RESEARCH CONCERNING THE INFLUENCE OF VARIOUS CARBOHYDRATE COMPOSITION ON THE AROMA COMPOUNDS DURING BEER FERMENTATION

Camelia Bonciu, Antoaneta Stoicescu
„Dunarea de Jos" University Galati, Food Science and Enginery Faculty
Domneasca Street, no. 111, tel. 0745914376, e-mail camelia_bonciu@yahoo.com

Abstract

One of the most important factors that affect the fermentation process is wort composition. In this paper we have studied the impact of various carbohydrate syrups (as type and amount) on the aroma of the final beer. Using maltose, glucose, sucrose and fructose syrups, the original extract of the wort was increased and the amount of some flavour compounds was measured using gas-chromatography. The type and the amount of the different carbohydrate syrups significantly affected the aroma compounds in the final beer.
Keywords: *Flavour, carbohydrate syrups, high gravity.*

Introduction

Brewing process is a complex mechanism that involves a number of distinct steps. Fermentation step is the process of transformation of wort into beer. During this step the sugars from wort are fermented by enzymes in the yeast to ethanol and carbon dioxide. In the fermentation process yeast synthesizes a wide range of by-products that have a considerable impact on beer's flavour.

Two of the most important factors that affect beer's fermentation are wort composition and concentration. The use of different sugar syrups in the brewing process is a common practice in many breweries and the aim of this use is to increase the wort original extract, increasing the plant productivity too.

To perform its vital functions yeast use organic substances which it can utilize, especially sugars. For beer production it is important what sugars are utilized by the yeast. In the brewer's wort the principal fermentable carbohydrates are maltotriose, maltose, sucrose, glucose and fructose. Sucrose is hydrolyzed by invertase at the cell surface, while maltose and maltotriose are hydrolyzed within the cell by a single maltase (Hough J. S., 1971).

Brewers use carbohydrate syrups to increase wort density. This practice is frequently used in high gravity brewing and it has been adopted by many breweries. In essence, high gravity brewing is a strategy to produce a smaller amount of stronger beer, which will be then diluted to a larger amount of "normal" beer, with the desired concentration of alcohol. High gravity brewing has a lot of advantages, such are: enhances the capacity of brewing plant by 10-50%, the water input and energy and labour costs per unit of beer are lower than standard practices, the precipitation of polyphenols and protein compounds is promoted leading to an improved colloidal stability, and the microbial stability is improved due to higher alcohol content before dilution. High gravity brewing has some disadvantages too: the yeast cells are stressed by the increased concentrations of the pitching wort and high ethanol content. This results in slow and sluggish fermentations. (Almeida (2004), Debourg (2002) and Wille (2002).

In this work, different types of sugar syrups were used for increasing wort initial concentration to 18˚Plato and 20˚Plato. We've studied the influence of various syrups types on the by-products formation during fermentation.

Experimental

The fermentation process was conducted in Erlenmeyer flasks. For the experiment industrial wort was used having next properties: original extract 17.06˚P, pH - 5.28, colour – 12.3 EBC units, bitterness – 60.8 BU, FAN – 289.8 ppm, polyphenols – 239.5 mg/l. The wort was pasteurized at 85˚C for 5 minutes.

The syrups used for increasing wort density were 50% dry matter syrups of glucose, fructose, sucrose and maltose. The syrups were sterilized at 121˚C for 15 minutes before using them to increase wort initial concentration to 18˚P and, respectively to 20˚P.

The wort was pitched with industrial slurry brewing yeast with a viability of 94.9%, consistency of 67.3% and pH of 5.27. The pitching rate was 15×10^6 cells/ml and the yeast was introduced at the beginning of the assay.

