 3. *Barnea* olives.

Plate 4. *Frantoio* olives.

Plate 5. *Kalamata* olives.

Plate 6. *Leccino* olives.

Plate 7. *Manzanilla* olives.

Plate 8. *Picholine* olives.

Plate 9. *Sevillana* olives.

Plate 10. Four large-fruited olive varieties. (From left to right: *Barouni*, *UC13A6*, *Hardy's Mammoth* and *Nab Tamri*.)

Plate 11. *Jumbo Kalamata* olives and stones. Note the large white patches (lenticels) on the surface of this variety. (See also Fig. 3.4.)

Plate 12. *UC13A6* (Californian Queen) olives.

Plate 13. *Verdale* olives.

Plate 14. Burnt olive leaf tips typical of excess salinity or potassium deficiency.

Plate 15. Chlorosis of olive leaves typical of nutritional deficiencies.

Plate 16. Signs of iron deficiency in olive leaves. Note green venation.

Plate 17. Black Scale with typical Sooty Mould on stems and leaves of an infested olive tree. (Photo: Australian Mediterranean Olive Research Institute.)

Plate 18. Olive trees infested with Olive Lace Bug. Note the sparse grey foliage.

Plate 19. Olives infested with Olive Fruit Fly. Note entry marks. (Photo: Paul Vossen, California.)

Plate 20. Single olive with grub consuming the flesh. (Photo: Paul Vossen, California.)

Plate 21. Olive leaves with characteristic lesions due to Peacock Spot, *Spilocea oleaginea*. (Photo: Paul Vossen, California.)

Plate 22. Evaporation pond with heavy plastic liner for the disposal of table olive wastewater. (Photo: Newton Ellaby and Merryl Ellaby, Australia.)

Plate 23. Loose olives for sale at the Victoria Markets, Melbourne, Australia.

Plate 24. Cracked turning colour *Manzanilla* olives prior to processing.

Plate 25. Heat-dried olives with olive oil, crushed chilli and rosemary.

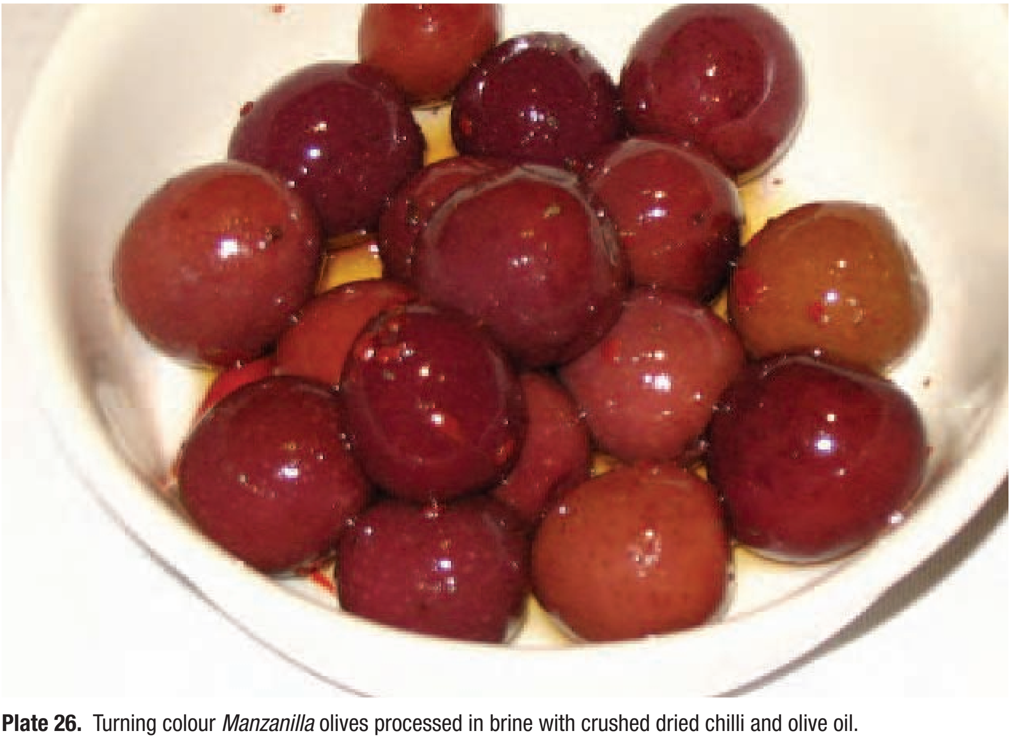

Plate 26. Turning colour *Manzanilla* olives processed in brine with crushed dried chilli and olive oil.

Plate 27. Provencale-style black *Leccino* olives, processed in brine, with crushed dried chilli, sliced garlic, rosemary and olive oil.

Plate 28. Destoned green-ripe *Ascolana Tenera* olives processed in brine, with added crushed chilli, chopped garlic, fennel seeds and olive oil (Sicilian style).

Plate 29. Various tapenades prepared with processed green-ripe, turning colour or naturally black-ripe olives.

Plate 30. Lye treated *Sevillana* olives with and without fermentation. Note yellow coloured olives are the ones that have undergone fermentation after lye treatment, whereas the green olives have undergone lye treatment only.

Plate 31. Oxidative moulds growing on the brine surface during processing of olives in a poorly controlled barrel.

Plate 32. A number of problems that can occur during processing. Notice the black gas pockets and fissures on the brown *Kalamata* olives, white yeast spots on the *Kalamata* and green *Sevillana* olives, and pressure marks on the *Sevillana* olives.

General facilities and equipment required

Facilities should be designed and built for easy cleaning and maintenance and to minimise the entry of contaminants. Makeshift facilities should be avoided, as in the long term it may be more practical and cost effective to construct new purpose-built facilities rather than trying to alter existing structures.

The main equipment required includes washing machines, sorters, graders, tanks (stainless steel or food grade fibreglass), pumps and packing equipment. Large-scale commercial olive processing tanks can hold up to 10 tonnes of olives and 5000 litres of brine (approximately 15 tonnes capacity). They are cylindrical or spherical in shape and made of polyester and fibreglass. Tanks can be placed underground, above ground, in large sheds or in covered areas. Washing machines for table olives are similar to those used for washing olives for olive oil production. Storage areas, chemical stores, wash-up and toilet facilities should be segregated and away from receiving and production areas. All chemical materials should be of food grade quality and under inventory control to prevent errors, mix-ups or contamination. All equipment must meet food grade standards and be of a design that allows for easy cleaning, maintenance and safe use by workers. The use of equipment made of galvanised iron or aluminium should be avoided because of the risk of corrosion and contamination.

The table olive processing facility should be divided into a number of physically or functionally delineated areas:

- management and service area;
- laboratory for records, testing;
- receiving and storing chemicals;
- receiving raw materials;
- raw material storage area;
- pre-processing operations;
- primary processing operations;
- bulk storage of processed olives;
- secondary processing operations;
- packaging operations;
- pasteurisation and/or sterilisation facility;
- storage of packed products; and
- loading area for finished products.

Buildings and work sites should meet the standards required for food processing, including adequate lighting and ventilation. Walls, ceilings and floor surfaces should be made of approved material for cleaning and drainage. Equipment used for table olive processing will depend on the scale of the operation and the products to be produced. The list below is indicative of the types of equipment that can be used:

- sound and functional building and work site;
- conveyor system for olives entering the facility;
- washing machines to rinse olives before processing;
- sorting machine for size-grading raw olives;
- sorting tables with moveable belt to facilitate removal of defective olives;

- slitting machines to slit olives to facilitate processing (Fig. 4.2);
- bruising or cracking olive machines to facilitate processing;
- tanks for solution preparation, fermentation procedures (Figs. 4.3–4.4) and rinsing;
- brine pumps to transfer and circulate brines;
- olive pumps to transfer olives from tanks;
- destoning machines to destone olives for stuffing, slicing or making tapenade and olive pastes;
- tapenade and olive paste machines, purpose-built or commercial food processors;
- stuffing machines to stuff olives with food fillings;
- slicing machines to slice destoned olives;
- commercial ovens for heat drying olives;
- storage tanks and barrels;
- filling, packing and labelling equipment;
- pasteurisation or sterilising equipment; and
- laboratory for testing olives and brine.

Figure 4.2 Australian developed olive slitting machine. (Photo: The Olive Centre, Queensland.)

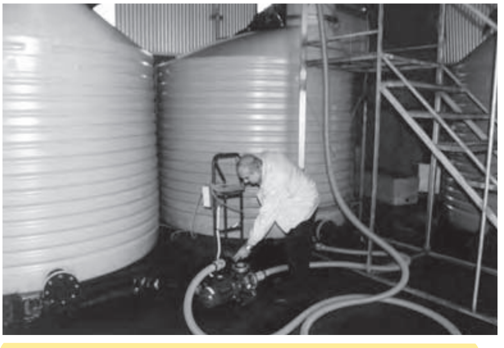

Figure 4.3 Medium-scale table olive processing tanks with brine pump. (Photo: Koorian Olives, Gingin, Western Australia.)

Figure 4.4 Large-scale table olive processing tanks. (Photo: Viva Olives, Loxton, South Australia.)

Plant maintenance and sanitation. Because table olive production involves food processing activities, sanitation is important to prevent consumer illness and spoilage of the olives. Cleaning procedures should be defined, particularly for the chemical agents used. Pest control is best left to a licensed third party that can provide records to ISO standards for inspection by health surveyors. Workers must conform to stringent hygiene protocols including the need to report to employers any illness that can impact on the safety of the table olives being produced. Cleaning procedures should ensure against microbiological, physical and chemical contamination. Records should be kept so that an effective maintenance program can be developed.

Cleaning procedures. The processing plant and all equipment should be kept in a clean state. Cleaning procedures are undertaken with food grade detergents (often based on sodium lauryl sulfate) and water that generally removes chemical contaminants, soil, organic matter and microorganisms from surfaces. It should be noted that detergents are not lethal to residual microorganisms. The processing plant and all equipment used should be kept in a clean state.

Sanitising procedures. Sanitising procedures significantly reduce the number of residual microorganisms after cleaning procedures have been undertaken, but do not kill all microorganisms. Common sanitising agents suitable for surfaces and equipment include: steam sprays, chlorine compounds, iodine compounds, quarternary ammonium chloride compounds, peroxy compounds and carboxylic acids.

Care must be taken to ensure that residual levels of sanitisers on equipment are within food safety limits.

Protocol for cleaning and sanitising equipment

The facility, fittings and equipment must be kept clean and in a good state of repair.

The item or equipment is rinsed with cold water, rinsed with hot water, rinsed with caustic rinse (1.0–1.2% w/v sodium hydroxide in water) if required, sanitised with peroxide-sanitiser or steam, and dried with compressed air or disposable paper towels.

Protocol for cleaning and sanitising food contact surfaces

Sanitising of contact surfaces can be achieved by using hot water (77°C or above), a food grade sanitiser and dilute bleach (sodium hypochlorite solution).

After treatment the surfaces are allowed to air dry or are dried with disposable paper towels.

Trained operatives. People working in the processing plant must have an understanding of all the activities within the facility, particularly as they relate to occupational health and safety. More specifically they should understand the importance of personal hygiene so the risk of contamination or cross contamination of the olive products is minimised. Those workers involved more directly in processing must understand the procedures and controls to produce olives that meet quality and safety standards. The table olive processing facility must have personnel trained to the level of the operations required, especially in the areas of hygiene, food handling and record keeping. Workers must be provided with information for the safe handling of toxic and microbiological materials and other possible hazards that may be encountered when using equipment and machinery. As processing involves the use of salt, lye and concentrated acids, workers must be trained to handle chemicals, prepare solutions and be able to handle spills and emergencies especially for personal and third party safety. Workers must be aware of Material Safety Data Sheets (MSDS) for all chemicals used in the processing of table olives. Health and safety implications and decontamination procedures need to be documented and brought to the attention of operatives. Processing procedures should include pre-calculated quantities of raw materials for safety and quality purposes.

Operator health and hygiene. Adverse medical conditions, such as food borne problems, should be reported to management and a clearance obtained before returning to food handling operations. Unsanitary practices such as smoking, eating and drinking should not be undertaken in production areas. Clothing must be clean and suitable for the task. Operatives should not wear cosmetics and jewellery during processing and packaging of table olives to prevent accidental loss or contamination. As long as personal hygiene procedures and requirements (hand washing, no open cuts or sores, no infectious disease) are adhered to, wearing gloves while undertaking table olive processing procedures is not necessary. Gloves should be worn when hand stuffing table olives, for example with cheese, nuts and fish. Workers should wear approved closed footwear and disposable head or beard covers. However, approved gloves and safety glasses should be worn when handling corrosive substances, preparing brines and where spillage or spoilage may occur.

Practicalities of operatives' health and hygiene. Clothing worn by operatives in food processing areas should be clean and changed daily. Eating, drinking and smoking should never occur inside the processing area or when olives are being unloaded and loaded. Hands should be washed and/or sanitised before starting work, after each toilet visit, after eating and smoking, after blowing the nose or coughing, after handling rubbish or undertaking maintenance procedures, and after any break in work from the processing area. Operatives with colds need to take extra precautions to prevent contamination, such as blowing the nose rather than sneezing and coughing over the olives. Increased handwashing and using disposable tissues can help. It may be best for affected persons to undertake non-food contact duties. With more serious health conditions where the risk of contamination with pathogenic microorganisms is likely, such as gastroenteritis, diarrhoea, vomiting, sore throat with fever, fever or jaundice, it is best for them to stay away from the table olive processing plant or, where practical, be given non-food contact duties.

Clothing and practicalities when working in a food production area. Olive processors should be aware of the desirable clothing and practices for operatives working in food production areas. Furthermore, these should not be considered as 'Rolls Royce' requirements but best practice that will reduce the risk of contamination and spoilage of food products, such as table olives.

Clothing. Clothing to be worn in food production areas to protect the worker from spillage and reduce the risk of contamination includes a two piece suit made up of a V-neck cotton top with no pockets and elastic-waisted cotton pants with an inside pocket. It is optional as to whether workers wear a clean T-shirt and/or light pants inside the suit or just their underclothes. Suits are changed daily and more often if they are soiled. Clothing is also changed when working in high-risk areas. Workers are not allowed to sit on the facility floor, on equipment or outside, for example on grass. Steel-cap safety work shoes (not rubber boots) supplied by the establishment are worn in the facility, but left in the facility at the end of the shift. Generally, gloves are not worn during processing procedures except when the foodstuff is closely handled. In this case disposable gloves are worn, with regular changes during the day. Circumstances relevant to table olive processing are destoning olives and stuffing olives with food fillings, such as cheese and peppers, by hand. Gloves are also worn when the worker has a hand injury, which should be protected with a coloured adhesive dressing. Workers should also wear protective gloves and safety glasses when handling corrosive liquids such as lye solutions and acids.

A typical procedure follows. The worker arrives at the facility and changes into their two piece working suit and puts on safety shoes, a hair net and, if appropriate, a beard mask before entering the processing area. The worker then walks in a shoe sanitiser bath containing chlorine or iodine based solutions. They should then dry-clean their vest, particularly at the shoulders, with a roller with a disposable sticky surface to remove hair and specks. Hands are then washed with food grade non-perfumed liquid soap and hot water at 55°C or above (no-touch soap dispenser, no touch taps or infra-red sensor panel to turn on water), rubbed with an alcohol sanitiser (optional), liquid or wipes (tissues impregnated with sanitiser), then with a disposable towel.

Note: Effective hand sanitisers, especially wipes, remove and absorb germ laden biofilm from hands preventing cross contamination when handling food. The sanitiser kills most pathogenic skin organisms within 20 seconds and is effective against *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Salmonella choleraesuis*, *E. coli* and *Streptococcus pyogenes*.

Recall procedures. Table olive processing facilities must have a recall system for unsafe or contaminated products. All olives, whether stored in bulk or final consumer containers, should be traceable through records and batch numbers. The recall process must be within guidelines of government agencies responsible for public health surveillance. Responsible persons such as processors, packers, wholesalers and government health agencies can initiate recalls. All products requiring recall should be reported immediately to the appropriate authorities.

Products are recalled when there is a real or perceived health risk (see Chapter 6 for more detail).

The first scenario is that a local health department receives notification or a complaint regarding a food poisoning incident. This matter is then investigated, a procedure that includes testing of the suspected foodstuff, for example to detect the presence of organisms such as *Escherichia coli*, coagulase positive Staphylococci, *Clostridium perfringens* and *Listeria monocytogenes*, and calling for information from the point of sale or use and from the manufacturer.

A second scenario is when the manufacturer has found a contaminant in their product, or some other problem that impacts on safety, for example stones in stuffed olives or pH outside the safe range.

A third scenario is that a food is produced in a way that the absence of harmful organisms such as *Clostridium botulinum* or its toxin cannot be guaranteed.

A fourth scenario occurs where an ingredient that may cause an allergic reaction in susceptible persons has been left off the ingredient list, for example nuts and milk protein.

In all four cases the suspect product needs to be recalled. These four scenarios illustrate the need to ensure that documented procedures with the appropriate controls are used along the processing chain to the consumer and that samples of the final packaged products are cleared by a registered laboratory.

Table olive processing

As defined by the Codex Alimentarius (1987)/IOOC (2004) Table Olive Standards, table olives are prepared from the sound fruits of suitable varieties of the cultivated olive tree (*Olea europaea* L.). When treated or processed the olives are ready for consumption subject to packaging requirements. Olives used for processing are harvested at the appropriate level of maturation and processed so that microbiologically safe and edible products are produced. For international trade in olives, as per the IOOC, individual countries are required to indicate the varieties considered suitable for processing.

The table olive processing method, together with variety and growing conditions, has a major impact on the taste of the final product. Olives are edible after primary processing, but they are often finished off (secondary processing) in a number of ways, for example by the addition of vinegar, extra virgin olive oil, herbs and spices.

Sources of inputs. Sources of olives should be secured well ahead of processing and contingency plans put into place in case there are shortfalls in supply. Processors must ensure that the olives used meet quality and safety criteria. They must also be certain that the source of potable water is secured and the amounts required for processing are available. Water sources other than from water authorities or agencies should be tested for physical, chemical and microbiological contaminants and treated to potable water standards before use. All chemicals, cleaners, disinfectants and ingredients used must meet food safety standards. Salt, sodium hydroxide and acids must be of food grade quality and only dried herbs, spices and condiments of satisfactory microbiological quality should be used for commercial products.

Herbs and spices. Herbs and spices should be suitably decontaminated for microorganisms before incorporating into table olive products. Traditionally, herbs and spices have undergone decontamination with chemical agents such as ethylene oxide and disinfestation with methyl bromide. Irradiation of herbs and spices is also used to destroy microorganisms, such as yeasts and moulds that can cause spoilage and may be harmful to health, as well as insects. This technique involves passing the food through a radiation field of gamma rays generated from a Cobalt–60 source or from an 'electron beam' generated from electricity. With irradiation the food remains cool, does not become radioactive, or lose flavour, aroma or nutritional value.

Salt use in table olive processing. Salt, chemically known as sodium chloride, is commonly used in table olive processing and packaging of table olive products. Coarse, dry salt is used for processing salt-dried olives, while coarse salt in water (salt brine) is used in fermentations and packaging brines.

Food grade salt with no additives must be used for all table olive operations. Non-conforming salt can cause the following problems and should be avoided in olive processing:

- anticaking agents (as in table salt) make brines cloudy;
- lime impurities can reduce the acidity of final products;
- iron can darken olive products;
- magnesium impurities can impart a bitter taste;
- carbonates can alter texture, causing softening; and
- iodised salt may darken olives and possibly give the olives a chemical taste.

Sodium chloride is soluble in water. One gram of salt will dissolve in 3 ml of water. This amount is not much lower than if the salt is dissolved in boiling water, so there is no advantage in using hot water to speed up its dissolution. A saturated solution of pure salt (100 degrees) contains 26.36 g/100 ml of solution.

To convert salt concentrations to approximate Salometer (Salinometer) degrees, multiply salt concentration by 3.8; for example, for a 10% w/v salt solution: $10 \times 3.8 = 38$ Salometer degrees.

Conversely, to convert Salometer degrees to approximate salt concentrations, divide Salometer degrees by 3.8; for example, for a 40 Salometer degree solution: $40 \div 3.8 = 10.5\%$ w/v salt solution.

Alternatively, the graph in Fig. 4.5 can be used. After measuring the salt level in a particular brine, by extrapolation on the graph below, the % w/v salt concentration can be determined. If required, additional salt can be added and checked with the salometer or other salt measuring instrument.

The use of glass equipment such as salometers, where practicable, should be discouraged in table olive processing. Portable conductivity meters, salt refractometers and a titration method are a more suitable means by which salt content in brines can be assessed. If glassware is used, strategies need to be in place to handle situations such as breakages or if the device is accidentally dropped into brines.

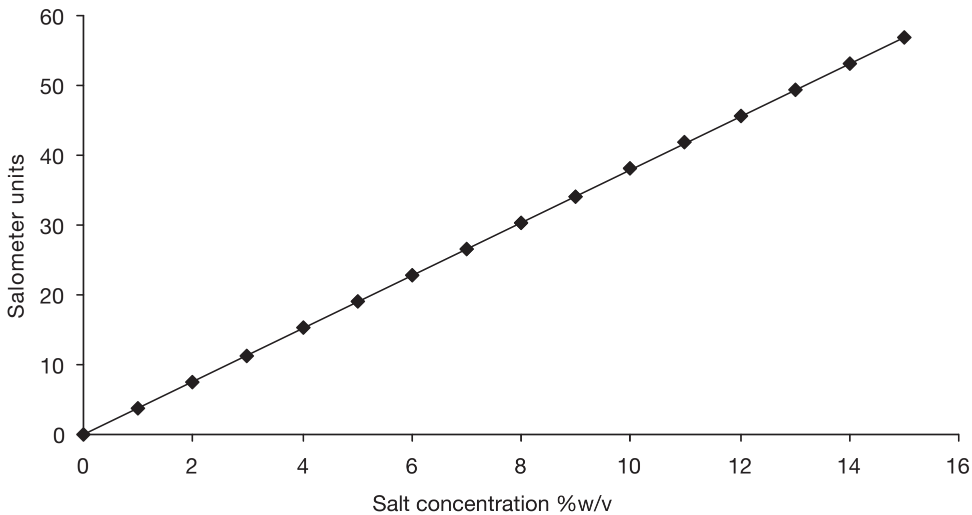

Figure 4.5 Graph for correlating salt concentration in % w/v with salometer units.

Care must be taken when preparing salt solutions. Following these procedures will reduce problems:

(a) double check calculations and weighed quantities;
(b) wear safety glasses to avoid salt solutions splashing into the eyes;
(c) add salt to water and ensure that all the salt has dissolved; solutions must be clear, not cloudy before adding to olives; and
(d) check salt concentration using a salometer, refractometer, conductivity meter or by titration.

Note: More research is required in developing and promoting low-salt table olive products. Salt, made up of sodium and chloride, is essential in the diet, but all too often intake is excessive. Health advice is to reduce salt intake, particularly in people with high blood pressure. As it has been estimated that 75% of salt intake comes from manufactured foods, low-salt table olive products, where technically and microbiologically possible, could help reduce salt loads.

Sodium hydroxide used to debitter olives in table olive processing. Sodium hydroxide solutions are used to debitter olives, for example Spanish-style green olives and Californian/Spanish-style black olives. Lye, caustic soda and 'alkali' are alternative names for sodium hydroxide. Potassium hydroxide has also been used as a debittering agent, as has wood ash. The use of wood ash, because of possible impurities and its variable quality, needs careful consideration before using in commercial table olive production.

Sodium hydroxide, which generally comes in the form of pellets, is very soluble in water (1.0 g/1.0 ml). It should be stored in sealed containers to prevent it reacting with carbon dioxide in the air forming sodium carbonate.

Sodium hydroxide is an extremely dangerous substance to handle and if it comes into contact with skin and eyes, severe burns can occur. Therefore, gloves, protective clothing, industrial footwear and safety glasses should be worn at all times when handling sodium hydroxide, preparing sodium hydroxide solutions and when transferring these solutions during processing operations. These comments also apply to the use of potassium hydroxide in table olive processing.

Care must be taken when preparing sodium hydroxide solutions because dissolving sodium hydroxide in water is an exothermic reaction generating a significant amount of heat. Using the following procedures will reduce problems:

(a) double check calculations and weighed quantities;
(b) wear safety clothing at all times;
(c) always add sodium hydroxide to water when making lye solutions rather than adding water to solid sodium hydroxide to prevent spattering and the risk of burns to skin and eyes; and
(d) ensure all the sodium hydroxide has dissolved before adding the solution to olives.

Table olive methods and styles

Numerous table olive processing methods are available. These depend on olive variety, degree of ripeness, processing technology, cultural and traditional factors. Using any processing method, one can process most olives, regardless of variety. However, from a commercial viewpoint, specific varieties are preferred because of superior technological and organoleptic factors and consumer preference. Examples are given below. *Manzanilla* is used for Spanish-style green olives, *Kalamon* (*Kalamata*) for Kalamata-style, Californian *Mission* for Californian green and black-ripe olives and *Conservolea* for Greek naturally black-ripe olives. (Also see Table 4.1.)

Kalamata-style: *Kalamon*
Greek-style black or green: *Conservolea*
Spanish-style green (Sevillian): *Manzanilla*
Spanish/Californian black: *Mission* (Californian), *Manzanilla* and *Hojiblanca*
Sicilian green: *Nocellara di Etnea*

Ligurian: *Taggiasca*
Dried olives: *Thrumbes*
Olive de Nimes: *Picholine*

Important international table olive trade products listed in the International Olive Oil Council's Codex Alimentarius (1987)/IOOC (2004) Table Olive Standards are provided in Section 4.11. All listed trade products are available in Australia, either loose or packed in containers, from fresh food markets, supermarkets, delicatessens and specialty food shops. Australian table olive processors are currently producing or have the ability to produce most of these trade products in competition with imported products, albeit in relatively small quantities. Australian growers/processors should be familiar with these, especially if they are to enter the international table olive trade or compete against imported table olive products.

Raw olives used for table olive production

Olives used for table olive production are classified in one of the following categories according to the degree of ripeness of the raw olives. Only firm, sound, unmarked olives are used for top quality table olives (Fig. 4.6).

Green olives. These are olives that are yellow-green in colour prior to pigmentation developing.

Olives turning colour. These are olives that are multicoloured or ones that have not reached complete ripeness. Turning colour olives are ones that have started to develop colours such as rose, wine-rose or brown before the olives are fully ripe.

Note: For practical purposes, turning colour olives have a partially pigmented flesh. When olives are nearly fully pigmented, they are used for preparing black olives.

Figure 4.6 *Manzanilla* olives at different stages of maturation (turning colour, black and green).

Black olives. These olives are harvested when fully ripe, or slightly before full ripeness. With the latter the flesh is not fully pigmented; the red/purple colour can be seen at least halfway between skin and the stone. Depending on the region 'black' olives can be reddish black, violet-black, deep violet, greenish-black or deep chestnut with both the skin and the flesh coloured.

Common trade preparations of table olives

A brief summary of common olive preparations based on the Codex Alimentarius (1987)/ IOOC (2004) Table Olive Standards is given below.

Natural olives. Raw green, turning colour or black olives are placed directly in brine where they undergo partial or complete fermentation and may be preserved by the addition of acidifying agents. The resulting products are natural green olives, natural turning colour olives (Fig. 4.7) or natural black olives (Fig. 4.8).

Natural olives in brine are relatively firm and smooth with a glossy skin. The finished product retains some fruity and bitter flavours. During processing, raw black or turning colour olives can lose some of their black purple pigments resulting in pale to dark brown coloured olives. The colour of black olives can be partially restored by exposing them to air after processing where the phenolic compounds present in the skin and flesh oxidise.

Note: With incomplete fermentations or when new packing solutions are used, food acids are often added to ensure preservation. Fermentation brines from black olive processing take on a rich burgundy colour due to the presence of anthocyanins and are strong in aroma and flavour compounds, and where practical should be used to prepare packing brines. The latter also applies to green and turning colour olives where brine colours range from pale yellow to pale orange to pink. Some repackers of table olives add caramel to covering solutions when packing black olives, giving them a brown colour. Also the antioxidant, ascorbic acid, is often added to covering solutions or brines for green or turning colour olives to prevent discolouration (see Chapter 6).

Figure 4.7 Turning colour *Jumbo Kalamata* olives processed as natural olives. (Photo: Australian Mediterranean Olive Research Institute, Perth, Western Australia.)

Figure 4.8 Black-ripe *Conservolea* olives processed as natural olives. (Photo: Australian Mediterranean Olive Research Institute, Perth, Western Australia.)

Treated olives. Here, raw green, turning colour or black olives are debittered with lye then placed in brine in which they undergo partial or complete fermentation and may be preserved by the addition of acidifying agents. The resulting products are treated green olives in brine (Fig. 4.9), treated turning colour olives in brine or treated black olives in brine.

Curing olives in lye is fast and cost efficient. Because lye can leach out flavour (fruitiness), and leave a slight chemical taste, they are less popular with discerning consumers and by boutique table olive processors than naturally processed table olives. However, in traditional olive producing countries such as Spain, lye treated table olives (*Sevillana*, *Manzanilla* and *Hojiblanca*) are well accepted, as are the naturally processed *Arbequina* olives.

