Comparison of Oil, Shortening, and a Structured Shortening on Wheat Dough Rheology and Starch Pasting Properties

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ABSTRACT

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Monoacylglycerol-stabilized oil in water emulsion (MAG gel) is an alternate shortening that is free of *trans* fatty acids, and low in saturated fatty acids. However, the behavior of MAG gels in comparison to other lipids has not been studied. This study investigated effects of structured MAG gel, a mixture of MAG gel unstructured components (Mixture), canola oil (Oil), or interesterified soy shortening (IE Soy) at different levels (6–24%) on hard or soft wheat dough properties. Doughs were prepared with different lipid types at equivalent lipid contents. Dough mixing and water absorption parameters were evaluated using a farinograph; gluten behavior was measured using a gluten peak tester (GPT); and pasting characteristics were measured using a micro-viscoamylograph (MVAG). Water absorption values decreased with increasing lipid content. Dough development times were similar between the MAG gel and IE Soy, but farinogram curve characteristics during mixing were similar between MAG gel, Mixture, and Oil. The trend for peak max time in GPT was similar between MAG gel and IE Soy exhibiting delayed gluten aggregation; whereas Mixture and Oil exhibited earlier gluten aggregation. In MVAG, starch interaction with monoglyceride component of MAG gel and Mixture appeared to be the dominating factor resulting in increased pasting temperature and a second viscosity peak during cooling at higher levels of lipid addition.

Lipids are utilized in a majority of baked products: in bread formulations at 2–5%, in cakes at 5–25%, in sweet goods at 20–30%, in puff pastry at 30–40%, and in pie crust at 20–35% on a flour weight basis (fwb). Lipids in baked goods serve multiple purposes including shortening, lubrication, aeration, help with heat transfer, extension of shelf life, as well as provide structure and desirable textural properties such as tenderness, richness, and improved mouthfeel. Lipids used in baked products such as liquid oils or high melting plastic fats have a range of properties depending on the specific applications. In recent years, the baking industry has been seeking alternatives to solid hydrogenated shortening that provide unique functionality to baked products but are low in *trans* fatty acids. Interesterified fats are one alternative but they still contain high levels saturated fatty acids (Table I) that also are linked to negative health effects (WHO 2004).

Applications of lipids and emulsifiers in baked products have been studied extensively for their effects on different characteristics, particularly dispersion, lubrication, and softening in bread (Baldwin et al 1972; Ghotra et al 2002; Azizi et al 2003; Azizi and Rao 2004b; Goesaert et al 2005) and biscuits and cookies (Baldwin et al 1972; Maache-Rezzoug et al 1998; Manohar and Rao 1999; Chevallier 2000; Ghotra et al 2002; Zoulias et al 2002; Jissy et al 2007; Sudha et al 2007; Pareyt and Delcour 2008). Lipids and emulsifiers have also been investigated for interactions with starch (Stauffer 1999; Ghotra et al 2002; Watanabe et al 2002; Azizi and Rao 2005; Mira et al 2005). Starch-lipid complexes can have a great effect on starch gelatinization and retrogradation characteristics (Goesaert et al 2005).

The structured shortening alternative (MAG gel) used in this study is a cellular-solid that is an oil-in-water emulsion with water-swollen monoacylglycerol multilamellae surrounding 1–5 µm oil globules (Fig. 1). The globules are interconnected with each other through hydrogen bonding and stearic acid aids in emulsion formation, water-binding, and surface charge modulation (Marangoni et al 2007). The physicochemical and structural attributes of MAG gels have been well characterized and it was demonstrated that the consumption of MAG gels lowers triglyceride levels and free fatty acids after ingestion, as well as decreasing insulin sensitivity compared to oil consumption (Marangoni et al 2007). MAG gel is composed of canola oil (55.25%), water (40%), monoglyceride (4.5%), and stearic acid (0.25%). Monoglycerides and diglycerides are the most widely used food-grade emulsifiers and are generally added to bakery products at a level of 0.75–1% to improve dough softness and for shelf life extension (Stauffer 1999). Structured MAG gel is a solid at room temperature, similar to other commercial shortenings, but is composed of structured liquid oil, water, and monoglyceride.

While the effects of individual components that make up MAG gel on dough and baked product attributes have been investigated extensively, questions remain about the functionality of structured

TABLE I
% Total Lipids, Saturated Fatty Acids, *Trans* Fatty Acids, and Water for Lipid Sources in This Study

	Interesterified Soy Shortening	MAG Gel	Mixture	Canola Oil
% Total lipids	100	60	60	100
% Saturated fatty acids	38	7	7	6
% *Trans* fatty acids	0	0	0	0
% Water	0	40	40	0

