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Gelatinization Properties of Sago and Wheat Flour Mixtures

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Abstract: Gelatinization or pasting properties of sago-wheat flour mixtures (10-50% sago) were studied for mixtures of sago-high protein wheat flour (HPW), sago-medium protein wheat flour (MPW) and sago-low protein wheat flour (LPW). Gelatinization temperature (T_G) increased as the sago portion in HPW, MPW and LPW increased. The peak temperature (T_P) and peak viscosity (V_P) increased with increasing sago in the sago-wheat mixtures. The setback values (S_B) in sago-LPW mixtures were higher than in sago-HPW and sago-MPW mixtures. The setback viscosities (V_S) were not much different for any mixtures or control flours. The breakdown viscosities (V_B) increased with increased sago in the mixtures. The breakdown value (B_D) increased with increased sago in the sago-wheat mixtures.

Keywords: Sago, wheat, gelatinization properties, composite flours

INTRODUCTION

Sago starch is derived from the pith of several kinds of palm trees native to South East Asia, particularly from *Metroxylon sagu*, which grows extensively in the peat swamps of Malaysia, Indonesia, Papua New Guinea and also in South America. In Malaysia, the major area is in Sarawak.

Sago is widely used as a raw material to make a variety of traditional foodstuffs like tabaloi and sago pearls. Sago starch gives out a rather stringy 'long' paste – a property that has discouraged its use in many cases. However, a number of applications have been found for it in the manufacture of prepared products, especially jelly confections and breakfast food. During the Second World War, it was used in certain puddings, pastries and breads to supplement the food supplies of the occupied Netherlands (Rositawati and Masano, 1990).

When water is added to dry starch granules the volume of the granules increases because of hydration. As the temperature of the suspension is raised, the starch granules swell as water is absorbed. At temperatures ranging from 50-80°C, depending on the botanical source of the starch, the granule structure starts to break down and a paste results. This irreversible breakdown of structure is referred to as gelatinization (Dengate, 1984). Viscosity depends not only on the botanical source of the starch but also on its concentration, the rate and duration of heating, and the presence or absence of stirring during the heating and cooling.

In Malaysia, sago is relatively inexpensive compared to wheat. Sago produces an opaque paste similar in clarity to that of wheat, has medium paste strength under mechanical shear and heating, and shows pronounced setback. It is possible that sago flour could be used as a partial

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substitute of wheat in certain types of foods and bakery products.

Other flours (corn, oat, semolina, soy and other cereals), like sago, can replace wheat flour without causing major changes in quality of the final products and without considerable adjustments in the manufacturing procedures. As a general rule, small additions with a neutral taste do not present problems in terms of either technology or consumer acceptance. However, if the principal aim is to promote the use of indigenous flours, these flours must represent a considerable proportion of the composite flour products. This may cause problems in both manufacture and consumer acceptance (Md Zaidul, 2000; Md Zaidul *et al.*, 2002; 2003).

Composite flours are intended for use as raw materials not only in baked goods and pasta products but also for family meals. Furthermore, there may be applications in breakfast cereals and in snacks. The bulk of research centres on the manufacture of breads, biscuits, crackers, cookies, pastas and other baked goods. Their shape, composition, and mode of preparation may vary from country to country (De Ruiter, 1978). The main objective of this work was to study the effects of substituting wheat flours with sago on the gelatinization properties, determined using a Brabender Amylograph. The information obtained from this study would hopefully give some insight into the possibility of using sago as a partial substitute for wheat-based products and in product development.

MATERIALS AND METHODS

Materials

Samples of high protein wheat flour (HPW) (sold as bread flour), medium protein wheat flour (MPW) (sold as rose flour, typically used in noodle-making) and low protein wheat flour (LPW) (sold as super soft flour, typically used in cookie-making) were bought from a local supermarket. Sago flour was generously supplied by Craun Research Sdn. Bhd. Kuching, Sarawak, Malaysia.

Methods

Moisture, Protein, Fat and Amylose Content

The moisture contents of the flours were determined by the approved AACC air-oven method no. 44-15 (AACC, 1984). Protein contents were determined by the micro-Kjeldahl distillation method. Soxhlet extraction was used to determine the fat contents (AOAC, 1990) using petroleum ether (b.p. 40-60°C) to extract the fat. The amylose contents were measured using the methods of Williams *et al.* (1970).

