DISCUSSION
6. DISCUSSION

Poultry farms especially layer farms play a significant role in providing nutrients supplement to the people. Eggs are having rich protein, minerals and vitamins. The availability of eggs to the people throughout the year is a matter of great concern. This is because of the fact that there is concentration of layer farms in a few parts of the world. At the same time, there is fluctuating trend in the production of eggs in the layer farms owing to many factors such as environment, health hazardous associated with the hens, legal and economic factors that chiefly influence the egg production. Nevertheless exporting eggs from surplus place to deficit place help to meet the demand for eggs among the people. There is certain amount of time is being consumed while transporting of eggs from one place to other place. During the transportation period, the quality of egg diminishes. Consumers are very particular on the physical as well as internal qualities of eggs during their buying process. Therefore, the egg producers or sellers have to maintain certain standards with respect to internal and external qualities of eggs.

Maintaining good internal and external qualities of eggs fetch substantial economic gains to the producers. The availability and quality of eggs throughout the year can be ensured by preserving eggs by adopting various preservative techniques.

It is essential to analyze various factors that influence the internal and external qualities of eggs and find some preservative techniques.
The present study analyzed the efficacy of different egg preservative techniques, viz., vegetable oil coating, wax coating, glycerin coating, silicon oil coating and cold storage in sanitized and unsanitized eggs of 20 week old and 60 week old hens. The changes in the quality traits such as egg weight, Haugh Units, egg breaking strength, specific gravity, shell thickness, shape index, yolk colour were analysed and changes in the chemical and microbial traits were also dealt with a period of 8 weeks duration.

6.1. Effect of vegetable oil coating on egg preservation

The coating method of the egg shell with oil was first used by Dutch farmers as early as 1807, and it was reported that coating the egg with mineral oil greatly improved the shelf-life of the eggs (Spamer, 1931).

Vegetable oils have been widely used in egg preservation, and various degrees of efficiencies have been reported (Park et al., 2003). The efficacy of oils in eggs preservation has been attributed to ability of oil in blocking the air pores of the egg shells, thereby preventing the flow of air in and out of the eggs and degradation by the contaminants. For vegetable oil mixing, oils such as rice bran oil, corn oil, coconut oil and neem oil were selected. The efficiency of preserving egg quality using rice bran oil was studied by many researchers previously. It was found that corn oil is effective in retaining moisture content of the eggs. The coconut and neem oils possess the antimicrobial substances which prevent foreign bodies to enter into the eggs. It is noteworthy to analyze the combined effect of these oils in preserving the chicken
eggs. Therefore, mixing of these oils was chosen as one of the preservative material in the ratio of 2:2:1:3.

6.1.1. Egg weight

Egg weight is an important parameter as far as the egg quality is concerned. In general, the egg weight decreases with the increasing storage time (Anderson, 2004). Eggs preserved under this preservative technique experiencing weight loss during the storage period. The change in egg weight during storage period is mostly due to the evaporation of moisture through the thousands of pores contained in egg shell surface, and it is an indicator of the deterioration of egg quality (Park et al., 2003).

The non-sanitized eggs of 20 week old hens experienced a decreasing trend in the mean egg weight among the weeks of the experiment. Similarly, the sanitized eggs of 20 week old hens also experiencing weight loss among the weeks of the experiment. The same trend was also observed in sanitized and non-sanitized eggs of 60 week old hens. The greater weight loss in sanitized egg may be due to the damage of the cuticle layer, which is another protective cover in eggshell. The cuticle acts as a layer that impedes evaporation or bacterial penetration by closing the pores in the shell (Park et al., 2013).

It was found that there was direct relationship between the storage time and loss in the mean egg weight. The similar observations were found by Samili et al (2005) that there was dramatic loss in the egg weight when eggs stored at 29°C. The egg weight dramatically decreased at room temperature. In the present study, it was observed that losses in the mean egg weight of the sample eggs that belong to 20 week
old hens were lower than the losses in the mean egg weight of eggs that belong to 60 week old hens. The same results were obtained by Ahmet (2009) that the egg weight loss was found more in older hens than the younger hens’ eggs. The freshly laid eggs contain more amount of carbon dioxide at its peak. The two shell membranes of the egg separate at the broad pole to form the air cell as eggs cool to ambient temperature. Thereafter water and CO₂ are continuously lost by evaporation through the gaseous exchange through pores of the shell. As a result, the air cell gets larger, egg weight decreases (Travel, 2011). This is the reason for the loss of weight with increasing storage period. Weight loss of vegetable oil mixture coated eggs was significantly lower than control eggs. Because vegetable oil mixture that coated on the eggs prevents the evaporation of carbon dioxide from the eggs. The reports of Olamide et al (2016) stated that egg weight loss could be reduced to certain extent for eggs coated with vegetable oil. The fatty acids found in the vegetable oil play a crucial role in preserving eggs during the storage time by covering pores of egg shell and prevent egg weight loss (Okiki and Ahmed, 2017).

6.1.2. Specific gravity

Specific gravity measures the quality of egg shell. The marketers want to have eggs with high quality shell which reduces the amount of damages during the transportation. Higher the specific gravity stronger would be the quality of egg shell (George, 1983). Specific gravity and egg shell thickness are highly positively correlated. As specific gravity goes down the number of cracks generally increase (Butcher and Miles, 2014).
The mean specific gravity values of sanitized and non-sanitized eggs of 20 week old hens decreased among the weeks of the experiment. The mean specific gravity values decreased with the increasing storage period. Maureen (1991) found that the specific gravity is related to percentage of shell and it is in turn related to the thickness of the shell. Similar observations were found in the case of sanitized and non-sanitized eggs of 60 week old hens. This is because of the fact that the water loss in the eggs due to evaporation through pores of eggs attributed to this. The shell thickness and shell weight also influenced the specific gravity of eggs. These results are in agreement with the results of Hasan (2009) who found that increasing storage of time and temperature lead to slight decrease in the specific gravity values of the sample eggs of both younger hens and older hens. The similar observation was made by Samli et al (2005) that the value of specific gravity decreased with the increasing storage time and temperature.

As far as the eggs coated with vegetable oil are concerned, the sanitized and non-sanitized eggs of both 20 week and 60 week old hens witnessed a decrease in their mean specific gravity values throughout the storage period. However, specific gravity of the vegetable oil mixture coated eggs was found to be similar to that of fresh egg. It indicates that the quality of egg shell could not be changed due to storage.

6.1.3. Shape index

The shape index is calculated based the measurement of length and width of egg. Shape index of eggs is very important in placing the eggs in the egg trays during
transportation. Any changes in the shape index leads to damage of eggs in the form of cracking and breaking of egg shell (Mohamed, 2011).

The mean shape index values of the sanitized and non-sanitized eggs of 20 week old hens decreased slightly only at the last week of the experiment and it is not a matter of great concern. There was no any change in the shape index of the sanitized and non-sanitized eggs of 60 week old hens during the eighth week storage period. These similar observations were obtained by Hasan (2009) that there were no significant changes in the shape index of the sample eggs that belong to 22 and 52 week old hens. Padhi et al (2013) observed that there were no significant changes in the shape index values among the eggs of 28 week and 72 week old hens respectively during the experiment. Similarly, Mohamed (2011) observed that there were no changes in the shape index of eggs of 68 week old hens at room temperature. From these observations, it was concluded that the shape index of the eggs of different hen age did not change at ambient temperature.

There were no changes in the shape index of the sample eggs of all types coated with vegetable oil. Slight fluctuations were found only at the last two weeks of the experiment. The vegetable oil keeps eggs from drying of shell due to changes in the weather and humidity. These results are in line with the results of Raji et al (2009). In their study they examined the effect of time and temperature on the external and internal traits of oil coated eggs during dry and hot climate and it revealed that there were no significant changes in the length, width and shape index of eggs during the 28 days of storage period. Oiling is a perfectly acceptable way to extend the shelf-life.
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6.1.4. Shell strength

Shell strength is an important factor as far as the egg quality is concerned. Higher the egg shell strength stronger would be the physical quality of eggs. Eggs with higher breaking shell have more commercial values since these eggs can be maintained without any damage during transportation and the economic losses would be minimum to the marketers.

The shell strength of fresh eggs is around 4.5 in the case of younger hens’ eggs and it is 3.5 in the case of older hens’ eggs. Regarding the egg strength of 20 week and 60 week old hens during the storage period under this study, the mean shell strength of the sample eggs decreased slightly up to eighth week of the experiment. The environmental surroundings of the eggs influence the shell strength. For example, the moisture level in the ambient air and temperature affect the shell strength. The egg strength was affected adversely by high environmental temperature (Deaton, 1981). However, the egg shell strength is not affected by the constant moisture level in the ambient air. The breaking strength is lowered by the ambient air in which there is higher level of moisture level (Lott et.al, 1981).

