Journal of Food Technology 9 (5): 129-138, 2011
ISSN: 1684-8462

Effect of Different Climatic Conditions, Storage Methods and Treatment of Shell Eggs on the Foaming Qualities of Eggs for Muffin Making

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Abstract: Eggs procured in three different seasons (Winter, summer and rainy) were subjected to storage studies after treatment. During the storage studies, eggs were evaluated at regular intervals for exterior interior and functional quality for all the three seasons. Percent loss in egg weight increased significantly ($p<0.05$) with increase in storage period beyond 3rd day during all the three seasons. Air cell size increased significantly with increase in storage period beyond 3rd day in all the three seasons. The albumen index decreased during storage with maximum decline in uncoated eggs stored at room temperature. The Haugh unit values decreased during storage in all the three seasons. The yolk index decreased during storage with maximum decline in uncoated eggs stored at room temperature. Mean albumen pH increased significantly ($p<0.05$) with increase in storage period. Muffins were prepared with eggs from all the seasons at each storage interval to evaluate the functional quality of eggs during storage. For all the three seasons, the mean value for specific volume of muffins decreased during storage and maximum decline was observed for muffins prepared with uncoated eggs stored at room temperature. The mean value for scores regarding appearance, flavour, texture and overall acceptability decreased during storage with maximum decrease for muffins prepared with uncoated eggs stored at room temperature in all the three seasons.

Key words: Storage, eggs quality, climatic conditions, foaming quality, muffins, India

INTRODUCTION

Chicken eggs are a excellent source of high quality proteins and offer a balanced distribution of minerals and vitamins, particularly vitamins E, A, B_{12}, B_2 and folate (Surai and Sparks, 2001; Caner, 2005) as well as high amounts of lipids such as triacylglycerols, phospholipids and cholesterol (Watkins, 1995). Furthermore, eggs hold important functional properties such as coagulation, solidification, aeration, emulsification, coloration and texturisation (Stadelman, 1999; Hatta *et al*., 1997) meeting the requirements of a variety of food formulations which has wide application in the food industry providing many desirable attributes as a food ingredient (Hsieh and Resenstein, 1989; Chang and Chen, 2000). In bakery products, both albumen and yolk proteins of whole egg contribute to the formation and stabilization of the aerated structure (Kiosseoglou and Paraskevopoulou, 2006). The excellent foaming capacity of egg white protein and the stability of the resulting foams (even when subjected to heating) are applied in food industry in the preparation of meringues and cakes (Van der Plancken *et al*., 2007).

Freshly laid eggs have best internal quality and the rate of decline in internal quality of eggs depends upon the holding temperature and the duration of storage since, these two factors regulate the rate of carbon dioxide and moisture loss from within the eggs which is directly related with thinning of albumen. The albumen height, Haugh unit value, albumen and yolk indices of all eggs are at maximum in freshly laid eggs and decrease with storage. Various coating materials have been applied to the surface of egg shells for preserving the internal quality of eggs. polysaccharides (No *et al*., 2005; Kim *et al*., 2006; Caner and Cansiz, 2008), proteins (Cho *et al*., 2002; Xie *et al*., 2002; Rhim *et al*., 2004) and oils (Obanu and Mpieri, 1984; Waimaleongora-Ek *et al*., 2009). Research on simple techniques of egg quality preservation like oil coating and thermo stabilization under local climatic conditions needs further study. Various studies have been conducted to evaluate the functional quality of eggs (Mleko *et al*., 2010; Rossi *et al*., 2010). This study was undertaken to study the effect of different storage methods, climatic conditions and treatment on the foaming qualities of eggs in baked products.

MATERIALS AND METHODS

The eggs used for the study were procured from Punjab Agricultural University Poultry Farm. For each trial, 120 fresh eggs were used to study the effect of

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preservation and/or storage methods on quality of eggs in winter, summer and rainy seasons. The eggs laid before 8 am were not included in this study to avoid any possibility of using eggs laid in the previous evening. The eggs laid on the same day up to 5 pm were used.

Treatments: The following treatments were given taking a minimum of 5 eggs for each storage interval for trials (winter/summer/rainy seasons) at room temperature and under refrigeration and the muffins prepared:

- Control (untreated) at room temperature
- Control (untreated) at refrigerated condition
- Paraffin oil coated eggs at room temperature
- Paraffin oil coated eggs at refrigerated condition

The time for storage for the different treatments is shown in Table 1.

Control: Untreated eggs were kept at room temperature and under refrigeration conditions in a domestic refrigerator (4±1°C). Clean, un-cracked eggs were marked and kept in paper pulp egg trays.

Oil coating: Liquid paraffin of chemical grade was used during trials. The marked eggs were given a quick dip in liquid paraffin and drained. The drained eggs were weighed, placed in paper pulp egg trays and kept at room temperature and in refrigerator.

The quality of eggs was evaluated as per USDA standard procedures for egg quality and grading. At the end of each storage period, each egg was again weighed (g) to observe the loss in weight. The shape index was taken by measuring length and breadth of shell egg with the help of vernier calliper.