Gelatinization Properties

Sago flour was mixed with HPW, MPW and LPW at sago substitutions of 10, 20, 30, 40 and 50%. Sago flour and wheat flour were used as controls.

The pasting properties of the sago, wheat and mixtures were determined with a Brabender Amylograph (model, 1800120, Brabender Ohg Duisburg Germany). Forty grams of flour (dry basis) were added to 450 ml of water (i.e. 8% slurry). The test was run from an initial temperature of 25°C to a final temperature of 95°C for 46.67 minutes, at a uniform heating rate of 1.5°C/minute with constant stirring at 75 rpm. The viscosity, in Brebender unit (BU), at 95°C was recorded. Temperature was held constant at 95°C for 20 minutes. The paste was then cooled to 50°C at 1.5°C/min and held at that temperature for another 30 minutes. Setback (S_B) is the difference in viscosity after cooking at 95°C and cooling to 50°C. Duplicate determinations were conducted. The gelatinization parameters (Figure 1) used the method described by Juliano (1985).

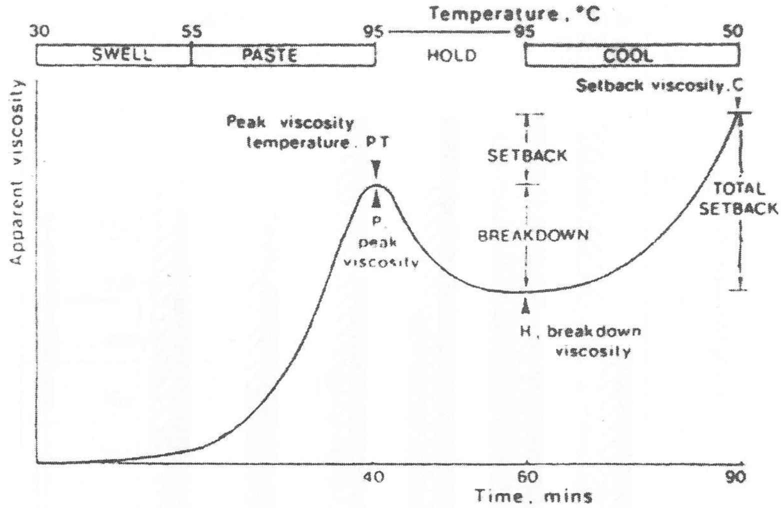

Figure 1: A typical amylograph showing a gelatinization cycle curve, typical of wheat starch in the concentration range 8-12% (dry basis) showing definition of gelatinization parameters (Dengate, 1984; with permission)

RESULTS

The moisture, protein, fat and amylose contents of the wheat and sago flours are shown in Table 1.

Figure 1 shows the typical amylograph parameters of a gelatinization cycle. The pasting or gelatinization temperatures (T_G) with varying sago levels in the mixtures are depicted in Figure 2. The T_G increased with added sago in the mixtures. The T_G started to decrease as the sago level in the mixtures was further increased. However, for sago-HPW mixtures, the T_G increased to a maximum of 72°C for 10% sago substitution and remained the same for 20% and 30% sago, and then decreased to 69°C for 40% sago, and remained the same for 50% sago in the mixture. For sago-MPW mixtures, the T_G increased with increasing sago in the mixtures and reached a maximum of 70.8°C for 50% sago. Each of the LPW-sago mixtures had a higher T_G than any of the wheat flours.

The peak viscosity (V_P) results are shown in Figure 3. Peak viscosity is the viscosity in BU at peaks, irrespective of the temperature at which it is attained. The V_P is plotted as a function of sago percentage in the mixtures. Figure 3 shows the V_P increased monotonically with increases up to 50% sago in the mixtures. The peak viscosities for

Table 1: Chemical composition of samples (dry wt. basis)

Sample	Moisture (%)	Protein (%)	Fat (%)	Amylose (%)
High protein wheat	12.9	14.2	1.1	26.8
Medium protein wheat	12.9	10.4	1.1	25.7
Low protein wheat	12.8	6.8	1.8	23.5
Sago starch	13.0	-	-	27.5

