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Calorimetric measurements on the swelling of green tea

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Abstract

The heat of swelling of green tea with water was measured. The heat of swelling decreased exponentially with increasing water content and assumed negative values at $>0.08\,g\,g^{-1}$ of water content. The dissolution of green tea extracts was endothermic and the swelling of tea ghost (tea grounds) was exothermic. When the curves for dependence of water content on the heat of swelling of tea ghost and that for the heat of dissolution of tea extract are combined, the synthesized curve agreed quite closely with the curve for the heat of swelling of tea.

We thus conclude that the heat of swelling of tea is the sum of the heat of swelling of hydration of the insoluble materials and the heat of dissolution of soluble components of tea.

Keywords: Kinetics of swelling; Swelling of green tea; Heat of swelling

1. Introduction

It is generally accepted [1–4] that the swelling of dried foods in water involves an exothermic reaction because of the accompanying hydration of hydrophilic groups in the food substances. In our previous paper [5], however, the swelling of dried Kombu (*Laminaria japonica*) was shown to be endothermic. The reason, we pointed out, was that a large proportion of the soluble components, ≈ 50% in Kombu, elutes into water, and the reaction of the elution is endothermic. As a result, the apparent thermal behavior is the sum of the heat of hydration of hydrophilic groups and the heat of dissociation of soluble substances. About 35–40% of dried tea comprises soluble

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components such as amino acids, theanie and catechins [6]. Therefore, the heat of swelling of green tea is assumed to be affected by soluble components, as in Kombu.

In the present studies, the heats of swelling of green tea, green tea extracts, and green tea ghost were measured, and a discussion is presented on the swelling of green tea.

2. Experimental

Dried green tea of the common grade "Sen-cha" was secured from The Tea Institute of Kagoshima Prefecture.

Because the amounts of components such as amino acids, caffeine, theanine and catechins are not evenly distributed in each leaf, the green teas were ground and sieved and the 100–150 mesh fraction was used. The theoretical background and the methods of measurement were reported in a previous paper [5]. Green tea ghost (residue) was prepared by boiling the tea in a large amount of water for 30 min to remove the water-soluble components, and was then air dried. Extracts of green tea were prepared from the above extracted broth by freeze drying.

Water contents of the samples were adjusted over different concentrations of various salts, silica gel or phosphorus pentoxide. Final water contents were measured after drying at 105°C.

Heats of swelling were measured with a twin conductive calorimeter (Tokyo Riko Model TCC-21).

3. Results

3.1. Heat of swelling of green tea and its dependence on moisture content

Abount 50 to 100 mg of the dried green tea sample was enclosed in a thin glass ampoule. After thermal equilibrium was reached, the sample was thrown into 20 cm^3 of water at 20°C. Some of the thermograms are shown in Fig. 1.

As shown in Fig. 1(a) and (b), the swelling of green tea with a water content below 0.07 $g\ g^{-1}$ is exothermic. By contrast, the swelling of green tea with a water content of 0.099 $g\ g^{-1}$ is endothermic (Fig. 1(c)).

To clarify the above phenomena, the effects of the moisture contents of green tea were examined. As shown in Fig. 2, the heats of swelling of green tea with different water contents showed an exponentially decreasing curve and negative values at water contents $> 0.08\ g\ g^{-1}$.

From the above results, we suggest that the heat of swelling of green tea is due not only to hydration of hydrophilic components but also to some endothermic reactions which occur at the same time.

3.2. Heat of swelling of "green tea ghost"

In green tea, various amino acids, theanine, caffeine, catechins and some other water-soluble substances are present in fairly large quantities [2]. The water-soluble

