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RESEARCH NOTE

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Maillard Browning Reaction of D-Psicose as Affected by Reaction Factors

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Abstract This study examined the effects of temperature, D-psicose concentration, pH, and various amino acids on the Maillard browning reaction of D-psicose and glycine mixture and compared browning color intensity with those of other sugars, such as sucrose, D-glucose, D-fructose, and D-tagatose. When D-psicose (0.1 M) and glycine (0.1 M) mixture was heated at 70-100°C for 5 hr, the absorbance at 420 nm increased with increasing reaction temperature and time. The Hunter a, b values, and color difference (ΔE) increased with increasing D-psicose concentration and pH within the range of pH 3-7 except at pH 6, while the L value decreased. The rate of Maillard browning reaction was in order of D-tagatose>D-psicose ≒ D-fructose>D-glucose>sucrose. The browning color intensity of the D-psicose-basic and non-polar amino acids mixtures was higher than that of the D-psicose-acidic amino acids.

Keywords: D-psicose, sweetener, Maillard browning reaction

Introduction

The consumption of sucrose has resulted in several nutritional and medical problems, including diabetes, obesity, atherosclerosis, and dental caries, which are related directly or indirectly (1). Therefore, various types of natural low calorie sweeteners have been examined as sugar substitutes. D-Psicose, a C-3 epimer of D-fructose, has recently attracted considerable attention on account of its low calorie level and various clinical effects (2-5). However, the biological functions, physicochemical properties, and food applications of D-psicose have not been established due to its very small quantities in nature and high cost.

Many foods cause a browning reaction during processing. When a non-enzymatic browning reaction occurs in the presence of nitrogenous compounds, it is known as the Maillard reaction, whereas a caramelization reaction occurs in absence of nitrogenous compounds. The Maillard browning reaction affects flavor development, texture alteration, anti-nutritional value, particularly the loss of essential amino acids, such as lysine, and brown color formation. Maillard reaction is influenced by a variety of factors, such as the types and concentration of sugars and amino acids, temperature, pH, time, etc (6-12).

Recently, research on D-psicose has focused on a manufacturing method or its nutritional effects. Although D-psicose might help reduce the caloric intake, its physiological properties as a sweetener have not been evaluated. In addition, the physicochemical properties of D-psicose, particularly Maillard browning reaction, need to be evaluated before it can be applied as a sugar substitute in the food industry. Therefore, the aims of this study were to examine the effects of the Maillard reaction parameters, such as reaction temperature, time, and pH, on the Maillard browning reaction in a D-psicose and glycine mixture and to compare Maillard reaction rate of D-psicose with those of other sugars, such as sucrose, D-glucose, D-fructose, and D-tagatose.

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Materials and Methods

Materials Sugars (D-fructose, D-glucose, and sucrose), amino acids (glutamic acid, isoleucine, tyrosine, alanine, leucine, methionine, histidine, aspartic acid, lysine, tryptophan, serine, phenylalanine, valine, proline, asparagine, cysteine, glycine, glutamine, arginine, and threonine), and other chemicals for the experiments were purchased from Sigma-Aldrich (St. Louis, MO, USA). D-Tagatose and D-psicose were supplied by the Department of Bioscience and Biotechnology, Konkuk University (Seoul, Korea).

Effects of temperature, D-psicose concentration, and pH on the Maillard browning reaction of D-psicose For the effect of temperature on the Maillard browning reaction, D-psicose (0.1 M) and glycine (0.1 M) mixture in a test tube (20 mL) was placed in a water bath at 70, 80, 90, and 100°C for 1-5 hr, respectively (8,9). The test tubes were removed at 1 hr intervals for analyses during the experiment. In order to test the effect of the D-psicose concentration on the Maillard browning reaction, D-psicose was dissolved in distilled water at concentrations of 0.1, 0.2, 0.4, and 0.8 M. This mixture was transferred into a tightly closed screw capped tubes, respectively. Test tubes containing the reaction mixture were heated in a shaking water bath at 100°C for 5 hr. For the effect of pH on the Maillard browning reaction, D-psicose (0.1 M) and glycine (0.1 M) mixture was adjusted to pH 3, 4, 5, 6, and 7 using 0.1 M NaOH and 0.1 M HCl. The resulting mixture was transferred to tightly closed screw capped test tubes, which were heated in a shaking water bath at 100°C for 5 hr, respectively.

Effect of types of amino acid on the Maillard browning reaction In order to test the effect of the type of amino acid on the Maillard browning reaction, 0.2 M D-psicose and 0.1 M each amino acid (glutamic acid, isoleucine, tyrosine, alanine, leucine, methionine, histidine, aspartic acid, lysine, tryptophan, serine, phenylalanine, valine, proline, asparagine, cysteine, glycine, glutamine, arginine, and threonine) mixtures were dissolved in distilled water with pH adjustment to 9, and transferred into tightly closed screw capped test tubes. The test tubes were then heated in a shaking water bath at 100°C for 5 hr.

