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Controlled Water Content, Crispness and Retrogradation of Fried Coatings with Monosodium Glutamate-compounded Starch

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Abstract: A mono sodium glutamate (GluNa)-compounded starch prepared by autoclaving a mixture of tapioca starch and GluNa under limited water content was applied to improve the physical properties of the fried coatings of Vienna sausages. The GluNa-compounded starch could reduce the total and surface water contents of the fried coatings, retard retrogradation, and maintain a fragile porous structure over 24–48 h storage at 25°C and a relative humidity of 70%. Crispness of the fried coatings also could be enhanced with the GluNa-compounded starch, and was maintained during 24 h-storage. It is thus concluded that the GluNa-compounded starch could be effectively applied to improve the crispy texture of fried coatings.

Key words: amino acid-compounded starch, crispness of fried coatings, improved physical properties, sodium glutamate, heat-moisture treatment

The amount of consumption of fried foods has been increasing recently. They are popular and often sold at delis and take-out food markets in Japan.1,2) Frying is a very useful processing method, because it brings about many beneficial changes in foods due to the gelatinization of starch, denaturation and coagulation of protein, development of characteristic aromas and browning, as well as textural changes due to dehydration.3) The textural changes, in particular the crispness of the fried coatings that appear after vaporization of water at a high temperature are extremely important because they strongly influence the quality of fried foods. However, triggered by a migration of water from internal food material, the fried coatings progressively lose crispness and retrogradation of starch, resulting in a deteriorated quality of fried foods and a shortening of their shelf life. It is therefore very desirable to control the vaporization and mobility of water in order to maintain crispness, and to control retrogradation of starch in the fried coatings in an appropriate manner.

In order to improve crispness of the fried coatings, such acid-treated starch, heat-moisture-treated starch, cross-linked and gelatinized starch, powdered silicon dioxide and isolated soybean protein have been blended with wheat flour.4,5) However, no satisfactory improvement in crispness could be achieved with these methods because they could not prevent the crispness of the fried coatings being progressively lost due to migration of water from internal food material.

We previously demonstrated that compounding with charged amino acids by autoclaving a starch and amino acid mixture with a limited water content was an effective method to achieve a marked rise in the gelatinization temperature, large reductions in viscosity of starch paste and swelling of starch granule, and provide an improved paste with less residual moisture resulting from easy vaporization of the external water of the swollen starch granules.6,7) This suggests that compounding with a charged amino acid could contribute to providing a basis for controlling the vaporization of water from starchy batter during frying in hot oil. However, in order to achieve improved crispness of fried coatings, it is necessary to clarify the contributive effect of the charged amino acid-compounding on the water vaporization and retrogradation of starch behavior of the fried coatings.

In this study, monosodium glutamate (GluNa), a commonly used amino acid in many foods, was used to prepare GluNa-compounded starch as a charged amino acid and to clarify that GluNa-compounded starch could achieve improved crispness and retrogradation of fried coatings from wheat batter in terms of a more weakened morphological structure, reduced moisture, raised mobility of water, reduced retrogradation, improved breaking property and enhanced broken sound.

MATERIALS AND METHODS

Materials. Hydroxypropylated tapioca starch [Yuri2; degree of substitution = 0.02 equivalent/glucose residue;
Preparation of GluNa-compounded starch. The GluNa-compounded starch was prepared according to the method previously described. In brief, starch (1 kg) was adjusted to 17% (w/w) moisture by the addition of an appropriate amount of distilled water and 1 mol of GluNa were well mixed in a retort pouch. The pouch was then tightly heat-sealed and autoclaved at 120°C for 60 min. The heated product was passed through a 100 mesh-screen to obtain GluNa-compounded starch.

Preparation of fried Vienna sausage. Wheat flour (68.5 g), 30 g of the GluNa-compounded starch and 1.5 g of baking powder were mixed with 80 mL of cold water (15°C) while stirring with a whisker for 1 min to give a mixed wheat batter. A wheat batter composed of wheat flour (98.5 g), 1.5 g of baking powder and 80 mL of cold water were also used as the control.