Egg breaking: For breaking, the egg was picked up with right hand with the large end of the egg to left. The egg was broken by striking it on the blunt edge. Placing the thumb in the cracked position of the shell and separating the egg perpendicular with a hinge like movement of the two halves of the shell. The egg was held not more than one inch from the glass of egg breaking table. The breaking glass was smooth, clear plate placed on leveled background. This type of background made it possible to detect more easily the rupture in the structural thick white.

The contents of the egg were spread out on the glass plate showing clearly the yolk in the centre surrounded immediately by thick albumen and thin albumen at the periphery. The measurements taken were as follows:

Shape index: The width and height of eggs was measured by vernier calliper and their shape index was determined by the following equation (Anderson *et al*., 2004):

$$\text{Shape index (\%)} = \frac{\text{Width (cm)}}{\text{Height (cm)}} \times 100$$

Egg weight loss: Calculated by subtracting the final weight from the initial weight and expressed as percentage:

$$\text{Egg weight loss (\%)} = \frac{\text{Initial egg weight} - \text{Final egg weight}}{\text{Initial egg weight}} \times 100$$

Weighing of eggs was done by using a 0.01 g sensitive electronic weighing balance.

Shell thickness: Shell thickness was measured with the help of shell thickness measuring gauge with 0.01 mm sensitivity. One precaution taken was that shell membrane was properly removed before measuring egg shell thickness. It was a mean value of measurements at 3 locations of the eggs (air cell, equator and sharp end).

Yolk color: Yolk color was observed by comparing with Roche color fan. It consisted of a series of 15 colored plastic tabs arranged as a fan corresponding to the range of yolk color found in eggs i.e., very pale to deep yellow (North and Bell, 1990).

Yolk height and yolk width: Height of the yolk was measured by using a three legged micrometer sensitive to 0.1 mm. The diameter of yolk was measured by using vernier calliper.

Table 1: Treatments and storage intervals of eggs for different seasons

	Storage days		
Seasons	Treatments	Ambient temperature	Refrigerated temperature (4±1°C)
Winter (December-January)	Untreated (Control)	0, 4, 8, 12, 16, 20 (WT1)	0, 7, 14, 21, 28, 35 (WT3)
	Treated (Oil-coated)	0, 6, 12, 18, 24, 30 (WT2)	0, 8, 16, 24, 32, 40 (WT4)
Summer (June-July)	Untreated (Control)	0, 3, 6, 9, 12, 15 (ST1)	0, 7, 14, 21, 28, 35 (ST3)
	Treated (Oil-coated)	0, 5, 10, 15, 20, 25 (ST2)	0, 8, 16, 24, 32, 40 (ST4)
Rainy (August-September)	Untreated (Control)	0, 3, 6, 9, 12, 15 (RT1)	0, 7, 14, 21, 28, 35 (RT3)
	Treated (Oil-coated)	0, 5, 10, 15, 20, 25 (RT2)	0, 8, 16, 24, 32, 40 (RT4)

Yolk index: It is defined as the ratio of the height to the width of the yolk. The mean width and maximum height was measured by vernier calliper and micrometer, respectively. The yolk index was calculated by the following equation (Stadelman, 1995; Lee *et al*., 1996):

$$\text{Yolk index (\%)} = \frac{\text{Height (cm)}}{\text{Mean width (cm)}} \times 100$$

Albumen height and width: Height of the albumen was measured by using a three legged micrometer sensitive to 0.1 mm. Albumen height was measured half way between yolk and edge of the inner thick albumen. The width of albumen was measured by using vernier calliper.

Albumen index: The mean width and maximum height of albumen were measured by vernier calliper and micrometer, respectively. The albumen index was calculated by the equation:

$$\text{Albumen index (\%)} = \frac{\text{Height (cm)}}{\text{Mean width (cm)}} \times 100$$

Haugh unit: Individual Haugh unit score was calculated using the egg weight and albumen height. Haugh unit values were determined using Haugh meter (B.C. Ames and Co.).

Albumen pH: Albumen was separated from yolk and pH of the albumen was measured by electronic pH meter. The pH meter calibrated at pH 7 was dipped in egg white and pH was recorded.

Air cell size: Air cell size was measured by micrometer. The broken portion was kept vertically and air cell size was measured.

Raw material used for the preparation of muffins: Commercial wheat flour for use in muffins was obtained from Luxmi Flour Mills Ltd., Ludhiana. Ground sugar, Salt (Tata), Bakery shortening (Amrit Vanaspati Ltd.,) which had melting point of 37°C was procured from local market. Commercial (Weikfield) baking powder was used as leavening agent in muffin preparation. Eggs kept for different storage intervals were used in muffin preparation. For making muffins, formula used is shown in Table 2.

Method for the preparation of muffins is shown in Fig. 1. Muffins prepared were analyzed for weight and volume from which the specific volume was calculated. The muffins were organoleptically evaluated. Sensory evaluations were conducted by a panel of semi trained judges for appearance, texture, flavor and overall acceptability using a 9 point hedonic scale (Larmond, 1977): 1-dislike extremely, 2-dislike very much, 3-dislike moderately, 4-dislike slightly, 5-neither like nor dislike, 6-like slightly, 7-like moderately, 8-like very much, 9-like extremely. The data collected on different characteristics were analyzed statistically with the help of methods of Steel *et al.* (1996). Each value is a mean of three observations.