Measurement of browning color intensity After heating, the test tubes were cooled immediately in tap water. The color intensity of each mixture from a mixture of D-psicose and glycine was determined at 420 nm using a UV-vis spectrophotometer (DU 650, Beckman Coulter Inc., Fullerton, CA, USA). The Hunter L (lightness), a (+ redness to − greenness), and b (+ yellowness to − blueness) values were measured using a color difference meter (CT-320; Minolta Co., Osaka, Japan). The instrument was calibrated using a standard plate (L=92.30, a=0.31, and b=0.33). The color difference (ΔE) was calculated using the following equation:

$$\Delta E=[(L_1-L_0)^2+(a_1-a_0)^2+(b_1-b_0)^2]^{1/2}$$

Where L_0, a_0, and b_0 are Hunter color values of standard plate and L_1, a_1, and b_1 are experimental Hunter color values of D-psicose and glycine mixture.

Results and Discussion

Effects of temperature, D-psicose concentration, and pH on the Maillard browning reaction Effects of temperature, D-psicose concentration, and pH on the Maillard browning reaction of D-psicose were examined by measuring the absorbance at 420 nm and the Hunter color values. Figure 1A shows the absorbance of the D-psicose and glycine mixture heated to 70, 80, 90, and 100°C for 5 hr. The absorbance of the heated D-psicose and glycine mixture increased with increasing reaction temperature and time. The absorbance of an unheated D-psicose and glycine mixture was 0.001, which increased slightly to 0.004, 0.010, 0.066, and 0.238 at 70, 80, 90, and 100°C after heating for 5 hr, respectively. The absorbance at 100°C was higher than that at the lower temperatures.

Figure 1B shows the change in the Hunter color values in 0.1, 0.2, 0.4, and 0.8 M D-psicose and 0.1 M glycine mixtures at 100°C. As the concentration of D-psicose increased, the Hunter a, b, and ΔE values increased from 3.80±0.12 to 36.41±0.74, 15.68±0.95 to 41.89±0.25, and 13.17±1.04 to 62.05±0.95, respectively, while the L value decreased from 89.34±0.54 to 59.74±0.69.

D-Psicose and glycine mixture was prepared with a 0.1 M HCl and 0.1 M NaOH solution at pH 3, 4, 5, 6, and 7, respectively. Figure 1C shows the Hunter color values of this resulting mixture heated at 100°C for 5 hr. Because the pH of most food stuff is below pH 7, the effect of pH on Maillard browning reaction was measured at pH 3-7. The browning reaction accelerates with increasing pH in the range of pH 3-8 due to an increase in the reactivity of the amino acid (13). A similar trend was observed in this study,

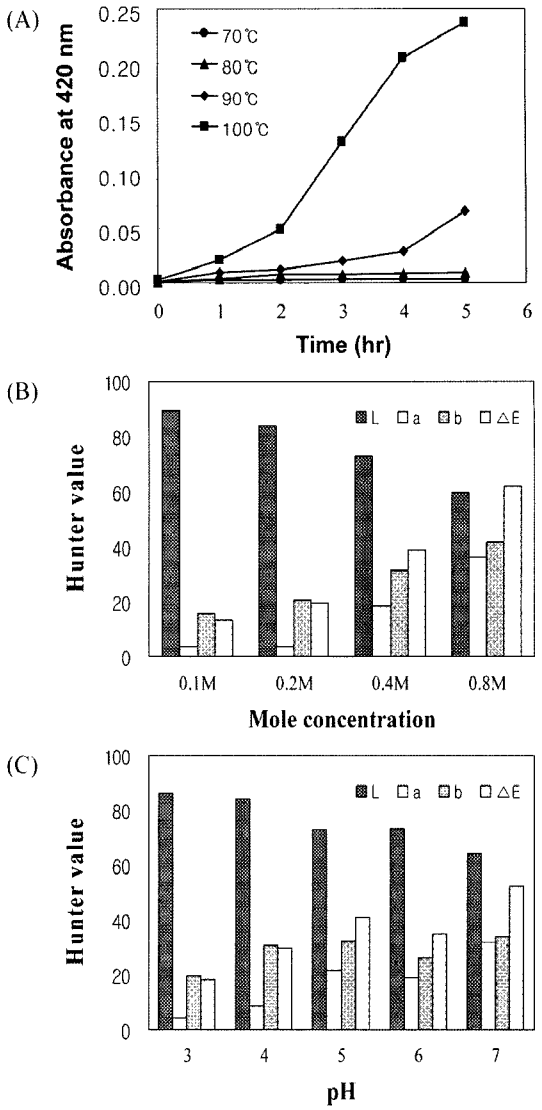

Fig. 1. Effects of temperature (A), D-psicose concentration (B), and pH (C) on the Maillard browning reaction of D-psicose and glycine mixture.

