Effect of fats and oils on pasting and textural properties of wheat flour

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Abstract Effects of fats and oils on pasting and textural properties of soft and hard wheat flours were investigated. Fats and oils significantly diminished peak viscosity, trough, breakdown, setback, final viscosity and escalated the pasting temperature. Effects on pasting properties were found more noticeable for soft wheat flour. Pasting properties of soft and hard wheat flour were significantly affected by coconut oil and hydrogenated fat. Texture analyser results divulged that fats and oils decreased the flour gel hardness, adhesiveness, gumminess and chewiness of flour gel of both varieties, whereas gel springiness was improved. Textural properties of wheat flour gels of both soft and hard wheat varieties were influenced most extensively by groundnut oil.

Keywords Pasting properties · Pasting temperature · Fats and oils · Textural properties

Introduction

The widespread cultivation and human consumption of wheat makes it a primary cereal crop across the world (Barak et al. 2015). Wheat flour is a major ingredient of baked products such as chapatti, cakes, cookies and bread (Singh and Khatkar 2005). Based on the hardness of kernel, wheat can be classified as soft and hard category. Hard wheat is more suitable for the bread making as it produces the coarser-flour with better level of the damaged starch and coarse texture (Ikeda et al. 2005). On the other hand, soft wheat is more suitable for cookies, pie crusts, biscuits, muffins, crackers, doughnuts, and cakes because the soft wheat yield fine flour and starch with low damage (Chioielli et al. 2004).

For food products texture and gelatinization are the important properties where the gelatinization behaviour is key factor related to the textural and structural traits of several end products. Pasting behavior has wide differences in the flours through varied wheat cultivars, and it will be attributed to major differences within the starch components. The amalgamation of oils and fats in wheat flour has a potential for improving textural traits. Singh et al. (2011) and Blazek and Copeland (2008) suggested that the viscoelastic properties of wheat flours are influenced by the non-starch ingredients (such as non-starch polysaccharides, lipids, and proteins). Previous research by Hahn and Hood (1987) and Raphaelides and Karkalas (1988) investigated amylose complex formation with fatty acids. The effect of fatty acids on pasting temperature and viscosity of wheat starch has been reported by Nierle and Baya (1990). The effect of fatty acids on the rheological properties of rice flour was investigated by Kaur and Singh (2000).

Limited literature is available on the effects of different types of fats and oils on pasting and textural characteristics

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of wheat flours. This study was aimed to investigate the effects of different types of fats and oils on the pasting and texture properties of hard and soft wheat flours.

Materials and methods

Material

Two commercial wheat varieties HS 490 and HD 2967 were acquired from DWR, Karnal, India. The grains of both varieties were milled on a Chopin laboratory mill (Model CD1, Villeneuve laGarenne, France) into refined flours.

Physical analysis of grain

Thousand kernel weight (TKW) was calculated by measuring weight of 100 seeds and multiplying obtained weight by a factor of 10. Hectoliter weight (HLW) was determined using Chopin Aqua TR (Villeneuve La Garenne, France). The hardness of the kernels was estimated with the help of Single Kernel Characterization System.

Chemical analysis of flour

The wheat flour samples were analyzed for moisture content (AACC 2000), ash content (AACC 2000) and protein content (AACC 2000). Both varieties were studied for SDS sedimentation volume by the method explained by Axford et al. (1979). The damaged starch content of wheat flour was examined using SDmatic. The enzyme activity (α -amylase) of the wheat flour was observed using Falling Number Apparatus according to AACC method (2000). SRC was analyzed as per the AACC 56–11 method. Alkaline water retention capacity (AWRC) was studied according to the AACC 56–10 method. Amylose content of the isolated starches and their fractions was estimated by iodine binding method as described by Williams et al. (1970). Gluten content and gluten index (GI) of the wheat flour were evaluated as per standard AACC method using Glutomatic (Perten Instruments, Sweden). All determinations were made in triplicate.

