RESEARCH ARTICLE

Assessment of different pickling solutions on quality characteristics of pickled quail *(Coturnix coturnix japonica)* eggs

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ABSTRACT

The study was conducted to determine the influence of different pickling solutions on the quality characteristics of pickled quail (Coturnix coturnix japonica) eggs. Quail eggs were pickled in seven different pickling solutions (Dill, Mustard, Garlic, Rosy, Simpal, Marion's and British PU) and stored for 28 d at room temperature. Four pickling solutions (Dill, Mustard, Garlic and Rosy) were selected according to results of sensory evaluation and some modifications were done as per the comments of the sensory evaluation. The pickled egg quality from modified four pickling solutions and the control were evaluated weekly during storage. As per the observations, color and tenderness of egg white were significantly ($P<0.05$) different during the storage. The control and the Rosy pickle had better consumer acceptability. The Rosy pickled eggs contained 65.30±0.04% moisture, 10.42±0.12% crude fat and 13.16±0.08% crude protein. Thus, it can be introduced as a preserved product.

Keywords*: Egg white, hard-cooked, pickling, quail eggs, quality*

INTRODUCTION

Egg industry in Sri Lanka is strongly developed to self-sufficient level and there is an increasing demand for eggs due to its greater nutritional value with reasonable price (DAPH Annual Report, 2019). Eggs are highly perishable food product and more prone to quality deterioration during the storage period, transportation, handling and processing (Wardy *et al*., 2010). Egg is considered as the basic ingredient which plays an important role in obtaining desirable volume, texture and color of the baked food products. As well as, egg act as a binding, leaving, tenderizing and emulsifying agent and helps to develop flavor and color of the product (Ratnayake *et al*., 2012). Therefore, there is a trend in the egg industry to develop egg products in several ways to ensure the quality of the product until human consumption and improve the consumer preference in many ways such as pickled eggs; dried eggs; egg powders (whole, albumen and yolk); ready-to-eat scrambled eggs, blended and dried eggs; hard-cooked shell eggs; hard-cooked, peeled eggs; frozen; liquid and fried eggs (Hope *et al*., 2002). As a result of increasing economic pressure with higher profit margins and consumers' demand, different forms of value-added egg-based products have a good market in all over the world. At present, the pickled egg products are developed from chicken eggs, duck eggs as well as

quail (*Coturnix coturnix japonica*) eggs in different forms even though they had different as an important food item for human diets because it has high quality protein, lipids, vitamins, minerals and growth factors that are essential for the developing of embryo and defensing mechanism by protecting against bacterial and viral infection (Kovacs-Nolan *et al*., 2005).

According to Genchev (2012), Japanese quail (*Coturnix coturnix japonica*) eggs have the essential amino acid content in 50.36% of albumen protein and in 48.65% of yolk protein. The quail eggs are rich in fat soluble vitamins, vitamin B complex, proteins (amino acids), macro and micro elements but they are low in cholesterol and saturated fatty acids. Furthermore, the quail eggs have an ability to prevent liver and kidney diseases, and gallbladder stones. When considering other eggs, quail eggs have higher nutritional value and functional value because of their high levels of minerals, vitamins and antioxidants (Bayomy *et al*., 2017). Pickling of egg is one of the food preservation methods practiced with the purpose of producing an attractive naturally preserved and minimally processed food for consumers (Scheinberg *et al*., 2013). Commercially manufactured hard cooked pickled eggs can be used as instant food or snacks which have different flavors and different eating patterns especially for busy people (Richard and Cutter, 2011). The pickled eggs have massive benefits to both producers and consumers such as reduction of egg breakage, easy to transportation, handling, expansion of shelf life, remove barriers of peeling eggs, value addition and enhancing variety egg protein patterns (Yaping *et al*., 2018). An avian egg can be considered as an important food item for human diets because it has high quality protein, lipids, vitamins, minerals and growth factors that are essential for the developing of embryo and defensing mechanism by protecting against bacterial and viral infection (Kovacs-Nolan *et al*., 2005).

In the egg pickle industry, there are different egg pickles available on the basis of various techniques and ingredients (water, acidulants, vegetables, preservatives, natural coloring agents and spices) used for preparation of pickling which results in changing quality characteristics of eggs (Zhao *et al.,* 2020). There is a huge opportunity for pickled quail eggs in the market with increasing popularity of consumption of quail eggs because of small size and attractive appearance (Abeyrathna, 2015). The pickled quail eggs have been served as nutritious, ready-to-eat and value-added food item to the consumers in the same manner of pickled chicken eggs (Bayomy *et al*., 2017).