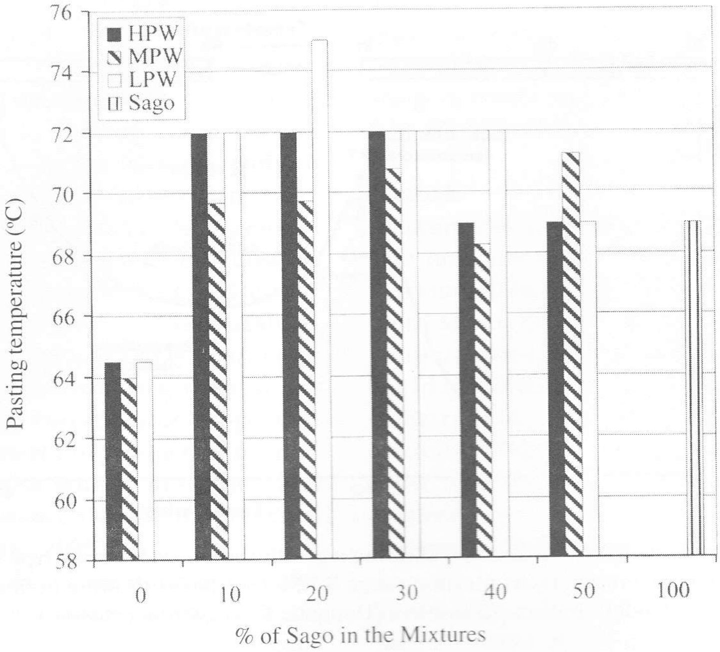

Figure 2: Gelatinization temperatures for wheat-sago mixtures

control wheat flours were the lowest, and the control sago the highest. A high V_P shows maximum swelling of the starch granules. In the mixtures, the sago granules swell more than the wheat causing increased V_P, which is maximized in the control sago flour.

Figure 4 shows the result of peak temperature or peak viscosity temperature (T_P) as a function of sago percentage in the mixtures. The T_P was the highest for control wheat flour and the lowest for control sago. The T_P tends to decrease with an increase in substitutions up to 40% sago in HPW and MPW flour mixtures, but remained the same for 50% in HPW, MPW and LPW mixtures.

The mixture with 40% sago in HPW and MPW exhibited different T_P values. For LPW there was no change at 40% sago and the reason was not clear. However, T_P was different for all percentages of sago in the mixture and decreased with the increase of sago at 50% for HPW, MPW and LPW.

Figure 5 shows the breakdown viscosity (V_B) as a function of % sago in the mixtures. The V_B increases almost linearly with sago up to approximately 620 BU for 50% sago. Control wheat flours had the minimum V_B (200 BU) whereas control sago flour exhibited the maximum V_B (775 BU).

Viscosity after cooling for 30 min at 95°C is the viscosity in BU after holding for 30 min at 95°C. It illustrates the stability of paste during cooking.

The change in breakdown (B_D) value with sago substitution is shown in Figure 6. The B_D value for 20% sago in the mixtures is the lowest. However, the B_D value for control wheat was lower than control sago.

The setback (S_B) value with sago in the mixtures is shown in Figure 7.

Setback reflects the retrogradation tendency of starch, with inhibited starch exhibiting minimum viscosity increase on cooling. The S_B values in sago-LPW mixtures

