ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)
Food Science and Technology

DOI: https://doi.org/10.1590/fst.11619

Reporting the utilization and perspectives of different surface active agents for bread making

Nazish ARSHAD[1], Asif AHMAD[1,2,3]*, Muhammad NADEEM[4], Rai Muhammad AMIR[1], Muhammad Sajid ARSHAD[5]

Abstract

The present study was planned to use surfactants in different concentrations along with varying amounts of shortening in the form of gels to prepare breads. For that purpose, SSL, CSL, PS-60 and GMS were used at level of 0.25, 0.50, 0.75 and 1.00 parts in combination with shortening @ 4.00, 3.75, 3.50 and 3.25 parts. The dough having surfactants gels resulted in longer resistance time and overall dough stability. The moisture and protein content of breads increased which is due to interactions of surfactant gels with starch and gluten fractions that result in increasing dough strength and baking quality. Significant increase in specific volume is observed in breads of GMS and PS-60 gels. The sensory evaluation was carried out by a panel of trained judges and the breads having GMS gels ranked highest for quality attributes. The average quality scores were higher for the SSL, CSL and PS-60 as compared to the control bread. On the whole, breads having surfactants gels were acceptable for all sensory characteristics.

Keywords: breads; surfactants; rheology; chemical analysis; sensory evaluation.

Practical Application: The results of this study are helpful for baking industry to produce the products with better physiochemical and sensory properties.

1 Introduction

Bread is one of the most widely consumed food products in the world and bread making technology is possibly one of the oldest technologies known (Sawa et al., 2009). The major ingredients for bread making are flour, water, salt, fat and sugars. The most commonly used additives for improving the dough and bread quality are enzymes, oxidants, surface active agents, emulsifiers, soy flour, reductants, stabilizers, emulsifiers, supplementary enzymes e.g. α-amylases, lipases, exogenous proteases, lipoxygenases, hydrolases for non-cellulosic polysaccharides, and gums (Orthoefer, 2008). The intensifying addition of surface active agents in the bakery industry has increased to a great extent because of the advantage of more improved bread volume, improved texture, crumb, shelf-life and slicing properties of bread (Ahrné et al., 2007; Azizi & Rao, 2005; Grigoriev et al., 2006).

The term "surface active agent" collectively known as surfactants, are the substances that are most extensively used in the bread industry in the form of either monoglycerides or diglycerides since 1920s and serve as dough conditioners, crumb softeners, dough strengtheners and anti-staling agents. These functionalities are attributed to formation of complexes either with starch or proteins thus increased the strength of the gluten to hold up tightly expanded dough structure and reduce the rate of starch crystallization (Demirkesen et al., 2010).

Different types of surfactants e.g. Calcium stearoyl-2-lactylate (CSL), Sodium stearoyl-2-lactylate (SSL), Polysorbate-60 (PS-60), Glycerol monostearate (GMS) have been used in the bread making process (Asghar et al., 2007) as they exert a positive effect in bread manufacturing (Curic et al., 2008). These are also believed to improve the technological characteristics in bread by altering the multiphase food systems. These functionalities are attributed to formation of complexes either with starch or proteins thus increased the strength of the gluten to hold up tightly expanded dough structure and reduce the rate of starch crystallization (Kralova & Sjöblom, 2009).

So, keeping in view all of the above, this project was designed to study the effect of different surfactants on dough rheology and to study the effect of surfactant alone and with shortening on the physiochemical and sensory characteristics of bread.

2 Materials and methods

2.1 Wheat flour analysis

The moisture and ash contents of the flour was determined according to the procedure of American Association of Cereal Chemists (2000) method No.44-15 and 08-01, respectively while for the determination of ash content muffle furnace (Thermolyne F6058, Barnstead International, Dubuque) was used. The Kjeldhal's

Received 18 Apr., 2019
Accepted 24 June, 2019
[1] *Institute of Food and Nutritional Sciences, PMAS-Arid Agriculture University, Rawalpindi, Pakistan*
[2] *Department for Management of Science and Technology Development, Ton Duc Thang University, Ho Chi Minh City, Viet Nam*
[3] *Faculty of Applied Sciences, Ton Duc Thang University, Ho Chi Minh City, Viet Nam*
[4] *Department of Environmental Sciences, COMSATS University Islamabad, Vehari Campus, Pakistan*
[5] *Institute of Food and Home Sciences, Government College University, Faisalabad, Pakistan*
*Corresponding author: asif.ahmad@tdtu.edu.vn

method using Kjeldhal's analyzer (Hanon, K9860, China) as described in American Association of Cereal Chemists (2000) method No. 46-10 was used to determine nitrogen content in flour and crude protein percentage was calculated by multiplying the nitrogen percent with a conversion factor 5.7. The gluten content of flour was determined according to the American Association of Cereal Chemists (2000) method No. 38-10.

2.2 Preparation of treatments for bread making

Different treatments were made by using Sodium steoryl-2-lactylate (SSL), Calcium steoryl-2-lactylate (CSL), Polysorbate-60 (PS-60) and Glycerol Monosorbate (GMS) at (0.25%, 0.50%, 0.75% & 1%) as surfactants, shortenings at (4%, 3.75%, 3.50% & 3.25%) and water (4%) as shown in Table 1. All the components were then heated until desired consistency was obtained with continuous agitation followed by cooling. To make dough flour 100 g, salt 1.8 g, sugar 5 g, water adjusted according to farinograph water absorption, yeast was used for leavening, shortening and surfactants was added as mentioned above in treatment plan.

2.3 Rheological properties of dough

The samples for determination of rheological properties were run through Brabender Do-Corder farinograph (Model 2200-3, C. W. Brabender, South Hackensack NJ) according to the guidelines outlined in American Association of Cereal Chemists (2000) method No.54-21. The physical dough characteristics such as water absorption, arrival time, dough development time/peak time, departure time, dough stability, tolerance index and softening of the dough were interpreted from farinograms.

2.4 Bread preparation

Breads were made by using straight dough bread baking method No.10-09 with some modification in method as described in American Association of Cereal Chemists (2000). Bread was made on the basis of 100% flour with the addition of 1% yeast and almost 2% salt along with the addition of surfactants (.25, .50, .75 & 1%), shortenings (4, 3.75, 3.50 & 3.25%) and water (4 dose%). The surfactants and shortenings varied as per the treatments. These ingredients were weighed and mixed for 5 min in a chef mixer (Kenwood, Britain) to form dough followed by dough mixing to give the shape of a ball and put in a bowl and placed in a fermentation cabinet (National Manufacturing Company, Lincoln, USA) for fermentation at 30 °C and 75 percent R.H. for 180 min. First and second punch was made after 120 and 150 min, respectively followed by rest period of 30 min. After this the dough was moulded by hands and placed in proofing cabinet (Pentagram Equipment, Salva AR 2201, Essex, UK) for 55 min at 86 °F (30 °C) and 85% R.H. The loaves were baked for 25 min at 220 °C (425 °F) in oven (Mondial Forni, Verona, Italy) and used for further studies.

