Effects of incorporation of groundnut oil and hydrogenated fat on pasting and dough rheological properties of flours from wheat varieties

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Abstract The effects of incorporation of groundnut oil (GO) and hydrogenated fat (HF) at different levels (1%, 3% and 5%) on pasting, dough rheology and mixing properties of strong wheat flour (SWF) and weak wheat flour (WWF) were evaluated. SWF showed higher paste viscosities as compared to WWF. However, higher setback viscosity for SWF than WWF was observed. Paste viscosity and mixograph peak time of both flours decreased with an increase in level of GO and HF. Pasting temperature of both flours decreased with an increase in GO. Storage modulus (G') was higher than loss modulus (G'') for dough from both SWF and WWF. G' increased while G'' decreased with an increase in levels of GO and HF. Dough prepared from SWF needed longer time for mixing and showed wider peak width, indicating strong and stable dough as compared to WWF. Addition of GO up to 3% level progressively decreased dough consistency and mixing tolerance and further addition led to an increase in both properties. Contrarily, addition of HF showed opposite effect in WWF. Both GO and HF showed variables effects towards mixing in both flour types. Dough tolerance and breakdown during mixing improved with increase in GO while adversely affected with increase in HF.

Keywords Wheat flour · Pasting · Mixograph · Rheology

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Abbreviations

BDV	Breakdown viscosity
FV	Final viscosity
GO	Groundnut oil
G'	Elastic modulus
G''	Viscous modulus
HF	Hydrogenated fat
LPV	Left peak value
LPW	Left peak width
MPT	Mixograph peak time
MPV	Mixograph peak value
MPW	Mixograph peak width
PT	Pasting temperature
PV	Peak viscosity
RPV	Right peak value
RPW	Right peak width
SBV	Setback viscosity
WS	Weakening slope

Introduction

Wheat flour functionality is influenced by factors like composition, grain hardness, the difference in the milling process, wheat varieties, variability crop season and growing conditions (Nemeth et al. 1994). The various wheat varieties are suitable for different products such as muffins, chapattis, cakes and breads to obtain best quality attributes. Generally weak varieties are preferred for cakes and cookies whereas strong varieties are preferred for bread preparation. Variation in compositions (fat and damaged starch) also affected the rheological properties and quality of food products (Bonnand-Ducasse et al. 2010;

Ren et al. 2008). Blake et al. (2015) reported that the characteristic of weaker dough of waxy flours related higher to starch as compared to the protein fraction of flour. The changes in G' and G'' could be due to the aggregation of proteins instead of the gelatinization of starch during heating (Singh and Singh 2013). Various types of oils are used in the baking industries. Hydrogenated fat (HF) is hydrogenated vegetable oil and also known as vanaspati ghee. Fat acts as a plasticizer, improves volume, gives softness and has antistaling properties when added to flour for bread making (Moore and Hoseney 1986). Fat levels and sodium chloride showed significant effect on maximum dough height for bread making (Gujral and Singh 1999). Under optimum mixing of 3 min, maximum height of gaseous release during bread making increased with the increase in fat concentration (Gujral and Singh 1999). Many studies have shown that the addition of fats and oil in the wheat dough resulted in the increase in the loaf volume of the dough (Leissner 1988). GO is known by several names such as peanut oil and earthnut because the seed develops under the ground. Lipids are used in majority of products for instance; bread (2–5%), cakes (5–25%), pastries (30–40%), pie crust (20–35%) on flour weight basis. Lipids addition has been reported to change the physical and chemical properties of starchy foods (Singh et al. 1998). These changes in starchy foods might be due to the complex formation between oil and amylase (Fan et al. 1997). Leissner (1988) reported dough as a foam and showed that the fats and oils affect the stabilization of the aqueous gas interface. However, some studies have reported that the loaf volume increases due to the addition of the fats and not due to the addition of oils (Baker and Mize 1942). Some studies reported that the expansion of the dough can occur even at room temperature due to addition of fats and oils (Bell and Fisher 1977). The rheological properties of dough are necessary for preparation of bakery products as it determine its behavior during handling of product, thereby affecting the finished product quality (Bloksma et al. 1988). The objectives of present study are to evaluate the effect of incorporation of groundnut oil and hydrogenated fat on pasting, mixing and dough rheological properties of flours from SWF and WWF.

