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Effect of monopalmitin on pasting properties of wheat starches with varying amylose content

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ABSTRACT

The influence of varietal differences among wheat (*Triticum aestivum* L.) starches on properties of starch pastes and gels was studied. Wheat varieties with elevated total amylose content within a narrow range (36–43%) displayed widely differing pasting properties in a Rapid Visco Analyser (RVA). The pasting properties of the wheat starches were influenced significantly by the addition of monopalmitin. Increase in final RVA pasting viscosity of starch–monopalmitin mixtures was correlated positively with increasing amylose content. The textural characteristics of the respective retrograded starch gels also differed greatly and were affected by varietal differences between the starches. There was no correlation between textural properties of aged gels with amylose content or the viscoelastic characteristics measured by the RVA. The strength of gels may be affected by subtle differences in starch structure that influence retrogradation, but have only limited effect on starch pasting properties.

1. Introduction

Starch contributes to the viscosity, texture, mouth-feel and consistency of many food products. The functionality of starch in foods is related largely to its gelatinization, pasting, gel-forming and retrogradation characteristics. On heating in water, usually above 60 °C, starch granules swell and lose their crystallinity and molecular organization. The swollen granules eventually rupture, resulting in preferential leaching of amylose and partial solubilization of amylopectin molecules. The gelatinization characteristics of starch pastes and gels depend on a multiplicity of factors including concentration, type and origin of the starch, processing conditions (for example, temperature, rate of heating and cooling, shear, time, pH, sample history) and the presence of other components, such as sugars, lipids, protein, emulsifiers, gums and salts (Sopade, Hardin, Fitzpatrick, Desmee, & Halley, 2006). The entanglement and interaction between amylose and amylopectin molecules and entrapped incompletely disrupted granules are responsible for the viscosity characteristics of starch pastes and gels (Debet & Gidley, 2007; Evans & Lips, 1992; McGrane, Mainwaring, Cornell, & Rix, 2004). On cooling, gelatinized starch dispersions form gels, which retrograde and result in the starch molecules re-associating into a partially ordered structure that differs from that of native granules. Lipids can alter the physical and chemical properties of starch through their surface-active properties and their ability to form inclusion complexes with amylose (Morrison, Tester, Snape, Law, & Gidley, 1993; Zobel, 1988). Interactions between starch and lipids can influence gelatinization, viscoelastic properties of pastes and gels, retrogradation and the susceptibility of starch to enzyme attack (Copeland, Blazek, Salman, & Tang 2009; Crowe, Seligman, & Copeland, 2000; Eliasson, 1985; Eliasson & Krog, 1985; Gudmundsson, 1992; Seneviratne & Biliaderis, 1991; Tang & Copeland, 2007a).

The Rapid Visco Analyser (RVA) has been used to study the effects of additives on rheology of starch systems (Ravi, Sai Manohar, & Haridas Rao, 1999). Tang and Copeland (2007a) showed that starch–lipid complexes can be formed directly in the RVA and that viscoelastic parameters can be correlated with the formation of starch–lipid complexes. While the effects of the lipid component on the formation of starch–lipid complexes have been studied extensively, there is little information on the influence of the starch component. In the present study, we have used a set of wheat varieties from a breeding program to investigate the varietal influences of wheat starch on rheological properties of pastes and the strength of the respective gels formed by the starches alone and in mixtures with monopalmitin.

2. Materials and methods

2.1. Materials

Thirty-six wheat (*Triticum aestivum* L.) varieties from the Value Added Wheat Cooperative Research Centre Ltd. (VAWCRC) breeding program and a waxy wheat variety provided by George Weston

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Technologies (Enfield, NSW, Australia) were used in the study. Flour was prepared from grain, and starch extracted from flour, as described previously (Blazek & Copeland, 2008). The method for preparing starch granules included a protease step. Content of total (T-AM), free (F-AM) and lipid-complexed (L-AM) amylose, amylopectin chain-length distribution and swelling power of flour and extracted starch were taken from the study published by Blazek and Copeland (2008). Additionally, a commercial starch obtained from Penford Australia Pty Ltd. (Lane Cove, NSW, Australia) with specifications as described by Tang and Copeland (2007a) was used in the study.