The mean egg strength values of sanitized and non-sanitized eggs that belong to both 20 week and 60 week old hens decreased during the eighth week storage period. The ingredients used while preparing the vegetable oil affect the shell strength. Vegetable oils of different mixtures produced different results in the case of egg shell strength during the storage period. The present study applied vegetable oils prepared from mixture of various ingredients and only single coating was done. Therefore the
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egg shell strength experienced decreasing trend in its mean values during the study period. Xie et al (2002) reported that egg coatings based on soy protein, whey isolate, or wheat protein coated carboxy methyl cellulose also improved the strength compared to uncoated eggs. However, coating solution prepared from the soy protein was used and studied by Jong (2004) and it revealed that there was no significant difference in the egg shell strength for single coated eggs from the control ones however the double-coated eggs showed a significant increase in the egg shell strength. Safavi and Javanmard (2016) analyzed the shell strength of eggs using whey protein-rice bran oil coating and observed that the shell strength of coated eggs was more than that of uncoated eggs and whey protein concentrate and 0.2 g of rice bran oil coated eggs had higher shell strength.

6.1.5 Shell thickness

As far as untreated eggs are concerned, there were no significant changes in the average values of mean shell thickness of the sample eggs of all types during the storage period and there were minimal decreases found in the sanitized and non-sanitized eggs of 60 week old hens at the end of the experiment. The similar results were observed by Hasan (2009) that there was no any change in the shell thickness in the eggs of 22 week old hens at 20° C and the egg shell thickness in the eggs of 52 week old hens slightly decreased during the storage period. There were no any visible changes in the egg shell thickness and mineral contents of the shell maintain a long term stability of egg shell thickness (Mareh, 2017).
The sanitized and non-sanitized eggs of 20 week old hens coated with vegetable oil did not experience any losses in the average mean shell thickness. However, the 60 week old hens’ eggs experienced slight decrease in the average mean shell thickness at the end of the experiment. The similar results were observed by Juliet (2004) that the shell quality decreases with increasing age of the hens. The vegetable oil keeps the surfaces of the egg shell from the damage and deterioration caused by the environment. However, many factors are responsible for egg shell quality including health problems, management practices of the layer farms, environmental conditions, breeding and adequacy of nutrition (The Poultry Site, 2008).

6.1.6. Yolk colour

As far as the unsanitized eggs of 20 week old hens are concerned, more number of sample eggs had medium yellow yolk colour and some eggs had pale yellow yolk in the control group. As far as the vegetable oil coated sample eggs are concerned, a substantial number of the sample eggs coated with vegetable oil had medium yellow yolks and only a few sample eggs had pale yellow yolks. During the initial weeks of the experiment, it was observed that more than fifty per cent of the sample eggs had golden yellow yolks and a vast majority of the sample eggs had medium yolk at the later weeks of the experiment. No eggs had dark yolk during the storage period. In contrast, Suresh et al (2015) analyzed that there was no significant differences in the yolk colour of chitosan coated and control eggs.
In the case of unsanitized eggs of 60 week old hens, majority of the sample eggs had pale yellow and medium yellow yolks in the control group. Regarding the eggs coated with vegetable oil, medium yellow and golden yellow yolks were found among the more sample eggs and dark yellow yolks were also observed in few sample eggs during the entire storage period. All categories of yolks were observed.

Under the sanitized eggs of 20 week old hens, the sample eggs under control group witnessed pale yellow, medium yellow and golden yellow yolks during the storage period. The yolk colour slightly moved from pale yellow to golden yellow from the initial weeks to the last weeks of the experiment during the storage period. More than fifty per cent of the sample eggs coated with vegetable oil had medium yellow yolks and pale yellow yolks were found in the more number of sample eggs at the end of the experiment. Only a few sample eggs had golden yellow yolks and none of the eggs had dark yellow yolks.

The sanitized eggs of 60 week old hens under control group, witnessed more number of pale yellow and media yellow yolks. In contrast to this result, Feddern et al (2017) found that there was no any significant difference in the yolk colour of the sample eggs which were stored at room temperature. In the case of vegetable oil coated eggs, the pale yellow yolks of the sample eggs turned into medium and golden yellow colour during the first half of the storage period and again they turned into medium and pale yellow during the later weeks of the experiment.
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6.1.7. Haugh unit

The egg quality decreases when there is a decrease in the Haugh unit (Ana et al., 2004). Haugh unit values differ from egg to egg depending upon age of the birds, storage periods and method of preservation. A Haugh unit of 60 is desirable for commercial purpose (Jacqueline et al., 2011). Further, stated that the albumin quality can be kept good by dipping the eggs into oil within 24 hours of lay.

In general, the Haugh unit values were found to be lower in old aged hens than younger hens. The eggs under control group stored at ambient room temperature were found that there had been continuous losses in Haugh unit values during the storage period. The Haugh unit values of the non-sanitized sample eggs that belong to 20 week old hens under control group decreased with the increasing storage time. Similarly the Haugh unit values of sanitized eggs that belong to 20 week old hens stored at ambient temperature also witnessed a decreasing trend during the storage period. It was found that the Haugh unit values decreased with the increasing storage period irrespective of sanitization. The quality of the sanitized and non-sanitized sample eggs of 20 week old hens in terms of Haugh unit deteriorated during the storage period up to eighth week at room temperature.

These results were supported by the results of the study made by Hosseini et al. (2007) that the Haugh unit values decreased at higher temperature and the albumin height was lower in 68 week old hens and higher in 28 week old hens. These results were in accordance with the results of Ishan (2015) that eggs of 35 week old hens kept at high temperature (25 to 30 °C) were deteriorated very fast and these eggs were not
fit for consumption after two weeks and this study suggested that eggs should not be stored for more than one week in the ambient temperature of 25 to 30 °C otherwise eggs turned into unfit for consumption. Similar study carried out by Olugbenga (2015) observed the effect of room temperature on quality of 36 week old hens’ eggs and concluded that the quality of eggs decreased when they were stored at room temperature. The quality of eggs deteriorated before seventh day of storage at room temperature in the hot humid tropics.

Regarding the non-sanitized sample eggs that belong to 60 week old hens stored at room temperature, there were losses in the Haugh unit values among the weeks of the experiment. The qualities of the sample eggs in terms of Haugh unit deteriorated from the first week to last week of the experiment. This is in line with the study undertaken by Sheikh (2016) in the 48 week old hens and 63 week old hens and revealed that the Haugh unit values decreased significantly with increasing storage period. The study also revealed that the fresh eggs had Haugh unit values of 76.37 and it significantly decreased to 24.25 at 28th day of storage period.

The sanitized eggs that belong to 60 week old hens stored at ambient temperature experienced losses in the Haugh unit values among the weeks of the experiment. The qualities of the sample eggs under this group were found to be “fair” except for the Haugh unit values for eggs in the first two weeks. Eke et al (2013) observed the effect of storage conditions on egg quality revealed that during storage period the loss of CO₂ from the egg white and the change in the pH owing to alkaline state caused the mucin fibers which give egg white its gel structure to lose strength
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and albumen became watery which resulted in loss in Haugh units. Yeasmin (2014) concluded that the Haugh unit values of fresh eggs declined significantly with the increasing storage time. On account of decrease in the thick albumen height, there was decrease in the Haugh unit. This is because of the fact that during storage the ovomucin–lysozyme complex breaks down which helps to increase the pH of eggs. Eggs stored at hot temperature promote the breakdown of ovomucin—lysozyme complex. As a result Haugh unit of eggs stored at room temperature reduce significantly (Alsobayel and Albadry, 2011).

Eggs that belong to 20 week old hens without sanitized and coated with vegetable oil experienced losses in the Haugh unit values among the weeks of the experiment. Though there had been losses in the Haugh unit values, the quality of eggs were maintained under “good” grade since their Haugh unit values were found to be more than 60 except last week of the experiment. The sanitized eggs that belong to 20 week old hens coated with vegetable oil also experienced losses in the Haugh unit values from the initial experiment to the last week of the experiment. The qualities of these eggs were found to be under “excellent” grade up to third week of storage and the eggs during the last three weeks come under “fair’ grade.