High osmotic pressure from salt and sugar in pickling recipes ties up water and make it unavailable for microorganisms that can cause cell dehydration, create proton gradient across biological membrane, acidify the cytoplasm and interfere with chemical transport across the cell membrane (Jahn, 2000). In the shelf-stable pickled egg industry, there is a special concern on selecting a proper packaging material in order to obtain the expected shelf life (9-12 months) without adverse quality changes; changing odor, flavor and lipid

oxidation (Usaga *et a*l., 2017). In addition, acidic environment in the pickling process not only limits the microbial growth but also enhances the destruction of microorganisms such as *Clostridium botulinum* synergistically with other antimicrobial systems due to drop of oxygen (David and Shapton, 2001). Vinegar or acid in pickling solution may react with egg proteins and, it contributes to the toughness of egg whites (Sheldon, 1986). According to the study of Ball and Saffores (1973), tenderness of egg white of pickled egg made from the pickled solution which had more than 45% sugar been reduced. On the other hand, Suey-ping and Kuo-hsuen (1998) reported that the addition of salt in the pickling solution tended to effect on hardness of egg whites because salt content is increased with pickling time and salt is migrated from coating into egg white. Even though quail egg production is growing up in Sri Lanka, there is no proper domestic or commercial storage facility of eggs and it creates issues on freshness of eggs and consumer acceptance (Renukadevi *et al.*, 2018). Therefore, wastage or spoilage of eggs can be seen during the storage period causing an economic damage, raising risk of bacterial contamination, creating issues in food safety and reducing quality of the product (Mertens *et al*., 2006). According to the present situation in Sri Lanka, there is a high interest to produce quail eggs among farmers due to its high demand from the customers (Abeyrathna, 2015). Developing of value-added products from quail eggs will help to attract customers by producing the pickled quail eggs in the range of new pickling recipes and ready-to-cook quail- based meals (Minvielle, 2004). During the pickling process, shelf life of eggs can be extended up to 8 - 15 months (Singh and Panda, 1989) and that creates major developments in the egg industry such as improve food safety, sensory qualities and convenience for the consumers. Hence, pickling of quail eggs is a good remedy to preserve eggs and provide novel experience of egg consumption with different flavors to egg lovers. The main purpose of the current study was to explore the effects of different pickling solutions on physio-chemical properties and quality characteristics of pickled quail eggs. Furthermore, other objectives of the present study were to select the preferable egg pickling solutions and improve them to enhance quality characteristics of pickled quail eggs during the storage period.

MATERIALS AND METHODS

Location of the study

All preliminary trials, preparation of pickles and all the analysis of different pickling solutions and the pickled quail eggs were carried out at Nutrition Laboratory, Department of Animal Science, Faculty of Agriculture, and University of Peradeniya, Sri Lanka.

Materials

Newly laid quail eggs were obtained from Livestock Field Station-Mawelawatta, Department of Animal Science, Faculty of Agriculture, and University of Peradeniya. The ingredients (vinegar, sugar, salt, spices and vegetables) required for the preparation of pickling solution were obtained from a retailer market, in Peradeniya.

Methodology

The pickling solutions and pickled quail eggs were prepared according to the method described by Bayomy *et al*. (2017) with slight modifications. The production of quail egg pickles mainly consisted of three steps: preparation of hard-boiled quail eggs, preparation of pickling solution and finally preparation of pickled quail eggs. In this study, two experiments were carried out. Experiment 1 was conducted to find out the best pickling solutions out of the seven treatments and Experiment 2 was conducted to modify the selected pickling solutions with the objective of evaluating its performances on quality characteristics of quail eggs.

Experiment 1: Preparation of the pickled quail eggs from different pickling solutions

Preparation of pickling solution

Seven different formulated pickling recipes (Garlic, Rosy, Dil, Mustard, Simpal, Marion's and British PU) and control pickling solutions were used for the preliminary trails of this study. The above-mentioned pickling solutions were selected and slightly modified by adding different ratio of vinegar, water, salt and spice mixture containing minced garlic, ginger and cinnamon with different compositions as described by Panda and Singh (1990). The required ingredients used for the preparation of seven pickling solutions are shown in Table 1. The mixture of all the ingredients of each recipe was boiled and allowed to simmer for 12 min.

Preparation of hard-boiled quail eggs

The quail eggs were held at refrigerated temperature (5 °C) for 24 h before being preparation of hard-boiled quail eggs to prevent the discoloration of egg white interface (Maurer, 1975). The eggs were cooled in an uncovered stew pan and the water simmered approximately at 97 °C for 4 min. As soon as after cooking, the hot water was drained and the eggs were cooled under a stream of cold tap water. The peeled eggs were placed in glass bottles equipped with screw-type lids until pickling (Zhao *et al*., 2020).

Preparation of pickled eggs

The prepared pickling solution was poured over the peeled boiled quail eggs. All bottles were covered with lids with keeping a head space and they were

placed in a water bath (YCW-010E, Gemmy Industrial Corp., Taiwan) to boil and allowed to simmer for 15 min until the internal temperature of egg reaches to 74 ºC to pasteurize the product (Luo *et al.*, 2010). The bottles of pickled eggs were stored at room temperature for evaluating of consumer acceptability.

Table 1: The composition of seven different formulated pickling recipes that used for preparation of pickled quail eggs.

