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Effect of surfactant and fat on chapati making quality and control of its staling

Hemalatha M.S., U.J.S. Prasada Rao *

Department of Biochemistry, CSIR-Central Food Technological Research Institute, Mysore, India

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ABSTRACT

Chapati is an unleavened flat baked product and it is prepared using whole wheat flour. One of the problems with chapatis is that they stale rapidly during storage and therefore, they have to be consumed immediately after their preparation. With changing socio-economic conditions and lifestyles, there is an increasing demand for ready to eat chapatis. In the present study, to control staling, chapatis were prepared using whole wheat flours of four different varieties by incorporating additives such as surfactant and fat. The chapatis stored at room temperature for 24 h, 48 h, 72 h and 96 h were evaluated for their quality parameters such as moisture content, chemical properties, sensory attributes, microstructure and amylograph characteristics. The moisture, soluble starch and soluble amylose contents in control chapatis decreased steadily with storage time and at the end of 96 h, the decrease in moisture, soluble starch and soluble amylose contents in chapatis prepared from different varieties were 3–8%, 80–82% and 78–85%, respectively. However, these changes were found to be at a very lesser rate in chapatis prepared from doughs treated with glycerol monostearate (GMS) and fat compared to that of control. Decrease in amylograph paste viscosity was more in control chapatis during storage compared to that of treated chapatis. Scanning electron microscopic studies of chapatis stored up to 96 h revealed that starch granules were uniform in both GMS and fat treated chapatis, when compared to control chapatis. Sensory studies showed that overall quality scores for chapatis prepared from GMS and fat treated doughs did not show any significant differences on storage. Thus, the results suggested that incorporation of surfactant and fat in dough not only improved the overall quality attributes of chapatis but also controlled their staling, during their storage.

1. Introduction

Wheat products like bread and chapati stale on storage and staling leads to decreased consumer acceptance (Rathnayake et al., 2018). Staling is a complex phenomena and it is characterized by hardening of bread crumb and softening of crust, due to starch retrogradation (Karim et al., 2000), interactions between gluten proteins and swollen starch granules (Martin and Hoseney 1991), and migration of water from crust to crumb and starch to gluten (Baik and Chinachoti, 2000). To control these factors, additives like amylases (Lauro et al., 2016) and hydrocolloids (Sciarini et al., 2010) were incorporated into bread dough. Amylases hydrolyze starch into dextrins, which has capacity to hold water resulting in decrease of crystallization of starch (retrogadation) (Lin and Lineback, 1990). On the other hand, hydrocolloids control staling due to their water holding capacity and inhibiting starch-gluten interactions (Gray and Bemiller, 2003).

Surfactants and fat were also incorporated into bread dough to control staling (Orthoefer and Kim, 2019). Fat and surfactants are amphiphilic compounds and they act as emulsifiers. Fats perform as a lubricant contributing to the smoothness of the dough (Canalis et al., 2018). It imparts desirable eating qualities and contributes soft texture and acceptable flavor to baked products (Jacob and Leelavathi, 2007). Surfactants break down the starch-protein interactions by breaking the secondary bonds and also by denaturation of proteins, while fat weaken the protein-starch interactions through formation of starch-lipid complexes (Gray and Bemiller, 2003; Park and Kim, 2021; Smith and Johansson, 2005). Surfactants also control migration of water from starch to gluten during storage by interacting with starch and gluten network (Asghar et al., 2011).

Chapati is a traditional staple food of majority of the people in Indian

; GMS, Glycerol Mono Stearate; SSL, sodium stearoyl-2-lactylate; SEM, Scanning Electron Micrographs; GS, Gelatinised Satrch; PA, Protein Aggregation; TP, Thin Protein.

* Corresponding author. Department of Biochemistry, CSIR-Central Food Technological Research Institute, Mysore, 570 020, India.
E-mail address: prasadarao_ummiti@yahoo.com (U.J.S. Prasada Rao).

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Table 1
Sensory properties of chapatis treated with surfactant and fat.

