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Effects of heating on thermal denaturation of several green vegetables suitable for dehydration

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A b s t r a c t. Most vegetables suitable for dehydration are thermo-labile materials. In order to find an appropriate dehydrating technology by means of thermal analysis, a differential scanning calorimetry (DSC) has been used for studying temperature denaturation processes. Four vegetables (kidney bean, sweet pepper, Chinese cabbage, Chinese onion) with five moisture contents were chosen for the DSC tests. Five heating rates were used for observing changes in denaturation. Finally, effects of blanching, breed characteristics and an instantaneous increasing temperature on denaturation were discussed.

K e y w o r d s: vegetable, dehydration, thermal analysis, differential scanning calorimetry

INTRODUCTION

Most vegetables suitable for dehydration are thermo-labile materials. At present, determination of thermal denaturation of some dehydrated vegetables is mainly practical [1-6]. In order to eliminate technological errors, it is necessary to study thermal denaturation using advanced research methods. In the present study, differential scanning calorimetry has been used for determining denaturing temperature levels with the view of finding an appropriate dehydrating technology by means of thermal analysis. Four vegetables with five moisture levels were used for the differential scanning calorimetry (DSC) tests. Five heating rates were applied for observing changes in denaturation.

The following three stages of thermal food denaturation can be distinguished: protein denaturation, starch gelatinization and water (or ice) phase change. Most of the research on the subject concentrate on various pure protein and starch forms. Only few research works considered the three phases quoted above. The basic assumption of the present study is that a vegetable can be treated as a chemical compound.

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MATERIALS AND METHODS

Material and testing procedure

Four kinds of fresh vegetables suitable for dehydration, i.e., kidney bean (*Phaseolus vulgaris* L.), Chinese cabbage (*Brassica chinensis* L.), sweet pepper (*Copsicum annum* L.) and Chinese onion (*Allium fistulosum* L.), were purchased from the local market. Various pre-treatment methods were selected for the present test. Samples, with a weight of 9~10 mg, were sealed in a box and placed in a DSC furnace for the testing.

Testing equipment

A DSC7 analysing apparatus with an accuracy of ±0.1°C, produced by Perkin Elmer was chosen for the tests (see in Fig. 1). A German micro-balance, Sartorius, with an accuracy of up to ±0.1 mg was used for weighing. An EB-330MOC moisture meter made in Japan, with an accuracy of ±0.1%, was used to determine sample moisture content. Five different moisture levels were obtained with a Consol 24 freeze-dryer made in the USA. Moisture content was expressed at wet basis.

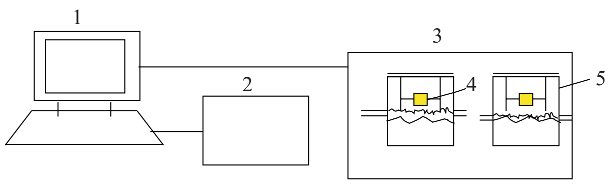

Fig. 1. Set-up of the DSC apparatus: 1 - personal computer, 2 - printer, 3 - sampling furnace, 4 - sample box, 5 - reference box.

Testing indices

The temperature (T_o) at the onset of denaturation and the peak denaturing temperature (T_p) were chosen as test indices. The higher the indices, the stronger the ability to resist heat denaturation. Dehydrating temperature levels during drying can be determined for individual vegetables.

RESULTS AND DISCUSSION

Heat denaturation tests for various moisture levels

Drying is a process of moisture changes. Heat denaturation tests were carried out on four green vegetables with different moisture contents in order to simulate the effect of moisture changes on heat denaturation after blanching. The results are shown in Fig. 2. The T_o and T_p values for all four vegetables were lower when moisture was at a medium level, and higher at high or low moisture levels. Moreover, the values at high moisture are higher than those at low moisture. Hence, it seems reasonable to apply high temperature at high moisture, and low temperature at medium moisture levels and medium temperature at low moisture levels. The above does not influence determination of drying temperature at the later drying stages as compared to traditional technology of vegetable dehydration. At present, a common drying temperature for the four samples studied is 60~70°C. However, Fig. 2 shows T_o>55°C and T_p>80°C, which means that the temperature of drying for all four vegetables could be increased by 5~10°C at high and medium moisture contents, and by 10~30°C at low moisture, if lower denaturation levels (less than 5%) are allowed.

Heat denaturation tests at various heating rates

In order to save energy by changing temperature, it is necessary to study heat denaturation at various heating rates. Five heating rates of 5, 10, 20, 40 and 60°C min^{-1} were adopted for the tests on kidney bean. The results are shown in Fig. 3. It is clear, that the higher the heating rate, the higher T_p value for kidney bean. The effect of the heating rate on T_p at high moisture is obviously more significant than at a low moisture content. It seems plausible that a fast-heat drying technology at high moisture and a slow-heat technology at a low moisture contents should be adopted. The above effect could be due to water plasticization.

Effects of blanching and strains on heat denaturing temperature district (HDTD)

The DSC curves for kidney bean and sweet pepper before and after blanching are shown in Fig. 4. After blanching of the samples, the T_p values for the two vegetables increase significantly, which indicates that blanching is of benefit for raising the ability to resist heat denaturation. Differences among vegetable strains should be considered when selecting heat denaturation temperature. It is well known that the contents of denatured material is different in the four vegetables studied. On the other hand, kinds and contents of inorganic salts influences the peak position. Hence, it is possible to apply various rates and values.

