Chapter 1
Vinegars of the World

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1.1 General Overview

The history of vinegar production, which dates back to around 2000 BC, has taught us a great deal about microbial biotransformation. However, vinegar has been always considered a 'poor relation' among fermented food products: it is not considered to be a 'food', it does not have great nutritional value, and it is made by the transformation of richer and more nutritive fermented foods. Vinegar is used as a flavouring agent, as a preservative and, in some countries, also as a healthy drink. It can be made from almost any fermentable carbohydrate source by a two-step fermentation process involving yeasts as the first agent, followed by acetic acid bacteria (AAB): the most common raw materials are apples, pears, grapes, honey, syrups, cereals, hydrolysed starches, beer and wine.

Since vinegar is generally an inexpensive product, its production requires low-cost raw materials, such as substandard fruit, seasonal agricultural surpluses, by-products from food processing, and fruit waste. However, there are also some very expensive vinegars, produced from regional foods according to well-established methods, although these are the exception to the rule: examples include traditional balsamic vinegar from Modena in Italy, sherry vinegar from Spain, and oxos from Greece. There are also spirit vinegars obtained directly by acetic oxidation of ethanol derived from the distillation of fermented mashes or petrochemical ethanol. In addition, pyroligneous liquor (or 'wood vinegar'), collected during wood carbonization, is used as an agricultural feedstuff, an animal health product, an ingredient in cosmetics, and a traditional medicine in Japan and East Asia (Mu et al., 2003; 2006). In this book, these distilled solutions have not been considered as vinegars because no fermentative process occurs in their production. Another separate group consists of flavoured vinegars: herbal or fruit vinegars. Herbal vinegars are wine vinegars or white distilled vinegars flavoured with garlic, basil, tarragon, cinnamon, cloves, nutmeg or other herbs. Fruit-flavoured vinegars are wine and white vinegars sweetened with fruit or fruit juice to produce a characteristic sweet-sour taste. In these cases the name 'X vinegar' does not indicate the raw materials

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Figure 1.1 Fermentation of herbal flavoured vinegar in glass demijohns

used in vinegar fermentation but the ingredients added to obtain specific taste and flavour characteristics (Figure 1.1).

1.2 Vinegars: Raw Materials and Geographical Distribution

According to the international definition of vinegar, in this book we consider only vinegars derived from a two-stage fermentation process of agriculturally produced raw materials. A list of vinegars is presented in Table 1.1, but cannot be considered exhaustive, since many different varieties of vinegar are produced all over the world, and some of them are unknown outside their area of origin. Most vinegars have a plant origin, with two exceptions: those produced from whey or honey. Whey, which is the milk serum residual of the cheese-making process, is rich in lactose and/or its corresponding hydrolysed sugars, galactose and glucose, depending on the cheese-making technology. Furthermore, sour whey is heavily contaminated with lactic acid bacteria (LAB) and needs to be pasteurized before alcoholic and acetous fermentation. Honey is very rich in sugars (70-80% w/w), mostly sucrose, fructose and glucose, the proportions of which are influenced by the botanical origin of the nectar collected by the bees. Honey is always diluted before alcoholic fermentation occurs; honey wine contains up to 17% (v/v) ethanol (Steinkraus, 1996). This alcoholic beverage is well known around the world by different names, such as mead, ambrosia, metheglin, hydromel, aguamiel, medovukha and ogol, and is also used to produce vinegar.

Table 1.1 Overview of vinegars from around the world: raw materials, intermediate product, vinegar name and geographical distribution