2.5 Chemical analysis of breads

Breads were analyzed for moisture contents, ash and protein contents as per their respective methods described in American Association of Cereal Chemists (2000). Ash content was determined through muffle furnace (ThermolyneF6058, Barnstead International, Dubuque). Kjeldhal's analyzer (Hanon, K9860, China) was used to determine nitrogen content in bread and crude protein percentage was calculated by multiplying the nitrogen percent with a conversion factor 5.7 while the moisture was analyzed through a convection oven.

2.6 Physical analysis of breads

Bread samples were evaluated for their volume, weight and weight to volume ratio (specific volume). The volume of the bread was measured by rape-seed displacement loaf-volume meter (Volscan profiler, VSP300, UK) as described in American Association of Cereal Chemists (2000) method No.10-09. The weight of each bread loaf was measured on digital balance (Denver Instruments, USA) at 0, 24, 48 and 72 hour's (h) intervals of storage at room temperature.

Table 1. Different treatments by use of surfactant, shortening and water for the preparation of breads.

Treatments	Surfactants	Dose Parts (surfactant)	Dose Parts (shortening)	Dose Parts (water)
$\mathbf{T_1}$	Sodium stearoyl-2-lactylate (SSL)	0.25	4.00	4
$\mathbf{T_2}$	SSL	0.50	3.75	4
$\mathbf{T_3}$	SSL	0.75	3.50	4
$\mathbf{T_4}$	SSL	1.00	3.25	4
$\mathbf{T_5}$	Calcium stearoyl-2-lactylate (CSL)	0.25	4.00	4
$\mathbf{T_6}$	CSL	0.50	3.75	4
$\mathbf{T_7}$	CSL	0.75	3.50	4
$\mathbf{T_8}$	CSL	1.00	3.25	4
$\mathbf{T_9}$	Polysorbate- 60	0.25	4.00	4
$\mathbf{T_{10}}$	PS- 60	0.50	3.75	4
$\mathbf{T_{11}}$	PS- 60	0.75	3.50	4
$\mathbf{T_{12}}$	PS- 60	1.00	3.25	4
$\mathbf{T_{13}}$	Glycerol Monosterate (GMS)	0.25	4.00	4
$\mathbf{T_{14}}$	GMS	0.50	3.75	4
$\mathbf{T_{15}}$	GMS	0.75	3.50	4
$\mathbf{T_{16}}$	GMS	1.00	3.25	4
$\mathbf{T_{17}}$	Control	0	0	0

2.7 Sensory evaluation of breads

To assess the quality of breads, the slices were cut and placed in the plastic bags while the bags were coded and presented to a panel of trained judges and evaluation was made for internal characteristics such as grain, color of crumb, aroma, taste, mastication and texture and external characteristics as volume, color of the crust, evenness of bake, character of crust and break and shred (portion of the loaf between the top and the sides that shreds somewhat during baking). The sensory evaluation was carried out for internal and external characteristics of bread on the basis of 100 points. External characteristics contributing the total score of 30 among which volume, color of crust, evenness, crust character and break and shred possessed score of 10, 8, 4, 4 and 4 respectively while internal characteristics contributed the score of 70 among which crumb grain, crumb color, aroma, taste, mastication and texture possessed score of 8, 8, 15, 20, 9 and 10 respectively. Approval for sensory experiments was taken from ethics committee of Food Technology Department (IFNS, PMAS-Arid Agriculture University).

2.8 Statistical analysis

The data obtained from above parameters was analyzed statistically by using SPSS 16 statistical package and significant differences were explained by DMRt (Steel et al., 1997).

3 Results and discussion

3.1 Wheat flour analysis

Wheat flour was analyzed for moisture, protein, ash, wet and dry gluten contents. The results showed that wheat flour contain moisture content 15.37 percent, protein content 11.37 percent, ash content 0.50 percent, wet gluten content 25.37 percent and dry gluten content 12.27 percent (Table 2). The results of the present study are in consistent with the results reported by Anjum et al. (2005) who reported variation in protein content from 9.68 to 13.45 percent among Pakistani wheat varieties. The ash content generally represents the concentration of the mineral element in a given product. The ash content is considered to be an important flour quality parameter by the milling industries throughout the world. The results for ash content are in line with the findings of Afzal (2004) who reported that Pakistani wheat varieties have been found to vary in ash content from 0.37 to 0.58 percent.

The results of gluten content of Pakistani wheat have been found in line with the findings of Pasha et al. (2007) who observed differences in dry gluten content among different wheat varieties ranging from 7-17 percent. The results are also consistent with the findings of Miralbés (2003) who found variation from 15.6 to 39.3 percent in wet gluten content of different wheat varieties.

Table 2. Proximate composition of wheat flour for the preparation of bread.

Parameters	Percentage ± S.D.
Moisture (%)	15.37 ± 0.15
Ash (%)	0.50 ± 0.01
Protein (%)	11.37 ± 0.15
Wet Gluten (%)	25.37 ± 0.15
Dry Gluten (%)	12.27 ± 0.20

S.D. = Standard Deviation.

3.2 Rheological properties of dough

The details of rheological characteristics are as under and the results are described in Table 3.

Water absorption

The water absorption is the amount of water required to reach the center of the curve on the 500 Barbender Unit (B.U) line. The water absorption is within the range of 27.16% in T_{15} (0.75%GMS+3.50% shortening+4%water) and 53.40% in T_6 (0.50% CSL+3.75% shortening+4%water. The results indicated that highest water absorption is found in T_{17} (Control) 53.40% followed by T_1 (0.25% SSL+4% shortening+4%water) 51.07% and T_2 (0.50% SSL+3.75% shortening+4%water) 50.03%.

The increase in water absorption of treatments T_1 (0.25% SSL+4% shortening+4%water), T_5 (0.25% CSL+4% shortening+4%water), T_9 (0.25% PS-60+4% shortening+4%water) and T_{13} (0.25% GMS+4% shortening+4%water) in SSL, CSL, PS-60 and GMS respectively may be due to holding of more water by the starch surfactants network that may in turn affect the physiochemical properties of the dough. This is also in line with previous research of Watson & Walker (1986) who observed that surfactants also have ability to absorb moisture from the environment. The results indicated decreasing trends in water absorption as compared to the control.. The decrease in the water absorption of treatments T_4 (1% SSL+4% shortening+4%water), T_8 (1% CSL+4% shortening+4%water), T_{12} (1% PS-60+4% shortening+4%water) and T_{16} (1% GMS+4% shortening+4%water) in SSL, CSL, PS-60 and GMS respectively may be due to increase in concentration of the surfactants gels which affect the gluten networks (Gašić et al., 2002).