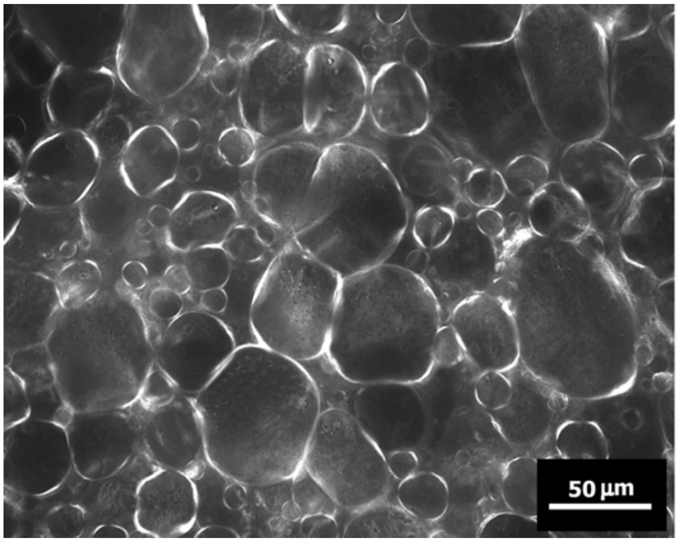

Fig. 1. Polarized light micrograph of monoacylglycerol-stabilized oil in water emulsion (MAG) gel.

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MAG gels in baked products. This study compares the functionality of the MAG gel to a mixture of its unstructured components, interesterified soy shortening (IE Soy), or canola oil with hard or soft wheat flour with lipid contents of 6–24%, which is the standard lipid content (fwb) in an AACC cookie procedure.

MATERIALS AND METHODS

Hard wheat flour (HWF, 12% moisture, 12% protein) and soft wheat flour (SWF, 12% moisture, 8% protein) were provided by Griffith Laboratories (Toronto, ON, Canada). Wheat starch (Midsol 50) was provided by MGP Ingredients (Atchison, KS). Interestserified soy shortening (IE Soy) was provided by Archer Daniels Midland (Decatur, IL). Canola oil was provided by Sunspun (Toronto, ON, Canada). MAG gel is composed of 55.25% canola oil (Sunspun), 40% deionized water, 4.5% distilled monoglyceride (Caravan Ingredients, Lenexa, KS), and 0.25% stearic acid (Caravan). MAG gel was vigorously mixed a hot (75°C) oil-monoglyceride solution with alkaline deionized water using an immersion hand blender and a static mixer (Marangoni et al 2007). The mixture was produced by combining the same proportions of deionized water (40%), canola oil (55.25%), and monoglyceride (4.5%) in the MAG gel at room temperature.

Microscopy

Monoacylglycerol crystals are birefringent and the microstructure encapsulating the liquid oil droplets in the MAG gel can be conveniently observed using polarized light microscopy (PLM). For the PLM study, a small droplet (≈10 µL) of MAG gel was placed on the glass slide, and then a glass cover was placed over the sample and slightly compressed to form a uniform film ≈10–15 µm thick. The microstructure of the MAG gel was observed using an BH microscope (Olympus, Tokyo, Japan). Images were acquired with a XC-75 CCD video camera (Sony, Japan) and an LG-3 PCI frame grabber (Scion, Frederick, MD) using a 40× long range objective lens with a numerical aperture of 0.9.

Farinograph

Hard or soft wheat flour samples with 0, 6, 12, 18, or 24% of MAG gel, Mixture, IE Soy, or Oil on an equal lipid basis were analyzed (Farinograph-E, Brabender GmBh, Duisburg, Germany) using Approved Method 54-21.01 (AACC International 2010) in a 50-g mixing bowl at a constant temperature of 30°C. The amount of water added was adjusted to obtain a consistency of 500 BU MAG gel, Mixture, IE Soy, and Oil were added directly to the flour on an equal lipid basis (Table II) and on a flour weight basis. Lipids were blended in the farinograph to obtain homogenous mixture for 1 min before adding water. Water absorption values at 500 BU and dough development times were obtained from software. All analyses were conducted in duplicate. Statistical analysis was conducted on water absorption percentages and dough development times (v.9.2, SAS Institute, Cary, NC). ANOVA was preformed with averages compared using Tukey's test ($P < 0.05$). Statistical comparison is referenced between flour types as well as levels within MAG gel, Mixture, IE Soy, or Oil and within levels between MAG gel, Mixture, IE soy, or Oil.

TABLE II
Lipid Source (% flour weight basis) Added to Obtain Standardized Lipid Contents Within Dough

	Added Lipid (% fwb)			
Lipid Source	6	12	18	24
MAG gel	10	20	30	40
Oil/monoglyceride mixture	5.5/0.5	11.1/0.9	16.6/1.4	22.1/1.9
Interesterified soy shortening	6	12	18	24
Oil	6	12	18	24

Gluten Peak Tester

HWF or SWF samples with different levels of lipid addition were analyzed using a gluten peak tester (GPT) (Brabender GmBh, Duisburg, Germany). HWF and SWF samples were evaluated at flour-to-water ratios of 0.85 and 1.19, respectively. Total weight of samples in the cup was 20 g. Lipids at 6–24% (fwb) were added. Tests were conducted at 30°C and the samples were mixed at 3,000 rpm for 10 min. The moisture content of the MAG gel and mixture were included in the water calculation to obtain the same flour-to-water ratio for all samples. The GPT records the torque generated by the sample and the peak maximum time (PMT) was determined using Brabender software. All analyses were conducted in duplicate. Statistical analysis was conducted on peak maximum times using SAS software. ANOVA was preformed with averages compared using Tukey's test ($P < 0.05$). Statistical comparison is referenced between flour types as well as levels within MAG gel, Mixture, IE soy, or Oil and within levels between MAG gel, Mixture, IE Soy, or Oil.