Materials and methods

Materials

Wheat varieties viz. HUW468 (strong) and WR544 (weak) were procured from Indian Agriculture Research Institute, New Delhi. Samples were selected on the basis of different

dough stability (DS). HUW 468 (13.50 DS) and WR544 (2.60 DS) reported earlier by Singh et al. (2016).

Methods

Pasting properties

Pasting properties of flours from different wheat varieties were determined using a rheometer (MCR-301, Anton Paar, Austria) as described earlier (Kaur et al. 2014).

Mixographic characteristics

The mixing properties of flour from different wheat varieties were analysed using Mixograph (National Mfg. Co. Lincoln, NE, USA) as described earlier (Kaur et al. 2014).

Dynamic rheometry of dough

Dynamic rheology of dough prepared from flour of different wheat varieties was performed using a RheoStress 6000 rheometer (Haake, Karlsruhe, Germany) as described earlier (Kaur et al. 2013).

Statistical analysis

Minitab statistical software (Minitab Inc., state college, PA, USA) was used for statistical analysis of the data. The data obtained were subjected to ANOVA analysis to find out significant difference in different properties of flours.

Result and discussion

Pasting properties

Effect of addition of GO and HF on pasting properties of both SWF and WWF is shown in Supplementary Table 1. SWF showed higher PV as compared to WWF. PV of WWF and SWF was 2160 cP, and 2820 cP, respectively (Table 1). The difference in proportion of polymeric or monomeric proteins were responsible for the variation in PV amongst flours from different varieties (Singh et al. 2016). PV of flours containing 1%, 3% and 5% groundnut oil ranged from 2150 to 2740 cP, 1980 to 2600 cP and 1910 to 2420 cP, respectively. Results indicated that PV decreased with increase level of GO. ANOVA revealed the oil level showed significant effect on PV, BDV, FV, SBV and PT of both flour types while oil type showed significant effect on PV, BDV and PT of WWF (Table 3). Interaction plot indicated that addition of GO and HF progressively decreased pasting parameters in both flour types (Fig. 1a, b). PV of flour containing 1%, 3%, and 5% HF ranged from

Table 1 Effect of incorporation of GO and HF on pasting properties of SWF and WWF

Cultivars	Wheat type	Oil type	Oil level (%)	PV (cP)	FV (cP)	BDV (cP)	SBV (cP)	PT (°C)
WR544	Weak	Control	0	2160 ± 60	2170 ± 40	1100 ± 100	1110 ± 0	61.6 ± 0.4
HUW468	Strong	Control	0	2820 ± 25	2480 ± 40	1570 ± 25	1250 ± 52	62.1 ± 0.3
WR544	Weak	GO	1	2150 ± 50	2190 ± 60	1070 ± 20	1170 ± 30	60.2 ± 0.2
HUW468	Strong	GO	1	2740 ± 60	2370 ± 45	1540 ± 35	170 ± 20	61.1 ± 0.4
WR544	Weak	GO	3	1980 ± 20	2020 ± 30	982 ± 10	1022 ± 20	60.1 ± 0.1
HUW468	Strong	GO	3	2600 ± 55	2280 ± 30	1420 ± 35	1100 ± 10	61.1 ± 0.3
WR544	Weak	GO	5	1910 ± 30	1990 ± 50	911 ± 10	991 ± 30	60.1 ± 0.1
HUW468	Strong	GO	5	2420 ± 35	2190 ± 20	1300 ± 20	1070 ± 5	60.6 ± 0.4
WR544	Weak	HF	1	2100 ± 25	2140 ± 30	1040 ± 15	1080 ± 20	60.6 ± 0.3
HUW468	Strong	HF	1	2670 ± 60	2390 ± 40	1480 ± 40	1200 ± 20	60.1 ± 0.1
WR544	Weak	HF	3	1990 ± 30	2060 ± 35	980 ± 15	1050 ± 20	61.6 ± 0.4
HUW468	Strong	HF	3	2560 ± 50	2270 ± 30	1420 ± 30	1130 ± 10	60.6 ± 0.3
WR544	Weak	HF	5	1830 ± 20	1940 ± 25	885 ± 10	995 ± 15	61.1 ± 0.3
HUW468	Strong	HF	5	2470 ± 40	2210 ± 20	1330 ± 25	1070 ± 5	61.1 ± 0.8

