Influence of moisture, particle size and pulse flour composition on phase transition behavior of rice flour

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Revised: 3 September 2014 / Accepted: 16 September 2014 / Published online: 23 September 2014
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Abstract Study on the phase transition characteristics is an important parameter in extrusion processing. The influence of Moisture Content (MC), particle size and level of cereal-pulse blend on the glass transition (T_g) and melt (T_m) temperatures of a ready to eat cereal-pulse formulation was determined. All samples were moisture conditioned in a 9 to 27 % with 3 % interval. T_g and T_m were measured by phase transition analyser (PTA). A substantial decrease in T_g and T_m was observed as moisture content level increased from 9 to 27 %. However T_g and T_m values could not be clearly defined below 9 % moisture content and above 27 % moisture content. The T_g and T_m values of the cereal-pulse formulation were found to be increased with increasing pulse composition (5 to 30 % with 5 % interval). Increase in particle size (150, 180, 212, 300, 425 and 500 μ) exhibited significant increase effect on T_g while less significant effect on T_m . This may be due to crystalline regions which play a role in cross linking amorphous regions of the polymeric network and thus suppress the mobility of amorphous regions. The observed differences in T_g and T_m induced by the moisture content, concentration of Bengal gram and particle size will be useful in simulation and optimization of barrel temperature set during extrusion processing.

Keywords Glass transition · Melt temperature · Moisture content · Particle size

Introduction

Application of polymer science in food industry is becoming popular now a day. Mainly the polymer science technology is

applied to extruded products technology. A polymer science is the study of glass and melt transitions of polymer. The principle of polymer science applies only to amorphous or partially amorphous state. They can undergo both glass transition (T_g) and melt (T_m) at characteristic temperatures. The glass transition temperature is a very important physical parameter, which serves to explain the physical and chemical behavior of food systems (Bell and Touma 1996). When the temperature of the compound is above T_g and below T_m the compound will become rubbery or leathery. When the temperature is below T_g it will be in glassy state. During extrusion, the melted material extrudate that is heated and plasticized sufficiently to flow through the extruder die (Strahm 1998).

Amorphous (non-crystalline) compounds have adjacent polymer strands that do not interact with each other thereby exhibits distinct glass and melt transition temperatures. A perfectly crystalline polymer melts at a defined temperature in an amorphous polymer at lower temperature, the molecular motion of the polymer chain is frozen at a random conformation, rendering it glassy and immobile. When the thermal energy is applied, the molecular motion is initiated and molecules have sufficient energy to slide past one another (Levine 1983). At this stage the compound become viscous, flexible and rubbery. This physical change in polymer backbone (20 to 50°C) is called T_g (Eisenberg 1984). Polymers such as starch are normally found in foods with high hydrophilic capacity. As with other food stuffs, food stability of starch and starchy products greatly depend on their composition, the surrounding relative humidity and temperature (Bertuzzi et al. 2003 and Haque and Roos 2004). The way these variables are related to the water present within the food matrix and its T_g will determine its physical properties, as well as its chemical and microbial stability. The plasticizing effect of water on food biopolymers is very small at low water activity values, therefore T_g associated with amorphous regions in the sample will be typically high and at room temperature the material will be

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glassy. Water access will be higher in the rubbery state than in the glassy state, since the free volume increase above T_g.

T_g and T_m have become an important parameter for designing the pre-requisite set temperature during extrusion processing. A sample transition temperature compared mass and energy of the extruder will enable a food technologist to map the extrusion process. The transition temperatures can be measured by differential scanning calorimeter, dynamic mechanical thermal analysis and thermal mechanical analysis. The best suited method to study the transition temperatures for extrusion processes is closed chamber capillary rheometer, which is automated with PC control interface attached with the phase transition analyzer (PTA). Advantage of PTA over other methods is prevention of moisture loss, allowing analysis to be performed at temperatures greater than 100 °C for sample containing higher moisture (Strahm et al. 2000). However due to many generalized statements conflicting comments about the influence of particle size and moisture content on T_g and T_m have been reported. The extreme sensitivity to water or temperature plasticization on food biopolymers and their effect on T_g, underlines the importance of determining the particle size characteristics of food materials at different temperatures. In this way, particle size can be used together with glass transition values as a function of moisture content to define storage conditions that enhance the stability or increase the shelf life of food products.

Rice brokens is one of the byproduct obtaining during rice milling process. This has low value and often used as animal feed. Likewise roasted Bengal gram brokens are the byproduct of roasted Bengal gram production. This is also used as animal feed in spite of the nutrients present in it. This study has to be done to increase the value of byproducts into value added products. This study was done with the objectives: to examine rice flour and Bengal gram (BG) composition by Phase Transition Analyser (PTA) for the occurrence of T_g and T_m, to characterize the influence of crystallinity and water on T_g and T_m.

Materials and method

Rice brokens and Bengal gram brokens

Parboiled Rice brokens (ADT 49 variety) and roasted Bengal gram brokens were purchased from local milling industry, Thanjavur, Tamil Nadu and stored in air tight containers.

