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Effect of Hydrocolloid and Surfactant Agents on the Chemical and Rheological Characteristics of Egyptian Balady Bread Dough

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ABSTRACT

There are more than 40 different varieties of bread made in Egypt. However, balady bread is the most popular among these varieties. Replacing 20% of wheat flour with corn flour (recommended by the Egyptian government) to narrow the gap between production and consumption of wheat resulted in a faster rate of bread staling. The effect of tested materials (guar gum GG, carboxymethylcellulose CMC, sodium stearoyl-2-lactylate SSL, α-amylase and dry masa flour DMF) on the chemical composition, rheological properties of balady bread dough were investigated using farinography, extensography, and viscoamylography. The results indicated that dough stability and elasticity, and amylograph peak viscosity have significantly improved when hydrocolloid agents were used. The addition of guar gum improved the rheological properties greater than carboxymethylcellulose and the effect was more pronounced with increasing concentrations.

Keywords: Balady bread, chemical characteristics, Egyptian bread, hydrocolloid, rheological characteristics, wheat corn bread
Abbreviations: CF, corn flour; **CMC**, carboxymethylcellulose; **DMF**, dry masa flour; **EBB**, Egyptian Balady bread, **GG**, guar gum; **SSL**, sodium stearoyl-2-lactylate; **WF**, wheat flour

INTRODUCTION

Bread is the major component of Egyptian meals, providing up to 70% of the daily calorie intake in Egypt (Iskander *et al*. 1990). Ancient Egyptian bakers made bread and cake in many different shapes and sizes but the most popular bread was flat circular bread similar to 'Nan bread'. Egyptian Balady bread (EBB) is a simple baked product that has a simple formula and special characteristics, two of which are the high water absorption of the dough (85%) and the high baking temperature (about 500°C) for 1-2 min (Faridi and Rubenthaler 1983; Morad *et al.* 1984). EBB is normally made from 100% wheat flour (WF). Furthermore, there is a gap between production and consumption of WF in Egypt. This gap continuously increases with the fast increase of population growth. Several serious attempts have been made to narrow the gap between production and consumption of wheat in Egypt. The most important method is blending WF with 20% corn flour (CF). Noteworthy, the blended bread suffers from many technical problems like limited shelf life and rapid staling. This staling of bread is responsible for a significant financial loss to consumers and EBB producers, which means a loss in the Egyptian national economy. Thus, careful assessment of the inclusion of non-wheat cereals to EBB and its impact on overall bread quality is of importance to minimize the adverse effect of adding CF to WF. The systematic incorporation of additives into dough formula is a common practice in bread making to enhance dough by machine and overall quality of fresh bread and to maintain the quality of bread during storage. The functional effect of emulsifier, enzymes and gums as dough conditioners strengthen, crumb softeners and or anti-staling agents has been extensively investigated (Armero and Collar 1996). The rheological properties of the dough have an immediate impact on the functionality of dough and could, therefore, be used as reliable predicators of its behavior during the baking process, as well as the quality of the final product (Rasper 1993). Stress/strain measuring instruments are designed to measure the elasticity and extensibility of dough (Shuey 1975).

The main objective of this investigation was to study the effect of guar gum (GG), carboxymethylcellulose (CMC), sodium stearoyl-2-lactylate (SSL), α-amylase and dry masa flour (DMF) on the chemical composition and rheological properties of EBB dough.

MATERIALS AND METHODS

WF (82% extraction rate) and CF (97% extraction rate) were obtained from South Cairo Milling Co., Pyramids Mill, Giza, Egypt. GG (0.25, 0.50 and 0.75%) was donated by Gums Laboratory at the National Research Center, Egypt. CMC (0.25, 0.50 and 0.75%) was purchased from Sigma Co., Egypt. SSL (0.25, 0.50 and 1%) was donated from Chemtech Co., Egypt. Commercial α-amylase (2000 U/100 g) was obtained from Loba Chemie Pvt. Ltd., Mumbai, India. Corn kernels were lime cooked and transformed into DMF according to Almeida Dominguez *et al*. (1991). DMF was obtained after nixtamalization. Salt (sodium chloride) and active dry yeast (*Saccharomyces cerevisiae*) were purchased from the local market. Composite flour production, the percent flour mixtures and different additives for making EBB are presented in **Table 1**.