2.2. Complexation of starch with palmitic acid and monopalmitin

Starch was complexed with palmitic acid and monopalmitin in an aqueous medium according to the following method. Starches were first freed of endogenous lipids by dissolving 20 mg of starch in 1 ml of dimethylsulphoxide with heating in a boiling water bath for 15 min. Ethanol (5 ml) was added and the starch samples were kept at 60 °C for 30 min before precipitated starch was collected by centrifugation at 3000*g* for 5 min. The pellet was dissolved in 5 ml of deionized water with heating in a boiling water bath. Palmitic acid or monopalmitin dissolved in 0.1 ml of ethanol was added to the starch solution and the mixtures incubated for 60 min at 80 °C with continuous mixing.

The complexing index (CI) of starch was measured by the method of Gilbert and Spragg (1964) with modifications as follows. An aliquot of starch solution (0.1 ml) was added to 5 ml of deionized water and 0.05 ml of iodine solution (0.13% w/v I_2 and 0.3% w/v KI in water) was added with mixing. The absorbance at 620 nm was read after 30 min at 25 °C. The CI was calculated from $CI = 100(A_S - A_{S-L})/A_S$, where A_S is the absorbance of the starch solution without added lipid, and A_{S-L} is the absorbance of the starch solution with added lipid.

2.3. Pasting properties

Pasting properties of the starch samples were analyzed in a Rapid Visco Analyser 4 (Newport Scientific, Warriewood, Australia) according to AACC Method 76-21 (American Association of Cereal Chemists, 2000) as described by Tang and Copeland (2007a). Starch (10% moisture, 3 g) was pasted in 25 ml of deionised water using the 13-min STD1 profile (heat–hold at 95 °C – cool) supplied with the instrument. Monopalmitin (30 mg) was added directly to the starch–water mixture in the RVA canister in the amounts indicated in the figures. Peak viscosity, viscosity at trough (also known as minimum viscosity), and final viscosity (FV) were recorded, and breakdown (which is peak minus minimum viscosity) and setback (which is final viscosity minus minimum viscosity) were calculated using the Thermocline software provided with the instrument. The lipid-induced increase in FV (ΔFV) was calculated as the percentage difference between FV of starch pastes with added lipid compared to starch alone.

2.4. Texture profile analysis

Starch pastes formed in the RVA canisters were prepared for texture profile analysis (TPA) as follows. The paddle was removed from the canister immediately after the completion of the RVA run and the bottom of the canister was tapped several times on the bench to create a flat surface on the top of the paste. Canisters were sealed with Parafilm to prevent moisture loss and left overnight at 4 °C. Texture analysis was carried out using a TA-XT2 Texture Analyser (Stable MicroSystems, UK) fitted with an ebonite cylindrical probe 12 mm in diameter. Canisters were positioned centrally under the probe and upon attainment of a trigger force of 4 g the probe was allowed to penetrate into the starch gel at a constant rate of 0.5 mm/s to a compression depth of 10 mm. A single compression cycle with zero gap between compression and release was applied. From the force–time curve obtained, gel strength (height of the force peak) was computed using the Texture Expert software supplied with the instrument.

2.5. Amylase digestions

The extent of β-amylase hydrolysis of the starches was determined from the iodine-binding value of the β-limit dextrin expressed as a percentage of the iodine-binding value of the initial starch solution. Starch (20 mg) was gelatinized in 3 ml sodium acetate buffer (100 mM, pH 7.2) by heating in a boiling water bath, and β-amylase from *Bacillus* sp. (EC 3.2.1.2; 100 IU, Megazyme International Ireland, Ltd., County Wicklaw, Ireland) was added. The mixtures were incubated for 24 h at 40 °C and heated in a boiling water bath for 5 min at the end of the incubation. Iodine-binding value before and after β-amylolysis was measured by the method of Chrastil (1987). The increase in iodine-binding value due to debranching of starch by iso-amylase was determined similarly, except that sodium acetate buffer (100 mM, pH 4.5) and iso-amylase from *Pseudomonas sp.* (EC 3.2.1.3; 10 IU, Megazyme International Ireland, Ltd., County Wicklaw, Ireland) were used. The extent of iso-amylolysis was calculated as the percentage of the iodine-binding value of the debranched starch compared to the initial starch solution.