*Ingredients %	Recipes							
	Garlic	Rosy	Dill	Mustard	Simpal	Marion's	British PU	Control
Vinegar	92.00	34.75	57.00	54.50	85.00	63.00	90.00	98.50
Water	-	34.75	38.00	13.50	-	21.00	-	-
Salt	0.75	0.20	1.00	1.00	0.56	4.80	-	1.50
Sugar	3.50	0.05	-	21.50	-	4.80	3.00	-
Mustard past	-	-	-	3.50	-	-	-	-
seeds	-	-	0.45	-	-	-	-	-
Cardamom seed	0.50	-	-	-	0.08	-	-	-
powder	-	-	-	-	-	0.20	-	-
Garlic cloves	3.07	-	-	-	-	-	-	-
powder	-	-	0.20	-	0.50	-	-	-
Whole cloves	-	0.05	-	-	0.05	-	-	-
powder	-	-	-	-	-	0.30	-	-
Cinnamon powder	-	0.60	-	-	0.11	0.20	-	-
Ginger powder	-	-	-	-	0.50	-	2.34	-
Black pepper powder	-	-	0.35	1.00	4.00	0.30	2.33	-
Tarragon	0.18	-	-	-	-	-	-	-
Sliced beet	-	18.50	-	-	-	-	-	-
Onion sliced	-	10.50	-	5.00	-	-	-	-
Onion juice	-	-	1.40	-	-	-	-	-
Red chili powder	-	-	-	-	4.00	-	-	-
Red dried chili pieces	-	-	-	-	4.00	-	-	-
Dill seeds	-	-	1.60	-	-	-	-	-
Fenugreeks seed powder	-	-	-	-	0.28	-	-	-
Cumin seed powder	-	-	-	-	0.75	-	-	-
Asafetida	-	-	-	-	0.17	-	-	-
Lemon juice	-	-	-	-	-	5.04	-	-
All spice powder	-	0.60	-	-	-	-	2.33	-

Evaluation of organoleptic characteristics and consumer acceptability of pickled eggs

There was no any discoloration, microbial count, presence of yeast and mold in the picked quail eggs and then they were subjected to the sensory evaluation in order to select the best four (4) recipes out of seven formulated recipes. The

pickled quail eggs from each treatment were cut into halves and served to untrained 10 members of taste panel. The panelists were selected from academic and non-academic staff members of the Department of Animal Science, Faculty of Agriculture, University of Peradeniya. The panelists were asked to evaluate the organoleptic characteristics of the product as appearance, color, aroma, texture, taste and overall acceptability using a seven-point hedonic scale with higher scores indicating better preference and acceptability (Wang *et al*., 2012).

Experiment 02: Modification of the pickling process

The modification of preparation method of pickling solutions was done for the selected four recipes (Dill, Garlic, Rosy and Mustard) that accepted by the sensory evaluation. During preparation of the pickling solution for Experiment 2, the particle size of all ingredients was reduced by grinding. The pickling solutions were prepared in the same manner as described under Experiment 1. At last, the pickling solutions were sealed and stored in the containers at room temperature for one week for aging without eggs. Then, the solutions were subjected to centrifugation (CUR-1A, Hitachi koki Co Ltd., Japan) at 3000 × *g* for 4 min. The filtrate of the pickling solution was poured over the eggs. Then, the bottles were pasteurized and stored for quality evaluation (Wang *et al*., 2013). Then, the samples from four treatments and control were subjected to evaluate the quality of the pickled quail eggs and pickling solutions by analyzing physico-chemical, and sensory parameters and proximate composition.

Physico-chemical analysis

Before pickling and after 7, 14, 21 and 28 d of pickling, the samples were evaluated for pH of whole egg as well as pickling solution, tenderness of egg whites and color of egg whites in triplicates.

Determination of pH of whole egg and pickling solution

Five (5) g from ground samples of whole egg from each treatment were weighed (SHIMADZU UW220H, Japan) and homogenized (Model BM-4, Nihoneseiki Kasisha Ltd., Japan) with 50 mL of distilled water for 2 min. The pH of whole egg was measured by using a calibrated pH meter (Model pH 211, Hanna Instrument, TOA Electronic Ltd., Japan) according to the procedure described in Association of Analytical Chemistry (AOAC, 1995). Fifty milliliters of pickling solutions from each treatment were placed in a beaker and pH was measured by digital pH meter according to AOAC protocols, (AOAC, 1995).

Determination of the tenderness of egg white

The egg white from two (2) eggs from each four modified pickles were evaluated for tenderness using cutting rod of Universal Instron machine (INSTRON model 4456, USA) which was set to speed of 100 mm/min and

the weight was considered as 2 kN (McCready, 1973).

Determination of color of egg white

Three different points of the pickled egg from each treatment were measured using a tristimulus colorimeter (CR-10, Konica Minolta Sensing, Japan) calibrated using a standard white tile. Color of egg whites was expressed according to Hunter values as L* (lightness), a* (redness/greenness) and b* (yellowness/blueness) of solid color system (Suey-ping and Kuo-hsuen, 1998). The colorimeter was calibrated before the evaluation by using a standard white tile and the values for L*, a* and b* which expressed as 95.95, 0.34 and 0.13, respectively.