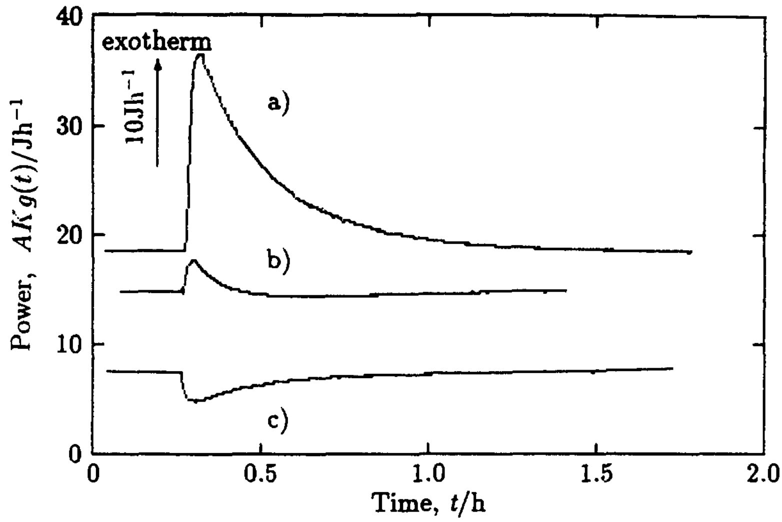

Fig. 1. Thermograms of swelling of green tea: (a) water content 30.0 mg g^{-1} and 259.5 mg dry weight; (b) water content 70.0 mg g^{-1} and 287.9 mg dry weight; (c) water content 99.0 mg g^{-1} and 268.8 mg dry weight. After the system had reached thermo-equilibrium at 20°C, the sample was thrown into 20 cm^3 of distilled water.

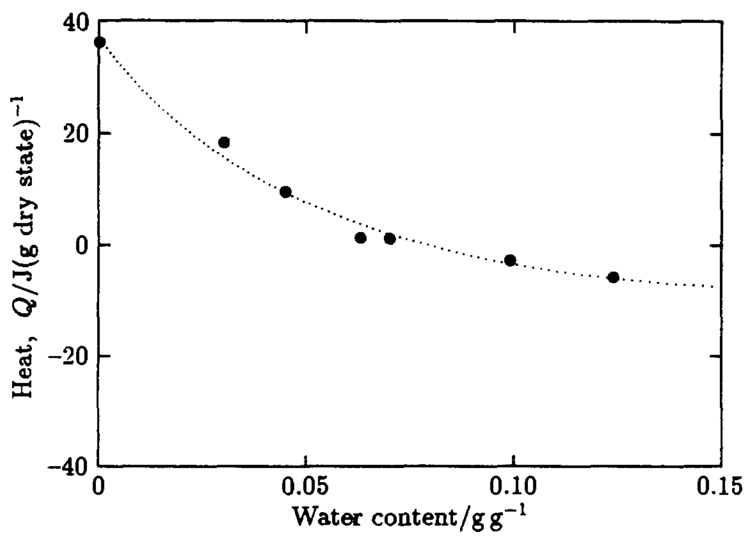

Fig. 2. Effects of moisture content on the heat of swelling of green tea.

substances, the green tea extract and insoluble substances, the green tea ghost, were separated. Green tea was gently boiled for 30 min in a large amount of water. The insoluble green tea ghost was dried and its moisture content was determined, then the heats of the swelling were measured at 20°C.

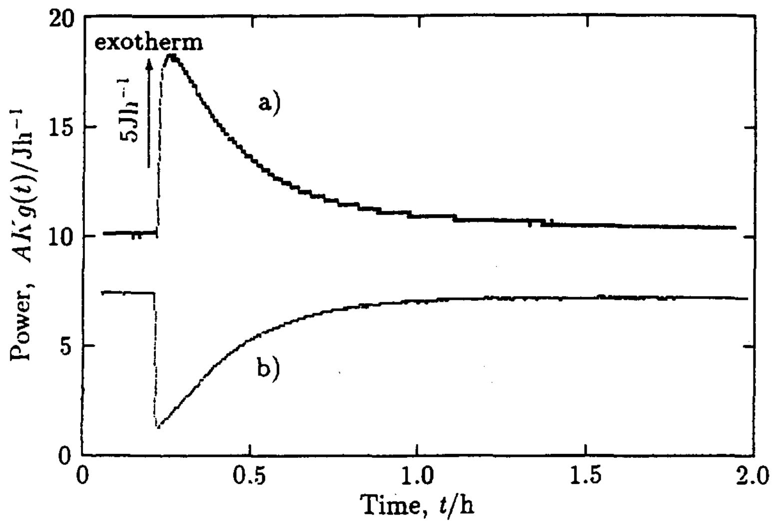

Fig. 3. Thermograms of swelling of green tea ghost and extract fractions. The dotted line is fitted by a single exponential function. (a) Green tea ghost; water content 63.0 mg g^{-1} and 108.2 mg dry weight; (b) green tea extract; water content 61.6 mg g^{-1} and 50.3 mg dry weight. After the system had reached thermo-equilibrium at 20°C, the sample was thrown into 20 cm^3 of distilled water.