2.6. Statistical analysis

All chemical analyses were performed using separate duplicate starch samples. For each measured characteristic, mean, minimum and maximum values were calculated across the samples (Table 1). Correlation analysis was performed using XLStat software (Addinsoft, New York, NY). Pearson's correlation coefficients (r) were calculated between pairs of measured characteristics. A statistically significant relationship between two variables is indicated at the level of statistical significance of $p < 0.05$. The waxy line and commercial starch were excluded from the statistical analyses so as not to distort the correlation coefficients by artificially increasing the range of measured characteristics. Also, the samples from the VAWCRC were grown, stored and milled under comparable conditions, which were different from those for the waxy and commercial starches.

Table 1
Summary of the properties of the starches used in this study. Total (T-AM), free (F-AM) and lipid-complexed (L-AM) amylose content (%), swelling power and RVA data (peak viscosity, viscosity at through, breakdown, final viscosity and viscosity at setback expressed in RVU) were adopted from Blazek and Copeland (2008). β- and iso-amylolysis, expressed as % change in iodine-binding, were determined as described in the text. The increase in FV (ΔFV) was calculated as the percentage difference between FV of starch pastes with added 1% monopalmitin compared to starch alone. The waxy and commercial starches were not included in these data.

	Minimum	Maximum	Mean
F-AM	26.3	35.3	31.6
T-AM	35.2	42.8	38.6
L-AM	4.1	14.2	7.1
Swelling power of flour	7.7	11.6	9.4
Swelling power of starch	5.4	6.9	6.1
Starch peak viscosity	181.4	268.0	222.5
Starch trough	142.0	217.7	169.0
Starch breakdown	30.0	90.5	53.5
Starch final viscosity	228.7	313.5	265.7
Starch setback	72.5	111.6	96.7
β-Amylolysis	24.2	34.9	28.9
Iso-amylolysis	6.6	18.8	14.2
ΔFV	8.7	64.9	34.3

3. Results

Initial experiments were performed using the commercial wheat starch to compare *in vitro* complexing ability of palmitic acid and monopalmitin. The CI increased with increasing concentration of monopalmitin up to a maximum value at approximately 1.5% w/w of starch. Further increases of monopalmitin concentration did not lead to any further change in complexation index (Fig. 1). In contrast, CI with palmitic acid reached a maximum around 1% w/w of starch and further increases in lipid concentration resulted in a decrease in CI (Fig. 1). Based on these results, all subsequent experiments were performed with monopalmitin because of its good complexing abilities and limited tendency to form micelles under the experimental conditions (Larsson, 1980; Tang & Copeland, 2007a).

The peak viscosity of the starches used in this study, excluding the waxy wheat, ranged between 181 and 268 RVU, whereas final viscosity ranged from 229 to 314 RVU (Table 1; Blazek & Copeland, 2008). The addition of 1% monopalmitin resulted in a ΔFV of between 9 and 65%, depending on the starch (Table 1). The examples of RVA traces in Fig. 2 show that ΔFV of varieties Ega Hume (T-AM 37%) and SM1118 (T-AM 39%) were 12% and 65%, respectively, due to the addition of 1% monopalmitin. Correlations between ΔFV and physicochemical and pasting characteristics were calculated for all 36 VAWCRC starches (Table 2). There was a significant negative correlation between ΔFV and all starch paste viscosity characteristics, with the strongest correlations being with peak viscosity ($r = -0.766$, $p < 0.001$) and breakdown ($r = -0.712$, $p < 0.001$). Significant positive correlations were found between ΔFV and T-AM ($r = 0.611$, $p < 0.001$) and extent of β-amylase hydrolysis ($r = 0.515$, $p < 0.001$), whereas ΔFV swelling correlated negatively with swelling power of flour and starch ($r = -0.700$ and $r = -0.583$ at $p < 0.001$, respectively).

