WORT COMPOSITION AND BEER FLAVOUR.
II. THE INFLUENCE OF DIFFERENT CARBOHYDRATES ON THE FORMATION OF SOME FLAVOUR COMPONENTS DURING FERMENTATION.

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Wort, to which was added various amounts of solutions of glucose, fructose, sucrose or maltose, was fermented, and in the resulting beers the concentrations of the following flavour components were determined by gas chromatography: ethyl acetate, isobutyl acetate, iso-amyl acetate, 2-phenyl ethyl acetate, ethyl caproate, ethyl caprylate, n-propanol, isobutanol, amyl alcohols, 2-phenyl ethanol, caprylic acid and capric acid. The concentrations of these compounds were affected in different ways by the various amounts of sugar added, and some differences were observed etween the different carbohydrates.

Introduction

Among factors influencing beer flavour, the composition of the wort is of great significance.[11] In a previous paper we have shown the influence of some amino acids on the formation of higher aliphatic alcohols and esters.[3] Much work has been carried out on the amino acid composition of wort and its influence on fermentation and flavour, but considerably less has been done regarding the influence of different carbohydrates on beer flavour.

Jenard & Devreux[6] fermented different combinations of wort and a sucrose solution, and found an increase in higher alcohols with increasing sucrose addition. Drews & Riemann[2] also found an increase in higher alcohols when 50% of the wort was replaced by a sucrose solution. The greatest increase was found with isobutanol and iso-amyl alcohol.

Kamiyama & Nakagawa[8] also determined the effect of sucrose addition to wort, and found that n-propanol decreased with increasing addition of sucrose, isobutanol was not significantly affected, and amyl alcohols

increased somewhat when the sucrose solution was added in the ratio of 50, 100 or 200 parts to 100 parts of wort.

Maule[12] found that artificial enrichment of wort by glucose led to the production of considerably more isobutanol, isoamyl alcohol and iso-amyl acetate, and less n-propanol than in the fermentation of a wort which had been brewed at an increased gravity so as to contain the same amount of fermentable sugar. This effect seemed, however, to depend on the yeast strain.

Hough & Stevens[5] found that addition of sugar to wort led to diminished production of higher alcohols, while Äyräpää[1] showed that different sugars may give different effects. He stated that "any lowering of the nitrogenous nutrient level of brewing wort must be associated with an increase in the biosynthetic production of higher alcohols. However, as the catabolic production of the same alcohols from exogenous amino acids is thereby decreased, the total yields may be nearly unchanged, increased or even decreased, depending on the conditions of fermentation and the properties of the yeast strain used."

Other authors have also stressed the importance of carbohydrate composition for beer flavour.[7,10]

We have examined the effect of addition to wort of different amounts of glucose, fructose, sucrose and maltose on the formation of a number of flavour components, using a single strain of bottom fermenting brewer's yeast.

Experimental

Fermentations were performed with pilsener all-malt wort having an original extract of 10·9% Balling, and with mixtures of this wort with a 10% solution of glucose, fructose, sucrose or maltose.

The amino acid concentration in the wort was determined by a TNBS method,[9] and the mean value was found to be 240 mg α-amino nitrogen per litre of wort.

The oxygen content of the wort was approximately 7 mg per litre, and the sugar solutions were aerated to about the same level. These estimations were performed with an OXI-54 oxygen meter (Wissenschaftlich-Technische Werkstätten GmbH, Weilheim, Germany).

The following combinations of wort and carbohydrate solution were fermented:

(1) 100% wort
(2) 95% wort + 5% sugar solution
(3) 87·5% wort + 12·5% sugar solution
(4) 75% wort + 25% sugar solution
(5) 50% wort + 50% sugar solution
(6) 25% wort + 75% sugar solution

The fermentations were performed in 500-ml batches in tall glass cylinders, in duplicate or triplicate at room temperature (*ca.* 20° C). After 100 h at room temperature, the fermentation cylinders were placed at 0° C for 2 days before being analysed.

A number of flavour compounds were analysed by gas chromatography, using both a head space technique and extraction with CS_2. The methods and their reproducibilities have been described previously.[4]

Results and Discussion

The following flavour components were estimated: ethyl acetate, isobutyl acetate, iso-amyl acetate, 2-phenyl ethyl acetate, ethyl caproate, ethyl caprylate, n-propanol, isobutanol, amyl alcohols (2-methyl butanol + 3-methyl butanol), 2-phenyl ethanol, caprylic acid and capric acid.

