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EFFECT OF SOME TECHNOLOGICAL FACTORS ON THE CONTENT OF ACETALDEHYDE IN BEER

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Abstract: The purpose of this work was to examine the influence of the temperature, the pitching rate of yeast and wort composition (Free Amino Nitrogen) on the content of acetaldehyde in beer. It is known, that higher fermentation temperatures stimulate the formation of acetaldehyde, as well as the higher rate of acetaldehyde reduction, leading to lower concentrations in the final beer. Beer produced with increased pitching rate of yeast (26 and 35 $\times$ 10^6 cells·mL^{-1}), contains lower quantities of acetaldehyde as compared to the control beer. Lower content of α-amino nitrogen in result of substitution of 5 to 10% of the malt with rice, sugar or a combination of both does not lead to considerable differences in the acetaldehyde concentration in beer.

Keywords: *wort, brewing yeast, beer, α-amino nitrogen, acetaldehyde*

INTRODUCTION

Aldehydes belong to the group of the carbonyl compounds, which are characterized with a great flavor-determining potential and greatly influence the flavor stability of beer. Over 200 carbonyl compounds have been established in beer, from which acetaldehyde has the highest concentration [1]. Aldehydes with greater chain-length are more flavor-active in comparison with acetaldehyde [2]. Acetaldehyde content varies significantly and is about 60% of the overall aldehyde content [3]. Normal ranges for acetaldehyde are between 1 and 20 mg·L^{-1} [4], and according to other authors – below 16 mg·L^{-1} [5].

Acetaldehyde is an important flavor compound. It induces flavor of freshly cut green apples, grass or green leaves in beer [4, 6]. Higher concentrations of this metabolite are undesirable, due to the unpleasant off-taste [7], which is characterized as "young", "green" it leaves in beer [8].

Aldehydes are intermediate metabolites in alcohol fermentation. They could also result from alcohol oxidation [8 – 12]. Acetaldehyde is produced in the carbohydrate metabolism as a result of the decarboxylation of piruvic acid. During fermentation and maturation of beer, acetaldehyde concentration varies greatly, reaching a maximum during the main fermentation and then decreasing. The decarboxylation reaction takes place in the first 48 hours of the primary fermentation and is catalyzed by the enzyme piruvate decarboxylase. After that acetaldehyde synthesis is decreased, and reduction to ethanol is increased, catalyzed by the enzyme alcohol dehydrogenase [10].

Acetaldehyde could also be a result of bacterial contamination of beer with micro-organisms from the genes *Zymmomonas* and *Acetobacter* [4, 8, 13].

It is known from numerous scientific studies and observations in practice, that wort composition, yeast strain and the fermentation conditions are the essential factors determining not only the course of the fermentation process, but also the flavor quality of beer [14, 15]. Purpose of the current paper was to investigate the influence of temperature, brewing yeast concentration and wort composition on the acetaldehyde content in beer.

MATERIALS AND METHODS

Industrial wort was used in two of the experimental series, characterized as follows: extract content – 11.78%, *p*H – 5.60, α-amino nitrogen – 176 mg·L^{-1}, dissolved oxygen - 7.5 mg·L^{-1}. In the third experiment in order for a varying assimilable N-compound concentration to be obtained, different raw materials were used – malt, sugar and rice in the following ratios: *K* – 100% malt, V_1 – 90% malt and 10% sugar, V_2 – 90% malt and 10% rice, V_3 – 90% malt, 5% sugar and 5% rice.

The experiment scheme of the different fermentation temperature variations is as follows: initial temperature 6.5 °C, end-point temperature – 5.0 °C, and maximum temperature: *K* – 8.5 °C, V_1 – 6.5 °C, V_2 – 12.0 °C, V_3 – 16 °C. The pitching rate is 18×10^6 cells·mL^{-1}.

Research on influence of the pitching rate is carried out at a maximum temperature of 8.5 °C, and the following cases: *K* – 18×10^6 cells·mL^{-1}, V_1 – 10×10^6 cells·mL^{-1}, V_2 – 26×10^6 cells·mL^{-1}, V_3 – 35×10^6 cells·mL^{-1}.

The experiments were conducted in a 2.5L fermenter with a strain of *Saccharomyces carlsbergensis*. After conclusion of the primary fermentation, the green beer was transferred for maturation in hermetically sealed bottles at temperature 2 – 4 °C for 20 days. In all of the analyses, methods commonly accepted in Bulgaria and the EBC (European Brewing Convention) were used. The amount of acetaldehyde was determined according to the method described by Arsenault and Yaphe [16].

RESULTS AND DISCUSSION

The results from the experiments conducted for establishing the influence of the temperature are presented on Figure 1.