Note: With incomplete fermentations or where new packing solutions are produced, food acids are often added to ensure preservation. The term ‘treated’ is used when olives

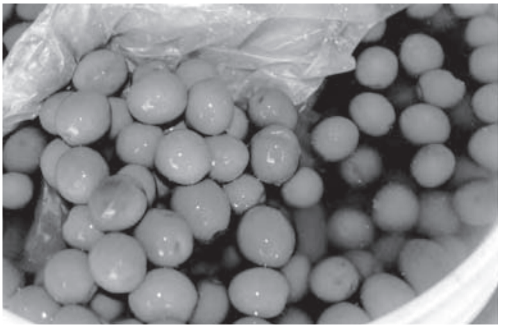

Figure 4.9 Green-ripe *Manzanilla* olives processed as lye treated Spanish-style green olives.

are debittered by immersing them in an aqueous solution of sodium hydroxide, lye or caustic soda. This produces irreversible physical and chemical changes in the skin and flesh of the olives causing the loss of water-soluble compounds (including reducing sugars, proteins, organic acids, salts and amino acids) and softening the flesh. The latter is less of a problem in Spanish/Californian black olives (see below), which are processed when green. Changes in the skin and flesh after lye treatment increases its permeability to soluble components from olive flesh into the brine as well as sodium chloride and flavour compounds into the olive.

Dehydrated and/or shrivelled olives. Raw green, turning colour or black olives that may have undergone a mild alkaline pre-treatment are preserved in brine, or partially dehydrated in dry salt and/or by heating or by any other technological process. The resulting products are dehydrated and/or shrivelled green olives, dehydrated and/or shrivelled olives turning colour, or dehydrated and/or shrivelled black olives.

Shrivelled black olives are popular with consumers. Variations in preparation include processing naturally black-ripe or nearly black-ripe olives in a low temperature oven, with or without lye treatment in brine or with dry salt (Figs 4.10–4.12). During processing the olive flesh dehydrates resulting in a soft, slightly moist, shrivelled product. With salt drying, processing is undertaken in containers or crates where the moisture with bitter substances drawn out of the olives by the salt is allowed to drain away. Green-ripe or turning colour olives when salt-dried are relatively firm, and when exposed to air turn a chocolate brown colour rather than black.

Note: After curing, salt-dried olives can be plunged briefly into boiling water to remove the excess salt, allowed to dry, then stored in extra virgin olive oil. Home processors can also add olive oil, herbs and spices. Salt-dried olives can be vacuum packed to aid in their preservation.

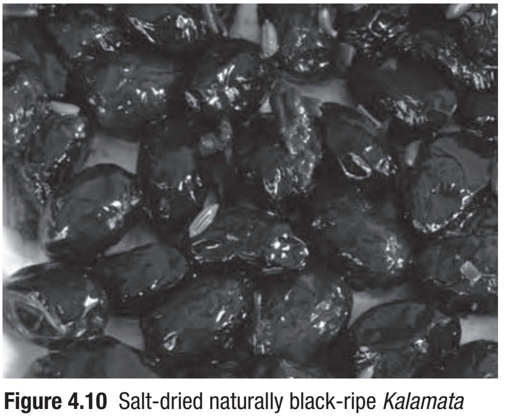

Figure 4.10 Salt-dried naturally black-ripe *Kalamata* olives with olive oil and fennel.

Figure 4.11 Salt-dried green-ripe *Manzanilla* olives. (Photo: Australian Mediterranean Olive Research Institute, Perth, Western Australia.)

Figure 4.12 Heat-dried naturally black olives. (Photo: Australian Mediterranean Olive Research Institute, Perth, Western Australia.)

Figure 4.13 *Hojiblanca* olives processed as Spanish-style black olives.

Olives darkened by oxidation. Green or turning colour olives preserved in brine that may have been fermented are darkened by oxidation in an alkaline medium and preserved in hermetically sealed (airtight) containers subjected to heat sterilisation. These olives, often called Californian- or Spanish-style black olives, are characteristically pitch black in colour (Fig. 4.13).

Note: In some centres, raw green-ripe olives are used, while at others, the olives are placed in brine as a storage procedure or naturally fermented olives are purchased from others. Olives stored in brine for sufficiently long periods undergo natural fermentation.

Specialty table olive products

A number of specialty products can be prepared from green, turning colour or black processed table olives. Such specialties retain the term 'olive' as long as the fruit used complies with expected standards, allowing the consumer to understand that the products are prepared from olives. These products include green and black olive pastes, tapenades, stuffed olives, olives in marinades and olives with pickled vegetables.

Figure 4.14 Commercially available green 'Queen' size olives of the *Sevillana* variety, whole, destoned and stuffed with pimento.

After primary processing, large olives of any style can be destoned then stuffed, segmented, sliced or crushed into a paste. Large-sized olives called 'Queens' are most suited to pitting and stuffing (Fig. 4.14).

Table olive styles

The Codex Alimentarius (1987)/IOOC (2004) Table Olive Standards indicate a number of styles for processed table olives.

Whole olives. Whole olives (Fig. 4.15) are those that have retained their natural shape, with or without stems, and their stone is intact. Examples include primary processed (by any method) olives. Whole olives are commonly packed randomly (Fig. 4.14) or, less commonly, in an orderly arrangement (Fig. 4.16) into containers.

Figure 4.15 Whole green-ripe *Chalchidikis* olives processed with lye.

Cracked/bruised olives. These are olives that have undergone a procedure whereby the olive flesh is opened while leaving the olive stone intact and still attached to the flesh. Clingstone olive varieties are more suitable for cracked olives than freestone varieties (see Chapter 2). Bruised olives are mostly prepared from raw green-ripe or turning colour olives or green olives that have already undergone primary processing. Naturally processed black olives, because of their soft characteristics, are less suitable. When preparing cracked/bruised olives, the olives are struck with a blunt object or passed through a device so that the flesh is exposed without removing or breaking the stone. If raw, the olives are processed with or without lye treatment. Raw cracked olives are placed into brine where they may undergo a partial or complete natural fermentation. Where lye is used the olives are washed before placement into brine as for Spanish-style green olives. Once processed, the olives are placed in brine into which herbs, spices, vinegar and olive oil are added to extend aroma and taste.

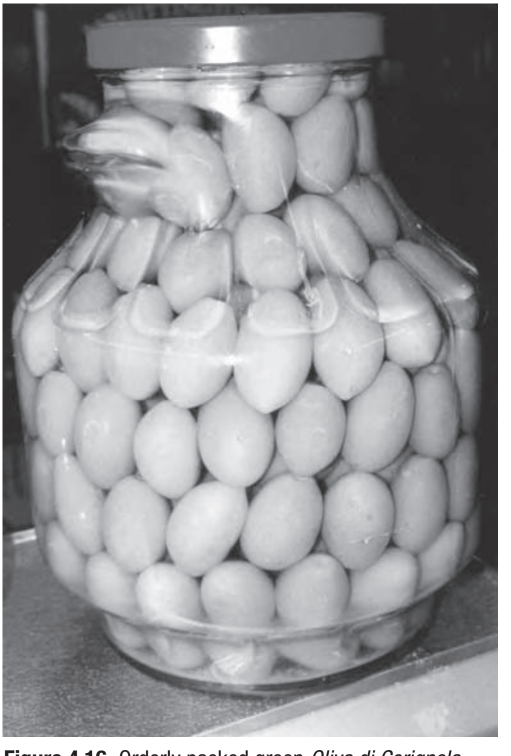

Figure 4.16 Orderly packed green *Oliva di Cerignola* olives processed and packed in Italy.

Split/slit olives. Split/slit olives are prepared from raw olives: naturally black-ripe, green-ripe or turning colour olives, or olives that have already undergone primary processing. The olives are slit longitudinally with a knife or by some other device (such as a mechanical slitter) so that the skin is breached and the flesh is penetrated. Raw olives are processed with or without treatment with lye. The olives are placed into brine where they may undergo partial or complete natural fermentation. Where lye is used the olives are washed before placement into brine. As for bruised olives, once processed the olives are placed in brine into which herbs, spices, vinegar and olive oil are added to extend aroma and taste. A variation of the method, often used with Kalamata-style olives, is to split or slit the intact olives after primary processing, so that when embellishments are added, for example garlic, wine vinegar and lemon flavours, they penetrate into the flesh.

Stoned/pitted olives. Olives of this style have their stones removed while retaining their original shape. Removing the stone can be undertaken before or after processing. For this style, olives should be medium to large in size. *Manzanilla*, *Sevillana* and *Kalamata* olives are commonly available in the destoned form. Of these three varieties, *Kalamata* loses most of its original shape but this is not a major problem as olives of this variety are mostly used on pizzas or in prepared food.

Destoned olives are also sold in the following divided forms for use in cooking, salads and pizzas.

Halved olives. Stoned or stuffed olives sliced transversely into two approximately equal parts (Fig. 4.17).

Quartered olives. Stoned olives sliced lengthwise and transversely into four approximately equal parts.

Divided olives. Stoned olives cut lengthwise into more than four equal parts.

Sliced olives. Stoned olives or stuffed olives sliced transversely into segments of fairly uniform thickness. Sliced Spanish-style green and black olives are commonly available in this form (Fig. 4.18).

Pitted and stuffed. Stoned olives with various fillings, such as pimento (sweet chilli), anchovy, onion, garlic, almonds, celery, orange or lemon peel, hazelnuts or capers.

Chopped (minced) olives. Small pieces of destoned olives without a definite shape.

Broken olives. Olives accidentally broken when being destoned and stuffed.

Stuffed olives. Stoned olives stuffed with natural fillings or pastes, for example pimento, onion, almond, celery, anchovy, olive, citrus peel, hazelnuts, capers and cheeses.

Figure 4.17 Halved cracked Sicilian-style *Manzanilla* olives suitable for adding to salads and cooked food. Note the freestone has been ejected during the cracking procedure.

Figure 4.18 Sliced Spanish-style black olives suitable for adding to salads, cooked food and pizzas.

Salad olives. Whole broken olives (or broken and stoned) with or without capers or any filling product.

Olives with capers. Whole or stoned olives, generally of small size, packed with capers and peppers.

Note: With substantial destoning and stuffing operations, large quantities of stones are produced. In Spain, olive stones are used for the extraction of seed oil, but they are also used as a fuel. In California, major olive processing plants have burnt olive stones to produce steam for use in sterilising canned olives. Other uses are as BBQ fuel, fuel bricks, starting material for plastics and for the production of high quality activated carbon.

Common table olive methods and products

Common table olive styles and methods are summarised in Table 4.4. They are the types of products imported into Australia and eaten by most Australians. Australian table olive producers have developed similar products except for Californian/Spanish-style black olives. Products are sold in their primary processed form (loose or packed in brine) or as specialty products (secondary processing). Information in this table can direct Australian growers/processors to which table olive products to produce.

Plant and process control. Controlling table olive processing by using documented procedures and relevant tests ensures the quality of the final products is maximised. Microbiological, pH and salt tests are used to monitor fermentation during processing as well as for quality management and safety purposes. Microbiological tests are used to test for the presence and absence of pathogens and spoilage organisms. Orderly records should be maintained and in a form others can follow in the absence of key workers. Records should be kept for at least three years and archived if appropriate.

Primary processing specifications for table olives

The concepts of *primary* and *secondary* processing have been developed by the authors to simplify the understanding of processing table olives. After discussions with a large number of potential and existing table olive processors and home table olive processors around Australia, it became obvious that they were having difficulty grappling with basic principles.

Primary processing involves any process used to debitter and preserve the olive, such as fermentation and drying. The product may or may not be suitable for immediate consumption at this point; that is, packed in consumer size containers, or have not been embellished.

Specifications. Specifications must be drawn up prior to starting the manufacture of table olives.

Process specifications must be clearly documented for primary processing and should include:

- product specifications: intermediate and final;
- amount and type of olives to be processed;
- processing steps to follow;
- quantities of chemicals and additions to be used;
- information for operators on the safe handling of chemicals;
- additional preservation steps: pasteurisation, sterilisation, preservatives; and
- testing procedures.

Note: Workers in the olive processing plant should be in-serviced and made aware of the requirements of the standards to ensure production of quality table olives.

Table 4.4. Commonly available commercial table olive products

Olive styles	*Processing method*
Black olives (primary processing)	
Naturally black-ripe olives in brine (Greek-style)	Whole or slit naturally black-ripe olives are processed by spontaneous fermentation in 8–10% salt solution for three to six months. Exposing processed olives to air returns some of the original black colour.
Kalamata-style	Whole or slit naturally black olives, usually *Kalamata*, are either debittered in water and brine or subjected to spontaneous fermentation in brine followed by the addition of wine vinegar and olive oil.
Heat-dried naturally black olives	Whole naturally ripe black olives are: • Sun-dried until bitterness has reached an acceptable level • Ripe fruit is blanched then oven-dried at low temperatures (50°C) for a few days until bitterness disappears.
Spanish/Californian-style black olives (olives darkened by oxidation) Note: starting material is not black-ripe olives	Whole green turning colour olives treated with several lye solutions of different strengths to remove bitterness, washed, transformed to a black colour by oxidation in an alkaline medium with air and then packed in brine. Processed olives are heat sterilised in their final containers.
Treated black olives (primary processing)	Whole black olives are given a short treatment with lye solution followed by natural fermentation in brine until debittered.
Untreated naturally black olives in dry salt (Thrumba-style)	Whole naturally full ripe black olives, fresh or partially dried, are packed in alternating layers of dry salt until debittered.
Green olives (primary processing)	
Untreated green olives in brine	Whole, slit or bruised green-ripe olives are processed by a natural fermentation in an 8–10% salt solution for 3–12 months until debittered.
Spanish-style green olives (Sevillean-style)	Whole green-ripe olives are treated for a short period with 1–2% lye solution, washed and then partially or completely fermented (lactic) in brine.
Turning colour olives (primary processing)	
Untreated turning colour olives in brine	Whole, slit or bruised turning colour olives are processed by natural fermentation in an 8–10% salt solution for 3–12 months.
Treated turning colour olives in brine	Whole olives are treated with lye, then preserved by natural fermentation in brine or heat treatment.
Specialty products (secondary processing)	
Marinated green or black olives	Marinades added to processed olives: untreated green, turning colour or naturally black-ripe olives in brine, Spanish-style green or Kalamata-style olives.
Destoned olives	Green or black olives destoned by hand or machine.
Stuffed olives	Processed green or black olives destoned then stuffed with garlic, pimento, onion, almonds, celery, anchovy, citrus peel, hazelnuts and capers.
Olive pastes and tapenades	Destoned processed green or black olives crushed to a paste with or without the addition of other foodstuffs (e.g. capers, anchovies, olive oil, garlic, sun-dried tomato).

Secondary table olive processing specifications

Secondary processing involves procedures for marinating and stuffing olives, making olive pastes, tapenades and olive pickles. It can be undertaken by the grower or processor, and can involve the preparation of the packing solution and additions such as oil (vegetable, olive, sunflower or canola) wine vinegar, herbs, spices and aromatics.

Specifications. Processing specifications must be clearly documented and should include:

- product specifications: intermediate and final;
- amount and type of olives to be processed;
- processing steps to follow;
- quantities of packing brines, olives and additives (olive oil, herbs, spices and aromatics);
- information for operators on the safe handling of chemicals, additives, adjuvants, herbs, spices and aromatics;
- alerts on health and safety matters during secondary processing; and
- testing procedures.

Note: Workers should be in-serviced on these specifications.

Finished table olive product specifications

To make primary or secondary processed table olives ready for consumption they may require an additional preservation method such as the addition of a preservative, pasteurisation or sterilisation.

Specifications should include:

- packing solution details;
- additives;
- additional preservation method;
- packaging information; and
- labelling information.

Generic processing protocol for table olives

The generic processing protocol in Fig. 4.19 can be used as the template for all processing methods. Specific procedures are added for the different olive methods/styles.

There are a number of procedures common to all processing methods/styles; however, specific details relate to the actual method/style. Furthermore, most people confuse the nature of the final product with the method/style, particularly where the olives are embellished with herbs, spices, aromatics, fillings and marinades. Olive recipes are often requested. It is best to separate the actual processing procedure as

- Accept only quality raw olives
- Store raw olives correctly
- Wash raw olives
- Size grade and sort raw olives
- Use processing method or style with HACCP controls
- Size grade and sort processed olives
- Pack processed olives in final packing solution
- Pasteurise/sterilise the packed processed olives if required
- Label packed processed olives in accordance with food standards
- Implement a safety recall system for faulty packed processed olives

Figure 4.19 Generic processing protocol for table olives.

primary processing and recipes as secondary processing. The latter relates to the embellishments of olives that have undergone primary processing. Trying to process olives when the embellishments are included at the beginning can result in variable or anomalous products and should not be practised for commercial table olive production.

Process control (microbiological, chemical and physical) is essential during table olive production. Procedures must be developed and documented consistent with the processing steps, including HACCP.

Acceptance of raw olives by processors

Each batch of olives should be examined for quality: olive size, shape, damaged olives and the presence of leaves. Processors should ensure that they are able to recognise and distinguish between varieties, for example *Manzanilla* v. *Sevillana*, *Verdale* v. *Conservolea*, *Leccino* v. *Frantoio* or *Kalamata* v. *Barnea*. Knowledge of the growing region and the growing technologies used, for example irrigated v. non-irrigated, can be related to skin and flesh properties, so processing conditions can be modified accordingly. Olives from irrigated trees, because of their higher water content, are more sensitive to salt damage than those from unirrigated olive trees. Processors buying olives from growers should ask for a chemical use diary for the delivered batch of olives. The chemical use diary should include chemical names, dates of application and the recommended withholding periods (see Chapter 3) to ensure these have been met. Processors should not accept olives where olives or orchards have been treated with non-approved chemicals. Random testing for chemical residues, although expensive, is useful in establishing supplier confidence. Growers and suppliers should understand the table olive processor's requirements before they enter into supply arrangements. The following protocol can be used as a guide.

Protocol for accepting olives. At the processing facility raw olives should be assessed for variety, ripeness and soundness before acceptance. With each olive batch or load, the following information should be provided by the grower and checked by the processor:

- supplier's name;
- receipt date;
- harvesting method and date;
- variety;
- maturation state;
- olive size;
- growing region;
- growing technologies;
- chemical use diary; and
- weight of olives delivered.

Batches of olives with high proportions of undersized or defective olives are uneconomical for table olive production and should be rejected.

Correct storage of raw olives at the processing facility

Careful post-harvest handling of olives is essential to achieve quality table olive products. Raw olives, particularly naturally black-ripe olives, are sensitive to damage during handling and storage. These must be processed as soon as possible after harvesting and certainly within 24 hours of delivery to avoid deterioration and poor table olive products. Bruised or marked raw olives fetch low prices compared with good quality olives (see Chapter 3).

Protocol for general storage of raw olives. To minimise the risk of contamination or damage, olives should be stored at temperatures between 5–10°C for no more than 24 hours in shallow ventilated crates under clean and hygienic conditions. Green olives can be stored for longer periods.

Protocol for storing raw olives in brine. Quantities required to prepare salt brines are given in Table 4.5. Commonly used brine solutions for pre-process storage of olives contain 8–10% w/v sodium chloride. The pre-storage of olives in brine is used when the capacity of the processing plant is exceeded and the processor wishes to 'buy' time, particularly where processing involves lye treatment.

Table 4.5. Quantities of sodium chloride required to prepare salt brines

Sodium chloride % w/v in potable water	*Brine volumes to be prepared*		
	100 litres	*500 litres*	*1000 litres*
5	5 kg	25 kg	50 kg
6	6 kg	30 kg	60 kg
7	7 kg	35 kg	70 kg
8	8 kg	40 kg	80 kg
9	9 kg	45 kg	90 kg
10	10 kg	50 kg	100 kg
Potable water to	100 litres	500 litres	1000 litres

Such a procedure means that storage in air, with the risk of damage to the olives, is avoided. Of course, placing olives in brine is the exact procedure for processing natural untreated olives in brine by spontaneous fermentation.

Storage tanks are partially filled with the salt solution before the olives are introduced to prevent bruising or pressure damage. Depending on the storage time, a partial fermentation takes place. The salt concentration in the brine should be checked with a suitable instrument before adding the olives (see Chapter 6).

To reduce the risk of the olives shrivelling, a problem which is often variety dependant, an initial solution starting at 5.0–7.5% w/v food grade sodium chloride in potable water should be used.

The container should be filled to the brim with olives and brine so there is minimal air space above the brine, then tightly sealed to ensure anaerobic conditions. Keeping the olives submerged with a grating made of food grade material prevents them discolouring, but does not necessarily prevent the growth of fungi on the brine surface. After a few days, more food grade salt is added to increase the strength of the brine to 8–10% w/v salt. Brines should be mixed either manually or mechanically with pumps, initially every three days, then weekly to ensure homogeneous mixing and prevent uneven salt levels within the tank. If experience shows that shrivelling is not a problem with particular varieties and maturation states, the higher salt solutions can be used initially.

If anaerobic conditions are not achieved, oxidative yeasts and moulds develop on the surface of the brine, releasing enzymes that attack the fibrous structural components of the olives, causing them to soften. This can be avoided by carefully controlling the brine strength, having well-filled tanks with minimal air space between the lid and brine surface, and by keeping tanks well sealed. Prevention is better than cure but if yeasts or moulds start to develop on the surface of brines they should be skimmed off regularly. Allowing extensive fungal mats to develop on the surface of brines increases the risk of spoilage and more rarely the likelihood of these fungal contaminants producing cancer-inducing agents such as mycotoxins. In the case of large tanks, having only small openings at the top of the tank for loading olives can markedly reduce the surface area of the brine, thus reducing the problem of moulds.

Note: If there are heavy mould growths or bad smelling olives, the olives should be destroyed.

As indicated earlier, with prolonged storage a weak spontaneous fermentation occurs typical of processing olives in brine without initial lye treatment or the addition of starter cultures. Under these conditions the pH of the brine falls and the free acid levels should reach the equivalent of 0.40–0.45% lactic acid. The brine conditions need to be controlled for pH and salt levels to prevent spoilage such as olive softening and gas pocket formation by Gram negative bacteria. Ensuring the salt concentration is at least 8% w/v and ensuring a pH of around 4 can prevent spoilage. If a rapid lowering of pH is required, a food grade acid (lactic acid or acetic acid) is added to give tank concentrations of 0.5% w/v lactic acid, or 0.25% w/v acetic acid.

Protocol for storing raw olives in salt-free solutions. Salt-free storage solutions have been developed at some centres for storing olives prior to processing with lye. This method confers an environmental advantage; using such solutions avoids the need to dispose of large amounts of salt storage solution. Researchers have found salt-free storage solutions do not support fermentation and there is no deterioration in organoleptic qualities when olives are processed. A typical salt-free solution is presented in Table 4.6. It includes both acidulants and preservatives.

Table 4.6. Quantities of chemicals for preparing salt-free olive storage solutions

Chemical component	*Action*	*%*	*100 litres*	*500 litres*	*1000 litres*
Lactic acid	Acidulant	0.67	0.67 kg	3.35 kg	6.70 kg
Acetic acid	Acidulant	1.00	1.00 kg	5.00 kg	10.00 kg
Sodium benzoate	Preservative	0.30	0.30 kg	1.50 kg	3.00 kg
Potassium sorbate	Preservative	0.30	0.30 kg	1.50 kg	3.00 kg
Potable water to		100	100 litres	500 litres	1000 litres

Raw olives enter the table olive processing line

Special care must be taken when unloading and handling olives. With small enterprises most operations are undertaken manually, whereas in large-scale operations these procedures are mechanised, using belts and conveyors to move olives from collection areas to the sorting and washing facilities. Individual varieties should be processed separately to avoid variable final products.

Protocol for washing raw olives. Olives should be washed with potable quality water before entering the processing line. Spray washing is more effective than static washing. The olives are washed with spray rinsing machines using potable water to remove contaminants such as leaves, orchard dust, dirt, chemicals and soil microbes, such as *Clostridia*, *Bacilli* and coliforms, thus reducing the risk of spoilage during processing and harm to consumers. In the case of boutique/small-scale table olive producers, spray washing olives packed in slotted crates with a spray hose should suffice. Washing does not remove microorganisms on the skin that are required for natural fermentation processing procedures. If water of unknown quality from sources such as rainwater tanks and bores is used, it should be checked and treated so that it meets potable water standards. A diagrammatic representation of a typical line for washing, sorting and size grading olives for table olive production is presented in Fig. 4.20.

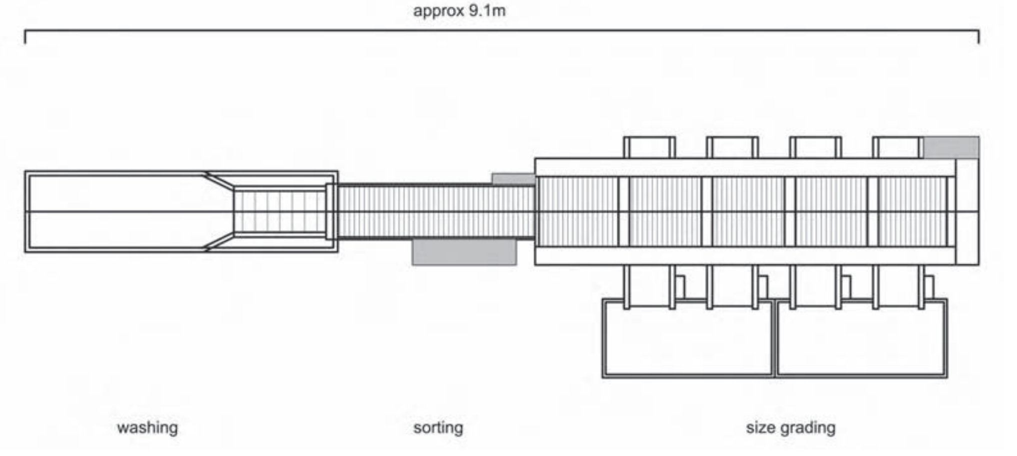

Figure 4.20 Diagrammatic representation of a raw olive washing machine with sorting table. (Image: Australia Olive Oil Supplies, Victoria, Australia.)

In some enterprises, where olives are processed with lye (caustic soda), the initial washing step is omitted as multiple washes with water are used during processing. In this case, the olives are generally washed in the same tanks as the lye treatment step.

Note: Lye solutions should be prepared in separate tanks and then fed into the processing tanks.

Protocol for preliminary size grading of raw olives and removal of damaged olives. Before the olives are placed in the processing tanks or containers they should be size graded into three to four sizes to remove undersized, misshapen and damaged fruit using a grading machine and sorting table respectively. Either the grower and/or the processor can undertake these operations. If there are sufficient culled olives they can be used for olive oil production.

Preliminary grading and sorting of raw olives has a number of advantages.

- Similar sized olives process at the same rates.
- Increased efficiency because reject olives are not processed.

- Reduced risk of contamination if large numbers of defective olives are present.
- Facilitates final sorting and packaging operations.

Note: All equipment should be in a clean and sanitary condition before commencing preliminary size grading of olives.

Placement of table olives into processing tanks

Processors should have a selection of different sized tanks made of food grade material (food grade plastic, fibreglass or stainless steel) – 250 kg barrels to 10–15 tonne fermentation tanks – and develop a processing plan for the season based on quantities, varieties and styles. Attention needs to be paid to loading and unloading olives to reduce any damage and contamination. Tanks with sloping bases and large valved outlets at the bottom facilitate unloading of the olives, otherwise pumps need to be used (Fig. 4.21).

Processing media for table olives include potable water, brine (salt 8–10% w/v in potable water) or lye (caustic soda) depending on the method used. Tanks are partly filled with water or appropriate processing medium then filled with olives. This procedure prevents bruising and pressure on the olives. The tank filling procedure should be undertaken as quickly as possible especially with green-ripe or turning coloured olives, certainly in less than 20–30 minutes, so that olives are not damaged by pressure or by exposure to air, resulting in discolouration. When filled with olives, the tanks are topped up with water or processing medium.

Figure 4.21 Stainless steel pump for pumping olives in brine.

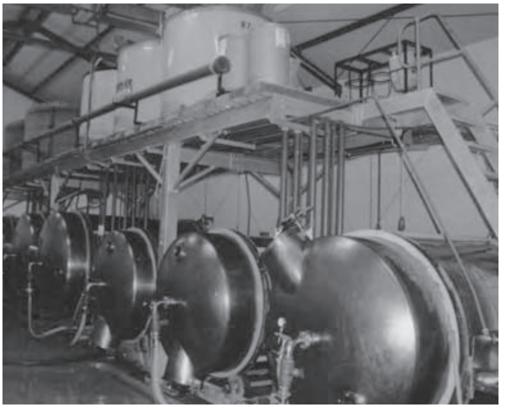

Figure 4.22 Rotating stainless steel olive processing tanks. (Photo: Buffet Olives, Paarl, South Africa.)