Variations	Storage period	Color & Appearance	Tearing Strength	Pliability	Taste & Aroma	Mouthfeel	Overall Quality
	GW-322						
Control	0 hrs	7.6^{a} ±0.3	7.3^{a}±0.4	7.5^{a}±0.6	7.1^{a}±0.5	7.4^{a}±0.6	7.3^{a}±0.4
	24 hrs	7.2^{b} ± 0.6	6.1^{b} ± 0.2	6.8^{b} ± 0.3	6.6^{b} ± 0.2	6.6^{b} ± 0.2	6.5^{b} ± 0.2
	48 hrs	6.9^{c}±0.1	5.3^{c}±0.2	6.2^{c}±0.3	6.2^{c}±0.5	6.0^{c}±0.4	6.1^{c}±0.2
Surfactant	0 hrs	7.8^{a}±0.5	7.6^{a}±0.2	7.8^{a}±0.4	7.7^{a}±0.3	7.7^{a}±0.5	7.8^{a}±0.4
	24 hrs	7.8^{a}±0.2	7.5^{ab} ± 0.2	7.5^{ab} ± 0.3	7.6^{a}±0.3	7.5^{ab} ± 0.4	7.6^{a}±0.2
	48 hrs	7.8^{a}±0.1	7.4^{b} ± 0.3	7.3^{b} ± 0.2	7.5^{b} ± 0.4	7.4^{b} ± 0.2	7.4^{a}±0.4
Fat	0 hrs	8.0^{a}±0.1	7.6^{a}±0.2	8.1^{a} ±0.2	7.9^{a}±0.3	7.9^{a}±0.1	8.0^{a} ±0.3
	24 hrs	8.0^{a}±0.3	7.5^{a} ±0.1	8.0^{a} ±0.3	7.9^{a}±0.1	7.9^{a}±0.2	7.9^{a}±0.4
	48 hrs	8.0^{a}±0.2	7.3^{a}±0.4	7.9^{a} ±0.3	7.9^{a}±0.3	7.9^{a}±0.4	7.9^{a}±0.1
	NI-5439						
Control	0 hrs	7.4^{a}±0.1	7.2 ^{a}±0.2	7.3 ^{a}±0.2	7.3 ^{a}±0.3	7.3 ^{a}±0.1	7.1 ^{a}±0.1
	24 hrs	7.1^{b} ± 0.3	6.9 ^{b} ± 0.1	6.9 ^{b} ± 0.2	6.8 ^{b} ± 0.1	6.7 ^{b} ± 0.2	6.5 ^{b} ± 0.2
	48 hrs	6.8^{c}±0.2	6.5 ^{c}±0.1	6.4 ^{c}±0.3	6.3 ^{c}±0.1	6.3 ^{c}±0.1	6.2 ^{c}±0.1
Surfactant	0 hrs	7.7 ^{a} ±0.1	7.4 ^{a} ±0.2	7.9 ^{a} ±0.3	7.6 ^{a} ±0.2	7.6 ^{a} ±0.3	7.7 ^{a} ±0.2
	24 hrs	7.7 ^{a} ±0.2	7.4 ^{a} ±0.2	7.8 ^{a} ±0.1	7.6 ^{a} ±0.3	7.6 ^{a} ±0.2	7.6 ^{a} ±0.2
	48 hrs	7.6 ^{a} ±0.3	7.4 ^{a} ±0.3	7.7 ^{a} ±0.2	7.4^{b} ± 0.2	7.5 ^{a} ±0.1	7.6 ^{a} ±0.3
Fat	0 hrs	7.8 ^{a} ±0.1	7.7 ^{a} ±0.2	7.9 ^{a} ±0.3	7.8 ^{a} ±0.3	7.8 ^{a} ±0.2	7.9 ^{a} ±0.1
	24 hrs	7.8 ^{a} ±0.2	7.7 ^{a} ±	7.9 ^{a} ±0.2	7.8 ^{a} ±0.1	7.8 ^{a} ±0.3	7.9 ^{a} ±0.3
	48 hrs	7.8 ^{a} ±0.3	7.6 ^{a} ±0.1	7.8 ^{a} ±0.3	7.8 ^{a} ±0.2	7.7 ^{a} ±0.3	7.7^{b} ± 0.3
	MACS-2496						
Control	0 hrs	7.6 ^{a}±0.1	7.0 ^{a}±0.1	7.2 ^{a}±0.2	7.2 ^{a}±0.2	7.2 ^{a}±0.3	6.8 ^{a}±0.3
	24 hrs	7.1 ^{b} ± 0.2	6.4 ^{b} ± 0.1	6.6 ^{b} ± 0.1	6.5 ^{b} ± 0.3	6.6 ^{b} ± 0.2	6.3 ^{b} ± 0.3
	48 hrs	6.5 ^{c}±0.3	6.0 ^{c}±0.2	6.1 ^{c}±0.2	6.1 ^{c}±0.1	6.2 ^{c}±0.1	5.9 ^{c}±0.1
Surfactant	0 hrs	7.6 ^{a} ±0.1	7.2 ^{a} ±0.2	7.5 ^{a} ±0.3	7.5 ^{a} ±0.1	7.5 ^{a} ±0.3	7.5 ^{a} ±0.3
	24 hrs	7.6 ^{a} ±0.2	7.2 ^{a} ±0.1	7.5 ^{a} ±0.2	7.5 ^{a} ±0.2	7.5 ^{a} ±0.1	7.5 ^{a} ±0.3
	48 hrs	7.5 ^{a} ±0.3	7.2 ^{a} ±0.3	7.4 ^{a} ±0.1	7.5 ^{a} ±0.3	7.4 ^{a} ±0.3	7.4 ^{a} ±0.1
Fat	0 hrs	7.6 ^{a} ±0.1	7.6 ^{a} ±0.2	7.5 ^{a} ±0.2	7.7 ^{a} ±0.1	7.7 ^{a} ±0.2	7.8 ^{a} ±0.1
	24 hrs	7.6 ^{a} ±0.3	7.5 ^{a} ±0.1	7.5 ^{a} ±0.3	7.7 ^{a} ±0.3	7.6 ^{a} ±0.3	7.7 ^{a} ±0.2
	48 hrs	7.6 ^{a} ±0.3	7.5 ^{a} ±0.3	7.4 ^{a} ±0.1	7.6 ^{a} ±0.3	7.6 ^{a} ±0.1	7.7 ^{a} ±0.3
	HD-2781						
Control	0 hrs	7.7^{a} ± 0.3	7.3^{a} ± 0.4	7.2^{a} ± 0.5	7.2^{a} ± 0.4	7.2^{a} ± 0.2	7.1^{a} ± 0.3
	24 hrs	6.9^{b} ± 0.3	6.3^{b} ± 0.3	6.0^{b} ± 0.2	6.5^{b} ± 0.2	6.8^{b} ± 0.1	6.5^{b} ± 0.1
	48 hrs	6.3^{c} ± 0.3	5.8^{c}±0.2	5.4^{c}±0.3	6.1^{c}± 0.3	6.6^{c}± 0.1	6.2^{c}± 0.2
Surfactant	0 hrs	7.8^{a} ± 0.6	7.6^{a} ± 0.6	7.7^{a} ± 0.4	7.8^{a} ± 0.2	7.6^{a} ± 0.3	7.8^{a} ± 0.5
	24 hrs	7.8^{a}± 0.5	7.5^{a}±0.4	7.5^{ab} ± 0.4	7.6^{ab} ± 0.4	7.4^{ab} ± 0.4	7.7^{a}± 0.3
	48 hrs	7.7^{a}± 0.4	7.4^{a}±0.3	7.5^{ab} ± 0.3	7.5^{b} ± 0.2	7.0^{b} ± 0.3	7.6^{a}±0.3
Fat	0 hrs	7.7 ^{a}±0.2	7.7 ^{a}±0.2	7.5 ^{a}±0.3	7.6 ^{a}±0.2	7.7 ^{a}±0.2	7.9 ^{a}±0.2
	24 hrs	7.7 ^{a}±0.2	7.7 ^{a}±0.3	7.5 ^{a}±0.2	7.6 ^{a}±0.3	7.7 ^{a}±0.3	7.9 ^{a}±0.3
	48 hrs	7.7 ^{a}±0.3	7.6 ^{a}±0.3	7.4 ^{a}±0.3	7.5 ^{a}±0.3	7.7 ^{a}±0.2	7.8 ^{a}±0.3