Category	Raw material	Intermediate	Vinegar name	Geographical distribution
Vegetable[a]	Rice	Moromi	Komesu, kurosu (Japanese)	East and Southeast Asia
			Heicu (Chinese)	
	Bamboo sap	Fermented bamboo sap	Bamboo vinegar[b]	Japan, Korea
	Malt	Beer	Malt vinegar	Northern Europe, USA
	Palm sap	Palm wine (toddy, tari, tuack, tuba)	Palm vinegar, toddy vinegar	Southeast Asia, Africa
	Barley	Beer	Beer vinegar	Germany, Austria, Netherlands
	Millet	Koji	Black vinegar	China, East Asia
	Wheat	Koji	Black vinegar	China, East Asia
	Sorghum	Koji	Black vinegar	China, East Asia
	Tea and sugar	Kombucha	Kombucha vinegar	Russia, Asia (China, Japan, Indonesia)
	Onion	Onion alcohol	Onion vinegar	East and Southeast Asia
	Tomato	–	Tomato vinegar	Japan, East Asia
	Sugarcane	Fermented sugar cane juice	Cane vinegar	France, USA
		Basi	Sukang iloko	Philippines
			Kibizu	Japan
Fruit	Apple	Cider	Cider vinegar	USA, Canada
	Grape	Raisin	Raisin (grape) vinegar	Turkey and Middle East
		Red or white wine	Wine vinegar	Widespread
		Sherry wine	Sherry (jerez) vinegar	Spain
		Cooked must	Balsamic vinegar	Italy
	Coconut	Fermented coconut water	Coconut water vinegar	Philippines, Sri Lanka
	Date	Fermented date juice	Date vinegar	Middle East
	Mango	Fermented mango juice	Mango vinegar	East and Southeast Asia
	Red date	Fermented jujube juice	Jujube vinegar	China
	Raspberry	Fermented raspberry juice	Raspberry vinegar	East and Southeast Asia
	Blackcurrant	Fermented blackcurrant juice	Blackcurrant vinegar	East and Southeast Asia
	Blackberry	Fermented blackberry juice	Blackberry vinegar	East and Southeast Asia
	Mulberry	Fermented mulberry juice	Mulberry vinegar	East and Southeast Asia
	Plum	Umeboshi[c] fermented plum juice	Ume-su	Japan
	Cranberry	Fermented cranberry juice	Cranberry vinegar	East and Southeast Asia
	Kaki	Fermented persimmon juice	Persimmon vinegar	South Korea
			Kakisu	Japan
Animal	Whey	Fermented whey	Whey vinegar	Europe
	Honey	Diluted honey wine, tej	Honey vinegar	Europe, America, Africa

[a] Vegetable is not a botanical term and is used to refer to an edible plant part; some botanical fruits, such as tomatoes, are also generally considered to be vegetables.
[b] Obtained by bamboo sap fermentation.
[c] Umeboshi are pickled *ume* fruits. *Ume* is a species of fruit-bearing tree of the genus *Prunus*, which is often called a plum but is actually more closely related to the apricot.

Table 1.2 Botanical species and edible parts used in vinegar production

Common name	Botanical name	Edible part	Main carbon sources[a]
Apple	*Malus domestica*	Fruits (pome)	Fructose, sucrose, glucose
Apricot	*Prunus armeniaca*	Fruits (drupe)	Sucrose, glucose, fructose
Bamboo	Species and genera of the family Poaceae, subfamily Bambusoideae	Bamboo sap	Sucrose
Banana	Species of the genus *Musa*	Fruits (false berry)	Sucrose, glucose, fructose
Barley	*Hordeum vulgare*	Seeds (caryopsis)	Starch
Carambola	*Averrhoa carambola*	Fruits	Fructose, glucose
Cashew	*Anacardium occidentale*	Fruits	Sucrose, inverted sugars
Cocoa	*Theobroma cacao*	Bean mucilage (sweatings)	Glucose
Coconut	*Cocos nucifera* and other species of the family Arecaceae	Coconut water (fibrous drupe)	Glucose, fructose
Date	*Phoenix dactylifera*	Fruits (drupe)	Sucrose
Fig	*Ficus carica*	False fruit (syconium)	Glucose, fructose
Grape	*Vitis vinifera* and other species of the genus	Fruits (berry)	Glucose, fructose
Oil palm tree	*Elaeis guineensis*	Sap (xylem fluid)	Sucrose
Onion	*Allium cepa*	Bulbs	Fructose, glucose, sucrose
Panicum	*Panicum miliaceum* and other species of the subfamily Panicoideae	Seeds	Starch
Pear	*Pyrus communis* and other species of the genus	Fruits (pome)	Fructose sucrose, glucose
Persimmon	*Diospyros kaki* and other species of the genus	Fruits	Fructose, glucose, sucrose
Pineapple	*Ananas comosus*	False fruit (syncarpel)	Sucrose, glucose, fructose
Plum	*Prunus domestica*	Fruits (drupe)	Sucrose, fructose, glucose
Potato	*Solanum tuberosum*	Tuber	Starch
Raphia palm	*Raphia hookeri* and *Raphia vinifera*	Sap (xylem fluid)	Sucrose
Ribes (Blackcurrant, Redcurrant, Gooseberry)	*Ribes* spp.	Fruits (berry)	Fructose, glucose
Rice	*Oryza sativa* and *Oryza glaberrima*	Seeds (caryopsis)	Starch
Sorghum	*Sorghum bicolor* and other species	Seeds (caryopsis)	Starch
Sugarbeet	*Beta vulgaris*	Roots	Sucrose
Sugarcane	Species of the genus *Saccharum*	Stalks	Sucrose
Wheat	*Triticum aestivum* and other species	Seeds (caryopsis)	Starch

[a] Listed in order, from the largest to the smallest amount.

1.2.1 Botanical Species

Many botanical species can be used for vinegar production since they only need to have two main basic attributes; first to be safe for human and animal consumption, and second to be a direct or indirect source of fermentable sugars.