and it was obvious that the browning reaction of the D-psicose and glycine mixture is related to pH. The Hunter a, b, and ΔE values increased slightly from pH 3 to 7 except at pH 6, and it was highest at pH 7. In contrast, the L value decreased with decreasing pH from pH 7 to 3, except for a slight increase at pH 6. These results are in good agreement with those as described by Ryu *et al.* (14). They reported that the slightly decreased browning at pH 6 may be due to the decreased mobility of glycine at pH 6 (isoelectric point of glycine).

Figure 2 shows the absorbance of the sugar-glycine mixtures heated to 100°C for 5 hr. The absorbance of sugar-glycine mixture heated at 100°C for 5 hr reached 0.018±0.001, 0.065±0.004, 0.238±0.002, 0.519±0.039, and 0.238±0.004 in sucrose, D-glucose, D-fructose, D-tagatose, and D-psicose, respectively. Maillard browning reaction of D-psicose was faster than those of sucrose and D-glucose, and showed similar reaction rates to D-fructose. D-Tagatose showed faster reaction rate than that of D-psicose. Only reducing sugars participate in Maillard

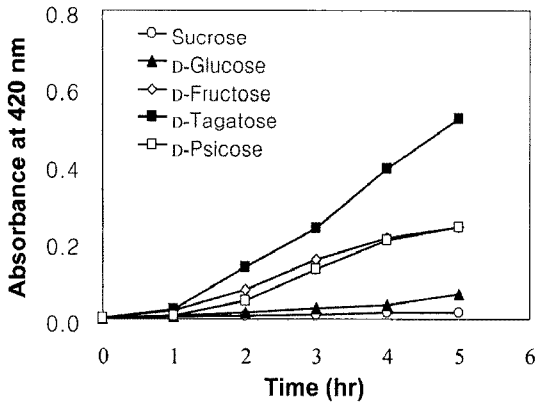

Fig. 2. Effect of kinds of sugars on the Maillard browning of sugar and glycine mixture at 100°C for 5 hr.

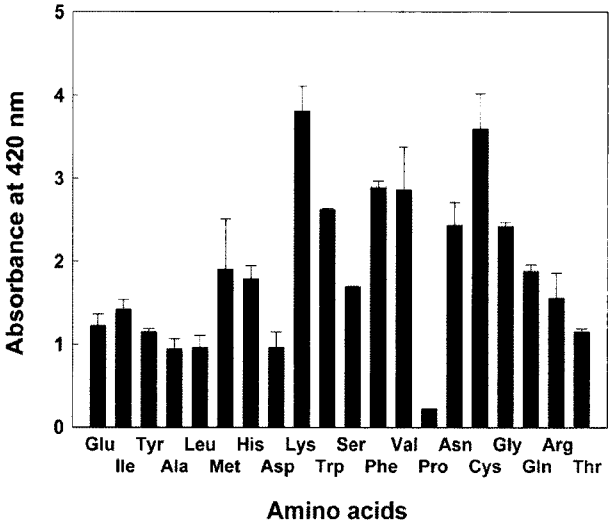

Fig. 3. Effect of the type of amino acid on the Maillard browning reaction of a D-psicose and amino acid mixture at 100°C for 5 hr.

browning reaction. Sucrose is a non-reducing sugar, which leads to the lowest Maillard browning reaction.

Figure 3 shows the effect of the type of amino acid on the Maillard browning reaction of D-psicose and amino acid mixture, as measured by the absorbance at 420 nm. D-Psicose and lysine showed the highest absorbance during the Maillard browning reaction, while the D-psicose and proline showed the lowest. In general, the absorbance of D-psicose-basic and non-polar amino acids (lysine, arginine, histidine, phenylalanine, valine, isoleucine, methionine, and tryptophan) mixtures were higher than that of D-psicose-acidic amino acid (such as aspartic acid and glutamic acid) mixtures (7). This suggests that the type of amino acid influences the color intensity of the Maillard browning reaction.

In conclusion, it was shown that D-psicose participated in Maillard browning reaction with the same characteristics as other sugars. Maillard browning reaction of D-psicose was dependent on reaction temperature and time, D-psicose concentration, and pH. The rate of Maillard browning reaction of D-psicose was compared with other sugars, which was in order of D-tagatose>D-psicose≒D-fructose>D-glucose>sucrose. The type of amino acids affected the Maillard reaction of D-psicose.

Acknowledgments

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