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Research Article
Influence of the Incorporation of Potato Granule on Quick-Frozen Dumpling Wrappers

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Abstract
Background and Objective: Quick-frozen dumpling is widely consumed in China. Inclusion Potato Granule (PG) into dumpling wrappers will extend utilization of this cheap flour in the staple food. The objective of this study was to evaluate the feasibility of partial substitution of wheat flour with PG in the dumpling wrappers. **Methodology:** In this study, cooking qualities of dumpling wrappers containing different levels of PG were measured after storage at -20°C for 2 weeks. Their tensile parameters, calorimetric properties, water mobility and microstructure were investigated by using dough extensograph, Differential Scanning Calorimeter (DSC), Low-Field Nuclear Magnetic Resonance (LF-NMR) and Scanning Electron Microscope (SEM). **Results:** The results revealed that the resistance to extension, extension energy and extensibility remained almost unchanged when PG addition was not more than 7.5% of wheat flour. After PG addition, water became more movable, while freezable water content decreased, especially when PG addition was less than 7.5%. Microstructure of the PG dough wrappers became porous after freezing storage. Both water absorption ratio and cooking loss ratio of frozen PG dough wrappers decreased as PG content increased. **Conclusion:** On a whole, when the PG addition was not more than 7.5%, quick-frozen dumpling wrappers with acceptable cooking qualities can be achieved.

Key words: Dumpling, potato granule, DSC, SEM, LF-NMR, extensograph, cooking characteristics, freezing, dough, water mobility

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the third most important food crop in the world after rice and wheat in terms of human consumption. It has an annual world production of 390 million tons, China being the leading producer[1]. Potato Granule (PG) is a pre-cooked, dehydrated potato product in particulate form[2]. Owing to its nutrition and original flavor of the fresh potato, PG is a good raw material and additive in the food industry. There are some reports regarding the breads supplemented with potato flour[3], dumpling wrappers[4] and noodles[5] supplemented with potato starch.

Dumpling is a traditional Chinese food. Commercial dumplings are usually frozen to aid in distribution and quality preservation. Quick-frozen dumplings contribute an important part of the ready-to-eat processed food in China. Both wrappers and fillings contribute to the final quality of cooked dumplings. Dumpling wrappers are usually shaped from non-fermented wheat flour dough. Freezing damages dumpling wrappers. In order to maintain cooking quality of dumpling wrappers after freeze storage, waxy wheat flour[6] and acetylated potato starch[7] have been investigated to be incorporated into dough formulation.

Ice formation and distribution affect microstructure and rheology of wheat flour dough[8,9] and quality of dough-based foods[10]. As ice crystal formation is associated to freezable water present in food matrix, ingredients with strong water-binding capacity, which can yield large amount of non-freezable water and thus reduce the formation of ice crystal, are desirable in frozen products[11]. Differential Scanning Calorimetry (DSC) is an often-used technique to measure freezable water content in foods[6,7]. Tananuwong and Reid[12] reported that potato starch has less freezable water after gelatinization[12]. Then, if PG is incorporated in dumpling wrapper dough, the gelatinized starch in PG should retard quality deterioration of dumplings during cold preservation. Additionally, potato starch has the ability to form clear and thick viscoelastic gel with higher storage and loss modulus than these of cereal starches[13]. It has been found that flour used for making quick-frozen dumplings should have high thermoviscosity[6]. The unique flavor of PG is another consideration for us to incorporate it in dumpling wrapper formulation.

The PG addition will inevitably dilute gluten network in wheat flour dough and modify dough rheology. Extensograpgh is widely used to characterize resistance and extensibility of dough. Extension energy and resistance of wrapper dough are related with firmness of boiled dumpling wrappers[14]. Water mobility plays key roles in the rheological behaviors of dough[15] and its products[16]. In recent years, Low-Field Nuclear Magnetic Resonance (LF-NMR) has been extensively applied to study water mobility of food products, in which water mobility was usually estimated by proton spin-spin relaxation time (T2)[15,17-20].