A non-exhaustive list of the main botanical species involved and their edible parts used is shown in Table 1.2. General classifications and groupings can be made on the basis of the chemical composition of the edible parts and their ease of fermentation:

- *Acid and easily fermentable*: pH <3.5, with glucose, fructose and sucrose as the main constituents, e.g. berries, grapes, apples, plums.
- *Moderate acid and easily fermentable*: pH 3.5-4.5, e.g. figs, dates.
- *Low acid and easily fermentable*: pH >4.5, e.g. palm sap.
- *Non-fermentable*: hydrolysis required before fermentation, e.g. seeds.

The chemical composition of the raw material exerts a strong selective pressure on microorganisms and determines the dominant species involved in acetification. Specific examples are given for the vinegars described in other chapters of this book.

The critical steps in vinegar production are the preparation and the fermentation of raw materials. Preparation of raw materials includes all the operations required to produce fermentable sugary and protein solutions, such as slicing and/or crushing to obtain fruit juice, enzymatic digestion of starch in cereals, as well as cooking and steaming in some cases. In general, fruits require less preparation than seeds. On the other hand, seeds are more easily stored and preserved, and consequently their use is independent of the harvest. Fruits are highly perishable, rich in water, and need to be processed very quickly; in some conditions, such as at high temperatures or in the case of damaged fruits, this will be immediately after harvest. These differences make seeds easier to transport and process in large factories, whereas fruits can be made into vinegar in small factories, with less technology, close to the production area.

1.2.2 Economic Importance

From an economic point of view, vinegar production is a small industry in the overall economy of industrialized countries (Adams, 1998). Global shares of the different kinds of vinegar in 2005 were balsamic vinegar (34%), red wine vinegar (17%), cider vinegar (7%), rice vinegar (4%), white vinegar (2%) and other vinegars (36%), as shown in Figure 1.2 (Vinegar Institute, 2006).

In the US market, white distilled vinegar has 68% of the unit share, cider vinegar accounts for 20%, and specialty vinegars account for 12%. In the specialty vinegar category, 39% comprises red wine vinegar, 30% balsamic, 13% all other wine, 12% rice vinegar, and 6% all other specialties (Vinegar Institute, 2006).

In Europe, the vinegar market was around 4.9×10^8 L in 2001 and 5×10^8 L in 2002, with business worth approximately € 268.6 million and € 234.3 million,

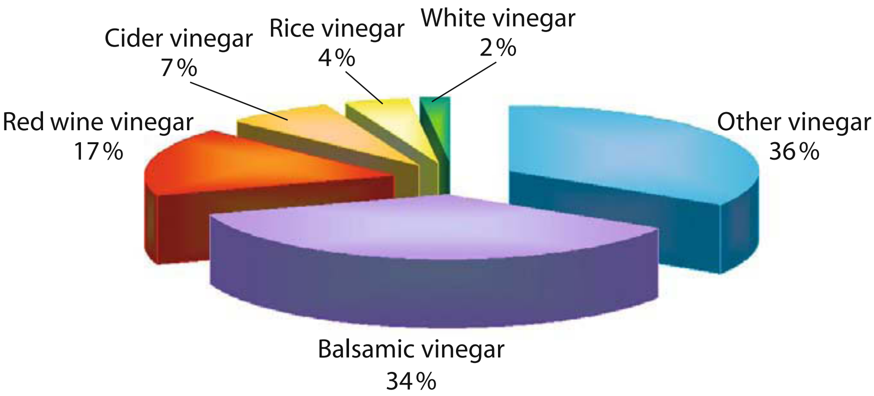

Figure 1.2 Global shares of the different vinegar types in 2005 (from the Vinegar Institute, 2006, available at http://www.versatilevinegar.org/markettrends.html#2)

respectively. European vinegar shares are shown in Figure 1.3. The main vinegar-producing countries are France, Italy and Spain.

In China, white fruit and brewed vinegars are popular. Every year, 8.0×10^9 kg of distilled spirit vinegar and 2.0×10^9 kg of brewed vinegar are produced (Wei, 2001). There are at least 14 types of traditional brewed vinegars, among which five types are the most widespread: Zhenjiang aromatic vinegar, Sichuan bran vinegar, Shanghai rice vinegar, Jiangzhe rose vinegar and Fujian red rice vinegar (Liu et al., 2004).

In developing countries, where food preservation and technology options are limited, vinegar is an important agent for preserving fresh fruit and vegetables from rapid deterioration. Especially in the tropics, the environmental conditions accelerate food spoilage. Developing and improving small-scale vinegar production, and food fermentation technologies in general, is one of the goals of the FAO (Anonymous, 1995; FAO, 1998).