[a] GMS*: Glycerol Monostearate.
[b] Data reported as mean ± SD of eight determinations. Means followed by different letters in the same group differ significantly ($p<0.05$) by Duncan Multiple Range Test.

subcontinent and Asian ethnic communities residing all over the world. As chapatis stale swiftly during storage, freshly prepared chapatis are preferred by the consumers. Due to change in lifestyles of consumers, there is an increase in demand for ready to eat chapatis. Although considerable work on the effect of surfactants and fat on bread staling is reported, only few studies on chapatis prepared from dough incorporated with surfactants, hydrocolloids, dextrins and enzymes are available. However, these studies were carried out for limited storage period of 2 days, or storage in refrigeration and in presence of preservatives. Gujral and Gaur (2005) evaluated the extensibility parameter of chapatis and reported that barley, glycerol monostearate (GMS) and NaCl showed higher extensibility up to 24h compared to control. Ghodke and Ananthanarayan (2007) reported that chapati dough treated with guar gum had less staling up to 2 days at refrigerated temperature. Later, these workers incorporated sodium stearoyl-2-lactylate(SSL), GMS, propylene glycol, sorbitol, α-amylase, xylanase, maltodextrin and guar gum in presence of preservatives into dough individually as well as in combination, and reported that maltodextrin was more effective, but combination of α-amylase+SSL was more effective at 4 °C due to its synergistic effect (Shaikh et al., 2008)

As fat and surfactants are less expensive and easy to handle compared to other additives like enzymes, a study on the effect of surfactant and fat was carried out by evaluating quality parameters such as moisture content, rheological properties, sensory attributes and microstructure of fresh and chapatis stored up to 96 h at room temperature without any preservatives.

2. Material and methods

2.1. Materials

Triticum aestivum wheat varieties, namely GW-322, NI-5439 (good chapati making varieties), MACS-2496 and HD-2781 (poor chapati making varieties) were obtained from Agharkar Research Institute, Pune, India. Wheat samples were ground to whole wheat flours (≤400 μm) using EGM-467 K disc mill. Glycerol monostearate (GMS) was obtained from M/s Fine Organic Industries, Mumbai and bakery fat (Marvo) was procured locally.

2.2. Preparation of surfactant emulsions

Emulsion was prepared by dispersing 1 part of GMS in 2 parts of water. The mixture was heated with constant stirring at 65 °C and cooled for further use.

2.3. Preparation of chapati

Dough was prepared by mixing 200g whole wheat flour with optimum quantity of water in a Hobart mixer (Model N-50) at speed 1 (61 rpm) for 3 min. To prepare dough using additives, 1 g of GMS emulsion

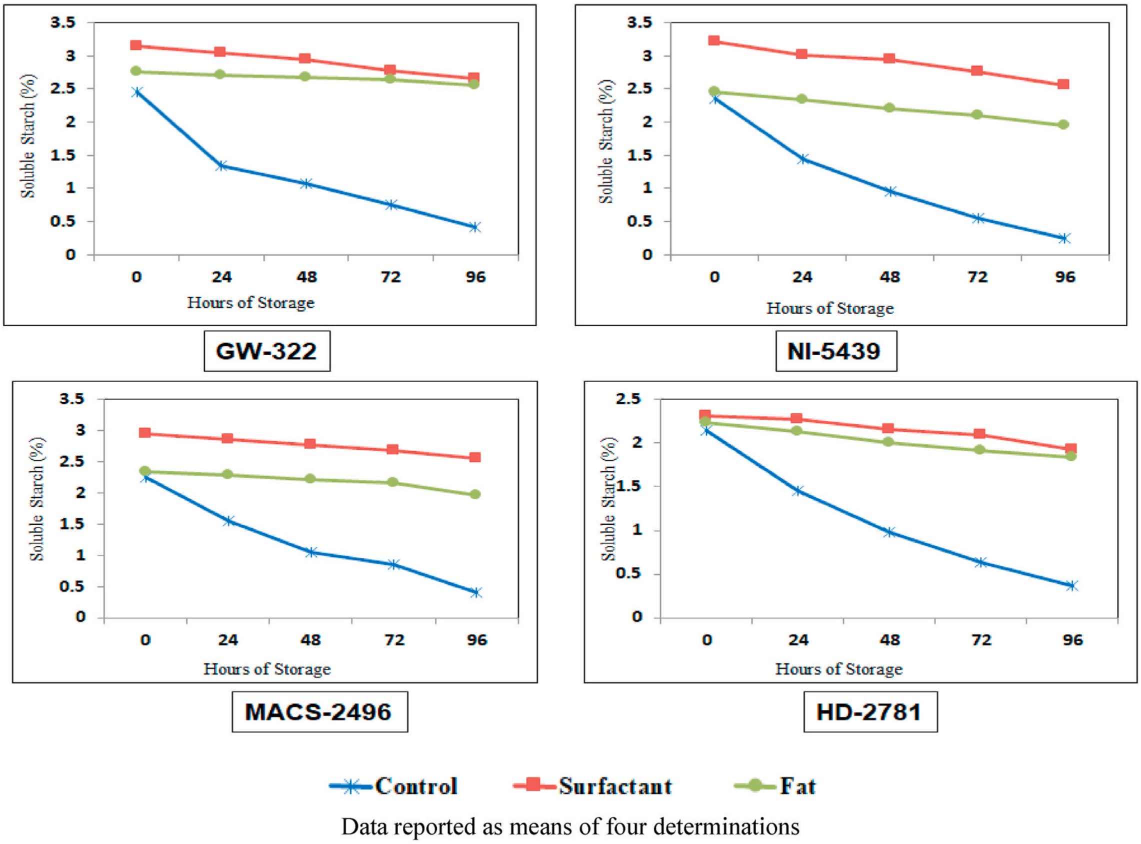

Fig. 1. Soluble starch contents of chapatis treated with surfactant and fat.