Table 2: Formulation for the preparation of muffins

Ingredients	Quantity (g)
Flour	100
Fat	57.13
Sugar	78.58
Salt	0.50
Baking powder	2.9
SSL (Sodium Stearoyl-2-Lactylate)	0.50
Essence (Vanilla)	1 mL
Eggs	100
Water	As required (mL)

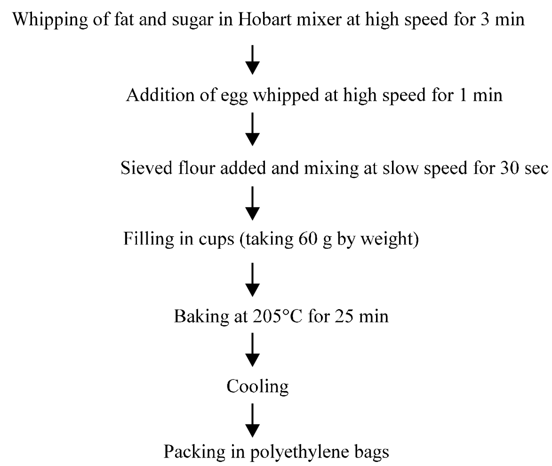

Fig. 1: Flow chart of muffin making

RESULTS AND DISCUSSION

Comparison between external qualities of eggs stored under different seasons: Eggs stored in winter and rainy season were of AA grade while eggs stored in summer season were of A grade on the basis of egg weight. Average egg weight was between 60.41-61.80 in winter, 58.67-58.85 in summer and 60.01-61.46 in rainy season, respectively. No shell abnormalities were observed during storage under different seasons (Table 3).

Effect of storage and treatments on the mean loss in weight (%) of eggs: In winter season, percent loss in egg weight increased significantly ($p<0.05$) with increase in storage period (Table 4). Maximum increase in mean percent loss in egg weight of stored eggs was observed

Table 3: Comparison between external quality eggs stored under different seasons

Treatments	Egg weight (g)	Grade	Shape index (%)	Shell abnormality
WT1	61.80	AA	72.94	Nil
WT2	61.77	AA	71.36	Nil
WT3	60.64	AA	71.89	Nil
WT4	60.41	AA	72.41	Nil
ST1	58.85	A	71.97	Nil
ST2	59.26	A	72.54	Nil
ST3	58.67	A	70.05	Nil
ST4	59.30	A	71.58	Nil
RT1	61.46	AA	72.30	Nil
RT2	61.85	AA	72.53	Nil
RT3	60.01	AA	72.32	Nil
RT4	61.09	AA	72.47	Nil

Each value is mean of five observations

Table 4: Effect of storage and treatments on the mean weight loss (%) of eggs

	Storage intervals					
Treatments	1	2	3	4	5	6
WT1	0.00	0.70	1.34	1.73	1.88	2.19
WT2	0.00	0.11	0.21	0.32	0.39	0.57
WT3	0.00	0.64	1.21	1.53	1.75	1.89
WT4	0.00	0.02	0.11	0.17	0.23	0.27
ST1	0.00	1.37	1.98	2.60	3.48	4.07
ST2	0.00	0.18	0.31	0.43	0.54	0.66
ST3	0.00	0.69	1.31	1.64	1.86	1.99
ST4	0.00	0.03	0.16	0.23	0.27	0.31
RT1	0.00	1.29	1.83	2.20	3.08	3.76
RT2	0.00	0.17	0.29	0.41	0.52	0.63
RT3	0.00	0.67	1.27	1.58	1.81	1.95
RT4	0.00	0.03	0.13	0.20	0.25	0.28

Each value is a mean of five observations; C D at 5% level of significance; Winter season: Intervals: 0.11; Treatments: 0.13; Interaction: 0.26; Summer season: Intervals: 0.14; Treatments: 0.17; Interaction: 0.33; Rainy season: Intervals: 0.09; Treatments: 0.11; Interaction: 0.22

in uncoated eggs stored at room temperature (2.19) while minimum rise in mean percent loss in egg weight was observed in coated eggs stored at refrigerated temperature (0.27).

At the end of sixth (last) storage interval, the mean percent loss in egg weight in ascending order was 0.27 in refrigerated coated eggs (40 days), 0.57 in coated eggs stored at room temperature (30 days), 1.89 in uncoated refrigerated eggs (35 days) and 2.19 in uncoated eggs stored at room temperature (20 days). These results showed that the means differ significantly ($p<0.05$) from each other.

During summer season, percent loss in egg weight increased significantly ($p<0.05$) with increase in storage period. Maximum increase in mean percent loss in egg weight of stored eggs was observed in uncoated eggs stored at room temperature (4.07) while minimum rise in mean percent loss in egg weight was observed in coated eggs stored at refrigerated temperature (0.31).

At the end of sixth (last) storage interval the mean percent loss in egg weight in ascending order was 0.31 in refrigerated coated eggs (40 days), 0.66 in coated eggs stored at room temperature (25 days), 1.99 in uncoated refrigerated eggs (35 days) and 4.07 in uncoated eggs stored at room temperature (15 days). These results showed that the mean values differ significantly ($p<0.05$) from each other.