Analytical methods

Moisture, ash, crude protein, fat and crude fiber contents were determined according to the methods outlined in (AOAC 2000). Carbohydrates were calculated by difference as mentioned by (Tadrus 1989).

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Table 1 The percent flour mixtures and different additives for making Egyptian balady bread.*

Sample	Wheat flour (WF)	Corn flour (CF)	Masa powder flour (MPF)	Guar gum (GG)	Carboxymethylcellulose (CMC)	Sodium Stearoyl-2-lactylate (SSL)	Commercial α-amylase
Control	80	20	-	-	-	-	-
A	80	20	-	0.25	-	-	-
B	80	20	-	0.50	-	-	-
C	80	20	-	0.75	-	-	-
D	80	20	-	-	0.25	-	-
E	80	20	-	-	0.50	-	-
F	80	20	-	-	0.75	-	-
G	80	20	-	-	-	0.50	-
H	80	20	-	-	-	0.75	-
I	80	20	-	-	-	1.00	
J	80	20	-	-	-	-	-
K	80	20	-	-	-	-	50
L	80	20	-	-	-	-	100
M	80	-	20	-	-	-	150
							-

Control; Wheat flour, A; 0.25% Guar gum, B; 0.50% Guar gum, C; 0.75% Guar gum, D; 0.25% carboxymethylcellulose, E; 0.50% carboxymethylcellulose, F; 0.75% carboxymethylcellulose, G; 0.50% sodium stearoyl-2-lactylate, H; 0.75% sodium stearoyl-2-lactylate, I; 1.00% sodium stearoyl-2-lactylate, J; 50 ppm α-amylase, K; 100 ppm α-amylase, L; 100 ppm α-amylase, M; 20% wheat flour and 80% dry masa flour.

Rheological analysis

Rheological measurements were carried out with farinograph, extensograph, viscoamylograph and falling number (FN) tests according to Kent-Jones and Amos (1967), Shuey (1975), and AACC (1995).

EBB making

EBB was prepared by mixing 1000 g flour (82%) with other ingredients e.g. 5 g active dry yeast, 10 g salt, 800-850 ml water. The mixture was placed in a mixer for 25 min. The resulting dough was left to ferment for 1 hr at 30°C and 85% relative humidity. Then the dough was divided into 130-g pieces. The pieces were then arranged on a wooden board previously sprinkled with a fine layer of bran and left to ferment for 45 min at room temperature 30°C and 85% relative humidity. The fermented dough pieces were flattened to about 20 cm diameter. The flattened loaves were proofed at 30-35°C and 85% relative humidity for 15 min, then baked at 500°C for 1-2 min. Bread making was done on a semi-automatic commercial baking line located at the Faculty of Agriculture, Giza, Egypt, according to Brown (1993). The loaves were allowed to cool at ambient temperature for 2 hr before being packed in polyethylene bags and stored at room temperature for further analysis (samples were taken daily for evaluation).

Statistical analysis

Sensory data of EBB were statistically analyzed using ANOVA and determination of Least Significance Difference (L.S.D.) as outlined by McClave *et al*. (1991).

RESULTS AND DISCUSSION

Chemical composition

The flour normally used for making EBB is flour rich in protein (gluten). The results in **Table 2** indicate that WF had the highest protein content and the lowest fiber content while DMF had the highest fat content. These results are in agreement with those obtained by Mabrook (2000) and Soliman *et al*. (1990). They studied the chemical composition of WF and found that WF contained a high ratio of protein and low percent of fiber. Results also indicated that the addition of 20% CF or DMF significantly ($P < 0.01$) decreased the protein content and increased the fiber content, compared with the control (100% WF). These results are in agreement with those obtained by other groups (Mohsen *et al*. 1997; Seleem 2000; Ramadan 2006). WF was separately blended with CF or DMF at 20%. The addition of CF to WF increased fat, fiber, ash and total carbohydrates of the blend while the protein content decreased. These results are in agreement with the findings of Mohsen *et al.* (1997), Seleem (2000) and Ramadan (2006). The blends from WF and DMF had higher fat (4.49%), fiber (0.96%) and ash (1.45%) contents than the control sample.