Arrival time (initial development)

The results indicated that shorter arrival time 1.87 minutes is found in treatment T_8 (1% CSL+4% shortening+4%water), T_{17} (Control) and longer arrival time is found in 2.43 minutes in T_{11} (0.75% PS-60+3.50% shortening+4%water).

The presence of surfactants markedly influences the rheological properties of wheat dough including arrival time (Gómez et al., 2008). The treatment T_3 (0.75% SSL+3.50% shortening+4%water), T_8 (1% CSL+4% shortening+4%water), T_9 (0.25% PS-60+4% shortening+4%water) and T_{15} (0.75% GMS+3.50% shortening+4%water) resulted in longer arrival time in SSL, CSL, PS-60 and GMS respectively as compared to control treatment which may be due to optimum concentration of surfactants in gel formation that results in wheat dough strengthening by formation of complexes with gluten proteins. This is in the line of findings of Azizi & Rao (2005) who reported that the arrival time is increased with the addition of surfactant gels.

Table 3. Effect of surfactants and shortenings on farinographic characteristics of flours.

Treatments	Water Absorption (%)	Arrival Time (min)	Dough Development Time (min)	Dough Departure Time (min)	Dough Stability (min)	Tolerance Index (BU)	Softening of Dough (BU)
T_1	51.07 b	2.10d-g	1.23 f	6.50 i	4.40 i	92.33 c	81.00 j
T_2	50.03 c	2.00fgh	1.47abc	7.10 h	5.10 h	73.00 d	74.67 h
T_3	49.77 ef	2.27 bc	1.23 f	9.07 e	6.80 f	89.67 e	71.67 i
T_4	49.63 f	1.97 gh	1.20 fg	8.07 fg	6.10 g	66.33 fg	91.00 j
T_5	49.37 g	2.33 ab	1.57 a	6.47 i	4.13 i	50.00 l	72.00 i
T_6	48.97 h	2.33 ab	1.43 bcd	10.17 d	7.83 e	62.33 i	81.33 fg
T_7	48.00 i	2.13cef	1.23 f	10.47 d	8.33 cd	65.00 gh	79.67 g
T_8	47.40 j	2.43 a	1.25 ef	11.07 c	8.63 c	63.67 hi	74.00 h
T_9	47.43 j	2.03efg	1.10 g	8.43 f	6.10 g	72.67 e	82.67 f
T_{10}	47.30 j	2.33 ab	1.37 cde	7.97 g	5.93 g	58.33 k	103.33 c
T_{11}	47.10 k	1.87 h	1.40 cd	8.03 g	6.17 g	58.33 k	111.00 b
T_{12}	47.03 k	2.13cef	1.27 ef	8.03 g	5.90 g	60.33 j	88.67 e
T_{13}	49.97 cd	2.13cef	1.37 cde	11.83 b	9.70 b	104.67 a	81.67 f
T_{14}	49.87 de	2.20bcd	1.53 ab	12.43 a	10.23 a	90.67 d	110.33 b
T_{15}	49.83 de	2.23bcd	1.25 ef	10.17 d	7.93 de	90.33 d	122.33 a
T_{16}	49.73 ef	2.43a	1.32 def	10.17 d	8.00 de	100.33 b	92.33 d
T_{17}	53.40 a	2.17cde	1.10 g	10.07 d	7.63 e	67.33 f	82.67 f

Parameters sharing similar letter in a column are non significant ($p < 0.05$).

Dough development time/peak time

There is highly significant difference ($p < 0.05$) among treatments for dough development time. The dough development time is found to be shortest (1.10 minutes) in T_9 (0.25% PS-60+4% shortening+4%water) and T_{17} (Control) and longest (1.57 minutes) in T_5 (0.25% CSL+4% shortening+4%water).

The treatments T_4 (1% SSL+4% shortening+4%water), T_7 (0.75% CSL+3.50% shortening+4%water), T_9 (0.25% PS-60+4% shortening+4%water) and T_{15} (0.75% GMS+3.50% shortening+4%water) in SSL, CSL, PS-60 and GMS respectively resulted in decreased dough development time which may be due to their complex forming ability with the proteins fractions and this aggregation could retard the dough development time. This is also in line with previous research of Watson & Walker (1986) who reported that addition of ionic surfactants (SSL and CSL) tends to reduce the time to peak.

Departure time/dough resistance

There is highly significant difference ($p < 0.05$) among treatments for departure time. The results indicated that the departure time is lowest in T_1 (0.25% SSL+4% shortening+4%water) of 6.5 minutes and longest (12.43 minutes) in T_{14} (0.50% GMS+3.75% shortening+4%water).

The surfactants increase resistance time of dough which may due to stronger interaction with the glutens proteins and starch fractions. The results are in accordance with previous studies of Sungur & Ercan (2011) and Azizi et al. (2003) who reported that stronger flour results in long resistance time, the surfactants improve gluten structure, strengthen the flour which in turn increases the resistance time of dough.

Dough stability (tolerance)

The dough stability is interpreted as the difference in time between the point where the top of the curve first intersected the 500 B.U. line (Arrival time) and the point where the top of the curve left the 500 B.U. line (Departure time). The lowest mean values for dough stability is found in T_5 (0.25% CSL+4% shortening+4%water) which is 4.13 minutes and the highest mean values for dough stability is found in T_{14} (0.50% GMS+3.75% shortening+4%water) which is 10.23 minutes.

The treatments T_3 (0.75% SSL+3.50% shortening+4%water), T_8 (1% CSL+4% shortening+4%water), T_{11} (0.75% PS-60+3.50% shortening+4%water) and T_{14} (0.50% GMS+3.75% shortening+4%water) in SSL, CSL, PS-60 and GMS respectively resulted in increased dough stability which may be due to their complex forming ability with the gluten proteins by hydrophobic interactions of their alkyl residues with unpolar side-chains of amino acids present in gluten. The present result shows that maximum dough stability is achieved by CSL and GMS which are in line of findings of Gómez et al. (2004) who also reported that polysorbate produces same effect when used at high concentration.

Tolerance index

The maximum value for the tolerance index is found in T_{13} (0.25% GMS+4% shortening+4%water) which is 104.7 BU and minimum tolerance index is found in T_5 (0.25% CSL+4% shortening+4%water) which is 50 BU.

The present research indicates that GMS has most remarkable effect against tolerance index due to its strong ability of complexes formation with proteins fractions which promotes strengthening effect.. The trends of surfactants gels result in decreasing tolerance index which may also be affected by the shortening content. The higher levels of shortening results in gradual increase in tolerance index, indicating that tolerance to mixing decreases in the presence of shortening.