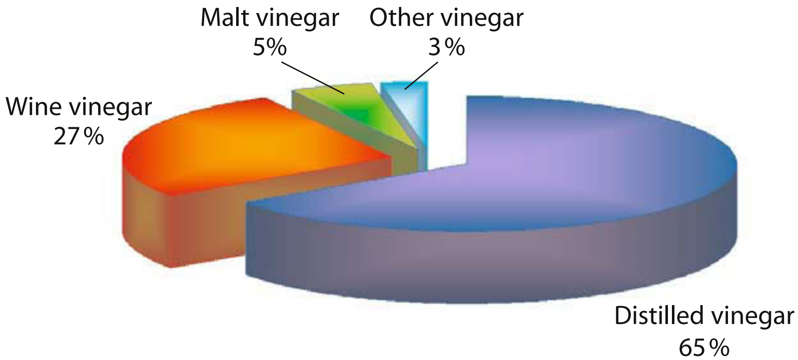

Figure 1.3 European vinegar share in 2002 (from Comité Permanent International du Vinaigre, available at http://vinaigre.fr)

1.3 Vinegar Processing: the Role of Fermentation

As for any other food, the global view of vinegar processing from producer to market can be summarized as shown in Figure 1.4. In general, basic safe food operating principles, such as good agricultural practices (GAP), good manufacturing practices (GMP) and good hygiene practices (GHP), should be in place in all the steps, but in particular before starting fermentation, when environmental factors may permit the growth of dangerous microorganisms such as aflatoxin-producing moulds and harmful bacteria, especially since these steps are often carried out at room temperature. After acetification, there is no real danger of spoilage, since acetic acid has strong antibacterial activity at low pH. Vinegar also requires pack-