MicroViscoAmyloGraph

Pasting profiles of HWF, SWF, and wheat starch with different levels of lipid addition were determined in a Brabender microviscoamylograph (MVAG). An 8% dry basis (db) slurry was used in the study. The moisture content of the MAG gel and Mixture were included in calculation of the water added to the slurry so all samples had the same water content. The MAG gel, Mixture, IE Soy, or Oil was added in addition to starch or flour at 6, 12, 18, or 24% levels on a starch or flour weight basis. Suspensions were premixed for 60 sec and then subjected to stirring (250/min and using a 235 cmg cartridge) with a temperature profile of heating from 30 to 95°C at 7.5°C/min, holding at 95°C for 5 min, cooling from 95 to 30°C at 7.5°C/min, and holding at 30°C for 5 min. Pasting temperature, peak viscosity, and breakdown viscosity were determined using the applicable software. All analyses were conducted in duplicate. Statistical analysis was conducted on pasting temperature, peak temperature, peak viscosity, second peak temperature, second peak viscosity, and final viscosity using SAS software. ANOVA was performed with averages compared using Tukey's test ($P < 0.05$). Statistical comparison is referenced between flour types and starch as well as levels within MAG gel, Mixture, IE Soy, or Oil and within levels between MAG gel, Mixture, IE soy, or Oil.

RESULTS AND DISCUSSION

Effect of Lipids on Water Absorption and Dough Development

A representative farinogram curve at the 24% lipid addition level is shown in Fig. 2A and B for HWF and SWF, respectively. The curves exhibited different characteristics for MAG gel, Mixture, IE Soy, or Oil for SWF and HWF. In HWF, IE Soy dough displayed an initial hydration peak, then decreased in consistency and did not reach 500 BU in the 20-min test time. MAG gel, Mixture, and Oil in HWF had low consistencies initially, displaying no hydration peak developed at 18, 17.7, and 18.6 min, respectively. In SWF at 24% lipid addition, IE Soy dough developed at 1 min, where MAG gel and oil dough displayed low consistencies initially with gradual development at 6.4 and 9.9 min, respectively. The Mixture displayed an initial hydration peak and then a gradual development at 14 min. The MAG gel, Mixture, and Oil provided stability to the SWF at the 24% addition level and did not break down to the same extent as the control.

Farinogram values for dough development time and water absorption of HWF and SWF at different levels of MAG gel, Mixture, IE Soy, or Oil are shown in Fig. 3. The amount of water required to reach 500 BU was lower at all lipid levels and types, compared to the control for both flour types. The added water to reach 500 BU was higher when IE Soy shortening, Mixture, or Oil was added compared to MAG gel. Furthermore, differences between lipid types were more noticeable in HWF dough than SWF dough. The solid lines (Fig. 3) represent total water, including the 40% water present in MAG gel. When the 40% water present in the MAG gel is compensated for in the water absorption percentage (dotted line, Fig. 3), there is a difference between the water absorption values for all lipid types in HWF, but not between Oil, Mixture, or MAG gel in SWF. The dotted line for MAG gel is significantly ($P < 0.05$) lower than IE Soy or Oil in HWF at 18 and 24% addition, but was not significantly ($P < 0.05$) different from Oil at any addition level in SWF. The differences between lipid types were most noticeable at the higher lipid addition levels in both HWF and SWF dough.

Dough development time of HWF and SWF at different levels of lipid addition is displayed at the bottom of Fig. 3. Dough development time for HWF at 6 or 12% of MAG gel or IE Soy addition were not significantly ($P < 0.05$) different compared to the control dough, while dough development was delayed at 18 or 24% level of MAG gel and IE Soy addition. The development time for 24% addition of IE Soy is not displayed because the lipid level was too high for the flour to reach 500 BU. The hydration peak was apparent and the curve showed an upward slope similar to the 18% IE Soy addition, but did not develop within the 20-min test time. Dough development times with oil and mixture at 6, 12, or 18% addition for HWF were significantly ($P < 0.05$) lower than for control, and dough development time was significantly ($P < 0.05$) delayed only at the 24% level of lipid addition. Development time at the 24% lipid level was not significantly ($P < 0.05$) different between MAG gel, Mixture, or Oil. SWF dough development times at 6 or 12% added lipids were not significantly ($P < 0.05$) different from each other or from the control dough. Dough development time with IE Soy was not significantly ($P < 0.05$) different from control at any addition level, whereas dough development time was delayed with 18 and 24% MAG gel addition and with 24% Oil and Mixture addition compared to control SWF dough. The development time with Oil and Mixture at 24% addition level was significantly ($P < 0.05$) higher than the development time for dough with MAG gel at the 24% addition level in SWF dough.