Softening of dough

Degree of softening was measured as the difference between the center of the curve at peak and center of the curve 12 minutes after the peak. The values for the softening of the dough is minimum (60.67 BU) in T_1 (0.25% SSL+4% shortening+4%water) and maximum (122.3 BU) in T_{15} (0.75% GMS+3.50% shortening+4%water). The results of present studies indicate that GMS gels T_{15} (0.75% GMS+3.50% shortening+4%water) T_{14} (0.50% GMS+3.75% shortening+4%water) reduce frequency of dough collapse as compared to the T_{17} (Control) which is in line with the findings of Ahmad et al. (2014). The surfactants form complexes with proteins fractions resulting in delaying softening of dough. The bread made from these dough results in improved texture and increase volume.

3.3 Chemical analysis of bread

Moisture content

The results for moisture content of different surfactants in combination with varying amount of shortening are shown in Table 4 which are in the range of 27.16 percent in T_{15} (0.75% GMS+3.50% shortening+4%water) and 44.83 percent in T_6 (0.50% CSL+3.75% shortening+4%water). The values indicated that highest amount of moisture content is found in T_6 (0.50% CSL+3.75% shortening+4%water) which is 44.83% followed by 44.58% in T_2 and lowest (27.16%) in T_{15} (0.75% GMS+3.50% shortening+4%water) followed by 28.36% in T_1 (0.25% SSL+4% shortening+4%water).

Table 4. Physiochemical analysis of breads prepared with the addition of different surfactants and shortenings.

Treatments	Ash (%)	Moisture (%)	Protein (%)
T_1	1.30 ef	28.36 h	13.02 abc
T_2	1.33 ef	44.58 a	13.45 ab
T_3	1.45 cdef	33.55 f	12.95 abcd
T_4	1.48 cdef	34.85 ef	12.03 cde
T_5	1.97 a	37.17 cd	11.73 ef
T_6	1.84 ab	44.83 a	12.61 bcde
T_7	1.52 cde	36.91 cd	12.61 bcde
T_8	1.70 bc	37.26 bcd	12.03 cde
T_9	1.23 f	38.02 bc	10.45 g
T_{10}	1.25 f	31.49 g	12.56 bcde
T_{11}	1.71 bc	34.50 ef	11.84 def
T_{12}	1.85 ab	36.11 de	10.87 fg
T_{13}	1.55 cde	38.93 b	12.20 cde
T_{14}	1.65 bcd	38.31 bc	12.90 abcd
T_{15}	1.99 a	34.62 ef	13.43 ab
T_{16}	1.85 ab	30.55 g	13.84 a
T_{17}	1.43 def	27.16 h	12.17 cde

Parameters sharing similar letter in a column are non significant ($p < 0.05$).

The present research shows that treatments T_2 (0.50% SSL+3.75% shortening+4%water), T_6 (0.50% CSL+3.75% shortening+4%water), T_9 (0.25% PS-60+4% shortening+4%water) and T_{13} (0.25% GMS+4% shortening+4% water) in SSL, CSL, PS-60 and GMS respectively resulted in highest moisture content as compared to the T_{17} (Control) which may be due to interaction of surfactants with amylose fractions. The increase in moisture content is formation of complexes between the surfactants and amylopectin molecules which cause reduction in granule swelling by reducing starch polymer mobility and results in less crystallization (Ahmad et al., 2014). The hydrophilic nature of the surfactants may be another reason for the increase moisture content in all the treatments as compared to the control as the surfactants complexes resulted in overall baking process may results as obstacle to the gas diffusion, lessening water vapors losses and rising the final moisture content of the loaves.

Protein content

The mean values for the protein content of different surfactants in combination with varying amount of shortening are shown in Table 4. The values for protein content are within the range of 10.45 percent in T_9 (0.25% PS-60+4% shortening+4%water) and 13.84 percent in T_{16} (1% GMS+4% shortening+4%water).

The protein content is found highest in T_2 (0.50% SSL+3.75% shortening+4% water), T_7 (0.75% CSL+3.50% shortening+4%water), T_{10} (0.50% PS-60+3.75% shortening+4%water) and T_{16} (1% GMS+4% shortening+4%water) in SSL, CSL, PS-60 and GMS respectively as compared to the control which may be due to interaction of surfactants with starch molecules resulting in decrease starch swelling during the baking process which results in less solubilization of starch molecules. As little exterior surface is expose to the gluten so weaker bonds are formed with proteins that results in the decrease staling rate. High molecular weight glutenin polymer can cause variations in baking quality and related to variation in dough strength and baking quality (Ahmad et al., 2014).

Ash content

The lowest values for the ash is found in T_9 (0.25% PS-60+4% shortening+4%water) which is 1.23% and highest in T_{15} (0.75% GMS+3.50% shortening+4%water) which is 1.99% (Table 4)

Ash is a significant chemical component for quality of flour and is an indicator of flour purity. The surfactants also show differences in their ash contents. The highest ash content is found in T_4 (1% SSL+4% shortening+4%water), T_5 (0.25% CSL+4% shortening+4%water), T_{11} (0.75% PS-60+3.50% shortening+4%water) and T_{15} (0.75% GMS+3.50% shortening+4%water) in SSL, CSL, PS-60 and GMS respectively as compared to the control treatment which may be due to chemical nature of the surfactants. The results are in line with studies of Asghar et al. (2007) who reported variation in the ash contents by the use of surfactants.

3.4 Physical analysis of bread

Specific volume

The results regarding the effect of different surfactant gels and shortenings on the specific volume of bread are presented in Table 5. The mean values for specific volume indicated that highest

Table 5. Effect of surfactants and shortenings on specific volume (volume-weight ratio) of breads.

Treatments	Volume (cm^3)	Weight (g)	Specific volume (W/V)
T_1	3143.33	417.67	7.49 fg
T_2	3252.33	411.33	7.78 cdef
T_3	3344.33	421.23	8.13 abc
T_4	3081.67	411.47	7.32 g
T_5	3417.00	408.40	8.31 ab
T_6	3199.33	408.13	7.83 cdef
T_7	3217.67	407.13	7.88 cdef
T_8	3406.00	406.37	8.37 a
T_9	3215.00	409.20	7.91 bcde
T_{10}	3077.33	405.60	7.52 efg
T_{11}	3292.00	408.60	8.12 abc
T_{12}	3206.67	412.20	7.84 cdef
T_{13}	3324.00	410.80	8.06 abcd
T_{14}	3253.33	411.30	7.93 bcde
T_{15}	3188.33	403.60	7.75 cdef
T_{16}	3062.67	411.13	7.58 efg
T_{17}	3140.67	420.30	7.64 defg

Parameters sharing similar letter in a column are non significant ($p < 0.05$).

Table 6. Effect of surfactants and shortenings on weight of breads during storage.