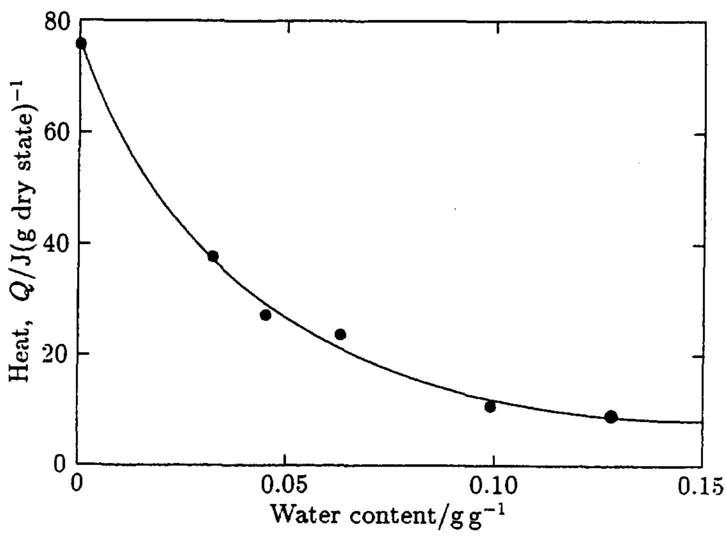

Fig. 4. Effects of moisture content on heat of swelling of the green tea ghost.

As shown in Figs. 3 (a) and 4, the swelling of the green tea ghost was exothermic and the heats decreased with increasing water content. The solid line in Fig. 4 is the best fit curve obtained by least squares treatment with a simple exponential function.

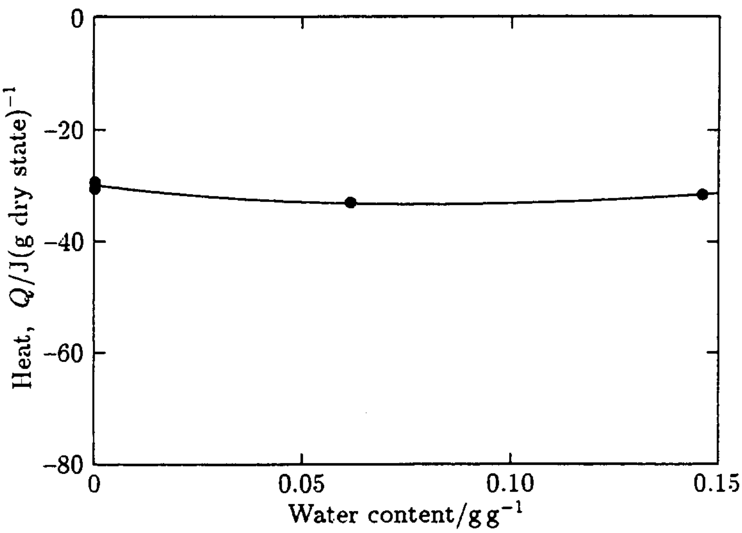

Fig. 5. Effects of moisture content on heat of swelling of green tea extract.

3.3. Heat of dissolution of green tea extract

Water-soluble substances (green tea extract) were obtained from the tea broth by freeze-drying. The heats of dissolution of green tea extract were measured after preparation of the water-soluble fraction. As shown in Fig. 3 (b), the heat of dissolution was endothermic, and the values did not vary much with water content; see Fig. 5.

4. Discussion

The main constituents of green tea are polysaccharides; these are hydrophilic polymers. Water may react with surface and internal polysaccharides of green tea by hydrogen bonding.