During processing, particularly with brine, the liquid should be well mixed by circulating brine with a pump, stirring or barrel rotators to allow an even reaction in the tank and prevent the formation of salt gradients. In some centres, rotating stainless steel processing tanks are used. These tanks are often fitted with plumbing and valves to allow the addition and removal of processing solutions as a batch or continuous process (Fig. 4.22).

Tanks should be filled to capacity with olives only of the same variety, maturation stage and size before processing commences. This favours even processing of olives. Once processing has commenced, further additions of raw olives should not be made. Processing temperatures should be maintained between 20°C and 25°C during fermentation. If temperatures are too low, processing is stalled or processing time is prolonged. To overcome this problem, in-line heat exchangers can be used or air conditioners installed to maintain brine temperatures. Tank temperatures higher than 30°C should be avoided as high temperatures can lead to the growth of anomalous organisms resulting in spoilage and possibly food poisoning in the consumer.

General methods for processing table olives

Olives are processed using one of the following procedures to remove the bitter principles and in their preservation (more details on olive processing procedures are presented in Chapter 5):

- repeated soaking in water followed by placement in brine;
- fermentation in brine;
- lye treatment followed by fermentation in brine;
- lye treatment without fermentation, in brine; or
- drying with salt or heat.

The first three methods involve a fermentation process, albeit weak in some cases.

When raw olives are debittered through multiple soakings in water (where the water is changed daily) and then placed in brine, a weak fermentation may proceed. With olives placed directly in brine a spontaneous anaerobic fermentation bacteria and/or yeast (depending on the brine pH and salt concentration) is initiated by native organisms on the fruit. With lye treated olives, for example Spanish-style green olives, the olives are placed in brine after washing out the excess lye and undergo a bacterial lactic fermentation. In the latter case, the addition of starter cultures of lactic acid bacteria, for example *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*), to the fermentation tanks is often required as lye treatment destroys the natural flora on the olives that would have normally supported fermentation. In well-established olive processing facilities in olive producing countries of the Mediterranean, addition of starter cultures is not standard practice.

Starter cultures. The effect of the addition of pure starter cultures on the organoleptic qualities of finished products is yet to be concluded, with different researchers having opposing views. Some believe that organoleptic characteristics of olives processed with added pure cultures lack the nuances of the traditional product, whereas others believe there is improvement. In Australia, the starter culture Vege-Start™ (Chr. Hansen Laboratories, Melbourne, Australia), comprised of *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*) culture, is available for a range of pickling operations and can be used for producing Spanish-style green olives. When starter cultures are used, in principle, complete fermentation can be achieved in three to nine weeks. In practice a sufficient amount of starter culture is added to the fermentation brine so that after a few days, when the acidity of the brine falls to around pH 6, the number of fermentative organisms reaches about 10^6/ml of brine. The amount of starter culture used will depend on the size of the tank. For example, a 50 g sachet of Vege-Start™ is added to tanks with an approximate capacity of 10 tonnes holding 6000 kg of olives. Samples taken from active fermentation brines can also be used as starter cultures. The effectiveness of starter cultures as identified by Spanish and Italian researchers depends on the variety, competing microorganisms and brine characteristics such as:

- fermentative substrate levels;
- growth factor levels: additional nutrients, such as vitamins and amino acids;
- salt concentration;
- pH and acid levels;
- temperature; and
- inhibitor levels, for example polyphenols released from olives.

Vege-Start™. Vege-Start™ is a freeze-dried culture, in a lactose carrier, of the homofermentantive (produces only lactic acid) lactic acid bacteria *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*), used for pickling of olives and cucumbers. The *Lactobacillus pentosus* in Vege-Start™ has been selected by the manufacturers to have a high salt tolerance and a wide pH and temperature range. The product specifications are as follows:

- cells per gram = minimum of 4.8×10^{10} CFU/g;
- viable temperature range 15°C to 40°C with an optimum temperature of 30°C;
- viable pH limits are minimum pH 3.7 and maximum pH 8.0;
- principle fermentation product is a 50/50 mixture of the D and L forms of lactic acid;
- shelf-life is 18 months at –18°C and three months at +5°C; and
- levels of other microorganisms (in 25g of Vege-Start™): *S. aureus* <100 CFU/g; *B. cereus* <100 CFU/g; *E. coli*/coliforms <100 CFU/g; Streptococci <100 CFU/g; yeasts/moulds <100 CFU/g, and *Salmonella*-negative.

Vege-Start™ is effective in carrying out fermentations at salt concentrations from 0 to 8% sodium chloride. However, as the salt levels in the brine increase, fermentation rates decrease with the final pH of brines all reaching around pH 3.5. Optimal salt levels are 4–8% w/v. At salt concentrations of 9% w/v Vege-Start™ survives and grows, but the lag phase (period of low growth and activity) is prolonged so undesirable organisms early in fermentation could dominate. If brine salt levels are less than 4% w/v the risk of undesirable salt sensitive organisms growing increases.

The optimal pH conditions for inoculation with Vege-Start™ are between pH 5–7 but it can be used up to pH 7.5 and as low as pH 4.5. If adjustment of brine pH is required, the manufacturers recommend hydrochloric acid be used rather than acetic acid, as the *Lactobacillus* in Vege-Start™ is sensitive to the latter. If brine pH is too high (after lye treatment) or too low (over-correction with acid), when an inoculum of Vege-Start™ is made, the starter culture is inhibited. This problem can be managed in part by reducing the brine salt levels to below 7% w/v.

Optimal fermentation with this starter culture occurs at 25–30°C with very good results at 20–35°C. Reasonable fermentation results can be achieved at 15–20°C. Lower temperatures slow growth of the starter culture and result in acidification of the brine.

The Vege-Start™ culture is added directly to olives and brine already placed in the fermentation tank. Ideally the brine should have an initial pH of 5–7 (adjusted with a food grade acid, preferably hydrochloric acid) and salt levels of 6–8% w/v. The freeze-dried powder is quickly dissolved in water or brine then added to the tank as soon as possible with gentle agitation to ensure its dispersion.

Note: Leaving cultures too long in brine is detrimental so it should be added to the fermentation tank immediately after dissolution. Also, for optimal results, once the sachet has been opened it should be used straight away and not stored.

Starter culture research. Processors and researchers in Spain and Italy, as well as Australia, are collaborating with microbiologists to develop specific starter cultures that are advantageous to table olive fermentations. Sought-after characteristics include the ability to:

- resist the action of polyphenolic inhibitors;
- grow at low levels of growth factors;
- compete with other microorganisms, including wild strains;
- tolerate the extreme chemical conditions in brine;
- speed up fermentation to reduce processing time;
- be freeze-dried without losing potency when stored; and
- have multiple functions such as beta-glucosidase activity to break down oleuropein as well as support fermentation that produces lactic and acetic acids.

Californian-style/Spanish-style black olives are produced from green-ripe olives (the skin can have some pigmentation) by chemical processing with lye. They are then oxidised and brined without fermentation. Although there is an expectation by consumers that blackness in an olive is indicative of ripeness, artificially turning green olives into black is a contradiction. Olives processed by this method require heat sterilisation. Sterilisation is unnecessary for olives when fermented in brine as long as the brine/salt concentration and pH are favourable for preservation.

A major disadvantage of spontaneous brine fermentation is that it can take from three months for black-ripe olives and 12 months for green-ripe olives, whereas lye treated olives can be in the market-place four weeks after processing.

The final flavour of primary processed olives depends on the variety, processing method and final packing procedure. After primary processing, adding vinegar, marinades, and herbs and spices extends the flavour of the olives. Addition of food acids such as vinegar (acetic acid), lactic acid or citric acid is used to optimise shelf-life and the flavour of the olives. Olive oil is often added to dried olives.

Microorganisms relevant in table olive processing

Bacteria and yeasts are the main microorganisms of importance in table olive processing, particularly with respect to fermentation. Moulds, another important group, play no role in fermentation but can cause spoilage. Generally with fermentations, the order of organism growth is: bacteria, yeasts then moulds. Smaller organisms, *Leuconostoc* and *Streptococcus* spp., grow and carry out fermentation more rapidly than other related bacteria and are, therefore, the first species to appear in the fermentation brine.

Bacteria. Bacteria are a large group of unicellular organisms lacking chlorophyll and a nucleus. They mostly multiply rapidly by simple fission: each bacterium growing and then splitting into two bacteria and so on.

Lactic acid bacteria. Relevant to the fermentation of table olives is a group of Gram positive lactic acid bacteria that utilise reducing sugars to produce acids (lactic acid and acetic acid) that are released into the fermentation brine. The net effect is an accumulation of acids and a lowering of brine pH. The main taxa involved are *Lactobacillus*, *Leuconostoc*, *Pediococcus* and *Streptococcus*. *Streptococcus* and *Leuconostoc* species produce the least acid. Heterofermentative *Lactobacillus* species produce intermediate amounts of acidic compounds, followed by *Pediococcus* and then homofermentative *Lactobacillus* species producing the most acid.

Heterofermentative bacteria, *Leconostoc* spp. and some *Lactobacillus* spp. produce 50% lactic acid + 25% acetic acid and ethanol + 25% carbon dioxide.

Homofermentative bacteria, *Streptococcus* spp. and some *Lactobacillus* spp. produce 100% lactic acid. *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*), a homofermenter that plays a major role in olive fermentations, produces high levels of acidity.

Note: When all conditions are favourable, the amount of acid produced depends on the availability of fermentative substrates in the processing system. At low brine salt concentrations the pH levels of brine can fall to <4 with the total acid produced reaching 1% w/v or more when calculated as lactic acid. At high salt concentrations the pH levels of brine are between 4.0–4.5 with the total acid produced reaching around 0.5% w/v or more as lactic acid. During spoilage, if organisms consume acid the pH of the brine increases and the total acid levels fall, jeopardising the commercial value and safety of the table olive product.

Spoilage bacteria. Bacteria can cause olives to soften. Three malodorous fermentations due to spoilage bacteria – putrid, butyric and '*Zapateria*' – are associated with table olive processing (see Chapter 6).

Yeasts. Yeasts and yeast-like fungi are unicellular organisms that reproduce asexually by budding, or in some cases sexually by conjugation. They are present in the environment, in the air and in the soil, in orchards and the intestinal tracts of animals. They are active at temperatures between 0–50°C with an optimum range of 20–30°C, which is also the temperature range for natural fermentations. As yeasts are usually acid tolerant (that is, able to grow at pH 4.0–4.5), they can be associated with spoilage of acid foods. Commonly found yeast species in natural fermentations include *Candida boidinie*, *Debaryomyces hansenii*, *Saccharomyces cerevisiae* and *Torulopsis candida*. Some yeasts, such as *Saccharomyces cerevisiae*, have the ability to shift their metabolism from a fermentative to oxidative pathway depending on how much oxygen is available, hence the need to keep strict anaerobic conditions during table olive fermentation. As yeasts produce alcohol and carbon dioxide from sugars such as glucose and fructose, lower lactic acid levels and higher pH values result. One advantage of yeasts growing in fermentation brines is that the texture and fruitiness of the olives improves. Yeasts are not inhibited by polyphenols released from the olives into the brine during processing. In fact some yeasts, like *Candida veronae*, can split oleuropein into a less bitter compound and sugar which is then available to *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*) for fermentation. It is possible that some strains of *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*) may be able to carry out both debittering and fermentation.

Spoilage due to yeasts. Yeasts create food spoilage by producing brines with a slimy or cloudy appearance or by producing unwanted metabolic by-products that taint the olives. Yeasts have not been found to produce human toxins or cause food poisoning. Yeasts, in particular *Saccharomyces oleaginosus* and *Hansenula anomala*, are also involved in gas pocket formation.

Note: A chemical combination of alcohol and acetic acid results in the formation and accumulation of ethyl acetate, an ester with a characteristic 'nail polish' odour.

Moulds. Moulds are a group of multicellular fungal microorganisms, some of which can cause olive spoilage. Although plant-like, they do not have chlorophyll and must absorb organic nutrients from their surroundings. They are often found growing as a mycelial mat, for example *Penicillium*, *Aspergillus* and *Rhizopus* spp., with powdery growths (spores) on the surface of brines when the conditions (pH, salt concentration and degree of anaerobiosis) are poorly controlled. Moulds are aerobic (require oxygen for growth) and grow in a temperature range of 8–35°C. As moulds are usually acid tolerant and able to grow at pH 2.0 to 8.5, they are associated with spoilage of acid foods. Moulds release chemicals into brines that can taint the olives, for example by giving them a mouldy taste. Others release enzymes or can colonise and grow on olives, particularly those at the brine surface. Some like *Aspergillus* can produce carcinogenic toxins called 'aflatoxins'.

In summary, with fermentations, the order of organism growth is bacteria, yeasts, then moulds. Smaller organisms *Leuconostoc* and *Streptococcus* spp. grow and ferment more rapidly than other related bacteria and are, therefore, the first species to appear in the fermentation brine.

Food spoilage. Spoilt foods are those that have become unpalatable due to microbial growth. Such products can have undesirable odours, flavours, appearance or texture. Food poisoning occurs when harmful microorganisms in food cause human illness or death. In addition to bacteria, yeasts and moulds, food contaminated with viruses, protozoa or nematodes can also cause food-related illness. (See Chapter 6 for a more detailed review of table olive spoilage and safety.)

Manipulation of microbial activity

Controlling microorganisms is of the utmost importance in table olive processing.

Prevention of contamination. As olives are grown in open orchards, controlling microbial contamination in this setting is mostly impossible. Establishing reliable procedures that can eliminate some microbial diseases (particularly fungal) from the olive tree could possibly help, but needs further investigation. Using quality irrigation water and undertaking harvest and post-harvest operations in a clean hygienic manner helps reduce contamination of olives. During processing, measures must be in place so that contamination from unpurified water, contact with sewage and air containing microbial spore laden dust is minimised. Equipment should be cleaned and sanitised before use. Preventing damage to the olive skin during harvesting and transport of raw olives also protects against microbial damage. Worker hygiene, another important factor, has been discussed in an earlier section of this chapter.

Physical removal of contaminants. Filtration of water through various types of filters reduces physical, chemical and some microbiological contaminants. Washing olives prior to processing is a basic form of microbial control.

Controlling the following six major factors that can affect growth and survival of microorganisms associated with table olive processing is also important:

- moisture;
- oxygen levels;
- temperature;
- nutrients;
- acidity and pH; and
- inhibitors.

It is the interplay of these factors that ultimately determine the viability of specific microorganisms.

Moisture. All living organisms, including bacteria, yeasts and moulds, require water for survival. The quantity of water required by these organisms is termed water activity (A_w). Water activity is defined as the ERH (equilibrium relative humidity) divided by 100. Pure water has an $A_w = 1$. When A_w is less than 0.6 the growth of most microorganisms is inhibited. For the different categories of microorganisms (accepting there will be exceptions) broad critical values of A_w are given below:

- bacteria: inhibited below A_w of 0.9;
- yeasts: inhibited below A_w of 0.8;
- fungi: inhibited below A_w of 0.7.

Moisture or water in living organisms and foodstuffs exists in two forms, free and bound. Water activity is a measure of the free water calculated by dividing the water vapour pressure of the material by the water vapour pressure measured at the same temperature.

The 'effective' water activity of olives can be lowered by reducing moisture (heat-dried olives), adding salt (natural olives and salt-dried olives) or adding sugar (such as in jams and conserves). With natural olives, the salt binds free water, whereas in salt-dried olives salt binds water as well as reducing the amount of water in the flesh.

The A_w of a food may not be a fixed value; it may change over time, or may vary considerably between similar foods from different sources. An A_w value stated for a microorganism is generally the minimum A_w that supports growth. At the minimum A_w, growth is usually minimal, increasing as the A_w increases. At A_w values below the minimum for growth, microorganisms do not necessarily die, although some proportion of the population may do so. The microorganisms remain dormant but still retain the potential to grow. Most importantly, A_w is only one factor and other factors such as pH and temperature of the food must also be considered.

Lactic acid bacteria can tolerate the high salt concentrations used in fermentation brines. Such tolerance is advantageous for these lactic acid fermenters over less tolerant species of microorganisms. The acids produced by the lactic acid bacteria lower the pH of fermentation brines, further inhibiting the growth of undesirable organisms. *Leuconostoc* spp. initiate the majority of lactic acid fermentations because of their high salt tolerance.

Oxygen levels. All forms of life, including microorganisms, require oxygen in one form or another. On the basis of this, microorganisms can be divided into two main categories: (1) aerobic microorganisms use atmospheric oxygen, and (2) anaerobic microorganisms use oxygen bound to compounds such as carbohydrates.

Some microorganisms, classified as 'facultative organisms', are able to switch from one form to another depending on the available oxygen levels.

Most olive fermentations are anaerobic, although research has shown that aerobic fermentations also have a place. Key organisms in olive fermentation such as lactic acid bacteria utilise reducing sugars (glucose, fructose) from the olive flesh to produce lactic and other food acids that lower brine pH, a requirement to ensure consumer safety. Moulds do not grow well under the anaerobic conditions created during fermentation. However, surface mould will grow if enough air space is available above the brine surface.

Since many yeasts and all moulds are strict aerobes, removing air by applying a vacuum or replacing it with a gas (such as carbon dioxide or nitrogen) as in the principle of vacuum packing will prevent their growth. However, it is still possible for anaerobic organisms such as *Clostridium botulinum* to reproduce in the absence of oxygen.

Temperature. Temperature affects the growth and activity of microorganisms. The temperature range for optimal fermentation conditions is between 15°C and 30°C with 25°C being very favourable. Below 15°C fermentation is very slow and above 30°C growth of anomalous food spoilage organisms is more prevalent. Most lactic acid bacteria operate more effectively at temperatures of 18–22°C including the *Leuconostoc* species that initiate fermentation. Temperatures above 22°C favour the *Lactobacillus* species.

Very low temperatures (refrigeration) improve the storage life of table olives, whereas exposure to high temperatures, for example during pasteurisation or sterilisation, destroys microorganisms. High temperatures kill spores and vegetative cells and destroy some microbial toxins. The effectiveness of heat treatments depends upon the temperature and duration, type and number of microorganisms present, pH and salt levels and the stability of the olives. The higher the temperature the less time is needed. In general, most olives show physical changes after pasteurisation. Pasteurisation is not necessarily designed to kill all microorganisms, just pathogens, whereas when olives are canned and sterilised the goal is to eliminate all organisms, including spores.

Note: When checking the temperatures of fermentation brines electronic thermometers should be used rather than glass mercury thermometers.

Nutrients. All microorganisms require nutrients for growth and survival. In the case of olive fermentation, nutrients released from the olive include reducing sugars, amino acids, vitamins and minerals. When all the sugars have been used to produce food acids and other metabolites, microorganisms are inhibited and growth rates decline. If environmental temperatures increase or the temperature of the fermentation tanks is poorly controlled, then anomalous organisms can utilise the food acids produced, raising the brine pH and increasing the risk of spoilage.

Acidity and pH. pH is a measure of the hydrogen ion concentration in a solution, such as fermentation brine or packing solution. It is measured by using specific pH papers or pH meters. pH values, which are based on a logarithmic scale range from 1–14, where a value of one represents high levels of hydrogen ions (acidic) and a value of 14 represents a low concentration (alkaline). A value of seven is classified as neutral (see Chapter 6 for testing details). The actual amount of acid produced during fermentation or added to brine for adjustment is generally calculated as grams of lactic acid per100 millilitres equivalent, and must also be considered in the preservation of table olives.

The optimum pH for most microorganisms is pH 7 (neutral) or slightly acid. Foods with a pH 4.5 or less are classed as high acid foods. The growth of bacterial spores associated with food poisoning will not occur at these levels of acidity. Foods with pH values greater than 4.5 are prone to spoilage due to the growth of bacterial spores. Effective fermentations of table olives achieve brine pH values between 4.3 and 4.5 or less. If these pH values are not achieved, food acids, for example lactic or acetic acids, can be used to lower brine pH making the olives safe and resistant to bacterial spoilage. *Lactobacillus* spp. and *Streptococcus* spp. are acid tolerant bacteria.

Yeasts can grow at pH ranges of 4.0–4.5, so in spontaneous fermentations yeasts are often present with fermentative bacteria. Moulds prefer acid environments, but they can grow over a wide range of pH values (pH 2.0–8.5).

Inhibitors and preservatives. All substances, synthetic or naturally occurring, that can interfere with microbial cell membranes, enzymatic action or genetic, or act in a way to negatively affect the microbial environment, can be considered to be inhibitors or preservatives. Acid build-up during fermentation inhibits many bacteria. Fermentative bacteria such as *Lactobacillus* spp. can also be inhibited in acid environments and if too much acid is added during correction procedures no fermentation occurs and the possibility exists of not debittering the olives. Furthermore, polyphenols in olive flesh can inhibit a number of useful as well as harmful microorganisms.

Chlorine (sodium hypochlorite), used as a sanitiser, injures cell membranes, inhibiting or killing harmful microorganisms. Chemical preservatives if added to olives should have minimal impact on the health of consumers and not impart off-flavours to the olives. Preservatives such as sorbic acid injure microbial cell membranes. Salts of sorbic acid can also dehydrate microbial cells as well as inhibit enzyme activity within the microbes. Potassium sorbate, commonly included in table olive products as a preservative, should be held at concentrations within the range of 0.02–0.05% w/w.

Fermentation and table olives

Fermentation is the process by which organic substrates, such as sugars (for example glucose and fructose), undergo biochemical changes by the action of microorganisms or enzymes to produce food acids, ethanol, carbon dioxide and other metabolites. Fermentation involving microorganisms is a natural process, hence its use in the production of 'natural' olives. Controlled fermentation is generally an efficient process requiring low energy inputs and increasing the safety (when consumed) and shelf-life of olives.

The fermentation process, in most cases, occurs in the brine. Fermentable substrates need to diffuse out of the olive flesh into the brine and fermentation products (lactic and acetic acids) and salt need to pass into the olives. When processed correctly, preservation is due to the combined effects of salt, pH and the organic acids, and the olives will not need heat treatment to ensure safety and stability. However, as a precaution many fermented table olive products are packed and pasteurised with or without preservatives such as salts of sorbic or benzoic acids.

It is essential with olive fermentation to ensure that only the desired bacteria or yeasts start to multiply and grow in the brine at the expense of undesirable pathogenic and spoilage microorganisms. Most spoilage microorganisms cannot survive the salt/acidic environments of table olive processing.

Fermentation of olives involves the action of lactic acid producing bacteria, for example *Lactobacillus* spp. and/or yeasts, on fermentable substrates, such as sugars, released from the olives during placement in water or brine. During fermentation, acids such as lactic and acetic acid are produced, which increase the acidity level of the brine and lower its pH. Alcohol is also produced during some types of fermentations. The combination of high salt and low pH greatly reduces the risk of microbial spoilage of the olives. Controls are essential to reduce the risk of overgrowth of undesirable or harmful microorganisms that can lead to product deterioration or food poisoning. Process control involves maintaining the salt and acid levels by targeted additions of sodium chloride and food acids respectively. Such processing, generally undertaken at temperatures between 20°C and 25°C, requires negligible energy input. However, where average daily temperatures are low, additional heating is required. Where processing tanks are not under cover and tank temperatures are expected to exceed 30°C, they should be made of materials with a reflective colour and cooled with water sprays on excessively hot days.

A simple debittering process for any olive, green-ripe, turning colour or black-ripe, is placing them in 8–10% w/v salt brine solution for a period of time. Fermentation then takes place in the processing tank, and flavour compounds are formed through the interaction of microorganisms. Textural changes in the flesh also occur. If the process is well controlled, safe nutritious olives are produced and the fermentation brine can be used to prepare the final packing solution for 'natural' and 'traditional' olives.

Continuous records should be kept and the process controlled, especially pH, salt levels, microbiology, organoleptic changes and spoilage. All operatives need to be trained in food processing methods, handling chemicals and processing olives. Total quality management and HACCP systems should be in place.

Anaerobic fermentation

Anaerobic fermentation is commonly used in table olive production either as the first step or after debittering with lye. Processing olives by anaerobic fermentation in brine involves a number of sequential stages. Aerobic fermentation methods for table olive processing are also used, but to a limited extent in the olive industry. An advantage of aerobic fermentation of olives is a reduction of gas pockets in the product.

The process of fermentation involves the splitting of organic compounds by microbial enzymes into simpler substances, for example sugars are converted to lactic acid, acetic acid and alcohol. Raw olives have a natural microflora: Gram negative bacteria; homofermentative and heterofermentative lactic acid bacteria and/or yeasts; oxidative yeasts and moulds; and *Clostridia*, *Propionibacteria* and *Bacillus* spp. Some of these microorganisms are integral to processing and fermentation whereas others, if not controlled, can eventually lead to soft and malodorous olives. The exact combination of microorganisms varies with the olive maturation stage, but the principles above apply.

Olives are generally fermented in brine (8–10% w/v salt brine). The initial brine has a pH of around 6.5–7.5 and possibly higher if the olives are pre-treated with lye (Fig. 4.23). At the beginning, Gram negative bacteria predominate even in the nutrient-poor brine. These bacteria produce copious amounts of carbon dioxide, as does the fruit that is still technically alive. The carbon dioxide released dissolves in the brine producing carbonic acid. Some natural acids released from raw olives can also contribute to the initial acidity. Oxygen is also consumed. The net result is a moderate increase in the brine acidity and a fall in pH to around 5, which helps establish anaerobic conditions in the brine for fermentation. This process generally takes three to four days. If the pH does not fall, then Gram negative bacteria persist and the olives can develop gaseous spoilage: gas pockets and soft olives. The addition of food acid, for example lactic acid, so that the brine pH falls to around 5 can avoid this problem. The salt levels in the brine should be maintained around 8% w/v during processing.

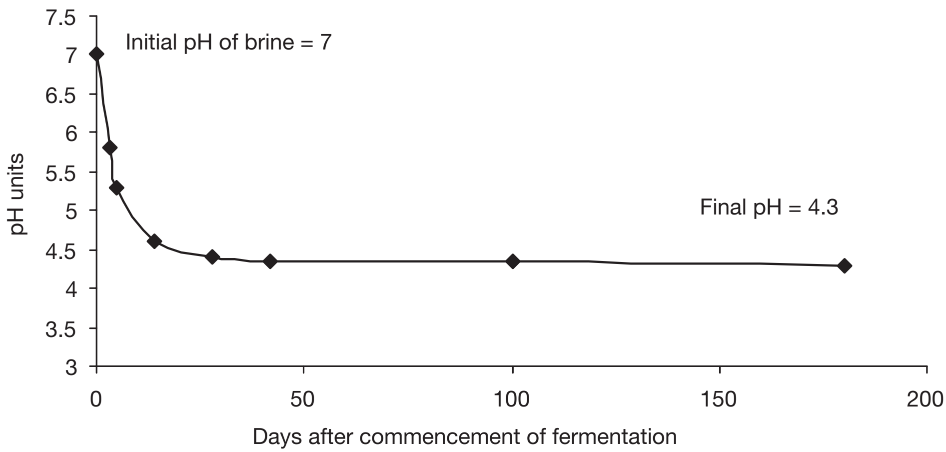

Figure 4.23 Typical changes in brine pH during spontaneous anaerobic fermentation of untreated raw olives.

Note: The fermentation containers (barrels, tanks) must be kept full of brine at all times. During the period of active fermentation (four to five days) when gas production causes excessive frothing and bubbling, care must be taken to replace all lost brine. When gas production subsides, the closures or lids should be tightened firmly to exclude air and keep oxidative yeast and mould growth at the surface to a minimum. If the olives being fermented are low in sugars, sugar (dextrose, sucrose or corn syrup) can be added three to four days after fermentation is underway.

Depending upon the final product, homofermentative and heterofermentative lactic acid bacteria and/or yeasts are able to proliferate under these anaerobic conditions and lowered brine pH. Normally, faster growing heterofermentative species dominate at this stage, utilising sugars and other fermentable substrates released into the brine from the olive flesh producing carbon dioxide, lactic acid, acetic acid and ethanol. A further lowering of brine pH occurs and anaerobic conditions are maintained, which prevents further proliferation of Gram negative bacteria. By ensuring that strict anaerobic conditions are maintained during processing, the growth of surface moulds and yeasts is inhibited. Otherwise these organisms would consume acids produced during fermentation, resulting in an increase in brine pH, hence reducing the stability of the olives and increasing the risk of spoilage.

As brine acidity increases, heterofermentative species are replaced by homofermentative lactic acid bacteria, for example *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*), producing predominantly lactic acid. As indicated earlier, heterofermentative bacteria do not produce as much acid as the homofermentative bacteria. If the brine sugars are low or depleted, insufficient acid is produced and preservation problems can occur. During natural fermentations, yeasts are often present with the lactic acid bacteria; namely, mixed flora, and in some cases, for example Greek-style olives, yeasts predominate. If well controlled, the final products have desirable organoleptic qualities. If poorly controlled the olives soften, change colour and become gassy or 'fritzy'.

When fermentation is complete, the olives can be stored in the same brine for up to two years, particularly if the salt level is maintained at 10% w/v or more.

Environmental considerations with table olive processing

All processing must be undertaken in ways that minimise environmental impacts. Methods that use less energy and water and produce lower volumes of wastewater, such as natural fermentation in brine or the use of dry salt, are more favourable than methods involving lye treatments or heat. Processing brines can be filtered, pasteurised and reused, following suitable salt and pH adjustments. Also, heat or sun-dried olives do not produce any solid or liquid wastes. Salt-dried olives produce some salt/black water that requires disposal.