Proximate analysis of pickled quail eggs

The moisture, protein and fat contents of fresh cooked and pickled eggs for four weeks were determined. The moisture content of all samples was measured according to the procedure described by Nielsen (1998). The crude protein and crude fat contents of fresh cooked and pickled quail eggs were determined according to the protocols of AOAC, (2005).

Organoleptic qualities and consumer acceptability of pickled eggs

The sensory evaluation was conducted to evaluate the organoleptic quality of pickled eggs for 28 d that obtained from four pickling solutions and the control pickle. The pickled eggs from each treatment were cut into serving size pieces and served to evaluate the appearance, color, aroma, texture, taste and overall acceptability using a seven-point hedonic scale with untrained 10 members of the panelists from the academic and non-academic staff members of the Department of Animal Science, Faculty of Agriculture, University of Peradeniya (Brar *et al.*, 2015).

Statistical analysis

Data collected from sensory evaluation of pickled quail eggs were analyzed from non-parametric ranking procedure with Friedman rank sum test by MINITAB 17 software. In sensory data, the critical absolute rank sum of differences for all treatments comparison were made at 0.05 level of significance. The Completely Randomized Design (CRD) was used and data were analyzed by using one-way ANOVA using SAS program (SAS Institute Inc., 2004) version 9.0 with a 95% confidence interval. Mean separation of all treatments was carried out by Least Significant Difference (LSD) test. Results of pH of pickling solution and pickled eggs, tenderness of egg whites and color of egg whites obtained during the storage period were analyzed by repeatable measures using SAS program (SAS Institute Inc., 2004) version 9.0 with a 95% confidence interval.

RESULTS AND DISCUSSION

Organoleptic qualities and consumer acceptability of quail pickles in the experiment 1

According to the sensory evaluation of Experiment 1, the pickled quail eggs obtained from Rosy, Mustard, Garlic and Dill pickling solutions were acceptable for (90%) of panelists and other three pickling solutions (Simpal, Marion's and British PU) were unacceptable for them (data not shown). It could be explained that some panelists did not accept above mentioned three types of pickling solutions due to spices or color, type of seasoning, chopped vegetables (onions, beet) in the pickling solution etc. According to the results of Acton (1981), panelists preferred vinegar marinated pickled eggs to pickled eggs that not containing the significant flavor of vinegar such as salty or sugar. According to Angalet *et al*. (1976), the pickled quail eggs made from Kansas spicy, sweet and sour and dill pickling solutions were selected over the other two formulations; red beet and dark spicy. Panda and Singh (1990) stated that the most suitable pickling solutions for the pickled quail eggs was the solution that consisted with vinegar and water (1:1 V/V) ratio, 8% common salt, 2% each of spice mixture with minced garlic and ginger. Further, peeled, hard-cooked pickled quail eggs pickled in pickling solutions consisting of mustard oil, acetic acid, common salt and spices could be organoleptically acceptable within 8 to 15 months under ambient and refrigerated conditions 19 - 38 ºC; RH 36 - 85% and 4 - 6 ºC RH 80-85%, respectively (Singh and Panda, 1989).

Physico-chemical analysis

Effect of acid strength of pickling solution and storage time on pH of the whole egg of quail

As shown in Table 2, pH of the whole pickled quail eggs was significantly (P<0.05) different among all treatments during four weeks of the entire experimental period while Rosy pickled egg showed somewhat higher pH value in numerically compared to other treatments. The results showed that decreasing trend of pH values in all the preserved egg (P<0.05) at seventh day of the pickling process because of the acidic solution penetrate into egg white at early stages. There was no significant (P>0.05) change of pH of the pickled whole egg from 7 to 28 d during the entire storage period which indicates a possible relationship between initial pickling solution and pH of whole egg. Agreeing to the above-mentioned observation, with the time of the storage period, the pH of the pickled eggs have been decreased due to biochemical reactions occurred in the preserved eggs and production of series of compounds (alcohols, aromatics and volatile compounds) during that period (Chen *et al*., 2015; Zhang *et al*., 2015). This result agrees with the findings reported by Acton and Johnson (1973) who found that the pH of the egg white and yolk components of the hard-cooked pickled eggs in 3% acetic acid vinegar decreased to 4.0 - 4.1 after six days of the pickling.

Table 2: The pH values of freshly cooked quail egg, pickle solution and whole pickled quail eggs during four weeks of storage period.

Treatment	pH of freshly cooked egg	Initial pH of the solution	pH of whole pickled eggs Storage time (d)			
			7	14	21	28
Rosy	8.3±0.00^{A}	3.13	3.25±0.01^{aB}	3.13±0.15^{aB}	3.10±0.02^{aB}	3.21±0.18^{aB}
Mustard	8.3±0.00^{A}	2.57	3.35±0.02^{aB}	2.97±0.01^{bB}	3.03±0.12^{aB}	3.00±0.11^{abB}
Garlic	8.3±0.00^{A}	2.99	2.99±0.03^{abB}	3.00±0.05^{aB}	2.93±0.06^{bB}	2.94±0.08^{bB}
Dill	8.3±0.00^{A}	2.56	3.04±0.06^{abB}	3.00±0.05^{aB}	3.04±0.03^{aB}	3.02±0.07^{abB}
Control	8.3±0.00^{A}	2.00	2.89±0.01^{bB}	2.90±0.16^{bB}	2.81±0.14^{bB}	2.87±0.12^{bB}