PV peak viscosity, BDV breakdown viscosity, FV final viscosity, SBV setback viscosity, PT pasting temperature, GO groundnut oil, HF hydrogenated fat

Fig. 1 **a** Effect of GO and HF addition in SWF and WWF on PV by using interaction plot, **b** effect of GO and HF addition in SWF and WWF on PT by using interaction plot

2100 to 2670 cP, 1990 to 2560 cP and 1830 to 2470 cP, respectively. Both flour types and oil level did not show any significant effect on PT (Table 3). PV, FV and SBV

decreased with increase in level of GO and HF. Earlier, increase in PT and PV of rice flour with an increase in levels of fatty acids was also observed. The change in PV

and PT with the addition of fatty acids was attributed to the formation of amylose–lipid complexes (Kaur and Singh 2000). Addition of GO decreased PT while reverse was observed for HF in both flour types. Singh et al. (2000) reported that HF showed the greater reduction in PV as compared to peanut oil. Huschka et al. (2011) reported that flours pasting properties with monoacylglycerol-stabilized oil in water emulsion (MAG) gel exhibited differences that depends upon amount of lipid added in hard and soft wheat flour. Nakamura et al. (2010) reported that PV showed strong correlation with the sponge cake volume. Singh et al. (2000) reported that HF showed more pronounced effect on water solubility and absorption whereas the peanut oil showed the lowest effect. HF showed the highest capacity towards complex formation in comparison to other oils. The complexing index (an indicator of formation of amylose–lipid complexes) of HF was 21, 24.5 and 25.7% at 1.25, 3.75 and 5% levels while peanut oil showed 12.56, 17.8 and 19.4% on similar levels (Singh et al. 2000). The less capacity of peanut oil to form complex was attributed due to the presence of greater amount of polyunsaturated fatty acids. Schweizer et al. (1986) reported a decrease in viscosity with the addition of linoleic acid and soya oil at 1 and 2% level in wheat flour. Nierle and El Baya (1990) reported the effect of different lipids on pasting properties of wheat starch. An increase in PV and consistency when wheat starches were incorporated with 2% wheat lipids was reported (Takahasahi and Seib 1988).

Mixographic properties

Effects of incorporation of GO and HF on mixographic parameters (MPT, MPW, LPV, LPW, RPV, RPW and WS) of SWF and WWF are shown in supplementary Table 1. MPT of WWF and SWF was 2.68 and 3.72 min, respectively (Singh et al. 2016). Kaur et al. (2014) also reported MPT of different wheat varieties ranged from 2.55 to 6.97 min, respectively. MPT of flours from different varieties containing 1%, 3% and 5% GO ranged from 2.18 to 4.35 min, 1.88 to 4.54 min and 2.14 to 3.68 min, respectively while ranged from 2.14 to 3.46 min, 1.69 to 4.12 min and 2.28 to 4.06 min, respectively, when HF was added at similar levels. WWF and SWF showed MPW of 23.76% and 39.83%, respectively (Table 2). ANOVA revealed that varieties showed significant effect on MPT and MPW; however oil level did not show significant effect on MPT (Table 4). MPT and MPW of flours with and without are shown in Fig. 2a–d. Singh et al. (2002) reported that fat and sugar interaction played a significant role in dough development and peak height of wheat flour. Mixing tolerance continuously decreased with increase in fat concentration (Singh et al. 2002). The addition of GO and HF up to 3% level decrease MPT and further addition