Olives treated with lye require multiple washes and can use up to five times the amount of potable water compared with natural methods. Furthermore, with lye treatments, energy requirements increase general costs and possibly labour costs. However, methods using lye treatments have a number of advantages, including shorter processing times than natural methods and specific organoleptic characteristics that are agreeable to many consumers. In table olive production, Spanish and Australian researchers have estimated the following likely levels of wastewater (per kilogram of olives) are produced during the processing stages:

- Water cured and Kalamata-style (fast method), 5–7 l/kg;
- Brine cured: natural, traditional green, turning colour, naturally black-ripe and Kalamata-style (slow method), 0.5 l/kg;
- Lye treated green olives: Spanish-style green, Californian-style green, 1.0–3.0 l/kg;
- Spanish/Californian-style black olives (lye treated), 1.5–6.0 l/kg;
- Heat/sun-dried olives, 0; and
- Salt-dried olives (depends on variety), 150 ml/kg.

Waste products, such as brines/black water containing salt, polyphenols, dissolved organic solids and cell debris, can be removed from the processing facility by contractors, but this can be impractical or expensive. It is more usual to place unwanted table olive liquid wastes into shallow evaporation tanks. In one such facility, presented in Plate 22, the wastewater is collected on a thick composite rubber liner where the water evaporates assisted by the wind tunnel created by the structure. It is important that liquids do not leak and contaminate the water table. Initial rinsing water and washing solutions, depending on pH and salt content, can be used to irrigate olive trees. Scientific studies have shown that wastewater from table olive processing, if high in salt content, is less favourable when applied to olive trees compared with controls. Physiological changes observed in the olive trees included decreases in leaf water potential, stomatal conductance to water, and rates of photosynthesis after two weeks of application. The observed reductions were greater after two months of irrigation. Furthermore, applications of the wastewater reduced nitrogen levels in the olive trees as well as yield.

Common methods of preservation for table olives

Common methods used in preserving foods such as table olives to prevent microbial spoilage and food poisoning are given below. (More than one preservation method may be used.)

- *Salting*, stops growth of most microbes by reducing the water activity of the flesh;
- *Acidifying*, stops growth of most bacteria;
- *Refrigeration*, inhibits microorganisms;
- *Preservatives*, as permitted by legislation;
- *Preserving atmosphere*, partial or total removal of air and its substitution with an inert gas;
- *Vacuum pack*, total air removal;
- *Drying*, stops growth of all microbes if the water activity (A_w) is less than 0.6;
- *Blanching*, at temperatures greater than 95°C vegetative bacteria and yeasts are killed;
- *Pasteurising*, olives undergo a thermic treatment at temperatures between 60°C and 80°C that kills non-sporing (vegetative forms) of pathogenic, non-pathogenic and spoilage bacteria and yeasts; and
- *Sterilising* (canning), olives undergo a thermic treatment, at temperatures greater than 100°C, which kills all pathogenic bacteria, making the product 'commercially sterile'.

Lowering the water activity of table olives by adding large amounts of salt or drying the olives increases the osmotic pressure in the cells of microorganisms and so impairs their ability to grow. When water activity is low, microorganisms must compete with other dissolved molecules (solutes) for free water molecules. Bacteria are poor competitors for water, except for *Staphylococcus aureus*, whereas moulds are excellent competitors. *Staphylococcus aureus*, a skin pathogen, if present in brines, can release life-threatening toxins during processing, increasing the risk of food poisoning.

Acidification of table olives by fermentation acids produced during processing or the addition of food acids impairs the activity of microorganisms by a direct pH effect and by the uptake of undissociated forms of acids, such as acetic and lactic, resulting in an increase in intracellular acidity and lowering of pH.

Heat application, for example blanching, pasteurisation and sterilisation, is commonly used to preserve foods. The exact effect of heat on microorganisms is not fully understood, but it most likely disrupts macromolecules in their cell membrane and cytoplasm as well as nucleic acids, for example DNA and RNA. Microorganisms can adapt to mild heat; they develop protective mechanisms such as modifications in their cell membranes, production of heat shock proteins and increased enzyme stability to heat. Some, such as *Clostridia* spp. and *Bacillus* spp., however, can develop heat resistant spores, hence the need for high temperature sterilisation in an autoclave for some olive products.

Novel methods for food preservation being developed by researchers may have future applications for table olive preservation. One such process involves the use of ultra high pressure; microorganisms in food are inactivated or destroyed when subjected to hydrostatic pressures of 130 mPa or more.

Packaging of table olive products

Once processed, table olives are packed for sale in containers made of tin, glass, plastic or other material (but not wood) that meets technical and health standards. Whichever material is used, it should ensure the preservation of the olives and not release harmful substances into the brine or olives. Containers should be well filled with the product (table olives and packing solution) and should occupy not less than 90% of the water capacity of the container when sealed. Using the IOOC Table Olive Standards (2004), the water capacity is determined by completely filling the container with distilled water at 20°C. For non-metallic rigid containers, such as glass jars, the basis of the calculation is the weight of distilled water at 20°C that the sealed container will hold, when completely filled less 20 ml. Containers that do not meet the requirements for minimum fill are classed as defective. However, some tolerance is allowed in product lots.

Drained weight. The net weight for a container with olives in brine is made up of the weight of the olives and the weight of the brine, for example 360 g. The drained weight is only the weight of the olives, for example 230 g. It is not unusual to see both net weight and drained weight on the label, particularly with table olives imported in original containers. The IOOC Table Olive Standards (2004) prescribes tolerance levels for drained weight. The tolerance concerning the net drained weight, as indicated on the container label, shall not exceed the following percentage scale, providing the sample's mean drained weight is equal to, or in excess of, the declared weight.

5% For containers with drained weight less than 200 g
4% For containers with drained weight between 200 g and 500 g
3% For containers with drained weight between 500 g and 1500 g
2% For containers with drained weight in excess of 1500 g

To achieve the correct drained weight, the required amount of olives is packed into the container then packing solution added to the desired fill volume. The container is tightly sealed ensuring there are no leaks or air above the olives.

Safety aspects. Packed table olives should comply with statutory/international microbiological criteria and be free of any objectionable matter. The olives and brine should also be free of any microbiological spoilage, especially putrid, butyric or 'zapatera' fermentation. When table olives are tested they should be free of pathogens or contaminating microorganisms likely to develop in the packaged product under normal storage conditions. Furthermore, the table olives should be free of any substances such as toxins in quantities that represent a health hazard when eaten. Olives preserved by heat sterilisation such as Spanish/Californian-style black olives (olives darkened by oxidation) should receive a processing treatment that ensures the destruction of *Clostridium botulinum* spores.

Bulk table olive products. Table olives in bulk, for example 200 L plastic barrels containing 150 kg of olives, are sold on the basis of their net weight, for example 150 kg. Bulk olives can also be transported in a food grade liner bag (Pallecon System, TNT, Australia). Fermented olives held in bulk in a covering liquid may contain fermentative organisms such as lactic acid bacteria and yeasts at levels of up to 10^9 CFUs/ml (Colony Forming Units) of brine, or per gram of flesh (using a selective culture medium) depending on the level of fermentation. Plastic barrels can be reused as long as they are in good condition and have been cleaned and sanitised in a manner that does not compromise the safety and organoleptic quality of table olives when refilled.

Consumer size table olive products. Table olives are mainly packed in glass or plastic jars. Where plastic jars are used they should be of food grade quality and capable of withstanding pasteurisation temperatures, such as polypropylene polymer. Table olives are also available in vacuum packs: plastic bags filled with olives and a small amount of brine and sealed after the air has been removed or replaced with an inert gas. Spanish/Californian-style black olives are packed and sterilised in specially lined cans or glass jars of various sizes.

Pasteurisation of table olives

The aim of pasteurisation is to reduce the numbers of pathogenic and spoilage organisms in the olives and brine. Although not all types of table olives need pasteurisation, its application is common for many types of olive products (see Chapter 5 for specific applications). Specifically for pasteurising olives, the maximum pH of the brine should be 4.3 for a salt content of 2% w/v or more and pH 4 if the salt content is less than 2% w/v. Brines with a total free acid value of between 0.6% w/v and 0.9% w/v, expressed as lactic acid, are consistent with the above pH values.

In practical terms, pasteurisation involves submerging the packed olives in a bath of boiling water for a sufficient time to bring the container and contents to a temperature of 70–80°C. Heating time depends on the container size and the type of olive product. During pasteurisation, air and liquid expand and escape past the lid. When the containers cool down, a partial vacuum is created. Note that deterioration in texture and flavour occurs if higher temperatures are used. Pasteurisation is unnecessary for bulk olive production with fermentation as long as brine salt, pH and acid levels are controlled.

Containers to be treated must be of a height dimension such that when submerged in the water bath their tops are 5 cm below the water level. An additional 5 cm headspace is also required if the water in the bath is allowed to boil.

An indicative pasteurisation procedure typically involves the following steps:

(a) Ensure that the containers, especially glass or plastic jars, and lids are food grade and will withstand prolonged heating.
(b) Check jars for cracks or chips.
(c) Clean/wash jars with potable water before use to ensure any factory contaminants are removed.

(d) Pack the required weight of olives into containers.
(e) Add the packing solution, preheated to 70°C, to the containers leaving a small headspace to allow for any expansion of the contents.
(f) Secure the lids onto the containers.
(g) Place the containers in the water bath preheated to around 45°C to prevent breakage or damage to the container.
(h) Raise the temperature of the water bath and maintain this at 70–80°C for a period of time so that the olives and brine reach this temperature for the prescribed period (with the contents at 70–80°C, small containers require five to six minutes, whereas larger ones require up to 20 minutes).
(i) Representative samples of the packaged table olives should be cleared for safety by a microbiology laboratory before sale.

Note: Over-heating may change the organoleptic qualities of the olives such as colour and texture. Also, if plastic containers are used, they should be heat resistant.

Codex Alimentarius (1987)/IOOC (2004) Table Olive Standards – Characteristics for Thermal Pasteurisation. From a standards point of view the Codex Alimentarius (1987)/IOOC (2004) Table Olive Standards provide guidelines for pasteurising and sterilising olive products. For lye treated olives, natural olives (untreated), dehydrated and/or shrivelled olives a minimum of 15 pasteurisation units are required, where pasteurisation units are defined as the cumulative lethal rate during heat processes performed at temperatures below 100°C. The reference microorganism for these types of table olive products is *Propionibacteria* for which a reference temperature (Rt) of 62.4°C and a z curve of 5.25 defines the equation of the thermal death time (TDT). Rt is the temperature corresponding to a decimal reduction time which, together with the z curve, defines the logarithmic representation of the thermal death time curve of a given microorganism. The z curve plots the logarithmic representation of the thermal death times according to temperature (TDT curve); it is equivalent to the number of degrees necessary for the curve to transverse one log cycle. The TDT is the heating time, at a specific temperature and in specific conditions, required to reduce the initial microbiological population by a factor of 10^{12}. In practical terms this is achieved by heating the table olives to 62.4°C for 15 minutes. Note that if higher temperatures are used, the exposure time can be reduced. All pasteurisation procedures should be validated by a microbiology laboratory.

Alternative procedures

Instead of immersing the packed olives in a water bath, packed olives are placed in a steam chamber that can achieve the required temperatures. Again, the contents must be brought up to the pasteurising temperatures, then maintained at temperatures from 70–80°C for the required time. In some processing plants the olives, packed in jars without their caps, are passed through a steam tunnel for a set time. The bottles are capped after passing through the steam tunnel.

Another common procedure for olives preserved by fermentation in brine follows. This procedure is carried out under aseptic (clean) conditions to reduce the risk of bacteria and moulds entering the containers.

(a) Clarify the fermentation brine (salt concentration 6–7% w/v and pH 4.0–4.5) by filtration.
(b) Heat the brine to 80°C and maintain this temperature for approximately five minutes.
(c) Add the hot brine to final containers prefilled with processed olives.
(d) Spray the tops of the containers with steam if possible.
(e) Screw on the lids.
(f) Send representative samples of the packaged table olives to a microbiology laboratory for safety clearance before sale.

Note: This procedure kills a number of potential pathogens and prevents any secondary fermentation or spoilage occurring in the final containers. If fermentation brines are used as packing solutions, they should be filtered and preferably pasteurised after checking and adjusting salt and acid levels. Further information on sterilising Spanish/Californian-style black olives is provided in Chapter 5.

5

Specific table olive processing methods

The types of table olives and table olive products available on the Australian market are reviewed in this chapter. The specific types of table olive processes and the potential problems that may occur in the production system are also introduced. The major processing procedures discussed are soaking in water, in brine, with lye (caustic soda/sodium hydroxide), Californian/Spanish-style (caustic soda and oxidation), heat, and salt-dried olives. A detailed protocol for processing olives has been developed and is presented. An alternative method of debittering olives by microbial means rather than with the use of caustic soda is introduced. Safety and spoilage issues are examined. The chapter also explains how to overcome stuck fermentations. The topic of secondary table olive production – pitting and stuffing table olives, marinades, packaging processed olives in different solutions and spices, olive pastes and tapenades – is discussed in detail. Methods of preservation such as pasteurisation and sterilisation are further covered.

Processed table olives available in Australia

Knowing the types of table olive products available is a guide to important products that are consumed by Australians.

Table olives are sold from a number of diverse outlets and these are listed in Table 5.1. In season, raw unprocessed olives are also available for home processing from growers, continental delicatessens, wholesale fruit and vegetable markets and popular food markets in major Australian cities. Bulk quantities are available from food wholesalers and grower/processors (Fig. 5.1). In Australia, many households have planted at least one olive tree for home use. Others, especially Greek and Italian Australians pick olives off those planted as street trees, from feral olive trees and their own trees.

Table 5.1. Australian enterprises supplying processed and unprocessed table olives

Enterprise category	*Processed olives*			*Unprocessed olives*
	Loose	*Packaged*	*Bulk commercial quantities*	
Continental delicatessen	yes	yes	yes	yes
Local supermarket	no	yes	no	no
Major supermarket	yes	yes	no	no
Specialty/gourmet/cellar door	yes	yes	no	no
Food wholesaler	no	yes	yes	no
Grower/processor – boutique	no	yes	yes	yes
Grower/processor – small scale	no	yes	yes	yes
Grower/processor – medium scale	no	yes	yes	no
Wholesale fruit/vegetable market	no	no	no	yes
Popular food market	yes	yes	no	yes

Figure 5.1 Raw olives in cartons for the fresh fruit market.

Loose processed olives are mainly available from continental delicatessens, gourmet shops, popular food markets and more recently from state and national supermarket chains. Packaged olives are widely available in small and large supermarkets, continental delicatessens, gourmet shops, cellar doors and regional food shops. The latter provide a variety of locally produced products including olives and olive pastes that are often sought after by tourists.

Wholesale table olive trade in Australia

Table olive products are generally imported from Spain and Greece, with some products, such as *Kalamata* olives, produced or transformed into specialty styles in Australia. Container sizes vary from a few kilograms in cans and jars to plastic barrels containing up to 200 kg of olives (Table 5.2). Most olives available to Australian consumers are either lye treated, for example black and green Spanish-style, or naturally processed in brine, for example Kalamata-style, Greek-style black and green olives. They are sold in large, 150–200 kg barrels, and are often purchased by third parties for preparing specialty products to be sold loose in 100 g to 1 kg lots or packed into consumer size containers with or without further embellishment such as stuffings and marinades. Wholesalers also sell processed olives (Greek, Spanish and Italian) to retail establishments packaged in consumer size containers in carton lots. Some Australian processed olives are also available for wholesale purchase.

Table 5.2. Table olives available from Australian wholesale enterprises

Olive style	*Container type*	*Quantity*	*Origin*
Black Spanish			
Manzanilla, *Hojiblanca*	Cans, jars and plastic barrels	1.5 kg–200 kg	Spain
Sliced	Jars and cans	1–3 kg	Spain
Green Spanish-style			
Manzanilla, *Sevillana*, *Chalchidikis*	Cans, jars and plastic barrels	1 kg–200 kg	Spain, Greece
Cracked	Plastic barrel	12 kg	Greece
Destoned (pitted)	Jars and plastic barrels	2 kg–200 kg	Spain, Greece
Stuffed with pimento	Jars, cans and plastic barrels	1 kg–200 kg	Spain
Sliced	Jars and cans	1–3 kg	Spain
Kalamata-style (*Kalamon*)			
Plain	Plastic barrels	5–200 kg	Greece, Australia
Marinated	Plastic barrels	5 kg	Greece, Australia
Extra jumbo (large size)	Plastic barrels	12 kg	Greece, Australia
Continental mixture	Plastic barrels	5 kg	Greece, Australia
Home-style split	Plastic barrels	5 kg	Greece, Australia
Greek-style			
Naturally black – brine fermentation			
Conservolea (*Volos*)	Plastic barrels	200 kg	Greece
Manzanilla	Plastic barrels	200 kg	Australia
Salt-dried (date) black-ripe	Plastic barrels	50–100 kg	Greece, Australia
Green – brine fermentation			
Manzanilla	Plastic barrels	200 kg	Australia
Turning colour – brine fermentation			
Jumbo Kalamata	Plastic barrels	200 kg	Australia

Sale of loose table olives in Australia

Table olives are available loose for sale in small lots at larger national supermarkets, continental delicatessens, markets (Plate 23), and at specialty and gourmet food outlets A large number of different products are available (Table 5.3); however, most of these are based around the types and variety of olives that are available at the wholesale level.

Generally there is no indication as to the source or origin of these olives, such as whether they are Australian or imported. In supermarkets they are displayed in low temperature glass showcases with the name and style of the product, but mostly out of reach of customers. There is less control of the olives in continental delicatessens where customers can sample before they buy. Black Spanish-style olives are the least expensive, selling for as little as A$6/kg, whereas embellished olives, for example stuffed olives packed in olive oil with herbs, spices and sun-dried tomatoes, can retail at around A$40/kg. In this case, customers purchase the required quantity of olives, which are placed in an unlabelled plastic container and sealed. It is assumed that these olives will be consumed soon after purchase, as storage information is not provided.

Across a wide range of retail outlets innumerable table olive products are available, with the majority in marinades. National supermarkets often have the largest selection compared with continental delicatessens and smaller local supermarkets. Olives sold as mixtures of several varieties are marketed under trendy names such as 'Provencale', 'Mediterranean mix', 'Connoisseur' or 'Continental blend'. These contain olives that have been processed separately then mixed with olive oil, herbs and spices, before presentation for sale either as loose or packaged olives.

Table 5.3. Different types of loose table olive products available to consumers in Australia

Olive style/product	*Olive style/product*
Black, Kalamata	Marinated, Thai-style herbs
Marinated, chilli and oregano	Marinated, pitted
Marinated, chilli and garlic	Marinated, pitted, anchovy in oil
Marinated, lemon and garlic	Marinated, pitted, fetta cheese in oil
Marinated, with mixed herbs	Marinated, pitted, marinade, chilli and garlic
Destoned (pitted)	Marinated, pitted, pimento
Salt-dried black-ripe (date or shrivelled)	Marinated, pitted, pimento, marinade, herbs and spices
Black Greek-style	Marinated, pitted, sun-dried tomato in oil
Black Spanish-style	Marinated, sliced
Black Spanish-style, pitted	Cracked marinated, chilli
Black Spanish-style, sliced	Mixed selections (several olive varieties)
	Connoisseur marinated, herbs and spices
Greek-style donkey, herbs and spices	Continental marinated, herbs and spices
Green Spanish-style	Green and black Spanish-style, sliced
Marinated, chilli and garlic	Destoned (pitted) marinated, chilli and herbs
Marinated, marinade, lemon and vinegar	Destoned (pitted) marinated, herbs and spices
Marinated, marinade, lemon and garlic	Provencale, marinade, herbs and spices

Provencale olives. The Provencale mix referred to above should not be confused with the French Provencale olives. Traditional Provencale olives are prepared from whole or pitted green or black *Picholine* olives processed in brine and marinated in brine, olive oil, thyme, lavender and garlic. Some recipes include citric acid, giving the olives a slight citrus flavour. Cracked Provencale olives (Olives cassées de la Valée des Baux) are prepared from green *Salonenque* or *Verdale* olives harvested in the middle of the season. These olives are cracked (bruised), processed in brine, then flavoured with anise or fennel.

Packaged table olive products in Australia

There is no shortage of packaged table olive products available for sale from Australian supermarkets, continental delicatessens and specialty food shops (Table 5.4).

Packaged table olive products in small jars and tins include whole, pitted and sliced olives (with or without embellishments), antipasti with olives and pickled vegetables, and tapenades and olive pastes (Figs 5.2 and 5.3). Most products are imported, with many packed in Australia. Few products are of truly Australian origin indicating the lack of penetration of Australian table olives into the retail market. Australian products are available in regional areas where they are sold at specialty food shops, gourmet shops, specialty olive shops and from wineries.

Table 5.4. Packaged table olives available in Australia

Olive style/product	*Olive style/product*
Antipasti, Green Spanish-style olives and fetta cheese	Green Spanish-style, pitted, natural pepper
Antipasti, Mediterranean Gourmet	Green Spanish-style, pitted
Antipasti, Mediterranean Mix	Green Spanish-style, pitted, pimento
Antipasti, Tapas	Green Spanish-style, halves (bacchetta)
Antipasti, Char grilled, Mediterranean	Green Spanish-style, marinade, herbs and spices
Black, Kalamata	Green Spanish-style, marinade, Mediterranean
Black, Kalamata, halves	Green Spanish-style, pimento, marinade, herbs and spices
Black, Kalamata, marinade, chilli	Green Spanish-style, pitted
Black, Kalamata, marinade, garlic and vinegar	Green Spanish-style, pitted, pimento
Black, Kalamata, marinade, herbs and spices	Green Spanish-style, pitted, anchovy
Black, Kalamata, pitted	Green Spanish-style, pitted, blue vein cheese
Black, Kalamata, sliced	Green Spanish-style, pitted, fetta cheese
Black, Kalamata, marinade, balsamic vinegar	Green Spanish-style, pitted, Parmesan cheese
Black, Kalamata sliced, marinade, balsamic vinegar	Green Spanish-style, pitted, pimento, tuna
Black heat-dried olives	Green Spanish-style, pitted, smoked salmon
Black Greek-style	Green Spanish-style, pitted, tuna
Black Greek-style, low salt	Green Spanish-style, Queen
Black Greek-style, lemon and garlic	Green Spanish-style, Queen, pitted
Black Spanish-style	Green Spanish-style, Queen, pitted, pimento
Black Spanish-style, pitted	Green Spanish-style, sliced
Black Spanish-style, pitted, almonds	Green Spanish-style crushed, marinade, seasoned
Black Spanish-style, pitted, anchovies	Green Spanish-style marinade, lemon and garlic
Black Spanish-style, pitted, spices	Mixed, cocktail, marinade, herbs and spices
Black Spanish-style, sliced	Mixed, Mediterranean, marinade, herbs and spices
Green, natural fermentation in brine – Frizantina-style	Mixed, Provencale, marinade, herbs and spices
Green, natural fermentation in brine – Ligurian-style	Olive paste, black
Green Spanish-style	Olive paste, green
	Olive paste, tapenade

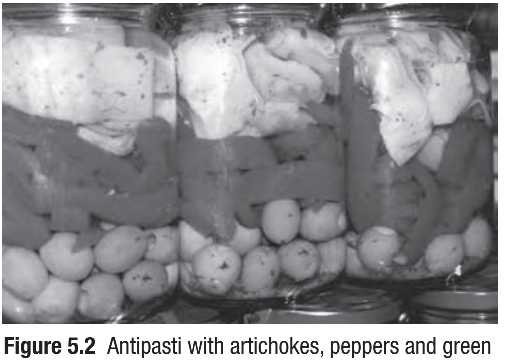

Figure 5.2 Antipasti with artichokes, peppers and green olives.

Figure 5.3 Australian grown and processed table olives. (Photo: Frankland River Olives, Western Australia.)

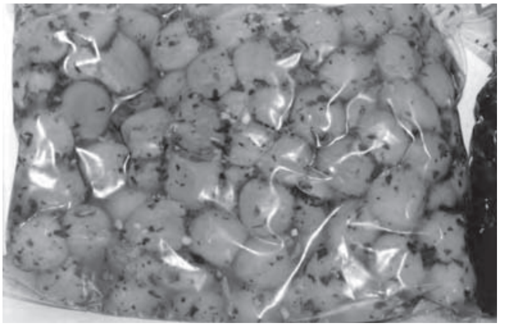

Figure 5.4 Vacuum packed green olives with herbs and spices.

Olives are packed mostly in glass jars and some, generally imports, in cans. A small number of products are vacuum packed in plastic bags (Fig. 5.4). Vacuum packed olives sold in 1–5 kg lots are popular in the food services industry as they are easy to store and handle. Most packaged table olive products use basic olive types with different embellishments such as garlic, chilli, Mediterranean herbs, lemon and vinegar.

Processing olives with water (water-cured)

Traditional processing methods involve subjecting raw olives to many water changes (or weak brines) over 10–14 days until they debitter. Green-ripe, turning colour or naturally black-ripe olives can be processed in this way. The bitter glycoside oleuropein is leached out of the olives and removed from the tank/container when soaking solutions are discarded. Generally no fermentation occurs using this method. Once debittered, after the last wash 10% w/v sodium chloride (salt) is added. Over time, when the brine equilibrates with the olives, final brine concentrations fall to approximately 6–7% w/v salt.

Figure 5.5 Turning colour *Azapa* olives processed by multiple soakings in water.

This method is popular with home processors because the olives are ready to eat within a few weeks from the start of processing (Fig. 5.5), but is unsuitable for serious commercial olive processing.

Disadvantages of this method are the large amounts of water required that need to be disposed of, and the increased risk of spoilage through microbial contamination. With water and low salt brines, proteolytic enzymes break down protein in the flesh to amino acids that further degrade to ammonia and hydrogen sulphide (H_2S). The resulting olives may have a urine (ammonia) and/or faecal or rotten egg odour (hydrogen sulphide) if not processed carefully. Over-soaking leads to soft olives with a 'washed out' taste.

Naturally black-ripe *Kalamata* olives that have been debittered by this method and embellished with olive oil, lemon and red wine vinegar gives the traditional Kalamata-style olive. However, in modern processing establishments a simple fermentation in brine (8–10% w/v salt) is used as the preferred method, rather than prolonged water soaking steps (see later for more detail on processing Kalamata-style olives).

With some traditional recipes, for example Ligurian (Benedictine-style), *Taggiasca* olives are soaked in water for weeks to months to debitter the olives. Salt, herbs and spices are then added to the debitterred olives. Today, most Ligurian-style olives are prepared by placing them in brine where they undergo a weak fermentation.

Packing specifications. The packing solution for olives produced by this method should contain at least 6% w/v salt, have a minimum acidity of 0.3% calculated as lactic acid and a pH of 4.3 or less to ensure their safety and preservation. The same conditions apply if a preservative is included or they are to be stored under refrigeration. Alternatively, if the olives are to be pasteurised or sterilised then the packing solution should have a pH of 4.3 or less. In this case, salt and acid concentrations are not specified, but should be at levels that do not compromise the safety and organoleptic qualities of the olives as determined by Good Manufacturing Practice. Outside of these parameters, the processor has to guarantee the safety of the olives by having them cleared by an accredited microbiology laboratory.

Note: With commercial table olive products, preservatives such as sorbic acid (or its salt potassium sorbate) and/or benzoic acid (or its sodium salt) are often added to packing brines to prevent the growth of oxidative yeasts, particularly after the containers are opened. Ascorbic acid, an antioxidant, is also added to processed green olives to prevent discolouration of the olives and the brine.

Step-by-step procedure for water-cured olives

(a) Use/accept quality raw olives (green-ripe, turning colour, naturally black-ripe).
(b) Store raw olives correctly before processing.
(c) Wash olives with potable water.
(d) Size grade and sort raw olives; remove damaged olives.
(e) Use whole, slit or cracked olives.
(f) Pack olives into containers with water; make sure olives are submerged and held in place with a grate.
(g) Remove and replace water daily for 10–14 days.
(h) After last water soaking step add brine 10% w/v sodium chloride (salt) to the brim.
(i) Monitor brine levels to achieve final levels of 6–7% w/v.
(j) Size grade and sort processed olives (optional).
(k) Pack the processed olives in a 6–7% w/v salt brine or alternatively in brine made with 3 parts 10% w/v salt + 1 part vinegar.
(l) Check pH and salt content to meet safety requirements.
(m) Pasteurise the packed processed olives if required.
(n) Send samples to a microbiology laboratory for testing.
(o) Label packed processed olives in accordance with food standard requirements.
(p) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

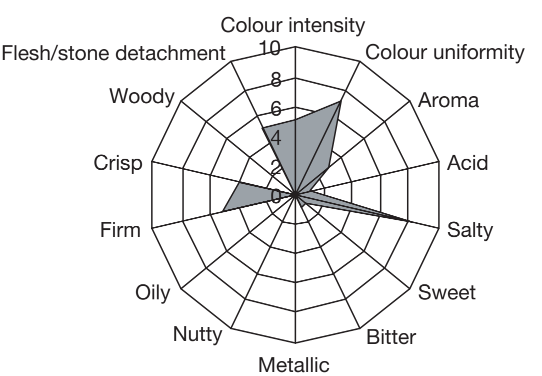

Figure 5.6 Organoleptic profile of water-cured green-ripe *Ascolana* olives packed in brine.