In this context, cooking characteristics of dumpling wrappers with different quantity of PG were measured after storage at -20°C for 2 weeks, then extensograph parameters, calorimetric properties, water mobility and microstructure of the wrapper dough were determined. The present study aimed to give a mechanistic explanation of the cooking quality deterioration in terms of dough rheology, microsturcture and water state and evaluate the practicability of partial substitution of wheat flour with PG in the dumpling wrapper formulation.

MATERIALS AND METHODS

Materials: Premium household wheat flour (12.4% water, 12.0% protein, 0.4% ash) and potato granule flour (10.3% water, 8.0% protein, 3.0% ash) were purchased from local supermarket.

Preparation of dumpling wrappers: The wheat flour was homogeneously mixed with the PG (5, 7.5, 10, 12.5 and 15% (w/w) of wheat flour) and abbreviated as PG5, PG7.5, PG10, PG12.5 and PG15, respectively. Each flour blend of 300 g was mixed with 120 g of distilled water (containing 3 g of NaCl) in a dough mixer for a period equal to the farinographic development time and allowed to rest for 30 min. Then the dough was laminated and extruded to form dumpling wrappers of 65 mm diameter and 2 mm thickness. The dumpling wrappers were quick-frozen at -40°C for 30 min, then stored at -20°C for 2 weeks before further analyses.

Optimal cooking time: Ten pieces of quick-frozen dumpling wrappers were put into 800 mL boiling water. Two minutes later, the dumpling wrappers were taken out from the water, each wrapper at an interval of 20 sec. After being cooled to room temperature, the wrappers were cut through along the diameter on a glass pan to observe weather the wrapper was thoroughly cooked. Optimal cooking time was determined to be the time at which the wrapper was just thoroughly cooked.

Water absorption ratio and cooking loss ratio: One piece of quick-frozen dumpling wrapper was weighed then cooked in a breaker containing 200 mL boiling distilled water. Just after being cooked for the optimal cooking time period, the dumpling wrapper was fished up and put on a filter screen, then washed using 30 mL distilled water and weighted. The washing water was returned to the breaker and the soup mixture was condensed to about 100 mL by boiling and dried in an air drying oven at 105 to constant weight. The cooking loss ratio (CLR, %) and water absorption ratio (WAR, %) were calculated using Eq. 1 and 2, respectively. Each measurement was conducted in triplicate:

$$CLR = 100\frac{m_2 - m_1}{m_0} \quad (1)$$

$$WAR = 100\frac{m_3 - m_0}{m_0} \quad (2)$$

where, m_0 is the mass of the frozen dumpling wrapper (g), m_1 is the mass of the beaker (g), m_2 is the total mass of beaker and dried substance (g) and m_3 is the mass of the cooked dumpling wrapper (g).

Dough extensograph: The frozen wrappers were thawed at room temperature then proofed at 37°C, 85-90% RH for 45 min in a proofing chamber before conducting extensogrpah analysis. Extensograph properties of the thawed dough were measured using an Extensograph-E (Brabender GmbH and Co., Duisberg, Germany) according to GB/T14615-2006[21].

SEM: A square of 1×1 cm was cut out from the center of each dumpling wrapper. All the squares were frozen at -80°C and freeze-dried in a vacuum freeze drier. The dried squares were broken and their fracture surfaces were exposed to gold sputtering. Microstructure was photographed using a scanning electron microscope (JSM-7001F, JEOL, Tokyo, Japan) with 20 kV acceleration voltage.

DSC: Thermal properties of quick-frozen dumpling wrappers were analyzed, at least in triplicate, with a DSC Q20 (TA Instruments, New Castle, Del., U.S.A.). Approximately 10 mg of dough was removed from the center of each dumpling wrapper, put into an aluminum pan and hermetically sealed immediately. An empty pan was hermitically sealed and used as reference. The samples were cooled to -40°C at a rate of 10°C min^{-1} with liquid nitrogen, held for 5 min at -40°C, then heated to 20°C at a rate of 5°C min^{-1} under nitrogen gas. Freezable water content (FWC, %) was calculated using the Eq. 3[7]:

$$FWC = \frac{\Delta H_{fw}}{\Delta H \cdot MC} \quad (3)$$

where, ΔH_{fw} is the melting enthalpy of ice fusion for the sample (J g^{-1} sample), ΔH is the latent heat of ice fusion (334 J g^{-1}) and MC is water content of the sample determined by dehydration at 105°C with a vacuum drying oven.