RVA analysis of wheat flour

The pasting profile of wheat flours were established using a Rapid Visco Analyzer-TechMaster (Perten Instruments). Flour (3.0 g, 14% mb) suspension was prepared using distilled water to get a sample weight of 28.0 g. Butter, hydrogenated fat, palm oil, coconut oil, groundnut oil and sunflower oil were added to the flour suspension at 20 g/100 g level. The temperature–time conditions included a

heating step from 50 to 95 °C at 6 °C/min, a holding phase at 95 °C for 1.5 min, a cooling step from 95 to 50 °C at 6 °C/min, and a holding phase at 50 °C for 2 min. The deliberated parameters were pasting temperature, peak viscosity, trough, final viscosity, breakdown viscosity, and setback viscosity.

TA analysis of wheat flour gel

After the RVA measurement, the wheat flour samples were sealed with paraffin film to prevent loss of moisture and kept at a temperature of 4 °C for 24 h in order to allow gelation. The gel was then analyzed using Texture Analyzer (TA-XT 2i), Stable Micro Systems, U.K. following the method Wu et al. (2006) and the textural parameters were estimated.

Statistical analysis

The experimental data collected was evaluated for significant differences with the help of analysis of variance (ANOVA) using SPSS 16.0 software.

Results and discussion

Grain and flour quality

The results of the flour quality analysis of wheat varieties HS 490 and HD 2967 are presented in Table 1. It was inferred from the data that the variety HD 2967 had considerably higher hardness index (HI) than the variety HS 490. Thousand kernel weight (TKW) is a useful tool for assessment of the potential milling yield, and it was greater (73.2 g) for HD 2967 than HS 490 (37.3 g). Hectoliter weight depends on the shape, size, and soundness of grains and should be higher than 76 kg/l for industrial application. Wheat composition is a major criterion to determine the quality of wheat (Bilgin and Korkut 2005).

The protein content of the variety HD 2967 was higher (12.88%), while the protein content of HS 490 was lower (10.02%). The HD 2967 had higher SDS sedimentation volume (68 ml), falling number and damaged starch (6.7 g / 100 g). Similar results were observed by previously by Farrand (1972), who reported that hard wheat offered larger flour particle having higher damaged starch levels while comparing it with the soft wheat kernel. Oil absorption capacity, solvent retention capacity, amylose content, and amylopectin to amylose ratio were significantly higher for variety HD 2967, while amylopectin was observed higher for HS 490. Water absorption capacity differed slightly among both varieties. Wheat variety HS 490 with minimum damaged starch demonstrated lower

Table 1 Grain and flour quality characteristics of wheat varieties

Quality Characteristics	Parameters	Wheat varieties	
		HS 490	HD 2967
Physical quality of grain	HI	26 ± 8	55 ± 6
	TKW (g)	37.3 ± 0.3	73.2 ± 0.5
	HLW (kg/l)	78.7 ± 0.1	81.7 ± 0.2
Flour characteristics	MC (%)	12.86 ± 0.4	12.38 ± 0.4
	Ash content (g/100 g)	0.08 ± 0.2	0.98 ± 0.2
	PC (g/100 g)	10.02 ± 0.1	12.88 ± 0.2
	SDS vol (ml)	32 ± 0.4	68 ± 0.3
	FN (sec)	331 ± 3	388 ± 4
	DS (%)	4.3 ± 0.2	6.7 ± 0.2
	OAC (%)	85.3 ± 0.2	122.6 ± 0.5
	WAC (%)	41.07 ± 0.2	42.57 ± 0.2
	AWRC (%)	186.94 ± 0.2	202.46 ± 0.3
	WSRC (%)	60.79 ± 0.1	72.76 ± 0.1
	SUSRC (%)	79.51 ± 0.1	107.77 ± 0.2
	SCSRC (%)	77.76 ± 0.2	104.82 ± 0.1
	LASRC (%)	91.57 ± 0.4	108.21 ± 0.6
	AM (%)	20.16 ± 0.1	26.94 ± 0.1
	AP (%)	79.84 ± 0.1	73.06 ± 0.1
	AP/AM ratio	3.96 ± 0.1	2.71 ± 0.1
Gluten quality	DG (g/100 g)	8.7 ± 0.2	11.6 ± 0.3
	WG (g/100 g)	25.35 ± 0.4	36.41 ± 0.2
	GI (g/100 g)	80.01 ± 0.2	95.32 ± 0.2

