Chapter 17

METABOLISM OF WORT BY YEAST

17.1 Nutritional requirements [1]
Yeast will grow fermentatively in simple media which contain fermentable carbohydrates to supply energy and carbon 'skeletons' for biosynthesis, adequate nitrogen for protein synthesis, mineral salts and one or more growth factors. Yeasts also require molecular oxygen (see Chapters 16, 18 and pp. 604–608, this chapter).

Sources of carbon include the monosaccharide hexose sugars D-glucose, D-fructose, D-mannose and D-galactose. Saccharomyces strains are able to use xylulose but not other pentose sugars e.g. xylose [3]. Disaccharides may also serve as sources of carbon and energy, thus sucrose and maltose, but not lactose, are utilized by brewing yeasts. The disaccharide melibiose (α-4-D-glucopyranosyl-D-galactopyranose) is metabolized by S. carlsbergensis but not by S. cerevisiae and growth on this sugar may be employed to distinguish ale and lager yeasts. The trisaccharides raffinose (used completely by S. carlsbergensis and partially by S. cerevisiae) and maltotriose may also serve as carbon sources. Higher polymers of glucose such as maltotetraose and dextrins are not metabolized by brewers' yeast.

Under aerobic conditions yeast may also use glycerol, ethanol and lactic acid which are themselves the products of anaerobic (fermentative) growth. Similarly the organic acids acetic, citric and malic are also metabolized by some species. Other compounds, generated by cellular metabolism, which appear in the medium and may be subsequently taken up by the cells, include pyruvic acid and acetaldehyde. In addition yeast cells may 'fix' carbon dioxide to provide up to 5% of their carbon requirement [4].

The nitrogen requirement of the brewing yeast cell may be met by ammonium ions (in which case the cell synthesizes the necessary carbon constituents of amino acids from fermentable sugars), amino acids or low molecular weight peptides [5]. Brewing strains do not appear to produce extracellular proteolytic enzymes and thus are unable to use polypeptides or proteins. Many yeast strains do however possess these abilities [6] and one strain of Saccharomyces has been reported to produce an extracellular protease [7]. Saccharomyces strains are unable to use either molecular nitrogen or nitrate ions.

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The requirement for minerals resembles that of other living cells and a supply of potassium, iron, calcium, magnesium, manganese, copper and zinc is necessary. Many of these metal ions and others are essential for the activity of enzymes. Relatively large amounts of phosphate and sulphate are also needed by brewing yeasts.

17.1.2 GROWTH FACTORS [3, 8]
It is usual for brewing yeasts to require one or more accessory nutrients (nutrilites), and most if not all strains show an absolute requirement for biotin. In the absence of growth factors, the yeast cells may fail to grow, grow very slowly or grow only after a prolonged lag. In many cases addition of nutrilites will stimulate the rate of growth even though there is no absolute requirement for them (Fig. 17.1). Strains vary considerably with respect to their need for growth factors (Table 17.1). In a survey of 61 strains of S. carlsbergensis [9], biotin was required by all strains. Pantothentic acid, meso-inositol, nicotinic acid, thiamine, p-aminobenzoic acid and pyridoxine were found to stimulate the growth of some (but not all) strains. In some cases strains required either thiamine or pyridoxine for growth. The roles of various growth factors in yeast metabolism are indicated in Table 17.2. With the exception of meso-inositol they all act as essential cofactors of enzyme function. In addition to the nutrilites already mentioned, some yeast strains require the nucleotides uracil and guanine. Some instances are also known where particular amino acids are required (e.g. methionine) when ammonium ions represent the only major source of nitrogen.

![Fig. 17.1](image)

*Fig. 17.1* The amount of growth obtained over a period of days when a particular yeast strain was cultured in a series of media differing in the accessory growth factors present. Medium 1 is deficient in inositol, 2 in pantothenic acid, 3 in biotin, 4 in thiamine, 5 in pyridoxine, 6 in thiamine plus pyridoxine, 7 in nicotinic acid, 8 in p-aminobenzoic acid, and 9 is a complete medium. A represents moderate, B poor growth levels.