Esters.—As shown in Fig. 1, ethyl acetate was little influenced by sugar addition, up to a replacement of 50% of the wort. With 25% wort and 75% sugar solution, the

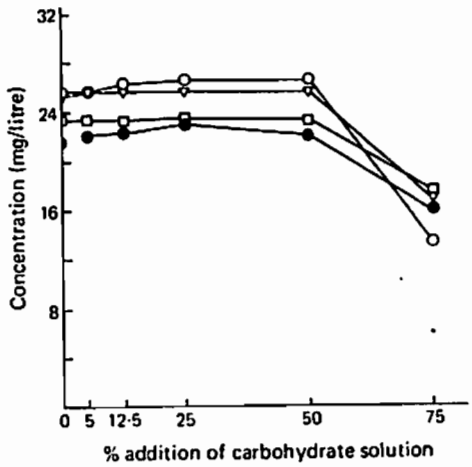

Fig. 1.—Concentration of ethyl acetate at different levels of carbohydrate addition.
○ — glucose
▽ — fructose
□ — sucrose
● — maltose

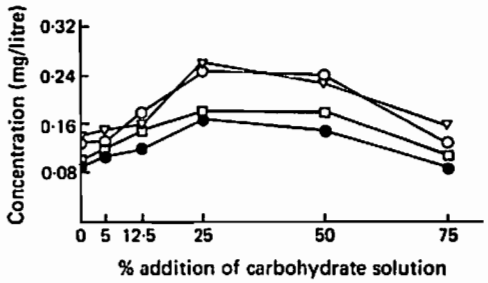

Fig. 2.—Concentration of isobutyl acetate at different levels of carbohydrate addition. Symbols as in Fig. 1.

concentration was sharply decreased. No significant difference was observed between different carbohydrates.

The other esters seemed to be more influenced by carbohydrate addition. The concentrations of isobutyl acetate, isoamyl acetate and 2-phenyl ethyl acetate are increased up to replacement of 25–50% of the wort with sugar solution (Figs. 2, 3 and 4). Again a decrease was observed at addition of 75% sugar solution.

Ethyl caproate and ethyl caprylate showed greater variations both between the different carbohydrates and at different levels of sugar addition, as shown in Fig. 5 and Fig. 6. Maximum yield was in most cases reached with 25% sugar addition.

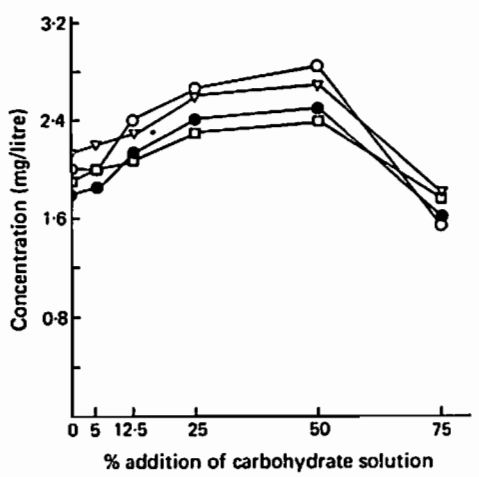

Fig. 3.—Concentration of isoamyl acetate at different levels of carbohydrate addition. Symbols as in Fig. 1.

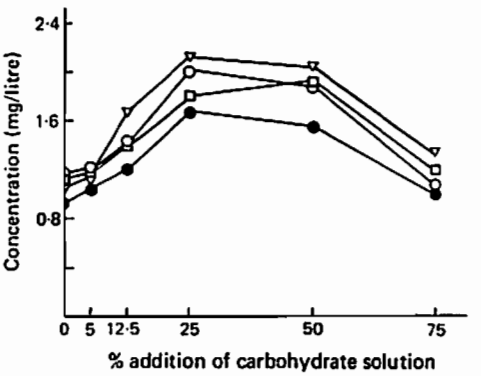

Fig. 4.—Concentration of 2-phenyl ethyl acetate at different levels of carbohydrate addition. Symbols as in Fig. 1.

Alcohols.—As shown in Fig. 7, the concentration of n-propanol increased up to addition of 25% sugar solution, except in the case of fructose, where the maximum was reached at 12·5% addition. At 75% sugar addition the concentration was in all cases considerably lower than with pure wort.