Data presented as mean±standard deviation
a-b Means with different superscripts within the same column differ significantly (P<0.05)
A-B Means with different superscripts within the same row differ significantly (P<0.05)

Effect of storage time on the pH of the pickling solution

There were no significant (P>0.05) difference of pH in the pickling solutions among the treatments during the storage period as shown in the Table 3. Results of this study showed that the pH of the pickling solutions of the treatments during the storage period was slightly increased in numerically over the initial pH of the pickling solution and it indicated that egg whites caused to increase the pH. As mentioned above, the possible reason for that was the absorption of acid by both egg white and egg yolk and also neutralization of acid by spices in the pickling solution (Acton and Johnson, 1973). Initial pH of the solutions was varied due to ratio of acid to water and pickling spices in the solution (Ball and Saffores, 1973).

Table 3: Ratio of acid to water, initial pH and change of pH of pickling solutions during four weeks of the storage period.

Treatment	Acid water ratio	Initial pH of the pickling solution	pH of the pickling solutions Storage time (d)			
			7	14	21	28
Rosy	1:1	3.13±0.05^{aA}	3.87±0.08^{A}	3.85±0.13^{A}	3.87±0.18^{A}	3.87±0.12^{A}
Mustard	4:1	2.57±0.14^{bA}	3.51±0.16^{A}	3.29±0.02^{A}	3.44±0.14^{A}	3.47±0.01^{A}
Garlic		2.99±0.11^{bA}	3.31±0.14^{A}	3.33±0.17^{A}	3.37±0.21^{A}	3.34±0.06^{A}
Dill	3:1	2.56±0.08^{bA}	3.40±0.02^{A}	3.42±0.04^{A}	3.48±0.10^{A}	3.49±0.24^{A}
Control		2.00±0.04^{bA}	3.16±0.25^{A}	3.18±0.22^{A}	3.22±0.18^{A}	3.24±0.07^{A}

Data presented as mean±standard deviation
^{a,b} Means with different superscripts within the same column differ significantly (P<0.05)
$^{A-B}$ Means with different superscripts within the same row differ significantly (P<0.05)

However, in this study, initial pH of the pickling solution of Garlic and control samples showed a variation because it contains only vinegar and spices. According to Acton and Johnson (1973), the initial acid strength of the pickling solution is directly influenced to totally penetration of acid through egg white to yolk to extent an equilibrium concentration within 3 to 6 d. The different initial

acid strengths in the pickling solution could change the properties (taste, flavor) and yield of the pickled eggs (Ball and Saffores, 1973).

Effect of pickling solutions and storage period on the tenderness of pickled quail egg white

There was a significant (P<0.05) difference in shear forces (tenderness) among all the treatments as well as during the storage period of pickling as shown in Table 4. In the present study, the lowest (P<0.05) tenderness was recorded by the control pickle solution which contained no sugar and no water at 7 and 14 d of the storage period. The low weight losses of the control pickled eggs that happened from the declining of percent albumen moisture may be caused to low shear values in the control pickled eggs as described by McCready (1973). Ball and Saffores (1973) found that the initial shear forces required to shear cooked egg white averaged as 0.6 kg g^{-1} and the forces that needed to shear the pickled egg in the range up to 1.6 kg g^{-1}. The study of Luo *et al*. (2010) further explained that the shear force had a trend to increase within the time period due to dehydration (syneresis) of egg whites during the pickling process. As a result of destruction of egg white protein gel due to water and Na+migration into the eggs, rougher sections in the egg white appeared at 16 d of the curing (Bao *et al.*, 2020). According to McCready (1973) a significantly (P<0.05) greater shear value of the pickled eggs was observed compared to the non-pickled hard cooked eggs and it could happen due to differences of pH, spices and sugar content in the pickling solution.

Table 4: Shear force of freshly cooked quail eggs and shear value of the pickled egg whites during four weeks of the storage.

Treatment	Freshly cooked egg (day 0)	Shear force (k N), Storage period (d)			
		7	14	21	28
Rosy	0.0021 ± 0.01^{C}	0.0060 ± 0.11^{aAB}	0.0068 ± 0.13^{bAB}	0.0044 ± 0.05^{dB}	0.0078 ± 0.11^{aA}
Mustard	0.0021 ± 0.01^{C}	0.0068 ± 0.04^{aB}	0.0065 ± 0.06^{bB}	0.0083 ± 0.00^{aA}	0.0079 ± 0.01^{aAB}
Garlic	0.0021 ± 0.01^{C}	0.0062 ± 0.12^{aB}	0.0072 ± 0.01^{aA}	0.0065 ± 0.11^{cB}	0.0065 ± 0.15^{bB}
Dill	0.0021 ± 0.01^{C}	0.0060 ± 0.02^{aB}	0.0073 ± 0.00^{aA}	0.0071 ± 0.01^{bA}	0.0063 ± 0.03^{bB}
Control	0.0021 ± 0.01^{C}	0.0048 ± 0.13^{bB}	0.0045 ± 0.02^{cB}	0.0063 ± 0.01^{cA}	0.0060 ± 0.03^{bA}