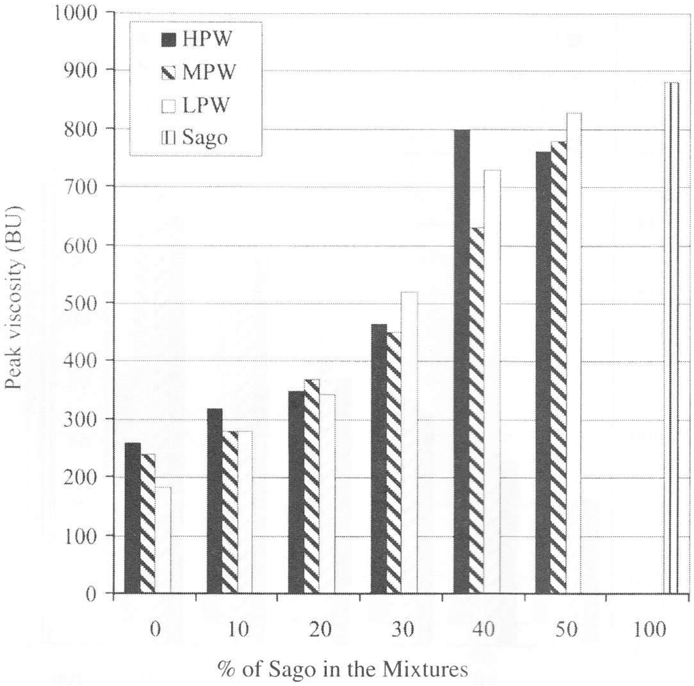

Figure 3: Peak viscosities for wheat-sago mixtures

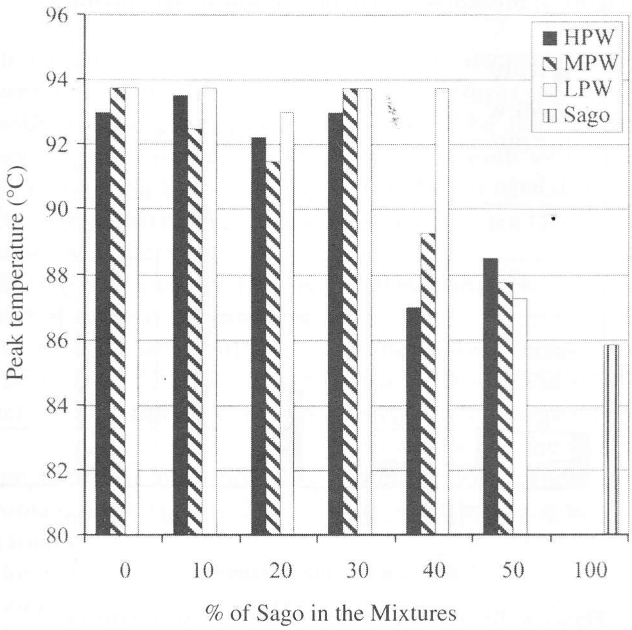

Figure 4: Peak temperatures for wheat-sago mixtures

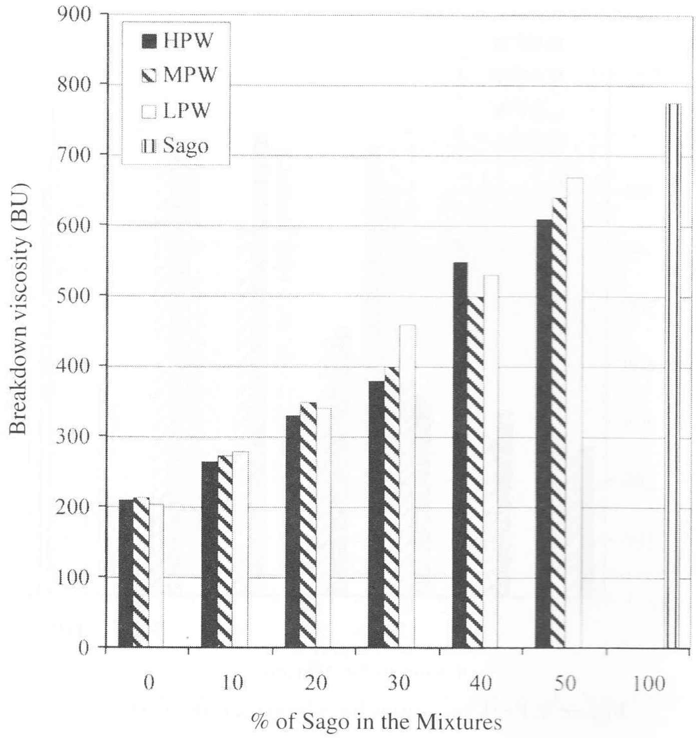

Figure 5: Breakdown viscosities for wheat-sago mixtures

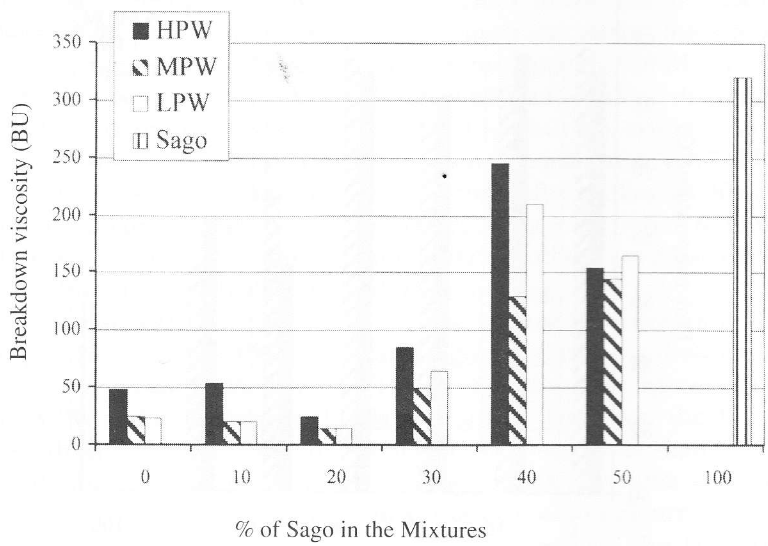

Figure 6: Breakdown values for wheat-sago mixtures

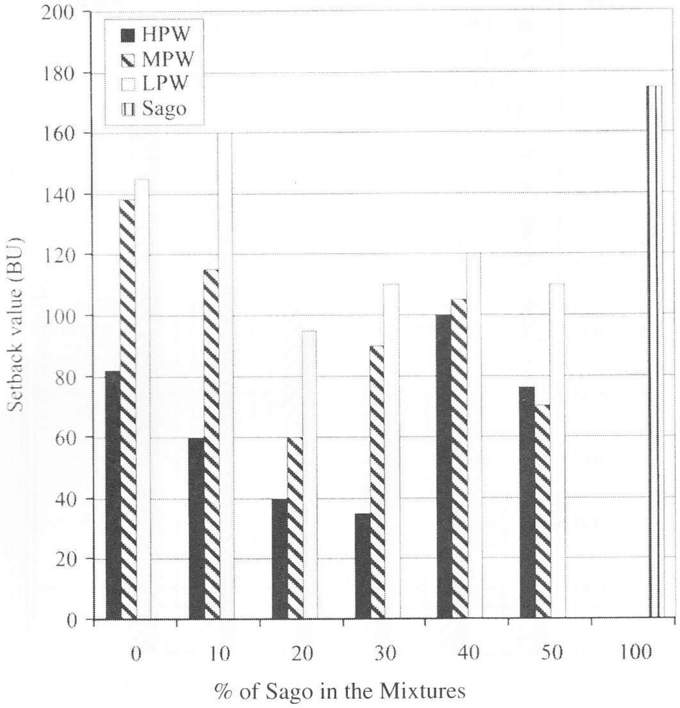

Figure 7: Setback values for wheat-sago mixtures

were always higher than in sago-MPW and sago-LPW mixtures. For all mixtures, the S_B values decrease with increasing sago portion up to 20%. However, S_B increases up to 40% sago substitution and is then followed by a decrease at 50%. The control sago flour shows the maximum S_B value.

In Figure 8, setback viscosity (V_S) is plotted as a function of sago portion. For all mixtures, the V_S increased with sago portion up to 20%, followed by a rapid increase with increases in sago portion up to 50%.

Viscosity after 30 min at 50°C indicates the stability of cooked paste (Figure 1).

The data on total setback (S_T) in Figure 9 shows that the total setback initially decreased with increasing sago up to 20% followed by a further increase with an increase of the sago portion up to 50% in the mixtures. For control sago, the S_T value tends to decrease slowly. S_T for the controls and mixtures did not show any significant trend. The high S_T value represents the gelatinization behaviour, which is different for different starch flour from different wheat species (Md Zaidul, 2000).