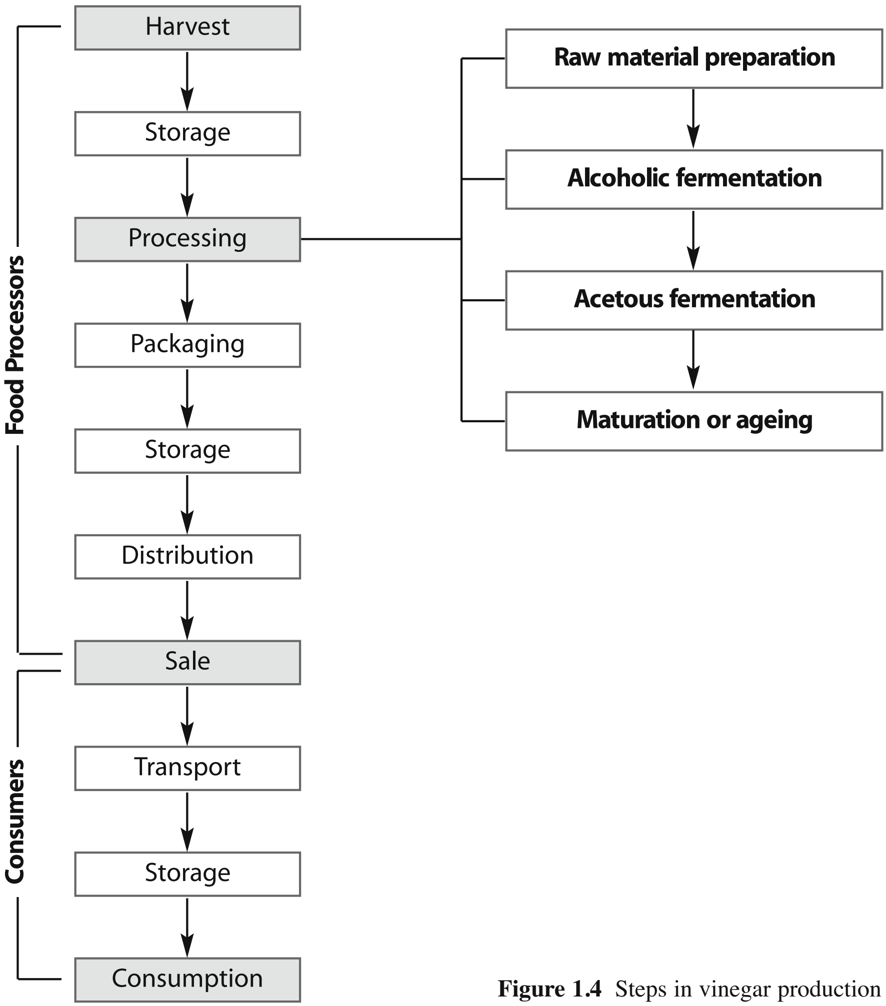

Figure 1.4 Steps in vinegar production

Table 1.3 The main microorganisms involved in vinegar production

Vinegars	Moulds	Yeasts	LAB	AAB	References
Kombucha vinegar	–	*Z. kombuchaensis*, *Z. rouxii*, *Candida* spp., *Sc. pombe*, *S'codes ludwigii*, *P. membranaefaciens*, *B. bruxellensis*	–	*Ga. xylinum*, *Ga. intermedius*, *Ga. kombuchae*	Hesseltine, 1965; Liu et al.,1996; Boesch et al., 1998; Teoh et al., 2004; Dutta, Gachhui, 2007
Beer/malt vinegar	–	*Saccharomyces sensu stricto*	*Lb. brevis*, *Lb. buchneri*, *P. damnosus*	*A. cerevisiae*, *Ga. sacchari*	White, 1970; Greenshields, 1975a,b; Fleet, 1998; Cleenwerck et al., 2002
Coconut water vinegar	nd	*Saccharomyces* spp.	nd	*A. aceti*	Steinkraus, 1996
Nata de coco		*Saccharomyces* spp.	nd	*Ga. xylinus*	Steinkraus, 1996; Iguchi et al., 2004
Fruit vinegars	–	*S. cerevisiae*, *Candida* spp.	nd	*A. aceti*, *A. pasteurianus*	Maldonado et al., 1975; Uchimura et al., 1991; Suenaga et al., 1993
Honey vinegar	–	*S. cerevisiae*, *Zygosaccharomyces* spp., *Torulopsis* spp	*Lactobacillus*, *Streptococcus*, *Leuconostoc* and *Pediococcus* spp.	*Acetobacter* spp., *Gluconacetobacter* spp.	Adams, Nielsen, 1963; Snowdon, Cliver, 1996; Ilha et al., 2000; Bahiru et al., 2006
Palm wine vinegar	–	*S. cerevisiae*, *S. uvarum*, *C. utilis*, *C. tropicalis*, *Sc. pombe*, *K. lactis*	*Lb. plantarum*, *Lc. mesenteroides*	*Acetobacter* spp., *Zymomonas mobilis*	Okafor, 1975; Uzochukwu et al., 1999; Ezeronye, Okerentugba, 2000; Amoa-Awua et al., 2007
Rice vinegar					
Komesu	*Aspergillus oryzae*, *Aspergillus soyae*, *Rhizopus* spp.	*S. cerevisiae*	*Lb. casei* var. *rhamnosus*	*A. pasteurianus*	Hesseltine, 1983; Otsuka, 1990

(continued)

Table 1.3 (continued)

Vinegars	Moulds	Yeasts	LAB	AAB	References
Kurosu	*Aspergillus awamori*, *Aspergillus usami*, *Aspergillus oryzae*	*S. cerevisiae*	*Lb. fermentum*, *Lb. lactis*, *Lb. brevis*, *P. acidilactici*, *Lb. acetotolerans*	*A. pasteurianus*	Nanda et al., 2001; Haruta et. al., 2006
Red rice vinegar	*Monascus purpureus*	*S. cerevisiae*	nd	*Acetobacter* spp.	Liu et al., 2004
Sorghum vinegar					
African sorghum vinegar	nd	*S. cerevisiae* and other *Saccharomyces sensu stricto*	*Lc. meseteroides*, heterofermentative LAB	*Acetobacter* spp.	Steinkraus, 1996, Konlani et al., 1996; Naumova et al., 2003
Chinese sorghum vinegar	*Mucor* spp., *Aspergillus orzyae*, *Monascus* spp.	*S. cerevisiae*, *Hansenula* spp	nd	*Acetobacter* spp.	Liu et al., 2004
Traditional balsamic vinegar	–	*Z. bailii*, *S. cerevisiae*, *Z. pseudorouxii*, *C. stellata*, *Z. mellis*, *Z. bisporus*, *Z. rouxii*, *H. valbyensis*, *H. osmophila*, *C. lactis-condensi*	nd	*Ga. xylinus*, *A. pasteurianus*, *A. aceti*, *Ga. europaeus*, *Ga. hansenii*, *A. malorum*	De Vero et al., 2006; Gullo et al., 2006; Solieri et al., 2006; Solieri et al., 2007
Whey vinegar	–	*K. marxianus*	nd	*Ga. liquefaciens*, *A. pasteurianus*	Parrondo et al., 2003
Wine vinegar	–	*S. cerevisiae*	nd	*Ga. europaeus*, *Ga. oboediens*, *A. pomorum*, *Ga. intermedius*, *Ga. entanii*	Sievers et al., 1992; Sokollek et al., 1998; Boesch et al., 1998; Schüller et al., 2000

Abbreviations: nd, not determined; – not detected; A., *Acetobacter*; B., *Brettanomyces*; C., *Candida*; Ga., *Gluconacetobacter*; K., *Kluyveromyces*; Lb., *Lactobacillus*; Lc., *Leuconostoc*; P., *Pediococcus*; S., *Saccharomyces*; S'odes, *Saccharomycodes*; Sc., *Schizosacharomyces*; Z., *Zygosaccharomyces*.