LF-NMR: A Niumag desktop pulsed NMR analyzer (Niumag Co., Ltd., Shanghai, China) with a magnetic field strength of 0.54 T and a corresponding resonance frequency for protons of 22.6 MHz was used for spin-spin relaxation (T2) measurements. Approximately 2 g of thawed dumpling wrapper dough was placed in a 10 mm diameter glass tube and inserted in the NMR probe. The T2 was measured using the Carr-Purcell-Meiboom-Gill pulse sequence. Typical pulse parameters were as follows: Dwell time = 4 μs, echo time = 420.00 μsec, recycle time = 600 msec, echo count = 350, scan repetitions = 16. Each measurement was performed in triplicate.

The T2 relaxation time was analyzed by the distributed exponential fitting analysis using the MultiExp Inv Analysis Software (Niumag Co., Ltd., Shanghai, China). For a better fit, a multi-exponential fitting analysis was performed on the relaxation data in the software algorithm. This analysis resulted in a plot of relaxation amplitude for individual relaxation processes versus relaxation time. From such analyses, time constants for each process were calculated from the peak position.

Statistical analysis: Statistical analysis were performed using SAS statistical software, version 9.4 (SAS Institute, Cary, NC, USA). For each experiment, one-way analysis of variance (ANOVA) was used to study significant differences ($p<0.05$) among treatments. Significant differences ($p<0.05$) between treatments were calculated using Tukey's multiple range test[22].

RESULTS AND DISCUSSION

Cooking characteristics: Optimal cooking time is considered as an important index reflecting cooking characteristics of food products. Reducing cooking time is of great important for improving production efficiency. The wrappers with 5% or 7.5% PG had the same optimal cooking time as that of the control (Table 1). More PG addition resulted in a increase of the optimal cooking time, which is similar to the results of Tian and Sun[6] on waxy wheat flour addition. Water diffusion is the rate-limiting step for dumpling wrapper cooking in excessive water. It was reported that diffusivity of water in starch system decreases after gelatinization[23]. The gelatinized starch in PG should had retard the diffusion of water molecules into dumpling wrappers and led to a longer cooking time.

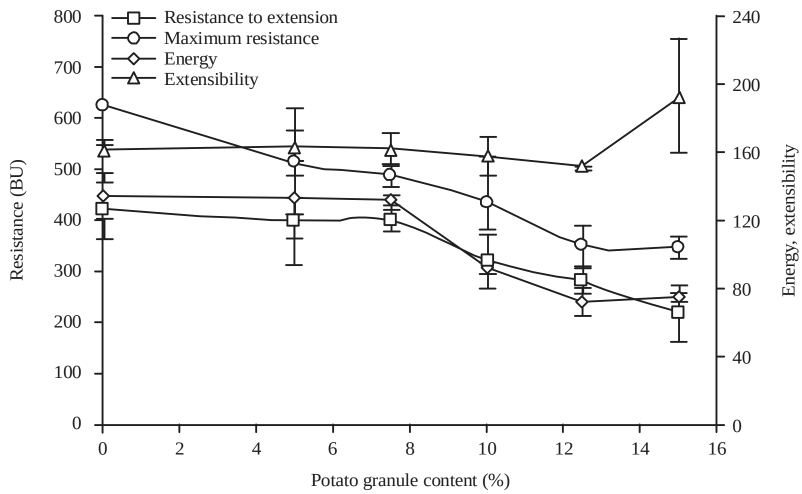

Fig. 1: Extensograph parameters of thawed dumpling wrappers with different PG contents after storage at -20°C for 2 weeks

Table 1: Cooking characteristics of quick-frozen dumpling wrappers with different PG contents after storage at -20°C for 2 weeks