Preparation of sample

Moisture content

Moisture content of broken rice samples and Bengal grams were adjusted to desired moisture content (9 to 27 % with 3 %

interval) by spraying calculated amount of distilled water and mixing continuously (120 rpm) in the planetary mixer (Berjaya Model, I/BSP-BM5). The samples were packed in polyethylene bags and kept in the refrigerator for 24 h to equilibrate the moisture. The samples were brought to the room temperature before subjecting to analysis. The moisture content on dry basis of the feed and extruded samples were determined by official standard methods AACC 44-15A (2000).

Particle size

Rice brokens and roasted Bengal gram brokens were milled and sieved to different particle size (150, 180, 212, 300, 425 and 500 µ).

Incorporation of roasted Bengal gram flour in rice flour

The phase transition characteristics of rice flour incorporated with 5 to 30 % of roasted Bengal gram flour was studied using PTA.

Phase transition analyser

PTA (Wenger) is a closed chamber capillary rheometer. PTA consists of two sealed chambers separated by an interchangeable capillary die. The two chambers host electric heaters and contain a hollow cavity that allows a cooling fluid to be used. The pistons mounted together as sidebars, are held in a fixed position during testing. Air cylinders, mounted to the bottom of the PTA maintain constant pressure on the sample. A linear displacement transducer measures the samples deformation, compaction and flow relative to initial sample height (Plattner et al. 2001). Two grams of the sample is taken for the analysis with the constant pressure of 100 bars and heating rate: 10 °C/min.

Statistical analysis

Two factor ANOVA was performed to assess the significance between the treatments.

Results and discussion

Effect of moisture content on T_g and T_m of rice flour

The effect of different moisture content on the T_g and T_m of the rice flour was studied for its phase transition characteristics. Figure 1 shows that there is substantial decrease in T_g and T_m as moisture content level increased from 9 to 27 %. However T_g and T_m values could not be clearly defined

Fig. 1 Tg and Tm of rice flour at different moisture content

below 9 % moisture content and above 27 % moisture content. The glass transition behavior is attributed to water which acts as a plasticizer in starch/water system by depressing thermal transitions (Maurice et al. 1985). Similar results were reported in cassava starch by Perdomo et al. (2009), that anti-plasticizing effect of water is evident at moisture level below 11 % and water acts as a plasticizer when there is intermediate moisture of 11 to 23 % and high moisture of above 23 % where a larger plasticizing effect was observed. Zeleznak and Hosney (1987) reported that moisture content greater than 22 %, Tg occurred at room temperature. Low molecular weight hydrophilic compounds act as plasticizers for most biopolymers, but none will be effective as water with Tg of -135 °C (Strahm, 1998). The Tg of ready-to-eat cereal formulation decreased as the moisture content increased (Sandoval et al. 2009). The Tg of brown rice kernels decreased with increase in moisture content (Siebenmorgen et al. 2004). The statistical analysis revealed that there is no significant difference in Tg and Tm between different moisture content.

Effect of particle size of rice flour on Tg and Tm

The Tg and Tm values of the cereal-pulse formulation were found to be increased with increasing BG composition (5–30 %). Increase in particle size (100 μ –500 μ) exhibited significant increase effect on Tg while less significant effect on Tm as shown in Fig. 2. This may be due to crystalline regions which play a role in cross-linking amorphous regions of the polymeric network and thus suppress the mobility of amorphous regions (Ronkart et al. 2006). Matz (1993) and Williams et al. (1977) suggested that particle size of raw ingredients is important when extruding but did not discuss it in any more detail. General observations have led to conflicting conclusions about the influence of particle size on Tg and Tm of rice flour. Hsu (1983) and Yeh et al. (1992) showed that the time needed for water diffusing into the rice particles decreases with decreasing particle size and increasing water temperature. Since water needed to diffuse into rice particles

Fig. 2 Tg and Tm of rice flour with different particle size

for gelatinization, the degree of gelatinization of rice decreased with increasing particle size. Bigger the particle size results in lesser gelatinization potential. However, flow property of flour at higher temperature is not determined by different particle size with the same percentage moisture content. The statistical analysis showed that there is no significant difference in Tg and Tm between different particle size.

Effect of percentage incorporation of roasted bengal flour on Tg and Tm of rice flour

The Tg and Tm values of the cereal-pulse formulation were found to be increased with increasing BG composition (5–30 %). Figure 3 shows the change in Tg and Tm of different percentage of roasted Bengal gram flour incorporated rice flour. This may be due to the protein content of pulse which acts as crystallites and restricts the movement of the polymer backbone (Zeleznak and Hosney 1987). The statistical analysis revealed that there is no significant difference in Tg and Tm between percentage incorporation of roasted Bengal gram flour.

Fig. 3 Tg and Tm of rice flour incorporated with different percentage of roasted Bengal gram flour

Summary

It was clearly observed that moisture content plays a key role in dictating the T_g and T_m of the rice flour. Particle size vitally influence in determining the T_g property of the rice flour. With the PTA ability to clearly define the controlling T_g and T_m, it will be yet another vital tool for a food scientist to understand the complex property of polymer in the food industry. Information on the relation of T_g of a raw material with the product property, as a function of moisture sorption property will be yet another important study of great significance in relevance to the storage property. Low moisture and increase pulse incorporation gives a much higher shear viscosity than particle size which is related to a higher T_g and T_m. This may be expected to have implications not only for extrusion processing but for the performance of gluten in baked products.

Acknowledgments The authors acknowledge the National Agriculture Innovative Projects for funding the project.

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