As shown in Fig. 2, with up to 0.08 g g^{-1} of water content, heats of swelling of the dried green tea were exothermic; heats of swelling were endothermic above 0.08 g g^{-1}. From these results, it is assumed that the heat of swelling of green tea must arise from both the interaction of polysaccharides with water and some other reactions.

Considerable amounts of water-soluble components such as amino acids, caffeine, theanine and catechins, up to 40% by weight, are contained in green tea [6]. As shown in Fig. 5, the dissolution of the green tea extract was endothermic and the absolute values did not vary greatly with water content. In contrast, the swelling of the green tea ghost was exothermic and the heat of swelling decreased exponentially with increasing water content, as shown in Fig. 4.

If the elution efficiency for the dissolution of green tea and the heat of swelling are taken as α and Q_{tot}, the heat of swelling is the sum of the heats for the tea extract Q_{ext} and

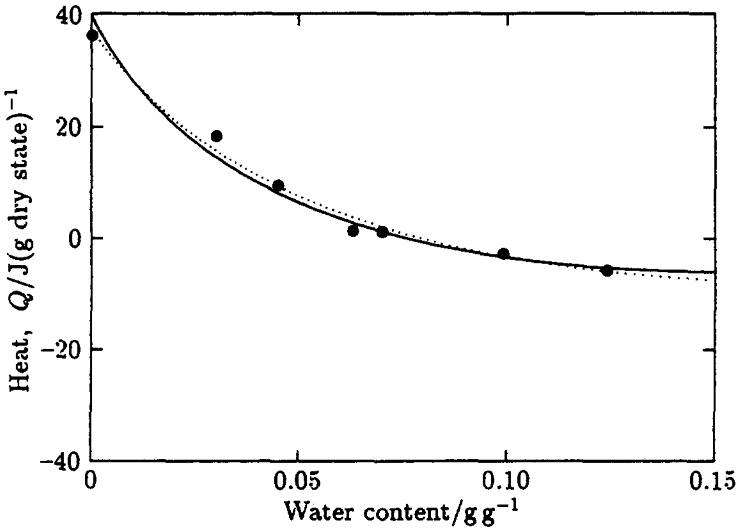

Fig. 6. Additivity of heats of the ghost fraction and the extract of green tea. The solid line is fitted by regression curve analysis and the dotted line is fitted by a single exponential function.

the ghost Q_{gho}. Thus, the heat of swelling can be expressed as

$$Q_{tot} = \alpha Q_{ext} + (1 - \alpha) Q_{gho}$$

An elution efficiency $\alpha = 34.3\%$ is obtained from the best fitting curves of Figs. 4 and 5, and gives the solid line in Fig. 6. The observed and the best fitting curves agree quite closely. Accordingly, we may conclude that the heat of swelling of green tea is the sum of the endothermic reaction of hydration of the hydrophilic skeleton of the insoluble material, the green tea ghost, and the exothermic reaction of dissolution of water-soluble material. This is similar to the observation made for Kombu [5].

5. Conclusions

Large amounts of water-soluble materials, such as amino acids, are contained in green tea. We can separate green tea into two fractions, one is water-soluble and the other is the insoluble green tea ghost. The heat of dissolution of water-soluble materials is endothermic and the heat of swelling of the green tea ghost is exothermic. By addition of the heat for the two fractions, we obtained the heat of swelling of green tea. From the above results, we conclude that the heat of swelling of green tea is the sum of the heat of hydration of the insoluble skeleton of tea and the heat of dissolution of the soluble materials in tea. The endothermic reaction of dissolution of water-soluble materials in green tea contributes greatly to the observed heat of swelling.

References

[1] W.G. Schrenk, A.C. Andrews and H.H. King, Ind. Eng. Chem., 39 (1947) 113.
[2] R. Collison and A. Dickson, Stärke, 23 (1971) 45.
[3] T. Kanemitsu and K. Miyagawa, Cereal Chem., 51 (1974) 336.
[4] T. Kanemitsu and K. Miyagawa, Cereal Chem., 53 (1976) 821.
[5] K. Miyagawa, I. Ogawa and H. Yamano, Thermochim. Acta, 257 (1995) 75.
[6] M. Nakagawa, T. Anan and N. Ishima, Study Tea, 17 (1981) 69.