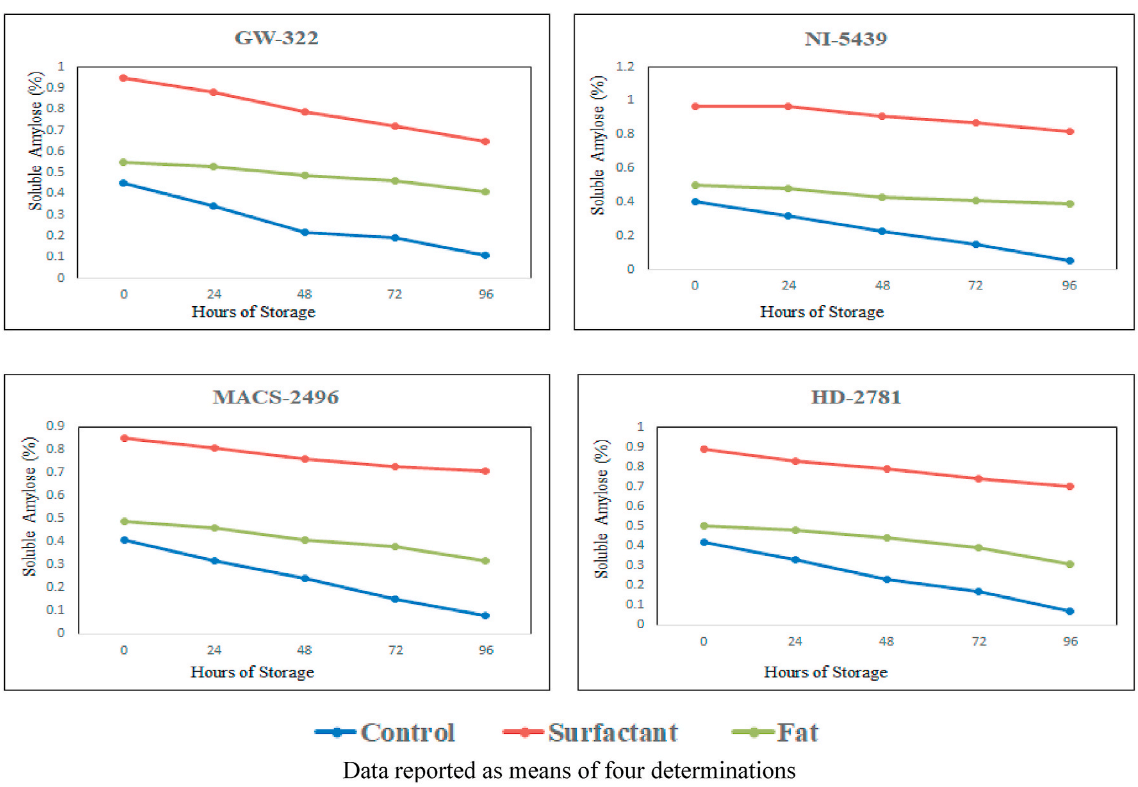

Fig. 2. Soluble amylose contents of chapatis treated with surfactant and fat.

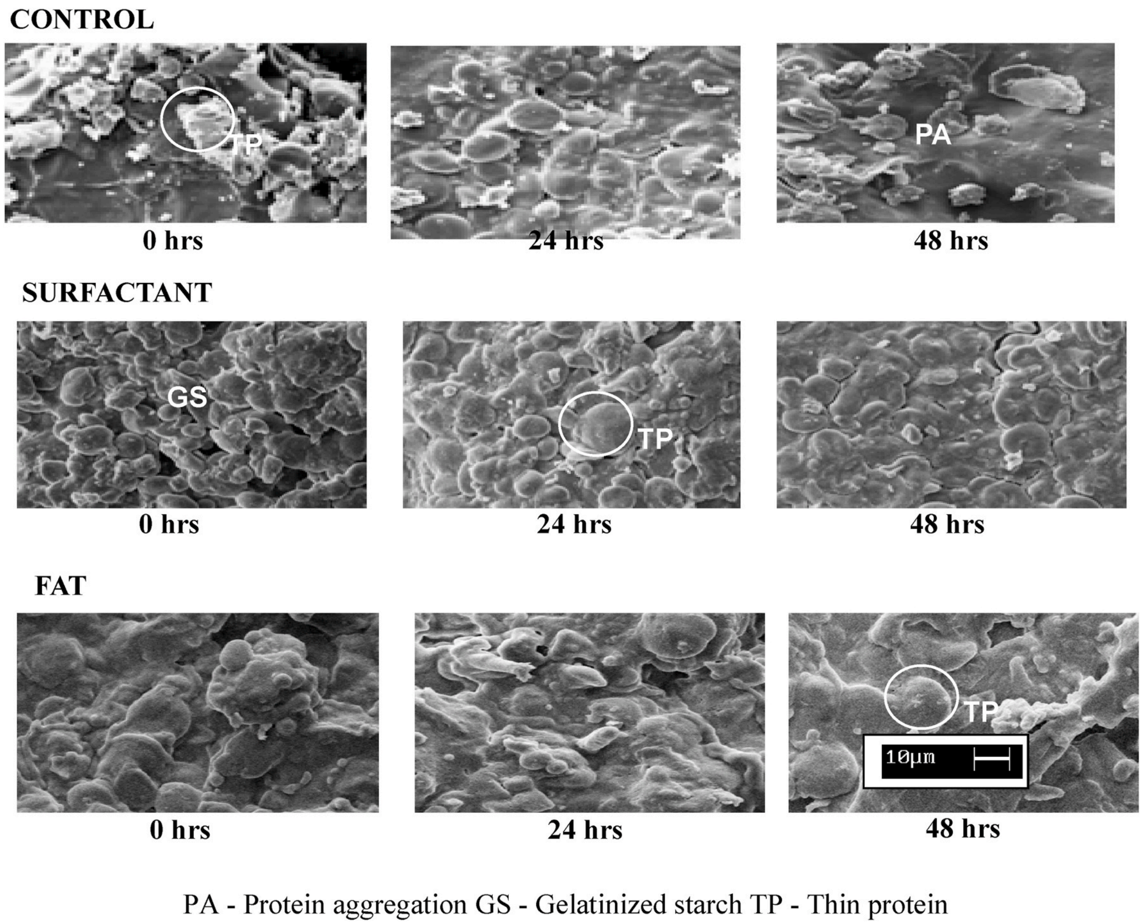

Fig. 3. Scanning electron micrographs of GW-322 chapatis.

and 5% of fat were added to whole wheat flour. The dough rested for 30 min at room temperature was divided into small portions (25g). Each portion was sheeted into a thickness of 1.5 mm and was cut into circular shape (12 cm diameter) using a die and baked on hot plate (Haridas Rao et al., 1986). Chapatis were cooled, packed in polypropelene pouches and stored at room temperature until further use.