Rheological properties of the EBB dough blend

The rheological properties of the dough have an immediate impact on the functionality of dough and could, therefore, be used as reliable predictors of its behavior during the baking process, as well as of the quality of the final product (Rasper 1993). The rheological properties of WF dough and WF-CF dough blends were evaluated by using a farinograph, an extensograph and a viscoamylograph.

1. Farinograph parameters

Water absorption and dough stability are important factors in evaluating dough rheology. Results in **Table 3** show that farinograph parameters of WF dough were affected by adding CF and that this reduction in water absorption could be attributed to the ability of wheat starch to absorb water 2.47 times more than corn starch (Whistler and Bemiller 1984). These parameters also correlated positively with the protein level: 12.31% in WF but 11.53% in the mixture. These results are in agreement with those obtained by Unver and Domolds (1976) who found a significant positive correlation between water absorption and protein content in WF dough. The results in **Table 3** indicate that the water absorption of WF and WF-CF blend increased for all treatments by adding hydrocolloids. Doughs with hydrocolloids required a relatively long mixing time to reach maximum consistency. Adding SSL to wheat bread doughs increased water absorption and dough stability. According to Chung and Tsen (1975) dough stability improves with increased SSL levels due to the interaction with the starch lipid-protein fraction. The SSL can partially prevent gluten breakdown by over mixing. Flour with amylase blends had higher water absorption and lower dough stability than the control. Armero and Collar (1996) found that incorporation of amylase into the formula induces dextrization of starch granules reducing the ability of damaged starch to immobilize water. This increases the amount of water available to interact with other components of the dough and increase dough mobility. The alkaline conditions convert the starch part of the corn into a cohesive DMF with better handling properties. In this study corn grains were lime cooked according to Almeida-Dominguez *et al.* (1991). The gelatinization process could affect the farinograph parameters of dough. GG was best among all additives. These results are in agreement with those obtained by Ahmed (1999) who found that dough stability was extended for all treatments

Table 2 Chemical constituents of wheat, corn and their blends (on dry weight basis).

Sample	Moisture (%)	Protein (%)	Fat (%)	Crude fiber (%)	Ash (%)	Total carbohydrate
A	13.99 ± 0.96a	12.31 ± 0.28a	2.44 ± 0.24c	0.77 ± 0.00 d	0.97 ± 0.05 b	69.52
B	12.44 ± 1.21ab	10.59 ± 0.01b	5.43 ± 0.35b	1.78 ± 0.01 b	1.33 ± 0.09ab	68.43
C	11.65 ± 0.29ab	11.53 ± 0.03b	4.45 ± 0.11b	0.94 ± 0.01c	1.04 ± 0.08 b	70.39
D	8.64 ± 0.12c	0.19 ± 0.13d	13.36 ± 0.11a	2.67 ± 0.06a	1.53 ± 0.01a	73.61
E	10.05 ± 0.54bc	9.88 ± 0.03b	4.49 ± 0.01b	0.96 ± 0.01c	1.45 ± 0.19a	73.17

*Total carbohydrate by difference; L.S.D. at 0.01 levels.
A; Wheat flour, B; Corn flour, C; 80% WF + 20% CF, D; Masa powder flour, E; 80% WF+ 20% MPF.

Table 3 Effect of improvements on farinogram values of wheat and corn flour dough blends at 500 BU.

Sample	Water absorption (%)	Dough development (min)	Dough stability (min)	Tolerance index (BU)	Dough weakening (BU)
Control	53.5	5.0	6.0	40	60
A	54.3	4.0	10.0	40	40
B	54.8	9.0	11.0	20	40
C	55.0	9.0	13.0	10	20
D	54.2	4	8.5	30	60
E	56	4	9	30	50
F	57	4	9	30	70
G	55.2	4	6	40	70
H	54	4	8	40	80
I	57	4	9.5	30	50
J	55.5	2	3.5	70	110
K	55	2	3.5	80	130
L	54.6	1.5	3.2	65	110
M	62.5	7.5	12	10	200

Control; Wheat flour, A; 0.25% Guar gum, B; 0.50% Guar gum, C; 0.75% Guar gum, D; 0.25% carboxymethylcellulose, E; 0.50% carboxymethylcellulose, F; 0.75% carboxymethylcellulose, G; 0.50% sodium stearoyl-2-lactylate, H; 0.75% sodium stearoyl-2-lactylate, I; 1.00% sodium stearoyl-2-lactylate, J; 50 ppm α-amylase, K; 100 ppm α-amylase, L; 100 ppm α-amylase, M; 20% wheat flour and 80% dry masa flour.