Values are mean ± standard deviations of determinations made in triplicates

HI Hardness index, *TKW* thousand kernel weight, *HLW* hectolitre weight, *MC* moisture content, *PC* protein content, *SDS vol* Sodium dodecyl sedimentation volume, *FN* falling number, *DS* damaged starch, *OAC*-Oil absorption capacity, *WAC* water absorption capacity, *AWRC* alkaline water retention capacity, *SRC* solvent retention capacity, *WSRC* water SRC, *SUSRC* sucrose SRC; *SCSRC* sodium carbonate SRC, *LASRC* lactic acid SRC, *AM* amylose, *AP* amylopectin, *AP/AM* amylopectin/amylose, *DG* dry gluten, *WG* wet gluten, *GI* Gluten index

water absorption, while wheat variety HD 2967 depicted higher water absorption. The value of alkaline water retention (AWRC) was found lower (186.94%) for HS 490 and higher (202.46%) for HD 2967. Good cookies making wheat flours should have lower AWRC values that confer cookies with higher diameters.

Variety HD 2967 depicted a higher gluten index of 95.32 g/100 g than HS 490 (80.01 g/100 g). Gluten index implies the flour strength. Wheat varieties differed remarkably for their wet and dry gluten contents. The greater value of 36.41 g/100 g wet gluten was observed in flour of wheat variety HD 2967 and the variety HS 490 contained 25.35 g/100 wet gluten. A lower dry gluten yield was obtained from variety HS 490 than the variety HD 2967, and its gluten was sticky and crumbly. Similar results were reported in previous studies by Devi et al. (2018).

Effects of fats and oils on pasting properties of wheat flour

Pasting characteristics are important and used to understand the gelatinization behaviour of flour. The pasting curves of both varieties are displayed in Fig. 1. Pasting profile of both varieties differed considerably. The data obtained (Table 2) showed that soft wheat flour (HS 490) possessed the greater peak viscosity (1832 cP), trough viscosity (936 cP), breakdown viscosity (896 cP), final viscosity (1729 cP), while hard wheat flour (HD 2967) revealed lower values of PV (1254 cP), TR (812 cP), BD (442 cP), and FV (1576 cP). The difference in peak viscosity amongst wheat flours from different varieties can be attributed to the variation in proportion of monomeric or polymeric proteins (Singh et al. 2016). Sabularse et al. (1992) reported that damaged starch had negative association with peak viscosity. It was perceived from Table 1 that HD 2967 had higher damaged starch content and

Fig. 1 Pasting properties curves of soft wheat (HS 490) flour (1) and hard wheat (HD 2967) flour (2)

Table 2 Effects of fats and oils on pasting properties of soft and hard wheat flour

Fat/oil type	Pasting properties of wheat flour											
	PV (cP)		TR (cP)		BD (cP)		FV (cP)		SB (cP)		PT (°C)	
	HS 490	HD 2967	HS 490	HD 2967	HS 490	HD 2967	HS 490	HD 2967	HS 490	HD 2967	HS 490	HD 2967
Control	1832f	1254g	936f	812f	896g	442f	1729f	1576g	793e	764f	86.35a	86.30a
B	956e	603c	540e	447c	416f	156b	1049d	924c	509c	477b	89.60b	88.75d
HF	955e	499a	540e	380a	415e	119a	1060e	775a	520d	395a	89.60b	89.70f
PO	887c	597b	488c	432b	399c	165c	998c	892b	510c	460b	89.70d	88.85e
CO	745a	621d	441a	453c	304a	168c	890a	934d	449a	481c	91.35f	87.15b
GO	817b	648e	466b	474d	351b	174d	967b	1002e	501b	528d	90.45e	87.15b
SO	946d	705f	526d	503e	420d	202e	1040d	1041f	514d	538e	89.65c	87.20c