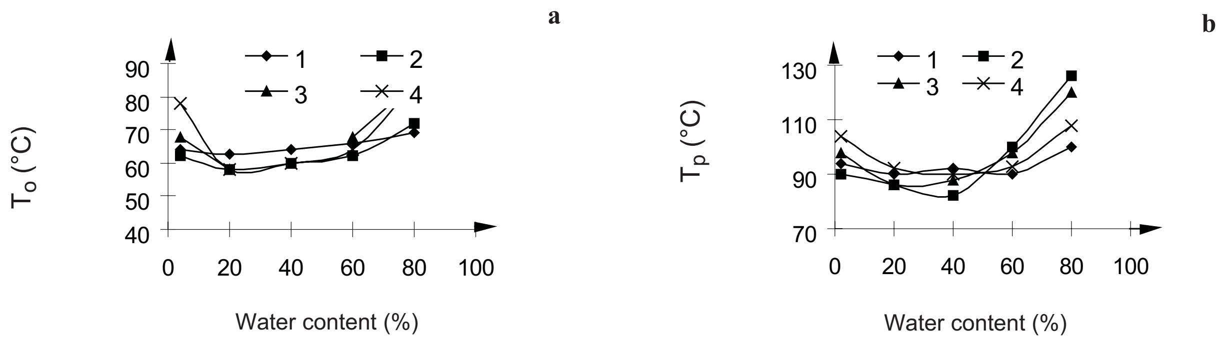

Fig. 2. Changes in the denaturing temperature levels at five moisture contents studied (a heating rate of 10°C min^{-1}): a - effect on T_o; b - effect on T_p. 1 - Chinese onion, 2 - kidney bean, 3 - Chinese cabbage, 4 - sweet pepper.

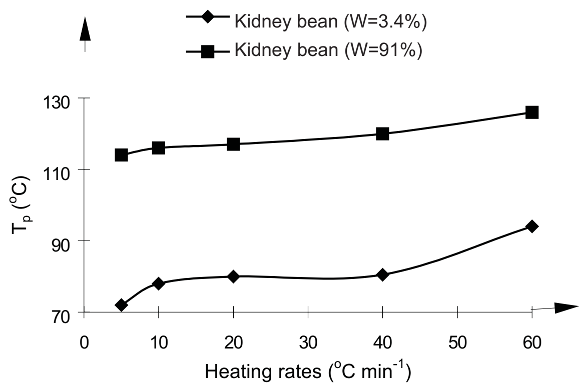

Fig. 3. Changes in the denaturing temperature in the five tested heating rates.

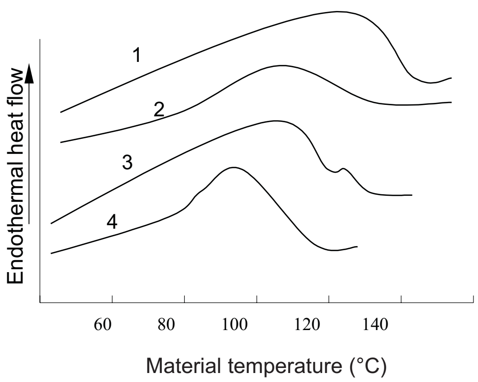

Fig. 4. Effects of blanching on denaturation (a heating rate of 10°C min^{-1}). 1 - sweet pepper after blanching, 2 - sweet pepper before blanching, 3 - kidney bean after blanching, 4 - kidney bean before blanching.

Effect of an instantaneous increasing temperature (IIT) on HDTD

At present, application of instantaneous increasing temperature for dehydration of powdered or thin materials is limited. In our study, kidney beans with three moisture contents (91, 72 and 3.4%) was used for simulating IIT dehydration (the sample box was not sealed). The effects on heat denaturation are shown in Fig. 5. With an increase in moisture and application of IIT (100°C min^{-1}, more than 200°C), the HDTD of the samples moves towards the high temperature range. The HDTD under low moisture (3.4%) is in the range of 150°C. Hence, it is possible to adopt IIT as a method of increasing productivity at an initial stage of dehydration.

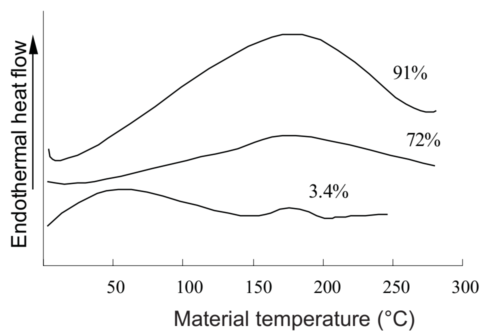

Fig. 5. Effects of IIT on denaturation (a heating rate of 80°C min^{-1}).

CONCLUSIONS

1. The T_o and T_p values for all four vegetables were low at a medium moisture content and high at a high or low moisture content

2. The higher the heating rate, the higher T_p value for kidney bean.

3. Blanching is beneficial as it raises the ability to resist heat denaturation, and contents of denatured materials which differentiates denaturation processes in four vegetables.

4. With an increase in moisture in the condition of IIT (100°C min^{-1}, more than 200°C), the HDTD of the samples moves towards high temperature ranges.

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