led to increase in MPT in both flour types (Supplementary Fig. 3a). Interaction plot indicated that addition of GO up to 3% level decrease MPW and further addition led to increase in MPW in SWF while the addition of HF showed the opposite trend. WWF and SWF showed LPV of 61.89% and 52.99%, respectively. LPV of flour containing 1%, 3% and 5% GO ranged from 34.977 to 44.186%, 32.137 to 42.109% and 34.35 to 37.197%, respectively. LPV of flour containing 1%, 3% and 5% HF ranged from 33.503 to 46.072%, 34.628 to 44.325% and 32.703 to 40.420%, respectively. WWF and SWF showed LPW of 32.75% and 54.47%, respectively. LPW of flour containing 1%, 3% and 5% GO ranged from 31.69 to 31.81%, 23.30 to 24.45% and 22.09 to 24.1%, respectively. LPW of flour containing 1%, 3% and 5% HF ranged from 24.794 to 48.389%, 30.861 to 41.333% and 19.651 to 24.412%, respectively. ANOVA revealed that both varieties and oil level showed significant effect on LPV and LPW of flour; however interaction did not show any significant effect (Table 4). Interaction plot indicated that increased level of GO progressively decreased MPV and RPV in both flour types. WWF and SWF showed RPW of 15.43% and 35.07%, respectively. ANOVA revealed that both flours and oil level showed significant effect on RPW; however the effect of flours type was also significant but less pronounced (Table 4). The addition of GO up to 3% level increased RPW and further addition led to decrease in RPW while addition of HF up to 3% level decreased RPW and further addition led to increase in RPW in SWF (Supplementary Fig. 3d). Interaction plot showed that the addition of GO and HF up to 3% level increased RPW and further addition led to decreased in RPW for WWF (Supplementary Fig. 3d). WS of 10.72 Tq* and 11.81 Tq*min, respectively was observed for WWF and SWF. WS of flour containing 1%, 3% and 5% GO ranged from 6.449 to 11.938 Tq*min, 5.153 to 10.561 Tq*min and 5.8257 to 10.228 Tq*min, respectively. WS of the flour containing 1%, 3% and 5% HF ranged from 8.08 to 10.414 Tq*min, 6.479 to 11.04 Tq*min and 6.04 to 12.586 Tq*min, respectively (Table 2). WS indicated the rate of breakdown while mixing and was calculated as the difference of curve height at MPT and curve height at tail (Martinant et al. 1998). Results showed that with increase in the concentration of both GO and HF the mixographic properties (MPV, LPV and RPV) decreased. Interaction plot showed that with the addition of GO and HF, continuously decreased LPV and RPV for SWF. Interaction plot showed that with the addition of GO, LPW initially decreased and then increased (Supplementary Fig. 3c). On the other hand, with the addition of HF a continuous decrease for SWF was observed. Interaction plot indicated that with the addition of GO and HF, WS decreased continuously for SWF (Supplementary Fig. 3e). Interaction plot showed that with the addition of GO, LPV

Table 2 Effect of incorporation of GO and HF on mixographic and dough rheological properties of SWF and WWF