Nature of product. The nature of the product depends on the variety and maturation state. Olives may be firm to soft, and are usually salty with a little bitter taste. When embellishments such as olive oil, herbs, spices or other foods are added, aromas and flavours will change accordingly. The organoleptic profile of water-cured green-ripe *Ascolana* olives packed in brine is presented in a graphic form above (Fig. 5.6).

Processing olives with brine (brine-cured)

This is a traditional olive processing method that is gaining popularity as a commercial method even though some believe there are commercial limitations. There are many variations of this method depending on the country of origin, for example Greece, Italy, Turkey, Cyprus, Lebanon and Egypt. The principal differences are: sometimes several water soaking steps are used prior to brining, brine strengths vary, and there is variability in the bitterness of the final products.

Processing time is dependent on olive variety, maturation state, size and the Flesh:Stone ratio. All varieties at any maturation state can be processed by this method. Green olives can take up to one year to debitter whereas naturally black-ripe olives take as little as three months. Fermentation is slow because fermentable substrates (sugars) need to diffuse through the intact skin of the olive into the brine. Diffusion of substrates is faster when olives are subject to a short pretreatment with lye or blanched with near boiling water for one to two minutes. Debittering occurs by oleuropein diffusing into the brine (where it is diluted), and by the hydrolysis, or breakdown, of oleuropein into less bitter by-products, possibly by the action of some microorganisms. Small amounts of sugar are released during the hydrolysis of oleuropein, which also contribute to fermentation. Slitting, cracking or bruising the olives also speeds up the diffusion of fermentable substrates, reducing processing time.

Naturally fermented olives are either sold to consumers or the food services industry in bulk 5–20 kg buckets. Small consumer size packages – glass or plastic jars, tins or vacuum packs – are pasteurised before sale. Alternatively a preservative can be added. For example, Spanish researchers have found that fermented naturally black-ripe olives preserved with 0.05% potassium sorbate compared favourably with those pasteurised at 80°C for four minutes after nearly one year of storage.

Naturally black-ripe olives processed in brine

Black olives prepared by this method are often termed Greek-style black olives. Similar products are prepared in most Mediterranean countries, particularly Turkey. The following discussion, which relates to the processing of naturally black-ripe olives by spontaneous fermentation, in principle also applies to the natural processing of green-ripe and turning colour olives.

With this method, washed olives are placed directly into brine (8–10% w/v salt), after which anaerobic (no oxygen present) conditions are established and over time the olives take up salt and undergo spontaneous fermentation. In colder regions, brine with lower salt concentrations (6% w/v) is used to facilitate processing. An aerobic process is also available for preparing natural olives and is briefly described later in this chapter.

Features of anaerobic conditions

Anaerobic conditions:

- encourage Gram negative organisms to produce carbon dioxide;
- allow yeasts to produce alcohol and carbon dioxide;
- prevent oxidative organisms, particularly fungi, growing as a film on the surface of the brine; and
- provide the environment for fermentative bacteria to function and multiply.

Salt in the brine draws water-soluble components, sugars, organic acids and minerals out of the flesh into the brine. These substances provide substrates and nutrients required by fermentative bacteria and yeasts. During fermentation, sugars are converted to lactic and acetic acids, alcohol and other compounds that contribute to the taste of the olives. Overall, during processing by this method, the pH of the brine falls from near neutral (pH 7) to pH 4–5, depending on the amount and types of acid produced during fermentation (see Chapter 4). The levels of fermentative substrates also influence the final amounts of acid produced.

During long processing periods other water-soluble compounds diffuse into the brine including oleuropein. The net result is the debittering of the olives with oleuropein converted to by-products including hydroxytyrosol. Olives processed by the brine method are self-preserving because of the pH/salt balance achieved during processing. It takes six to eight weeks for the salt levels in brines and olives to equilibrate. In some cases, brine levels of oleuropein are high enough to inhibit the action of fermentative microorganisms such as lactic acid bacteria, *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*). If this occurs, corrective action is needed to replace part or all of the brine with fresh brine.

The high salt levels used in this method inhibit proteolytic bacteria, which if unchecked can lead to spoilage. During processing, salt levels of 6–7% w/v are achieved with initial brines of 8–10% w/v salt. In centres where the olives are subject to high environmental temperatures (summer/autumn) during processing, the final brine strength needs to be increased to 8–10% w/v or more to prevent spoilage.

During processing, olives can lose weight, with olives from irrigated orchards affected more than those from unirrigated orchards. Also, large olives lose proportionally more weight than small olives.

A mixed flora of yeasts and bacteria are involved in the fermentation. Once the raw untreated olives are placed in the brine, and the container sealed, anaerobic conditions are established. This is achieved by excluding air from tanks/barrels, and through the activity of bacteria and yeasts. Any residual oxygen is consumed by oxidative organisms and carbon dioxide is released into the brine, resulting in an initial lowering of the pH. Carbon dioxide is produced by Gram negative organisms (species of the genus *Citrobacter*, *Achromobacter*, *Aeromonas* and *Escherichia*), by yeasts, and by the olives themselves. Note that raw olives are still alive and respiring (produce carbon dioxide) in the first few days after brining.

During fermentation, yeasts (including species of the genera *Saccharomyces*, *Hansenula*, *Torulopsis*, *Debariomyces* and *Candida*) and lactic acid bacteria (including species of the genera *Pediococcus*, *Leuconostoc* and *Lactobacillus*) are active. On the other hand, *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*) is not the dominant organism because of the high salt levels and the inhibitory action of oleuropein and other phenolic compounds. The phenolic composition changes during processing because of the acid conditions created by fermentation. Phenolic glucosides in the flesh (oleuropein, verbascocide and luteolin 7-glucoside) are hydrolysed to new compounds. This results in lower oleuropein levels in the brine, which are always less than 1.5 mM, and a continuous increase in brine hydroxytyrosol levels. Higher temperatures favour the diffusion of polyphenols from the flesh into brines, facilitating the debittering process. So, maintaining fermentation temperatures at around 25°C is advantageous. After several months of storage the main residual phenols in the flesh are hydroxytyrosol, verbascocide, tyrosol, vanillic acid, caffeic acid, *p*-coumaric acid and oleuropein. Metabolic products formed during fermentation contribute to the organoleptic qualities of the olives.

Fermentation of naturally processed olives occurs in two stages (Table 5.5).

Table 5.5. Summary of events during the fermentation stage of naturally processed green-ripe olives

Parameter	*Early*			*Late*
Brine pH	Initial pH 7	pH 6	pH 5	Falls to pH 4.3–4.5
Brine salt levels	10% w/v, which falls over 6–8 weeks to 6%			
Gram negative organisms	Low	Maximum numbers by 3–4 days → disappear after 7–15 days Gas production: potential for gas pockets		
Lactic acid bacteria *Pediococcus* spp. *Leuconostoc* spp. *Lactobacillus mesenteroides* *Lactobacillus brevis*	Present when salt levels in the fermentation brine are low			
Yeasts	Present	Increase in number	Reach maximum numbers in 10–25 days	Yeasts dominate
Lactobacillus pentosus (Lactobacillus plantarum)	Present during the whole fermentation period as long as salt is 8% w/v or less. At lower salt levels they are the predominant organisms.			

Stage 1. When the olives are first placed in the brine a robust fermentation by a heterogeneous group of microflora occurs.

(a) Copious amounts of carbon dioxide are produced by Gram negative organisms (coliforms), yeast and fruit. The carbon dioxide formed creates enough pressure to cause brine to bubble and overflow.
(b) Water-soluble substances – minerals, sugars, food acids and oleuropein – begin to diffuse from the flesh into the brine. With black-ripe olives, the brine takes on a rich magenta colour due to anthocyanins, whereas with green-ripe olives the brine is yellow-pink due to oxidised phenolic compounds.
(c) Brine pH falls from 7 to 5.

Stage 2. A mild fermentation occurs, supported predominantly by yeasts and to a lesser extent by the following lactic acid bacteria (LAB):

(a) *Pediococcus* spp.
(b) *Leuconostoc* spp.
(c) Heterofermentative bacteria: *Lactobacilli* spp. (e.g. *Lactobacillus brevis*)
(d) Homofermentative bacteria: *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*)

By manipulating the initial salt levels in the brine a predominantly yeast fermentation or a predominantly *Lactobacillus* fermentation can be effected.

Yeast fermentation. Yeast fermentation occurs when salt levels in brine are kept above 8% w/v; final acidity, measured as lactic acid, is 0.2–0.4% w/v with a pH range of 4.3–4.5. At high salt levels, yeasts produce acetic acid.

Lactic fermentation. Lactic fermentation occurs when salt levels in brine are kept at 3–6% w/v; final acidity, measured as lactic acid, is greater than 0.6% w/v with a pH range of 3.9–4.1.

Note: The final acid concentration in the brine depends on the type of fermentation and the available fermentable substrates, such as sugars.

Processing takes at least three months and up to 12 months depending on the variety, maturation level of the fruit, temperature, salt and pH levels of the brine. Green-ripe olives take longer to process than naturally black-ripe olives. As mentioned earlier, processing time can be reduced, particularly with green-ripe olives, by damaging the skin.

Advantages of the brine method are its simplicity and low water requirements compared with processing olives with lye (Spanish-style green olives). Water is only required for the initial rinsing step and for preparing fermentation brines. Washing water has only low levels of low-grade contaminants and so can be disposed of through grey water systems or standard sewerage systems or used for irrigation purposes. Water is further conserved if the fermentation brine is filtered and reused as packing brine. The major disadvantage with methods using spontaneous fermentation in brine is the relatively long processing times. However, once an annual cycle is established, a continuous supply of processed table olives is ensured.

Bulk product of naturally black-ripe olives in brine. After processing, indicative parameters of the brine are: pH 4.5–4.8; titratable (free) acidity as lactic acid, 0.1 to 0.6% w/v; and a final sodium chloride concentration of 10% w/v. If salt levels are lower, then more salt is added. If it is desired that salt levels are lower, then the brine needs to be acidified to pH 4.0–4.2. A small quantity of residual sugar is present.

After processing, the olives can be packed in the fermentation brine, in new brine or a combination of the two. Fermentation brines should be clarified by filtration and pasteurised before reuse. Naturally black-ripe olives processed by this method give the traditional Greek-style black olive. Adding red wine vinegar and olive oil to Greek-style black olives gives a product similar to Kalamata-style olives.

Packing specifications. The packing solution for olives produced by this method for sale to consumers should contain at least 6% w/v salt, have a minimum acidity of 0.3% calculated as lactic acid and a pH of 4.3 or less to ensure safety and preservation. The same conditions apply if a preservative is included or they are to be stored under refrigeration. Alternatively, if the olives are to be pasteurised or sterilised then the packing solution should have a pH of 4.3 or less. Salt and acid levels are not specified in this case, but should be determined by Good Manufacturing Practice, so as not to compromise the safety and organoleptic qualities of the olives. With products that have parameters outside of these levels, the processor has to guarantee the safety of the olives through the use of appropriate testing methods. Typically, packaged olives produced by the brine method have the following parameters: pH 3.6–4.5; titratable (free) acidity, 0.3–1.0% as lactic acid w/v, and sodium chloride 8–10% w/v.

Note: To ensure preservation in containers, the product can be pasteurised or a preservative added, for example sodium or potassium sorbate, to give a final equilibrium level equivalent to 0.05% sorbic acid. Sorbic acid, a preservative, prevents the formation of a layer of oxidative yeast at the air-brine interface a few days after olive containers are opened. Ascorbic acid can be added to cover solutions/brines for naturally processed green-ripe and turning olives to prevent discolouration on storage.

Gas pockets. When olives are processed by the traditional anaerobic fermentation method they can develop gas pockets ('fish eyes') because of the evolution of copious amounts of carbon dioxide by Gram negative bacteria, some of which probably colonise the flesh, particularly in naturally black-ripe olives, in the early stages of the process. Other microorganisms, including yeasts, have been implicated in gas pocket formation in olives. Gas collects in pockets under the skin and/or in the flesh, resulting in soft, wrinkled olives. Using contaminated water and processing under unhygienic conditions increases the likelihood of gas pocket defects. In addition to using potable quality water and undertaking processing under hygienic conditions, this problem can be prevented in two ways:

(a) Acidify the brine to pH 4.5 with acetic acid at the beginning of processing, hence bypassing the early gas producing phase.
(b) Undertake fermentation under aerobic conditions.

Aerobic fermentation of untreated olives. With aerobic fermentation of olives, the fermenter is fitted with a central column, through which air is passed through the fermentation brine. The brine (10–11% w/v salt) is aerated by bubbling air (0.1–0.3 volumes per fermenter per hour) into the fermentation tank for eight hours per day during active fermentation to remove carbon dioxide gas produced by the olives and microbial activity. The pH is maintained between 4.0–4.5 with acetic acid to prevent the growth of spoilage bacteria. As some oxygen from the air passing into the brine dissolves and residual carbon dioxide is expelled, aerobic conditions are established. Under aerobic conditions, facultative anaerobic organisms (those that can adapt to aerobic conditions) and oxidative organisms, rather than fermentative organisms, predominate. These include Gram negative bacteria (Enterobacteriacae) and yeasts that are present throughout the fermentation. (Facultative yeasts include: *Torulopsis candida*, *Debaryomices hansenii*, *Hansenula anomala* and *Candida diddensii*. Oxidative yeasts include: *Pichia membranaefaciens*, *Hansenula mraki* and *Candida bodinii*.) When the salt levels of the brine fall to 8% w/v salt or less, the lactic acid bacteria *Leuconostoc* and *Pediococcus* predominate, whereas three weeks later, *Lactobacillus* bacteria prevail. Implementing aerobic conditions speeds up processing. This is attributed to brine circulation and faster effective diffusion of fermentation substrates and oleuropein through the olive skin. Processing times can be halved by this method. A disadvantage of aerobic fermentation, however, is that enhanced growth of yeasts can occur, resulting in soft olives. (For more details refer to Garrido Fernández *et al.* 1997.)

Green-ripe olives processed in brine

Green-ripe olives processed by the anaerobic fermentation method give products similar to Greek-style green or Sicilian-style olives (Fig. 5.7). Adding herbs, spices and aromatics – for example lemon, fennel, garlic and oregano, or mixed herbs, mustard seeds and chilli – further enhances flavours.

Note: Another type of Sicilian olive, Castelvetrano-style, debittered with lye, is discussed later.

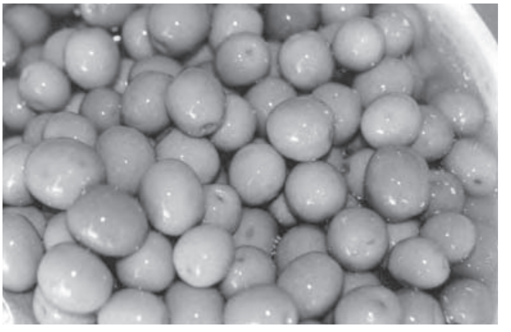

Figure 5.7 Green-ripe *Manzanilla* olives processed by spontaneous fermentation in brine.

Turning colour olives processed in brine

Turning colour olives of the varieties *Taggiasca* or *Frantoio* processed by the anaerobic fermentation method give a Ligurian-type olive (Fig. 5.8). Turning colour *Jumbo Kalamata* olives processed by natural fermentation in brine, then packed in brine, olive oil and herbs and spices, is a popular Australian olive product. Large olives such as *Jumbo Kalamata* should be slit or bruised before processing to reduce processing time and the risk of gas pockets spoilage.

Figure 5.8 Turning colour *Taggiasca* olives processed as Ligurian-style olives.

Step-by-step method for processing untreated olives in brine under anaerobic conditions

(a) Use/accept only quality raw olives (green-ripe, turning colour, black-ripe).
(b) Store raw olives correctly before processing.
(c) Spray wash olives with potable water.
(d) Size grade and sort raw olives.
(e) Use whole, slit or cracked olives.
(f) Pack olives into barrels/tanks with brine (10% w/v sodium chloride in potable water); make sure olives are submerged.
(g) Fill containers/tanks to brim and loosely seal.
(h) Monitor brine pH daily and salt weekly (pH of brine will fall from around 6–7 (initial) to pH 5 in the first few days).
(i) Replace lost brine so that there is as little air space as possible between surface and lid.
(j) Seal the barrel/tank so that anaerobic conditions are established. The brine pH will fall progressively to between pH 4 and 4.6 by about 40 days from the start of processing.
(k) Monitor brine pH levels weekly and salt levels monthly.
(l) If the brine pH does not fall, add sufficient food grade acid, for example lactic acid or acetic acid, to give pH 5.

(m) Monitor brine sodium chloride levels to achieve final levels of 6–7% w/v and pH 4.0–4.5. Olives are ready when the bitterness is acceptable. Approximate processing times: black, three months; turning colour, six months; and green, 12 months.
(n) Size grade and sort processed olives (optional).
(o) Pack the processed olives in a brine made up with 3 parts of 10% w/v sodium chloride + 1 part of vinegar (the final solution has a salt level of approximately 7% w/v salt).
(p) Check pH and salt content (see below for limits).
(q) Pasteurise the packed processed olives if required.
(r) Send samples to a microbiology laboratory for testing.
(s) Label packed processed olives in accordance with food standard requirements.
(t) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

Darkening processed traditional black olives in brines. If naturally black-ripe olives are pale in colour after processing by anaerobic fermentation, they can be darkened by one of two methods:

(a) Pass compressed air through the olive mass in the fermentation tank.
(b) Pack the processed black olives into small perforated crates (20–25 kg) or trays, leaving them exposed to air under hygienic and dust-free conditions for up to 48 hours.

Nature of the final product. This depends on the state of maturation and fermentation conditions. Green olives are grey-green in colour, firm, crisp, salty, with a distinct but acceptable bitter taste. Turning colour olives are buff coloured, less firm but crisp, salty and have a slightly bitter, nutty flavour. Black olives have variable colours from pale to dark purple, are salty, slightly sweet, mildly bitter, firm, but with a succulent texture. Brine-cured olives appear moist when removed from brine, and at the time of serving the addition of a small amount of olive oil enhances appearance and flavour. The organoleptic profiles of naturally fermented untreated olives are presented in a graphic form below (Figs 5.9–5.13).

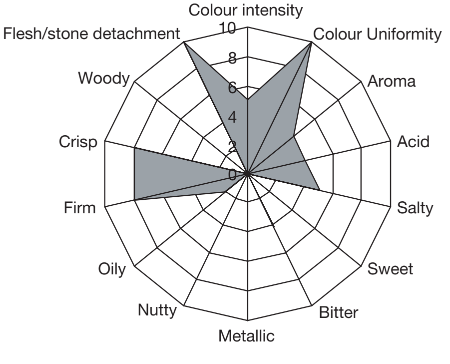

Figure 5.9 Organoleptic profile of naturally fermented (anaerobic) untreated green-ripe *Manzanilla* olives.

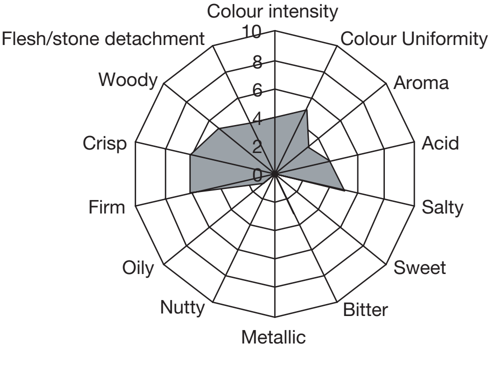

Figure 5.10 Organoleptic profile of naturally fermented (anaerobic) untreated turning colour *Jumbo Kalamata* olives.

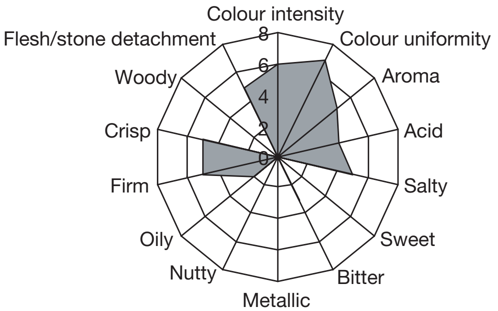

Figure 5.11 Organoleptic profile of naturally fermented (anaerobic) untreated black-ripe *Volos* (*Conservolea*) olives.

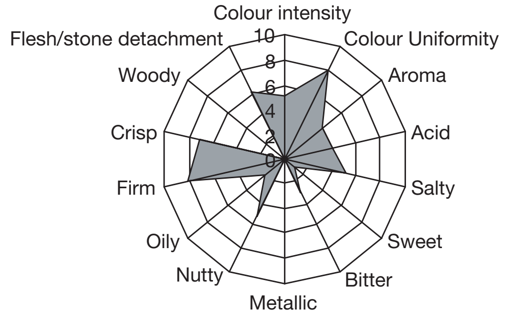

Figure 5.12 Organoleptic profile of naturally fermented (anaerobic) untreated turning colour *Kalamata* olives.

Bruised/cracked olives processed in brine

Method 1: *Bruise olives before processing*. Green-ripe or early turning colour olives (Plate 24) are given two slits (optional) then passed through a bruising machine. Machine harvested or marked olives can be used to prepare bruised olives if processing is undertaken immediately after harvesting. The olives are placed in 10% w/v salt brine where they undergo a weak fermentation. When the fermentation is over, the olives can be packed in filtered, pasteurised fermentation brine. To speed up the debittering process the bruised olives can be immersed in potable water for 10–12 days, changing the water every day or so. If the water is not changed, the risk of spoilage increases. Bruised green and turning colour olives discolour quickly because of the oxidation of polyphenols. They must be submerged in water or brine to prevent such discolouration. For small-scale processing, olives can be bruised by hitting them with a blunt instrument.

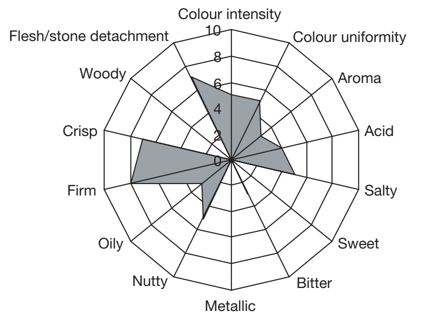

Figure 5.13 Organoleptic profile of naturally fermented (anaerobic) untreated turning colour *Frantoio* olives.

Method 2: *Bruise olives during processing*. If debittering whole green-ripe or turning colour olives is slow, they can be passed through a 'bruising machine' after 50 days of brining and then repacked in brine to continue processing. Bruising crushes the flesh while the stone is allowed to remain intact but still in contact with the flesh. *Verdale* olives are very suitable for this style of olive preparation. Care must be taken not to contaminate the olives or brine during transfer of olives and brine.

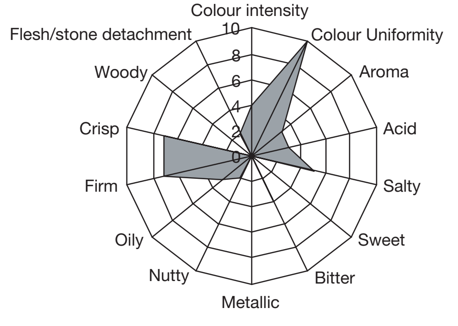

Figure 5.14 Organoleptic profile of naturally fermented (anaerobic) cracked untreated green *Verdale* olives.

Method 3: Bruise olives after processing. Any type of processed green or turning colour olive can be bruised by tapping with a blunt object or passing them through a 'bruising machine'. These bruised olives show no discolouration because the phenol oxidase enzymes that oxidise polyphenols in raw olive flesh are inactivated during processing. Care must be taken not to contaminate the olives during the bruising operation.

Nature of the final product. The final product is green to buff in colour, with salty, slightly bitter taste, crisp in texture with nutty flavours reminiscent of the olive stone and condiments if added. Of course the quality is very much influenced by the characteristics of the original processed olives. Aromatics, herbs and spices, such as oregano, fennel, coriander, chilli and lemon slices are added to extend the flavour of the olives. The organoleptic profile of naturally fermented cracked untreated *Verdale* olives is presented in a graphic form in Fig 5.14.

Processing Kalamata-style table olives

Kalamata-style olives are recognised all over the world as a high quality table olive. The processing method is a variant of that used for naturally black-ripe olives in brine that is commonly practised in Greece and other Mediterranean countries. The raw naturally black-ripe *Kalamata* olives are generally less bitter than other olive varieties.

Short method. 'Original' Kalamata-style olives are prepared from naturally black-ripe *Kalamata* olives, a variety originating from the Greek Peloponnese region, by the traditional short method. It is called the short method because the olives are ready to eat in a much shorter time than the long method. Olive varieties such as *Barnea*, *Leccino*, *Hojiblanca*, *Conservolea* and *Mission* (Californian) can also be processed as Kalamata-style olives when *Kalamata* olives are unavailable. The short method involves debittering the olives by multiple soakings in water or weak brine over a week or so. Once the olives are debittered they are packed in brine of 6–8% w/v sodium chloride with added wine vinegar. A layer of olive oil or other vegetable oil and slices of lemon are added to the container packed with olives. Processing times are reduced by slitting the olives before placing them in the fermentation brine. If the olives are not slit or split before processing, this can be done after processing so the wine vinegar and lemon flavours penetrate into the olive flesh.

Long method. A second method used to prepare Kalamata-style olives involves placing slit naturally black-ripe olives in 10% w/v salt in potable water until they debitter

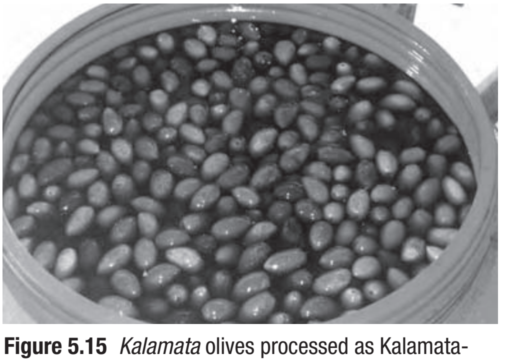

Figure 5.15 *Kalamata* olives processed as Kalamata-style olives by spontaneous fermentation in brine in plastic barrels. Note there is no mould growth.

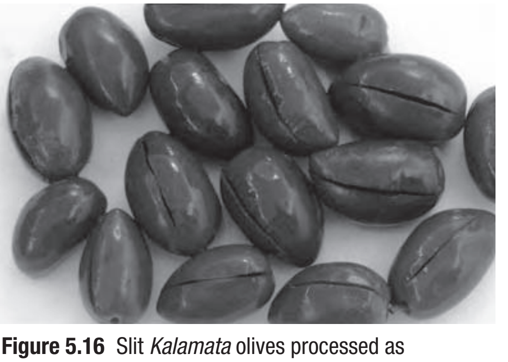

Figure 5.16 Slit *Kalamata* olives processed as Kalamata-style olives by spontaneous fermentation in brine.

(Figs 5.15 and 5.16). Depending on the processing facility, Kalamata-style olives can be processed in plastic barrels or large tanks. One system used in South Africa involves placing olives and brine in a squat fibreglass tank (one tonne) then covering the surface with thick plastic, held in place with a heavy fibre-cement lid to ensure anaerobic conditions are maintained. Regardless of the size of tank, processing can take around three months. During this time a weak fermentation takes place. After debittering, the olives are packed in brine, wine vinegar and olive oil as with the short method.

There are local variations in the process. The olives may be soaked in tanks of vinegar rather than adding vinegar. Indicative polyphenol levels remaining in the flesh of *Kalamata* olives after processing, which give the olives a slight bitter taste, range from around 500–1500 mg/kg of flesh with residual hydroxytyrosol levels at around 250–750 mg/kg of flesh.

Traditional short method for processing Kalamata-style olives

(a) Use/accept only quality raw, nearly black-ripe olives.
(b) Store raw olives correctly before processing.
(c) Spray wash olives with potable water.
(d) Size grade and sort raw olives.
(e) Slit olives lengthwise: two to three slits with a sharp knife or machine.
(f) Pack olives into barrels with water or weak brine (2% w/v salt in potable water); make sure olives are submerged.
(g) Remove and replace water or brine two to three times a day for five to eight days.
(h) Taste olives to determine their bitterness.
(i) Monitor brine sodium chloride levels to achieve final levels of 6–7% w/v.
(j) Size grade and sort processed olives (optional).
(k) Darken olives by exposing olives to air or by passing food grade air through the tank.
(l) Pack the processed olives in brine made up with 3 parts by volume of 10% w/v sodium chloride + 1 part by volume of red wine vinegar (alternatively with 4 parts by volume of 10% w/v sodium chloride + 1 part by volume of red wine vinegar).
(m) Check pH and salt content (see below for limits).
(n) Add extra virgin olive oil or quality seed oil (10 ml/100 ml of brine) and thin slices of lemon. (The number of slices depends on the size of the container. Half to one slice should suffice in consumer size containers.)
(o) Pasteurise the packed processed olives (if required).
(p) Send representative olive samples to a microbiology laboratory for testing.
(q) Label packed processed olives in accordance with food standard requirements.
(r) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

Long method for processing Kalamata-style olives

(a) Use/accept only quality raw, nearly black-ripe olives.
(b) Store raw olives correctly before processing.
(c) Spray wash olives with potable water.
(d) Size grade and sort raw olives.
(e) Slit olives lengthwise: two to three slits with a sharp knife or machine.