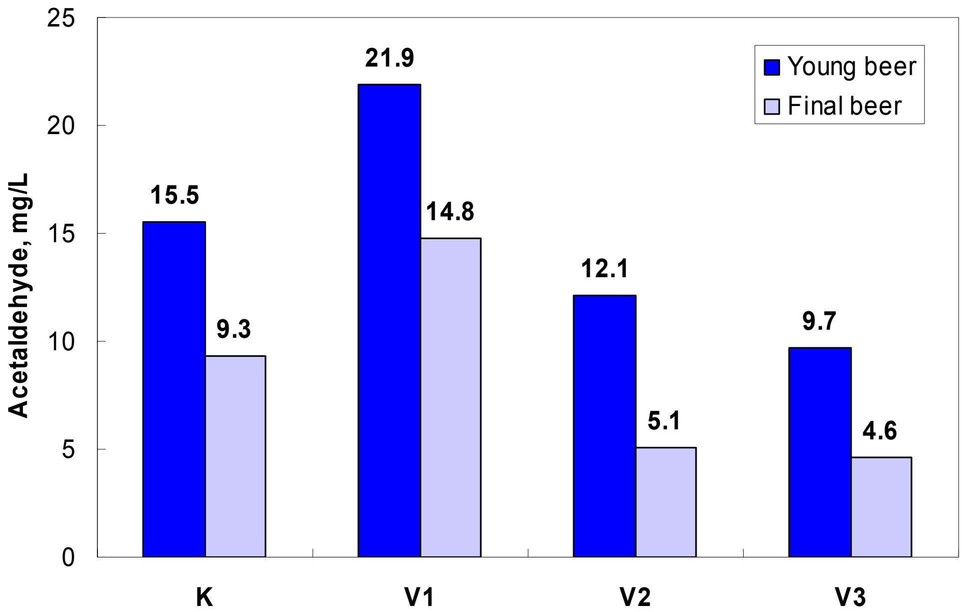

Figure 1. *Influence of temperature on the acetaldehyde content in beer: K – 8.5 °C,* V_1 *– 6.5 °C,* V_2 *– 12.0 °C,* V_3 *– 16 °C*

The data from the diagram show that on temperature increase, the concentration of acetaldehyde decreases. The higher temperatures induce acetaldehyde formation followed, however, by more intense reduction of the metabolite to ethanol. This is probably caused by the increased enzymatic activity in yeast, which leads to lower acetaldehyde concentrations at the end of the primary fermentation. Levels of acetaldehyde in beers, produced at fermentation temperatures 6.5 and 8.5 °C are relatively high. Irrespective of the fact, that acetaldehyde content in all variations and the control is lower than the 25 mg·L^{-1} threshold cited in literature [17, 18], it is considered that acetaldehyde concentration should not exceed 10 mg·L^{-1} [19]. These data corresponded with the tendency of increasing the ethanol content while acetaldehyde decreased.

On Figure 2 the results from the investigation of the pitching rate are presented. The pitching rate is known to influence the growth rate of yeast and the duration of the fermentation. The lower initial concentration of yeast cells correlates with the more intensive growth rate and the levels of acetaldehyde increase.

It is clear, that when the brewing yeast cell concentration rises in the range from 10×10^6 to 35×10^6 cells·mL^{-1}, the levels of acetaldehyde decrease. Higher acetaldehyde concentration was established in the young beer from V_1 and *K*. It can be assumed, that the reason for accumulation of lower amounts of acetaldehyde in the medium when greater pitching rates are used, is the earlier and more intense reduction, therefore acetaldehyde levels in the end of the primary fermentation are lower. The acetaldehyde concentration in the mature beers is within the normal range below 10 mg·L^{-1}. Therefore, the use of this technological factor for intensification of the fermentation process can be considered reasonable.