Treatments	Storage (hours)			
	S_4 (72)	S_3 (48)	S_2 (24)	S_1 (0)
T_1	417.67 e	413.83 g	412.60 h	412.40 h
T_2	411.33 i	407.27 rs	406.13 uvw	405.93 uvw
T_3	421.23 a	419.20 c	418.43 d	418.37 d
T_4	411.47 i	411.07 i	410.27 j	409.50 kl
T_5	408.40 nop	405.13 xyz	404.63 z	403.47 z-1
T_6	408.13 opq	404.60 z	403.53 z-1	402.50 z-5
T_7	407.13 rst	402.70 z-4	401.67 z-6	399.50 z-9
T_8	406.37 uv	399.73 z-8	399.20 z-10	398.0 z-13
T_9	409.20 lm	405.77 uvwx	404.47 z	403.13 z-3
T_{10}	405.60 vwxy	398.90 z-11	397.47 z-14	395.30 z-15
T_{11}	408.60 mno	404.87 yz	403.27 z-2	401.50 z-6
T_{12}	412.20 h	407.77 pqr	407.40 qr	405.93 uvw
T_{13}	410.80 ij	408.93 lmn	407.20 rst	405.53 wxy
T_{14}	411.30 i	410.13 jk	408.87 lmno	405.40 wxy
T_{15}	403.60 z-1	400.50 z-7	399.47 z-9	398.53 z-12
T_{16}	411.13 i	408.50 mnop	407.50 qr	406.50 tu
T_{17}	420.30 b	415.20 f	406.53 stu	400.77 z-7

Parameters sharing similar letter in a column are non significant ($p < 0.05$).

value is found in T_8 (1% CSL+4% shortening+4%water) which is 8.37 cm^3/g and lowest in T_4 (1% SSL+4% shortening+4%water) which is 7.32 cm^3/g.

The increase in the specific volume in treatments T_3 (0.75% SSL+3.50% shortening+4%water), T_8 (1% CSL+4% shortening+4%water), T_{11} (0.75% PS-60+3.50% shortening+4%water) and T_{13} (0.25% GMS+4% shortening+4%water) of SSL, CSL, PS-60 and GMS respectively as compared to the T_{17} (Control) may attributed to the fact that on high temperatures the chains of surfactants polymers which were hydrated, releases water molecules associated to them resulting in stronger interaction with the surfactants molecules. These processes help in creating a temporary network that will disintegrate during cooling. In the initial period of baking this network will give strength to the gas cells of the dough which expand during baking (Caballero et al., 2007). The results indicated that considerable improvement in the volume of bread was observed with the addition of surfactant gels. This is confirmation of previous results of Azizi & Rao (2005) who reported that at low levels surfactants had no improving effects but at moderate levels result in increased bread volume.

Weight of breads

There is significant difference ($p < 0.05$) among treatments for the weight of bread. The results for weight of bread indicated that highest value is found in T_3 (0.75% SSL+3.50% shortening+4%water) which is 419.31g and the lowest value of the treatments T_{10} (0.50% PS-60+3.75% shortening+4%water) which is 399.32 g (Table 5).

The results regarding the effect of different days on the weight of bread is presented in Table 6. There is significant difference ($p < 0.05$) among the days on the weight of bread. The values the effect of days on the weight of bread shows that 0, 24, 48 and 72 hours of storage have significant effect on weight loss. The highest value is found in S_2 (24hr) which is 407.30g and lowest at S_4 (72hr) which is 404.25g.

The gradual loss in weight during storage in surfactant added breads as compared to control may be due to complex networks of surfactants and starch which results in reduction of starch granule swelling and control swelling of granule during baking process by forming strong linkages with amylose starch granules periphery (Gelders et al., 2004). In excess of water surfactant prevent the dissolution by complexes with amylopectin molecules causing reduction in granule swelling hence reducing the mobility of starch polymer after tight linkages formation so that fewer crystallization can occur. The surfactants bound the water content so result in less evaporation as compared to the control treatments. Results are in line with findings of Tang & Copeland (2007), who reported similar results.

3.5 Sensory evaluation

The results revealed that addition of SSL, CSL, GMS and PS-60 gels improved the overall quality scores. The addition of 1 and 2 percent shortenings in the gels further significantly increased the scores. The data of sensory evaluation evidently signify that surfactant gels with the presence of shortening in gels are better performers in quality improvement of bread.

External characteristics of bread

Volume

The mean scores (Table 7) for the sensory evaluation of bread volume indicates that the Judges assigned highest scores to T_6 (0.50% CSL+3.75% shortening+4%water), T_{13} (0.25% GMS+4% shortening+4%water), T_{14} (0.50% GMS+3.75% shortening+4%water)

Table 7. Effect of surfactants and shortenings on sensory (external) characteristics of breads.

Treatments	Volume	Color of Crust	Evenness of Bake	Character of Crust	Break and Shred
T_1	4.0 d	6.0 c	2.0 d	3.0 ab	2.5 bc
T_2	5.0 c	6.0 c	3.0 bc	3.0 ab	3.0 b
T_3	5.0 c	7.0 ab	3.0 bc	3.0 ab	3.0 b
T_4	5.0 c	5.0 d	3.0 bc	3.0 ab	3.0 b
T_5	8.0 b	6.0 c	2.5 cd	2.5 bc	3.0 b
T_6	9.0 a	7.0 ab	4.0 a	3.0 ab	4.0 a
T_7	8.0 b	7.0 ab	3.0 bc	2.5 bc	3.0 b
T_8	8.0 b	6.0 c	3.0 bc	2.0 c	3.0 b
T_9	8.0 b	6.5 bc	3.0 bc	2.5 bc	3.0 b
T_{10}	8.0 b	6.0 c	3.0 bc	2.0 c	2.5 bc
T_{11}	8.0 b	6.0 c	3.5 ab	3.0 ab	3.0 b
T_{12}	8.0 b	6.0 c	3.5 ab	3.0 ab	3.0 b
T_{13}	9.0 a	7.5 a	4.0 a	3.5 a	3.0 b
T_{14}	9.0 a	7.0 ab	3.5 ab	3.0 ab	3.0 b
T_{15}	8.0 b	6.0 c	3.0 bc	3.0 ab	3.0 b
T_{16}	4.0 d	3.0 e	2.0 d	3.0 ab	2.0 c
T_{17}	4.0 d	3.0 e	2.0 d	3.5 a	2.5 bc

Parameters sharing similar letter in a column are non significant ($p < 0.05$).

and lowest to T_{16} (1% GMS+4% shortening+4%water), T_{17} (Control) and T_1 (0.25% SSL+4% shortening+4%water).

The volume scores increased by the addition of surfactants. The maximum scores for the bread volume for T_{13} (0.25% GMS+4% shortening+4%water), T_{14} (0.50% GMS+3.75% shortening+4%water), T_6 (0.50% CSL+3.75% shortening+4%water) as compared to control may be due to strong surfactant and proteins promoting aggregation of gluten proteins present in dough. A powerful protein network results in improved texture and bread volume. Another reason may be the hydrophilic nature of surfactants form lamellar liquid-crystalline phases in water, which associates with gliadin (Gelders et al., 2004). These complexes result in dough elasticity by allowing expansion of gas cells which further improves the bread volume.