The concentration of isobutanol (Fig. 8) increased up to 50% sugar addition. At 75% sugar a small decrease was observed. Fructose gave higher values of this alcohol than the other carbohydrates.

With the amyl alcohols (Fig. 9) and with 2-phenyl ethanol (Fig. 10) the concentrations increased with addition of sugar solution at all levels, except at the 5% level, where no significant difference was observed from the result with pure wort.

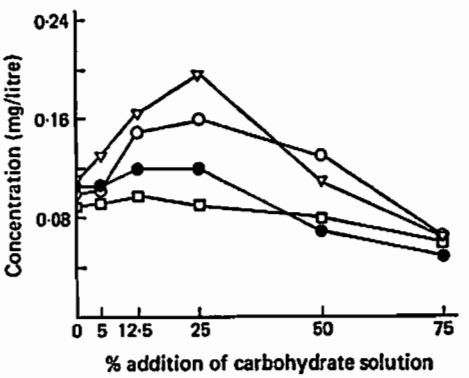

Fig. 5.—Concentration of ethyl caproate at different levels of carbohydrate addition. Symbols as in Fig. 1.

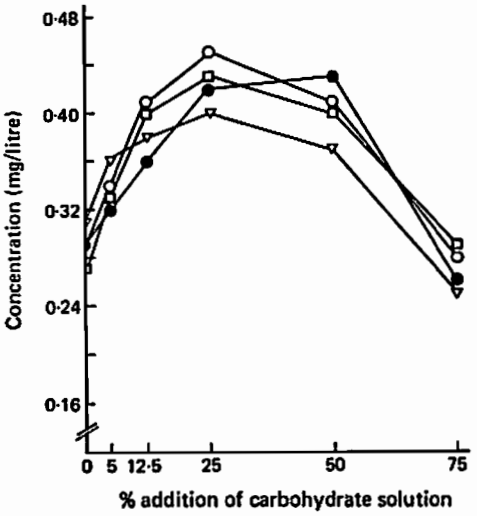

Fig. 6.—Concentration of ethyl caprylate at different levels of carbohydrate addition. Symbols as in Fig. 1.

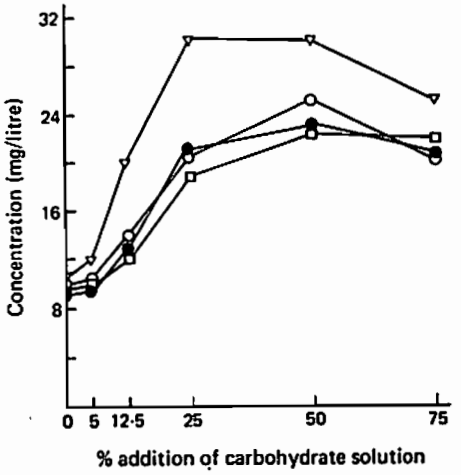

Fig. 8.—Concentration of isobutanol at different levels of carbohydrate addition. Symbols as in Fig. 1.

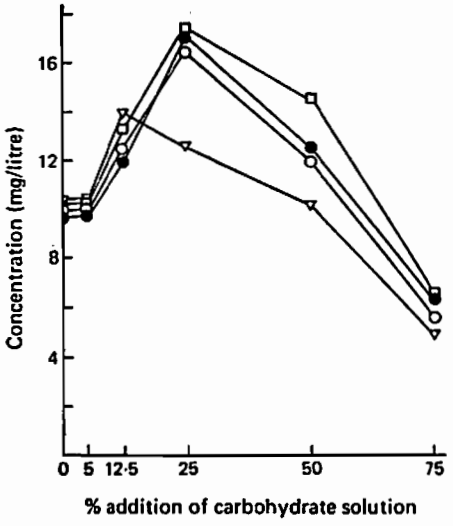

Fig. 7.—Concentration of n-propanol at different levels of carbohydrate addition. Symbols as in Fig. 1.