Table 4 Effect of improvements on extensograph values of wheat and corn flour dough blends.

Sample	Extensibility (mm)	Resistance to extension (BU)	Proportional No. (R/E ratio)	Extensogram area (cm^2)
Control	10.5	300	2.73	34
A	11	300	2.73	34
B	11	320	2.91	47
C	12.0	260	2.17	42
D	10.5	280	2.66	40
E	11	270	2.45	43
F	12	260	2.17	30
G	10.5	90	0.56	116
H	9.5	150	1.57	120
I	9	200	2.20	127
J	10	110	1.10	115
K	10	155	1.55	105
L	9.2	170	1.84	102.5
M	8.5	810	9.5	65

Control; Wheat flour, A; 0.25% Guar gum, B; 0.50% Guar gum, C; 0.75% Guar gum, D; 0.25% carboxymethylcellulose, E; 0.50% carboxymethylcellulose, F; 0.75% carboxymethylcellulose, G; 0.50% sodium stearoyl-2-lactylate, H; 0.75% sodium stearoyl-2-lactylate, I; 1.00% sodium stearoyl-2-lactylate, J; 50 ppm α-amylase, K; 100 ppm α-amylase, L; 100 ppm α-amylase, M; 20% wheat flour and 80% dry masa flour.

that contained GG.

2. Extensogram parameters

There were clear differences between all evaluated parameters of WF and WF-CF (**Table 4**). Extensibility, resistance to extension, proportional number, and extensogram area decreased from 11 to 10.5 mm, 420 to 300 BU, 3.81 to 2.73 and 64 to 34 cm^2, respectively. These decreases could be attributed to the effect of corn prolamin (zein) on the dough and gluten network. These results are in agreement with the findings of Seleem (2000) who found that the addition of 20% CF to WF decreased the extensibility, resistance to extension decreased from 400 to 250 BU, R/E ratio decreased from 2.80 to 2.60 and extensogram area decreased from 107.30 to 65.80 cm^2.

As shown in **Table 4** extensibility of the dough was almost constant except for samples containing 0.75% GG or CMC where it reached 12 mm. Resistance to extension, proportional number and extensogram area values decreased. The percentage decrease was higher in CMC than in GG. These data also confirmed the results obtained by Ahmed (1999) who reported that all doughs to which GG was added showed lower resistance values than the control and that the extensograph area data showed lower values for the area under the curve. Armero and Collar (1996) also used 0.3% CMC as an anti-staling agent of white/whole wheat bread. They found that this concentration decreased resistance to extension. It is generally accepted that dough with added gums are extensible but less elastic. The addition of hydrocolloids (GG or CMC) considerably increased both extensibility and energy of the dough compared with the control (80%-20%) addition of 0.75% from GG increased the extensibility from 105 for the control to 120 while the energy increased from 34 to 47 by the addition of 0.5% GG. These results are in agreement with those obtained by Ahmed (1999) and Armero and Collar (1996). Regarding the extensibility parameter the most marked impact was reported for DMF. With respect to SSL and amylase, increasing the percent of addition (1.00 and 150 ppm) induced a decrease in extensibility compared with the control.

3. Effect of additives on pasting parameters of EBB dough

The amylograph measures the changes in viscosity of a flour-water suspension as the temperature is raised at a uniform rate. The height of the amylogram peak is related to the gelatinization of starch and α-amylase activity

Table 5 Effect of improvements on viscoamylograph values of wheat and corn flour dough blends.