Color of crust

The results for the sensory evaluation of color of crust by the panel of Judges (Table 7) indicates that maximum scores to T_{13} (0.25% GMS+4% shortening+4%water) followed by T_3 (0.75% SSL+3.50% shortening+4%water), T_6 (0.50% CSL+3.75% shortening+4%water), T_7 (0.75% CSL+3.50% shortening+4%water) and T_{14} (0.50% GMS+3.75% shortening+4%water). The lowest scores are given to T_{16} (1% GMS+4% shortening+4%water) and T_{17} (Control).

Crust color is additional significant characteristic of baked products which is considered as a baking critical index (Zheng et al., 2000). By comparing different treatments, it was found that the color scores increased by the addition of surfactants with highest scores recorded in T_{13} (0.25% GMS+4% shortening+4%water) as compared to control. Surfactants may also influence the Maillard type non-enzymatic browning reactions which will result in the brown color. The proper distribution by the surfactants may be the reason for the uniformity in the color of crust during baking. These results are in accordance with Inoue et al. (1995).

Evenness of bake

There is significant difference ($p < 0.05$) among treatments for the sensory evaluation of bread for evenness of bake. The highest score is obtained by T_{13} (0.25% GMS+4% shortening+4%water), T_6 (0.50% CSL+3.75% shortening+4% water) while the lowest scores are assigned to T_1 (0.25% SSL+4% shortening+4%water), T_{16} (1% GMS+4% shortening+4%water) and T_{17} (Control) (Table 7).

It was found that evenness of bake scores also increased by the addition of surfactants with highest scores recorded in T_{13} (0.25% GMS+4% shortening+4%water) as compared to control. The proper distribution by the surfactants may be the reason for the uniformity in the color of crust. During flour mixing water help in even distribution of the ingredients resulting in formation of continuous gluten network (Mondal & Datta, 2008). The surfactants form complexes with the starch fraction and with the proteins resulting in firm structure that helps in proper distribution of the ingredients throughout the dough matrix and result in uniformity in crumb structure. The studies of Delcour & Carl Hoseney (2009) and Pisesookbunterng et al. (1983) also showed same results.

Character of crust

The results (Table 7) indicate that highest score is assigned to T_{13} (0.25% GMS+4% shortening+4%water) and lowest to T_8 (1% CSL+4% shortening+4%water) and T_{10} (0.50% PS-60+3.75% shortening+4%water).

The evenness of bake scores also increased by the addition of surfactants with highest scores recorded in T_{13} (0.25% GMS+4% shortening+4%water) as compared to T_{17} (Control). During bread baking the crispiness develops at the last stage of baking during the setting of sponge. The ingredients play vital role for giving crispness to the final product. During baking maximum evaporation take place from the bread crust and serve as limiting factor for the expansion of the dough. After baking continuous migration from crumb to dry crust occur resulting in improved crust water content and also cause reduction in the crust crispness. Another factor for the loss of crispiness is the storage conditions as the gradient between the environment and crust provides an additional moisture gradient resulting in water absorption/ desorption from/to the environment (Goesaert et al., 2009). The surfactants by forming complexes with the starch fractions retain the water in the crumb resulting in the crumb crispiness.

Break and shred

The mean scores for break and shred by the panel of Judges as presented in Table 7 indicate that highest score is obtained T_6 (0.50% CSL+3.75% shortening+4%water) and lowest to T_{16} (1% GMS+4% shortening+4% water).

By comparing different treatments, it was found that break and shred scores also increased by the addition of surfactants as compared to T_{17} (Control). At a specific temperature the gelatinization of starch granules started which is decreased in the presence of surfactants resulting in prolonged gas retention period (Veraverbeke & Delcour, 2002). During the process of gelatinization large amounts of water is redistributed in the dough. This water loss further results in gluten proteins coagulation (Tang & Copeland, 2007) by decreasing their gas holding capacity and discharge of bound polar lipids. The latter assemble themselves as lamellar aggregates at the interfacial zone between solid/ liquid phase and gas cell. In this way they are able to plug the openings produced by the coagulated gluten proteins and then gradually take over the complete interface resulting in further prolonged oven spring and an even break and shred (Goesaert et al., 2005).

Internal characteristics of bread

Crumb grain

The maximum scores for grain crumb was achieved by the T_{13} (0.25% GMS+4% shortening+4%water) and T_{14} (0.50% GMS+3.75% shortening+4%water) and lowest to T_{17} (Control).

It was found that crumb grain scores also increased by the addition of surfactants compared to control with maximum in T_{13} (0.25% GMS+4% shortening+4%water) and T_{14} (0.50% GMS+3.75% shortening+4%water) which may be due to high loaves moisture content as inverse relationship exists between hardness and moisture content (Goesaert et al., 2005). The surfactants interfere with the interactions among the starch polymers and between the proteins and starch, which would lead softer crumb. This is confirmation of the previous results of Armero & Collar (1996) who reported that addition of especially SSL at an optimum concentration in the dough results in a lesser surface tension which will lead to the incorporation of more and smaller bubbles during mixing resulting in finer crumb structure.

Color of crumb

The mean scores (Table 8) for color of crumb by the panel of Judges indicate that maximum scores are achieved by the T_{13} (0.25% GMS+4% shortening+4%water) and T_{14} (0.50% GMS+3.75% shortening+4%water) and lowest to T_{10} (0.50% PS-60+3.75% shortening+4%water) and T_1 (0.25% SSL+4% shortening+4%water).

The color of crumb scores also increased by the addition of surfactants compared to control with maximum in T_{13} (0.25% GMS+4% shortening+4%water) T_{14} (0.50% GMS+3.75% shortening+4%water) which may be due to capability of surfactants to form complexes with starch and protein fractions that result in improved crumb grain. The surfactants change

Table 8. Effect of surfactants and shortenings on sensory (internal) characteristics of breads.