Vienna sausages lightly coated with 1% of wheat flour based on those weight were entwined with the batter, and then fried with a frymaster RE17 (Manitowoc Company Inc., Shreveport, USA) at 170°C for 3 min. The fried Vienna sausages were washed with a stainless steel vat with an attached sieve for 10 min at room temperature to remove the excess oil. After collection in an another stainless steel vat, the fried Vienna sausages were stored for a given period in a cabinet controlled at 25°C and a relative humidity of 70% until the required measurements were performed. The control sample was also prepared in the same manner just described, except for using a batter without the GluNa-compounded starch.

NMR measurement. The fried coatings from the fried Vienna sausages stored at 25°C and a relative humidity of 70% for 2–24 h were cut into about 2 × 2 × 2 mm³ pieces with a knife, and then packed in a sample tube while tapping. The T2 relaxation time of each sample was measured according to the CPMG pulse sequence method by using a pulsed NMR JUM-MU25A instrument (Jeol Ltd., Tokyo, Japan). Differential scanning calorimetry (DSC). The thermal characteristics of the GluNa-compounded starch were determined using an SSC5020 DSC-6100 instrument (SII NanoTechnology Inc., Chiba, Japan), as described previously. After the fried coatings samples stored at 25°C and a relative humidity of 70% for 1–48 h were lyophilized, each dried sample was thoroughly defatted with ethanol, and then pulverized with a millmixer IFM-800DG (Iwatani Corporation, Tokyo, Japan). The powdered sample was sieved with a 100-mesh sieve, and the passed fraction was re-defatted with ethanol to obtain a dried sample. Each sample (10 mg) was weighed in a silver capsule (70 μL). The capsule was hermetically sealed after 40 μL of distilled water had been added, and then heated from 15 to 140°C at a rate of 5°C/min.

Distilled water was used as a reference, and duplicate measurements were performed. The onset temperature (To), peak temperature (Tp), conclusion temperature (Tc) and enthalpy change (ΔH) for re-gelatinization were evaluated from the obtained DSC curve.

RESULTS AND DISCUSSION

Controlled water content and its mobility. Vienna sausages entwined with the GluNa-compounded starch-containing wheat batter were fried as an inner food material of a model fried food in this study because they are uniform in composition and size compared with other food materials. The total and surface water contents for the GluNa-compounded starch-containing fried coatings (GluNa-coatings) were evaluated after storage at 25°C and a relative humidity of 70% for 1–48 h, and compared with those of the control fried coatings without the GluNa-compounded starch by the Student’s t-test (p<0.05). The control fried coatings showed a relatively high total water content (about 23%) just after frying. There was a gradual decrease with storage time (Fig. 1), which was probably due to vaporization from the surface of the fried coatings. On the other hand, GluNa-coatings exhibited significantly lower total water content (about 6%) just after frying than that of the control fried coatings. This low water content is probably caused by accelerated vaporization with the GluNa-compounded starch, because the paste of the GluNa-
compounded starch exhibited easy water vaporization similar to that of free water resulting from the limited swelling of starch granules. However, the total water content of GluNa-coatings increased to about 15% after 6 h-storage, significantly lower than that of the control fried coatings, and then slightly decreased in a manner similar to that of the control fried coatings.

The surface water content of the control fried coatings was undetected just after frying, whereas it immediately increased up to about 15% within the first 4 h of storage due to transfer of water from Vienna sausages, and then gradually decreased (Fig. 1) probably due to vaporization, corresponding to the decreasing total water content just described. On the other hand, GluNa-coatings held no surface water during the first 4 h (Fig. 1). After that, the surface water content increased up to about 5% due to migration of the inner water, and then gradually decreased due to vaporization. The surface water content of GluNa-coatings was significantly lower than that of the control fried coatings over the whole storage time. The GluNa-compounded starch is therefore suggested to have made a large contribution to improving and maintaining crispness of the fried coating.