aging; intermediate bulk containers and tanks should be manufactured of stainless steel, glass or plastic material resistant to corrosion. After raw material preparation, fermentation plays a key role in vinegar production. Different microbial species are involved at various stages of the fermentation process, such as LAB, yeasts, moulds and AAB, which often colonise vegetables, fruits and other raw materials used in vinegar production. From each microbial group, the main species associated with vinegars are listed in Table 1.3. The great microbial diversity reflects the variety of raw materials, sugar sources and processes, as well as the diversity of the physico-chemical characteristics (e.g. temperature, pH, water activity).

Two steps are common to all vinegars: alcoholic and acetic fermentation, due to yeasts and AAB, respectively, whilst other microorganisms, such as moulds and LAB, are involved only in specific vinegars. Among the yeasts, *Saccharomyces cerevisiae* is the most widespread species in fruit and vegetable vinegars; the lactose-fermenting yeast, *Kluyveromyces marxianus*, is the species responsible for whey fermentation; and a physical association of yeasts, LAB and AAB is involved in the fermentation of kombucha. Even though there are now ten generally recognized genera of AAB (Chapter 3), the majority of the species detected in vinegars belong to the genera *Acetobacter* and *Gluconacetobacter*. However, it is likely that several of the species and genera involved in vinegar production have not yet been described because of the difficulties in cultivating AAB. Furthermore, the taxonomy of the acetic acid bacteria is undergoing extensive revision at present, and many species and genera may soon be reclassified.

1.3.1 Spontaneous Fermentation

Fermentation can be induced either by spontaneous fermentation, by back-slopping, or by the addition of starter cultures. In spontaneous fermentation, the raw material is processed and the changed environmental conditions encourage the most appropriate indigenous microflora. The more stringent the growth conditions are, the greater becomes the selective pressure exerted on the indigenous microorganisms.

In a very acidic and sugary environment, such as some fruit juices, only yeast, LAB and AAB can grow. Spontaneous fermentation is suitable for small-scale production and only for very specific juices. However, the method is difficult to control and there is a great risk of spoilage occurring. In most spontaneous fermentations, a microbial succession takes place, and quite often LAB and yeasts dominate initially. These consume sugars and produce lactic acid and ethanol, respectively, which inhibit the growth of many bacteria species, determining prolongation of the shelf life of the goods. Moulds mainly grow aerobically and therefore their occurrence is limited to specific production steps or on crops before and after harvest. Moulds are a big safety concern, since some genera and species are aflatoxin producers. Therefore, the moulds used for starch hydrolysis of seeds should be GRAS (Generally Recognized As Safe). AAB are aerobic whole-cell biocatalysts involved in the conversion of ethanol to acetic acid. AAB are widespread on fruits and in many sugary and acid environments, and their growth is promoted by procedures that increase the availability of oxygen after yeast fermentation. Examples are submerged culture and solid state fermentations (Chapters 9 and 15).

1.3.2 Back-Slopping Fermentation

Back-slopping uses part of a previously fermented batch to inoculate a new batch. This procedure increases the initial number of desirable microorganisms and