Treatments	Crumb Grain	Color of Crumb	Aroma	Taste	Mastication	Texture
T_1	4.5 f	3.5 e	9.0 fg	12.0 f	4.5 ef	4.0 gh
T_2	6.5 b	4.5 d	9.5 ef	12.0 f	5.5 cd	4.5 g
T_3	5.0 e	6.0 bc	9.5 ef	12.5 ef	6.0 bc	6.5 de
T_4	6.5 b	6.5 ab	9.0 fg	10.5 g	6.0 bc	6.0 ef
T_5	4.0 g	4.5 d	9.0 fg	12.0 f	4.5 ef	5.5 f
T_6	4.5 f	5.5 c	11.5 cd	13.5 de	6.5 b	7.0 cd
T_7	4.5 f	6.0 bc	10.5 de	12.0 f	4.5 ef	6.5 de
T_8	4.0 g	5.5 c	9.0 fg	13.5 de	4.5 ef	5.5 f
T_9	4.0 g	4.5 d	8.0 g	12.0 f	4.0 f	4.5 g
T_{10}	4.5 f	3.5 e	9.0 fg	12.0 f	4.5 ef	6.5 de
T_{11}	6.0 c	6.5 ab	12.0 bc	14.5 cd	5.0 de	7.5 c
T_{12}	6.0 c	6.0 bc	12.0 bc	15.5 bc	5.0 de	7.5 c
T_{13}	7.0 a	7.0 a	13.5 a	18.0 a	7.5 a	9.5 a
T_{14}	7.0 a	7.0 a	13.0 ab	16.5 b	8.0 a	8.5 b
T_{15}	6.5 b	6.5 ab	13.0 ab	15.0 c	6.0 bc	7.0 cd
T_{16}	5.5 d	4.0 de	5.0 h	12.0 f	4.0 f	3.5 h
T_{17}	3.5 h	4.0 de	5.0 h	11.0 fg	3.0 g	3.5 h

Parameters sharing similar letter in a column are non significant ($p < 0.05$).

bread crumb structure and construct smaller air cells and more uniformly distributed (Caballero et al., 2007) and also reducing bread crumb darkness.

Aroma

The maximum score (13.5) for aroma of breads were achieved by the T_{13} (0.25% GMS+4% shortening+4%water) and lowest to T_{16} (1% GMS+4% shortening+4%water), T_{17} (Control) which is 5 each. The aroma scores also increased by the addition of surfactants as compared to control with maximum in T_{13} (0.25% GMS+4% shortening+4%water).

The possible reason for this is that when surfactants are added in the bread results in tight gluten structure and also generate fermentable compounds mainly maltose (Ahrné et al., 2007) in the dough which help in release of volatile compounds which impart characteristic aroma to the bread. The results are in accordance with the previous studies of Azizi et al. (2003) who reported improved aroma of bread due to surfactants gels containing shortening.

Taste

The mean scores for the sensory evaluation of taste of breads by the panel of Judges as presented in Table 8 indicate that maximum score (18) is achieved by the T_{13} (0.25% GMS+4% shortening+4%water) and the lowest 10.5 to T_4 (1% SSL+4% shortening+4%water) followed by 11.5 for T_{17} (Control).

The present research showed that all treatments except control improved taste scores of the bread with maximum improvement in T_{13} (0.25% GMS+4% shortening+4%water). The crust formation and browning reactions during baking mainly contributes to bread flavor development. The Millard reaction is significant for color and aroma development in the bread crust. All these reactions are supported by surfactants for better taste in the bread. The use of surfactants gels decreases the rate of staling by forming complexes with starch and protein fractions resulting in better taste (Tester et al., 2004).

Mastication

The scores (Table 8) mastication of bread indicated that maximum score (8 points) is achieved by the T_{14} (0.50% GMS+3.75% shortening+4%water) and the lowest 3 score to T_{17} (Control).

All treatments except control improved mastication scores of the bread with maximum improvement in T_{13} (0.25% GMS+4% shortening+4%water). The fresh bread mastication depends on the type of bread, ingredients and method of production. This is also in line with previous research of Hebeda (1996) who observed that bread added with surfactants due to improved Maillard reaction results in the formation of flavor in the bread. All these reactions are supported by surfactants for better taste in the bread and give improved mastication.

Texture

The highest scores (9.5) for texture of breads were achieved by T_{13} (0.25% GMS+4% shortening+4%water) followed by 8.5 scores of T_{14} (0.50% GMS+3.75% shortening+4%water). The panelists assigned the lowest scores (3.5) to the T_{16} (1% GMS+4% shortening+4%water) and T_{17} (Control).

The present research showed that all treatments except control improved texture of the bread. The terms crumb texture and crumb grain are used interchangeably to describe the cellular structure of the crumb at a cut surface when a loaf of bread is sliced (Zúñiga & Le-Bail, 2009). The surfactants by altering swelling of granules, amylopectin crystals disordering, leaching of amylose fractions help in the production of good crumb structured product. The results are in confirmation to previous studies of Azizi et al. (2003) who reported that surfactant gels improve bread texture by complexing with the amylose fraction and prevent the leeching of the granules resulting in reduced crumb firmness and improved texture.

4 Conclusion

Keeping in view all the above results, it could be concluded that the addition of surfactants gels in breads at levels of 0.75% surfactant+3.50% shortening+4% water and 0.50% surfactants+3.75% shortening+4% water, results in favorable baked product. The results of this study are helpful for baking industry to produce the products with better physiochemical and sensory properties.

References

Afzal, B. (2004). *Effect of different improvers on the functional properties of different wheat cultivars* (M.Sc. thesis). Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan.

Ahmad, A., Arshad, N., Ahmed, Z., Bhatti, M. S., Zahoor, T., Anjum, N., Ahmad, H., & Afreen, A. (2014). Perspective of surface active agents in baking industry: an overview. *Critical Reviews in Food Science and Nutrition*, 54(2), 208-224. http://dx.doi.org/10.1080/10408398.2011.579697. PMid:24188269.

Ahrné, L., Andersson, C.-G., Floberg, P., Rosén, J., & Lingnert, H. (2007). Effect of crust temperature and water content on acrylamide formation during baking of white bread: steam and falling temperature baking. *Lebensmittel-Wissenschaft + Technologie*, 40(10), 1708-1715. http://dx.doi.org/10.1016/j.lwt.2007.01.010.

American Association of Cereal Chemists – AACC. (2000). *Approved methods of American Association of Cereal Chemists*. St. Paul: AACC.

Anjum, F. M., Ahmad, I., Butt, M. S., Sheikh, M., & Pasha, I. (2005). Amino acid composition of spring wheats and losses of lysine during chapati baking. *Journal of Food Composition and Analysis*, 18(6), 523-532. http://dx.doi.org/10.1016/j.jfca.2004.04.009.

Armero, E., & Collar, C. (1996). Antistaling additives, flour type and sourdough process effects on functionality of wheat doughs. *Journal of Food Science*, 61(2), 299-303. http://dx.doi.org/10.1111/j.1365-2621.1996.tb14180.x.

Asghar, A., Anjum, F. M., Butt, M. S., & Hussain, S. (2007). Functionality of different surfactants and ingredients in frozen dough. *Turkish Journal of Biology*, 30(4), 243-250.

Azizi, M., & Rao, G. (2005). Effect of surfactant in pasting characteristics of various starches. *Food Hydrocolloids*, 19(4), 739-743. http://dx.doi.org/10.1016/j.foodhyd.2004.08.003.

Azizi, M., Rajabzadeh, N., & Riahi, E. (2003). Effect of mono-diglyceride and lecithin on dough rheological characteristics and quality of flat bread. *Lebensmittel-Wissenschaft + Technologie*, 36(2), 189-193. http://dx.doi.org/10.1016/S0023-6438(02)00201-3.