Varieties	Wheat type	Oil type	Oil level (%)	Mixographic properties					Rheological properties					
				MPT (min)	MPV (%)	MPW (%)	LPV (%)	LPW (%)	RPV (%)	RPW (%)	WS (%Tq*min)	G'	G''	Tanδ
WR544	Weak	WO	0	2.68 ± 0.15	67.68 ± 0.2	23.76 ± 0.1	61.89 ± 0.2	32.75 ± 0.2	64.23 ± 0.2	15.43 ± 0.1	10.72 ± 0.2	7390 ± 100	2584 ± 100	0.35
HUW468	Strong	WO	0	3.72 ± 0.06	65.15 ± 0.1	39.83 ± 0.2	52.99 ± 0.4	54.47 ± 0.2	62.77 ± 0.2	35.07 ± 0.4	11.81 ± 0.17	97,620 ± 300	26,391 ± 300	0.27
WR544	Weak	GO	1	2.18 ± 0.2	45.41 ± 3.9	15.02 ± 1.4	34.98 ± 1.9	31.69 ± 2.4	41.79 ± 2.5	33.47 ± 0.3	11.94 ± 1.4	10,560 ± 320	4732 ± 150	0.45
HUW468	Strong	GO	1	4.35 ± 0.9	45.42 ± 3.5	19.30 ± 1.9	44.12 ± 2.9	31.81 ± 2.5	43.31 ± 2.8	14.06 ± 0.9	6.44 ± 0.5	27,470 ± 500	10,277 ± 250	0.37
WR544	Weak	GO	3	1.88 ± 0.1	43.06 ± 1	18.78 ± 1.6	32.14 ± 1	23.30 ± 1.5	39.94 ± 2	10.31 ± 0.7	10.57 ± 1	11,050 ± 350	4659 ± 100	0.42
HUW468	Strong	GO	3	4.54 ± 0.1	42.81 ± 2.8	14.53 ± 1	42.11 ± 2.5	24.45 ± 1.8	40.92 ± 2.2	18.45 ± 1	5.153 ± 0.1	24,910 ± 400	9655 ± 290	0.39
WR544	Weak	GO	5	2.14 ± 0.15	40.57 ± 2.5	16.95 ± 1.7	34.35 ± 1.6	22.09 ± 1.2	37.19 ± 1.8	7.78 ± 0.5	10.29 ± 0.7	10,660 ± 250	4506 ± 100	0.42
HUW468	Strong	GO	5	3.68 ± 0.25	40.92 ± 2.1	34.42 ± 3.5	37.20 ± 2	24.92 ± 1.8	39.93 ± 1.9	19.06 ± 1.1	5.83 ± 0.4	18,140 ± 380	6761 ± 220	0.37
WR544	Weak	HF	1	2.14 ± 0.2	43.58 ± 2.7	15.72 ± 1.4	33.51 ± 1.4	24.78 ± 1.7	40.63 ± 2	8.09 ± 0.4	10.41 ± 0.7	11,019 ± 280	4381 ± 80	0.40
HUW468	Strong	HF	1	3.46 ± 0.3	48.38 ± 4	37.82 ± 4.8	46.08 ± 3	43.39 ± 3	47.25 ± 3	23.19 ± 1.3	8.08 ± 0.5	23,540 ± 430	9175 ± 300	0.40
WR544	Weak	HF	3	1.70 ± 0.1	43.21 ± 1.9	18.36 ± 2.2	34.63 ± 1.6	30.87 ± 2.2	40.1 ± 2.2	9.73 ± 0.5	11.05 ± 0.9	12,580 ± 200	5328 ± 180	0.42
HUW468	Strong	HF	3	4.12 ± 0.38	44.68 ± 2	20.66 ± 2.5	44.33 ± 2.8	41.33 ± 2.9	42.56 ± 2.9	14.93 ± 0.7	6.48 ± 1	22,980 ± 400	9085 ± 280	0.39
WR544	Weak	HF	5	2.28 ± 0.22	40.18 ± 1.5	15.43 ± 1.7	32.70 ± 1.2	19.66 ± 1	36.91 ± 1	9.23 ± 0.4	12.59 ± 0.3	8197 ± 100	3793 ± 70	0.46
HUW468	Strong	HF	5	40.06 ± 0.29	41.70 ± 1.8	16.77 ± 2	40.43 ± 2.5	24.42 ± 1.5	30.87 ± 1.5	18.75 ± 1.2	6.04 ± 0.2	15,260 ± 250	5892 ± 130	0.39

MPT mixograph peak time, *MPW* mixograph peak width, *WS* weakening slope, *G'*, elastic modulus, *G''* viscous modulus, *GO* groundnut oil, *HF* hydrogenated fat

MPT mixograph peak time, MPH mixograph peak height, MPW mixograph peak width, WS weakening slope, G', elastic modulus, G'' viscous modulus, GO groundnut oil, HF hydrogenated fat