DISCUSSION

The analysis shows differences at 20% sago for gelatinization temperature (T_G) for all sago-LPW, sago-MPW and sago-HPW mixtures. For the mixtures containing 10% and 30% sago, the difference in T_G for each type of mixture was not much but were different to that of flour mixtures containing 40% and 50% sago. T_G values for all percentages of sago in the mixtures mentioned are different from the control wheat (Figure 2). Sterling (1978) noted that the T_G seems to depend on the relative

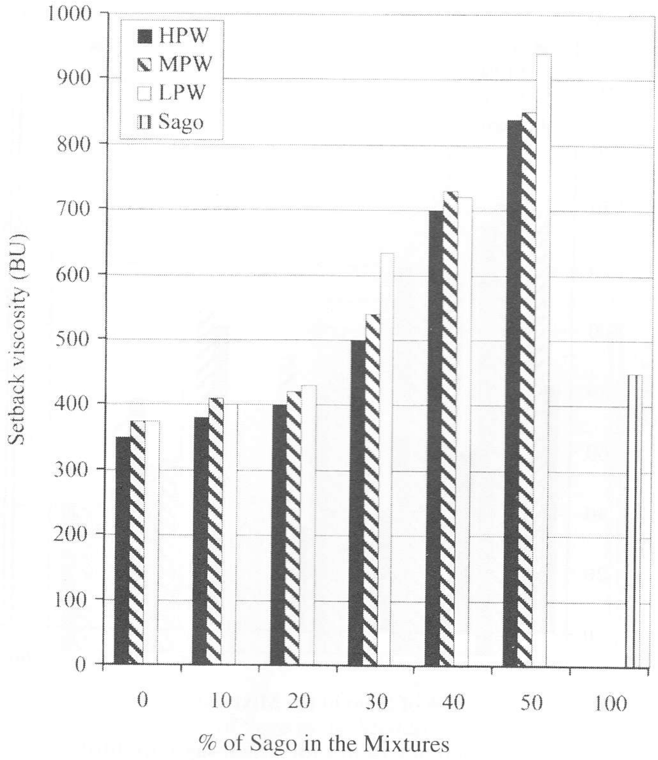

Figure 8: Setback viscosities for wheat-sago mixtures

proportions of amylose and amylopectin, such that higher amylose contents are associated with higher gelatinization temperatures. However for wheat starch, no such relationship was noted by Kulp (1973) or Medcalf and Gilles (1965). The starch amylose content varied from 23.4 to 27.6 %, with durum wheat tending to be highest and soft wheat tending to be lowest. In general, the higher amylose starches have a higher water-binding capacity (Medcalf and Gilles, 1965).

The presence and properties of protein complicate the gelatinization properties of flour. Anker and Geddes (1944) showed that substitution of gluten proteins for an equivalent weight of starch decreased peak viscosity but at equal starch concentrations, the presence of wheat gluten increased peak viscosity. Mathewson and Pomeranz (1978) concluded that the protein content of wheat flours did not affect the amylograph peak viscosity consistently. Elliasson *et al.* (1981) reported protein bound to granule surfaces at 1.5-4.7 mg/g. Olkku and Rha (1978) point out that protein forms complexes with the starch granule surface, preventing the release of exudates and so lowering peak viscosity.

At all concentrations of starch, viscosity increases markedly after gelatinization. This increase was formerly ascribed to lack of water to act as a lubricant between the moving swollen granules as they continue to swell (Schoch, 1969). As disintegration of granules becomes more important at elevated temperatures, viscosity drops, which provides the characteristic peak in the viscosity curve. Viscosity may be a function of temperature alone if a large amount of