Comparison of TPA curves of starch gels prepared from starch alone and with added monopalmitin showed the dramatic change in the textural properties of retrograded gels due to the added lipid (Table 3). Addition of 1% monopalmitin to the commercial starch, which had 35% T-AM, caused a reduction in the gel strength from 120 to 20 g (Fig. 3). On the other hand, tripalmitin, which does not form stable complexes with starch (Tang & Copeland, 2007a), had the opposite effect on the elasticity of commercial starch gel, causing a small increase of the gel strength to approximately 140 g.

TPA analysis was also performed on a subset of seven of the VAWCRC starches, selected on the basis of covering a wide range of lipid-induced increases in final RVA viscosity. There were significant differences in the textural properties of gels prepared from the starches, which had T-AM varying between 36% and 40% and ΔFV between 9% and 55% (Table 3). The strength of the gels prepared from these starches was lower than that of commercial starch. For example, Diamondbird I (36% amylose content) produced a gel with rupture strength of 50 g as compared to 120 g for the commercial starch, whereas the gel from variety Petrie II (38% amylose content) displayed rupture strength of 110 g (Fig. 4). The other varieties studied produced gels with textural parameters between these two extreme values (Table 3). Addition of monopalmitin resulted in a decrease of the gel strength, with

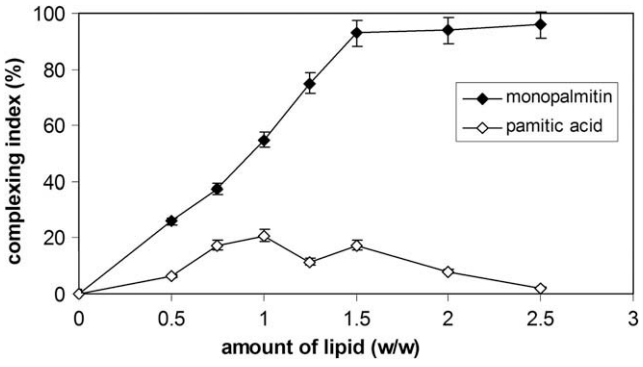

Fig. 1. Complexing index of commercial starch as a function of the amount of lipid added. Lipids were dissolved in ethanol and complexed with starch as described in the text.

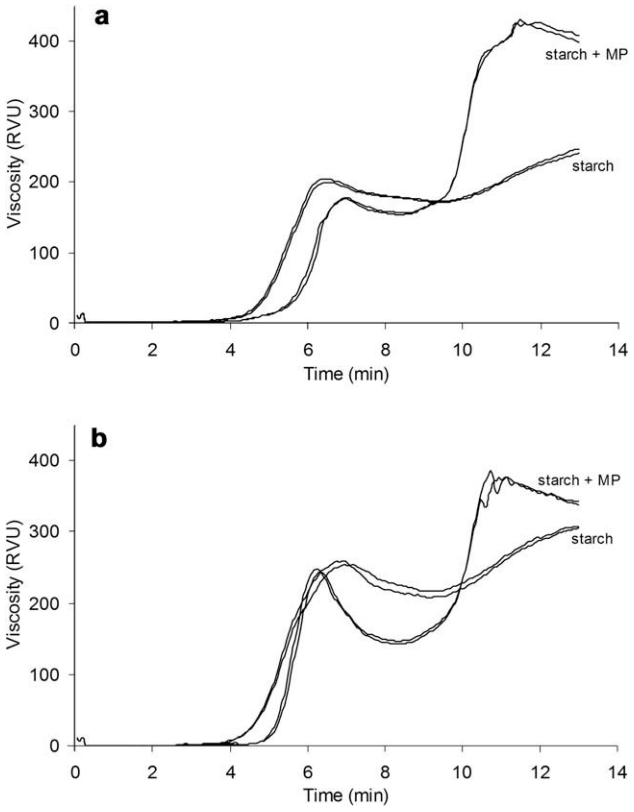

Fig. 2. Examples of RVA traces of pastes of starch and starch with 1% monopalmitin. Duplicate traces are shown for variety SM1118 (39% amylose content) (a); and variety Ega Hume (37% amylose content) (b).