During rainy season, percent loss in egg weight increased significantly ($p<0.05$) with increase in storage period. Maximum increase in mean percent loss in egg weight of stored eggs was observed in uncoated eggs stored at room temperature (3.76) while minimum rise in mean percent loss in egg weight was observed in coated eggs stored at refrigerated temperature (0.28).

At the end of sixth (last) storage interval the mean percent loss in egg weight in ascending order was 0.28 in refrigerated coated eggs (40 days), 0.63 in coated eggs stored at room temperature (25 days), 1.95 in uncoated refrigerated eggs (35 days) and 3.76 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

Effect of storage and treatments on the mean air cell size (cm) of eggs: In winter season, air cell size increased significantly with increase in storage period. Maximum increase in mean air cell size of stored eggs was observed in uncoated eggs stored at room temperature (1.06) while minimum rise in mean air cell size was observed in coated eggs stored at refrigerated temperature (0.69).

At the end of sixth (last) storage interval, the mean air cell size in ascending order was 0.69 in refrigerated coated eggs (40 days), 0.84 in coated eggs stored at room temperature (30 days), 1.06 in uncoated eggs stored at room temperature (20 days) and 1.21 in uncoated refrigerated eggs (35 days). These results showed that the means differ significantly ($p<0.05$) from each other (Table 5).

During summer season air cell size increased significantly ($p<0.05$) with increase in storage period. Maximum increase in mean air cell size of stored eggs was observed in uncoated eggs stored at room temperature (1.39) while minimum rise in mean air cell size was observed in coated eggs stored at refrigerated temperature (0.72).

At the end of sixth (last) storage interval the mean air cell size in ascending order was 0.72 in refrigerated coated eggs (40 days), 0.86 in coated eggs stored at room temperature (25 days), 1.19 in uncoated refrigerated eggs (35 days) and 1.29 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

During rainy season air cell size increased significantly with increase in storage period. Maximum increase in mean air cell size of stored eggs was observed

Table 5: Effect of storage and treatments on the mean air cell size (cm) of eggs

	Storage intervals					
Treatments	1	2	3	4	5	6
WT1	0.42	0.63	0.81	0.93	0.97	1.06
WT2	0.42	0.52	0.63	0.69	0.71	0.84
WT3	0.42	0.71	0.82	0.99	1.11	1.21
WT4	0.42	0.48	0.50	0.57	0.65	0.69
ST1	0.44	0.72	1.00	1.12	1.17	1.29
ST2	0.44	0.56	0.68	0.71	0.79	0.86
ST3	0.44	0.69	0.87	1.08	1.13	1.19
ST4	0.44	0.51	0.53	0.63	0.69	0.72
RT1	0.43	0.79	0.98	1.05	1.17	1.26
RT2	0.43	0.55	0.63	0.69	0.76	0.82
RT3	0.43	0.72	0.85	1.03	1.13	1.24
RT4	0.43	0.50	0.51	0.61	0.67	0.70

Each value is a mean of five observations; C D at 5% level of significance; Winter season: Intervals: 0.06; Treatments: 0.07; Interaction: 0.14; Summer season: Intervals: 0.05; Treatments: 0.06; Interaction: 0.13; Rainy season: Intervals: 0.04; Treatments: 0.05; Interaction: 0.10

Table 6: Effect of storage and treatments on the mean albumen index (%) of eggs

	Storage intervals					
Treatments	1	2	3	4	5	6
WT1	8.43	5.63	5.21	4.47	3.94	3.51
WT2	8.43	6.34	6.08	4.82	4.56	4.25
WT3	8.43	6.57	6.17	5.65	5.35	4.93
WT4	8.43	7.68	7.19	6.48	6.14	5.75
ST1	8.21	4.35	3.93	3.41	2.75	1.96
ST2	8.21	5.95	5.11	4.65	4.22	3.53
ST3	8.21	6.49	5.74	5.24	4.56	4.27
ST4	8.21	6.91	6.56	6.16	5.85	5.69
RT1	8.37	4.67	4.15	3.71	2.89	2.27
RT2	8.37	6.21	5.77	4.76	4.27	3.75
RT3	8.37	6.74	6.25	5.27	4.70	4.46
RT4	8.37	7.41	6.98	6.39	6.12	5.94

Each value is a mean of five observations; C D at 5% level of significance; Winter season: Intervals: 0.23; Treatments: 0.28; Interaction: 0.56; Summer season: Intervals: 0.30; Treatments: 0.36; Interaction: 0.73; Rainy season: Intervals: 0.25; Treatments: 0.30; Interaction: 0.61

in uncoated eggs stored at room temperature (1.26) while minimum rise in mean air cell size was observed in coated eggs stored at refrigerated temperature (0.70).

At the end of sixth (last) storage interval the mean air cell size in ascending order was 0.70 in refrigerated coated eggs (40 days), 0.82 in coated eggs stored at room temperature (25 days), 1.17 in uncoated refrigerated eggs (35 days) and 1.26 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

Effect of storage and treatments on the mean albumen index (%) of eggs: In winter season the mean albumen index of fresh eggs was 8.43. The albumen index decreased during storage with maximum decline in uncoated eggs stored at room temperature (3.51).