Sample	Heat of transition (°C)	Maximum viscosity (BU)	Temp. of maximum viscosity (°C)	Break down viscosity (BU)	Set back viscosity (BU)
Control	74	480	89	280	840
A	74	380	90.5	230	660
B	74	370	92	230	630
C	62	430	81	290	820
D	74	300	92	200	520
E	74	330	92	190	520
F	71	390	89	250	480
G	72	420	91.5	230	500
H	76.5	690	87	440	820
I	72	690	87	440	820
J	72	270	88.5	150	450
K	73.3	210	90	130	350
L	70.5	120	90	100	280
M	69	240	90	170	500

Control; Wheat flour, A; 0.25% Guar gum, B; 0.50% Guar gum, C; 0.75% Guar gum, D; 0.25% carboxymethylcellulose, E; 0.50% carboxymethylcellulose, F; 0.75% carboxymethylcellulose, G; 0.50% sodium stearoyl-2-lactylate, H; 0.75% sodium stearoyl-2-lactylate, I; 1.00% sodium stearoyl-2-lactylate, J; 50 ppm α-amylase, K; 100 ppm α-amylase, L; 100 ppm α-amylase, M; 20% wheat flour and 80% dry masa flour.

(Shuey 1975). The effect of the additives on the viscosity of the WF-CF blend is reported in **Table 5**. Addition of CF to WF increased viscosity at 50°C to 840 BU. This increase could be attributed to the retrogradation (recrystallization) phenomena by starch cooling (Larsson 1993).

Addition of CF to WF dough reduced the viscosity. This might be attributed to the starch molecular weight of CF and its solubility compared to that of wheat starch. The gelatinization temperature of wheat starch (54-62°C) is lower than that of corn starch (60-71.1°C; Colonna and Mercier 1985). Ahmed (1999) stated that corn starch granules are more rigid than wheat starch granules and require more heat energy to achieve complete swelling. Also, the decrease in viscosity at 95°C of the blend could be due to an increase in solubility of corn starch compared to wheat starch at this temperature (Whistler and Bemiller 1984). This could be attributed to the molecular weight and hence solubility of the starch, while wheat starch has a higher molecular weight and less solubility than corn starch. In all samples pasting properties increased except for temperature of maximum viscosity, which decreased. Even though maximum viscosity decreased for both GG and CMC, the decrease was more pronounced with CMC than GG. The difference in viscosity values between hot paste and paste cooled to 50°C, referred to as the set back value, reflects the retrogradation behavior of starch. A decrease in viscosity of cellulose gum solutions with temperature has been reported earlier (Glicksman 1982). CMC has a water-binding and water retention capacity which gives thick gravy with flour-water dough (Zecher and Gerrish 1999) but upon heating CMC releases bound water, thus set back remains less affected Ahmed (1999). Sidhu and Bawa (2000) used CMC at 0.1 to 0.5% to evaluate its effect on viscoamylograph parameters. They found that CMC levels significantly ($P < 0.05$) affected all the pasting characteristics except for peak viscosity and set back on cooling. There was an increase in the gelatinization temperature and pasting peak with an increase in CMC level. Viscosity after 15 min cooking at 95°C and viscosity at 50°C remained unaffected up to 0.4% CMC. Christianson *et al*. (1981) explained the effect of gums on the viscosity of wheat starch pastes. Viscosity was significantly increased by the addition of a small amount of polysaccharide gums. At the initial stage of gelatinization, gums and their inherent viscosity magnified the effect of swelling so that viscosity increases were apparent in the curves of the Brabender amylograph. The formation of soluble starch-gum associations contribute to the viscosity build up during the second stage of gelatinization. Serna-Saldivar *et al*. (1988) studied the effect of fortification of flour with SSL. They found that the addition of SSL had a marked effect on peak viscosity. A comparison of the fortified flours without SSL and flour with 0.5% SSL showed that the addition of dough conditioner increased peak viscosity, but the increase was small. SSL slightly delayed the on-set of starch gelatinization. The temperature at which starch started to gelatinize changed because conditioner, upon heating, binds strongly to the starch fraction. Results reflect the impact of adding different levels of SSL on the pasting properties. Results in **Table 5** indicate that the addition of SSL decreased the heat of transition (the temperature at which starch started to gelatinize) from 74 to 72°C, and the temperature of maximum viscosity from 89 to 87°C. Maximum viscosity increased compared with that of wheat and corn bread, which reached 690 BU at 1%. Temperature of maximum viscosity decreased by increasing the percentage SSL. The addition of α-amylase had a marked effect on all amylogram values. This effect was more pronounced by increasing the percent of α-amylase. Shuey (1975) reported that higher amylogram values indicate less amylase activity and *vice versa*. The possible explanation could be due to partial gelatinization during the preparation of DMF. It could be concluded that the process of preparing DMF induced a marked impact on the pasting properties that would lead to a possible prolonged shelf life.