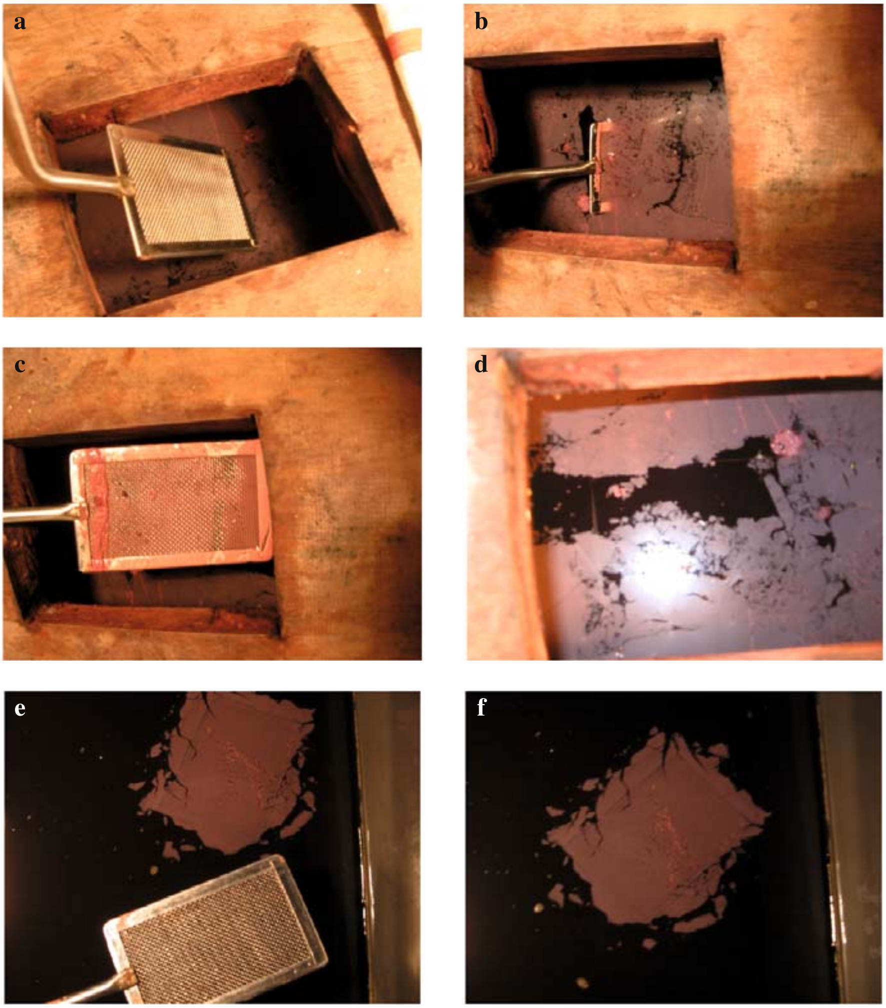

Figure 1.5 Succession of steps in back-slopping to transfer the AAB film from a vinegar culture to a new wine barrel. **a** Tool to collect AAB film **b** Tool inside the vinegar barrel **c** Tool covered with the AAB film **d** Vinegar barrel after removal of an AAB film portion **e, f** Film transferred into wine barrel to start the acetification process (from Giudici et al., 2006)

ensures a more reliable and faster process than spontaneous fermentation. Back-slopping is a primitive precursor of the starter culture method, because the best-adapted species are seeded over the indigenous population (De Vuyst, 2000). Nevertheless, the manufactured goods are still exposed to the risk of fermentation failure, since mould growth or harmful bacteria spoilage can occur.

In general, back-slopping is considered a useful practice because it improves the growth of useful yeasts, while inhibiting the growth of pathogenic microorganisms and reducing spoilage, and in addition the laborious and time-consuming starter selection process is avoided. The back-slopping practice is particularly useful for inoculating AAB cultures, as they are very fastidious microorganisms that need special attention in order to produce true starter cultures. In the semi-continuous submerged acetification process, at least one-third of the vinegar is left in the fermenter to inoculate the new wine (Chapter 6), whereas in surface-layer fermentation a physical transplant of the AAB film can be easily done in order to preserve the integrity of the cell layer, as shown in Figure 1.5. This procedure assures a better implantation of inoculum on the indigenous microbial population in a new barrel.

1.3.3 Starter Culture Fermentation

A starter culture can be defined as a microbial preparation of a large number of cells of a microorganism (in some case more than one), which is added to the raw material to produce a fermented food by accelerating and steering its fermentation process (Leroy and De Vuyst, 2004). Starter culture development is strictly related to the 'pure culture' technique, which is a practice originally elaborated by Robert Koch for bacteria (Raineri et al., 2003). By using this approach each microbial colony is made up of cells that all originate from the same single cell. This ensures that the cultures are not a mixture of different unknown individuals and they can therefore be relied upon to produce the desired biochemical reactions.

The use of starter cultures in food production is a well-accepted practice, as it increases the safety, the stability and the efficiency of the process and reduces production losses caused by uncontrolled fermentation, eliminating undesired features. In some Asian vinegars, a mixed starter culture of undefined moulds and yeasts, called *koji*, is used to saccharify and ferment rice and cereals. However, *koji* cannot be considered to be a true starter, as its exact microbial composition is often unknown. In other cases, true starter cultures of oenological *S. cerevisiae* strains, selected for winemaking, are used for producing the alcoholic bases for vinegars, such as beer, wine and cider. *S. cerevisiae* var. *sake*, selected for sake production, is mainly used in rice vinegar fermentation.

Regarding acetous fermentation, the use of starter cultures is a long way from being applied on a large scale, for two main reasons: first, the AAB are nutritionally demanding microorganisms, which are difficult to cultivate and maintain in laboratory media, or to preserve as a dried starter; and, second, vinegar is generally an inexpensive commodity and therefore its manufacture does not warrant an expensive starter culture selection.

1.4 Vinegar Definitions and Legislation

Vinegar production is regulated through an extensive set of statutes, and the definition of vinegar itself differs from country to country. FAO/WHO defines vinegar as any liquid, fit for human consumption, produced exclusively from suitable products containing starch and/or sugars by the process of double fermentation, first alcoholic and then acetous. The residual ethanol content must be less than 0.5% in wine vinegar and less than 1% in other vinegars (Joint FAO/WHO Food Standards Programme, 1998).