These results are in agreement with the results of Safavi and Javanmard, (2016) that there had been a decreasing trend in the Haugh unit values over the four week of storage period both in control and in oil treated sample eggs. Eggs coated with rice bran oil incorporated with Zataria multiflora had significantly higher amount of
Haugh unit than the control eggs. The mixing of rice bran oil coating significantly increased the Haugh units in these egg.

The Haugh unit values of the non-sanitized sample eggs that belong to 60 week old hens decreased among the weeks of the experiment. All the sample eggs under this group come under “fair” quality except fresh eggs. The qualities of eggs deteriorated due to losses in the Haugh units. Imai (1981) observed the effect of starch-vegetable oil coated eggs that belong to 58 to 60 grams on interior qualities of the eggs. It was found that the Haugh unit values were higher in the eggs stored at 3^oC temperature up to four months storage period and the Haugh unit values were found to be lower in the eggs that were stored at room temperature up to two weeks.

In the case of sanitized eggs that belong to 60 week old hens, a decreasing trend accompanied by slight volatility in the values of Haugh unit values were experienced among the weeks. However, no eggs were found under poor quality. Okki and Ahmed, (2017) in their study revealed that the vegetable oil coated eggs produced excellent results in keeping Haugh unit values in old laying hens’ eggs irrespective of sanitation. Based on Haugh unit values, eggs coated with soybean oil gave significantly superior quality.

6.1.8. Microbial analysis

The spoilage of eggs during storage is mainly caused by microorganisms. The occurrence of microorganisms depends on the surrounding environments, the state of handling, the conditions of storage and washing state (Gentry and Quarles, 1972; Goard and Fulter, 1994). These microorganism approach the eggs from the
environment in which the eggs are placed. The microorganisms easily invaded into eggs when there is higher temperature prevail in the environment. Salmonella is a serious microorganism which contaminated the egg (Baker and Bruce, 1994). *Salmonella enteritidis* associated with eggs and egg dishes has caused serious illness. It was shown that this organism better grow and multiply in eggs stored at 13°C but not in those stored at 7°C.

Ait (2004) found that food poisoning bacteria grow best at 37°C however, they still multiply at other temperatures. The bacteria are killed both at higher and lower temperature. The second type of microbial contamination is spoilage, which can be caused bacteria, yeast, fungi or moulds. The sources such as skin surface, feet and fecal matter are the sources of contaminations outside the animals. With regard to the unsanitized eggs of 20 week old hens, the eggs under control group exposed to minimum level of microbes at the fourth week and it was observed that there were uncountable colonies of these microbes at the eighth week. These results were supported by Pereira *et al* (2014) that the temperature influenced the egg quality and found that salmonella were found in eggs stored at 28°C.

In the present study, no microbial contamination was found in the sample eggs coated with vegetable oil at 4th week. These results are agreed with the results of Eke *et al* (2013) that the oil which was coated on the eggs prevents fast drying of cuticle and the pores’ size retained in its original forms and all these protect the invasion of microorganisms into egg. However, these eggs were exposed to six colonies of microbes during 8th week.
Under unsanitized eggs of 60 week old hens, eggs were found with less contamination initially and more than ten colonies invaded into these eggs during the later weeks in the storage period. This observation was similar with the observation made by Olamide et al., (2016) that the number of plates with bacterial colonies was not reduced in the eggs coated by coconut oil and palm oil.

In the case of sanitized eggs of 20 week old hens, the eggs were free of microbial contamination during the initial weeks of the storage period. The rice bran oil in the vegetable oil acted against microbial load on surface of eggs and therefore these eggs were free from such microbial contamination. The same observation was derived by Safavi and Javanmard (2016) that adding rice bran oil containing Zataria multiflora to whey protein concentration act as powerful against microbial load on egg surface. But, these eggs were found with the minimum microbial contamination at the later weeks of the experiment. The large number of pores within the shell can transfer microorganisms across the shell into interior part of the egg (Wang and Slavik, 1998).

Regarding the sanitized eggs of 60 week old hens, the invasion of microbes were found both at fourth and eighth week experiment and the number of colonies were lesser at the fourth week than at the eighth week. These observations were similar with the study carried out by Park et al (2003). They observed that the washing, sanitizing and coating process blocked the growth of the microorganisms in eggs.
6.1.9. Protein content

The protein content in the unsanitized eggs of 20 week old hens coated with vegetable oil slightly decreased. This decrease was not significant one. In the case of unsanitized eggs of 60 week old hens, there was no any notable change in the mean value of protein content from fourth week to eighth week. Regarding the unsanitized eggs of 20 week old hens, below one per cent hike in the protein content in the sample eggs coated with vegetable oils was observed and this variation was not a considerable one. The unsanitized eggs of 60 week old hens revealed that no considerable change was found in the protein content of the vegetable oil coated sample eggs during the eighth week storage period. In contrast to this result, Okki and Ahmed (2017) observed that protein concentration in the eggs coated with vegetable oil and control decline with duration of storage however the protein concentration was higher in vegetable oil than eggs under control group.

6.1.10. Cholesterol content

The quality deterioration in eggs is not only due to microbial invasion but due to the biochemical reaction with the egg. The cholesterol content of egg is very significant from the nutritional point of view. The unsanitized eggs of 20 week old hens showed that the mean cholesterol value of the vegetable oil coated eggs slightly increased during the storage period. Only a slight increase was found in the mean cholesterol content. The unsanitized eggs of 60 week old hens exhibited that the vegetable oil coated eggs witnessed a slight decrease in their mean cholesterol content during the storage period. Apart from coating materials, there are some other factors
that affect the cholesterol content in the eggs. The sanitized eggs of 20 week old hens were observed that the mean cholesterol content in these eggs slightly decreased during the experimentation under the eighth week of storage period. However, the mean cholesterol value of these eggs under unsanitized category slightly increased. The sanitized eggs of 60 week old hens revealed that there was an increase found in the mean cholesterol content of the vegetable oil coated eggs during the storage period. It was noted that besides the coating material, there are some other factors that affect the cholesterol content in the eggs. Hatice (2005) studied that the cholesterol content of egg is affected by many factors such as storage methods, duration, rearing system

6.1.11. Fatty acid analysis

Regarding the eggs coated with vegetable oil under unsanitized eggs of 20 week old hens, minimum variation was found in the fatty acids content during the experimentation. No change in the fatty acid content was also experienced. The fatty acid contents were changed during the storage period irrespective of storage method. In the case of unsanitized eggs of 60 week old hens, the changes such as slight increase, decrease and no change were experienced in the fatty acids content of the vegetable oil coated eggs during the experimentation. Niemiec et al (2001) stated that there were changes in fatty acid content in yolk during storage were found. Diet and storage had significant effect on oxidation of yolk lipids.
6.2. Effect of paraffin wax coating on egg preservation

It is known to coat the shell of eggs with wax, oil, protein, or a variety of other edible ingredients in order to seal the pores in the shell and maintain freshness and quality, and extend the shelf life of the egg. Application of various coatings to whole shell eggs for the purpose of increasing the shell strength and preserving the internal quality has been studied. Meyer and Spencer (1973) coated eggs with acrylic resin, casein, polyvinyl acetate, polyvinylidene chloride, prolamine, and epolene wax emulsion. They found that these coatings strengthened the shell, reduced moisture loss, and retarded loss of internal quality and increase in albumen pH. Edible lipids such as bee wax, candelilla wax and carnauba wax were used as coating materials over the fresh fruits and vegetables for preserving purposes. They have low affinity for water and therefore they have low water vapour permeability. This coating control desiccation of fruits and vegetables (Maria et al., 2008). Kolattukudy (1984) reported that coating of waxes on the fruits prevent moisture loss during storage. Thus the paraffin wax was selected to coat the eggs for the preservation under study.

6.2.1. Egg weight

The paraffin wax was used as a coating material in preserving the sample eggs and changes in the mean egg weights among the weeks were observed. The mean egg weights did not decrease in the sanitized and non-sanitized eggs of 20 week old hens among the weeks of the storage period up to fourth week. Since then they were contaminated and eliminated from the analysis. Paraffin was coating is preferred as coating material in preserving eggs. This is because of the fact that the paraffin wax
coating enhances the egg shell strength. In the case of sanitized and non-sanitized eggs of 60 week old hens, minimal decrease in the mean egg weights were observed during the storage period. It was observed that the mean egg weight loss in the wax coated eggs was found to be low when compared to eggs under control group. The similar results were reported by Biladeau and Keener (2009) and stated that the paraffin wax coated eggs had higher carbon dioxide and negligible water loss during the preservation.