With high levels of added lipids to dough, there is a high level of lubrication and little water is required to achieve desired dough consistency. D'Applonia et al (1984) reported a decrease in water absorption and stability on farinograph characteristics with the addition of shortening at 0–6%. If the same amount of water were added to dough containing lipids, then the dough with MAG gel would exhibit the least resistance. The dotted line in Fig. 3 shows decreased water absorption for MAG gel in hard wheat flour dough and suggests a softer dough than with IE Soy, Oil, or Mixture; this is a desirable property for lipids utilized in baked goods to "shorten" or soften dough. A surfactant gel made with 0.5% monoglyceride with varying amounts of shortening (0–2%) improved farinograph characteristics, but the improvements decreased as the amount of shortening within the gel increased (Azizi and Rao 2004a). Furthermore, a lipid structured of canola oil and caprylic acid lowered the elastic and viscous attributes of soft wheat flour; this was attributed to a dilution effect of increasing oil content (Agyare et al 2004). Dispersion of lipid plays a large role in reaching desired farinogram consistency (Maache-Rezzoug et al 1998). Liquid oils are dispersed in globule forms, which are not effective in coating flour proteins and therefore less effective at "shortening" which leads to an increase in dough consistency. Depending on the firmness of solid lipids, they may get dispersed as large lumps or smeared over flour particles (Baltsavias et al 1997). In this research, IE Soy was harder and had a higher solid fat index at room temperature than MAG gel and was likely to be dispersed in clumps, whereas the MAG gel is likely to be smeared over the flour particles; liquid Oil and the Mixture would be dispersed as globules. Therefore, if water absorption is influenced by the lubrication properties and consistency of the added lipid, then

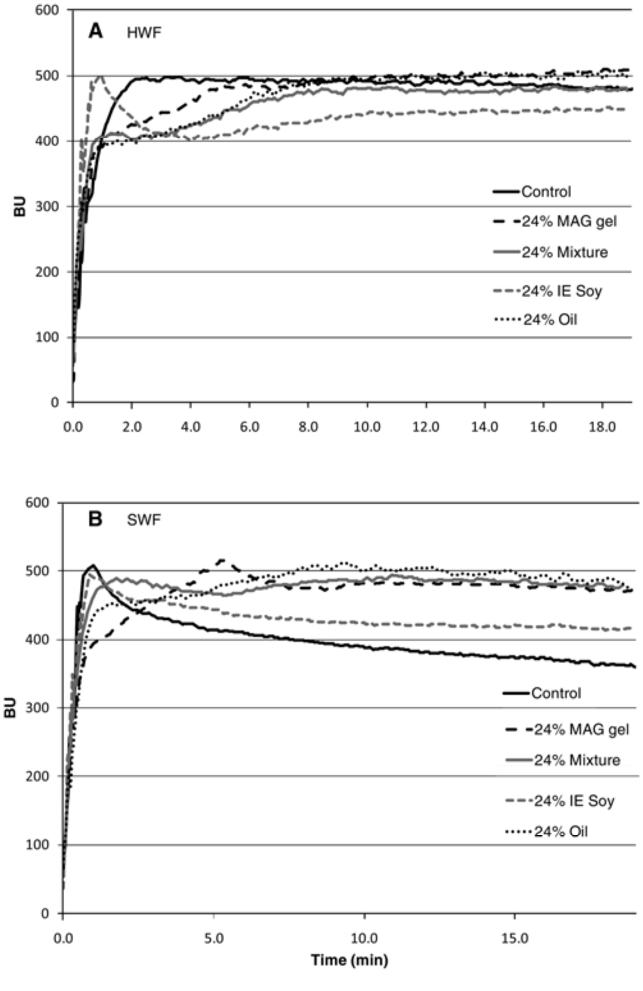

Fig. 2. Farinogram development curves for (**A**) hard wheat flour (HWF) and (**B**) soft wheat flour (SWF) after adding 24% monoacylglycerol-stabilized oil in water emulsion (MAG) gel, Mixture, interesterified soy shortening (IE soy), or Oil.

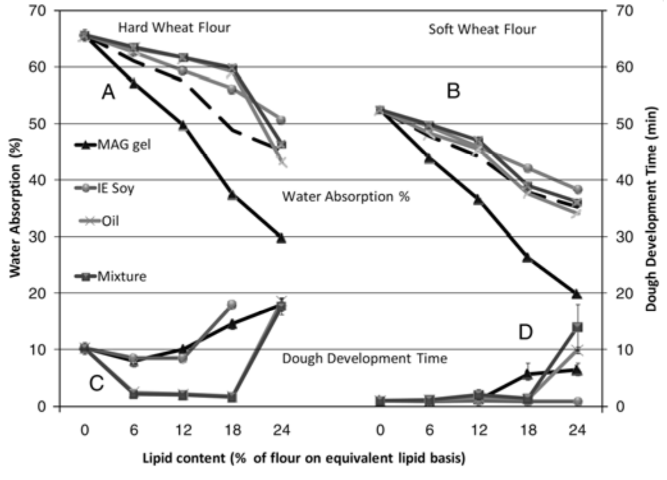

Fig. 3. Water absorption (graphs A and B) required to reach 500 BU and development time (graphs C and D) for hard and soft wheat flour after adding different levels of monoacylglycerol-stabilized oil in water emulsion (MAG) gel, Mixture, interesterified soy shortening (IE soy), or Oil. Dotted lines for MAG gel water absorption values represent added water. Solid lines are total water in dough (water present in MAG gel plus added water to reach 500 BU). Significance at $P < 0.05$; $n = 2$.