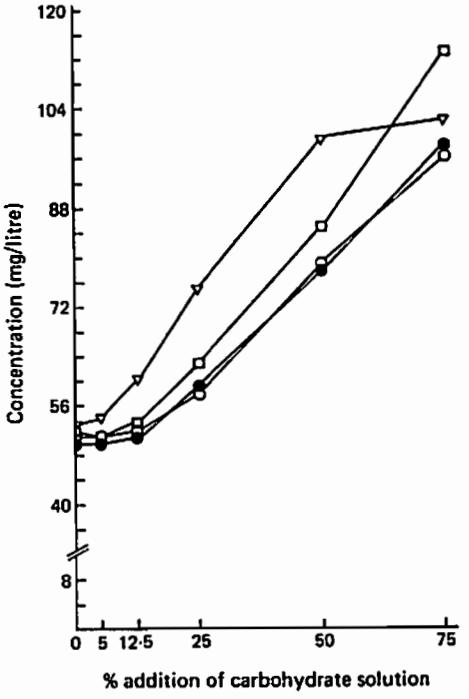

Fig. 9.—Concentration of amyl alcohols (2-methyl butanol + 3-methyl butanol) at different levels of carbohydrate addition. Symbols as in Fig. 1.

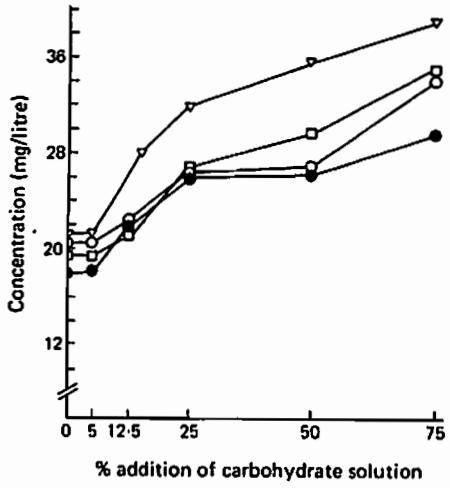

Fig. 10.—Concentration of 2-phenyl ethanol at different levels of carbohydrate addition. Symbols as in Fig. 1.

Fructose in most cases seemed to give higher values of these alcohols than the other sugars, and as previously observed by Äyräpää,[1] sucrose gave more amyl alcohols than maltose at low nitrogen levels (*i.e.* high levels of sugar addition).

Acids.—Both with caprylic acid (Fig. 11) and with capric acid (Fig. 12) the concentration seems to be more or less unaffected by sugar addition up to replacement of 12·5–25% of the wort. At higher additions the concentrations of the acids decreased.

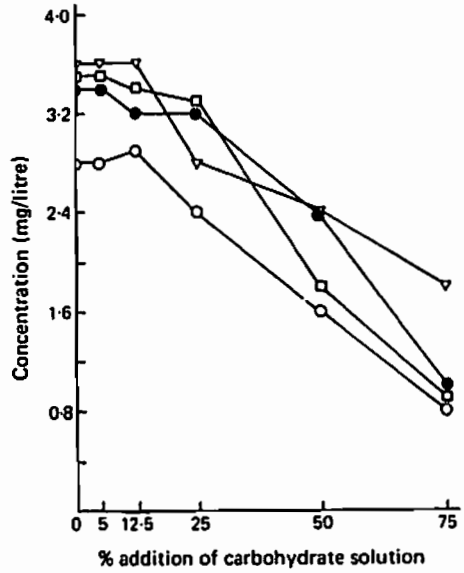

Fig. 11.—Concentration of caprylic acid at different levels of carbohydrate addition. Symbols as in Fig. 1.

Conclusion

The results have shown that different flavour compounds are affected in different ways when part of the wort is replaced by a carbohydrate solution. Different carbohydrates may affect the concentration of the flavour compounds differently, to a certain degree, but the general pattern seems to be unaffected by the type of sugar.

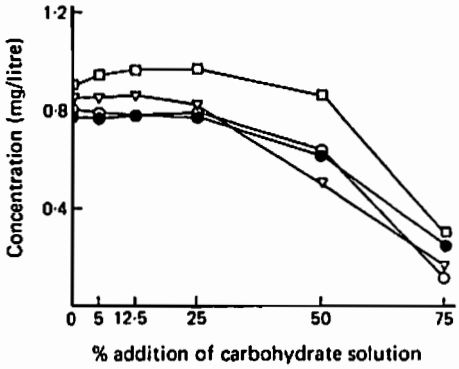

Fig. 12.—Concentration of capric acid at different levels of carbohydrate addition. Symbols as in Fig. 1.

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