Samples	Optimal cooking time (sec)	WAR (%)	CLR (%)
Control	200	54.97 ± 0.99^{d}	2.97 ± 0.28^{e}
PG5	200	60.84 ± 3.43^{cd}	3.37 ± 0.41^{d}
PG7.5	200	66.92 ± 3.66^{c}	3.89 ± 0.28^{c}
PG10	240	87.46 ± 8.43^{b}	4.79 ± 0.21^{b}
PG12.5	240	89.03 ± 0.75^{b}	4.80 ± 0.18^{b}
PG15	280	99.26 ± 3.44^{a}	5.13 ± 0.51^{a}

WAR: Water absorption ratio, CLR: Cooking loss ratio, PG: Potato granule, the number following PG indicates its weight percentage of wheat flour. The values followed by the same letter in the same column are not significantly different (p<0.05)

Water absorption ratio and cooking loss ratio are another two important indexes for cooking quality of dumpling wrappers. The water absorption ratio and cooking loss ratio all increased as the content of PG became higher. Both indexes presented a sharp increase when PG content was more than 7.5%. Water absorption of flour dough depends on water binding ability of starch and protein. The PG contains large amount of pre-gelatinized starch which can absorb more water, consequently the water absorption capability increased after PG addition. High water absorption ratio makes dumpling wrappers succulent and mouth-filling, while excessive water absorption will cause dumplings fragile during cooking.

Cooking loss ratio reflects the amount of starch dissolved in dumpling soup. The higher cooking loss ratio indicates that more cooked starch granules were dissociated from the gluten network of wrappers into the dumpling soup. After PG addition, the gluten network became tenuous and can not hold the gelatinized starch granules. High cooking ratio leads to a turbid soup, which is unfavorable for industrial manufacturing but coincides with the traditional Chinese repast habits.

Extensograph parameters: The extensograph determines the resistance and extensibility of dough by measuring the force required to stretch the dough with a hook until it breaks. Resulted extensograph indexes are presented in Fig. 1. Resistance to extension is a measure of dough strength and a higher resistance to extension requires more force to stretch the dough. Both resistance to extension and resistance energy kept almost constant when PG was not more than 7.5%, then presented a rapid decrease when further increasing PG content. The reduced resistance to extension is mainly attributed to the decreased gluten content in PG dough[10]. Extensibility indicates the ability of the dough to extend and a high extensibility means weak and slack dough. The extensibility kept at almost the same level as that of the control when PG addition was less than 12.5% (Fig. 1). The very higher extensibility of PG15 may be a result of the stick characteristic of the gelatinized potato starch. The maximum resistance to extension decreased almost linearly with the amount of PG. Lower maximum resistance to extension value indicates weaker flour dough. On a whole, PG addition had woken the wheat flour dough, which is in agreement with the results of Wu *et al.*[24] on dough rheology after sweet potato paste addition.

DSC: The DSC curves of various dumpling wrappers are presented in Fig. 2. The curves of PG5, PG7.5, PG10, PG12.5 and PG15 were shifted upword by 0.3, 0.6, 0.9, 1.2 and

Table 2: Characteristic temperatures, melting enthalpies and freezable water contents of dumpling wrappers with different PG contents after storage at -20°C for 2 weeks

Samples	T_{on} (°C)	T_p (°C)	T_{off} (°C)	T_{off}-T_{on} (°C)	H_{melt} (J g^{-1})	FWC (%)
Control	-5.82±0.03^a	-0.61±0.04^a	2.60±0.05^e	8.42±0.04^e	76.66±2.10	61.72±1.69^a
PG5	-8.54±0.02^b	-2.52±0.08^c	2.17±0.06^c	9.61±0.18^d	56.33±2.54	46.30±2.09^b
PG7.5	-8.12±0.10^b	-1.65±0.14^b	2.42±0.11^d	10.54±0.42^c	43.61±1.21	36.14±1.00^c
PG10	-10.37±0.13^c	-2.64±0.10^c	1.46±0.15^{ab}	11.83±0.52^b	42.77±2.50	35.62±2.08^c
PG12.5	-11.50±0.15^d	-2.58±0.12^c	1.26±0.16^a	12.76±0.64^a	36.70±1.52	31.09±1.29^d
PG15	-11.43±0.12^d	-2.30±0.08^c	1.34±0.04^a	12.77±0.42^a	34.08±1.90	29.07±1.62^d