At the end of sixth (last) storage interval the mean albumen index in descending order was 5.75 in refrigerated coated eggs (40 days), 4.93 in uncoated refrigerated eggs (35 days), 4.25 in coated eggs stored at room temperature (30 days) and 3.51 in uncoated eggs stored at room temperature (20 days). These results showed that the means differ significantly ($p<0.05$) from each other (Table 6).

During summer season the mean albumen index of fresh eggs was 8.21. The albumen index decreased during storage with maximum decline in uncoated eggs stored at room temperature (1.96).

At the end of sixth (last) storage interval the mean albumen index in descending order was 5.69 in refrigerated coated eggs (40 days), 4.27 in uncoated refrigerated eggs (35 days), 3.53 in coated eggs stored at room temperature (25 days) and 1.96 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

During rainy season the mean albumen index of fresh eggs was 8.37. The albumen index decreased during storage with maximum decline in uncoated eggs stored at room temperature (2.27). At the end of sixth (last) storage interval the mean albumen index in descending order was 5.94 in refrigerated coated eggs (40 days), 4.46 in uncoated refrigerated eggs (35 days), 3.75 in coated eggs stored at room temperature (25 days) and 2.27 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

Effect of storage and treatments on the mean Haugh unit values of eggs: In winter season the mean Haugh unit value of fresh eggs in winter season was 83. The Haugh unit values decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (46.40).

At the end of sixth (last) storage interval the mean Haugh unit value in descending order was 68.20 in refrigerated coated eggs (40 days), 59.80 in uncoated refrigerated eggs (35 days), 55 in coated eggs stored at room temperature (30 days) and 46.40 in uncoated eggs stored at room temperature (20 days). These results showed that the means differ significantly ($p<0.05$) from each other (Table 7).

During summer season the mean Haugh unit value of fresh eggs in summer season was 79.66. The Haugh unit values decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (32).

At the end of sixth (last) storage interval the mean Haugh unit value in descending order was 65.60 in refrigerated coated eggs (40 days), 57.40 in uncoated refrigerated eggs (35 days), 51.20 in coated eggs stored at

Table 7: Effect of storage and treatments on the mean Haugh unit values ofeggs

Treatments	Storage intervals 1	2	3	4	5	6
WT1	83.00	66.40	60.40	56.20	54.00	46.40
WT2	83.00	70.20	67.40	60.80	56.60	55.00
WT3	83.00	73.60	70.60	66.60	62.80	59.80
WT4	83.00	78.00	75.20	71.80	69.80	68.20
ST1	79.66	62.40	55.80	50.40	43.82	32.38
ST2	79.66	66.34	61.17	57.00	53.80	51.20
ST3	79.66	71.60	69.40	63.80	61.40	57.40
ST4	79.66	75.58	72.60	69.60	68.60	65.60
RT1	82.46	65.21	57.95	52.11	45.20	36.10
RT2	82.46	68.29	63.97	61.13	56.20	52.30
RT3	82.46	71.98	69.80	64.78	63.20	59.60
RT4	82.46	77.33	73.60	69.60	67.80	67.00

Each value is a mean of five observations; C D at 5% level of significance; Winter season: Intervals: 1.27; Treatments: 1.55; Interaction: 3.11; Summer season: Intervals: 2.27; Treatments: 2.77; Interaction: 5.57; Rainy season: Intervals: 1.79; Treatments: 2.20; Interaction: 4.40

Table 8: Effect of storage and treatments on the mean yolk index (%) of eggs in winter season

Treatments	Storage intervals 1	2	3	4	5	6
WT1	43.34	36.26	34.89	32.06	29.78	26.12
WT2	43.34	40.68	38.18	36.33	34.14	31.87
WT3	43.34	41.32	39.64	37.59	36.48	35.03
WT4	43.34	42.80	41.65	39.82	38.47	37.80
ST1	42.60	33.51	30.13	27.47	23.29	20.35
ST2	42.60	37.13	35.79	33.65	31.22	29.74
ST3	42.60	40.46	39.32	36.91	35.33	32.43
ST4	42.60	41.96	40.21	38.07	37.12	36.76
RT1	42.73	34.47	31.41	29.23	24.68	22.19
RT2	42.73	38.12	36.41	34.97	32.04	30.72
RT3	42.73	40.71	39.11	37.14	35.95	34.39
RT4	42.73	41.92	40.58	39.17	37.70	37.42

Each value is a mean of five observations; C D at 5% level of significance; Winter season: Intervals: 0.60; Treatments: 0.73; Interaction: 1.46; Summer season: Intervals: 0.82; Treatments: 1.01; Interaction: 2.02; Rainy season: Intervals: 0.70; Treatments: 0.85; Interaction: 1.71

room temperature (25 days) and 32.38 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

During rainy season the mean Haugh unit value of fresh eggs in rainy season was 82.46. The Haugh unit values decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (36.10).

At the end of sixth (last) storage interval the mean Haugh unit value in descending order was 67 in refrigerated coated eggs (40 days), 59.60 in uncoated refrigerated eggs (35 days), 52.30 in coated eggs stored at room temperature (25 days) and 36 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

Effect of storage and treatments on the mean yolk index (%) of eggs: In winter season the mean yolk index of fresh eggs was 43.34. The yolk index decreased during storage with maximum decline in uncoated eggs stored at room temperature (26.12).