6.2.2. Specific gravity

Paraffin wax influenced the specific gravity values of the sample eggs during the storage period. The mean specific gravity values of the sample eggs of all categories were found to be decrease as the storage time increases. However, these values decreased slightly during the initial weeks of the experiment. There were slight fluctuations found in the mean specific gravity values of the sample eggs during the later weeks of storage period. In contrast to this result, Amal et al (2016) found that the bee wax coated eggs enhanced the shell strength and prevent water loss and evaporation and it prevent the specific gravity values from decreasing.

6.2.3. Shape index

The paraffin wax coating enhanced the shell into thick form. Therefore, it was found that the mean shape index values of the sample eggs of all types were slightly changed during the storage period. Shape index showed no significant differences with increasing storage time (Mohamed, 2011).
6.2.4. Shell strength

Among the important quality consideration in eggs, shell strength is an important economic parameter (Biladeau and Keener, 2009). They found that there is no change in the shell strength during storage. However, they stated that shell strength of wax coated eggs had the highest shell strength when compared to uncoated eggs.

The mean egg breaking strength of paraffin wax coated sample eggs of 20 week old hens did not change during the storage period. This happened in both the case of sanitized and non-sanitized eggs. However, the sanitized and non-sanitized eggs of 60 week old hens decreased slightly during the storage period. In contrast to this study, the results observed by Lakhotia (2002) found that the paraffin based oil coating is of considerable value in maintaining both shell and egg quality. By applying paraffin wax over the shell, it serves as artificial cuticle instead of natural cuticle or bloom. It was reviewed from the study of Ball et al (1976) that the washing of shell leads to the removal of cuticle which is naturally present over the egg shell. Washing resulted in weakening of shell strength. In contrast, the present study showed no changes in the shell strength in sanitized egg.

6.2.5. Shell thickness

There were no any significant losses in the mean shell thickness of the sample eggs of all types that were coated with the paraffin wax during the storage periods. Paraffin wax is suitable for coating washed and pasteurized eggs to extend shelf life of the eggs in high humidity climates. Biladeau and Keener (2009) reported that it
maintains freshness, quality and life of the shell coated with wax and it will extend shelf-life beyond six week.

6.2.6. Yolk colour

The unsanitized eggs of 20 week old hens coated with paraffin wax experienced pale yellow, medium yellow and golden yellow yolks during the storage period. All the sample eggs up to a period of four weeks were examined and it was found that the sample eggs were fell under first three categories of yolk colour and none of the eggs was found under the dark yolk category. The unsanitized eggs of 60 week old hens showed that more number of paraffin wax coated sample eggs showed pale and medium yellow yolks. Only a few eggs had golden yellow yolks. The sanitized eggs of 20 week old hens coated with paraffin wax showed different results in the case of yolk colour. The colour of the yolks moved from pale yellow to dark yellow during the experimental period. However, most of the eggs had pale and medium yellow yolks. Regarding the sanitized eggs of 60 week old hens coated with paraffin wax, more number of eggs had pale and medium yellow yolks during the storage period.

6.2.7. Haugh unit

It was found that there had been a continuous decrease in the Haugh unit values of the sample eggs that belong to 20 week old hens without sanitation right from the initial week of the experiment to fourth week. There had been a sharp decrease in the Haugh unit values of the sample sanitized eggs of 20 week old hens among the weeks of the experiment. But none of the eggs were found to be as poor quality both in the
sanitized and non-sanitized eggs of 20 week old hens during the storage period. Some wax coating materials are used to coat the fruits and vegetables after washing their surfaces and stores for long period. In contrast to this result, Shittu and Ogunjinmi (2011) observed that eggs coated with odorless petroleum jelly and paraffin wax stored at refrigerator condition maintain the stability of Haugh unit. The eggs coated with odorless petroleum jelly and paraffin wax stored at ambient temperature resulted in better peeling qualities. Similarly, Amal (2016) studied the effect of beeswax coating on Haugh unit of eggs of 32 week old hens stored at 30°C. The results revealed that beeswax was better in preserving albumen quality during six weeks of storage period when compared to uncoated eggs. This was also tested with using gelatin and mineral oil and the same results were obtained.

There had been a decreasing trend in the Haugh unit values in the non-sanitized sample eggs that belong to 60 week old hens was found right from the first week to fourth week of the experiment. Regarding the sanitized eggs of 60 week old hens, losses in the Haugh unit values were found in the eggs during the first two weeks and sudden losses in the Haugh unit values were found in the later weeks of the experiment. In contrary, Biladeau and Keener (2009) in their study observed that paraffin wax may be a preferred coating material on eggs. The coating of paraffin wax on the egg shell maintained Haugh unit longer. Puttalingamma (2014) observed that Carnauba wax coated on the surfaces of the fruits and vegetables can improve the shelf life of the fruits and vegetables during storage both at room temperature and low temperature. Carnauba wax can prevent many microorganisms and protect the fruits
and vegetables. However in the present study, applying paraffin wax on egg shell failed to maintain Haugh unit quality at room temperature.

6.2.8. Microbial analysis

The unsanitized eggs of 20 week old hens coated with paraffin wax did not expose to microbial contamination up to fourth week and thereafter, they were spoiled due to contamination. The unsanitized eggs of 60 week old hens showed that unusual nature of microbial contamination was found with these eggs during the storage period. The result showed that these eggs started to contaminate right from the initial weeks of the experiment. It was noted that the wax coated eggs contaminated after fourth week of the experiment. In contrast to this result Amal et al (2016) observed that the antimicrobial property of the bee wax prevented microbial colonies in the eggs during the six week storage period.

Use of the paraffin-carnauba emulsion with high-density polyethylene provides stable and reliable coatings for eggs even in high humidity applications and it improved shelf life of pasteurized eggs in high humidity applications. In contrast, the paraffin wax coated eggs under the present study were spoiled at 4th week. So it is concluded the paraffin wax may not be used as egg coating material and thus proper coating method is to be studied.

6.3. Effect of glycerin coating on egg preservation

Glycerin is a viscous liquid listed as safe for human consumption by the Food and Drug administration. Similar to water and alcohol, glycerin is completely
6. Discussion

colourless and having a clear appearance. Since glycerin is colourless, it is useful as
an additive with other substances.

Widely used in pharmaceutical formulations, glycerol (glycerin) is a colorless,
odorless, and viscous liquid whose three hydrophilic hydroxyl groups impart both
solubility in water and hygroscopicity (water-absorption). Glycerol has excellent anti-
bacterial, anti-fungal, and anti-viral properties, well documented by literature on skin
and bone banking (Hoekstra et al., 1994). Therefore, the glycerin was chosen as egg
coating material for the present study.

6.3.1. Egg weight

Glycerin coated eggs experienced weight loss during the storage period. The
mean egg weights of both sanitized and non-sanitized eggs that belong to 20 week and
60 week old hens decreased considerably during the storage period. The similar
weight losses were also observed in the case of sanitized and non-sanitized eggs of 60
week old hens. These results are agreed with the results of Cengiz (2005) that glycerol
mixed chitosan coating solution on the surfaces of shell eggs witnessed an increasing
weight loss during the storage period. The losses in the mean egg weights in the eggs
of 20 week and 60 week old hens were highly correlated with the losses in the mean
egg weight of untreated eggs during the storage period. It was found that there was a
notable decrease in the mean egg weight loss from the first week of the experiment to
fourth week of the experiment.
6.3.2. Specific gravity

Eggs coated with glycerin showed minimal decreases in the mean specific gravity values of sanitized and non-sanitized sample eggs of younger and older hens up to fifth week of the experiment and substantial amount of losses were found in the mean specific gravity values during the later weeks of the experiment. It revealed that the specific gravity values decreased considerably with the increasing storage period. It was found that retaining moisture of the product is one of the properties of glycerin when it is coated on the surfaces of food items. However, in this case, glycerin coatings maintained the moisture of the eggs during the initial weeks of the experiment and the moisture became weak during the later weeks of the experiment. The manuscript reports of Soap and Detergent Association (1990) revealed that glycerin coated over the food articles maintained the quality of the products due retaining the moisture level.