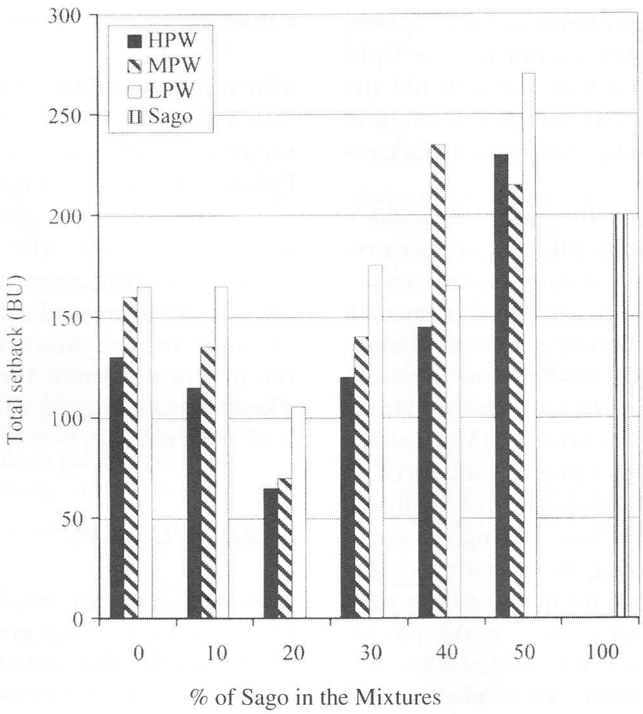

Figure 9: Total setback for wheat-sago mixtures

water is present, caused solely by the release of exudates (Longley and Miller, 1971), but the extent to which swollen granules contribute to viscosity in more concentrated suspensions is unclear. Miller *et al.* (1973) showed the maximum viscosity of a starch suspension heated in an excess of water occurred after most of the granule swelling had ceased.

Figure 4 shows that the mixture with 40% sago exhibited different peak temperature (T_P) values. However, T_P was different for all percentages of sago portions in the sago-wheat flour mixtures. It assumes that T_P decreased with the increment of sago in the mixtures due to dilution of protein content.

In Figure 5, sago substitution in the flour mixtures and protein content of wheat flour in the mixtures influence the breakdown viscosity (V_B). The ratio of flour has an effect on V_B. The same effect could be observed for the different wheat protein compositions. These factors influence the V_B (Md Zaidul, 2000).

V_B is regarded as a measure of the degree of disintegration of the granules (Mazurs *et al.*, 1957) or of "paste stability" (Olkku and Rha, 1978) and is not the true breakdown of rheology. It may suggest that amylopectin recrystallisation is retarded by complex formation of lipid surfactants with amylopectin (Kugimiya *et al.*, 1980).

Figure 6 shows that for sago-wheat (HPW, MPW and LPW) mixtures the B_D increased with increasing sago portion from 10 to 40%. For 50% sago it decreases, perhaps because a considerable proportion of the amylose molecules had already formed a complex with the natural lipids in wheat starch. This may support the suggestion of Md Zaidul (2000) that any effect on the recrystallization of amylopectin is due to complex formation of lipid surfactants with amylose and it belies the notion of substantial complex formation between amylopectin and lipid surfactants (Md Zaidul, 2000).

In Figure 6, for 40% sago, the sudden change in breakdown value for all mixtures is notable. Setback and paste consistency are the index to starch retrogradation with cooling. Retrogradation is a phenomenon, which involves recrystallization of starch molecules. Protein content also influences the paste setback value, S_B (Md Zaidul, 2000). The difference may be influenced by the increments of sago portion and dilution of protein in wheat flour. During storage of concentrated starch gels, an increase in the stiffness of the gels occurred, which must be due mainly to amylopectin recrystallisation (Keetels *et al.*, 1996). It is assumed that the formation of amylose-lipid complexes may retard the increase in stiffness during storage due to decreased local mobility.

Setback viscosity (V_S) varies with different ratios of sago-wheat (Figure 8). The different content of protein also gives different values. High amylose content in wheat starch may be influencing the high V_S value (Md Zaidul, 2000).

V_S is regarded as a measure of gelling ability or "retrogradation tendency" (Mazurs *et al.*, 1957). The cooled paste is often stirred for up to 60 minutes to measure stability (Olkku and Rha, 1978). It may occur due to the presence of lipids in wheat starch (Russell, 1987). The differences between concentrated sago and wheat starch systems cannot be ascribed solely to the lipids present in wheat starch. Another explanation for these different properties suggested by Keetels *et al.* (1996) was that it was due to the larger number of chain entanglements in swollen wheat starch granules than in swollen sago starch granules.

CONCLUSION

Wheat flours of different protein contents and different ratios of sago starch in mixtures affected gelatinization properties. Gelatinization temperature increased with increases of sago in the mixtures. Peak viscosity for control wheat flour decreased with decreasing protein content. Peak viscosity also increased with increasing levels of sago in the mixtures, while peak temperature showed the opposite trend. These results suggest that retrogradation had occurred.

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