At the end of sixth (last) storage interval the mean yolk index in descending order was 37.80 in refrigerated coated eggs (40 days), 35.03 in uncoated refrigerated eggs (35 days), 31.87 in coated eggs stored at room temperature (30 days) and 26.12 in uncoated eggs stored at room temperature (20 days). These results showed that the means differ significantly ($p<0.05$) from each other (Table 8).

During summer season the mean yolk index of fresh eggs was 42.60. The yolk index decreased during storage with maximum decline in uncoated eggs stored at room temperature (20.53).

At the end of sixth (last) storage interval the mean yolk index in descending order was 36.76 in refrigerated coated eggs (40 days), 32.43 in uncoated refrigerated eggs (35 days), 29.74 in coated eggs stored at room temperature (25 days) and 20.35 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

During rainy season the mean yolk index of fresh eggs was 42.73. The yolk index decreased during storage with maximum decline in uncoated eggs stored at room temperature (22.19).

At the end of sixth (last) storage interval the mean yolk index in descending order was 37.42 in refrigerated coated eggs (40 days), 34.39 in uncoated refrigerated eggs (35 days), 30.72 in coated eggs stored at room temperature (25 days) and 22.19 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

Effect of storage and treatments on the mean albumen pH of eggs: In winter season mean albumen pH increased significantly ($p<0.05$) with increase in storage period. Maximum increase in mean albumen pH increased of stored eggs were observed in uncoated eggs stored at room temperature (9.06) while minimum rise in mean albumen pH increase was observed in coated eggs stored at refrigerated temperature (8.15).

At the end of sixth (last) storage interval the mean albumen pH increase in ascending order was 8.15 in refrigerated coated eggs (40 days), 8.27 in coated eggs stored at room temperature (30 days), 8.87 in uncoated refrigerated eggs (35 days) and 9.06 in uncoated eggs stored at room temperature (20 days). These results showed that the means differ significantly ($p<0.05$) from each other (Table 9).

Table 9: Effect of storage and treatments on the mean albumen pH of eggs

	Storage intervals					
Treatments	1	2	3	4	5	6
WT1	7.88	8.47	8.72	8.86	8.97	9.06
WT2	7.88	7.96	8.10	8.16	8.22	8.27
WT3	7.88	8.28	8.56	8.68	8.77	8.87
WT4	7.88	7.92	7.96	7.98	8.13	8.15
ST1	8.12	8.94	9.03	9.14	9.23	9.30
ST2	8.12	8.22	8.27	8.34	8.37	8.41
ST3	8.12	8.72	8.89	8.96	9.08	9.24
ST4	8.12	8.16	8.20	8.26	8.29	8.36
RT1	7.94	8.67	8.94	9.06	9.18	9.27
RT2	7.94	8.06	8.10	8.16	8.21	8.24
RT3	7.94	8.57	8.72	8.80	9.01	9.13
RT4	7.94	8.00	8.04	8.07	8.10	8.16

Each value is a mean of five observations; C D at 5% level of significance; Winter season: Intervals: 0.03; Treatments: 0.04; Interaction: 0.08; Summer season: Intervals: 0.02; Treatments: 0.02; Interaction: 0.04; Rainy season: Intervals: 0.02; Treatments: 0.02; Interaction: 0.05

Table 10: Effect of storage and treatments on the specific volume (cc g^{-1}) of muffins

	Storage intervals					
Treatments	1	2	3	4	5	6
WT1	1.84	1.74	1.72	1.64	1.51	1.41
WT2	1.84	1.77	1.74	1.67	1.56	1.47
WT3	1.84	1.81	1.76	1.68	1.60	1.54
WT4	1.84	1.83	1.78	1.72	1.68	1.63
ST1	1.84	1.62	1.53	1.45	1.40	1.33
ST2	1.84	1.68	1.62	1.56	1.47	1.39
ST3	1.84	1.74	1.70	1.63	1.56	1.48
ST4	1.84	1.79	1.74	1.66	1.62	1.59
RT1	1.83	1.65	1.58	1.52	1.46	1.35
RT2	1.83	1.71	1.67	1.59	1.50	1.41
RT3	1.83	1.75	1.72	1.66	1.57	1.50
RT4	1.83	1.82	1.76	1.69	1.65	1.60

Each value is a mean of five observations; C D at 5% level of significance; Winter season: Intervals 0.02; Treatments 0.03; Interaction 0.05; Summer season: Intervals 0.02; Treatments 0.02; Interaction 0.05; Rainy season Intervals 0.02; Treatments 0.02; Interaction 0.05

During summer season mean albumen pH increased significantly ($p<0.05$) with increase in storage period. Maximum increase in mean albumen pH of stored eggs were observed in uncoated eggs stored at room temperature (9.30) while minimum rise in mean albumen pH increase was observed in coated eggs stored at refrigerated temperature (8.36).

At the end of sixth (last) storage interval the mean albumen pH increase in ascending order was 8.36 in refrigerated coated eggs (40 days), 9.24 in uncoated refrigerated eggs (35 days), 8.41 in coated eggs stored at room temperature (25 days) and 9.30 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

During rainy season mean albumen pH increased significantly ($p<0.05$) with increase in storage period. Maximum increase in mean albumen pH of stored eggs were observed in uncoated eggs stored at room temperature (9.27) while minimum rise in mean albumen pH increase was observed in coated eggs stored at refrigerated temperature (8.16).