(f) Pack olives into barrels/tanks with brine (10% w/v salt in potable water); make sure olives are submerged.
(g) Fill barrels/tanks to brim and loosely seal to allow gases, formed during processing, to escape.
(h) Monitor brine pH daily and salt weekly. The pH of brine will fall initially from around pH 6–7 to pH 5 in the first few days.
(i) Replace lost brine so that there is as little air space as possible between the surface and the lid.
(j) Seal the barrel/tank so that anaerobic conditions are established and maintained.
(k) The brine pH will fall progressively to 4.0–4.5 by about 40 days from the start of processing.
(l) Monitor brine pH levels weekly and salt levels monthly.
(m) If brine pH does not fall, add food grade acid, for example lactic acid or acetic acid.
(n) Monitor brine salt levels to achieve final levels of 6–7% w/v and pH 4.0–4.6. Olives are ready when the level of bitterness is acceptable. This occurs within three months.
(o) Size grade and sort processed olives (optional).
(p) Pack the processed olives in brine made up with 3 parts by volume of 10% w/v sodium chloride + 1 part by volume of red wine vinegar (alternatively with 4 parts by volume of 10% w/v sodium chloride + 1 part by volume of red wine vinegar).
(q) Check brine pH and salt levels (see below).
(r) Add olive oil or seed oil to give a thin layer at the surface, for example 10 ml/100 ml of packing solution.
(s) Pasteurise the packed processed olives if required.
(t) Send samples to a microbiology laboratory for testing.
(u) Label packed processed olives in accordance with food standard requirements.
(v) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

Packing specifications. The packing solution for olives produced by this method should contain at least 6% w/v salt, have a minimum acidity of 0.3% calculated as lactic acid and a pH of 4.3 or less to ensure safety and preservation. The same conditions apply if a preservative is included or they are to be stored under refrigeration. Alternatively, if the olives are to be pasteurised or sterilised then the packing solution should have a pH of 4.3 or less. Salt and acid levels are not specified in this case, but should (determined by Good Manufacturing Practice) not compromise the safety and organoleptic qualities of the olives. Outside of these parameters, the processor has to guarantee the safety of the olives through the use of appropriate testing methods.

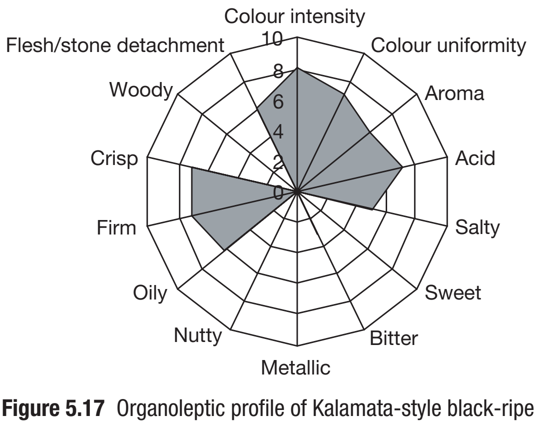

Figure 5.17 Organoleptic profile of Kalamata-style black-ripe *Kalamata* olives (olive oil and vinegar added).

Nature of final product. *Kalamata* olives have a homogeneous but variable chocolate to dark brown colour. The olives are firm and crisp with a distinct fruity taste that is also salty, slightly bitter and wine-like. When served on their own or in salads they have a distinct glistening appearance because of the added olive oil. Added condiments give extra flavour. The amount of wine vinegar can be reduced if a more subtle vinegar flavour is desired as long as the packing brine parameters are achieved. Unpleasant lemon flavour tones occur if too many lemon slices are added. The organoleptic profile of *Kalamata* variety olives processed as Kalamata-style olives is presented in Fig. 5.17. Note the high oil and acid levels compared with other organoleptic graphics, which are due to the added vinegar and olive oil.

Processing olives with lye (sodium hydroxide)

Spanish-style green olives. The commonest table olive produced by this method is the Sevillian-style, also known as Spanish-style green olives. Washed olives, generally green-ripe, are placed into tanks and soaked in a lye solution (1.3–2.6% w/v food grade sodium hydroxide in potable water) for five to seven hours or more to debitter. The concentration of lye used depends on the variety and the temperature of the operation. With higher processing temperatures the rate of lye penetration through the flesh is faster. When weak lye solutions are used, penetration through the flesh is slow. Under cold conditions, lye concentrations of up to 3.5% w/v need to be used. As some varieties are sensitive to high lye concentrations, for example *Ascolana Tenera* and *Sevillana*, then weaker solutions are used over a 9–10 hour period. Lye treatment is followed by a lactic fermentation to preserve the olives and produce the characteristic organoleptic features of this style.

Lye treatment. The lye is allowed to penetrate through three-quarters of the flesh, leaving a small volume of flesh around the stone unaffected. This part of the flesh provides the necessary sugars for subsequent fermentation and provides a slight bitter taste to the olives. Lye treatment debitters the olives by chemically converting the bitter oleuropein to non-bitter and less bitter chemical compounds including hydroxytyrosol and elenolic acid. Hydroxytyrosol diffuses rapidly from the flesh into the brine solution during fermentation where its concentration remains essentially unchanged during fermentation. Lye treatment also increases the permeability of the olive skin allowing a two-way interchange of soluble substances, especially fermentable substrates.

$$\text{Oleuropein} + \text{lye (sodium hydroxide)} \rightarrow \text{Hydroxytyrosol} + \text{elenolic acid}$$

When olives are pre-treated with lye, the level of lye penetration can be monitored by slicing the olives and observing colour changes of the olive flesh. The degree of lye penetration can be more easily visualised by placing several drops of phenolphthalein solution onto the cut flesh, changing its colour from green-brown to red (Fig. 5.18). Low concentrations of lye give the olives a less desirable green colour whereas high lye

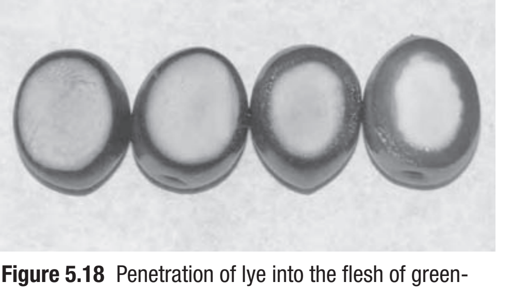

Figure 5.18 Penetration of lye into the flesh of green-ripe olives over five to six hours.

concentrations leach out water-soluble fermentable substrates and soften the olives because of textural changes in the flesh.

Lye treatment is followed by several rinse/wash cycles with potable water to remove excess lye:

Rinse. Drain lye solution from olives, add potable water to cover olives in barrels/tanks and drain immediately.

First wash. Add water to olives in barrels/tanks and drain after two hours.

Second wash. Add water to olives in barrels/tanks and drain after 10–20 hours.

In some centres, a first wash is eliminated for convenience and environmental considerations. The implications of this are high levels of lye in the wash water and olives. Partial neutralisation with food grade hydrochloric acid overcomes this problem.

Note: Over-washing results in loss of sugars required for subsequent fermentation, increasing the possibility of 'stuck fermentations' where microbiological acidification does not occur. If the wash periods are excessively long, the risk of bacterial contamination increases.

Brining the lye treated olives. Tanks with the lye treated olives are then drained of the last washing water and filled with brine (10–12% w/v salt in potable water), depending on the variety and maturation state of the fruit. As soluble substrates leave the flesh and accumulate in the brine, a culture medium suitable for fermentation develops. Furthermore, hydrolysis by-products of oleuropein, such as hydroxytyrosol and elenolic acid, pass into the brine. Indicative levels of phenols remaining in the flesh of *Conservolea* and *Chalchidikis* after processing by this method (based on research by others) range from around 150–550 mg/kg and 400–1200 mg/kg respectively. Residual hydroxytyrosol levels in flesh are around 150–500 mg/kg.

Table 5.6. Summary of events during the fermentation stage of Spanish-style green olives

Parameter	*Early*			*Late*
Brine pH	Initial pH 7	pH 6	pH 5	Falls to less than pH 4
Brine salt levels	10% w/v, which falls over six to eight weeks to 6%			
Gram negative organisms	Low	Maximum numbers by two days → disappear after 12–14 days Gas production		
Lactic acid bacteria *Pediococcus* *Leuconostoc*		Increase	Decrease with decreasing pH	
Yeasts		Increase	Yeasts persist	
Lactobacillus pentosus (Lactobacillus plantarum)			Maximum numbers by 7–10 days	Numbers diminish in 60–300 days

Although the initial brine has 10–12% w/v salt, this falls rapidly to around 6% w/v salt, depending on the variety being used and the Flesh:Stone ratio because of interchangeable water in the olives. When anaerobic conditions are established, lactic fermentation proceeds. The processed table olives can be kept in the fermentation brine until they are used or repacked for sale. Brine levels of bulk product should be maintained at 8% w/v salt or more to ensure effective preservation by topping up with concentrated brine.

Fermentation. A number of microbiological events occur in the brine during fermentation (Table 5.6). A starter culture of the fermentation organisms (Fig. 5.19) may need to be added as lye can destroy natural microflora on the olive skin. In long established processing facilities this may not be necessary, because fermentative microorganisms are widespread in the immediate environment. The salt levels used must not inhibit the growth of *Lactobacilli* but still inhibit the growth of spore-forming clostridial organisms when the pH is still high in the early stages of processing.

Early in the procedure Gram negative bacteria multiply. These organisms are found on the olives, in water and in the environment of the processing plant. These Gram negative organisms, species of the genera *Enterobacter*, *Citrobacter*, *Klebsiella*, *Flavobacteria*, *Aerochromobacter*, *Escherichia* and *Aeromonas*, require little in the way of nutrition. They reach maximum numbers two days after brining, producing copious amounts of carbon dioxide gas that lowers the brine pH from 7 to 6. Other microorganisms can also produce carbon dioxide.

Secondly, at pH 6 the lactic acid producing bacteria *Streptococcus* and *Leuconostoc* spp., also present in the brine, multiply and produce acid metabolites, further lowering the brine pH to around 5. Under these conditions Gram negative organisms disappear and *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*) activity increases, resulting in lactic acid production from fermentable sugars such as glucose. Brine pH levels fall to

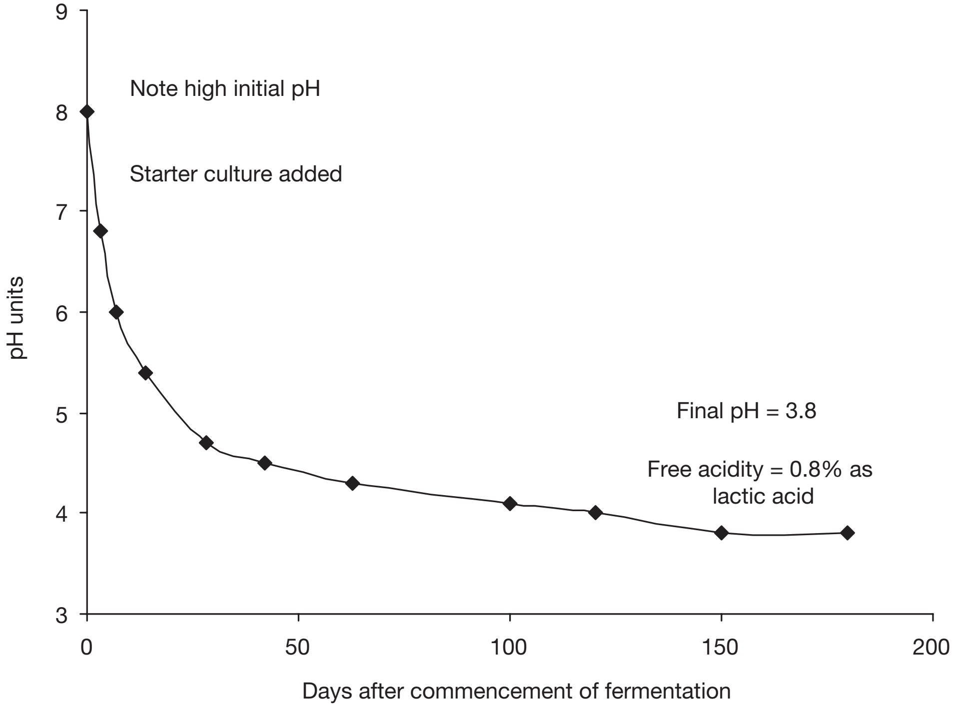

Figure 5.19 Typical changes in brine pH after the addition of a starter culture to lye treated green-ripe olives undergoing anaerobic fermentation.

less than 4. The maximum numbers of lactic acid bacteria are present around 7–10 days after brining, and then they gradually decline in number over 60–300 days.

In the third phase, the fermentable substrates from the olives are depleted and acid formation ceases. At this stage yeasts appear with the lactic acid bacteria. Fermentative yeasts can improve the organoleptic qualities of the olives but do not cause spoilage. These yeasts can include species of the genera *Hansenula*, *Candida* and *Saccharomyces*. However, oxidant yeasts are undesirable because they can consume lactic acid, thereby raising the brine pH and compromising the process.

Note: Lye treatment kills the natural microflora on the olive fruit and it may be necessary to introduce starter cultures of fermentative organisms to the olives in brine to establish fermentation. Sources of organisms for starting new fermentations come from the immediate environment in long established processing plants, brine from active fermentation tanks or starter cultures. Adding cultures of lactic acid bacteria to the lye treated olives and brine 24 hours after brining markedly reduces the risk of spoilage by swamping natural populations of spoilage organisms (coliforms) and rapidly reducing the brine pH. If coliform growth is not controlled in the early stages of brining, the risk of gas pocket formation increases and faecal odours can develop in the olives. The latter problem renders the olives inedible. As mentioned earlier, lowering the brine pH with food grade acids can also reduce the problem of gas pockets.

The level of coliforms in brine can be determined visually using a microscope. Using a Gram stain, Gram positive *Lactobacilli* stain blue and Gram negative coliforms are red. By using this simple test, early olive spoilage during processing can be prevented.

Green olives prepared by the Spanish-style method are ready to eat within four to five weeks, although a longer period of standing (up to three months) is recommended so that the olives equilibrate in the fermentation brine to enhance the organoleptic characteristics of the olives.

The main disadvantage of this method is the large amount of water required and the amount of waste-water produced. Also, significant technical skills, particularly in chemistry, are required to process olives with lye. The processed olives can be packed in the fermentation brine, new brine or a combination of both. When packing brines with low levels of salt are used, the packaged products need to be pasteurised.

Characteristics of lactic acid bacteria. As lactic acid bacteria are the predominant fermentative organisms when preparing Spanish-style green olives, it is of value to understand the relevant features of this group of organisms. They grow under anaerobic conditions; multiply in water and brine up to 8% w/v sodium chloride (inhibited above 8% w/v sodium chloride); are active in slightly acid conditions and until the pH drops to 3.5–3.8 and a (free) acidity of 1.2% w/v lactic acid or more is reached; and are active between 15°C and 27°C but are inactive below 15°C and above 30°C (therefore they are classified as a mesophilic-type organism).

Salt is used to inhibit undesirable microorganisms. The desirable lactic acid bacteria are reasonably salt tolerant (8% or less) whereas coliforms and other spoilage organisms are not.

Processing tips for treating green-ripe olives with lye

(a) Prepare lye solutions well in advance and allow to cool to around 15–20°C before adding to olives. When the sodium hydroxide dissolves in water, heat is produced and excessively hot lye solutions can cause skin blistering and sloughing of olives.
(b) Keep olives submerged during lye treatment to prevent skin discolouration due to oxidation of polyphenols. After processing in lye the olives sink in the liquid because of an increase in their relative density.
(c) Maintain brine temperature between 15°C and 25°C (<30°C) by air conditioning or by pumping the brine through a suitable heat exchanger. The main organisms active in brine during fermentation are lactic acid bacteria.
(d) Check total titratable (free) acidity and pH regularly; the acidity should increase and the pH should fall.
(e) Ensure enough salt and acidity is present in the brine to preserve olives of this type. Check salt. Without adjustment this falls to around 5–7% w/v depending on the initial salt concentration in the brine. Salt levels in the bulk product are adjusted to 8% w/v or more by adding a saturated solution of salt or dry salt.
(f) Replace part of the brine with a fresh salt solution and add lactic acid if the acidity needs to be adjusted.
(g) Final total (free) acidity should be 0.8–1.0% w/v calculated as lactic acid in the bulk product.
(h) Allow fermented olives to remain in the fermentation brine for one to two months to allow equilibration, stabilisation and development of the organoleptic characteristics of the olives.

It is possible to use other alkaline compounds, such as potassium hydroxide or lime, to prepare the lye solution; however, the resulting products may have a residual chemical bitterness. Although some traditional olive processing methods in the past have used wood ash to prepare lye solutions, such practice is of little importance in commercial table olive production as processing would be difficult and expensive to control. Home processors using wood ash to prepare lye solutions must ensure that the wood is not contaminated with chemicals, paints or toxins.

Step-by-step method for processing green-ripe olives with lye

(a) Use/accept only quality raw olives (green-ripe). Store raw olives correctly before processing.
(b) Spray wash olives with potable water (optional).
(c) Size grade and sort raw olives. Use whole olives.
(d) Pack olives into barrels/tanks with lye (1.3–2.6% w/v sodium hydroxide in potable water depending on variety, lye concentration and environmental temperature). Make sure olives are submerged.
(e) Allow lye treatment to proceed for five to seven hours or more.
(f) Monitor penetration of lye into olive flesh using phenolphthalein indicator.
(g) Drain solution from the olives. Rinse olives immediately with potable water, then with two static washes: one for two to three hours and a second for 10–20 hours.
(h) Add brine (10–12% w/v salt) to the brim of the barrel/tank and loosely seal.

(i) Check brine pH.
(j) Acidify the brine to pH 6.2–6.5 by adding food acids (lactic acid, acetic acid or hydrochloric acid) or pass carbon dioxide gas through the tank/container.
(k) Check sugar levels in the brine. Add dextrose if required to give brine concentrations of 1–2% w/v.
(l) Add starter culture from actively fermenting lots or commercial lactic acid bacteria culture (Vege-Start™) (Fig. 5.19).
(m) Monitor brine pH levels daily and salt levels weekly. The pH of the brine will fall from around 6–7 to pH 5 in the first few days. (Note the initial pH of the brine may be 8 or more depending on the effectiveness of the washing steps after lye treatment.)
(n) Check free acidity in the brine.
(o) Replace lost brine, ensuring minimal air space between the surface of the liquid and lid of the container.
(p) Seal the barrel/tank so that anaerobic conditions are established. The brine pH will fall progressively to between pH 4.0–4.5 in about 40 days from the start of processing.
(q) Monitor brine pH weekly and salt monthly. If pH does not fall this could indicate a 'stuck' fermentation. Check dextrose and/or starter culture and food acid (see below).
(r) Monitor brine sodium chloride and pH levels to achieve final levels of around 8% w/v and pH 4.0–4.2 or less. Add salt if required. Olives are ready when the bitterness is acceptable; the approximate time for this to occur is six weeks.
(s) Remove discoloured olives by hand or a photosensitive machine.
(t) Size grade and sort processed olives (optional) with a divergent cable machine.
(u) Pack the processed olives in brine.
(v) Pasteurise the packed processed olives if required.
(w) Send representative samples to a microbiology laboratory for testing.
(x) Label packed processed olives in accordance with food standard requirements.
(y) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

Potential problems: stuck fermentations and corrective actions

- Olive brine pH is too high, incomplete washing of lye treated olives: wash olives and add food grade acid.
- Salt levels in the brine are too high, inhibiting lactic acid bacteria: reduce salt levels.
- Insufficient sugar: add dextrose to the brine to give a concentration of 1–2% w/v (10–20 g/l).
- Brine pH is too high: add food grade acid to lower pH to around 5.
- Lack of fermentation microorganisms: add a starter culture of lactic acid bacteria.

Stuck fermentations and their management

If the fermentation becomes 'stuck' (nothing is happening), the cause should be determined and corrected.

Evidence for stuck fermentation includes no increase in total acid or a fall in pH. Stuck fermentations can be prevented. A simple approach is to exchange brine with that from a normally fermenting container of the same size, so that each container finishes up with 50% of the brine from the other container. Fermentation should continue or proceed in both containers.

Alternatively, the following parameters should be assessed and corrected:

- Check pH. If it is too high, fermentative organisms are inactive. Add food acid or pass carbon dioxide gas through the container/tank.
- Check the temperature of the brine and adjust temperature if necessary.
- Measure soluble sugars in the brine and add dextrose in two portions, a week apart, to give a titratable (free) acidity of at least 0.8% w/v of lactic acid by fermentation.
- Check levels of lactic acid bacteria. If necessary, add pure starter culture or brine from an active fermentation tank (Fig. 5.20).
- If yeasts predominate (check microscopically), discard brine and add fresh brine with a starter culture.
- If total (free) acid is less than 1% w/v of lactic acid, add lactic acid to raise levels to 1%; pH levels should be between pH 3.7 and 4.0 (Fig. 5.20).
- Check salt levels in brine and raise these to 8% w/v if necessary. If environmental temperatures are high (>30°C) then the salt levels are raised to at least 8.5% w/v to prevent *Zapateria* spoilage by microorganisms such as *Propionibacteria* (Fig. 5.21).

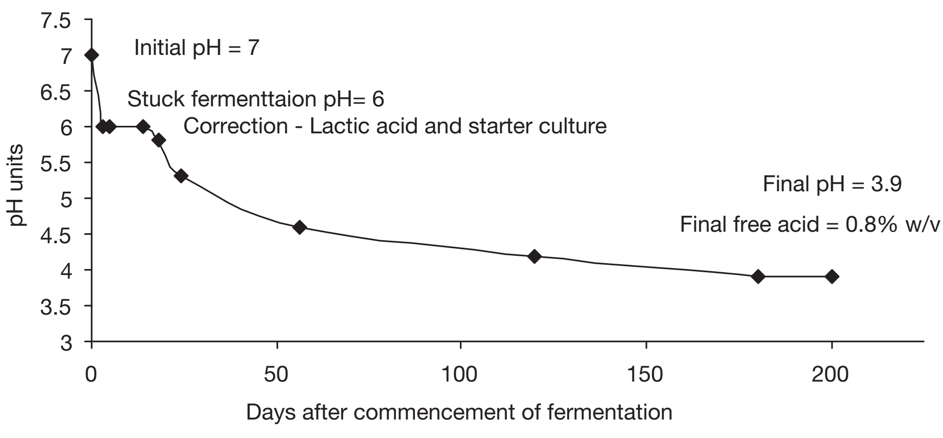

Figure 5.20 Typical changes in brine pH of a 'stuck' fermentation of lye treated raw green-ripe olives before and after correction with lactic acid and starter culture.

Bulk fermented product. The final bulk fermented product has typical brine parameters: pH 3.8–4.2; free acidity 0.8–1.2% w/v as lactic acid; combined acidity 0.09–0.11M; sodium chloride 7–8% w/v. If the pH is kept below 3.5, then a lower salt level of at least 5% w/v can be used.

Packing specifications. The packing solution for olives produced by this method should contain at least 5% w/v salt, have a minimum acidity of 0.5% calculated as lactic acid and a pH of 4.0 or less to ensure safety and preservation. When a preservative is used or the olives are to be refrigerated, the packing solution should contain at least 4% w/v salt, have a minimum acidity of 0.4% calculated as lactic acid and a pH of 4.0 or less to ensure safety and preservation. Alternatively, if the olives are to be pasteurised or sterilised then the packing solution should have a pH of 4.3 or less. Salt and acid levels are not

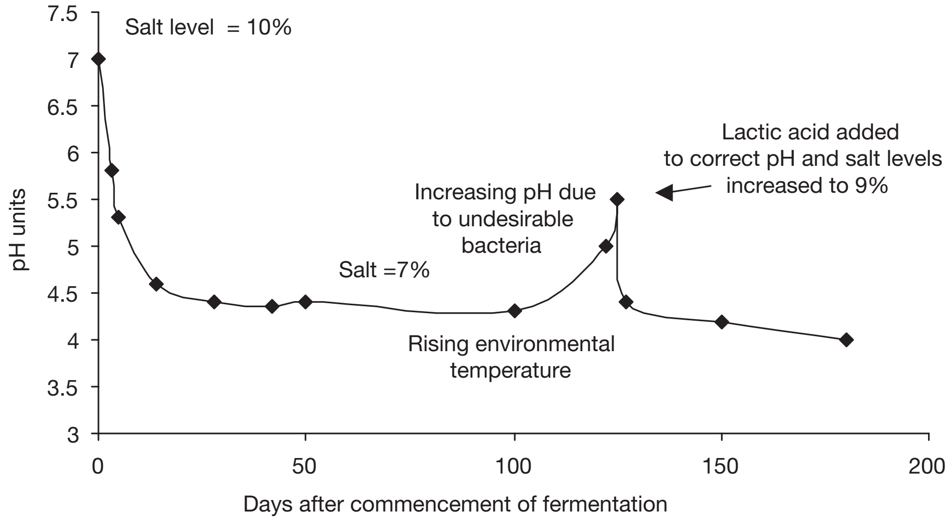

Figure 5.21 Possible pattern for undesirable bacterial activity during brine fermentation of table olives causing an increase in brine pH.

specified in this case, but levels should not compromise the safety and organoleptic qualities of the olives determined by Good Manufacturing Practice. With products that have characteristics outside of these parameters, the processor has to guarantee the safety of the olives through the use of appropriate testing procedures.

Packed products produced by this method have typical brine parameters: pH 3.2–4.1; titratable (free) acidity 0.4–0.6% w/v as lactic acid; combined acidity 0.02–0.07M; and sodium chloride 5–7% w/v. The salt levels can be reduced to 2% w/v sodium chloride if the packed products are pasteurised. Ascorbic acid can be added to cover solutions/brines for lye processed green-ripe olives to prevent their discolouration on storage.

New alternative directions to lye treatments. Research undertaken in Italy and elsewhere is being directed towards eliminating the use of lye as a debittering agent. One procedure is to use a specific microorganism such as the yeast *Candida veronae*, which has oleuropein hydrolysing properties. This treatment facilitates subsequent lactic fermentation by *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*). An alternative procedure is to use *Lactobacillus pentosus* strains isolated from brine of naturally ripe olives. These have beta-glucosidase activity that can split oleuropein into an intermediate aglycone and then through an esterase to hydroxytyrosol and elenolic acid. Using such procedures, debittering occurs after three weeks.

Debittering olives by microbial breakdown of oleuropein:

$$\beta\text{-glycosidase esterase} + \text{oleuropein} \rightarrow \text{oleuropein aglycone hydroxytyrosol} + \text{elenolic acid}$$

$$\text{glucose} \rightarrow \text{food acids}$$

Another problem that faces processors, particularly at sites with low environmental temperatures, is poor fermentation rates and prolonged processing times. To overcome this, researchers are investigating the use of *Lactobacillus pentosus* (formerly *Lactobacillus plantarum*) strains isolated from cold fermentation brines as starter cultures to process green table olives at 9–15°C.

Nature of the final product. Spanish-style olives are an even olive green colour, firm to touch, crisp with a mild salty taste, with little bitterness and a slightly acidic flavour. The organoleptic profile of green *Sevillana* olives processed by the Spanish-style method is presented in Fig. 5.22.

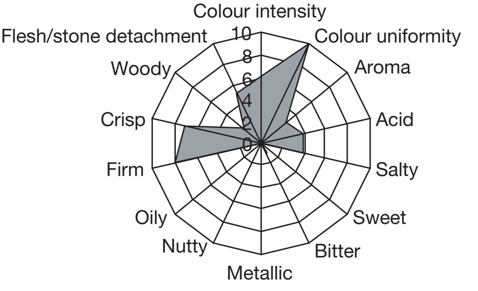

Figure 5.22 Organoleptic profile of green *Sevillana* olives processed by the Spanish-style method.

Lye treated green-ripe olives without fermentation

Different procedures for processing green-ripe olives with lye, but without a fermentation step, are used at the local or regional levels in traditional olive growing countries. Some of the more popular ones are presented below.

Spanish-style green 'look alikes'. Initially the process is the same as producing Spanish-style green olives. After the excess lye is removed, the washed olives are placed in 5–6% salt brine for two days. The olives are then drained and placed in salt brine (10.5–11.5% w/v salt) with food acid (hydrochloric acid, lactic acid or citric acid) to lower the pH to around 4. The olives are packed in brine with a final salt content of 7% w/v and a pH of 4.5. With salt concentrations of less than 2%, the pH of the brine should be 4 or less. The final product is pasteurised.