2.4. Sensory evaluation of chapati

Sensory evaluation of chapatis was done by a panel of eight judges using 10-point scale to assess various sensory attributes. Judges were asked to give maximum scores when chapatis had smooth surface with golden brown color (color and appearance), greater pliability (folding ability), soft texture and easy to tear (tearing strength), little chewiness (mouthfeel), typical wheatish aroma with slight sweetish taste. On the other hand, when chapatis had less pliability, whitish color, leathery texture, excessive chewiness and bland taste the judges were asked to give the lowest scores.

2.5. Chemical analysis of chapati

Moisture content of chapatis was determined by two stage method/ oven drying method (AOAC, 2006). Chapatis were cut into small pieces and taken in a petri plate, covered with a sieve and incubated at room temperature for overnight. Chapati pieces were powdered and weighed in an aluminum dish. The dish was kept in an oven maintained at 130 ± 1 °C for 4h and the powder weight was taken after cooling in a desiccator. The estimation of soluble starch was done as per the procedure described by Shaikh et al. (2008) and soluble amylose was done as described by Sowbhagya and Bhattacharya (1971). To determine the soluble starch content, chapati powder (200 mg) was soaked in 15 ml of water and stirred for 20 min and centrifuged at 5,000g for 10 min. The supernatant (10 ml) was treated with iodine solution. For soluble amylose estimation, to 0.5g of powder, 10 ml of 0.5N KOH was added and made up to 100 ml with water. To 10 ml of aliquot, 5ml of 0.1N HCl and 0.5 ml of iodine solution were added, made the volume to 50 ml. The absorbance of the blue color formed in these experiments was measured at 625 nm.

2.6. Scanning electron microscopic studies of chapati

Chapatis were cut into small pieces (0.5 cm × 0.5 cm) and freeze dried. These dried pieces were mounted on the sample holder of scanning electron microscope (Model 435VP, UK) with the help of double-sided scotch tape and sputter coated with gold (2 min, 2 mbar). The microscopic observation was done at 15 kV and at a vacuum of 9.75 × 10^{-5} torr. Micrographs of appropriate magnifications were selected.

2.7. Amylograph characteristics of chapati

Freeze-dried chapatis were powdered to pass through 400μ sieve. Powder (15 g) was dispersed in 100 ml of distilled water and heated to increase the temperature from 30 to 92 °C at a rate of 5 °C/min, held at 92 °C for 5 min, cooled to 50 °C and then held for 1 min with constant agitation in a Micro-visco-amylograph (Brabender OHG, Duisburg, Germany). Torque was measured at the range of 300 cmg and viscosity was expressed in Brabender Units (BU).