In the USA, the Food and Drug Administration (FDA) requires that vinegar products must possess a minimum of 4% acidity. This qualification ensures the minimum strength of vinegars sold in the retail market. There are currently no standards of identity for vinegar; however, the FDA has established ‘Compliance Policy Guides’ that the Agency follows regarding the labelling of vinegars, such as cider, wine, malt, sugar, spirit and vinegar blends (Food and Drug Administration, 2007, FDA/ORA CPG 7109.22).

European countries have regional standards for the vinegar produced or sold in the area. Unlike the USA, the EU has established thresholds for both acidity and ethanol content. ‘Vinegar of X’ is a general definition used for products having a minimum of 5% (w/v) acidity and a maximum of 0.5% (v/v) ethanol. Wine vinegar is exclusively obtained by acetous fermentation of wine and must have a minimum of 6% acidity (w/v) and a maximum of 1.5% (v/v) of ethanol (Regulation (EC) No. 1493/1999).

In China, the term ‘vinegar’ is used to indicate both fermented and artificial vinegars, according to the Chinese National Standard definitions (CNS14834, N5239) (Chinese National Standard, 2005). In the previous National Industrial Standard for vinegar, vinegar was classified in three grades, depending on its concentration of acetic acid (3.5-4.5%, 4.5-6% and >6%). More recently a new National Standard Code for Condiments was issued by the Chinese State Administration Bureau for Quality and Technology, in which vinegar definitions are introduced and vinegars are classified as either brewed or artificial (acetic acid blended with other ingredients, such as flavourings). Moreover, each major vinegar type also has its own local quality criteria and grading system.

Considering the different laws on vinegar, it is clear that acidity and residual ethanol are the two main parameters used to establish an all-encompassing vinegar classification (Table 1.4). The acetic acid and ethanol contents change on the basis of raw materials used, the microorganisms involved in the fermentation process, the technology employed, but mainly on the basis of culture and ‘vinegar lore’. Nowadays, it is a common practice in China to mix vinegar and wine to improve flavour and safety. In Europe, vinegar is considered as a flavouring or preservative and, with a few exceptions, it is generally sharp and sour. On the other hand, in Asia and Africa, vinegar is also a drink with a less sour taste. Several sweetened fruit vinegars characterized by low acidity and aromatic flavour are very popular in China and in East and Southeast Asia. In Africa, some fermented beverages can spontaneously acidify to produce alcoholic-acetous products, which are difficult to

Table 1.4 Acidity and residual ethanol content in several vinegars

Vinegar	Acidity (% w/v)	Ethanol (% v/v)
Malt vinegar	4.3-5.9	–
Cider vinegar	3.9-9.0	0.03
Wine vinegar	4.4-7.4	0.05-0.3
(semi-continuous process)	(8-14)	–
Rice vinegar	4.2-4.5	0.68
Chinese rice vinegar[a]	6.8-10.9	–
Cashew vinegar	4.62	0.13
Coconut water vinegar	8.28	0.42
Mango vinegar	4.92	0.35
Sherry vinegar	7.0	–
Pineapple vinegar	5.34	0.67

[a] Chinese rice vinegar data were reported by Liu et al., 2004.
–, not reported.

Modified from Adams, 1998

classify either as alcoholic beverages or as vinegars. Similarly, in Japan, black rice vinegar is usually diluted with fruit juice and consumed daily as a healthy tonic beverage, with a share of 20% of the Japanese vinegar market, corresponding to 21.46 billion yen in the year 2004. In some western countries, mainly the USA and Canada, apple cider vinegar is a traditional folk remedy that is claimed to be beneficial in treating a long list of diseases; it is drunk mixed with fruit juice.

According to EU legislation and the FAO/WHO vinegar definitions, many fruit vinegars cannot be considered to be ‘vinegar’, since they have a low acetic acid content and, in addition, they may still contain ethanol. In the traditional wine-producing countries of Europe it is very easy to differentiate between wine and vinegar, since the names are well-established and have a precise meaning. Wine must have a minimal acetic acid content which is less than $1.2\,g \cdot L^{-1}$ and, for special wines, acetic acid must be less than 1% of the ethanol content. Vinegar must have more than 6% of titratable acidity and residual ethanol less than 1.5%. However, fermented alcoholic beverages and vinegars share many process steps and it is easy to envisage products that do not match the definition of either vinegar or wine. In our opinion, the grouping of vinegars first requires a complete picture of the kinds of vinegar available throughout the world, and then at least three parameters need to be established: the lowest threshold of acetic acid, the upper ethanol limit, and the lowest acceptable value of the acetic acid : ethanol ratio.

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