The T2 relaxation time was determined by pulsed NMR. GluNa-coatings exhibited significantly longer T2 relaxation times than those of the control fried coatings over all storage times (Fig. 2). This indicates that the GluNa-compounded starch could enhance mobility of water in the fried coatings due to the limited increase in the amount of external water among the limitedly swollen starch granules in the fried coatings, probably resulting in easy vaporization of the external water. The T2 relaxation time increased up to 8 h probably due to increased free water resulting from a transfer of water from the Vienna sausages, while it decreased after that, probably due to a reduced free water fraction resulting from the decreased water content following vaporization of water from the surface of the fried coatings.

Reduced retrogradation of starch.

The retrogradation behavior of GluNa-coatings stored at 25°C and a relative humidity of 70% for 1–48 h was evaluated by DSC. The control fried coatings showed no re-gelatinization enthalpy during the first 3 h-storage, whereas the enthalpy increased with the stored time after that (Fig. 3). This indicates that retrogradation of starch did not substantially occur during the first 3 h-storage, then it progressed with the stored time. However, when the GluNa-compounded starch was added to the batter, the enthalpy-undetectable period of the fried coatings was extended to 6 h. In addition, the GluNa-compounded starch could reduce the enthalpy change to about half that of the control fried coatings thereafter (Fig. 3). The GluNa-compounded starch could thus reduce retrogradation of starch in the fried coatings probably due to the decreased water content as described above.

Control of morphological structure.

The morphological structure of GluNa-coatings stored at 25°C and a relative humidity of 70% for 4–48 h was observed by a fluorescence microscope after the proteinaceous components were stained with fuchsin acid. The both of control and the GluNa-compounded starch-containing fried coatings showed a porous structure just after frying.
However, the control fried coatings developed many fibrous-like aggregates of protenaceous components after 4 h-storage, and construction of a stable network structure after 48 h-storage (Fig. 4) corresponding to the decrease in the total water content of the fried coatings. On the other hand, GluNa-coatings exhibited a fragile porous morphological structure without developing the fibrous-like aggregates or 3-dimensional network structure over the whole storage time, suggesting a contribution to a crispy texture.

Improved breaking property and crispness.

The breaking property of GluNa-coatings was evaluated using 30 mm-long pieces from the samples stored at 25°C and a relative humidity of 70% for 4–48 h. The hardness values at breaking for GluNa-coatings and the control coatings gradually increased during storage (Fig. 5), suggesting a decrease in fragility with storage time in both coatings. However, GluNa-coatings remained fragile during the first 4 h-storage, while GluNa-coatings were slightly harder than the control fried coatings. After 48 h, the control coatings became very hard probably due to development of a 3-dimensional network structure and recrystallization of starch as shown by the morphological results and DSC measurements, respectively, whereas GluNa-coatings did not become so hard, suggesting maintained crispness.

The chewing sound of the fried Vienna sausages stored at 25°C and a relative humidity of 70% for 24 h was recorded by a voice recorder. The wave spectra of the instantaneous sound at chewing obtained from the sound format data are shown in Fig. 6. The chewing wave spectrum of the control...
Fried coatings just fried showed three characteristic peaks at a frequency of around 1.4, 2.3 and 3.1 kHz, similar to that (data not shown) of fried potato chips. The crispy sound of the control coatings was largely lost during 10 h-storage as shown by a marked drop in each sound volume, and lost about 50% after 24 h-storage (Fig. 7). However, GluNa-coatings maintained a crispy sound even if stored for 24 h, corresponding to the retard and reduced retrogradation results, kept a fragile porous structure and showed lower increased hardness of the fried coatings blended with the GluNa-compounded starch as described above. This indicates that the GluNa-compounded starch made a large contribution to improving the crispness of the fried coatings.

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