Step-by-step procedure for lye treated green-ripe olives without fermentation

(a) Use/accept only quality raw green-ripe olives.
(b) Store raw olives correctly before processing (optional).
(c) Spray wash olives with potable water.
(d) Size grade and sort raw olives.
(e) Use whole olives.
(f) Pack olives into barrels/tanks with lye (1.3–2.0% w/v sodium hydroxide in potable water); make sure olives are submerged.
(g) Allow lye treatment to proceed for 5–10 hours.
(h) Monitor penetration of lye into olive flesh using phenolphthalein indicator.
(i) Drain lye solution from the olives.
(j) Wash olives immediately with potable water then two static washes: one for two to three hours and a second for 10–20 hours.
(k) Add brine (10.5 to 11.5% w/v salt) to the olives in the barrels/tanks and food acid to lower the pH to 4.
(l) Size grade and sort processed olives (optional).
(m) Pack the processed olives in a brine (7% w/v salt) and pH 4 or less.
(n) Pasteurise the packed processed olives.
(o) Send representative samples to a microbiology laboratory for testing.
(p) Label packed processed olives in accordance with food standard requirements.
(q) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

Nature of the final product. Lye treated olives in brine without fermentation are an even green colour, firm to touch, crisp with a salty taste, a little bitterness and an acidic (lactic/citric) flavour. Some consumers comment on the sweetness of this type of table olive, which may be due to the presence of sugars that would have been utilised if a fermentation step was involved.

Picholine-style table olives (Olive de Nimes). Green-ripe *Picholine* olives from southern France (Languedoc and Luques) are processed in lye then packed in brine. Similar olives are prepared in Algeria and Morocco from other varieties and specifically after a lye treatment. Similar to Spanish-style green olives, the olives are placed in a brine of 5–6% w/v salt for two days, during which the flesh absorbs salt. The brine is then drained and the olives packed in a brine of 7% w/v salt brine and enough citric acid added to give pH 4.5. A concentrated aqueous solution of citric acid can be used and the final product can have maximum citric acid concentration of 1.5% w/w. The olives, which have an intense green colour, are ready to eat after 8–10 days. For long-term storage of bulk product, depending on the environmental temperature, brine with 8–10% w/v salt is required. The bulk product can be stored in a 3% brine solution under refrigeration at 3–7°C. When the final product is packed in consumer size containers it is pasteurised.

Step-by-step method for *Olive de Nimes*

(a) Use/accept only quality raw green-ripe *Picholine* olives.
(b) Store raw olives correctly before processing.
(c) Spray wash olives with potable water.
(d) Size grade and sort raw olives.
(e) Use whole olives.
(f) Pack olives into barrels/tanks with lye (1–2% w/v sodium hydroxide in potable water); make sure olives are submerged.
(g) Allow lye treatment to proceed for 8–10 hours.
(h) Monitor penetration of lye into olive flesh using phenolphthalein indicator.
(i) Drain lye solution from the olives.
(j) Wash olives immediately with potable water, then two static washes: one for two to three hours and a second for 10–12 hours.
(k) Place the olives in brine of 5–6% w/v salt for two days.
(l) Drain the brine.
(m) Pack the olives in brine of 7% w/v salt brine and citric acid corrected to pH 4.5.
(n) The olives, which are an intense green colour, are ready to eat after 8–10 days.
(o) For long-term storage, place olives in a brine of 8–10% w/v salt and pasteurise.
(p) Send representative samples to a microbiology laboratory for testing.
(q) Label packed processed olives in accordance with food standard requirements.
(r) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

Nature of the final product. Picholine olives in brine have an even green colour, are firm to touch, crisp with salty taste, and have a slight bitterness and an acidic (citric) flavour.

Castelvetrano-style olives. Castelvetrano-style olives are popular in Sicily. They are different to the Sicilian-style green olives that undergo a natural fermentation without a pretreatment with lye. With *Castelvetrano* table olives, a local variety, *Nocellara de Belice*, is used. After washing the raw green olives, they are placed in a 2–3% lye solution in a suitable plastic barrel or drum. After one hour, coarse salt (3–4 kg/100 L barrel) is added and agitated to mix and dissolve the salt. The barrel is sealed and further agitated to ensure mixing and to form the processing brine. The olives are ready to eat after two weeks. When the barrel is opened, the lye/salt brine is drained and the olives are washed to remove excess lye. Under ambient storage conditions the *Castelvetrano* olives have a shelf-life of only a few months, especially under hot conditions. Deteriorated olives lose colour and develop malodours. As this olive style is a seasonal product, long-term storage is not required. Future research, however, may refine the process and include steps for long-term storage under refrigeration or in packing solutions. The final product is salty and lacks bitterness.

Californian/Spanish-style black olives

This method/style of olive, inappropriately called 'black-ripe olives', was originally developed in California. It has also been adopted in Spain and some north African table olive producing countries. Fresh green olives or turning colour olives (often *Manzanilla*) are soaked in several caustic soda (lye) solutions of different strengths until the lye penetrates the flesh through to the stone. By using this process the olives debitter quickly. After each lye treatment, the lye is replaced with potable water and air is passed through tanks. The olives turn a brown/black colour through the oxidation/polymerisation of polyphenols (hydroxytyrosol and caffeic acid).

Although consumers often malign this type of olive as: 'the dreaded canned black-ripe olive'; 'they are basically rusted then petrified'; 'horrid little black things', if eaten slowly, not unpleasant subtle spicy flavours can be perceived.

After the last lye treatment, olives are drained and washed several times with water to remove residual lye. If the wash waters are acidified with hydrochloric acid or with carbon dioxide, fewer washes are required. They are then immersed in an iron salt, 0.1% w/v of ferrous gluconate, which stabilises the colour. The olives are washed to remove excess iron, then packed in a 2–3% w/v food grade sodium chloride solution and sterilised. The IOOC Table Olive Standards (2004) stipulates that residual iron in the olives should not exceed 150 mg/kg. No fermentation takes place during this method and the processed olives are preserved by sterilisation.

This method of olive processing is expensive because of the equipment required, the cost of inputs (especially water), and the high level of technical expertise needed. In large establishments, raw olives are processed in large horizontal tanks, for example 10 tonne stainless steel, or polyester and fibreglass tanks, that can be fed through different inlets for water, lye solution, brine and compressed air and can be drained easily during processing. Specifically designed rotating tanks that facilitate even processing are used in some centres. Processing is undertaken at around 20°C. The strengths of lye used depend on the olive variety, maturation state, size and whether they have been previously stored in brine before lye treatment.

In some centres, pre-brined olives are purchased from other sources, often from different regions or even different countries. Pre-brined olives if stored long enough in brine undergo a weak fermentation. Olives that have been previously stored in brine require lower strengths of lye for processing as they are already debittered.

At different olive processing centres, local modifications are made based on environmental considerations, the available equipment, olive varieties, source of olives and levels of technical expertise. Olives processed by this method have much lower residual phenolic levels than those processed as Greek-style naturally black olives, Kalamata-style olives or Spanish-style green olives. A marked decrease in olive flesh sugar (nearly thirty-fold) occurs during processing due to the extensive lye treatments and washing steps.

Step-by-step method for preparing Californian/Spanish-style black olives

(a) Use/accept only quality raw olives (green-ripe to early turning colour).
(b) Store raw olives correctly before processing.
(c) Spray wash olives with potable water (optional).
(d) Size grade and sort raw olives.
(e) Use whole olives.

At this point, olives can be treated immediately with lye or placed in 10% w/v sodium chloride holding brine and used later. Olives are given three lye treatments (0.5 to 1.5% w/v sodium hydroxide) for short periods.

Lye treatment 1

(a) Pack olives into a container/tank with lye solution 1.
(b) Allow olives to interact with 1.5% w/v lye solution just long enough to penetrate the skin. This takes one to two hours.
(c) Drain the lye solution for later use as Lye treatment 2.
(d) Add water to the tank and pass compressed air through the mass for 24 hours to darken the olives. (Oxidation and polymerisation of colourless phenolic compounds occurs under alkaline conditions.)
(e) Drain water and allow olives to dry and stand for 3–12 hours until the skin turns a uniform black colour. In some centres the olives are kept in water.

Lye treatment 2

(f) Add the used lye from Lye Treatment 1 and allow it to penetrate 1 mm into the flesh where oleuropein is hydrolysed. Debittering of the flesh begins.
(g) Pass compressed air through the tanks to mix the mass.
(h) Drain the lye solution for later use as Lye treatment 3.
(i) Add water to the tank/olives and pass compressed air through the mass for around 20 hours.

Lye treatment 3

(j) Add the used lye from Lye treatment 2 enriched with fresh lye and allow time to penetrate through all the flesh down to the stone. This takes four to six hours.
(k) Check penetration of lye through the flesh.
(l) Drain the lye solution.

Washing step

(a) Wash the olives with potable water and aerate for three to four days until the residual lye is removed.
(b) Drain and replace water two to three times a day.
(c) Check pH, which should fall from pH 11 to 9. Add hydrochloric acid, lactic acid or carbon dioxide to facilitate removal and neutralisation of lye.
(d) Use warm water (80°C) to prevent softening and gas pocket (fish eye) spoilage.
(e) The final pH should be around 7.0 (6.0–7.8).

Colour enhancing step

(a) Add ferrous gluconate or ferrous lactate to the last wash step to give final concentrations of 0.1% w/v or 0.05% w/v respectively.
(b) Leave the olives in the iron solution for up to 24 hours. The iron reacts with tannins in the olive flesh to form iron tannate.
(c) Drain the iron solution and remove the excess iron by further washing with water.

Brining step

(a) Add a fresh brine of 3% w/v salt to the washed olives and allow this to equilibrate for three days.
(b) Bulk pasteurise either by injecting steam into the brine until the temperature reaches 90–95°C or heat at 60°C for 45 minutes to prevent spoilage by aerobic bacteria.
(c) Allow the olives to cool naturally.

Further steps

(a) Size grade the olives if required.
(b) Pack the processed olives into a brine (2–3% w/v sodium chloride).
(c) Sterilise the packed processed olives in cans or glass jars (see Table 5.7).
(d) Send representative samples to a microbiology laboratory for testing.
(e) Label packed processed olives in accordance with food standard requirements.
(f) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

Final products of Californian-style black olives. As the olives produced by this method are sterilised, the packing solution is based on principles of good manufacturing practice. Typically, the pH is 5.8–8.0 and sodium chloride is 1–5% w/v (depending on the commercial product). The maximum iron level can be up to 0.15 g/kg of fruit.

Processing notes. The lye concentration used depends on the olive variety, maturation state and processing temperature. Olives are processed chemically and no fermentation occurs with this method. Advantages are that the olives retain the firmness of green-ripe/turning colour olives and, as processing only requires a few days, they are ready for the market within one to two weeks of harvest. Disadvantages are the large volumes of water required for lye treatments and washing as well as the disposal of the resulting wastewater. Australia currently imports large amounts of these olives. They are commonly available on supermarket shelves and the destoned form is frequently used in cooking and on pizzas. This type of olive is not currently produced in Australia.

Processing olives by this method should only be undertaken where complete processing and canning lines are available and where food scientists are employed to direct and control production.

Sterilisation. Californian/Spanish-style black olives require sterilisation to ensure safety. Sterilisation is undertaken in an autoclave under the indicative conditions shown in Table 5.7.

Table 5.7. Indicative sterilisation conditions for table olives
(After Garrido Fernandez, A., Fernandez Diez, M. J., and Adams, M. R. (1997).)

Can capacity	*Thermal treatment*	
	Temperature °C	*Time (mins)*
1 kg or less	115–116	60
3 kg or less	115–116	70
1 kg or less	121.1	45
3 kg or less	121.1	50

In principle, sterilisation involves exhausting the air from cans containing olives and brine using 93–95°C heat for five minutes, creating an anaerobic environment. This procedure results in an internal temperature of 71–77°C. The cans are then sealed and sterilised according to the above conditions. Such conditions assume an initial temperature of between 21°C and 71°C. For glass jars, a type of autoclave called a 'retort' is used with compressed air, otherwise the pressures that develop in jars during sterilisation would blow off the lids.

All facilities using sterilisation techniques should seek expert advice from engineers and food scientists when establishing conditions for specific products. If the olives are not properly sterilised, the anaerobic conditions inside the containers provide the environment for *Clostridium* spp., including *Clostridium botulinum*, to grow leading to spoilage, food poisoning and potentially the more lethal condition, botulism, in consumers.

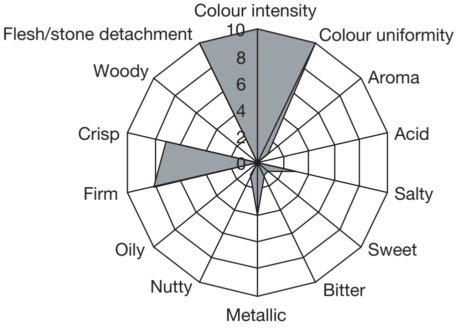

Figure 5.23 Organoleptic profile of lye treated *Manzanilla* olives followed by oxidation (Spanish/ Californian-style black olives).

Use of Californian/Spanish-style black olives. These olives are available whole or pitted to eat as snacks and aperitifs, sliced for pizzas, and made into pastes to be used in hot and cold collations.

Nature of the final product. Californian/Spanish-style black olives are a uniform dark colour, firm with compact textured flesh. They have no bitterness, have slight aromatic qualities, are low in salt and have a slightly sweet taste with subtle liquorice overtones. The organoleptic profile of this type of table olive is depicted in Fig. 5.23.

Processing dried table olives (shrivelled olives)

Heat-dried or salt-dried olives are popular with consumers (see also Chapter 4). Dried olives have a low water activity compared with the original raw olives that renders them self-preserving.

Both fresh and processed olives in brine can be dried by heating. However, when processed olives are heat-dried the salt concentrates in the olive flesh. If the salt concentration is too high the olives are inedible. To avoid this problem the olives can be pre-soaked in potable water for one to two days to remove salt prior to drying.

Note: Dehydration is an effective means of inhibiting the growth of microorganisms. Most moulds can grow on foods with as little as 16% moisture. Few organisms will grow at moisture contents of 5%. Bacteria and yeasts generally require high moisture levels, usually greater than 30%. Fruits dried to 16–25% moisture are susceptible to mould if exposed to high humidity and air. Some pathogenic toxin-producing bacteria can withstand the less than favourable conditions of dried foods.

Traditional Greek products include Greek-style salted and Throuba-style olives.

Greek-style salted olives. *Megaritiki* olives are allowed to partially dry naturally on the tree, and then dried with coarse salt. Other varieties such as *Kalamata*, *Manzanilla*, *UC13A6* or *Leccino* can also be used to produce salt-dried olives.

Throuba-style olives. *Thrubolea* olives, growing mainly in Greece (Crete, the Aegian Islands and the Attica region), are thought to undergo debittering and transformation by a fungal enzyme. The olives, which change colour from black to copper green, are then sun-dried and salted. There is little evidence actually supporting the role of a fungus in debittering this type of olive.

Salt-dried olives

Salt-dried olives are prepared by packing naturally black-ripe olives in alternating layers with dry coarse salt (equivalent to 10–20% w/w of the weight of olives) in slatted containers that allow drainage of the vegetable water drawn out by the salt. The resulting olives, or 'date olives', are shrivelled in appearance and have a salty bitter-sweet taste. Salt is also taken up by the olive, which acts as a preservative. Processing time is around four to six weeks and the olives are best eaten within three months of processing. Addition of olive oil enhances the flavour of the olive; however, oxidation of the oil can give the olives a slight rancid taste.

Step-by-step method for preparing salt-dried black olives

(a) Use/accept quality raw olives. (Use naturally fully black-ripe olives, for example *Kalamata*, *Manzanilla*, *UC13A6* or *Leccino*.)
(b) Store raw olives correctly before processing.
(c) Spray wash olives with potable water.
(d) Size grade and sort raw olives (optional).
(e) Use whole olives.
(f) Slit or prick olives (optional). This speeds up the process.

(g) Allow olives to stand for two days in a cool place; they will lose some water through transpiration.
(h) Pack olives in alternating layers of coarse salt (10–20% of olive weight).
(i) If required, after a few days, mix the olives periodically to ensure good contact with salt.
(j) Allow the released black vegetable water to drain. Do not allow olives to sit in black water as this delays debittering.
(k) Add more coarse salt if required (coarse salt should always be visible).
(l) Olives are ready to eat in one to two months.
(m) Expose the olives to air to darken.
(n) Pack the olives in plastic containers or cans with potassium sorbate (an antifungal agent) under vacuum or in 10% brine.
(o) Send representative olive samples to a microbiology laboratory for testing.
(p) Label packed processed olives in accordance with food standard requirements.
(q) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

Salt-dried olives, which have more than 10% salt, may be unpalatable to some consumers. Even under high salt conditions these products are never sterile and can support mould growth if exposed to the environment, and have a short shelf-life. In some centres they are stored in a small quantity of olive oil.

The levels of phenols in salt-dried olives will depend on the variety, maturation state and the quantity lost after processing. Researchers in Greece have found that residual phenol levels in *Thassos* are between 600 mg/kg and 800 mg/kg but hydroxytyrosol levels are much lower than other olive styles, presumably because there is no fermentation step or acid conditions during processing. The sugar content in salt-dried olives decreases to about half that of fresh fruit. Some sugars and other water-soluble compounds are lost with the liquid drawn out of the olives during salting. A similar product produced by table olive processors in South Africa is called '*Kalahari*'. After salting, these olives are dipped in 5% acetic acid or the vinegar equivalent.

Nature of the final product. Black salt-dried olives have a brown to black wrinkled appearance, a pleasant chewy texture (like prunes) and a slightly bitter-sweet and very salty taste. Their intense flavour makes them very popular with consumers who like

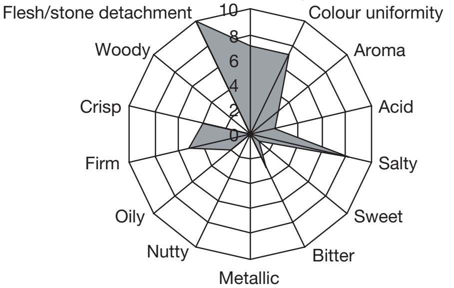

Figure 5.24 Organoleptic profile of salt-dried black-ripe *Manzanilla* olives.

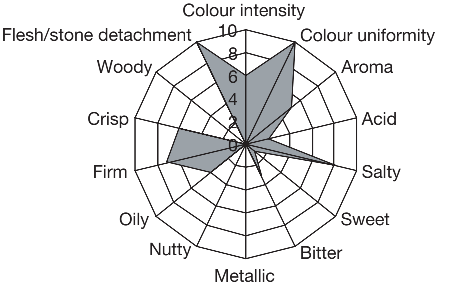

Figure 5.25 Organoleptic profile of salt-dried green-ripe *Manzanilla* olives.

full-flavoured olives. As they might be too salty for some consumers, soaking them in water for 24 hours before eating reduces the salt content. When exposed to air, particularly if olive oils have been added, salt-dried olives can develop a slight rancid taste. Green-ripe or turning colour olives can also be salt-dried using the above method for black salt-dried table olives. When packed in salt, green-ripe olives take on a green/brown colour and gradually shrivel. Because the green-ripe or turning colour olives are firmer than naturally black-ripe olives, the final products are crisp in texture and firm to touch. The organoleptic profile of salt-dried black-ripe and green-ripe *Manzanilla* olives is presented in Figs 5.24 and 5.25.

Heat-dried table olives

Heat-dried olives are dehydrated by placing naturally black-ripe olives in the sun or in an oven set to give gentle heat (40–50°C). Higher temperatures will cook the olives. Using this method the olives lose moisture and bitterness by chemical degradation and vaporisation resulting in a slightly bitter-sweet product. A small quantity of salt is added to enhance their flavour and keeping qualities.

Step-by-step method for preparing sun/heat-dried olives

(a) Use/accept quality raw olives. (Use naturally black-ripe olives, for example *Kalamata*, *Manzanilla*, *UC13A6* or *Leccino.*)
(b) Store raw olives correctly before processing.
(c) Spray wash olives with potable water.
(d) Size grade and sort raw olives (optional).
(e) Use whole olives.
(f) Slit or prick olives (optional). This speeds up the process.
(g) Weigh a sample of olives (original weight).
(h) Dry olives in sun or by heat (40–50°C). This can take several days.
(i) Monitor weight of a sample of olives.
(j) Re-weigh olive sample periodically. Olives are ready when their original weight falls by 15–20%.
(k) Check water activity if laboratory facilities are available. Values should be less than 0.8.
(l) Mix in solid salt to taste.
(m) Pack the dried olives with salt in plastic sachets or other containers, such as glass or under vacuum. Alternatively, pack dried olives without salt into olive oil.
(n) Send representative samples of olives to a microbiology laboratory for testing.
(o) Label packed processed olives in accordance with food standard requirements.
(p) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

Nature of the final product. Heat-dried olives have a brown-black wrinkled appearance, and a pleasant chewy texture with a slightly bitter but distinctly sweet prune-like taste (if not salted), particularly with *UC13A6*. The organoleptic profile of heat-dried black-ripe *UC13A6* (Californian Queen) olives is presented in Fig. 5.26. Heat-dried olives embellished with olive oil and herbs are shown in Plate 25.

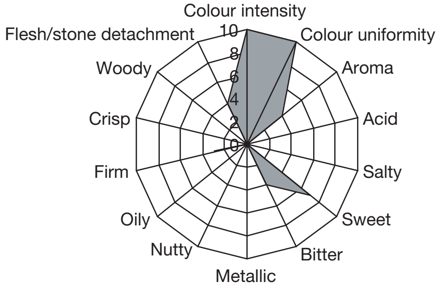

Figure 5.26 Organoleptic profile of heat-dried black-ripe *UC13A6* (Californian Queen) olives.

Chocolate-coated dried olives. A novel presentation of this style of olive is to dip small pitted dried olives, for example *Koroneiki*, into melted chocolate and allow the chocolate to solidify. This product complements chocolate-coated raisins, nuts and coffee beans. The final product has a distinct chocolate flavour with a subtle bitter-sweet taste of the olive. Salted olives are used if a salty taste is desired.

Ferrandina-style table olives

A variation of heat-dried olives is *Ferrandina* olives, a traditional style from Italy. Initially naturally black-ripe olives are blanched in water at 95°C for one to two minutes, which damages the skin (making it more permeable) and kills surface microorganisms. After draining the water, the olives are salted by soaking them in brine (10% w/v salt) for a few days (or packed in dry salt for two to three days). Olives drained of brine (or dry salted) are dried using gentle heat (40–50°C) in an oven over a few days or on racks exposed to the sun (which takes longer) until the bitterness of the olives falls to an acceptable level. The residual moisture falls to around 15–20% w/v and the water activity of less than 0.8 aids in their preservation.

Step-by-step method for processing *Ferrandina* olives

(a) Use/accept only quality raw olives. (Naturally black-ripe olives, for example *Kalamata*, *Manzanilla*, *UC13A6* or *Leccino*.)
(b) Store raw olives correctly before processing.
(c) Spray wash olives with potable water.
(d) Size grade and sort raw olives (optional).
(e) Use whole olives (slit or prick to speed up the process).
(f) Add hot water (95°C).
(g) Drain hot water after one to two minutes.
(h) Soak olives in brine (10% w/v sodium chloride) or pack in coarse salt for two to three days.
(i) Drain brine or gently wash off coarse salt.
(j) Weigh a sample of olives.
(k) Dry olives in an oven at 50°C over two to three days until the residual moisture falls to around 15%.
(l) Monitor the weight of a sample of olives.
(m) Re-weigh the olive sample periodically. (The olives are ready when they are debittered and the residual moisture is around 15–20% and water activity is less than 0.8.)
(n) Pasteurise processed olives for long-term storage.
(o) Send representative samples of olives to a microbiology laboratory for testing.
(p) Label packed processed olives in accordance with food standard requirements.
(q) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

Nature of the final product. *Ferrandina* olives have a black wrinkled appearance, a chewy texture and a slightly bitter salty taste.

Toasted olives. A similar product produced by olive growers in Italy is 'Toasted Olives' (*Olive Tostata*). The olives are dried to a firmer, more chewy consistency than *Ferrandina* olives.

Dried olives in olive oil. Dried olives, salted or plain, are often packed in olive oil as a specialty item. Olives are ready to eat after three to four months.

Post-processing table olive operations (secondary processing)

Post-processing operations include: preparing packing solutions, secondary table olive processing, preservation, packaging and labelling.

Packing solutions for table olives

Packing solutions are prepared by dissolving food grade salt in potable water, with or without the addition of vinegar (or other suitable food acid such as citric acid), olive oil, herbs, spices and aromatics (see below). The brine should be clean and free of abnormal odours and tastes. Fermentation brines can be used to store olives in bulk containers.

Once processed, most table olives are packed in brines or marinades. Fermentation brines can be used as packing solutions as long as they are filtered and pasteurised and they meet the salt, acid and pH levels required for a particular table olive product. Brine in glass containers should be clean and transparent (except where they have been embellished). The minimum sodium chloride concentration, minimum acidity and maximum pH levels accepted in packing solutions for different types of olive products, following the Codex Alimentarius (1987)/IOOC (2004) Table Olive Standards, are given in Table 5.8.

Table 5.8. Final packing/covering solutions/conditions for common table olive products

(After Codex Alimentarius (1987)/IOOC (2004) Table Olive Standards)
GMP, Good Manufacturing Practice

Product	*Minimum sodium chloride content % w/v*			*Maximum pH limit*			*Minimum acidity % w/v calculated as lactic acid*		
	Specific chemical attributes	Preservative Refrigerate	Pasteurise Sterilise	Specific chemical attributes	Preservative Refrigerate	Pasteurise Sterilise	Specific chemical attributes	Preservative Refrigerate	Pasteurise Sterilise
Treated olives e.g. Spanish-style green	5	4	GMP	4	4	4.3	0.5	0.4	GMP
Natural olives Green Turning colour Black	6	6	GMP	4.3	4.3	4.3	0.3	0.3	GMP
Dehydrated and/or shrivelled olives	10	10	GMP	GMP	GMP	GMP	GMP	GMP	GMP
Olives darkened by oxidation Californian-style Spanish-style	GMP	GMP	GMP	GMP	GMP	GMP	GMP	GMP	GMP

If fermentation brines are used to prepare packing/covering solutions, and the final product is not pasteurised, they should be heated at 80°C for 10–15 minutes to denature fermentative organisms that may initiate secondary fermentations when the olives are packed in their final containers.

Secondary table olive processing

Secondary processing of table olives involves all processes after the olives have been processed and debittered (primary processing) including: adding vinegar and olive oil; adding herbs, spices and marinades; pitting and stuffing table olives; making olive pastes and tapenades; and adding other pickled vegetables to processed olives.

Adding vinegar and olive oil

A simple packaging procedure is to add vinegar and extra virgin olive oil to the olives in brine. Additions contribute to the organoleptic properties of the olives. The addition of vinegar to brine increases its acidity as well as lowering the pH of table olive products, improving their keeping qualities.

Recipe for packing solutions with brine, vinegar and olive oil

(a) Make up a 10% brine solution (7–8% brine can also be used if the 10% brine is considered too salty).
(b) Use 3 parts of this brine and add 1 part of vinegar of choice (one litre of the brine/vinegar solution will require 750 ml of 10% brine and 250 ml of vinegar).
(c) Pack the olives in the containers and add the brine/vinegar solution nearly to the shoulder of the container.
(d) Check the salt content, pH and free acidity of the packing liquid.
(e) Add a layer of oil (enough to cover the surface of the solution, for example 10 ml in a 300 ml container).

Vinegar. As vinegar is a common addition to table olive products, the following information will be of interest to both commercial and home processors. Like the olive, vinegar production can be traced to ancient Egyptian, Greek and Roman civilisations. Some ‘vinegars’ are prepared synthetically, then diluted with water to have acetic acid levels similar in strength to fermented vinegars. Some countries will not allow these chemical derived ‘vinegars’ to be labelled vinegar.

Vinegar is a dilute solution of acetic acid and often produced by a two-stage microbiological process.

Stage 1. Conversion of fermentable sugars to ethanol by yeasts (usually *Saccharomyces* spp.).

Stage 2. Oxidation of ethanol to acetic acid by bacteria (usually *Acetobacter* spp.).

Vinegars from different sources, depending on the sugar source, have numerous flavour components, including a very small amount of alcohol (ethanol), that give the table olives desirable flavours and aromas when combined with the acetic acid.

With respect to table olive processing, vinegar has a number of functions: preservation, flavouring, a solvent for herbs and spices, and provides additional polyphenols.

Vinegar has a high antimicrobial action because it is a weak acid. Weak acids in solution are present in two forms, unionised (acetic acid) and ionised (acetate + hydrogen ions). The proportion of the two forms depends on the pKa of acetic acid, which is 4.76, and the pH of the solution it is put into. At pH values around the pKa of acetic acid most of the acetic acid is in the unionised form. As little as 0.1% of the unionised form will inhibit the growth of most food-poisoning and spore-forming bacteria. At a concentration of 0.3%, mycotoxigenic moulds are prevented from growing. Together with salt, acetic acid also lowers the water activity (W_A) of brines. The antibiotic activity of acetic acid is not only due to its acid properties. The unionised form can pass into microorganisms where it comes into contact with the essentially neutral (pH 7) cytoplasm and rapidly ionises releasing acid that lowers the pH inside the cells, inactivating essential enzymes.