Table 2
Correlation matrix based on Pearson's correlation coefficients between increase in final viscosity (ΔFV) and physicochemical properties of starches. Based on 36 samples, the minimum value of r significant at $p = 0.05$ is 0.329. Total (T-AM), free (F-AM) and lipid-complexed (L-AM) amylose content (%), swelling power and RVA data (peak viscosity, viscosity at through, breakdown, final viscosity and viscosity at setback expressed in RVU) were adopted from Blazek and Copeland (2008). β- and iso-amylolysis, expressed as the percentage change in iodine-binding, were determined as described in the text. The ΔFV was calculated as the percentage difference between FV of starch pastes with added lipid compared to starch alone. Values in bold are significant at the level of significance $\alpha = 0.05$ (two-tailed test).

Property	ΔFV
F-AM	0.241
T-AM	**0.611**
Swelling power of flour	**−0.700**
Swelling power of starch	**−0.583**
Starch peak viscosity	**−0.766**
Starch trough	**−0.395**
Starch breakdown	**−0.712**
Starch final viscosity	**−0.578**
Starch setback	**−0.581**
Starch peak time	−0.181
β-amylolysis	**0.515**
Iso-amylolysis	0.021

Table 3
Physicochemical and textural characteristics of starch from a selected subset of wheat varieties. Total (T-AM), free (F-AM) and lipid-complexed (L-AM) amylose content (%), swelling power and RVA data (peak viscosity, viscosity at through, breakdown, final viscosity and viscosity at setback expressed in RVU) and chain length distribution were adopted from Blazek and Copeland (2008). β- and iso-amylolysis, expressed as % change in iodine-binding, were determined as described in the text. The increase in FV (ΔFV) was calculated as the percentage difference between FV of starch pastes with added lipid compared to starch alone. Gel strength, as the height of the force peak, was derived from the texture profiles as determined by TPA as described in the text.

	T-AM	F-AM	Swelling power of flour	Swelling power of starch	Starch peak viscosity	Starch trough	Starch breakdown	Starch final viscosity	Starch setback	Starch peak time
Diamondbird III	35.6	26.3	9.8	6.9	236.8	173.2	63.6	278.1	104.9	6.53
Diamondbird I	36.1	29.9	11.6	6.3	258.5	176.0	82.5	272.5	96.5	6.44
Sunvale I	36.6	32.4	10.3	6.4	230.4	168.3	62.1	271.9	103.5	6.34
Petrie II	37.6	32.9	9.8	5.7	239.0	184.2	54.8	288.6	104.4	6.47
Vasco	38.9	30.7	9.8	6.1	243.4	191.8	51.6	300.6	108.9	6.73
V306	39.0	32.9	8.9	6.2	191.6	150.3	41.3	232.7	82.4	6.47
328-1 III	40.2	31.0	8.8	6.0	188.5	143.9	44.6	234.7	90.8	6.27

	β-Amylolysis	Iso-amylolysis	DP 6–12	DP 13–24	DP 25–36	DP 37–55	ΔFV	Gel strength	
								Starch	Starch + lipid
Diamondbird III	25.7	115.8	41.96	47.40	8.90	1.74	17.7	61.7	14.9
Diamondbird I	26.0	116.4	43.00	47.02	8.40	1.58	8.8	53.0	15.6
Sunvale I	26.8	112.7	43.07	47.79	7.72	1.43	19.8	67.3	26.0
Petrie II	30.2	111.2	41.45	48.58	8.32	1.65	34.1	105.0	20.5
Vasco	29.0	118.3	40.13	49.16	8.87	1.83	25.1	83.1	18.3
V306	28.6	113.7	40.98	48.32	8.94	1.75	52.6	76.3	18.0
328-1 III	29.7	114.2	42.29	47.69	8.37	1.64	55.0	106.0	19.0