FWC: Freezable water content, PG: Potato granule, the number following PG indicates its weight percentage of wheat flour. The values followed by the same letter in the same column are not significantly different (p<0.05)

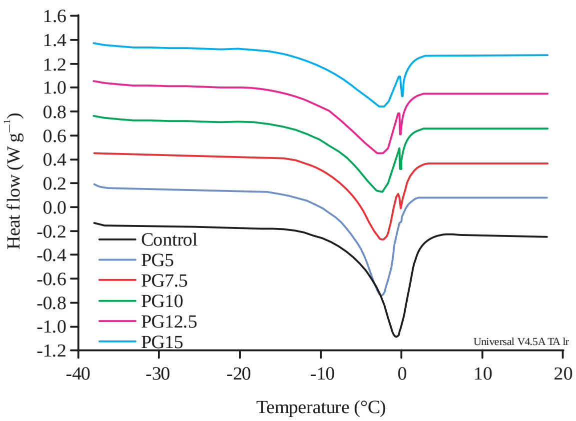

Fig. 2: DSC thermograms of dumpling wrappers with different levels of PG after storage at -20°C for 2 weeks

1.5 W g^{-1}, respectively. Their characteristic temperature values are listed in Table 2. When no PG was added, an endothermic event with peak at -0.61°C was observed. For the samples with PG, all the endothermic events shifted to lower temperature with peak points at -1.6 to -2.6°C depending PG content (Table 2). It is assumed that the low molecular weight carbohydrates in PG, such as dextrin, depressed the freezing points of the dough after PG incorporation[11]. In addition, the gelatinized potato starch can also contribute to the depressed peak temperature for ice melting[24]. Interestingly, a narrow "Spike" was observed in the major ice-melting peak of the wrappers with PG. Similar observation was also reported by other researchers[25]. The occurrence of this spike will be interpreted in the following section.

The onset temperature (T_{on}) shifted from -5.8 to -8.5°C when 5% PG was added and decreased to -11.4°C when PG addition increased to 15%. The end temperature (T_{off}) was depressed slightly when PG was added at levels of less than 10%, then kept almost unchanged at higher PG contents. As a result, the ice-melting temperature range became wider and wider when more and more PG was added. Previous research has shown that ice crystallization and recrystallization cause physical damage to the gluten network, leading to changes in the rheological properties of the frozen dough[8,9]. A broader temperature range of ice melting favors a less homogeneous ice crystal structure formed within dough[26]. So, in terms of the widened ice-melting temperature range, PG addition would have damage effects on dough microstructure and rheology.

The endothermic enthalpies (including the enthalpy of the spike) were used to calculate freezable water contents and the results were also listed in Table 2. The FWC of the control sample in present work is comparabie to the data of Rasanen *et al.*[27] (67% at -40°C, 53% at -10°C), but higher than that of Ding *et al.*[28] (~50%) and lower than that of Adams *et al.*[22] (~80%). The FWC showed a rapid decrease along with the amount of PG increasing from 0-7.5%, then a moderate decrease with further increasing PG content. The ice in the dumpling wrappers is formed by the freezable water. The lower freezable water contents at higher PG contents will reduce the mechanical damage of ice crystals to the dumpling wrappers. It has been stated that foods containing high amounts of low-molecular-weight sugars contain higher amounts of unfrozen water at lower temperatures than foods based on polymeric compounds with the same solid content[29]. Additionally, a recent report suggested that highly swollen starch gives less freezable water[30]. Therefore, the observed FWC reduction after PG addition should be attributed to the combined effect of low-molecular-weight substances and gelatinized starch in the PG flour.