Different types of vinegar can be used and their composition will obviously influence the flavour of the olives. Most vinegars contain 5–6% (0.8–1.0 M) acetic acid with a pH of less than 3. Apart from white vinegar, other vinegars listed below have other components that can contribute to the organoleptic characteristics of the olives. White vinegar, available in bulk or at supermarkets, is essentially a solution of acetic acid in water. It has a sharp acid/sour taste and pungent aroma. Other vinegars can have pigments, flavour compounds of the source material, for example malt, apple, grape, and varying amounts of residual fermentable substrates, such as sugar. Adding vinegar with fermentable substrates to table olives after packaging can initiate secondary fermentations if the final products are not pasteurised.

Types of vinegars. Types of vinegars include white and brown (often made synthetically), malt, honey, cider, wine (red and white), and balsamic vinegar.

Lighter coloured vinegars are generally used with green olives whereas coloured vinegars are used with black olives.

Extra virgin olive oil is the preferred oil to be added to table olives. However, if table olives with olive oil are stored under refrigeration, the oil solidifies and some consumers may believe the table olives are unsafe to eat. For this reason many processors/packagers of table olive products prefer to use seed oils, such as canola, or high oleic sunflower oil, that do not exhibit this effect. The effect of refrigeration on olive oil should be explained on the label.

Note: Some commercially available vinegar that contains 15% acetic acid is useful for adjusting brine pH during table olive processing. Glacial acetic acid can also be used, but this product is highly corrosive and needs careful handling. These should not be used for preparing packing solutions.

Adding herbs, spices and marinades to table olives

Herbs and spices can be added to final containers with table olive products and brine or as specific marinades. The objective is to embellish primary processed olives with additional flavours and aromas as well as enhance their nutritional qualities. Fresh herbs and spices such as garlic, chilli, basil and oregano should be pre-dried and free of harmful and spoilage microorganisms unless they are added just prior to consumption. Like all inputs, all herbs and spices should be controlled and backed up with specific input profiles as well as specifications for their use included in the final product profile.

Adding herbs and spices. It is best to use dried herbs rather than fresh herbs to prevent spoilage and the development of 'off' flavours, particularly if the processed olives are to be stored for more than a month or so. Herbs and spices provide additional aromas and flavours to the olives, have a mild preservative action and provide antioxidants that have health benefits. Olive oil, herbs and spices can be added to all processed olives including salt-dried, sun-dried and heat-dried olives. The flavours of the herbs and spices should be subtle and balanced. Also, the full effect of the additions can take up to a few weeks to stabilise. Although tastes and aromas depend on individual preference, as a guide 3–5 grams (about a heaped teaspoonful) of an individual herb or spice can be added to a 300 gram container of olives in brine. Olive oil tends to strengthen the flavours and aromas of herbs and spices, as many of their aromatic properties are oil soluble. Concentrated extracts of herbs and spices can also be used. The best flavour is obtained if dried whole spices are ground in a spice mill or coffee grinder when needed. Table 5.9 shows some of the herbs, spices and aromatics that can be used to embellish processed table olives.

Table 5.9. Typical herbs, spices and aromatic substances added to table olives

	Herbs, spices and aromatics	
Basil	Cinnamon quills	Lemon oil
Bay leaf	Coriander seeds	Preserved lemon peel
Black pepper	Fennel seed	Dried orange peel (zest)
Capers	Garlic	Marjoram
Cardamom seed	Ginger	Mustard seed
Chilli	Lemon grass	Oregano

Preserved lemons. Often preserved lemon is used as part of the embellishment of table olives, particularly in north Africa. Preserved lemons are expensive to buy so it is worth processing them for use in table olive products. The following simple method can be used:

(a) Divide six lemons (900 g–1000 g) into quarters.
(b) Sprinkle the flesh with coarse raw salt.
(c) Place 30 g of salt into a sterilised glass jar.
(d) Press the lemons so they release their juice into a clean glass jug.
(e) Place quartered lemons in layers in jar and press down.
(f) Add coarse raw salt between each layer.
(g) Pour lemon juice into the jar.
(h) Add coarse salt to the top of the lemons.
(i) Shake the jar daily to ensure mixing and salting.
(j) Lemons are ready after 20–30 days.
(k) Preserved lemons keep for up to one year.

Before adding to olive recipes, the lemon quarters are removed and rinsed with boiled, cooled tap water. The pulp is scooped out and discarded. The preserved lemon peel can be used whole or chopped coarsely or finely.

Simple combinations of herbs and spices that can be added to processed olives are:

- hot mixtures: chilli and mixed herbs;
- Mediterranean flavours: garlic, oregano and lemon slices (fresh or preserved);
- Greek flavours: rosemary, marjoram, wine vinegars;
- Italian herbs: basil, garlic, rosemary, marjoram, parsley, sage, thyme, chilli;
- Asian flavours: chilli, ginger, cardamom seed and lemon grass, with or without added sugar;
- tapas and antipasti: olives, peppers, small whole onions, cucumber, capers; and
- olives with added whole pickled peppers, salted capers, pickled onions, sun-dried tomatoes.

Note: When the olives are packaged as tapas or antipasti, the olives and vegetables are processed separately then mixed. For commercial production of aromatised olives, herbs, spices and olive oil should never be added during the primary processing stage.

Embellishing olives for immediate consumption. The starting materials for producing aromatised table olives are all types of primary processed olives: green, turning colour, black and dried. Olives in brine are rinsed with tap water and drained well. In principle, the amounts of olives to be prepared or served are placed in a container (jar or bowl) and the additions made. When olive oil is used, this is added to the olives first, followed by the herbs and spices. Slitting, cracking or destoning the olives allows for better penetration of herbs and spices. Olives and additives are then gently mixed. Olives can be eaten immediately; however, they are more flavoursome several days later. The prepared olives will keep in a refrigerator for at least one month. Combinations of aromatics can be used. A touch of wine, balsamic vinegar, orange zest or lemon juice can also be added. When served in a bowl, a sprig of fresh rosemary or oregano gives the finishing touch. Different ways of presenting olives are shown in Plates 26–28.

The following recipes are not prescriptive, so ingredient quantities may be increased, added to, or deleted. The authors acknowledge that everyone has his or her own and often 'better' recipe for preparing table olives! The ideas presented in the recipes can be translated to brine marinades, but fresh herbs and spices should be replaced with dried ones. For olives in marinades, place olives and other ingredients into a suitable container with lid and shake gently. Remove the lid and add salt brine vinegar. Salt brine vinegar can be prepared as follows:

10% w/v salt brine (3 parts by volume) + vinegar (1 part volume)
= approximately 1.25% acetic acid

10% w/v salt brine (4 parts by volume) + vinegar (1 part volume)
= approximately 1.0% acetic acid (The second mixture is used if olives
with a lighter vinegar/wine-like taste are desired.)

The addition of vinegar increases the free acidity of the brine. The final pH of the covering solution in packaged olives should be less than 4.3 and for commercial purposes the olives should be pasteurised. Pasteurised, aromatised table olives have a shelf-life of at least two years. Aromatised table olives that are not pasteurised have a three month shelf-life if a combination of the preservatives sorbic acid (500 ppm) and benzoic acid (1000 ppm) are used. The reasons for the short shelf-life of this type of product are the effects of vegetative microorganisms and enzymatic action of the added herbs and spices.

Recipes

Calabrese green cracked olives

Processed green cracked olives	approximately 1 kg
Chopped garlic	20 g
Chopped oregano	5 g
Crushed dry red chilli	5–10 g
Chopped fennel	5 g
Whole roasted fennel seeds	5 g
Extra virgin olive oil	80 ml

Chilli garlic marinated mixed olives

Processed green and black olives*	approximately 1 kg
Chopped garlic	20 g
Dried Italian mixed herbs	5 g
Crushed dry red chilli	5–10 g
White wine vinegar	40 ml
Extra virgin olive oil	80 ml

* mix naturally processed green *Manzanilla* and black *Kalamata* olives. Initial flavours are subtle with strong garlic overtones developing gradually.

Connoisseur/Continental marinated olives

Processed mixed olives*	approximately 1 kg
Chopped oregano	5 g
Crushed garlic	20 g
Chopped dry red chillies	5 g
Small whole red chillies	2
Lemon slices	4 thin half slices
White wine vinegar	40 ml
Extra virgin olive oil	80 ml

* mix equal proportions of olives of different sizes, colour and variety. Use naturally processed green olives (*Manzanilla*, *Picholine*), turning colour olives (*Verdale*, *Jumbo Kalamata*) and naturally black-ripe olives (*Kalamata*, *Leccino*). Initially the olives have subtle aromatic flavours, followed by the hot chilli taste.

Cypriot-style marinated green cracked olives

Processed green cracked olives	approximately 1 kg
Crushed dry coriander seeds	10 g
Chopped dry oregano	10 g
Chopped garlic	20 g
Lemon juice	to taste
Extra virgin olive oil	80 ml

Greek-style marinated green cracked olives

Processed green and black olives	approximately 1 kg
Crushed dry rosemary	10 g
Whole dried hot chillies	4
Chopped garlic	20 g
Lemon slices	4 quarters
Extra virgin olive oil	100 ml

Italian-style marinated black shrivelled olives

Toasted Italian olives (or dried olives)	approximately 1 kg
Chopped garlic	20 g
Cracked dried fennel seeds	5 g
Extra virgin olive oil*	80 ml

* some recipes use sunflower oil

Moroccan green olives

Processed unpitted green olives	approximately 1 kg
Preserved lemon peel strips	20 g
Crushed paprika	5 g
Chopped garlic	20 g
Roasted whole cumin seeds	5 g
Cracked red pepper	5 g
Roasted whole coriander seeds	5 g
Roasted whole fennel seeds	5 g
Extra virgin olive oil	100 ml

Moroccan black olives

Processed destoned black olives	approximately 1 kg
Preserved lemon slices	2–3
Bay leaves	4
Vinegar	40 ml
Whole dried cloves	5 g
Chopped cinnamon quills	10 g
Extra virgin olive oil	80 ml

Neapolitan black olives

Processed black olives	approximately 1 kg
Lemon juice	40 ml
Chopped marjoram	5 g
Chopped oregano	5 g
Extra virgin olive oil	80 ml

Niçoise olives (fennel and orange scented olives)

Processed small black olives*	approximately 1 kg
Chopped orange rind	10 g
Dried fennel flower or seed	10 g
Chopped garlic	20 g
Extra virgin olive oil	80 ml

* *Picholine*, *Frantoio*, *Leccino* or *Koroneiki*.

Oriental-style olives

Processed green olives*	approximately 1 kg
Quarter slices of orange	4 pieces
Quarter slices of lime	4 pieces
Chopped lemon grass	5 g
Chopped ginger	5 g
Cracked coriander seeds	5 g
Chopped chilli	5 g
Chopped garlic	20 g
Extra virgin olive oil	80 ml

* olives processed by spontaneous fermentation in brine. For a sweeter taste, sugar or honey can be added.

Tunisian-style marinated black olives

Processed black olives	approximately 1 kg
Harissa*	10–15 g
Extra virgin olive oil	100 ml

* harissa is a spice mixture containing red chillies, dry roasted cumin and coriander seeds, chopped garlic, salt and olive oil. Ingredients are placed in a food processor and blended into a paste. It is also available commercially as a powder. Similar flavours can be achieved by using the individual herbs and spices.

Antipasto

Antipasto, popular with Italians, are foodstuffs eaten as openers prior to having an entrée or the main meal. They consist of vegetables, olives, meats and fish. A vegetarian antipasto combination includes olives, cheese and the pickled, dried or salted vegetables listed below. The proportions of each will depend on consumer preferences.

Mix equal proportions from the following selection:

- naturally processed *Kalamata* olives (drained);
- sun-dried tomatoes;
- fetta cheese;
- pickled artichoke;
- pickled caperberries; and
- crisp pickled vegetables (carrots, celery and cauliflower).

Add extra virgin olive oil to taste.

Oil cured olives

To process dried olives, such as *Leccino* olives, soak in extra virgin olive oil (or sunflower oil) for several months.

For home use, pack black-ripe olives, without salt, in extra virgin olive oil then place them in a freezer for several months. The number of olives required is then removed, allowed to thaw and consumed immediately. The thawed olives are wrinkled in appearance. Salt, herbs and spices can be sprinkled over the olives to give additional flavours.

Pitting and stuffing table olives

Pitting and stuffing is a traditional way of presenting olives and is very popular with consumers. Green olives processed by the Spanish method (usually *Manzanilla* and *Sevillana*) and packed in glass jars are often sold in the destoned form or stuffed with pimento, sun-dried tomato, anchovy, nuts or cheeses. Pitted and stuffed olives are also placed in marinades of herbs and spices and sold loose as gourmet items.

Note: When destoned table olives are stuffed by hand, this should be undertaken under strict sanitary conditions (see Chapter 4). All equipment and surfaces should be cleaned and sanitised. Surfaces can be tested for microbial contaminants by taking regular swabs. Some quick tests have been developed for some microbes that can be done in-house; otherwise swabs have to be sent to an appropriate laboratory for testing.

Large 'Queens' rather than smaller olives are selected for destoning. Popular varieties for this purpose are green-ripe *Sevillana*, *Manzanilla* and *Chalchidikis*. Destoning and stuffing can be undertaken manually or with an automatic destoning/stuffing machine. Because of the high capital cost of equipment, boutique and small-scale table olive processors still use manual methods. Some table olive processors purchase imported destoned table olives from wholesalers, then stuff these by hand.

Pitted olives, for example black *Manzanilla* and *Kalamata*, are used in preparing cold and cooked foods including pizzas. Destoned and stuffed olives are popular at functions and parties, as there are no stones to dispose of. Naturally processed black olives, such as *Kalamata*, are too soft to maintain their shape during pitting and are less suited to eat as appetisers.

Common stuffing materials include pimento, peppers, jalapas, chilli, anchovy, cheese (various), sun-dried tomatoes and almonds. New fillings, such as dried apricot and pickled vegetables, are being developed. The dimensions of stuffing material have to match the cavity created by the pitting machine. If too narrow the stuffing falls out, whereas if it is too wide, the olive can bulge and crack. When pitted and stuffed olives are mass produced, fillings are prepared so that they can be fed easily into the olive by machine. In the case of pimento, the peppers are ground into a paste, mixed with guar gum and sodium alginate and allowed to solidify into a form that can be used in an automatic stuffing machine. Anchovy fillings are prepared in a similar way.

Hand stuffed olives are considered a superior product, as they have fresher tastes and aromas than those that are mass-produced. All operations should be undertaken under hygienic conditions and disposable gloves worn by operators to prevent physical and microbiological contamination of the olives.

Where fresh fillings are used, for example fetta cheese, anchovies, vegetables, herbs and spices, the final products should be refrigerated or pasteurised, otherwise their shelf-life is short and the risk of contamination or spoilage increases.

Stuffed marinated olives. Use large green olives, such as *Sevillana*, *Manzanilla* or *Hardy's Mammoth*, and destone with a hand or commercial pitter. Insert stuffing into the cavity, for example fetta cheese, pieces of pickled paprika, blanched almonds, tuna or anchovy. To serve, add olive oil and chopped oregano (or mixed herbs).

Step-by-step method for stuffing table olives

The olives are pitted then filled with pimento, anchovies, almonds, cheese, onions, capers or other desired filling.

(a) Process olives.
(b) Destone olives or buy destoned processed olives.
(c) Insert stuffing.
(d) Pack olives in jars with packing brine/marinade (see Table 5.8).
(e) Pasteurise to prevent secondary fermentation.
(f) Send representative samples of olives to a microbiology laboratory for testing.
(g) Label packed processed olives in accordance with food standard requirements.
(h) Implement a safety recall system for tracking faulty, contaminated or incorrectly labelled olives.

Note: Stuffed olives containing seafood, cheeses or nuts may cause allergic or other food related reactions in susceptible consumers, so containers should be labelled with appropriate warnings.

Olive pastes

Olive pastes originated in ancient times. They were probably made from whole olives or the remaining mash after olive oil production. Olive pastes are very popular with consumers, particularly in Italy and France, and are used to spread on dry biscuits or bread as appetisers or as condiments for pasta, fish or meat dishes. They can be made from most olive varieties, for example *Manzanilla*, *Kalamata* or *Leccino*. Pastes are prepared from processed green-ripe (green paste) to fully black-ripe olives (black paste). Tapenade is a French olive paste that generally contains salted anchovies and capers.

The organoleptic characteristics of olive pastes and tapenades depend on the quality of the processed olives used. Olives processed by spontaneous fermentation, such as *Kalamata*, Greek-style black and Sicilian-style green olives, will have a more distinct flavour than lye treated olives, for example Spanish-style green and Californian/Spanish-style black olives. Poorly processed olives with 'off' flavours should not be used, otherwise the paste will be tainted.

Destoned processed olives should be washed under running potable water then dried thoroughly to keep the amount of water in the paste as low as possible to aid preservation.

Olives are crushed into a paste in a food processor or similar device. For medium to large-scale manufacture of olive pastes, specialised equipment is used. The olives are fed via a hopper into a perforated stainless steel cylinder with small holes (2–3 mm). The olives are carried along the length of the cylinder by a screw that forces them against the walls. The olive flesh passes through the holes in the cylinder, while skin and stones are expelled at the end of the cylinder. The paste is allowed to stand so that vegetable water can drain, after which extra virgin olive oil is added (5–10% w/v).

Aromatics such as herbs, spices and essential oils (thyme, rosemary and lemon) can be added to the olive paste to enhance flavour.

Because of their high salt content, olive pastes are fairly stable, especially when kept in a cool place and the surface is covered with a layer of olive oil. For commercial purposes, olive paste preparations should be pasteurised with or without a preservative, such as potassium sorbate.

Olive vegetable paste. Olive vegetable pastes can be prepared from olives and various vegetables. For immediate consumption, fresh herbs, spices and other vegetables can be used; otherwise they should be dried or processed. Where fresh vegetables are used, more vinegar or lemon juice may be added to enhance the flavour of the paste. Vegetables should be pickled in salt/vinegar before incorporating into the paste. For commercial purposes the paste should be pasteurised.

The recipe for green olive vegetable paste that follows is an example of the idea.

Green olive vegetable paste

Destoned processed green olives	700 g
Celery	100 g
Cauliflower	100 g
Garlic (equivalent to 15 fresh cloves)	6 g
Carrots	100 g
Oregano	5–10 g
Flat leaf parsley	10 g
Red wine vinegar	10 ml
Balsamic vinegar	10 ml
Extra virgin olive oil	GMP*
Cracked pepper	to taste

* sufficient olive oil is added to give the desired consistency. This recipe makes approximately 1 kg of paste.

Two recipes for preparing aromatised black olive paste follow.

Black olive paste with oregano	
Destoned processed black olives	800 g
Garlic	10 g
Chopped oregano	20 g
Lemon juice	60 ml
Extra virgin olive oil	GMP*

* sufficient olive oil is added to give the desired consistency. This recipe makes approximately 1 kg of paste.

Black olive paste with fennel and mint	
Destoned processed green olives	800 g
Chopped fennel	20 g
Roasted cracked fennel seed	20 g
Chopped mint	10 g
Whole hot chilli	2
Orange or lemon juice	30 ml
Red wine vinegar	40 ml
Extra virgin olive oil	GMP*

* sufficient olive oil is added to give the desired consistency. This recipe makes approximately 1 kg of paste.

Typically, olive products have been mainly consumed by those living around the Mediterranean and in Middle Eastern countries. Olives are now also popular in Asian and south Pacific countries, which has led to innovation and the development of new products to meet the demands of different palates. An indicative recipe for one such product, Sweet Kalamata Olive Paste, is given below. This product needs to be pasteurised.

Sweet Kalamata olive paste	
Destoned processed *Kalamata* olives (drained)	610 g
Sugar	390 g
Wine vinegar or lemon juice to taste	Approx. 6 ml

Tapenade

Tapenade is an olive paste popular around the Mediterranean region, especially in France, and now internationally. It is used as spreads and dips. The basis of tapenade is the ground flesh of processed green, turning colour or black olives, to which capers, anchovies and other foods and spices are added. The addition of capers differentiates tapenades from other olive-based pastes. Various tapenades are presented in Plate 29.

Traditional French tapenade from Provence contains the flesh of Olives of Nice, 2% capers, thyme, savory and a small quantity of extra virgin olive oil. Olives of Nice are processed in brine for 6–12 months. The original recipe can be embellished with additional herbs and spices as well as other foodstuffs.

In addition to destoned, processed, black, turning colour or green olives, preserved capers and olive oil (preferably extra virgin olive oil) are added. The following ingredients are often included: garlic, salted anchovies (or tuna), lemon juice, cracked pepper, aromatics (herbs and spices) and foodstuffs (pine nuts, chilli, sun-dried tomatoes).

Almost any processed olive can be used to make tapenade, but it is very important that the tapenade is not too salty. Pitted processed olives should be drained and dried over

24–48 hours before crushing into a paste. Alternatively, commercially available olive paste can be used instead of pitted olives.

Salted anchovies in oil should be used, or alternatively the anchovies can be replaced wholly or partly with tuna. For commercial production, dried herbs and spices should be used. For home preparation or for immediate use, fresh herbs, spices and garlic can be used as long as the tapenade is stored under refrigeration. Cracked pepper is added to taste. Depending on the oil content of the processed olives, the amount of extra virgin olive oil required is gauged so that the desired final consistency is achieved (not too runny and not too dry).

Boutique level producers can make tapenade using a standard food processor whereas small- and large-scale producers will need to use commercial grade equipment.

Note: As there is substantial handling of ingredients during the preparation of tapenades, all aspects of hygiene and health and safety requirements must be observed to prevent contamination with potential food poisoning organisms.

Tapenade	
Destoned processed black olives (drained)*	900 g
Capers (drained)	180 g
Garlic (equivalent to 15 fresh cloves)	6 grams
Extra virgin olive oil	GMP**
Cracked pepper	to taste

* destoned green or turning colour olives can be used; **, sufficient olive oil is added to give the desired consistency. Also, anchovy fillets can be added. This recipe makes approximately 1 kg of tapenade.

Note: Tapenades containing seafood or nuts may cause allergic reactions in susceptible consumers, so containers should be labelled with appropriate warnings.

Step-by-step method for making tapenade

(a) Destone processed olives or use commercial destoned olives.
(b) Drain destoned olives if required.
(c) Rinse olives with potable water.
(d) Check that there are no stones.
(e) Place the olives, anchovies (if included), capers and garlic into the food processor.
(f) Apply short sharp impulses to the mixture to give a moderately coarse paste.
(g) Add sufficient olive oil and mix in to give a slightly granular firm paste (not runny).
(h) Pack into containers.
(i) Pasteurise.
(j) Send representative samples of olives to a microbiology laboratory for testing.
(k) Label packed processed olives in accordance with Food Standards.
(l) Implement a safety recall system for faulty packed tapenade.

Note: Additions can be made to the basic tapenade according to taste or commercial requirements.

The following tapenade is a variant of the basic recipe above. For immediate consumption, fresh herbs, spices and other additives can be used, otherwise they should be dried or processed.

Tapenade-style salsa	
Destoned processed black *Kalamata* olives	450 g
Destoned green or turning colour olives	450 g
Capers	180 g
Garlic (equivalent to 15 fresh cloves)	6 g
Sweet red peppers	50 g
Sun-dried tomatoes	100 g
Flat leaf parsley	10 g
Red wine vinegar	10 ml
Balsamic vinegar	10 ml
Cracked pepper	to taste
Extra virgin olive oil	GMP*

* sufficient olive oil is added to give the desired consistency. This product should have a pourable consistency. This recipe makes approximately 1 kg of salsa.

Packaging olive pastes and tapenades. Olive pastes and tapenades can be packed in 200 g to 1 kg glass jars.

(a) Undertake all steps hygienically.
(b) Wash and dry jars.
(c) Pack the paste into jars.
(d) Tap the jars to settle the paste and to eliminate air pockets.
(e) Leave a space of up to one centimetre from the top of the paste to the rim of the jar.
(f) Firmly close the lid.

Preservation of olive pastes and tapenades. When freshly prepared under hygienic conditions, olive pastes and tapenades can be stored under refrigeration for at least two weeks and up to three months in unopened containers. It is preferable, however, to reduce the risk of spoilage or food poisoning by pasteurising olive pastes or tapenades. Pasteurisation involves heating the pastes to a temperature that will kill spoilage and food poisoning microorganisms without altering their organoleptic properties.

The equipment required is a stainless steel tank fitted with a heater and thermostat. The tank is filled with water and jars placed individually by hand or by batches in stainless steel wire or perforated baskets.

The following is an indicative pasteurising procedure and should only be used as a guide. Conditions will vary according to the size of the containers.

(a) Raise the temperature of the water in the tank to 75°C.
(b) Immerse the packed jars of paste in the water and allow the contents to equilibrate (this can take up to 20 minutes).
(c) Over the next 25 minutes the water temperature is increased to 80°C (higher temperatures denature the paste).
(d) The heater is then turned off and the jars allowed to cool to 60°C before removal.
(e) Sample jars should be sent to a microbiology laboratory for safety clearance.

Note: Using this procedure, the shelf-life of the olive pastes and tapenades is at least 18 months. Other procedures involve bulk pasteurisation of the olive paste or tapenade, then packing aseptically while hot into washed and dried containers. Before this method is used, a food consultant should be engaged and the appropriate research and development undertaken.

Final table olive products

Table 5.10 gives a summary of the methods available for processing table olives.

Table 5.10. Summary of common table olive processing methods

Procedures shown in parentheses are optional. [1] *Frantoio*, *Taggiasca* – Ligurian-style.
[2] Sicilian-style olives can also be prepared with dry salt.

<table>
<tr><th>Sevillian-style</th><th>Spontaneous fermentation Greek-style[1]</th><th>Kalamata-style</th><th>Sicilian-style[2]</th><th>Californian/ Spanish-style black</th><th>Salt-dried</th><th>Heat-dried</th></tr>
<tr><td>Treated</td><td colspan="3">Untreated</td><td>Treated</td><td colspan="2">Untreated
(Treated)</td></tr>
<tr><td>Green-ripe</td><td>Green-ripe
Turning colour
Nearly black-ripe</td><td>Nearly black-ripe</td><td>Green-ripe</td><td>Green-ripe to turning colour</td><td>Green-ripe
Turning colour
Nearly black-ripe</td><td>Nearly black-ripe</td></tr>
<tr><td colspan="3">Hand harvest</td><td colspan="4">Hand harvest (facilitated manual harvest)</td></tr>
<tr><td colspan="7">Spray wash – optional for lye treated olives</td></tr>
<tr><td colspan="7">Sort and size grade</td></tr>
<tr><td>Whole</td><td>Whole or slit</td><td>Slit</td><td>Bruised or stoned</td><td>Whole
Can be fresh or prestored in salt brine</td><td>Whole, slit or pricked</td><td>Whole, slit or pricked</td></tr>
<tr><td>Lye solution 2%</td><td colspan="3" rowspan="3">Brine 10% salt
(Presoak in water for 10–14 days with water curing method)</td><td>Lye solution
Several strengths</td><td>(Treat in weak lye)</td><td>Blanch
(Treat in weak lye)</td></tr>
<tr><td>Washed</td><td>Oxidise at alkaline pH</td><td>(Wash)</td><td>(Wash)</td></tr>
<tr><td>Place in salt brine 10% salt</td><td>Wash</td><td rowspan="4">Add 10–20% dry coarse salt</td><td>Add dry coarse salt or soak in salt brine</td></tr>
<tr><td colspan="4" rowspan="2">Anaerobic fermentation
(Water cured: weak fermentation)</td><td>Add ferrous gluconate</td><td rowspan="3">Heat dry</td></tr>
<tr><td>Bulk pasteurise</td></tr>
<tr><td colspan="5">(Size grade)</td></tr>
<tr><td colspan="2">Pack in fermentation brine or fresh packing brine</td><td>Pack in fermentation brine or fresh packing brine with vinegar and olive oil</td><td>Pack in fermentation brine or fresh packing brine</td><td>Pack in weak salt brine</td><td colspan="2">Pack in brine or without</td></tr>
<tr><td colspan="4">(Pasteurise)</td><td>Sterilise</td><td colspan="2">(Pasteurise)</td></tr>
</table>

Processed table olives should retain some level of bitterness and fruitiness. The final salt and pH levels of packed olives depend on the style, variety and ripeness of the fruit as long as safety requirements are met. In all cases, processed table olives should be determined as microbiologically safe by an accredited laboratory before being offered for sale. Procedures should have checkpoints for calculations and quantities used, and monitoring procedures for pH and salt levels. Once packed, representative samples of the olives must be taken and the following parameters assessed: brine pH and free acidity, brine salt levels, brine and fruit microbiology, and organoleptic characteristics.

The final product may be preserved by one or more of the following procedures: brining, pH control, pasteurisation, sterilisation, or drying to prevent microbiological spoilage. Refrigeration is an option for short-term storage and preservatives can be used.