Falling number

FN determination is commonly used to estimate α-amylase activity in wheat meal and flour (Finney 2001). The effect of addition of CF and the tested materials on the falling number is presented in **Table 6**. The FN of WF was 285 sec. Graybosch *et al*. (2000) found that the FN of WF was 210 sec. Addition of CF to WF decreased the FN value and falling time. Liquefication number increased by the addition of CF, implying that the addition of CF increased the amylolytic activity of the dough and consequently decreased the maximum viscosity. These results are in agreement with the findings of Seleem (2000). Adding hydrocolloids – either GG or CMC – lead to an increase in FN, flour-GG showing higher FN compared to flour-CMC; FN was 331 sec when [GG] was 0.75% Christianson *et al.* (1981) explained that when starch soluble-gum mixtures were heated, both xanthan and GG formed associations with soluble amylase strong enough to inhibit amylolytic digestion. The extent of inhibition varied with each gum. The value of FN of samples increase from 242 for the control to 304 with SSL. The obtained results indicate that FN values increased from 242 to 287, 292 and 304 sec. Chung and Tsen (1975) explained that SSL interacts during hydration with gliadin, gluten and polar lipids. When the protein denatures due to heating, most SSL binds strongly to starch. De Stefanis *et al*. (1977) stated that SSL has the ability to complex with both amylose and amylpectin. Results show that adding α-amylase exhibited an opposite trend. For all treatments containing α-amylase, FN decreased to 218 as the percentage of α-amylase increased. Similar findings were observed by Boyaci-

Table 6 Falling number, falling time and liquefaction number of wheat-corn flour dough blends with tested materials.

Sample	Falling number (FN) (Sec.)	Liquefaction number (LN)	Falling time (Sec.)
Control	242	31.25	182
A	276	26.55	216
B	385	17.91	325
C	331	21.35	271
D	244	30.93	184
E	243	31.09	183
F	278	26.32	218
G	292	24.79	232
H	304	23.62	244
I	287	25.32	277
J	244	30.93	184
K	229	33.52	169
L	218	35.71	158
M	320	22.22	260

Control; Wheat flour, A; 0.25% Guar gum, B; 0.50% Guar gum, C; 0.75% Guar gum, D; 0.25% carboxymethylcellulose, E; 0.50% carboxymethylcellulose, F; 0.75% carboxymethylcellulose, G; 0.50% sodium stearoyl-2-lactylate, H; 0.75% sodium stearoyl-2-lactylate, I; 1.00% sodium stearoyl-2-lactylate, J; 50 ppm α-amylase, K; 100 ppm α-amylase, L; 100 ppm α-amylase, M; 20% wheat flour and 80% dry masa flour.

oglu and D'Appolonia (1994), who reported that lower levels of α-amylase results in a higher FN value. Yaseen (1985) also observed that germinated wheat grains had high α-amylase activity and a lower FN value than ungerminated wheat grain. The FN values increased by increasing the level of α-amylase. This trend was observed in all samples containing hydrocolloids. Concerning DMF dough the gelatinization process for corn grains affected the value of FN. The addition of DMF into WF caused a remarkable increase in FN. This increase may be attributed to the effect of the cooking process on the amylolytic activity and consequently an increase in FN value.

CONCLUSION

Natural and synthetic materials are normally added into dough formula in bread making to enhance the overall quality and to extend the shelf life. Our results indicated that using tested hydrocolloid and surfactant agents, particularly GG, could be a promising method to reduce the extent of bread staling and extend the shelf life.

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