The laboratory apparatus used were:

- Karl Zeiss Jena Microscope – for cell counting,

- Analytical balance Owalabor type 750.05 – for weighing the samples,
- Shimadzu gas-cromatograph with cappilary column Chromopack 7773, length 50 m, detectors FID and ECD, mobile phase N_2/H_2 – for the determination of aroma compounds,
- Anton Paar DSA 5000 – for alcohol content and extract determination,
- Centrifuge for yeast concentration (consistency) determination,
- Spectrophotometer for free amino nitrogen and polyphenols content, color and bitterness determination,
- pH-meter for pH measurements.

The methods used were:

- Direct counting of microorganisms with Thomas camera,
- Vitality staining of yeast with methylene blue according to EBC method,
- Head space by gas-cromatography for aroma compounds using EBC method,
- Ethanol determination using standardized method SR 13355-3/1999,
- Free amino nitrogen content using ninhydrin method,
- Color, bitterness and polyphenols were determined according to EBC methods.

Results and Discussions

The fermentation process was conducted in Erlenmeyer flasks; each flask was filled with 200 ml of wort with original gravity of 18˚P or 20˚P. The wort was pitched with 15×10^6 cells/ml Saccharomyces cerevisiae yeasts. The fermentation process was conducted at a constant temperature of 19˚C. The samples were weighted every 8 hours for establish the end of fermentation. At the end the samples were analyzed for bitterness and polyphenolic content, aroma compounds content, color, pH, apparent extract, alcohol content. There were major differences between the samples depending of the syrups used and of original gravity of the sample.

The samples were: 1G-wort with 18˚P containing glucose syrup, 4F-wort with 18˚P containing fructose syrup, 7Z-wort with 18˚P containing sucrose syrup, 12M-wort with 18˚P containing maltose syrup, 3G-wort with 20˚P containing glucose syrup, 6F-wort with 20˚P containing fructose syrup, 9Z-wort with 20˚P containing sucrose syrup, 14M-wort with 20˚P containing maltose syrup.

The apparent extract is varying but not excessively. The samples containing glucose, included the glucose from sucrose, have a lower drop of apparent extract and their alcohol content is higher as it can be seen in figures 1 and 2.

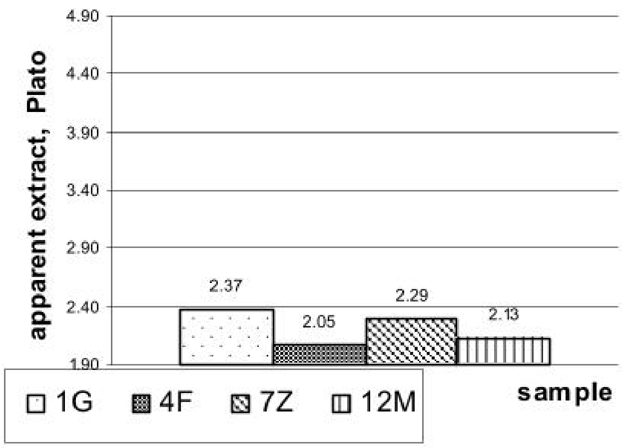

Fig. 1: The apparent extract for 18˚P samples

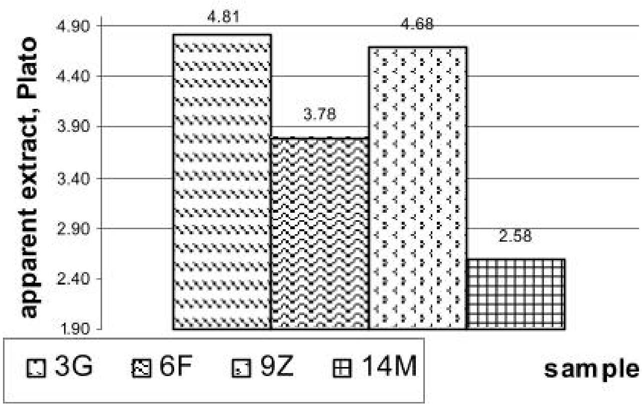

Fig. 2: The apparent extract for 20˚P samples

The alcohol content is according with apparent extract variation. The same variations have the bitterness, the color of the beer, and the polyphenols content.