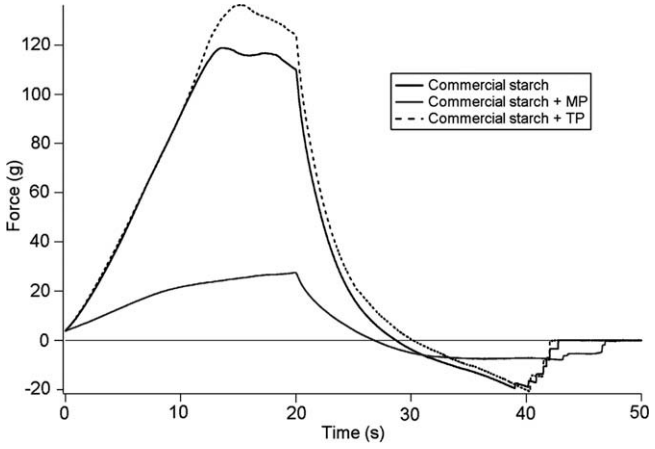

Fig. 3. TPA curves of starch gels prepared from the commercial starch alone, and with monopalmitin (MP) and tripalmitin (TP), each added at 1% w/w. Compression depth of 10 mm at a constant rate of 0.5 mm/s and zero gap between compression and release was applied as described in the text. Gel strength was calculated as the height of the force peak.

peak force values for all of the starches ranging between 15 and 26 g (Table 3).

A correlation matrix showed that there was a negative correlation between strength of starch-only gels and starch swelling power (Table 4). A significant positive correlation at $p < 0.05$ was also found between gel strength and β-amylolysis. In comparison, the only significant correlation found for gels prepared from starch with added monopalmitin, was a negative correlation between gel strength and the percentage of amylopectin chains of DP 25–36 (Table 4). Gel prepared from waxy wheat did not display any measurable resistance to the penetrating probe.

Debranching with iso-amylase increased the iodine-binding value of the commercial starch by 20%. This value gives an indication of the proportion of freed linear amylopectin chains that are long enough to potentially complex with iodine but do not do so in the native molecule because of steric effects. For the other starches used in this study, debranching by iso-amylase caused iodine value to increase by between 7% and 19% (Table 1). The iodine value of starch samples after β-amylolysis was between 24% and 35% of the original iodine value (Table 1). The ranges for these values reflect differences in the molecular structure of both the amylose and amylopectin components of the starches.

4. Discussion

The functional properties of a series of wheat starches with similar amylose content in a narrow range between 36% and 43% have been examined in the present study. The starches differed in their viscoelastic properties in the RVA, in their responses to the addition of monopalmitin, and in the textural properties of the retrograded gels. Many of the viscoelastic properties of starch pastes are influenced by the amylose content of the starch. For example, higher setback values are usually correlated positively with the amylose content of starch, whereas gelatinization temperature and peak viscosity, which are indicative of the water-binding capacity of the starch and the ease with which the starch granules are disintegrated, are in general inversely related to the amylose content of the starch (Copeland et al. 2009; McGrane et al., 2004). As the proportion of amylose content increases to a certain point, the degree of amylose aggregation increases, resulting in more closely spaced junction zones giving a tighter network (Blazek & Copeland, 2008).

The setback and final viscosity of pastes are increased when starch is mixed with lipids that can form complexes with amylose. The increase in final viscosity of starch pastes is correlated with decreased iodine-binding capacity and provides a measure of the extent of complexation between starch and lipid (Tang & Copeland, 2007a). Addition of complexing agents hinders the formation of double helical structures because single helical complex is a favoured conformation. An increased amount of amylose in a single helical conformation in the presence of complexing lipid reduces the ability of amylose to form networked double helical structures, resulting in an increased spacing between junction zones and a looser gel with higher final paste viscosity.

Upon cooling, retrogradation of the gelatinized starch leads to development of extensive molecular networks linked by amylose strands (Richardson, Kidman, Langton, & Hermansson, 2004; Tang & Copeland, 2007b). Starch gels that contain amylose are characterized by extended molecular networks, whereas gels of waxy