At the end of sixth (last) storage interval the mean albumen pH increase in ascending order was 8.16 in refrigerated coated eggs (40 days), 8.24 in coated eggs stored at room temperature (25 days), 9.13 in uncoated refrigerated eggs (35 days) and 9.27 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

Effect of storage and treatment on the quality of muffins specific volume (cc g^{-1}) of muffins: In winter season the mean value for specific volume of muffins prepared from fresh eggs was found to be 1.86 (cc g^{-1}). The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (1.41). At the end of sixth (last) storage interval the mean values for specific volume of muffins in descending order were 1.63 in refrigerated coated eggs (40 days), 1.54 in uncoated refrigerated eggs (35 days), 1.47 in coated eggs stored at room temperature (30 days) and 1.41 in uncoated eggs stored at room temperature (20 days). These results showed that the means differ significantly ($p<0.05$) from each other (Table 10).

During summer season the mean specific volume of muffins prepared from fresh eggs was found to be 1.84 (cc g^{-1}). The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (1.33). At the end of sixth (last) storage interval the mean values for specific volume of muffins in descending order were 1.59 in refrigerated coated eggs (40 days), 1.48 in uncoated refrigerated eggs (35 days), 1.39 in coated eggs stored at room temperature (25 days) and 1.33 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

During rainy season the mean specific volume of muffins prepared from fresh eggs was found to be 1.83 (cc g^{-1}). It decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (1.35). At the end of sixth (last) storage interval the mean values for specific volume of muffins in descending order were 1.60 in refrigerated coated eggs (40 days), 1.50 in uncoated refrigerated eggs (35 days), 1.41 in coated eggs stored at room temperature (25 days) and 1.35 in uncoated eggs stored at room temperature (15 days). These results showed that the means differ significantly ($p<0.05$) from each other.

Organoleptic evaluation of muffins

Appearance: In winter season the mean value of appearance scores of muffins prepared from fresh eggs

Table 11: Effect of storage and treatments on the appearance of muffins

Treatments	Storage intervals 1	2	3	4	5	6
WT1	8.58	8.25	8.08	7.92	7.67	7.50
WT2	8.58	8.33	8.17	8.08	7.83	7.67
WT3	8.58	8.42	8.33	8.08	8.00	7.75
WT4	8.58	8.42	8.33	8.25	8.17	8.00
ST1	8.50	8.08	8.00	7.83	7.50	7.42
ST2	8.50	8.17	8.00	7.92	7.67	7.50
ST3	8.50	8.25	8.17	8.00	8.00	7.67
ST4	8.50	8.25	8.25	8.17	8.00	8.00
RT1	8.50	8.17	8.00	7.83	7.58	7.50
RT2	8.50	8.25	8.08	8.00	7.75	7.58
RT3	8.50	8.33	8.25	8.00	7.92	7.67
RT4	8.50	8.33	8.25	8.25	8.08	8.00

Each value is a mean of five observations; C D at 5% level of significance; Winter season: Intervals 0.16; Treatments 0.20; Interaction NS; Summer season: Intervals 0.16; Treatments 0.20; Interaction NS; Rainy season: Intervals 0.17; Treatments 0.21; Interaction NS

was found to be 8.58. The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (7.50). No significant difference ($p<0.05$) was observed in appearance scores during the storage period (Table 11).

During summer season the mean value for appearance scores of muffins prepared from fresh eggs was found to be 8.50. The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (7.42). No significant difference ($p<0.05$) was observed in appearance scores during the storage period of eggs used.

During rainy season the mean value for appearance scores of muffins prepared from fresh eggs was found to be 8.50. The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (7.50). No significant difference ($p<0.05$) was observed in appearance scores during the storage period.

Flavour: In winter season the mean value for scores flavour scores of muffins prepared from fresh eggs was found to be 8.50. The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (7.92). No significant difference ($p<0.05$) was observed in flavour scores during the storage period (Table 12).

During summer season the mean value for flavour scores of muffins prepared from fresh eggs was found to be 8.42. The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (7.83). No significant difference ($p<0.05$) was observed in flavour scores during the storage period.

During rainy season the mean value for flavour scores of muffins prepared from fresh eggs was found to be 8.42. The same decreased during storage with maximum

Table 12: Effect of storage and treatments on the flavour of muffins

Treatments	Storage intervals 1	2	3	4	5	6
WT1	8.50	8.25	8.25	8.17	7.92	7.92
WT2	8.50	8.25	8.08	8.00	7.92	7.92
WT3	8.50	8.42	8.25	8.25	8.08	8.08
WT4	8.50	8.42	8.33	8.33	8.08	8.00
ST1	8.42	8.08	8.08	7.92	7.92	7.83
ST2	8.42	8.17	8.08	8.00	7.92	7.83
ST3	8.42	8.25	8.08	8.08	8.00	7.92
ST4	8.42	8.33	8.25	8.17	8.00	8.00
RT1	8.42	8.08	8.08	8.00	7.92	7.83
RT2	8.42	8.17	8.08	7.92	7.92	7.83
RT3	8.42	8.25	8.08	8.08	8.00	7.92
RT4	8.42	8.33	8.25	8.17	8.00	8.00