6.3.3. Shape index

On the line of paraffin wax coated eggs, the mean values of shape index of eggs coated with glycerin did not decrease during the storage period. The sanitized and non-sanitized eggs of 20 week and 60 week old hens did not experience any decrease in their mean shape indices and slight fluctuations were observed at the end of the experiment. Some glycerin based materials are used as coating materials on fruits and vegetables for preservation. Triglyceride was used as coating on fruits and vegetables and it is used to control the moisture transport and permeability of oxygen and carbon dioxide and reduce surface abrasion during handling (Maria et al., 2008).
6.3.4. Shell strength

In the case of glycerin coated eggs, the mean egg shell strength decreased during the storage period irrespective of hen age and sanitation. It was found that glycerin mixed coating material maintain egg quality. Some studies used mixer of triglyceride solution such as shea butter as coating material and found that presence of triglyceride in the coating materials preserve egg quality effectively (Okiki and Ahmed, 2017) by protecting the egg shell and preventing external organisms into the eggs. The coating materials like this do not lose the breaking strength to a certain extent. Glycerin coating on egg shell not only gives strength to outer surface parts of the food articles but also it control moisture level of the products. Moreover glycerin is added with the dried eggs, canned eggs and egg-based desserts to maintaining their quality (Jessica, 2009).

6.3.5. Shell thickness

The analysis of effect of glycerin coated preservative method on mean egg shell thickness of the sample eggs revealed that there were no much variations found in the mean egg shell thickness of the glycerin coated sanitized and unsanitized sample eggs of younger and older hens during the eighth week storage period. The average value of mean shell thickness of the sample eggs experienced a least variations at the end of the experiment however it was not a matter of great concern. This observation was similar with the observation made by Mohammad (2011) that there was no significant difference in the shell thickness of the eggs stored in the room temperature and stored in the refrigerator.
6.3.6. Yolk colour

Regarding the unsanitized eggs of 20 week old hens coated with glycerin, medium and pale yellow yolks were commonly found among the weeks of the experiment during the storage period. The sample eggs with golden yellow yolks limited in number and the dark yellow yolks were found in only two sample eggs. The unsanitized eggs of 20 week old hens revealed that more number of glycerin coated eggs had pale yellow yolks and medium yellow yolks. Only one sample egg had golden yellow yolk and none of the sample egg had dark yellow yolk.

More number of sanitized eggs belongs to 20 week hens coated with glycerin experienced pale yellow and medium yellow yolks. It was also observed that fifty percent of the sample eggs had golden yellow yolks during the initial weeks of the experiment. In contrast to this observation, Roberts et al (2013) observed that there was no significant difference in the yolk colour of the sample eggs which were immersed in cuticle blue dye. In the case of sanitized eggs of 60 week old hens, both medium yellow and pale yellow yolks were found in the most of the sample eggs during the initial weeks and later weeks of the experiment, respectively. A few sample eggs had golden yellow yolks during the initial weeks of the experiment. In contrast to this result, Roberts et al (2013) found that the yolk colour did not vary among the ages of different laying periods which were immersed in the cuticle blue dye.

6.3.7. Haugh unit

In the case of glycerin coated non-sanitized eggs of 20 week old hens, the Haugh unit values slightly decreased up to fourth week of the experiment and they
were under “excellent” and “good” quality since their Haugh unit values were found to be more than 72 up to third week and more than 70 at the fourth week. Sudden losses in the Haugh unit values were found from fifth week to last week of the experiment. The qualities of these eggs were found under “fair” grade during the last four weeks of the experiment since their Haugh unit values were found from 30 to 59.

The sanitized eggs of 20 week old hens coated with glycerin also experienced losses in Haugh unit values among the weeks of the experiment. The qualities of the sample eggs deteriorated from “excellent” to “good” up to fifth week and it further deteriorated to “fair” during the last three weeks of the experiment. These results were supported by Ashton (2013) that all oil coatings are effective in preserving internal qualities of eggs than eggs coated with glycerol. Wong (1996) used albumen coating solution mixed with glycerol and its efficacy in preserving Haugh unit values of the sample eggs which were stored at room temperature and observed that a significant decrease in Haugh unit values after five days of storage.

As far as 60 week old hens’ eggs without sanitized are concerned, it was found that there had been a decreasing trend in the Haugh unit values of the sample eggs. The sample eggs from third week of the experiment fell under “fair” grade. Just like in other groups, the sanitized eggs of 60 week old hens coated with the glycerin experienced losses in the Haugh unit values among the weeks and these sample eggs at the last week of the experiment were under “poor” grade. In contrast to this study Muhammed and Cengiz (2014) observed the coating effect of glycerol mixed lysozyme–chitosan on Haugh unit values of the large sized eggs stored at ambient
temperature and observed that all glycerol mixed lysozyme–chitosan coated eggs had significantly higher Haugh unit values than uncoated eggs during six weeks of storage. Dayane (2016) used glycerol mixed whey protein concentration as coating materials and observed the results from the sample eggs of 72 week old hens which were classified as “not cleaned and not coated”, “not cleaned but coated”, “cleaned but coated” and “cleaned and coated” and stored at room temperature. In this analysis it was revealed that eggs which were not cleaned but coated showed better results in maintain the Haugh unit values though there were losses in the Haugh unit values when compared to other sample eggs. Okki and Ahmed (2017) observed the effect of shea butter coating materials on the internal qualities of eggs of old laying hens revealed that triglyceride which is presented in shea butter could be effectively preserve egg quality.

6.3.8. Microbial analysis

With regard to unsanitized eggs of 20 week old hens, only low amount of colonies of microbes were found in these eggs at the eighth week and they were free from invasion of such microbes during the first half of the storage period. The glycerin coated eggs were stored at ambient temperature and microbial invasion into eggs was due to changes in the humidity. Olamide et al (2016) reported that higher population of mould on the eggs at ambient temperature was due to humid conditions in the environment. The microbial contamination of unsanitized eggs that belong to 60 week old hens was coped with the eggs served as control group. The microorganisms were easily penetrated in the egg shells of older hens and egg shell contamination
increased significantly with the age of the laying hens irrespective of rearing system (Huneau et al., 2010).

The sanitized eggs of 20 week old hens were found to be relatively higher microbial contamination when compared to other preservative eggs at the end of the storage period. No eggs were contaminated up to fourth week. Hutchision et al (2003) viewed that washing with inappropriate chemicals allows bacteria to gain entry into the eggs. The sanitized eggs of older hens experienced uncountable colonies of microbes during the later weeks of the storage period and they were found to be minimum invasion of microbes during the initial weeks. Older hens produce thinner shells and low specific gravity. The thinner shells with low specific gravity in the older hens’ eggs facilitate higher penetration of microorganisms into eggs.

6.3.9. Fatty acids analysis

In the case of unsanitized eggs of 20 week old hens, except a few fatty acids, there was decrease in other fatty acids and some fatty acids did not vary during the experimentation. Regarding unsanitized eggs of 60 week old hens, all types of minimum changes such as increase, decrease and no change were found in the fatty acids contents of glycerin coated eggs during the eighth week storage period. Under sanitized eggs of younger hens fifty per cent of the fatty acids content did not vary during the storage period and the remaining fatty acids experienced minimum amount of changes in their content. In the sanitized eggs of 60 week old hens, the observations of increase, decrease and no changes were found in the fatty acids content during the eighth week storage period. A study made by Lesic, et al (2017) revealed that the total
saturated fatty acids were found to be higher in the eggs laid by 21 week old hens and total polyunsaturated fatty acids were found to be higher in the eggs laid by 55 week old hens.

6.3.10. Protein analysis

A least variation was found in the glycerin coated unsanitized sample eggs of 20 week old hens with respect to changes in the protein content during the storage period. Insignificant variation was found in the protein content of the glycerin coated unsanitized sample eggs of 60 week old hens. A minimal decrease was experienced and it was not a matter of great concern. No changes were found in the protein content of the glycerin coated sanitized eggs of younger hens. The percentage of protein content in these eggs between the two experiments did not show any variation. Only a slight decrease was found in the protein content in the glycerin coated sanitized eggs of older hens. Insignificant variation was found in the protein content of the glycerin coated sample eggs. A minimal decrease was experienced and it was not a matter of great concern. Arza et al (2010) studied that egg is a primary source of high quality proteins and different egg processing method affect nutrient composition of egg products.

6.3.11. Cholesterol level

The mean cholesterol value of unsanitized eggs of younger hens slightly increased during the storage period. This increase was found to be low. The mean cholesterol content in the glycerin coated unsanitized eggs of older hens witnessed a decreasing trend during the storage period. The changes in the mean cholesterol
content of sanitized eggs of younger hens were examined and the mean cholesterol values of these eggs decreased from fourth week to eighth week. The experimentation results at the fourth and eighth week with respect to changes in the cholesterol content of the glycerin coated sanitized eggs of older hens revealed that the cholesterol content increased during the storage period. The related observation was found by Adeniyi et al (2016) that the cholesterol content of chicken egg becomes higher at five week of storage period.