Values followed by different letters are significantly different at $P < 0.05$

PV peak viscosity, TR trough viscosity, BD breakdown viscosity, FV final viscosity, SB setback viscosity, PT pasting temperature, B butter, HF hydrogenated fat, PO palm oil, CO coconut oil, GO groundnut oil, SO sunflower oil

displayed lower peak viscosity. The higher peak viscosity signifies the water binding ability, the ease with which the starch granules get easily disintegrated and associated with the quality of the final product (Ritika et al. 2010). Pasting property relies upon the flour's amylose content with few non starch ingredients like fat and protein. The less peak and breakdown viscosity of flour might be correlated to the high protein content. High amylopectin helps in absorption of water, swelling, and starch granules pasting while the lipids and amylose inhibit these properties (Tester and Morrison 1990). Flour of variety HS 490 had higher amylopectin content as shown in Table 1 than HD 2967 flour and it consequently displayed higher peak viscosity (Fig. 1, Table 2). HD 2967 exhibited the lowest breakdown

viscosity indicating the higher resistance for shearing at a higher temperature. The observed low pasting temperature of HD 2967 variety can be attributed to its higher protein content. Katyal et al. (2018) also reported that the pasting temperature was delayed by higher protein content.

The pasting profile of the wheat flour incorporated with different types of fats and oils are summed up in Table 2 and pasting curves are displayed in supplementary material. Addition of different types of fats at equal concentrations influenced pasting properties to different extents. The results displayed in Table 2 showed a drastic downturn in PV after fats and oils additions. The peak point exhibited by the heating cycle is called as peak viscosity. The data demonstrated that coconut oil decreased PV of HS 490

flour paste from 1832 to 732 cP, whereas for HD 2967 variety the highest decline was reported in case of hydrogenated fat i.e. from 1254 to 499 cP.

The results obtained for reduction in PV for HD 2967 variety by hydrogenated fat in this work are in agreement with the reported by Singh et al. (2000). This decline is owing to the fact that the peak viscosity symbolizes the resistance that a paste exerts on the rotating paddle and has major attribution towards the starch quantity and its quality in a specific wheat variant. The reduction in wheat flour peak viscosity was consistent with the inhibited swelling of starch granules by fatty acids. Wang et al. (2016) concluded that the shorter carbon chain length of the fatty acids, the more complex formed. Coconut oil has the highest proportion (59.36%) of short carbon chain Lauric acid (C:12) (Devi and Khatkar 2018). The observed decrease in peak viscosity supported this explanation, indicating that coconut oil displayed greater decrease in peak viscosity.

Trough viscosity, which determines the ability of the paste to withstand breakdown during cooling, also decreased upon fats and oils addition. At equal concentration of fats and oils, coconut oil downturn the TR most substantially from 936 to 441 cP in soft wheat flour of variety HS 490. In contrast, the higher decrease in TR for hard wheat flour of variety HD 2967 was brought by hydrogenated fat i.e. from 812 to 380 cP. Higher breakdown of viscosity was observed for soft wheat flour. It was perceived from the data that breakdown viscosity showed a depreciating trend with the incorporation of fats and oils in soft and hard wheat flours. Adding coconut oil and hydrogenated fat caused decrease in the breakdown viscosity from 896 to 304 cP in HS 490 and from 442 to 119 cP in HD 2967, respectively. The decline in breakdown was observed more notable in soft wheat variety (HS 490). It can be concluded that fats and oils addition imparts higher stability to flours paste during cooking. Adebawale et al. (2005) stated that higher the level of breakdown viscosity, the lesser the flour ability for enduring heating and shear stress when it is cooked. Kim and Walker (1992) proposed that lipids may cover the starch surface with a film, expanding hydrophobicity, and restraining water move into the granules. The perceived diminishing in breakdown strengthened this description, demonstrating that the starch granules with the addition of fats and oils exhibited more noteworthy resistance to the hydrothermal interruption amid gelatinization.

