3 The Nature of Alcohol

Aims and learning outcomes

This chapter aims to provide the knowledge necessary to understand the nature of alcohol. It explains its scientific composition and how it is produced, plus the general effects and strengths of alcoholic beverages. After reading this you should be able to:

- Explain how alcohol is produced and know the general effects of alcoholic beverages.
- Outline the scientific composition of ethanol and the role which aldehyde dehydrogenase plays in its breakdown.
- Identify the systems used for determining the strength of alcoholic beverages and apply formulas for calculating the grams and units of alcohol they contain.

3.0 Introduction

Alcohol has a long and chequered history, as we witnessed in Chapter 2, and over the centuries it has been used for many purposes around the world. Ethyl alcohol or ethanol is a chemical and in its primary form is found in most alcoholic beverages. It is used as fuel, and also has many scientific, medical, and industrial uses. In its natural form (i.e. without ageing or additives), it is a clear liquid which dissolves easily in water.

The human body contains a high percentage of water and blood streams act as a super highway for alcohol to roam freely. The body also contains powerful enzymes and organs which help to break down ethanol and to eliminate its by-products. The strength of alcoholic drinks varies and is based on how much ethanol they contain. It is crucial that people involved in the sale and service of alcoholic drinks understand these strengths. They can be easily calculated using the formulas supplied in this chapter. People consume alcohol because of the general effects it offers to their bodies. These effects are dependent on the amount of alcohol consumed and the outcomes can differ between different individuals, genders and ethnic backgrounds. They

can sometimes cause harmful behavioural patterns and unpleasant alcohol hangovers.

3.1 What is alcohol and how is produced?

The word 'alcohol' derives from the Arabic *al-kuhul* and is applied to the many members of the family of alcohols. The Persian physician and scientist Rhazes (ca. 865 – 925) discovered this substance, but because he wanted his book to be published in most of the then-known world, he used the Arabic language instead of Persian (although he made copies in Persian). The word was introduced into Europe, together with the art of distillation and the substance itself, around the twelfth century by various European authors who translated and popularized the discoveries of Islamic and Persian alchemists.

The term 'alcohol' originally referred to the ethyl alcohol (ethanol), the dominating alcohol in beverages like beer, wine and spirits. Ethanol is the only alcohol safe for human consumption. It is a simple molecule with the chemical formula C_2H_5OH, often abbreviated as EtOH. It is the presence of the –OH combination (the hydroxyl group) attached to a carbon atom that makes a molecule a member of the alcohol family (IUPAC, 1997). The simplest form of alcohol is methanol (methyl alcohol, CH_3OH), sometimes also called 'wood alcohol', because it can be produced by fermentation of wood. Other members of this family include glycol (found in anti-freeze for cars), propanol or propyl alcohol (rubbing alcohol), and cholesterol, a complicated molecule vital for many bodily functions and which, in excess, can cause serious illnesses such as heart disease (Charnley et al, 1995). For more on the family of alcohols, see Appendix I.

The nature of pure 100% alcohol as a chemical is such that:

- at room temperature it is a clear liquid
- it easily dissolves in water
- it can be used as a fuel and it is quite flammable

Alcohol is primarily made by fermentation, distillation and brewing. For the fermentation process, carbohydrate-containing plant materials are allowed to ferment, producing a dilute solution of ethanol in the process. The dilute solution can be separated by distillation, thus achieving a higher concentration level of alcohol, to create hard liquors or spirits.

Fermentation

Fermentation occurs in yeast and bacteria. It is employed for preservation in a process that produces lactic acid as found in such sour foods as pickled cucumbers, kimchi and yogurt (fermentation in food processing), as well as for

producing alcoholic beverages such as wine and beer. Fermentation can even occur within the stomachs of animals, including humans. Fermentation in its widest sense is also used to refer to the bulk growth of microorganisms on a growth medium. French microbiologist Louis Pasteur is often remembered for his insights into fermentation and its microbial causes (Pasteur, 1879), see *Pasteurisation* below.