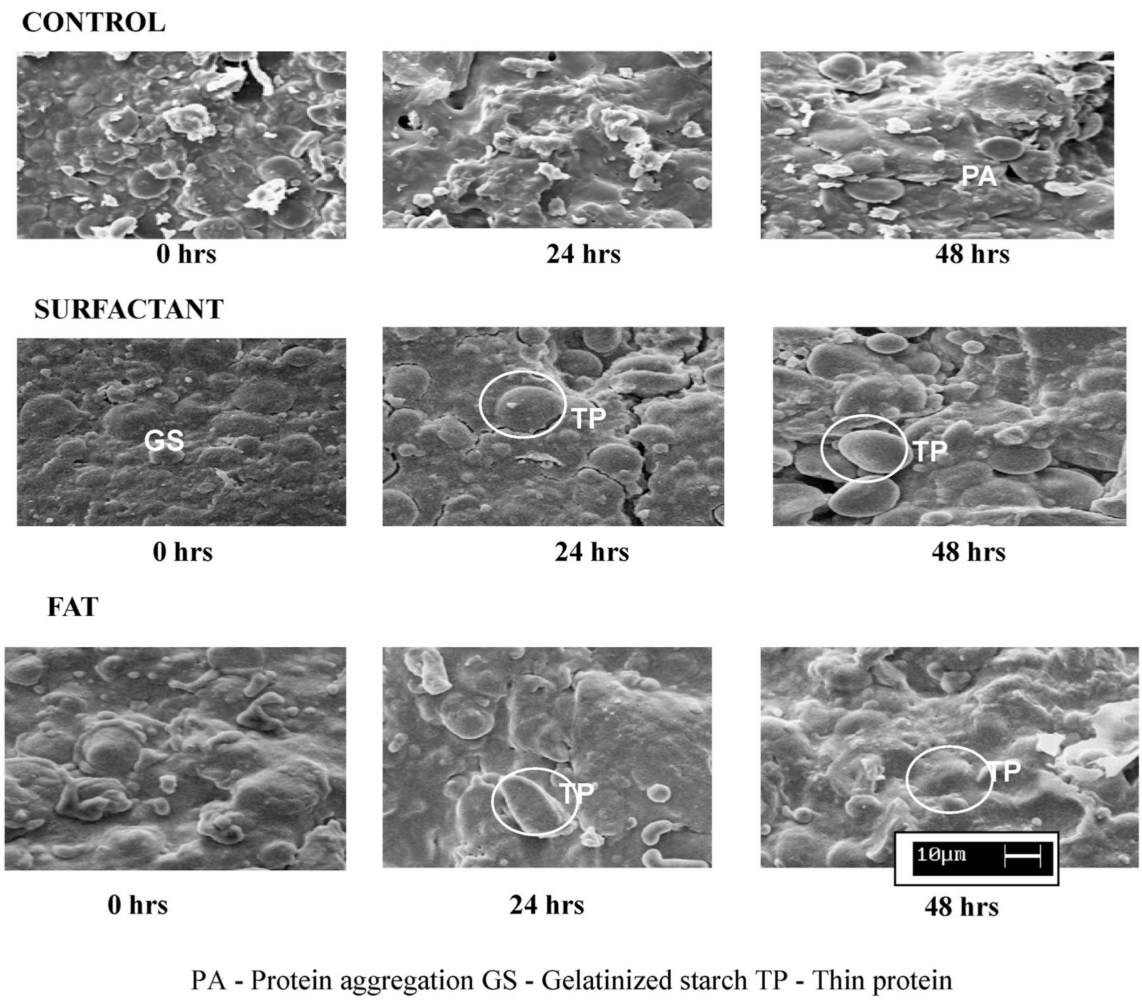

Fig. 4. Scanning Electron Micrographs of NI-5439 chapatis. PA - Protein aggregation GS - Gelatinized starch TP - Thin protein.

2.8. *Statistical analysis and graphical representation*

The data were treated statically by Duncan's new multiple range test to determine the significance of experimental data (Steel and Torrie, 1980) using the software SPSS (Statistical Products and Service Solution), Statsoft Incorporation, Tulsa, USA. Results were expressed as mean ± standard deviation. A value of $p<0.05$ was considered to be statistically significant.

3. Results and discussion

3.1. *Effect of surfactant and fat on moisture content of chapatis during storage*

Moisture contents of freshly prepared control chapatis from wheat varieties viz., GW-322, NI-5439, MACS-2496 and HD-2781 were 30.1%, 30.6%, 31.6% and 29.0%, respectively. However, the moisture content decreased to 24.1%, 26.9%, 28.5% and 21.0%, respectively, upon 96 h of storage. Baik and Chinachoti (2000) reported the decrease in crumb moisture content in bread on storage. The moisture contents in case of chapatis prepared from doughs treated with GMS of these four wheat varieties, upon storage for 96 h, were 29.3%, 29.1%, 30.3% and 28.6%, respectively showing that decrease in moisture was insignificant. Similar changes were observed in case of fat treated chapatis showing the moisture contents after storage of 96 h were 26.4%, 28.3%, 29.6% and 25.8%, respectively.

Thus, the percentage reduction in moisture content during storage for 96 h in control chapatis (untreated) of these four varieties was 3–8% moisture, while in case of treated chapatis the reduction in moisture content was very low (0.8–1.5%). Between the two additives, reduction in moisture content was found to be lower in case of chapatis prepared from surfactant treated doughs. Earlier studies on bread indicated that addition of surfactant to dough facilitated the formation of starch-surfactant complexes, which avoided the migration of moisture from crumb to crust (Xu et al., 1992).

3.2. *Effect of surfactant and fat on sensory properties of chapatis during storage*

There was no significant difference in the color and appearance of the fresh and stored chapatis prepared from dough treated with GMS and fat (Table 1). Good quality chapatis should have wheatish colour spread evenly over the surface with light brown spots (Parimala and Sudha, 2015). On the other hand, control chapatis on storage scored lower values as they were less appealing and tough requiring more strength to tear, whereas, chapatis prepared from surfactant and fat treated dough required less strength to tear.

The values for pliability of control chapatis were between 7.2 and 7.5 and upon storage these values decreased significantly (5.4–6.4). The pliability scores were significantly higher for surfactant (7.3–7.7) and fat (7.4–7.9) treated chapatis upon storage compared to control chapatis. Chapatis prepared from surfactant and fat treated dough had wholesome aroma and taste with sweetish aftertaste, which was found to be highly acceptable. The aroma and taste of control chapatis declined on storage