SEM: The microstructures of various dumpling wrappers viewed using SEM are presented in Fig. 3. The small and large starch granules in the photographs are B and A wheat starches, respectively. Potato starch granules are oval in shape and much larger in size (20-110 mm) than wheat starch granules[13]. So, it can be concluded that all the potato starch granules had lost their intact structure because of heating and drying during the PG processing. Dough can be considered as a two-phase dispersion, with gluten networks acting as continuous phase and starch granules wrapped in the continuous matrix. For the control sample, wheat starch granules were compactly embedded in the gluten matrix

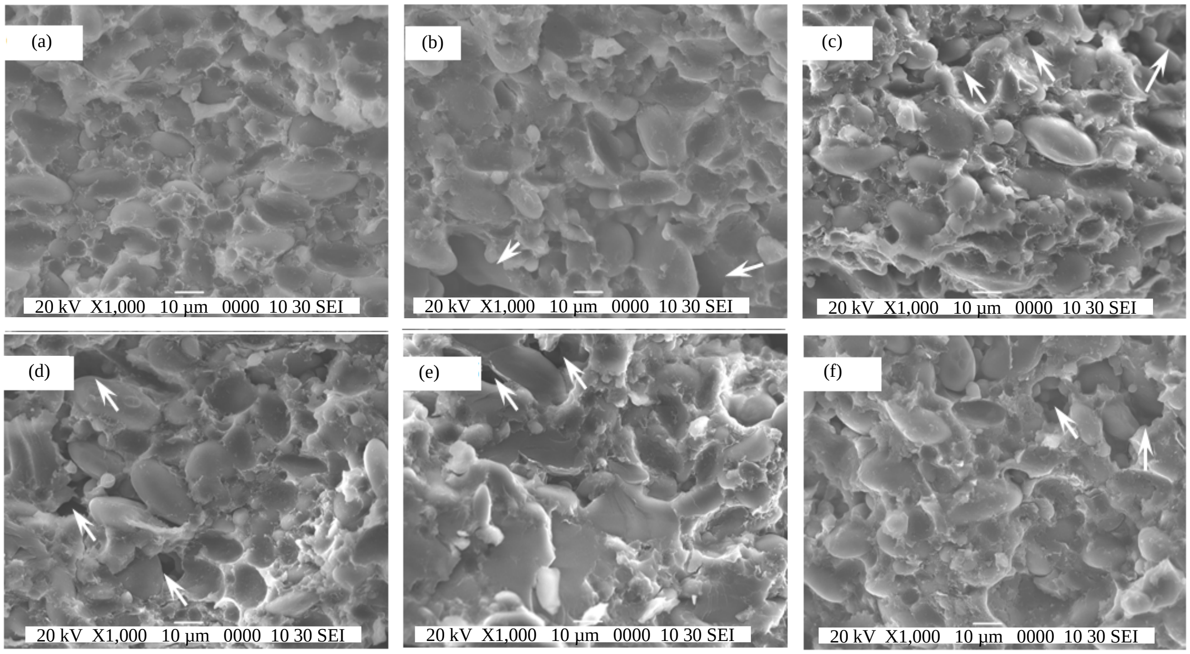

Fig. 3(a-f): SEM of dumpling wrappers with different PG contents after storage at -20°C for 2 weeks (1000×), (a) Control, (b) PG5, (c) PG7.5, (d) PG10, (e) PG12.5 and (f) PG15

(Fig. 3). For the wrappers with PG, the gelatinized potato starch also took part in the formation of the continuous matrix. The continuous phase then occupied more volume fraction in the dough system. Because of the gelatinized potato starch, the continuous matrix became sticker and more coherent and the interfaces between starch granules and matrix were spurred as shown in Fig. 3. These microstructural modifications should respond for the variation of extensograph characteristics of dough with PG (Table 1).