Fermentation is required for the production of ethanol in alcoholic beverages. Yeasts already contained in or introduced to grain or fruit juices or mixes, convert sugars such as glucose, fructose, and sucrose, into ethanol and carbon dioxide. The result is a dilute solution of ethanol. There are two types of fermentation relevant to the poduction of alcoholic beverages.

Ethanol fermentation

More commonly known as alcoholic fermentation, this is the biological process in which sugars such as glucose, fructose, and sucrose are converted into cellular energy and produce ethanol and carbon dioxide as metabolic waste products. Because yeasts perform this conversion in the absence of oxygen, alcoholic fermentation is considered an anaerobic process. All ethanol contained in alcoholic beverages (including ethanol produced by carbonic maceration) is produced by means of fermentation induced by yeast. The major types of alcoholic drinks produced by ethanol fermentation include:

- **Beer, whiskey, and vodka** are produced by fermentation of grain starches that have been converted to sugar by the enzyme amylase, which is present in grain kernels that have been malted through germination. Additional sources of starch, for example potatoes and un-malted grain, may be added to the mixture, as the amylase will act on those starches as well. Whiskey and vodka are distilled; gin and related beverages are produced by the addition of flavouring agents to a vodka-like feedstock during distillation.
- **Mead** is produced by fermentation of the natural sugars present in honey.
- **Rum** and some other beverages are produced by fermentation and distillation of sugarcane. Rum is usually produced from the sugarcane product molasses.
- **Rice wines** (including sake) are produced by the fermentation of grain starches converted to sugar by the mould Aspergillus Oryzae. Baijiu, Soju, and Shōchū are distilled from the product of such fermentation (see Sake below).
- **Wine** is produced by the fermentation of the natural sugars present in grapes. Cider and perry are produced by similar fermentation of natural sugar in apples and pears, respectively. Other fruit wines are produced from the fermentation of the sugars in the fruit.

In all cases, alcohol fermentation must take place in a vessel that allows carbon dioxide to escape but prevents outside air from entering. Exposure to oxygen would prevent the formation of ethanol, while a build-up of carbon dioxide creates a risk that the vessel could rupture or fail, which could cause serious injury and property damage (Stryer, 1975).

Lactic acid fermentation

This refers to two means of producing lactic acid (homolactic and heterolactic fermentation). They are biological processes by which glucose and other six-carbon sugars and disaccharides of six-carbon sugars (for example sucrose or lactose) are converted into cellular energy and the metabolite lactate.

- *Homolactic* fermentation (producing only lactic acid) is the simplest type of fermentation. One molecule of glucose is converted to two molecules of lactic acid.
- *Heterolactic* fermentation in contrast yields carbon dioxide and ethanol in addition to other acids.

Lactic acid fermentation is used in many areas of the world to produce foods and alcoholic beverages that cannot be produced through other methods. The most commercially important genus of lactic acid-fermenting bacteria is Lactobacillus, though other bacteria and even yeast are sometimes used (Campbell and Reece, 2005).Two of the most common applications of lactic acid fermentation are in the production of foods (yogurt and sauerkraut) and in alcoholic beverages (sour beers – Lambic and Berliner Weisse, see below).

Lactic in beer

The percentage of acids, primarily lactic and acetic, in a beer determines its sourness. Some beers have just a hint of tartness; others are overpoweringly sour. German Berliner Weisse and several Belgian beer styles are characterized by their sourness. Each style has a different level of sourness, and even within the same beer style this level varies. Fermentation with lactic acid bacteria is not an exact science, and one brand of beer may have different levels of sourness from batch to batch or from year to year (Nummer, 2012).

Aerobic respiration

Fermentation does not necessarily have to be carried out in an anaerobic environment. Dickinson (1999) maintains that even in the presence of abundant oxygen, yeast cells greatly prefer fermentation to aerobic respiration, as long as sugars are readily available for consumption, a phenomenon known as the Crabtree effect. Voet and Voet (1995) maintain that sugars are the most common substrate of fermentation, and typical examples of fermentation