Data presented as mean±standard deviation

^{a,b,c,d} - Means with different superscripts within the same column differ significantly (P<0.05)

$^{A, AB, B, C}$ - Means with different superscripts within the same raw differ significantly (P<0.05)

Effect of the pickling solution and storage time on color of pickled quail egg whites

Lightness (L value)

As shown in the Figure 1, there was a significant (P<0.05) difference between L* values (lightness) of egg whites among all the treatments during the storage period. In the pickled/preserved eggs, Maillard reactions and interactions among the compounds in pickling solution with egg white proteins that form pigments can be the reasons affecting the color of the preserved eggs (Shao *et al.*, 2017). The control egg whites had a slightly higher (P<0.05) L* value compared to others during the entire experimental period which indicated a possible relationship between the pickling solution and the egg white color. The possible reason of decreasing trend of L*value of four pickled eggs was the production of brown or even black melanoids during the storage period by Maillard reaction. As well as, changes of color of egg whites is mostly related to moisture losses of egg whites that contribute to accumulation of the pigments (Luo *et al.*, 2010). Moreover, significant (P<0.05) change of lightness of egg whites of Rosy, Mustard, Garlic and Dill pickles occurred during the first week of pickling time, because egg white absorbed coloring compounds from pickling solutions during the pickling period. During the storage period, the L* value of the egg whites were characterized by downward trend (P<0.05) and Rosy pickled quail eggs showed lower (P<0.05) L* value among of the pickled eggs and these eggs obtained lower (P<0.05) score for color in the sensory evaluation. It could be happened due to dehydration process during the pickling of quail eggs throughout the storage period which can be further explained by the lowest (P<0.05) moisture percentage in Rosy solution as 65.30±0.04%.

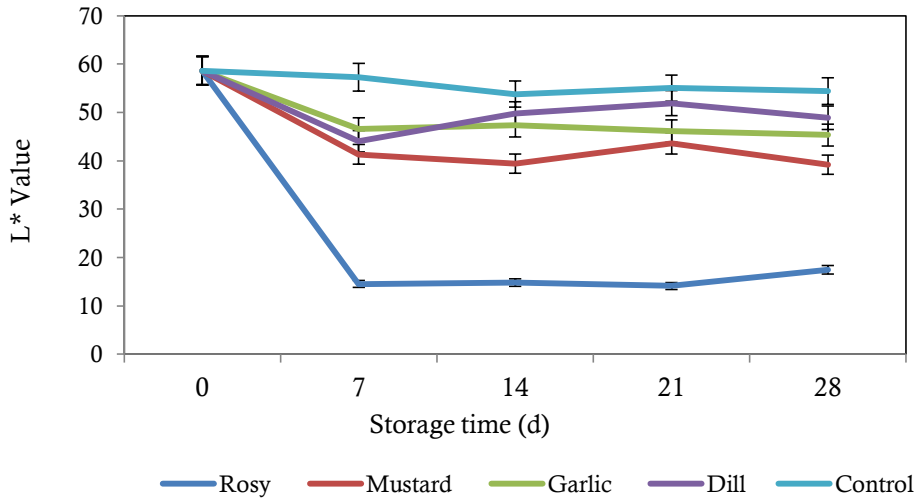

Figure 1: Lightness (L* value) of the pickled quail egg whites during the storage period.

Yellowness and blueness (b value)

According to Figure 2, yellowness and blueness (b* value) of egg whites showed that there were significant (P<0.05) differences among all treatments during the storage period. At 21 d of the storage period, pickled quail egg from Mustard pickling solution showed somewhat higher (P<0.05) b* value and that suggested that high concentration of pigments in that pickled egg. During seven (7) days of pickling, yellowness of the pickled egg whites of all treatments were significantly (P<0.05) increased. According to Boa *et al.* (2020), color of the pickled/marinated pickled quail egg yolk gradually changed from light yellow to darker orange yellow due to improvement of the pigments such as lutein, carotene with dehydration of egg yolk. Therefore, results suggested that the b* value of the pickled quail egg whites were increased and it also influenced by the moisture losses of the pickled quail eggs during pickling period.