The aroma by-products have different variations depending of the type of sugar added and wort concentration. Therefore, the vicinal diketones (diacetyl and 2, 3-pentadione) content is higher in the beers with 20˚P. For the wort with 18˚P the vicinal diketones content is not varying very much with the sugar's type, as it can be seen in figures 3 and 4.

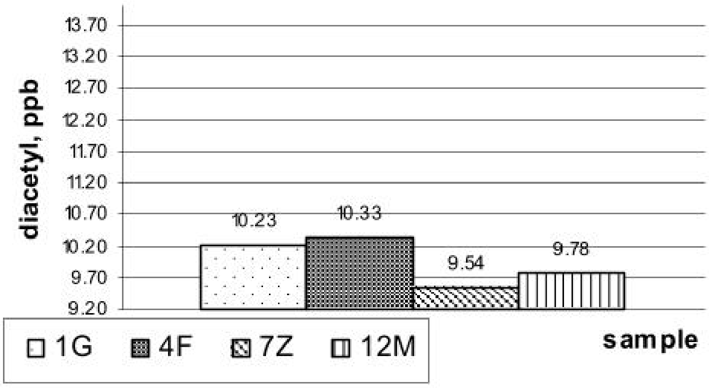

Fig. 3: The diacetyl content for 18˚P samples

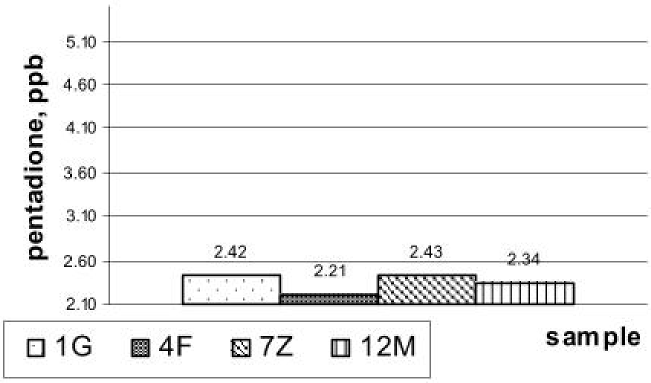

Fig. 4: The 2,3-pentadione content for 18˚P samples

For the 20˚P wort the vicinal diketones are in a lower concentration when the wort's gravity was grown with fructose syrup as figures 5 and 6 show.

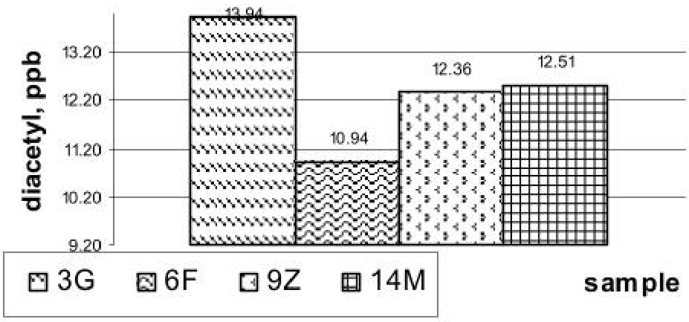

Fig. 5: The diacetyl content for 20˚P samples

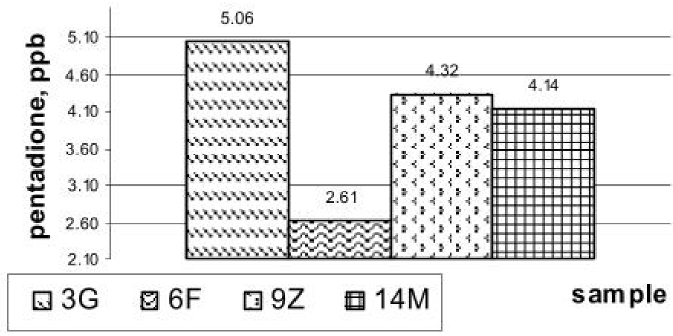

Fig 6: The 2,3-pentadione content for 20˚P samples

Acetaldehyde content is varying a lot with sugar's type. Its formation is stimulated by glucose and sucrose. It is well known that a higher content of acetaldehyde in beer is due to the stressed yeast. Therefore, glucose syrup has a negative effect on the yeast. For the same sugar, the acetaldehyde content is higher as the sugar's concentration is higher as it can be seen in figures 7 and 8.