After careful inspection of the SEM photographs, one can find various sizes of voids (indicated by white arrows) in all the wrappers with PG. Similar observation was reported by Mi *et al.*[7] for dumpling wrappers after acetylated potato starch addition. It is difficult to say that these pores were formed during freezing storage. If this is the case, the lower freezable water contents after PG addition, as measured by DSC, should result in less porous structures in the PG wrappers[8,9]. It seems reasonable that the pores were generated when the dough was mixed and shaped into dumpling wrappers. Some previous reports support this inference. The slack dough occludes a higher concentration of bubbles than the stiff dough[31]. Density measurements of dough made from flours of different strength also indicated that weaker dough entrains more air[32]. Extensograph results indicated that wrapper dough became weaker after PG addition (Fig. 1). The weakened dough should have retained more air incorporated during dough mixing than the control dough did and finally possessed a microstructure of many voids.

Baier-Schenk *et al.*[9] reported that freeze damage to dough is largely attributed to the structural changes induced by initial ice crystal formation and to the matrix deterioration induced by the growth of large ice crystals. The gas pore interfaces in dough, which are preferential sites for ice nucleation, favor the growth of ice crystals in these regions[8]. So, in term of freeze-induced damage to dough, ice nucleation sites are more important than ice growth. The porous microstructure of the PG dough wrappers provided more sites for ice nucleation and led to deteriorated rheological properties. The fact that the pores were observed only in the PG wrappers also helps explain why the spikes in the DSC curves occurred only for the PG wrappers. The spikes should indicate melting events of ice crystallized from free bulk water. In deed, peak temperatures of all the spikes were very close to 0°C, which is the freezing point of bulk water. In addition, the voids in the PG dough can be filled with water during cooking. The pore walls can act as the interfaces for solid materials leaching out of the dough matrix. So, for the PG wrappers, their porous microstructure should contribute, at least partially, to their high water absorption capacity and cooking loss as shown in Table 1.

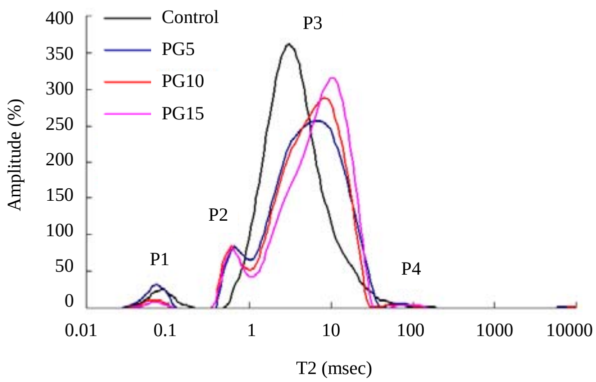

Fig. 4: LF-NMR T2 relaxation time distributions of dumpling wrappers with different PG levels after storage at -20°C for 2 weeks

LF-NMR: The continuous distribution of spin-spin relaxation time (T2) of the dumpling wrappers with various PG contents is shown in Fig. 4. Three proton populations were probed for the control sample. While for the samples with PG, four populations were observed. For convenience of discussion in the following parts, the spin-spin relaxation times of the four components are labeled as T21, T22, T23 and T24, respectively. For all the samples, T23 was the major population. The relaxation distribution of control sample was very similar to that of the wheat flour dough with 33.1% water content[33] and that of the noodle dough with 35% water content[34,35]. For the dough with 33.1% water content, the major population center at 3 msec[33], which is very close to the T23 of 2.81 msec in this study.

The population 1 is characteristic of non-freezing water molecules closely associated with solids in wheat flour dough[17,33]. The population 4, presenting the fastest relaxation, however cannot be regarded as bulk water, which has a T2 of about 2.5-3.0 sec[17]. This population should be assigned to the capillary bound water in dough[33]. Because of low abundance of populations 1 and 4, the following discussion will focus on the other two populations.