Caballero, P., Gomez, M., & Rosell, C. (2007). Improvement of dough rheology, bread quality and bread shelf-life by enzymes combination. *Journal of Food Engineering*, 81(1), 42-53. http://dx.doi.org/10.1016/j.jfoodeng.2006.10.007.

Curic, D., Novotni, D., Skevin, D., Rosell, C. M., Collar, C., Le Bail, A., Colic-Baric, I., & Gabric, D. (2008). Design of a quality index for the objective evaluation of bread quality: application to wheat breads using selected bake off technology for bread making. *Food Research International*, 41(7), 714-719. http://dx.doi.org/10.1016/j.foodres.2008.05.006.

Delcour, J. A., & Carl Hoseney, R. (2009). *Principles of cereal science and technology*. St. Paul: AACC.

Demirkesen, I., Mert, B., Sumnu, G., & Sahin, S. (2010). Rheological properties of gluten-free bread formulations. *Journal of Food Engineering*, 96(2), 295-303. http://dx.doi.org/10.1016/j.jfoodeng.2009.08.004.

Gašić, S., Jovanović, B. Ž., & Jovanović, S. (2002). The stability of emulsions in the presence of additives. *Journal of the Serbian Chemical Society*, 67(1), 31-40. http://dx.doi.org/10.2298/JSC0201031G.

Gelders, G., Vanderstukken, T., s, H., & Delcour, J. (2004). Amylose–lipid complexation: a new fractionation method. *Carbohydrate Polymers*, 56(4), 447-458. http://dx.doi.org/10.1016/j.carbpol.2004.03.012.

Goesaert, H., Brijs, K., Veraverbeke, W., Courtin, C., Gebruers, K., & Delcour, J. (2005). Wheat flour constituents: how they impact bread quality, and how to impact their functionality. *Trends in Food Science & Technology*, 16(1-3), 12-30.

Goesaert, H., Leman, P., Bijttebier, A., & Delcour, J. A. (2009). Antifirming effects of starch degrading enzymes in bread crumb. *Journal of Agricultural and Food Chemistry*, 57(6), 2346-2355. http://dx.doi.org/10.1021/jf803058v. PMid:19239186.

Gómez, M., Del Real, S., Rosell, C. M., Ronda, F., Blanco, C. A., & Caballero, P. A. (2004). Functionality of different emulsifiers on the performance of breadmaking and wheat bread quality. *European Food Research and Technology*, 219(2), 145-150. http://dx.doi.org/10.1007/s00217-004-0937-y.

Gómez, M., Oliete, B., Pando, V., Ronda, F., & Caballero, P. A. (2008). Effect of fermentation conditions on bread staling kinetics. *European Food Research and Technology*, 226(6), 1379-1387. http://dx.doi.org/10.1007/s00217-007-0668-y.

Grigoriev, D., Leser, M., Michel, M., & Miller, R. (2006). Component separation in spread sodium stearoyl lactylate (SSL) monolayers induced by high surface pressure. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 286(1-3), 57-61. http://dx.doi.org/10.1016/j.colsurfa.2006.03.002.

Hebeda, R. (1996). *Baked goods freshness: technology, evaluation, and inhibition of staling* (Vol. 75). Boca Raton: CRC Press.

Inoue, Y., Sapirstein, H., & Bushuk, W. (1995). Studies on frozen doughs. IV. Effect of shortening systems on baking and rheological properties. *Cereal Chemistry*, 72(2), 221-226.

Kralova, I., & Sjöblom, J. (2009). Surfactants used in food industry: a review. *Journal of Dispersion Science and Technology*, 30(9), 1363-1383. http://dx.doi.org/10.1080/01932690902735561.

Miralbés, C. (2003). Prediction chemical composition and alveograph parameters on wheat by near-infrared transmittance spectroscopy. *Journal of Agricultural and Food Chemistry*, 51(21), 6335-6339. http://dx.doi.org/10.1021/jf034235g. PMid:14518964.

Mondal, A., & Datta, A. (2008). Bread baking–a review. *Journal of Food Engineering*, 86(4), 465-474.

Orthoefer, F. (2008). Applications of emulsifiers in baked foods. In G. L. Hasenhuettl & R. W. Hartel (Eds.), *Food emulsifiers and their applications* (pp. 263-284). New York: Springer. http://dx.doi.org/10.1007/978-0-387-75284-6_9.

Pasha, I., Anjum, F. M., Butt, M. S., & Sultan, J. I. (2007). Gluten quality prediction and correlation studies in spring wheats. *Journal of Food Quality*, 30(4), 438-449. http://dx.doi.org/10.1111/j.1745-4557.2007.00133.x.

Pisesookbunterng, W., D'Appolonia, B., & Kulp, K. (1983). Bread staling studies. II. The role of refreshening. *Cereal Chemistry*, 60, 301-305.

Sawa, K., Inoue, S., Lysenko, E., Edwards, N., & Preston, K. (2009). Effects of purified monoglycerides on Canadian short process and sponge and dough mixing properties, bread quality and crumb firmness during storage. *Food Chemistry*, 115(3), 884-890. http://dx.doi.org/10.1016/j.foodchem.2009.01.010.

Steel, R., Torrie, J., & Dickey, D. (1997). *Principles and procedures of statistics: a biometrical approach* (3rd ed.). New York: McGraw-Hill.

Sungur, B., & Ercan, R. (2011). Effects of some hydrocolloids and surfactant on the rheological properties of hard wheat flour dough by using response surface methodology. *GIDA: The Journal of Food*, 36, 77-82.

Tang, M. C., & Copeland, L. (2007). Investigation of starch retrogradation using atomic force microscopy. *Carbohydrate Polymers*, 70(1), 1-7.

Tester, R. F., Karkalas, J., & Qi, X. (2004). Starch composition, fine structure and architecture. *Journal of Cereal Science*, 39(2), 151-165. http://dx.doi.org/10.1016/j.jcs.2003.12.001.

Veraverbeke, W. S., & Delcour, J. A. (2002). Wheat protein composition and properties of wheat glutenin in relation to breadmaking functionality. *Critical Reviews in Food Science and Nutrition*, 42(3), 179-208. http://dx.doi.org/10.1080/10408690290825510. PMid:12058979.

Watson, K., & Walker, C. E. (1986). The effect of sucrose esters on flour-water dough mixing characteristics. *Cereal Chemistry*, 63(1), 62-64.

Zheng, H., Morgenstern, M., Campanella, O., & Larsen, N. (2000). Rheological properties of dough during mechanical dough development. *Journal of Cereal Science*, 32(3), 293-306. http://dx.doi.org/10.1006/jcrs.2000.0339.

Zúñiga, R., & Le-Bail, A. (2009). Assessment of thermal conductivity as a function of porosity in bread dough during proving. *Food and Bioproducts Processing*, 87(1), 17-22.