Each value is a mean of five observations; C D at 5% level of significance; Winter season: Intervals NS; Treatments 0.18; Interaction NS; Summer season: Intervals NS; Treatments 0.18; Interaction NS; Rainy season: Intervals NS; Treatments 0.18; Interaction NS

Table 13: Effect of storage and treatments on the texture of muffins

Treatments	Storage intervals 1	2	3	4	5	6
WT1	8.42	8.00	7.75	7.75	7.50	7.33
WT2	8.42	8.00	7.92	7.67	7.67	7.42
WT3	8.42	8.00	8.00	7.83	7.83	7.67
WT4	8.42	8.25	8.17	8.17	8.00	7.92
ST1	8.42	8.00	7.75	7.75	7.50	7.33
ST2	8.42	8.00	7.92	7.67	7.67	7.42
ST3	8.42	8.00	8.00	7.83	7.83	7.67
ST4	8.42	8.25	8.17	8.17	8.00	7.92
RT1	8.42	8.00	7.83	7.75	7.58	7.33
RT2	8.42	8.00	8.00	7.75	7.75	7.50
RT3	8.42	8.08	8.00	7.92	7.92	7.75
RT4	8.42	8.25	8.25	8.25	8.00	8.00

Each value is a mean of five observations; C D at 5% level of significance; Winter season: Intervals 0.20; Treatments 0.25; Interaction NS; Summer season: Intervals 0.18; Treatments 0.22; Interaction NS; Rainy season: Intervals 0.18; Treatments 0.22; Interaction NS

decline being observed in uncoated eggs stored at room temperature (7.83). No significant difference ($p<0.05$) was observed in flavour scores during the storage period.

Texture: In winter season the mean value for texture scores of muffins prepared from fresh eggs was found to be 8.42. The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (7.33). No significant difference ($p<0.05$) was observed in texture scores during the storage period (Table 13).

During summer season the mean value for texture scores of muffins prepared from fresh eggs was found to be 8.42. The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (7.33). No significant difference ($p<0.05$) was observed in texture scores during the storage period.

During rainy season the mean value for texture scores of muffins prepared from fresh eggs was found to be 8.42. The same decreased during storage with maximum decline

Table 14: Effect of storage and treatments on the overall acceptability of muffins

	Storage intervals					
Treatments	1	2	3	4	5	6
WT1	8.50	8.17	8.03	7.94	7.69	7.58
WT2	8.50	8.19	8.06	7.92	7.81	7.67
WT3	8.50	8.28	8.19	8.06	7.97	7.83
WT4	8.50	8.36	8.28	8.25	8.08	7.97
ST1	8.44	8.11	7.97	7.83	7.67	7.53
ST2	8.44	8.17	8.06	7.92	7.81	7.64
ST3	8.44	8.25	8.14	8.03	7.94	7.81
ST4	8.44	8.33	8.28	8.25	8.06	8.00
RT1	8.44	8.06	8.00	7.89	7.69	7.53
RT2	8.44	8.14	8.03	7.86	7.81	7.64
RT3	8.44	8.22	8.11	8.03	7.97	7.81
RT4	8.44	8.31	8.22	8.19	8.03	8.00

Each value is a mean of five observations; C D at 5% level of significance; Winter season: Intervals 0.11; Treatments 0.13; Interaction NS; Summer season: Intervals 0.11; Treatments 0.13; Interaction NS; Rainy season: Intervals 0.12; Treatments 0.13; Interaction NS

being observed in uncoated eggs stored at room temperature (7.33). No significant difference ($p<0.05$) was observed in texture scores during the storage period.

Overall acceptability: In winter season the mean value for overall acceptability scores of muffins prepared from fresh eggs was found to be 8.50. The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (7.58). No significant difference ($p<0.05$) was observed in overall acceptability scores during the storage period (Table 14).

During summer season the mean value for overall acceptability scores of muffins prepared from fresh eggs was found to be 8.44. The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (7.53). No significant difference ($p<0.05$) was observed in overall acceptability scores during the storage period.

During rainy season the mean value for overall acceptability scores of muffins prepared from fresh eggs was found to be 8.44. The same decreased during storage with maximum decline being observed in uncoated eggs stored at room temperature (7.53). No significant difference ($p<0.05$) was observed in overall acceptability scores during the storage period.

CONCLUSION

Significant differences ($p<0.05$) were observed in specific volume of muffins prepared from fresh eggs from those prepared from stored at the sixth (last) storage interval in all the three seasons. Maximum decrease in mean specific volume was observed in uncoated eggs stored at room temperature in summer season (1.33 cc g^{-1}) while minimum decrease was observed in coated eggs stored at refrigerated temperature in winter season (1.63 cc g^{-1}).

No significant difference ($p<0.05$) was found in appearance, flavour, texture and overall acceptability scores of muffins prepared from eggs stored under different conditions in different seasons.

As per the results of the study, it was concluded that there was drastic decline in the quality of eggs from farm level to consumer home through the marketing channel in Punjab especially, during the summer and rainy seasons. To prevent the fast rate of egg quality decline, better infrastructure is required for the handling and cold storage of eggs at all levels in the marketing chain. The marketing process should also be shortened for the faster movement of eggs from farm to consumer home.

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