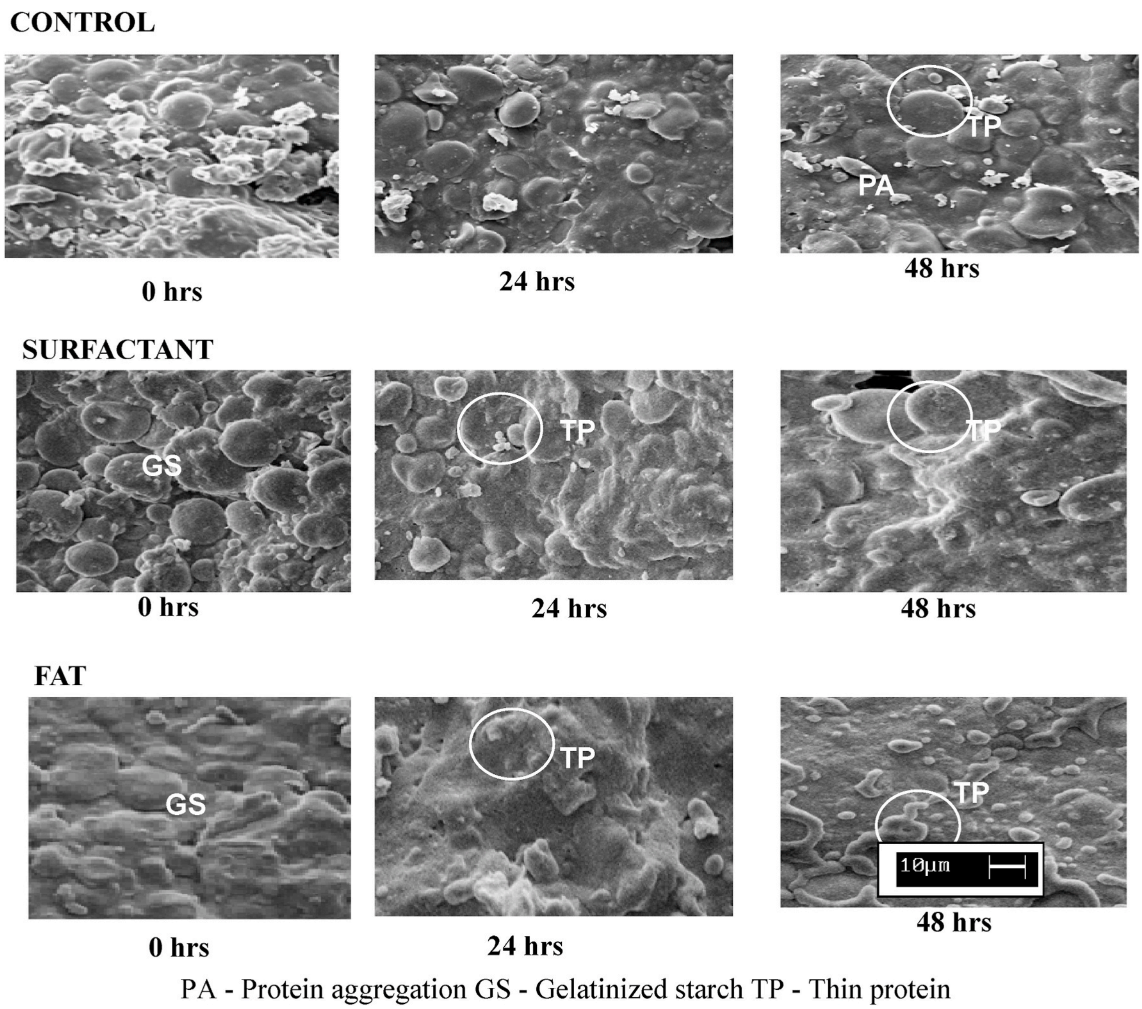

Fig. 5. Scanning Electron Micrographs of MACS-2496 chapatis. PA - Protein aggregation GS - Gelatinized starch TP - Thin protein.

compared to that of treated chapatis.

Mouthfeel scores correlate to chewing and other textural properties of food products (Sim et al., 2020). Sensory scores of control chapatis for mouthfeel ranged between 7.2 and 7.4 and decreased on storage (6.0–6.6). Chapatis prepared from GMS treated doughs on storage had sensory scores of 7.0–7.5, while for fat treated doughs, they were 7.6–7.9. The mouthfeel values for control chapatis were significantly lower than that of the treated chapatis (Table 1). Knightly (1988) reported that GMS forms a complex between monoglycerides and amylose contributing to decrease in firming.

Overall sensory quality of chapatis is attributed by all the above parameters, showing an improving effect when doughs were treated with surfactants and fats. The sensory properties of chapatis prepared from all the wheat varieties improved on treating with surfactant and fats during storage. Thus, treatment of dough with surfactant and fat in chapati preparation improves the overall quality of product and also decreases the rate of staling.

3.3. *Effect of surfactant and fat on chemical characteristics of stored chapatis*

Changes in starch characteristics during storage may contribute to staling of chapatis. As shown in Figs. 1 and 2, changes in soluble starch and soluble amylose contents were observed in control and treated chapatis. The soluble starch and soluble amylose contents in control chapatis significantly decreased on storage. Fresh chapatis prepared from dough treated with GMS and fat had higher content of soluble starch and soluble amylose compared to control chapatis. Although there was a significant decrease in the content of these components during storage, the decrease observed was significantly very low in case of treated chapatis stored for 96h. Surfactant has both hydrophilic and hydrophobic moieties in their molecular structure and it was reported that surfactants form complexes with amylose as well as amylopectin fractions (Gomez et al., 2004). Therefore, the changes in the contents of these components may influence the product quality.

3.4. *Scanning electron microscopic studies of chapatis during storage*

During baking, starch granules gets gelatinized and gelatinized starch (GS) forms into continuous starch net work. Partially GS particles were observed in control chapatis prepared from wheat varieties having good chapati making properties (GW-322 and NI-5439) (Figs. 3 and 4), while in wheat varieties having poor chapati making properties (MACS-2496 and HD-2781), less number of GS particles were observed. With respect to proteins matrix, protein aggregation (PA) was also less in good varieties, while PA was more prominent in poor chapati making varieties (Figs. 5 and 6). With the increase in storage time, increase in PA and further decrease in GS particles was observed. Earlier SEM studies, on bread also revealed continuous GS network in fresh breads and rigidity of starch particles on staling (Błaszczak et al., 2004).

In case of chapatis prepared from GMS treated doughs of all the wheat varieties, GS particles were distributed all over the area focused (Figs. 3–6). Thin protein (TP) film formed around the concentrated GS particles, which was contemplated by a glossy structure enfolded in a