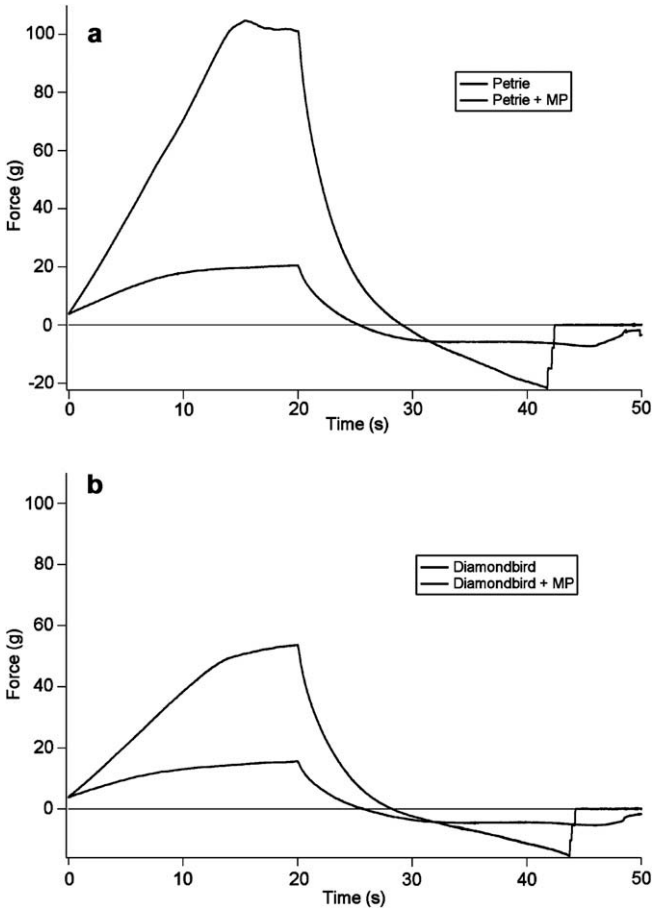

Fig. 4. TPA curves of starch gels prepared from the starch alone and with added monopalmitin (MP) added at 1% w/w. Compression depth of 10 mm at a constant rate of 0.5 mm/s and zero gap between compression and release was applied as described in the text. Gel strength was calculated as the height of the force peak. Gels made from variety Petrie (a) and variety Diamondbird (b) are shown as examples.

starch and starches mixed with lipids contain mostly aggregated globular structures (Tang & Copeland, 2007b). Amylose-based networks are considered to provide elasticity and strength against deformation of starch gels (Miles, Morris, Orford, & Ring, 1985; Mua & Jackson, 1997; Shi, Capitani, Trzasko, & Jeffcoat, 1998; Tang & Copeland, 2007b; Vandeputte, Vermeylen, Geeros, & Delcour, 2003), whereas aggregates form softer gels with easier penetrability and greater stickiness and adhesiveness. The reduced availability of amylose for intermolecular hydrogen bonding disrupts long distance interactions within the gel resulting in decreased cohesiveness of the structure. Accordingly, waxy wheat, which is essentially free of amylose, forms a soft translucent gel.

The extent to which monopalmitin modified the texture of aged starch gels was assessed by texture profile analysis. The peak force at the rupture point of the gel, referred to as rupture strength, was taken as an indication of gel firmness. The distance that the probe penetrates before this break occurs gives an indication of the elasticity of the gel; a short distance of penetration before the break occurs indicates a brittle gel, whereas longer penetration distance before rupture indicates a more elastic gel. In gels of starch alone, amylose retrogradation occurs within minutes to hours after cooling, whereas amylopectin takes hours to days to retrograde, depending on storage conditions (Copeland et al., 2009). In the present study, gels were stored at 4 °C for 16 h, which is likely to be sufficient time for amylose to retrograde substantially, whereas amylopectin is likely to have retrograded only to a limited extent during this time.

Table 4
Correlation matrix based on Pearson's correlation coefficients between starch gel strength and starch properties. Based on 7 samples, the minimum r value significant at $p = 0.05$ is 0.755. Total (T-AM), free (F-AM) and lipid-complexed (L-AM) amylose content (%), swelling power and RVA data (peak viscosity, viscosity at through, breakdown, final viscosity, viscosity at setback (expressed in RVU) and amylopectin chain length distribution were adopted from Blazek and Copeland (2008). β- and iso-amylolysis, expressed as % change in iodine-binding, were determined as described in the text. The ΔFV was calculated as the percentage difference between FV of starch pastes with added lipid compared to starch alone. Gel strength was derived from the texture profiles as determined by TPA as described in the text. Values in bold are significant at the level of significance $\alpha = 0.05$ (two-tailed test).