Fig. 2 **a** Mixographic properties of SWF without addition of GO and HF, **b** mixographic properties of SWF with addition of 1% GO, **c** mixographic properties of SWF with addition of 3% GO, **d** mixographic properties of SWF with addition of 5% GO

and LPW initially decreased and then increased while with the addition of HF both values increased and then decreased for WWF (Supplementary Fig. 3b and 3c). The addition of GO up to 3% level decrease LPV and LPW and further addition led to an increase in both values while the addition of HF showed opposite effect in WWF (Supplementary Fig. 3b and 3c). The addition of GO progressively decreased the WS while HF progressively increased WS in WWF. ANOVA revealed that oil level and oil type showed significant effect on MPW, LPV, LPW, RPW and WS for SWF. ANOVA revealed that oil level showed significant effect on MPT, MPV, MPW, LPW, RPV and RPW of WWF. MPT decreased with increase in GO level and reverse was observed when HF level was increased. Whereas WS and RPW increased with increase in GO and decreased with increase in HF.

Dynamic rheology of dough

The effect of different levels of GO and HF on dynamic rheological parameters (G' , G'' and $\tan \delta$) of dough from SWF and WWF are shown in Table 2. G' of WWF and SWF was 7390 Pa and 97,620 Pa, respectively. G' of dough from WWF and SWF containing 1%, 3% and 5% groundnut oil ranged from 10,560 to 27,470 Pa, 11,050 to 24,910 Pa and 10,680 to 18,140 Pa, respectively (Table 2). G' of the dough from weak and strong wheat flour

containing 1%, 3% and 5% hydrogenated fat ranged from 11,019 to 23,540 Pa, 12,580 to 22,980 Pa and 8197 to 15,260 Pa, respectively. ANOVA revealed that flour types, oil level and their interaction had significant effect on G' of dough (Table 3). Dough prepared from WWF and SWF showed G'' of 2584 Pa and 26,391 Pa, respectively. G'' of dough from WWF and SWF containing 1%, 3% and 5% groundnut oil ranged from 4732 to 10,277 Pa, 4659 to 9655 Pa and 4506 to 6761 Pa, respectively. G'' of the dough containing 1%, 3% and 5% hydrogenated fat ranged from 4381 to 9175 Pa, 5328 to 9085 Pa and 3793 to 5892 Pa respectively. WWF and SWF dough showed $\tan \delta$ of 0.35 and 0.27, respectively. $\tan \delta$ of dough containing 1%, 3% and 5% groundnut oil ranged from 0.45 to 0.37, 0.42 to 0.39 and 0.42 to 0.37, respectively. $\tan \delta$ of the dough containing 1, 3 and 5% hydrogenated fat ranged from 0.40 to 0.39, 0.42 to 0.40 and 0.46 to 0.39, respectively. ANOVA revealed that the flour types showed significant effect on $\tan \delta$ of dough, however oil level and interaction did not showed any significant effect (Tables 3, 4). G' of dough from both flours was greater than G'' (Table 2), which indicated that the dough exhibited a more elastic character (Singh et al. 2011). The lower $\tan \delta$ values indicated the more elastic structure. ANOVA revealed that oil level showed significant effect on G' , G'' and $\tan \delta$ of flours for both flour types. ANOVA revealed that oil type showed significant effect on G' , G'' and $\tan \delta$ of SWF. ANOVA revealed that oil level showed significant effect on G' , G'' and $\tan \delta$ of WWF (Table 3). Interaction plot indicated that addition of GO and HF up to 3% level increased G' , G'' and $\tan \delta$ and further addition led to decrease in both the moduli of WWF. Interaction plot indicated that addition of GO and HF progressively

Fig. 2 continued

Table 3 *F* values from ANOVA analysis of the (oil type vs. level of oil) reported in Tables 1 and 3