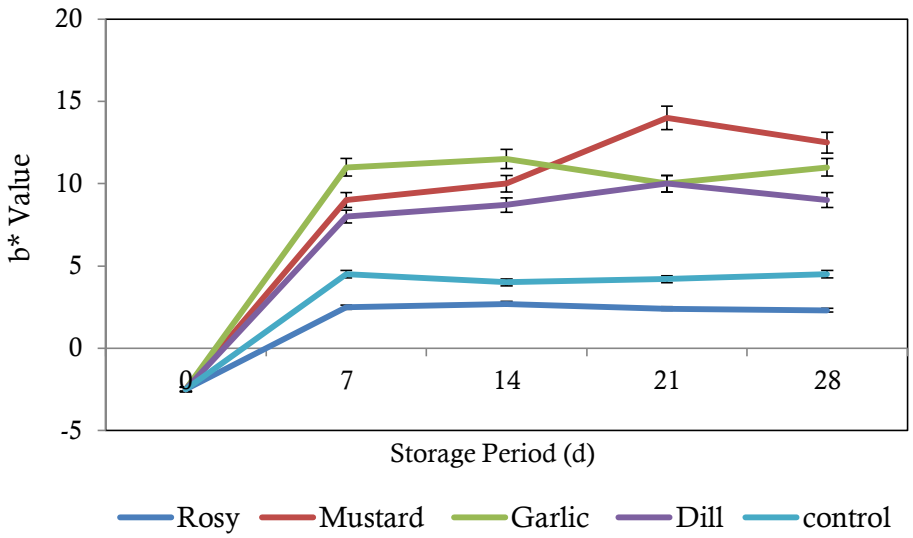

Figure 2: Yellowness and blueness (b* value) of the pickled quail egg whites during the storage period.

Redness and greenness (a value)

As illustrated in Figure 3, there was a significant difference for a* value among the treatments during the storage period. According to Luo *et al.* (2010) biochemical reactions between egg white and pickling solution and formation of volatile substances by Maillard reaction affected on trend of color change in a* value of the egg whites. In the current study, Rosy pickle had significantly higher a* value (redness) in egg white while the control pickled eggs had significantly negative value (greenness) throughout the entire study. The reason for the increase of a* value in Rosy pickled quail eggs may be due to the included beetroot in the pickling solution. Moreover, the control picked eggs

showed lower (P<0.05) a* value because of there aren't any spices or ingredients other than salt and vinegar in the control pickling solution. Light tan, black or brown color in the eggs was identified as unpleasant color as well as red and white are the preferred color for the pickled eggs (McCready, 1973).

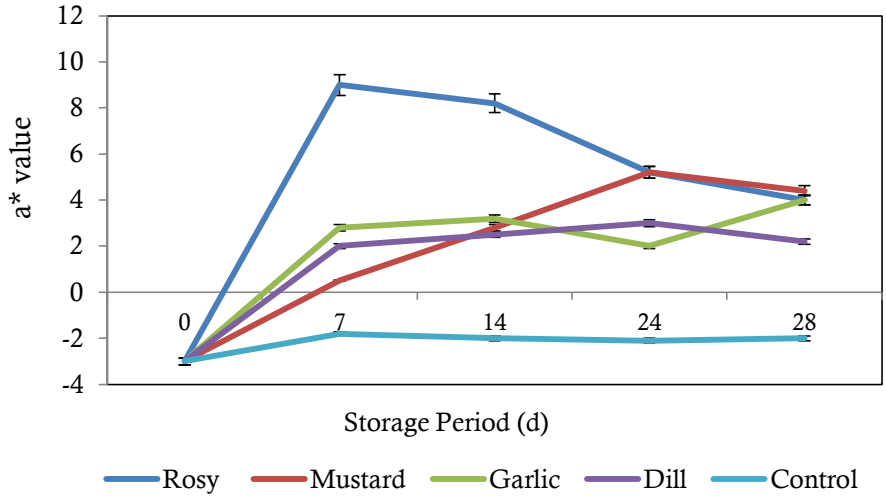

Figure 3: Redness and greenness (a* value) of the pickled quail egg whites during the storage period.

Effect of pickling on the proximate composition of the pickled quail eggs

The moisture, crude fat and crude protein contents of freshly cooked quail eggs and the pickled quail eggs obtained at the end of the storage period are shown in Table 5. Although the freshly cooked whole egg of quail prior to pickling contained approximately 74.53% of moisture and, the moisture contents of the whole eggs were declined after four weeks of the pickling. Results of the present study suggested that, the moisture percentage of all treatments and freshly cooked quail eggs were different (P<0.05). The moisture losses of 28 d pickled quail eggs could be related to the different ingredients and different initial acid strength used in each recipe. The findings of the studies of Brar *et al*. (2015) showed that, the moisture content of the egg albumen in the pickled eggs decreased during the storage period at ambient temperature (22 - 28 °C) due to movement of water from higher level to lower level (syneresis) during the pickling period.

Table 5: The proximate composition of freshly cooked egg and 28 d stored picked quail eggs.

Component (%)	Freshly cooked egg	Pickled eggs in different treatments				
		Rosy	Garlic	Dill	Mustard	Control
Moisture	74.53± 0.08^{b}	65.30± 0.04^{e}	69.67± 0.02^{d}	72.42± 0.01^{c}	58.56± 0.02^{f}	70.19± 0.03^{a}
Crude Fat	11.63± 0.11^{a}	10.42± 0.12^{c}	10.05± 0.04^{d}	10.12± 0.07^{d}	9.82± 0.02^{e}	11.05± 0.04^{b}
Crude Protein	9.83± 0.09^{e}	13.16± 0.08^{b}	12.86± 0.08^{c}	12.85± 0.10^{c}	12.74± 0.07^{c}	14.53± 0.10^{a}

All values are means of triplicate determinations ± standard deviation (SD)