Property	Gel strength	
	Starch	Starch + lipid
T-AM	0.743	0.115
F-AM	0.481	0.662
Swelling power of flour	−0.675	−0.098
Swelling power of starch	**−0.759**	−0.273
Starch peak viscosity	−0.485	−0.139
Starch trough	−0.180	−0.051
Starch breakdown	−0.707	−0.202
Starch final viscosity	−0.148	0.025
Starch setback	−0.075	0.162
Starch peak time	−0.166	−0.390
β-Amylolysis	**0.939**	0.244
Iso-amylolysis	−0.427	−0.586
DP 6–12	−0.371	0.240
DP 13–24	0.541	0.249
DP 25–36	−0.061	**−0.799**
DP 37–55	0.183	−0.662
Final viscosity increase	0.724	0.099
Starch gel strength	1	0.256

In general, stronger starch gels are associated with higher amylose content (Ishiguro, Noda, Kitahara, & Yamakawa, 2000). However, while the starches used in the present study had similar amylose content, they formed gels that differed by a factor of two-fold in strength (compare varieties Diamondbird I and 321-1 III). The textural properties of stored gels prepared from the starches alone, or from mixtures of the starches with monopalmitin, did not correlate with amylose content or rheological characteristics measured in the RVA. This indicates that there are differences of significance in the molecular architecture of the starch molecules between the wheat varieties, in addition to small differences in the amylose content. The large variation observed in the extent of iso-amylolysis and β-amylolysis is consistent with structural differences between the starches used in this study. Similar conclusions were reached by Shi et al. (1998) using maize hybrids. Gel

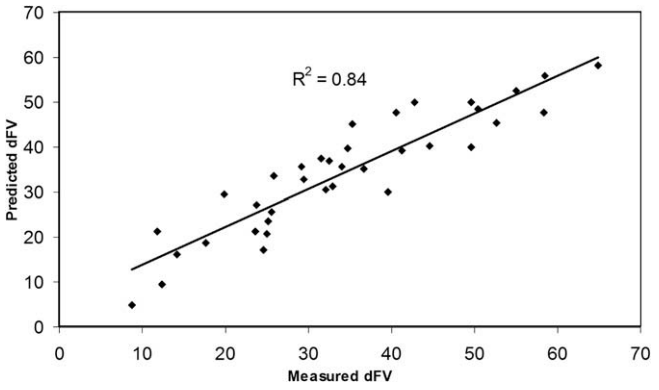

Fig. 5. Multivariate linear regression analysis showing predicted *versus* measured values of the monopalmitin-induced increase in final viscosity dFV, using the model described in the text.

strength was correlated most strongly with β-amylolysis and to a lesser extent starch swelling power. The weak correlation with total amylose content indicates that subtle differences in structure may have far-reaching consequences in relation to the strength of the gels.

In contrast, final RVA viscosity, which is a measure of the resistance of the starch paste to shear, was less sensitive to such subtle differences in architecture. A multivariate linear regression analysis performed with a model based on total and free amylose content and RVA parameters indicated that ΔFV following the addition of monopalmitin could be predicted from other properties. The coefficient of determination between experimental and predicted values of ΔFV from this model ($R^2 = 0.84$) represents the extent to which the modelled parameters account for the variability of ΔFV (Fig. 5). When the number of variables used to fit the model was taken into account an adjusted R^2 of 0.76 was obtained, confirming the predictive ability of the model. On the other hand, the effect of monopalmitin on gel strength did not correlate with amylose content, swelling power or any of the RVA parameters. This lack of correlation indicates that gel strength may be related more to factors that are less easily measured, such as variations in architecture of starch polymers and how these influence water distribution and activity and affect molecular interactions.

5. Conclusions

This study has shown that pasting and gelling properties of a series of wheat starches with enriched amylose content of between 36% and 43% were influenced significantly by varietal differences when mixed with monopalmitin. The effect of monopalmitin addition on final RVA viscosity was predictable to some extent from the amylose content and pasting properties of the starch. In contrast, the lack of correlation between viscoelastic properties of the starch pastes and textural properties of stored gels, indicated that subtle differences in starch structure affects gel strength to a much greater extent than RVA pasting properties.

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