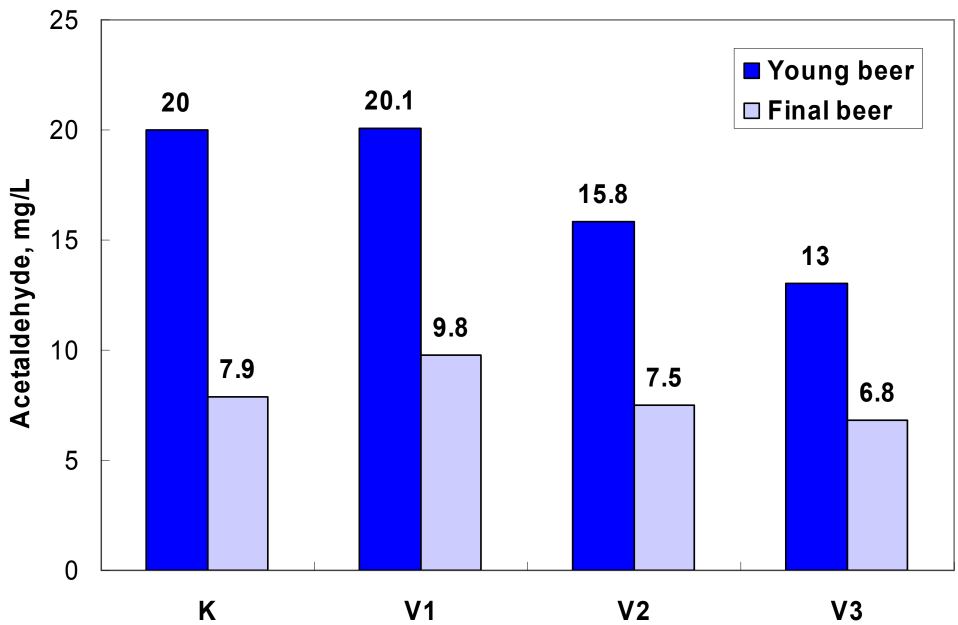

Figure 2. *Influence of the pitching rate on the acetaldehyde content in beer:*
K – 18×10^6 cells·mL^{-1}, V_1 – 10×10^6 cells·mL^{-1}, V_2 – 26×10^6 cells·mL^{-1},
V_3 – 35×10^6 cells·mL^{-1}

Data from Figure 3 indicate that in the percentage investigated, the malt substitution (with rice, sugar, or a combination of them) leading to α-amino nitrogen levels in the range 125 – 155 mg·L^{-1} does not have a substantial influence on the acetaldehyde content. The lowest value in the end of the primary fermentation is found in the control beer, which was produced with malt only. In all four final beers the acetaldehyde is within the normal range, i.e. below 10 mg·L^{-1}, and is significantly lower than the flavor threshold.

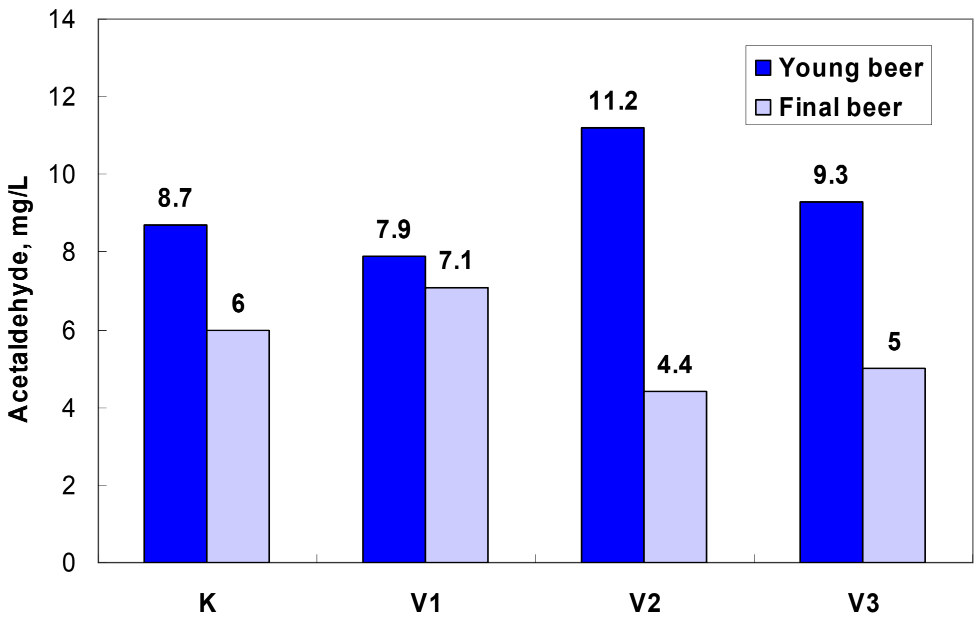

Figure 3. *Influence of the levels of free α-amino nitrogen on the acetaldehyde content in beer: K – 100% malt, V_1 – 90% malt and 10% sugar, V_2 – 90% malt and 10 % rice, V_3 – 90% malt, 5% sugar and 5% rice*

CONCLUSIONS

The higher fermentation temperature is known to enhance the reduction of the acetaldehyde concentration in the final beer. Beer, produced at an increased pitching rate (26 and 35×10^6 cells·mL^{-1}) exhibits lower acetaldehyde content. Therefore, altering the pitching rates and temperature could be effective methods for acetaldehyde concentration control. Substitution of 5 to 10% of the malt with rice, sugar, or a combination of the two induces a decrease in the α-amino nitrogen in the worts. In the range investigated (125 – 155 mg·L^{-1}) the amino nitrogen content does not influence the acetaldehyde concentration substantially.

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