liquid Oil and the Mixture should have the lowest water absorption levels. However, in this case, the MAG gel had lowest water absorption values. This could be due the presence of monoglycerides in the structured MAG gel. Monoglycerides are known to aid in uniform distribution of lipids in dough (O'Brien et al 2003). MAG gel could be more evenly distributed, coating the flour particles, resulting in lower amounts of water required to reach 500 BU than oil, which is unevenly distributed in globules and IE Soy, which would need more time to be distributed evenly and coat flour particles. In hard wheat flour dough, it is of particular interest that less water is required to reach the same dough consistency with the MAG gel as compared to both IE Soy shortening, Oil, and Mixture, even when taking into consideration the added water (dotted line) from the MAG. Therefore, the MAG gel structure appears to confer some additional functionality to the dough that is more evident in HWF dough when compared to SWF dough. These observations on dough development attributes highlight differences in the functionality of the monoglyceride in the structured MAG gel versus the unstructured mixture. The flour proteins in SWF appear to interact with the structured MAG gel, resulting in a rapid development time, suggesting either all the water in the structured gel becomes available for absorption or that the oil is released from the structure, resulting in reduced consistency. However, the same effect is not apparent in HWF, where the behavior of MAG gel and Mixture was similar. These differences in dough development time could be a function of several interacting factors: 1) availability of water during mixing when the water is present in the structure MAG gel or whether it is free added water; 2) presence of increasing amounts of monoglyceride; and 3) availability and activity of monoglyceride when it is in the structure versus when it is added in the mixture.

The development curves at 24% lipid addition level are similar to results described by Jacob et al (2007) with 30% lipid level cookie dough consistencies. The dough containing solid shortening initially displayed the highest consistency, similar to IE Soy described here and then after mixing it decreased in consistency, suggesting a softening and shortening effect. Cookie dough containing 30% (fwb) liquid oil displayed the lowest consistency initially, then after mixing increasing in resistance and displaying a higher consistency, suggesting less softening and shortening ability after mixing similar to the farinogram curves for liquid Oil, Mixture, and MAG gel described here.

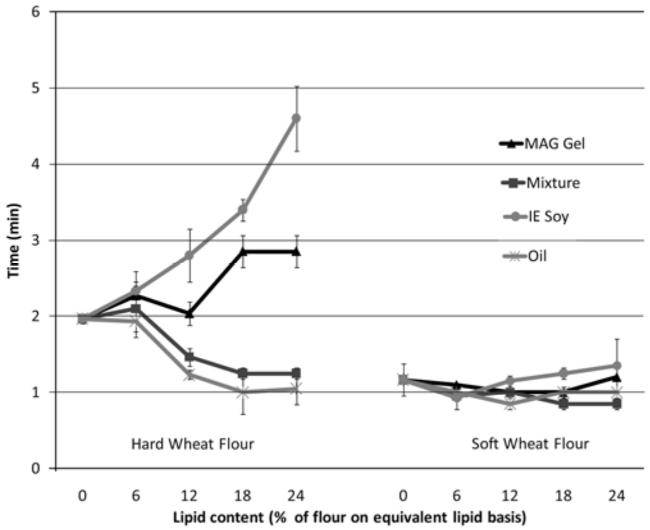

Fig. 4. Peak maximum time values measured using a gluten peak tester, of hard and soft wheat dough with increasing levels of lipids added as monoacylglycerol-stabilized oil in water emulsion (MAG) gel, Mixture, interesterified soy shortening (IE soy), or Oil. Significance reported at $P < 0.05$; $n = 2$.

Effect of Lipids on Gluten Aggregation

Gluten peak tester (GPT) profiles of peak maximum time (PMT) are shown in Fig. 4. The peak time of HWF and SWF cannot be directly compared because the flour-to-water ratios were different in the test; however, changes in trends are informative. The PMT of HWF dough with MAG gel significantly ($P < 0.05$) increased at levels >12% lipid; with IE Soy, PMT increased at all lipid addition levels when compared to control dough. However, the trend was opposite for dough with Oil or Mixture. The increasing trend with MAG gel and IE Soy and the decreasing trend for Oil and Mixture clearly observed in HWF were somewhat similar in SWF doughs, but the differences between them were smaller. PMT is reflective of the time required for gluten to aggregate and exhibit maximum torque on the spindle. We have established that native starch by itself does not generate torque in the GPT, even in the presence of lipids or monoglycerides (data not shown). Therefore, the effects are primarily due to the gluten proteins. In principle, PMT values of dough are similar to dough development time in a farinograph; SWF dough develops earlier in the farinograph compared to HWF dough. However, the interaction of MAG gel, Mixture, IE Soy, or Oil with gluten in particular, and the differences between hard and soft wheat gluten proteins, is better elicited in this test. This data also confirms the observations for water absorption obtained from the farinogram (Fig. 4; dotted line). When the water in the MAG gel is accounted for, it behaves similarly to IE Soy with PMT and water absorption values in HWF, and is similar to IE Soy, Mixture, and Oil for SWF.