Source	PV	FV	BDV	SBV	PT	G'	G''	Tan
WR544 (Weak wheat)								
Oil type	7.55**	NS	8.78*	NS	63.07**	NS	5.43*	NS
Oil level	102.55**	37.69**	193.12**	29.27**	4.57*	124.09**	74.41**	51.46**
Interaction	3.30*	NS	NS	NS	6.82*	92.46**	53.62**	199.22**
HUW468 (Strong wheat)								
Oil type	NS	NS	NS	10.29**	NS	50.93**	238.26**	34.42**
Oil level	39.14**	47.28**	57.39**	115.14**	NS	330.47**	826.27**	12.31**
Interaction	NS	NS	3.16*	NS	5.11*	NS	9.37**	NS

NS not significant; * $P < 0.05$; ** $P < 0.005$

PV peak viscosity, BDV breakdown viscosity, FV final viscosity, SBV setback viscosity, PT pasting temperature, G' elastic modulus, G'' viscous modulus

Table 4 *F* values from ANOVA analysis of the (oil type vs. level of oil) reported in Table 2

Source	MPT	MPV	MPW	LPV	LPW	RPV	RPW	WS
WR544 (Weak wheat)								
Oil type	NS	NS	NS	NS	NS	NS	3.38*	NS
Oil level	11.37**	4.45*	5.90*	NS	31.78**	7.26**	30.05**	NS
Interaction	NS	NS	NS	3.84*	37.70**	NS	7.13**	7.01*
HUW468 (strong wheat)								
Oil type	NS	NS	4.83*	3.86*	72.39**	NS	12.72**	17.76**
Oil level	NS	5.93*	22.06**	9.05**	47.64**	6.71*	7.88**	13.53**
Interaction	NS	NS	53.49**	NS	22.06**	NS	58.50**	2.96**

NS not significant; * $P < 0.05$; ** $P < 0.005$

MPT mixograph peak time, MPV Mixograph Peak Value, MPW Mixograph Peak Width, LPV left peak value, LPW left peak width, RPV right peak value, RPW right peak width, WS weakening slope

decreased G' and G'' in SWF (Fig. 3a, b). Fat provides a uniform distribution of the dough components thus expand easily and give rise to large loaf volume while oil provides a less uniform distribution of dough components that give rise to poor loaf volume (Watanabe et al. 2002). G' of dough prepared using GO and HF are shown in Table 2. The addition of HF resulted into a greater decrease in G' , whereas the addition of GO increased (Fig. 3a). HF and GO containing dough also showed difference in $\tan \delta$. GO containing dough showed more elastic behavior resulted in increased G' . With increase in concentration of both the GO and HF, G' and G'' decreased. $\tan \delta$ decreased with increase in GO level and increased with increase in HF. The addition of the solid fat at least up to 5% in wheat flour led to decrease in G' and increase in G'' and thus yielded an increase in the loaf volume of the bread (Watanabe et al. 2002). Watanabe et al. (2002) also reported that the oil containing dough showed higher G' values, which resulted in a less volume of bread.

Conclusion

The incorporation of GO and HF at different levels affect pasting, dough rheology and mixing properties of SWF and WWF. The addition of GO and HF progressively decreased pasting parameters in both flour types. With an increase in GO and HF, the mixographic properties (MPV, LPV and RPV) decreased in both flour types. MPT decreased with increase in GO level and reverse was observed for HF level. The addition of GO up to 3% level progressively decrease LPV and LPW and further addition led to an increase in both values while the addition of HF showed opposite effect for WWF. The addition of GO and HF up to 3% level increased G' , G'' and further addition led to decrease in both the moduli of WWF. GO containing dough showed more elastic behavior resulted in increased G' . With increase in concentration of both the GO and HF, G' and G'' decreased. $\tan \delta$ decreased with increase in GO level and increased with increase in HF. The presence of added fat during mixing of dough altered the dough's development and rheological properties.

Fig. 3 **a** Effect of GO and HF addition in SWF and WWF on G' by using interaction plot, **b** effect of GO and HF addition in SWF and WWF on G'' by using interaction plot

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