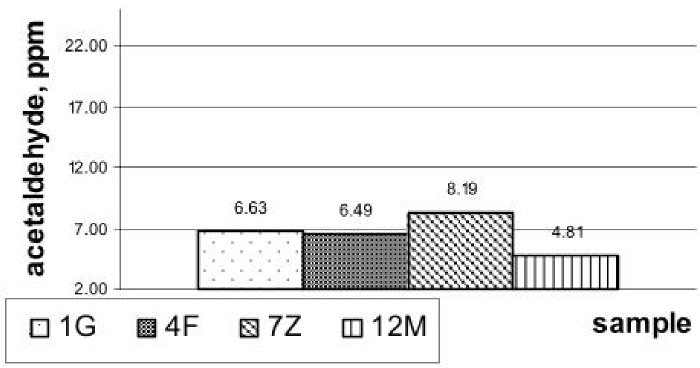

Fig. 7: The acetaldehyde content for 18˚P samples

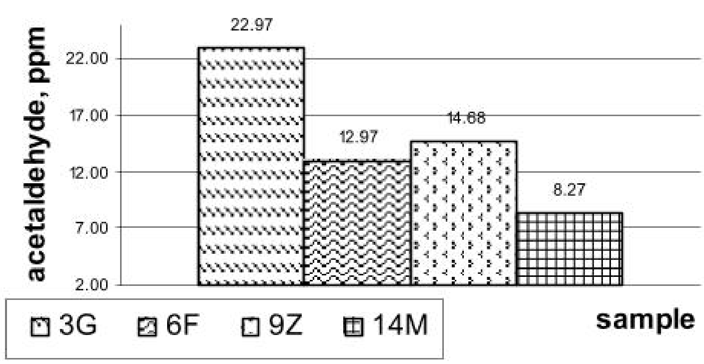

Fig. 8: The acetaldehyde content for 20˚P samples

The ester content is higher in the beer with 18˚P original gravity. The etylacetate content is higher in the samples containing fructose both for 18˚P and 20˚P, as it can be seen in figures 9 and 10.