The delay in gluten aggregation in HWF with MAG gel or IE Soy when compared to Mixture or Oil is likely due to the ability of MAG gel or IE Soy to coat flour proteins, "shorten" and prevent gluten aggregation. Oil and Mixture are dispersed in globules and therefore likely to promote gluten aggregation. The delay in gluten aggregation with MAG gel could also be influenced by the availability of its structured water. If the water is strongly bound, it could take more time and energy to become available for gluten aggregation. The water present in the MAG gel was compensated for during the addition of water to the GPT sample cup; therefore it is possible that the bound water in the gel was unavailable for flour proteins to absorb and utilize for gluten formation, which would cause a delay in the time for gluten to aggregate. It is also possible that MAG gel is dispersed quickly and evenly and is efficient at coating and lubricating flour particles to "shorten" them and prevent aggregation. The ability of the MAG gel to prevent gluten aggregation is apparent in this test compared to the mixture containing the same unstructured components that do not prevent gluten aggregation. This is beneficial because MAG gel mimics a similar delay in gluten aggregation as IE Soy shortening, which is industrially available as an effective shortening for numerous baked goods.

Effect of Lipids on Pasting Characteristics

The pasting properties of the flours and starch with MAG gel, IE Soy, and Oil are shown in Table III. The pasting properties with MAG gel and Mixture are shown in Table IV. Overall, MAG gel exhibited significant differences based on the amount of lipid added and between HWF, SWF, and WS. IE Soy and Oil exhibited similar pasting characteristics with little differences between levels of addition, but differences were observed between HWF, SWF, and WS. Pasting temperature of HWF did not change with increasing levels of either MAG gel or mixture.

Pasting temperature significantly ($P < 0.05$) increased with increasing levels of MAG gel addition in SWF and WS and did not change with the addition of mixture to SWF or WS. Different levels of IE Soy or Oil showed no reportable significant ($P < 0.05$) differences within HWF, SWF, or WS. Peak temperature significantly ($P < 0.05$) increased in HWF and SWF with the addition of either 6% MAG gel or Mixture but did not increase with increasing lipid levels thereafter. No significant ($P < 0.05$) differences in peak temperature were observed in HWF, SWF, or WS with IE Soy or Oil.

There was a significant ($P < 0.05$) increase in peak viscosity only in SWF with MAG gel addition at 18 and 24%. Final viscosity had a significantly ($P < 0.05$) decreasing trend with increasing lipid addition of MAG gel and Mixture in HWF and WS, and there was a greater decrease in final viscosity for WS. However, the trend was reversed for SWF wherein the final viscosity increased with lipid addition compared to control. MAG gel had a significantly ($P < 0.05$) lower final viscosity compared to IE Soy and Oil in HWF and WS. At 18 and 24% levels of MAG gel or Mixture addition, a second peak was observed for both flours and the starch samples during the cooling cycle shown in Table IV. A second peak was not observed with any level of addition of IE Soy or Oil and is not shown in Table III. The temperature and viscosity of the second peaks were higher at 24% MAG gel and Mixture addition for both flours but was not significantly ($P <$ 0.05) different for the starch. Furthermore, the temperature was not significantly ($P < 0.05$) different between flour with mixture or MAG gel, but was significantly ($P < 0.05$) different between starch with mixture or MAG gel. The viscosity for the second peak was lowest for SWF and highest for starch with added lipids. Zhang et al (2003) reported a second peak in the presence of starch, lipid, and protein together; but the second peak does not

TABLE III
MicroViscoAmylograph Data for Pasting Temperature, Peak Temperature, Peak Viscosity, and Final Viscosity for Hard Wheat Flour (HWF), Soft Wheat Flour (SWF), and Wheat Starch (WS) with Added Monoacylglycerol-Stabilized Oil in Water Emulsion (MAG Gel), Interestserified Soy Shortening (IE Soy), or Oil[a]