The highest final viscosity (1729 cP) was recorded for control sample for variety HS 490 and the lowest (729 cP) for variety HD 2967 upon addition of hydrogenated fat. Starch components, amylose, amylopectin, amylose/amylopectin ratio and starch content are primary contributors to final viscosity. Integration complex with lipids

predominantly form with the amylose component of the starch, and the amylose-to-amylopectin ratio is rather an important factor responsible for variations in the ability of starches to bind lipids (Copeland et al. 2009).

Final viscosity is generally used to determine the quality of starch-based flour as it implies the capability of the flour to form a viscous paste after cooking and cooling. Setback reflects the retrogradation tendency of starch. The higher setback is affiliated with synergies of gel and implies a quality defect in the products. Setback viscosity decreased after addition of fats and oils. The effect of starch retrogradation is probably reduced by the ability to form amylose–lipid complex with the added fats and oils. No remarkable difference was observed in the setback viscosity of HS 490 flour and HD 2967 flour. The lower setback viscosity was accounted for soft and hard wheat flours by adding coconut oil and hydrogenated fat. Similar results were observed by (Katyal et al. 2019) who reported that PV, FV and SBV of wheat flours decreased with increasing level of groundnut oil and hydrogenated fat.

Pasting temperature refers the minimum temperature at which viscosity begins to rise during the process of heating. Addition of oils and fats improved pasting temperature. On addition of coconut oil and hydrogenated fat pasting temperature increased considerably. The increase in wheat flour pasting temperature was consistent with the inhibited swelling of starch granules from fats and oils, which resulted in a delay in the development of viscosity. The increased pasting temperature indicated that fats and oils interacted with the amylose chain and the starch–lipid complex prevented hydration and swelling of the starch granule. Higher pasting temperature of starch-based flour signifies better capacity to bind water, improved gelatinization capacity, and less swelling property. Higher pasting temperature of starch-based flour signifies better capacity to bind water, improved gelatinization capacity, and less swelling property. Higher pasting temperature is required attributes for good cookies (Devi et al. 2018). It may be concluded from the above discussion that the effectiveness of fats and oils is variety specific.

The downtrend in PV, TR, BD, SB, and FV was more striking in soft wheat flour. Further, an elevation in pasting temperature was observed more significant in soft flour of variety HS 490. Pasting properties of both soft and hard wheat flours followed a similar specific pattern in the present study. It was perceived from Table 2 that oils were more effective in soft wheat flour, whereas fats displayed greater influence in hard wheat flour. It is essential to mention here that the pasting properties of HS 490 wheat variety at concentration of 20% of fats and oils declined to the range of pasting properties of control wheat flour paste of hard variety HD 2967.

Table 3 Effects of fats and oils on textural properties of soft and hard wheat flour gel

Fat/Oil Type	Textural properties of wheat flour gel											
	GHD (g)		GAD (g/s)		GCO (ratio)		GSP (ratio)		GGU (g)		GCH (g)	
	HS 490	HD 2967	HS 490	HD 2967	HS 490	HD 2967	HS 490	HD 2967	HS 490	HD 2967	HS 490	HD 2967
Control	669g	839g	– 422b	– 466d	0.38c	0.28b	0.50b	0.35a	252d	238f	124e	84f
B	518f	497e	– 427c	– 437b	0.36b	0.26a	0.49a	0.42c	187c	130c	91b	55c
HF	496d	427c	– 426c	– 432b	0.35a	0.30c	0.51b	0.49f	174b	128c	89b	63e
PO	423b	397b	– 429d	– 442c	0.40d	0.26a	0.54c	0.43c	169a	104b	90b	45b
CO	439c	460d	– 422b	– 416a	0.42d	0.30c	0.56d	0.45d	182c	135d	102c	61d
GO	348a	346a	– 385a	– 413a	0.47e	0.26a	0.70e	0.47e	164a	90a	115d	42a
SO	513e	540f	– 429d	– 441c	0.34a	0.28b	0.48a	0.40b	171b	153e	82a	60d