Compared with control sample, all the wrappers with PG presented an additional peak centered at around 0.6 msec. For the control, only a very slight shoulder can be discerned at the same relaxation time. For potato starch with 50% water content, Bosmans *et al.*[20] assigned the population with T2 of 0.3 msec to CH protons of amorphous starch in contact with water. In an earlier research about water-saturated potato starch, Tang *et al.*[17] suggested that the relaxation peak at ca. 1 msec probably arises from amyloperctin in the amorphous regions of the semicrystalline lamellae in starch granules. For wheat flour-water system with 47% water content, Bosmans *et al.*[19] assigned the population with T2 of about 0.2 msec to CH protons of amorphous starch and gluten in sheets (organized gluten strands) in contact with confined water. While for the dough wrappers, considering the fact that the population 2 in control sample is much smaller than that of PG samples, it seems safe to assign the population 2 to CH protons of amorphous regions in the pre-gelatinized potato starch. In deed, hydrothermal treatment of potato starch at 180°C for 25 sec makes its T2 population at 0.3 msec increase by more than four times[20]. Similar observation was also reported for wheat flour with 47% water conent[19].

Here, the assignment of the population 3 protons will be disscussed. In a research on dough with 44.5% water content, the T2 of ~2 msec was assigned to the water in exchange with labile protons (OH–, NH–, SH–) from starch and gluten and the T2 at 9-10 msec was assigned to water in exchange with gluten in the outside of the sheets and with amylose and pentosans in extragranular spaces of starch granules[16]. For a starch-water system, the former water fraction is usually called intragranular water, the later extra granular water. While for a dough system, this nomenclature seems unsuitable. For convenience of discussion, these two fractions will be called less movable water and more movable water, respectively. As for the dough systems tested in present study, because of their low water content (~36.5%), the less movable water and more movable water are assumed to have merged into one broad peak[36]. The mergence is presumably the result of exchange averaging by rapid water molecular diffusion between the two proton pools[17].

The PG addition greatly influenced the population 3 in both peak shape and relaxation time (Fig. 4). Comparison with that of control sample, the T23 peak curves of all the PG wrappers were skewed to the right, indicating that the T23 water of PG dumpling wrappers was redistributed from less movable component to more movable component. This redistribution of water may be a result of the high water absorb capacity of the gelatinized starch in PG. With PG content increase, the T23 increased from 2.81-10.49 msec, indicating water molecules became more movable. Several earlier reports demonstrated that the T2 assigned to intragranular water in potato is longer than the T2 in maize starch[17], rice starch[20] and wheat starch[37]. Although the T2 corresponding to intragranular water of potato starch-rice starch blend is much lower than that of rice starch, but still higher than that of potato starch[20]. As a merged peak from lower T23 of wheat flour (dominated by wheat starch[32]) and higher T23 of potato starch, the T23 of PG dough wrappers will logically increase as PG content increasing. Although a previous report suggested the mobility of extragranular water in potato starch is reduced after gelatinization[20], the gelatinized starch in PG may just play a minor role in modifying the T23 of PG dough wrappers.

Comparing the trends of FWC and T23 varying with PG content, one can find that PG addition led to a decrease in FWC, while an increase in water mobility. This paradoxical observation seems confusing. In fact, the FWC reduction is mainly attributed to the gelatinized potato starch in PG, while the T23 increase results mainly from the potato starch which has a higher T23 value.

CONCLUSION

It is concluded that after incorporation of PG, the quick-frozen dumpling wrapper dough became weak in extensograph and porous in microstructure, freezable water content decreased, while water molecules became more movable, in addition, both water absorption ratio and cooking loss ratio of frozen PG wrappers decreased. The microstructural modification induced by PG addition may play an important role in determining the cooking properties. The findings in this study provided evidence that PG could be used as a partial ($\leq$7.5%) substitute for wheat flour in quick-frozen dumpling wrapper formulation to get acceptable cooking qualities.

SIGNIFICANCE STATEMENTS

Incorporating potato granule into dumpling wrappers will extend the utilization of this cheap flour in the traditional food of China. This research evidenced that PG could be used as a partial ($\leq$7.5%) substitute for wheat flour in quick-frozen dumpling wrappers with acceptable cooking qualities. The microstructural modification induced by PG addition may play an important role in determining the cooking qualities of dumpling wrappers. In terms of retarding quality deterioration of frozen dumpling wrappers, PG addition had a favorable effect, viz., reducing freezable water content, while brought an unfavorable effect, viz., increasing water mobility.

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