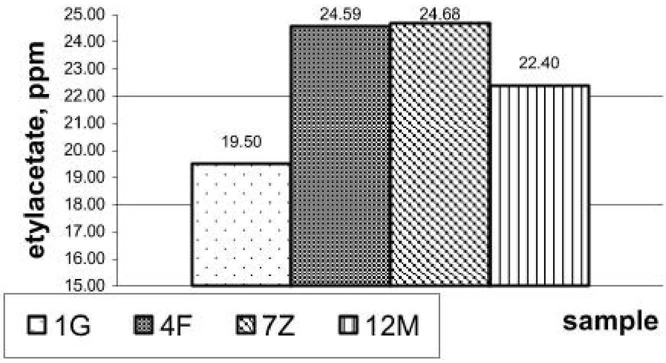

Fig. 9: The etylacetate content for 18˚P samples

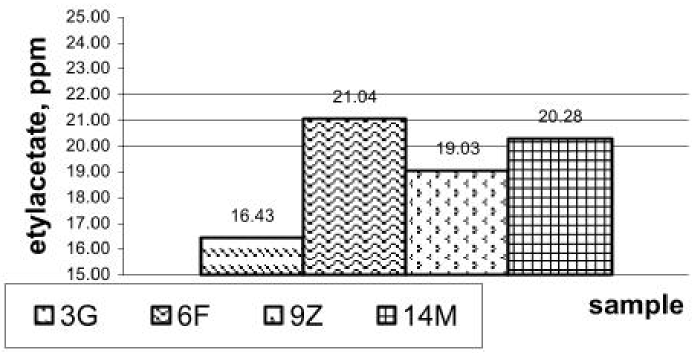

Fig. 10: The etylacetate content for 20˚P samples

The isoamyl acetate content is varying a lot with sugar's type and the highest concentration is in the medium containing maltose for both 18˚P and 20˚P worts (figures 11 and 12).

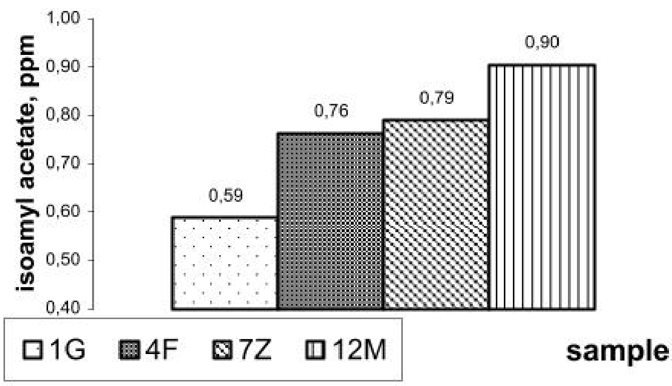

Fig. 11: The isoamyl acetate content for 18˚P samples

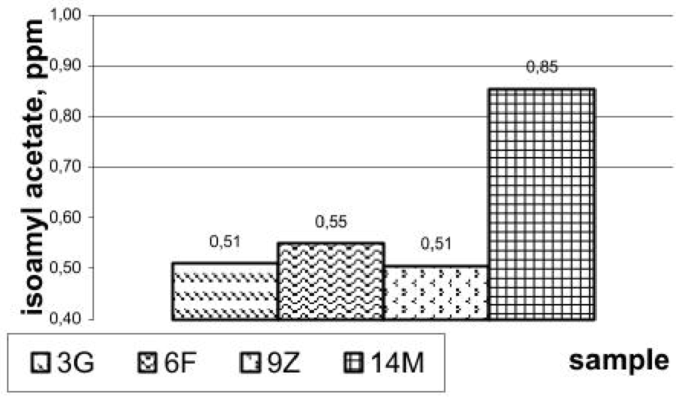

Fig. 12: The isoamyl acetate content for 20˚P samples

As Verstrepen (2003) shows, the ester content should be higher in the beer with 20˚P and in beers containing higher levels of glucose and fructose. But this variation depends of yeast strain and of the amount of higher alcohols formed during fermentation. In this assay we obtained a much lower content of higher alcohols in the most concentrated worts, therefore the ester content is lower in 20˚P samples.

The higher alcohols concentration is usually higher in the samples containing maltose.

Therefore, the izoamylic alcohol content has a low variation with wort gravity; only at 20˚P the inhibition is higher in medium containing sucrose. The higher differences are with sugar's type, in worts containing maltose its formation being stimulated (figures 13 and 14). Szlavko (1974) observes in her paper that the increasing of glucose level determines the decreasing of amylic alcohols level. This decreasing of isoamyl alcohol content is observed also in the case of fructose, maltose and sucrose additions.