6.4. Effect of silicone oil coating on egg preservation

Eggs are highly perishable and susceptible to internal quality deterioration when stored above 7°C. Refrigeration of eggs may be seldom practiced in some developing regions of the world. Therefore, an alternative method, that is inexpensive yet effective, to preserve the internal quality of eggs and to prevent microbial contamination is needed. Mineral Oil coating has been proven to preserve the internal quality, prolong shelf life, and minimize weight loss of eggs. This study demonstrated that, compared with other mineral oils, silicon oil was a more practical option as a coating material for eggs during storage at room temperature due to its low cost.

6.4.1. Egg weight

The mean egg weight losses in the sanitized and non-sanitized eggs of 20 week old hens were similar during the storage period. A minimal decrease was observed in the egg weights in these eggs.

However, there was no any decrease in the mean egg weights of sanitized and non-sanitized eggs of 60 week old hens during the entire storage period.
Interestingly noted that eggs coated with silicone oil under this study had the lowest weight losses when compared to mean egg weight losses observed under other groups of the preservation. The similar observations were made by Edwin et al (2013) that among the non-refrigerated treatment groups, the silicone oil coated eggs showed slowest percentage of egg weight loss up to eight weeks storage period. The minimal weight loss in silicon oil coated eggs may be attributed to the fact that the coating blocks the pores on the shell, preventing the evaporation of moisture and gases. Silicone oil is an oil-like, highly unreactive polymer. Park et al (2013) and Imai (1981) reported that the beneficial effect of coating on weight loss was marked both at 3°C and at room temperature.

6.4.2. Specific gravity

In the case of silicone oil coating, a decreasing trend was observed in the mean specific gravity values of the sample eggs of all types with slight volatility during the storage periods. More losses in the mean specific gravity values were found in the 60 week old hens’ eggs. According to Santos et al (2009) water loss that occurs in the eggs due to evaporation causes a progressive increase in the air chamber and, thus, the specific gravity of the egg decreases.

The eggs of 60 week old hens had the low percentage of shell when compared to 20 week old hens’ eggs. This observation is in agreement with the report of the Poultry Site (2008) that the percentage of shell influences the specific gravity of whole eggs. Therefore, losses in the mean specific gravity values of the younger hens’ eggs were found to be lower than in the older hens’ eggs.
6.4.3. Shape index

In the case of silicone oil coated eggs, there was no significant fall in the mean values of shape index in the eggs of all types during the entire storage period except in the sanitized eggs of 20 week old hens. Egg shell can be damaged by cracking due to friction. Eggs can be dried and molded during higher volatility in humidity and temperature. The shape index could be slightly affected by changes in the humidity and temperature. Silicone oil reduces the friction due to high boiling point and low freezing point. By applying silicone oil on the surfaces of the egg shell, the shape of eggs could be maintained amidst varying temperatures and weather.

6.4.4. Shell strength

Silicone oil coated sample eggs with sanitized and non-sanitized eggs of younger and older hens witnessed minimal decrease in the mean egg breaking strength during the storage period up to eighth week. In contrast to this result, Edwin et al (2013) found that there was no change in shell strength due to silicone oil treatment thought the storage period. The shell thickness and shell strength are the important economic parameter especially when eggs are transported for a long distance. They also stated that eggs dipped into silicone oil could be stored at ambient temperature of eight weeks. The egg shell strength is affected by weather and heat. The silicone oil which is coated over the egg shell protects the eggs from heat and changes in the weather conditions. The higher shell strength exhibited by the silicon coated eggs was probably a result of the mechanical properties of shellac. These results are in agreement with Caner and Cansiz (2008) where chitosan coatings improved shell
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strength with chitosan together with lactic acid being the best coating in this regard compared to acetic or propionic acids.

6.4.5. Shell thickness

The sanitized and non-sanitized eggs of 20 week old hens coated with silicone oil did not experience any losses in the average mean shell thickness values during the storage period. In contrast with this, the 60 week old hens’ eggs experienced slight losses in the average mean shell thickness at the end of the experiment. Edwin et al (2013) observed that no change in shell thickness was found in the sample eggs that were coated with silicone oil up to a period of eighth weeks.

6.4.6. Yolk colour

More number of silicone oil coated unsanitized sample eggs of 20 week old hens had medium yellow yolks and this was followed by pale yellow yolks. In contrast to these results, Edirisinghe et al (2013) studied the coating effect of mineral oil, beeswax, Gammalu coating on yolk colour of the sample eggs that belong to 38 week old hens. These eggs were cleaned but unwashed. It was found that there was no significant difference in the yolk colour of the sample eggs during the storage period.

Among the unsanitized eggs of 60 week old hens, medium yellow and golden yellow yolks were found in the more sample eggs and the number of eggs had pale yellow were limited in number. These results were in the line of Jayasiri et al (2017) who analyzed the effect of coating of beeswax, rubber seed extract and mineral oil coatings on various quality parameters including yolk colour of the sample eggs which were stored at room temperature. Initially the colour of yolk was not significantly
different in each treatment including control and it was found that there was significant difference in the yolk colour in all coated and non-coated eggs.

Regarding the yolk colour of the sanitized sample eggs of younger hens, though the pale and medium yellow yolks were found in the more sample eggs, a few sample eggs had golden and even dark yellow yolks. The sanitized eggs of older hens showed pale, medium and golden yellow yolks among the weeks of the experiment. A notable numbers of eggs were found under the category of golden yellow yolks.

6.4.7. Haugh unit

Silicone oil coated eggs without sanitized in the case of 20 week old hens experienced losses in the values of Haugh unit during the storage period. However, the sample eggs under this group were under “excellent” quality up to fourth week of the experiment and the eggs at the remaining weeks were under “good” quality. The sanitized eggs of 20 week old hens coated with silicon oil were not exempted from decreasing trend of Haugh unit values during the storage period. However, there was a slow decrease in the Haugh unit values were found. Therefore, the qualities of these eggs were under “excellent” during the initial weeks of the experiment and “good” during the later weeks of the experiment. These results were supported by Edwin et al (2013) and it was observed the effect of various non-refrigerator preservative methods on egg qualities at ambient temperature. Among the various non-refrigerator preservative methods, eggs coated with silicone oil produced better results in preserving the internal quality in terms of Haugh unit values. The Haugh unit values were measurable up to seven weeks out of eight weeks storage period.
Silicone oil coated non-sanitized eggs of 60 week old hens experienced losses in the values of Haugh unit during the storage period. The egg quality was stable and most of the eggs were under “good” grade. The sanitized eggs of 60 week old hens coated with silicone oil also witnessed loss in the Haugh unit values among the weeks however all the sample eggs were come under “good” quality. Rocculi et.al (2013) analysed the effect of innovative packing system for the shell eggs storage. For that they used a package of cent per cent carbon dioxide with silica gel as humidity absorber and stored eggs at 20°C temperature. It revealed that eggs packed in cent per cent carbon dioxide maintained the Haugh unit values during the whole storage period. Instead of silicone oil, mineral oil is also applied as coating material on shell eggs. Figueriedo et al (2014) studied the effect of application of mineral oil to the egg shell stored at refrigerator up to 125 days and observed that the higher Haugh unit values were maintained throughout the storage period.

Jacqueline et al (2011) observed that the Haugh Unit values differed on the basis of age of hens, storage period and method of preservation. The Haugh unit of 60 and more is preferable for marketing of eggs. The albumin quality of eggs can be better preserved by coating of oil on the shell egg within the lay of 24 hours of lay.

Wong et al (1996) reported that eggs coated with soy and corn remained at grade “fair” after 28 days of storage, while uncoated eggs changed from grade “good” to grade “fair” after one week of storage.
6.4.8. Microbial counting

The microbes did not invade in the unsanitized eggs of younger hens up to fourth week and however, these eggs minimally exposed to microbes during the later stage of the storage period. Silicone oil protected the cuticle and pores and provided strength to shell. Since the eggs of younger hens had more egg shell strength, these eggs exposed to lesser amount of bacterial invasion. This observation was similar with the observation of Jones and Musgrove (2005) that microbial contamination in egg contents was more common in older hens’ eggs than younger hens’ eggs. As far as the unsanitized eggs of 60 week old hens are concerned, these eggs exposed to microbes minimally during the storage period. These eggs were free from the microbial contamination at the earlier weeks of the experiment. Though the silicone oil protects the eggs from penetration of microbes, microorganisms were easily entered into the thinner egg shell of old laying hens. Michael, 2005 opined that thickness of egg shell is an important factor to be considered while analyzing the penetration of bacteria and other microorganisms.