^{a,b,c} Values within a row that not sharing a common superscript differ significantly

In the present study, the crude fat content of four pickled quail eggs were significantly (P<0.05) lower than the freshly cooked quail eggs and the crude protein content of all of the pickled quail eggs were higher (P<0.05) than that of the freshly cooked quail eggs. According to Brar *et al*. (2015), the protein content of egg albumen of the pickled egg was increased during the storage period due to moisture losses of the pickled eggs in that period. Similar results were reported by Singh *et al.* (1998). Even though, the fat content of the egg albumen of the pickled chicken eggs that marinated with different oils; mustard oil, groundnut oil, soybean oil and palm oil was increased in the studies done by Brar *et al*. (2015). The fat content of the pickled eggs was significantly (P<0.05) decreased in this study. This may be happened due to absorb of moisture to egg yolk by osmosis during the pickling process.

According to the findings of Bayomy *et al.* (2017), the moisture, dry matter, total lipids and proteins of pickled quail eggs are indicated as 53.32±1.74%, 46.68±0.86%, 20.09±0.85% and 20.38±2.03% in wet basis, respectively. In a similar study of the pickled quail eggs done by Fernando and Aidee (2011) found that the proximal composition of the pickled quail eggs with a protein content of 13.6±2.1% and total lipids of 12.59±2.2% in wet basis. Furthermore, Tunsaringkarn *et al.* (2013) indicated that the quail eggs have 9.89, 12.70 and 72.25 g/100 g values as for fat, protein and moisture, respectively. According to the results of this study, the moisture, fat and protein composition of 28 d stored pickled quail eggs were ranged within 58.56 - 72.42, 9.82 - 11.05 and 12.74 - 14.53%, respectively.

Effect of pickling of the quail eggs on the organoleptic characteristics and consumer acceptance

According to Figure 4, the highest organoleptic scores for color and aroma were given to the control (P<0.05) while the lowest values for above

mentioned both organoleptic characteristics were given to "Rosy pickle solution" (P<0.05). However, the hig hest scores for taste and texture were given to "Rosy pickle solution" (P<0.05). The beetroot juice in "Rosy pickling solution" may be caused to wide range of the tenderness and flavor variations of the pickled quail eggs which resulted the highest scores for texture and taste. Even, McCready (1973) stated that, red and white were the most preferred color for the pickled eggs, the pickled quail eggs of "Rosy pickling solution" which had reddish color showed the lowest scores for color attributes by the panelists (P<0.05). When considering the overall acceptability values, all treatments except Garlic pickled eggs showed significantly similar scores. However, results of the sensory evaluation concluded that Rosy and control pickled quail eggs could be more acceptable product for the market than the rest of the products. The modifications done in the pickling process in Experiment 2 caused to improve the quality and sensory attributes over to the Experiment 1 such as; reducing the cloudiness of the pickling solutions, pleasant flavor variations due to seasoning/aging in 7 d and safety of the product due to pasteurization during the pickling process.

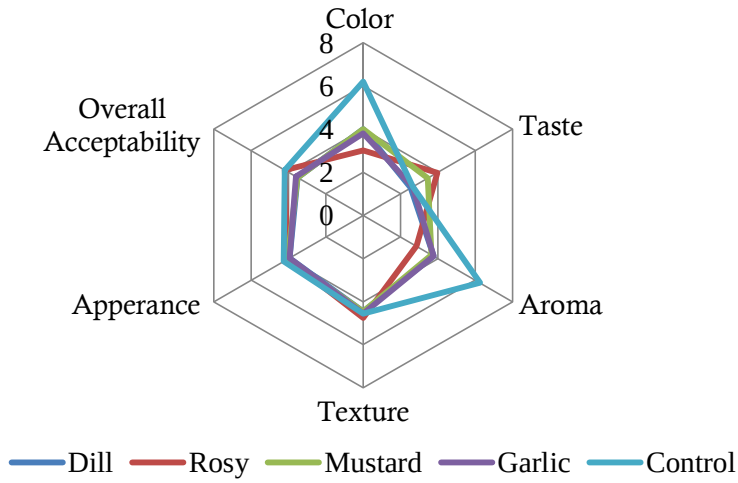

Figure 4: The pattern of sensory attributes of the pickled quail eggs at the end of the storage period.

CONCLUSIONS

The different pickling solutions influenced on the tenderness of egg whites of the pickled quail eggs. In the preparation of pickling solutions, reduction of particle size of solid ingredients, ageing of pickle solution, centrifugation and filtering of pickling solution may be caused to enhance the quality of quail egg pickles. The Rosy pickle solution showed a difference of initial pH of the pickling solution. The quail egg whites of all four types of pickles resulted

increase of darkness during the pickling period of quail eggs. Pickling of quail eggs resulted significant difference in moisture losses at 28 d of pickling period. Rosy and control pickled quail eggs showed similar response for the overall acceptability. The picked quail eggs with only vinegar and salt and the "Rosy pickle" have the most consumer acceptability and these two quail egg pickles can be recommended to introduce to Sri Lankan egg industry as value-added products.

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