Values followed by different letters are significantly different at $P < 0.05$

GHD gel hardness, *GAD* gel adhesiveness, *GSP* gel springiness, *GCO* gel cohesiveness, *GGU* gel gumminess, *GCH* gel chewiness, *B* butter, *HF* hydrogenated fat, *PO* palm oil, *CO* coconut oil, *GO* groundnut oil, *SO* sunflower oil

Effects of fats and oils on textural characteristics of gelatinized flour gel

The textural properties of flours gel prepared by the addition of 20% concentration of different fats and oils were evaluated. The textural features of soft and hard wheat flour gel prepared by addition of different fats and oils are displayed in Table 3. Gel hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness values of control flour gel ranged from 669 to 839 g, – 422 to – 466 g/s, 0.28 to 0.38, 0.35 to 0.50, 238.01 to 252.47 g, and 84.09 to 124.97 g, respectively. Results are in line with Yildiz et al. (2013). The hardness and adhesiveness values of flour gel were found higher for hard wheat variety HD 2967 than that of soft wheat variety HS 490. It can be linked with higher amylose content of variety HD 2967 as shown in Table 1. High amylose content yields a hard texture feature. Due to the linear conformation of amylose, it swells less than amylopectin, contributing to a harder gel structure and provides harder texture to the final food product. Gel cohesiveness, springiness, gumminess, and chewiness values were observed higher for soft wheat flour gel of variety HS 490.

Supplementation of groundnut oil reduced the hardness of flour gels significantly from 669 to 348 g of soft wheat flour gel and 839 to 346 g of hard wheat flour gel. This reduction in hardness was more striking in flour gel of the hard wheat when compared with soft flour. It could be clarified by the way that the addition of fats and oils can be credited to the development of amylose–lipid complex, which was assumed to accumulate as an insoluble film on the outside of granule in this manner upsetting the alliance of amylose by hydrogen bonds and decreased the gel strength.

Adhesiveness refers to gel ability to get isolated from the probe. Adding oils and fats to the base flour diminished the flour gel's adhesiveness and making it easy to get separated from the testing probe. Adhesiveness decreased from – 422 (control) to – 385 g/s in soft wheat flour gel and from – 466 g/s (control) to – 413 g/s in hard wheat flour gel upon addition of groundnut oil. Gel Cohesiveness (GCO) measures the tediousness to break down the internal structure of the gel. During gel formation starch gets embedded in the gluten network. Cohesiveness did not follow any specific pattern in both varieties. Table 3 displayed that the springiness increased significantly with addition of fats and oils and maximum springiness was observed for soft wheat flour gel upon addition of GO. The upgradation in GSP was more prominent in soft wheat flour gel.

Wheat flour gel gumminess (GGU) declined remarkably by adding different types of fats and oils. Addition of GO significantly declined the GGU from 252 to 164 g and from 124 to 90 g for HS 490 and HD 2967 wheat varieties, correspondingly. Further, wheat flour gel chewiness declined by adding fats and oils in both varieties. Both varieties followed a similar trend. Gel chewiness decreased from 124 to 82 g (sunflower oil addition) in soft flour gel, whereas in hard flour gel it decreased from 84 to 42 g (groundnut oil addition).

Conclusion

The results of the study revealed the role of fats and oils on flour pasting and textural properties. The base flour fortified with different fats and oils showed different pasting characteristics. Oils were more effective in soft wheat

flour, whereas fats displayed greater influence on pasting properties in hard wheat flour. The improvement in pasting temperature was more noticeable for soft wheat variety HS 490. Addition of fats and oils trim down gel hardness thereby implying the reduction in the strength of the flour gel. Groundnut oil was the most efficient in influencing textural properties of wheat flour gel for both soft and hard wheat varieties. The study findings will help to improve the traits of the hard and soft flours for improving the quality of the end product.

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