Silicone oil coated sanitized eggs of younger hens exposed limited colonies of microbes during the storage period. The sanitized and silicone oil coated eggs gave more egg shell strength which protected the cuticle and pores. The eggs of younger hens exposed to lesser amount of microbes since they had more shell strength. The sanitized eggs of older hens coated with silicone oil were found to be lesser amount of microbes among the eggs preserved under this method during the storage period. It was found that the microbial contaminant were more in the sanitized eggs of older
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hens than younger hens. This observation was supported by Jones et al (2002) that bacterial contamination in egg contents was more common in older hens’ eggs than younger hens’ eggs.

6.4.9. Protein level

In the case of unsanitized eggs of 20 week old hens, the differences in the protein content between the experiments were noticed and it was found that the protein content was slightly decreased. No significant changes were found in the mean value of protein content in the silicone oil coated unsanitized sample eggs of 60 week old hens during the storage period. A notable decrease was found in the silicone oil coated sanitized eggs of 20 week old hens during the storage period. Though there was a notable change occurred in the protein content, this change was not a bigger one. The silicone oil coated sanitized sample eggs of 60 week old hens experienced a decrease in their protein content during the storage period. Butter like silicone caulk can be used as sealant against water and air penetration and it does not support microbiological growth. Okki and Ahmed, (2017) observed that eggs coated with shea butter had higher protein concentration than control eggs.

6.4.10. Cholesterol level

The experiment conducted at the fourth and eighth week showed that the unsanitized eggs of 20 week old hens experienced slight increase in their cholesterol content. Under unsanitized eggs of 60 week old hens, the mean cholesterol content at the fourth week and eighth week experiment revealed that the cholesterol content slightly increased during this experimentation. With regard to sanitized eggs of 20
week old hens, the mean cholesterol content in these eggs decreased during the storage period. In the case of sanitized eggs of 60 week old hens, the cholesterol content slightly increased from fourth week experiment to eighth week experiment. Silicone fluid is extremely stable against thermal oxidation. As silicone oil is water repellent, it protects the surface area from drying. This property of silicone oil protects the inner parts of the eggs.

6.4.11. Fatty acid level

In the case of unsanitized eggs of 20 week old hens, minimum amount of changes like increase and decrease even there was no any change in the fatty acids content of the sample eggs coated with silicone oil were observed during the storage period. The silicone oil did not influence on fatty acid directly and there are several factors that affect fatty acid contents. Regarding unsanitized eggs of 60 week old hens, there were increases and decreases found in the mean fatty acids content during the storage period. Some fatty acids did not vary during the storage period. Silicon oil may not be influence the fatty acid content.

Under the sanitized eggs of 20 week old hens, the minimum amount of increase and decrease were found in the fatty acid content of the silicone oil coated eggs and some of these eggs experienced no change in it. The fatty acid was not much influenced by coating materials such as silicone oil. There were minimum amount of increases and decreases found in the mean fatty acids content of the silicone oil coated sanitized eggs of 60 week old hens during the storage period. Some fatty acids did not vary in their content during the experimentation. The coating materials did not
influence much on fatty acids and it is influenced by several factors. Esad et al (2013) stated that differences in the fatty acids contents may be related to differences between spices, different feeding habits, diet, age and geographical location.

6.5. Effect of storage of egg in refrigeration

United States Agricultural Department (USDA) recommended that eggs should be stored at 40°F in refrigerator. This level of temperature reduces microbes to enter into the egg. This temperature also reduces the chances of multiplying of microbes and resulted risk of illness (Jessica, 2009).

6.5.1. Egg weight

The mean egg weight losses were observed both in the sanitized and non-sanitized eggs of 20 week and 60 week old hens during the storage period. The sanitized and non-sanitized eggs of 60 week old hens had the lowest mean egg weight losses when compared to the mean egg weight losses observed in the sanitized and non-sanitized eggs of 20 week old hens. This is in agreement with studies by Sung (2014) in which it was found that eggs stored at 5°C had the lowest egg weight loss and eggs stored at room temperature had the maximum egg weight loss. The similar results were observed by Samli et al (2005) that there was no significant decrease in the egg weight loss when eggs stored at 5°C temperature.

It was found that the percentage of weight loss in eggs preserved in refrigerator was minimum than the percentage loss in egg weight preserved at room temperature. Loss in the egg weight is connected with the loss of water, carbon dioxide, ammonia and hydrogen sulphide which are produced as a results of an enzymatic breakdown of
proteins and fats in the egg content. Dynamics of these processes increases along with an increase in temperature, therefore lower loss in egg weight was found in eggs stored in refrigeration than at room temperatures (Mareh et al., 2017).

Higher loss of egg weight was found in eggs stored at ambient condition than in refrigeration and oiled. This is because of the fact that the cuticle plugging the air pores of the shell of eggs stored at room temperature dried faster and began to shrink therefore the shell pores increased in size at a faster rate make it easier for carbon dioxide and moisture to escape from the eggs. Refrigeration and oiling prevents cuticle drying and very less carbon dioxide and moisture loss (Eke et al., 2013).

6.5.2. Specific gravity

Regarding eggs stored in refrigerator, the mean specific gravity values of sanitized and non-sanitized eggs of both 20 week and 60 week old hens gradually decreased during the storage period. Butcher and Miles (2014) stated that egg specific gravity declines by an average of 0.001 units for each day the egg is stored in the cooler. The similar results were observed by Hasan and Aylin (2009) that there was minimum decrease in the specific gravity of eggs of 22 week and 52 week old hens was found when the eggs stored at 4°C temperature. The specific gravity of shell is more than two times higher than the other parts of egg and the amount of shell chiefly influence the value of specific gravity of whole egg (Poultry Site Report, 2008).

6.5.3. Shape index

The mean values of shape index of sanitized and non-sanitized eggs that belong to 20 week old hens stored in refrigerator did not show any decrease in it during the
storage period and only a slight decreases were found in the sanitized and non-sanitized eggs of 60 week old hens at the end of the experiment. But these changes were not significant one. This is agreement with the observation of Willy (2010) that the shape index of the eggs obtained from the open market was significantly differed from the shape index of the eggs obtained from the commercial outlets. The results were observed by Hasan (2009) that there were no any significant change in the shape index of the sample eggs that belong to 22 and 52 week old hens stored at 4°C during the storage period. The similar observation was found by Mohhamed (2011) that there were no any significant losses in the shape index of eggs of 68 week old hens at the refrigerator condition. The shape index did not vary among the hens of different ages and climate. In contrast to this Nedeljka and Kocevski (2006) stated that the layers up to the age of 45 week produced eggs with higher shape index and most of the eggs under this category were round shaped. The layers more than 45 weeks of age produced eggs with lesser shape index and most of the eggs were elongated eggs. Layers produced round shaped eggs during winter and elongated eggs during summer. In the case of Japanese quail, the shape of eggs was not affected by age of the birds (Sebastian et al., 2010).

6.5.4. Shell strength

The mean egg shell strength values of the sample eggs of all types with sanitized and non-sanitized experienced a minimum decrease during the study period. The eggs stored in refrigerator protect the egg shell strength from the heat and weather which prevailed in the ambient temperature. Therefore there was minimum decreases
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The shell strength is significantly affected by hen age, breeding, deposits of ingredients that form shell. On account of more concentration of calcium carbonate on the shell of younger hens’ eggs, the shell breaking strength of younger hens’ eggs was higher than that of those of old laying hens.

6.5.5. Shell thickness

There were no changes in the mean shell thickness in the sanitized and non-sanitized eggs of 20 week old hens stored in refrigerator and only a minimum decrease was found at the last week of the experiment in the case of sanitized and non-sanitized eggs that belong to 60 week old hens. The similar observations were made by Hasan (2009) that there was no significant changes in the egg shell thickness of eggs of 22 week old hens stored at 4°C and least variations were observed in the case of eggs of 52 week old hens that were stored at 4°C. Sung and Kyung (2014) observed that there were no any changes in the egg shell thickness in the sample eggs of 40 week and 60 week old hens that were stored at 4°C. Eggs stored in refrigerator had no any tangible effects on shell weight and shell thickness. This is because of the fact that the mineral in the egg shell strength were found. Jones et al (2005) found that there was no any change in the shell strength during the extended storage period in the case of eggs of old laying hens stored in refrigerated condition. Lidija et al (2017) stored eggs of 34 week old hens and 59 week old hens at 5°C and found that the shell strength of eggs of 59 week old hens was significantly lower than the shell strength of eggs of 34 week old hens.
compounds contained in the egg shell facilitate a long term stability and mechanical resistance to deformation (Mareh et al., 2017).