	Pasting Temperature (°C)			Peak Temperature (°C) Peak Viscosity (mPas)[b]			Final Viscosity (mPas)		
Lipid %	**MAG**	**Oil**	**IE Soy**	**MAG**	**Oil**	**IE Soy**	**MAG**	**Oil**	**IE Soy**
HWF									
0	68.9a	68.9a	68.9a	93.9a (210.0a)	93.9a (210.5a)	93.9a (210.5a)	475.5a	475.5a	475.5a
6	67.9ab	68.0b	68.2a	96.6bx (211.5a)	94.0ay (215.5a)	93.7ay (213.0a)	443.5ay	500.0abcx	489.0axy
12	68.9a	67.4bc	68.9a	96.6bx (214.0a)	94.1ay (214.5a)	93.6ay (215.5a)	373.5by	510.5bcx	467.5ax
18	67.9ab	68.1ab	68.0a	96.9bx (214.5a)	94.1ay (215.5a)	93.2ay (216.0a)	325.5cy	490.0abx	501.0ax
24	67.5b	66.9c	67.8a	96.6bx (212.0a)	94.2ay (211.5a)	93.6ay (219.0a)	318.0cy	523.0cx	514.0ax
SWF									
0	75.7a	75.7a	75.7a	91.7a (157.0a)	91.7a (157.0a)	91.7a (157.0a)	313.5a	314.0a	314.0a
6	77.3abx	75.2ay	76.1axy	95.2bx (156.5a)	91.1ay (158.5a)	91.1aby (159.5a)	347.0bc	312.5a	335.5a
12	79.7bcx	74.7ay	75.9az	95.7bx (158.5a)	90.9ay (156.0a)	90.6by (155.0a)	358.0cy	323.5ax	322.5ax
18	80.8cx	73.3ay	75.9az	95.4bx (187.5bx)	90.7ay (153.0ay)	90.8aby (158.5ay)	328.5ab	328.0a	324.5a
24	81.7cx	73.3ay	75.7az	95.8bx (203.0bx)	91.1ay (153.5ay)	90.9aby (152.5ay)	351.0bcy	328.0ax	322.5ax
WS									
0	75.1a	75.1a	75.1a	95.9a (363.5a)	95.9a (363.5a)	95.9a (363.5ab)	877.0a	877.0a	877.0a
6	83.4bx	75.1ay	75.3ay	95.9axy (385.5a)	96.4ax (377.0a)	95.7ay (355.0b)	828.5ay	1003.5bx	932.5axy
12	86.0cx	76.3ay	75ay	96.3a (370.0a)	96.1a (366.5a)	96.4a (374.0a)	739.0ab	874.0a	945.0a
18	87.1cx	77.1ay	76.3ay	95.3a (356.5a)	95.7a (372.0a)	96.3a (370.5ab)	602.0bcy	972.4abx	982.5ax
24	87.5cx	76.9ay	75.4ay	96.2a (359.5a)	95.7a (373.5a)	96.0a (358.5ab)	508.0cy	957.0abx	1005.0ax

[a] Mean values within treatment type (HWF, SWF, WS) for each pasting attribute within a row with the same letter (a, b, c) are not significantly different ($P <$ 0.05), $n = 2$. Mean within each lipid type (0, 6, 12, 18, 24%) for each treatment (HWF, SWF, WS) within a column with the same letter (x, y, z) are not significantly different ($P < 0.05$), $n = 2$.

[b] Peak viscosity values appear in parentheses after Peak temperature values.

TABLE IV
MicroViscoAmyloGraph Data for Hard Wheat Flour (HWF), Soft Wheat Flour (SWF), and Wheat Starch (WS) with Added Monoacylglycerol-Stabilized Oil in Water Emulsion (MAG Gel) or Mixture[a,b]

	Pasting Temperature (°C)		Peak Temperature (°C) Second Peak Temperature (°C)[b]		Second Peak Viscosity (mPas) Peak Viscosity (mPas)[b]		Final Viscosity (mPas)	
Lipid %	**MAG Gel**	**Mixture**	**MAG Gel**	**Mixture**	**MAG Gel**	**Mixture**	**MAG Gel**	**Mixture**
HWF								
0	68.9a	68.9a	93.9a (210.0a)	93.9a (210.5a)	na	na	475.5a	475.5a
6	67.9ab	68.3a	96.6b (211.5a)	96.5b (209.0a)	na	na	443.5a	423.0b
12	68.9a	68.1a	96.6b (214.0a)	96.8b (208.5a)	na	na	373.5b	359.5c
18	67.9ab	67.6a	96.9b (214.5a)	96.8b (214.0a)	58.8a (403.5a)	59.4a (412.5a)	325.5c	327.0d
24	67.5b	67.7a	96.6b (212.0a)	96.5b (226.0a)	65.7b (412.5a)	66.6a (412.0a)	318.0c	328.5d
SWF								
0	75.7a	75.7a	91.7a (157.0a)	91.7a (157.0a)	na	na	313.5a	314.0a
6	77.3ab	76.8a	95.2b (156.5a)	94.0ab (160.0a)	na	na	347.0bc	330.0ab
12	79.7bcx	75.8ay	95.7b (158.5a)	94.7b (172.5a)	na	na	358.0c	353.5b
18	80.8cx	76.0ay	95.4b (187.5b)	95.9b (190.5a)	50.1a (348.0a)	49.9a (357.5a)	328.5ab	333.0ab
24	81.7cx	75.1ay	95.8b (203.0b)	96.0b (188.0a)	63.6b (388.0b)	63.4a (370.0a)	351.0bcx	337.0aby
WS								
0	75.1a	75.7a	95.9a (363.5a)	95.9a (363.5a)	na	na	877.0a	877.0a
6	83.4bx	76.2ay	95.9a (385.5a)	96.4a (347.5a)	na	na	828.5a	786.0ab
12	86.0cx	77.7ay	96.3a (370.0a)	95.9a (352.5a)	na	na	739.0ab	723.0bc
18	87.1cx	75.1ay	95.3a (356.5a)	95.9a (352.5a)	69.9ax (830.5a)	66.3ay (835.0a)	602.0bc	616.5cd
24	87.5cx	75.7ay	96.2a (359.5a)	96.0a (340.5a)	72.0ax (818.0a)	66.6ay (805.0a)	508.0c	572.0d