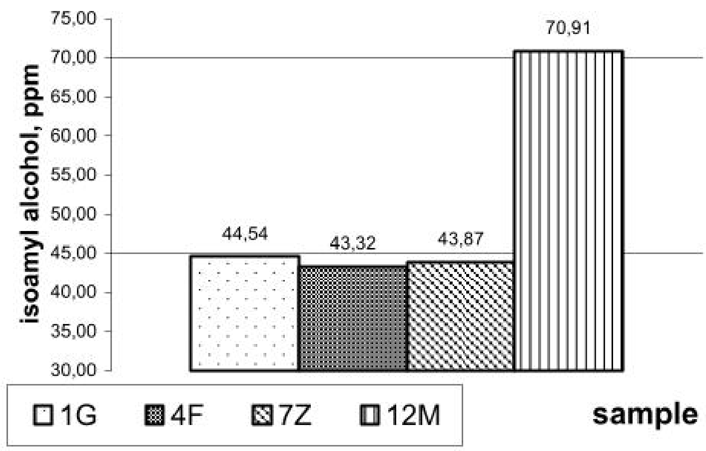

Fig. 13: The isoamyl alcohol content for 18˚P samples

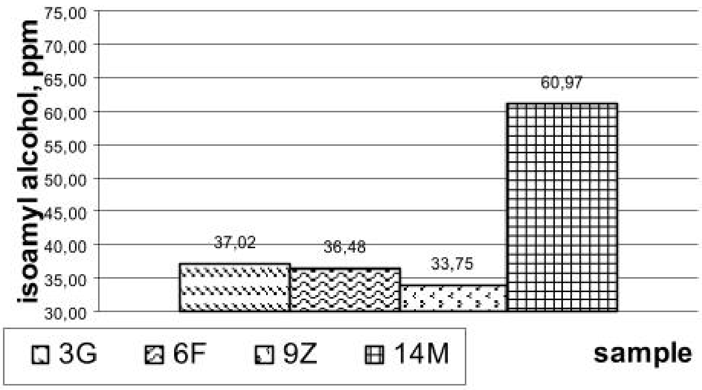

Fig. 14: The isoamyl alcohol content for 20˚P samples

The propanol and isobutanol concentrations vary very much with sugar's type. The highest concentrations can be found in medium with maltose (figures 15, 16, 17 and 18). The higher alcohols formation must be related to FAN content of wort. As Ayrapaa observed, a lower FAN content determines a lower concentration of propanol. (Szlavko, 1974)