There was significant difference in the egg shell thickness of eggs obtained from open market and eggs obtained from the commercial outlets. Egg shell thickness depends upon the amount of calcium present in the diet and capacity of hens to re-absorb the calcium deposited in the bones of hens (Willy, 2010).

6.5.6. Yolk colour

The unsanitized eggs of 20 week old hens witnessed pale and medium yellow yolks during the storage period. Jin et al (2011) used 24 to 29 week old hens’ eggs to analyse their yolk colour at different temperature and the sample eggs were stored at 5°C, 21°C and 29°C respectively for ten days. It was observed that there was no any change in the yolk colour of the eggs which was stored at 5°C temperatures. The minimum changes in the yolk colour were observed among the eggs stored at 21°C temperature and slow and low changes were observed among the eggs which were stored at 29°C temperature. The interaction effects between storage temperature and time were also significant which influence yolk colour along with the other quality parameters.

Regarding unsanitized eggs of 60 week old hens, the pale and medium yellow yolks were found in the more number of the sample eggs and the golden and dark yellow yolks were also found in a few eggs. These results are in agreement with the result of Lidija et al (2017) that there was significant difference in the yolk colour of the sample eggs stored at 5°C in the eggs of older hens.
With regard to sanitized eggs of 20 week old hens, it was found that a vast majority of eggs stored in refrigerator fell under the category of pale yellow and medium yellow yolks respectively. Vanessa et al (2011) observed the effect of omega 3 enriched eggs on pigmentation stability at refrigerated and room temperatures. The eggs of 22 week old hens were used for analysis. It was observed that the pigmentation observed with the yolk colour fan was steady during the experiment period when eggs kept under refrigeration and it reduced at room temperature. Saki et al (2010) observed the effect of vitamin C on change in the yolk colour between the 28 week old and 35 week old hens. It was observed that there was no any change in the yolk colour of the eggs between these groups. Substantial number sanitized eggs of 60 week old hens had medium and pale yellow yolk respectively. However, the observation made by Feddern et al (2017) found that there was no significant difference in the yolk colour of the sample eggs during nine weeks of the storage period except last week of the experiment.

6.5.7. Haugh unit

In the case of 20 week old hens’ non-sanitized eggs, eggs stored in refrigerator produced a good result in keeping Haugh Unit values and egg quality. It was found that a slight volatility in the Haugh units during the storage period. However, eggs stored up to sixth week were under “excellent” grade and the eggs during the last two weeks were under “good” grade. The sanitized eggs of 20 week old hens stored in refrigerator also gave good result in keeping the sample eggs’ quality. Though there had been a decreasing trend in the Haugh unit values during the storage period, the
rate of decreasing was found to be minimum and all the sample eggs up to a third week were under “excellent” grade and the remaining eggs were under “good” grade. These results are supported by Ihsan (2012) and it was observed the effect of refrigerator temperature on the quality of eggs that belong to 35 week old hens and revealed that refrigerated eggs were able to maintain their quality comparable to the fresh eggs.

When compared to other preservative techniques, the non-sanitized eggs stored in refrigerator temperature gave better result in keeping their qualities with regard to eggs of 60 week old hens. There was a slow decrease in the Haugh unit values of these eggs. However, their qualities were maintained under “good” grade. In the case of sanitized eggs of 60 week old hens, the Haugh unit values slightly decreased and all the sample eggs under this group were found as “good” grade. Dudusola (2009) observed that the higher Haugh unit values were found in the sample eggs stored in refrigerator among the Japanese quail eggs and this was followed by eggs coated with oil. It revealed that eggs stored in refrigerator and oil coated produced good results in preserving the internal qualities of eggs. Lidija et al (2017) studied the effect of storage and age of hens on quality of table eggs that belong to 34 week old and 59 week old hens and observed that Haugh unit values decreased both in 34 and 59 week old hens. The albumen quality was affected by hen age. Albumen height and Haugh unit values were lower in eggs from the older hens when compared to younger ones. Similarly Hosseini et al (2007) observed that the Haugh unit and albumen height were
6. Discussion

found to be lower in older hens than younger hens and it also revealed that the Haugh unit values would be higher at low temperature.

6.5.8. Microbial counting

The unsanitized eggs of 20 week old hens revealed that more colonies of microbes were found with the refrigerated eggs at eighth week of the experiment when compared to eggs under other preservative methods and no microbes were found at the fourth week. These results were supported by Anielli et al (2014) that the refrigerated temperature influenced the egg quality and found that salmonella were found in eggs stored at 5⁰C. and 28⁰C. Regarding the microbial contamination of unsanitized eggs of 60 week old hens, refrigerated eggs were totally differed from the eggs stored under other preservative methods. These eggs witnessed more than twenty colonies of microbes both at the fourth and eighth week of the experiment. Divya (2008) found that the salmonella count was increased from the first day to fourteenth day of storage period both in refrigerated eggs and eggs stored at abusive temperature.

The sanitized eggs of 20 week old hens stored in refrigerator were a matter of great concern since the concentration of microbes were more in numbers when compared to eggs under other preservative methods. In contrast to this result, Sharmeen et al (2014) suggested that the egg quality can be maintained and growth of microorganisms can be inhibited at chilled temperature. In the case of sanitized eggs of 60 week old hens, more than twenty colonies of microbial load were found in the refrigerated eggs both at fourth week and eighth week experiment. Amal et al (2015)
observed that the egg shell had the highest and the internal content had the lowest load of both bacterial and fungal contamination.

6.5.9. Protein level

The result of protein analysis for the unsanitized eggs of 20 week old hens revealed that a very minimum percentage of loss in the protein content was experienced during the storage period. In the case of unsanitized eggs of 60 week old hens, the mean value of protein content of the refrigerated eggs decreased at the eighth week. The sanitized eggs of 20 week old hens showed that though there was a decrease in the sample eggs’ protein content during the storage period, it was not a significant one.

The sanitized eggs of 60 week old hens exhibited that no significant change was found in the protein content of refrigerated eggs during the storage period. Schafer et al (1999) studied the changes in the egg white protein during the storage period of six weeks at temperatures of 5°C, 20°C and 30°C at 60 per cent of relative humidity and observed that storage period did not affect the protein composition. The eggs stored in refrigerator should be taken more care with respect to protein composition.

6.5.10. Cholesterol level

The experiments in the unsanitized eggs of 20 week old hens showed that the mean cholesterol content of these eggs decreased during the storage period. The unsanitised eggs of 60 week old hens witnessed an increase in the mean cholesterol content. However, this increase was found to be very low. The sanitized eggs of 20
week old hens exhibited that the mean cholesterol content of the refrigerated eggs under this preservative method decreased during the storage period. There was an increase found in the mean cholesterol content of the sanitized eggs of 60 week old hens stored in refrigerator during the storage period. Azhar et al (2014) pointed out that the storage time and temperature affect the yolk lipid oxidation. Yolk lipid oxidation increased significantly with the storage periods and temperature.

6.5.11. Fatty acid level

The unsanitized eggs of 20 week old hens which stored in refrigerator showed that only slight changes in the fatty acid content were found and these changes were not a significant one. The unsanitized eggs of 60 week old hens revealed that only minimum changes in the fatty acid content were found and these changes were not a significant one. In the case of sanitized eggs of 20 week old hens, fifty per cent of the fatty acids content did not vary during the storage period and the remaining fatty acids experienced minimum amount of changes in their content. Under the sanitized eggs of 60 week old hens, some of the fatty acids did not vary in their content during the experimentation and some other fatty acids experienced minimum amount of changes in it over the storage period.

The present study analyses the effectiveness of different preservative techniques in preserving chicken egg during eight week storage period. This study concludes that eggs coated with silicone oil, vegetable oil and refrigerated eggs were effective in preserving chicken eggs during eight week storage period as compared to other preservative techniques.
Minimum loss in egg weights in the sample eggs was found in the eggs coated with silicone oil, vegetable oil and refrigerated eggs. Better albumen quality during the storage period which was shown by Haugh unit values in these eggs. It was also found that the oil coated eggs had minimum number of microbes which reveals that oil coated eggs prevent microbial growth effectively when compared to other preservative techniques. The eggs coated with silicone and vegetable oils reduced the evaporation of carbon dioxide from eggs. The carbon dioxide content is more in the freshly laid chicken eggs which tends to equilibrate with the environment. Oiling prevented cuticle drying which retained moisture content in the eggs. The refrigerated eggs produced good results in keeping egg quality however the increasing microbial growth during the storage period was a matter of great concern.