[a] Mean values within treatment type (HWF, SWF, WS) for each pasting attribute within a row with the same letter (a, b, c) are not significantly different ($P < 0.05$), $n =$ 2. Means within each lipid type (0, 6, 12, 18, 24%) for each treatment (HWF, SWF, WS) within a column with the same letter (x, y, z) are not significantly different ($P < 0.05$), $n = 2$.

[b] Peak and Second peak viscosity values appear in parentheses after Peak and Second peak temperature values.

appear when only two of the three components are present. Oil or IE Soy with HWF, SWF, or WS did not display a second peak at any level of addition. But monoglyceride by itself did exhibit a second peak (data not shown). The monoglyceride portion of the structured MAG gel and unstructured Mixture seem to dominate the interaction with starch. Differences in the availability of the water and monoglyceride in the MAG gel versus the mixture are likely accountable for significant differences noted in Table IV, particularly the pasting temperature increase with MAG gel in SWF and WS and not with Mixture. This increase could result from a delayed availability of monoglyceride and water from the structure until the MAG gel reaches its dropping point and oil is released from the structure. The components of the MAG gel become available to interact with starch resulting in the increased temperature, which is more apparent in SWF and WS than HWF. Researchers have shown that starch helices interact with the hydrophobic domains of amphiphilic molecules such as fatty acids, monoglycerides, and surfactants (Stauffer 1999). Starch pastes made with emulsifiers, including monoglycerides, display increases in pasting temperature, hot viscosity, temperature to peak, and setback viscosity (Eliasson 1986; Condepetit and Escher 1992). Lipids added to bakery applications, such as shortening, also interact with starch, breaking the continuity of the protein and starch structure, reducing starch swelling and gelatinization, resulting in a soft texture (Ghotra et al 2002). Monoglyceride starch interactions are beneficial for bakery applications such as cakes because the complexes they form with amylose give cakes a softer texture and longer shelf life (Krog 1977). Azizi and Rao (2004b) showed that increasing shortening content at 0–2% with 0.5% monoglyceride added to wheat starch resulted in an increase in gelatinization temperature and an increase in final viscosities. MAG gel exhibited an increase in gelatinization temperature with wheat starch at increasing addition levels but decreased final viscosities, whereas IE Soy showed no significant ($P < 0.05$) difference in gelatinization temperatures at increasing addition levels but exhibited an increase in final viscosity with increasing addition levels. Increased final viscosity with IE Soy during cooling is expected because IE Soy solidifies at ambient temperatures, contributing to increased viscosity. Depending on the destruction of structured MAG gel during agitation in MVAG, the cooled monoglyceride would increase the final viscosity but the liquid oil portion would decrease the final viscosity. As monoglyceride levels increase, larger effects on pasting properties are expected because with the presence of more surfactant, there is more granule surface coverage or granule penetration and thus complex formation (Mira et al 2005). Again, differences were observed in pasting properties between flour type and lipid type. These observations suggest that MAG gel interacts differently with flour components compared to Mixture, IE Soy, or Oil, and also that gluten protein quality and gluten-starch interaction in flour play a role in the nature of interaction.

CONCLUSIONS

This research compared conventional lipid sources to MAG gel and a mixture of its unstructured components at equivalent lipid contents. The water, oil, and monoglyceride components structured in the MAG gel seem to give it attributes that 1) are not similar to the same components when added individually in an unstructured form; 2) that are different from other lipid sources such as water absorption parameters and pasting profiles; and 3) that are similar to shortening, such as development time and prevention of gluten aggregation. There are significantly ($P < 0.05$) different interactions between MAG gel and HWF or SWF, likely because of the interaction of protein and starch components with the structured monoglyceride component of the gel. Each of these parameters will play a part in the effectiveness of the MAG gel to replace other lipid sources in baked goods. For example in HWF, dough with MAG gel will require less water to reach optimal development and development time and mode of development will vary with the level of MAG gel replacement. The ability of MAG gel to "shorten" and prevent gluten aggregation will be beneficial for baked products that do not rely on gluten network formation for structure. Differences in the pasting properties with the inclusion of MAG gel will have an effect during heating of baked products, gelatinization of starch, as well as retrogradation and staling characteristics compared to other lipid sources.

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