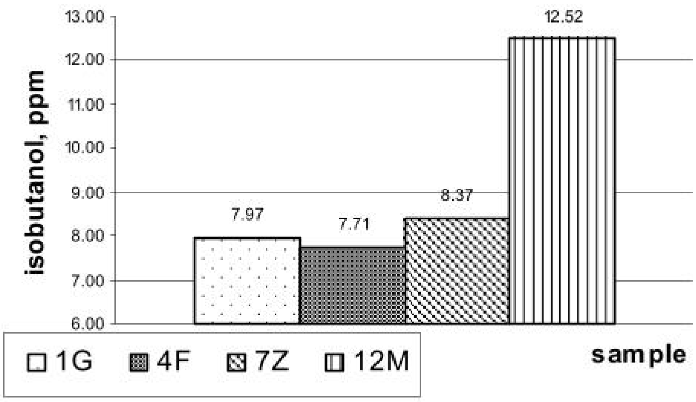

Fig. 15: The isobutanol content for 18˚P samples

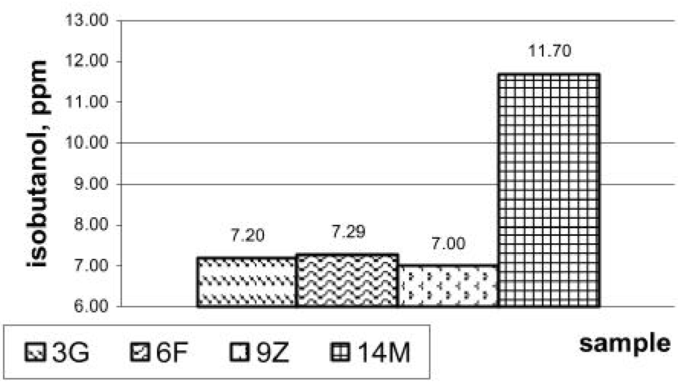

Fig. 16: The isobutanol content for 20˚P samples

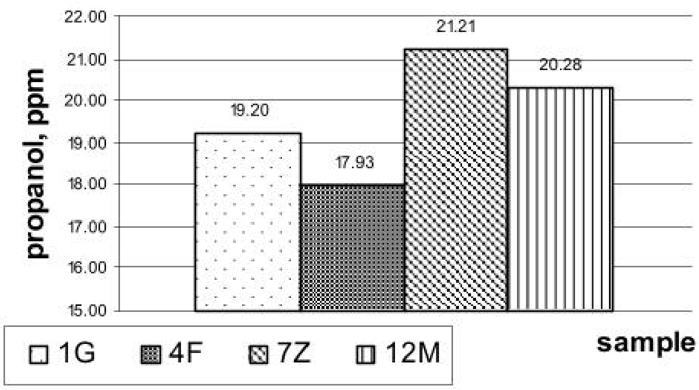

Fig. 17: The propanol content for 18°P samples

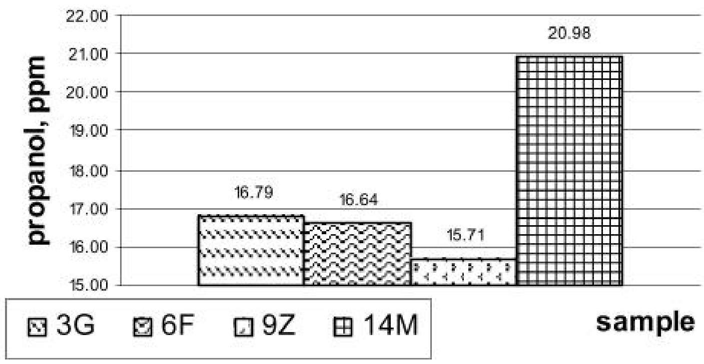

Fig. 18: The propanol content for 20°P samples

As Hough and Stevens (1961) observed, the production of higher alcohols is lower as the sugar's concentration is higher (Szlavko, 1974). This might be due to the lower content of free amino nitrogen (FAN), being well known that the formation of higher alcohols is closely linked to amino acid metabolism (Verstrepen, 2003).

Conclusions

Modern high productivity innovations such as high gravity brewing seem to affect the synthesis of flavour substances as it influence the cellular metabolism.

As it can be seen from the data before the beer's aroma substances content is varying with sugar's type and concentration. If wort's gravity is raised with glucose and sucrose the off flavour compounds content is higher. For worts with a higher content of maltose the ester and higher alcohols contents are increased. The flavour substances content is varying with original gravity of wort, too.

In order to increase wort's original gravity is recommended to use syrups with an increased content of maltose.

References

Almeida, R. B., Almeida e Silva, J. B., et al. (2004), Evaluation of factors involved in the concentration of vicinal diketones in beer produced by high gravity, *Cerevisia*, 29 (3), 147-153.

Debourg, A. (2002), Yeast in action: from wort to beer, *Cerevisia*, 27 (3), 144-153.

Hough, J. S., Briggs, D. E., Stevens, R. (1971), *Malting and brewing science*, London.

Szlavko, C. M. (1974), The influence of wort glucose level on the formation of aromatic higher alcohols, *Journal of the Institute of Brewing*, no. 6, 534.

Verstrepen, K. J., Derdelinckx, G., Delvaux, F. R. (2003), Esters in beer-part 1: The fermentation process more than ethanol formation, *Cerevisia*, 28 (3), 41-47.

Verstrepen, K. J., Derdelinckx, G., Delvaux, F. R. (2003), Esters in beer-part 2: Controlling ester levels during beer fermentation: a biochemical approach, *Cerevisia*, 28 (4), 22-29.

Wille, M., Petersen, F., Dufait, A. (2002), Influence of the carbohydrate composition of various glucose syrups on the fermentation of worts, *Cerevisia*, 27 (2), 94-98.