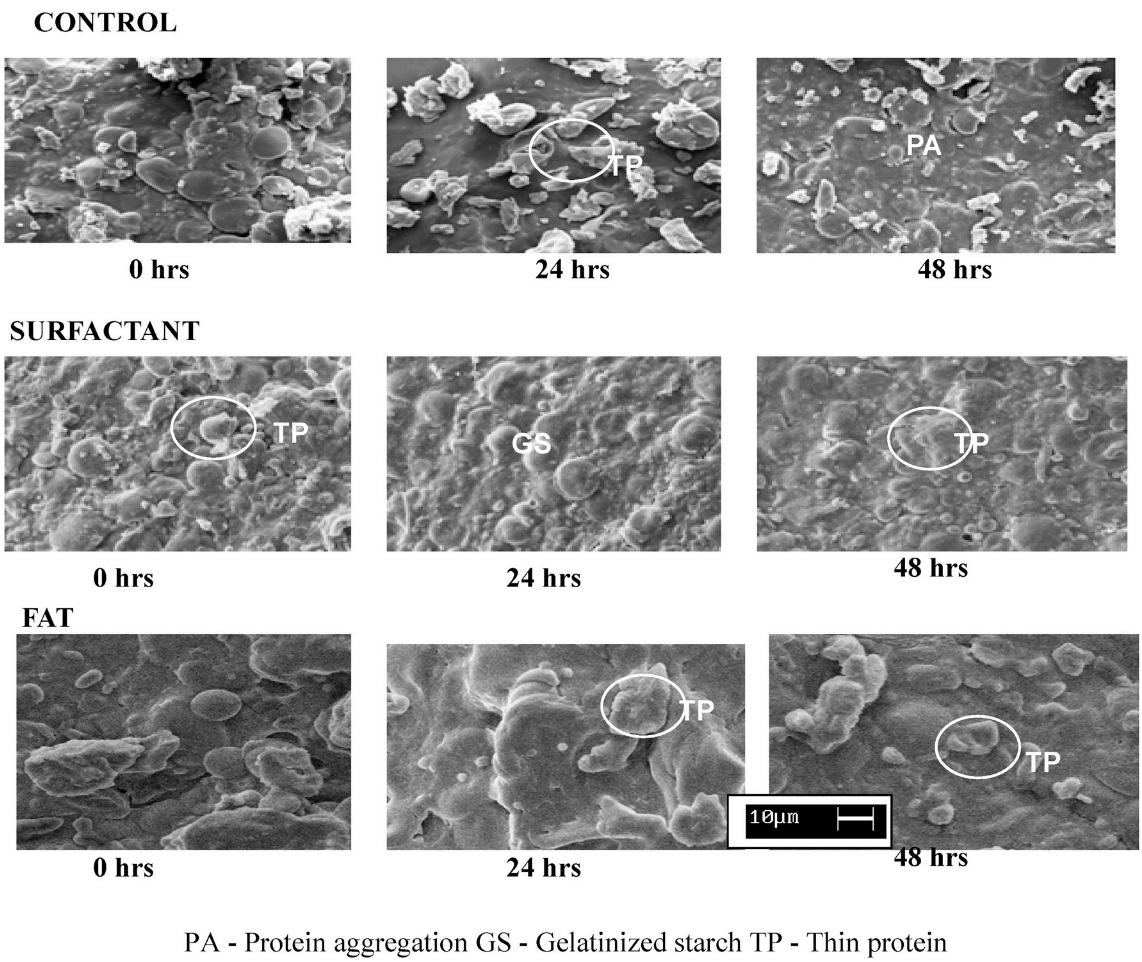

Fig. 6. Scanning Electron Micrographs of HD-2781 chapatis.

Table 2
Amylograph paste viscosity of chapatis treated with surfactant and fat.

Wheat Varieties	Hours	Maximum Paste Viscosity (BU)			Cold Paste Viscosity (BU)		
		Control	Surfactant	Fat	Control	Surfactant	Fat
GW-322	0	386	514	333	627	815	573
	24	294	508	284	539	808	483
	48	211	498	255	312	800	391
	72	139	484	202	206	780	345
	96	112	471	184	155	779	274
NI-5439	0	390	463	379	690	740	661
	24	301	431	293	530	667	497
	48	273	314	202	497	595	340
	72	242	285	187	413	473	303
	96	212	264	176	345	423	287
MACS-2496	0	232	326	137	369	471	256
	24	135	256	121	222	396	202
	48	119	188	109	194	259	119
	72	103	163	97	145	212	109
	96	85	112	81	123	185	98
HD-2781	0	332	422	206	601	757	432
	24	245	414	180	427	743	414
	48	109	403	165	229	738	362
	72	99	392	143	165	731	345
	96	82	384	134	143	726	312

[a] Data reported are as-is basis and expressed as means of two determinations.

circular shape delineating the starch granule. On storage for 24 h, there was no change observed in the microstructure. On further storage for 48 h, the microstructure showed slight difference in the matrix of protein conjugation. However, uniformity in starch structure was observed in fresh and stored GMS treated chapatis.

In the microstructure of fat treated chapatis, GS granular structure and protein network with glossy structure covered with TP around starch particles were observed (Figs. 3–6). There was slight difference in protein matrix with partial PA on storage and uniformity in starch structure was observed in fresh and stored chapatis prepared from fat treated doughs of all the wheat varieties.

3.5. Effect of surfactant and fat on amylograph characteristics of stored chapatis

Amylograph studies reveal the changes in viscosities during the complete process of gelatinization and retrogradation of starch (Zeng et al., 1997). The paste viscosities and cold paste viscosities of Control chapatis decreased on storage (Table 2) indicating the retrogradation of starch in chapati. During staling starch retrograde and form rigidity in starch granules. In confirmation with the present study, amylograph studies on bread crumb during storage showed a decrease in paste viscosity (Xu et al., 1992). The substantial binding of water on ageing causes rigidity in starch granules due to configuration of cross-linkages of starch molecules through hydrogen bonds (Redgwell et al., 2001). In the present study, paste viscosity was not significantly different on storage in treated chapatis. The decrease in paste viscosities of chapatis prepared from glycerol monostearate treated dough is around six times lesser than that of control chapatis on storage (Table 2). Surfactants are reported to delay pasting characteristics of bread (Gray and Bemiller, 2003).

The paste viscosities of fat treated chapatis were less in comparison with control and GMS treated fresh and stored chapatis. The paste viscosities of bread crumbs treated with shortenings are also known to give lower viscosities (Xu et al., 1992). The fat added do not form an inclusion complex with amylose, hence the lubricant between granules decrease. Amylose and amylopectin molecules entangle with each other and among themselves disassociating the lipids in which state lower paste viscosities are exhibited (Xu et al., 1992). However, the paste viscosities of fat treated chapatis did not decrease significantly on storage.

4. Conclusions

Staling of chapatis was controlled upon treating the doughs with additives, viz., surfactant and fat. These additives improved the overall quality attributes of chapatis. These quality enhancements are due to alterations in rheological properties of dough as well as microstructure of chapatis. As surfactant and fat are less costly and easier to handle compared to other additives like different enzymes, these compounds become more popular additives to control chapati staling.

CRediT authorship contribution statement

Hemalatha M.S.: Conceptualization, Methodology, Formal analysis, Data curation, Investigation, Writing – original draft, Visualization. **U.J.S. Prasada Rao:** Conceptualization, Validation, Resources, Writing – review & editing, Supervision, Project administration.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Dr U J S Prasada Rao reports administrative support and equipment, drugs, or supplies were provided by CSIR - Central Food Technological Research Institute. Dr U J S Prasada Rao reports a relationship with CSIR - Central Food Technological Research Institute that includes: employment, funding grants, non-financial support, and travel reimbursement.

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