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Physicochemical and Sensory Characteristics of Pickled Hen Egg and Its Calcium Content and Antioxidative Activity

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Abstract Pickled hen egg dipped in brewed apple vinegar for 7 and 14 days was prepared and changes of weight, pH, viscosity, calcium content, antioxidative effect, and sensory characteristics were determined. During a pickling, the egg weight was increased from 62.03 g at day 0 to 91.13 and 94.93 g at day 7 and 14, respectively. The pH of the egg white and yolk, initially at pH 10.24 and 6.56, was decreased, while that of the pickling solution was increased by the pickling days. Viscosity of the pickled egg white was significantly decreased with the pickling days ($p<0.05$). Significant antioxidative effect was found from the pickled egg mixture (egg white:yolk=1:1). Calcium content of the egg white after 7 and 14 days of the pickling was 280-300 times higher than the fresh egg white and 1.9 times higher than fresh egg yolk. Addition of plain yogurt and honey improved the sensory quality of a pickled egg and was able to mask the unpleasant sour taste. Results suggest that, in addition to the use of pickled egg by itself, egg-based foods such as mayonnaise with enforced calcium content can be developed using a pickled egg.

Keywords: pickled egg, physicochemical, sensory quality, calcium, antioxidative

Introduction

Hen egg is well known to be a perfect food for human with milk since it is an excellent source of proteins and essential amino acids, has a high digestibility, and is relatively cheap (1,2). The major food products using whole hen egg include smoked, marinated, pickled egg, and pidan. Pickled egg is prepared by adding vinegar to raw, whole eggs, followed by 5 to 10 days of a pickling, and then conventionally served as food without any further processing. The whole egg and its solution are served as a health-maintaining drink at an amount of 10-20 mL per dose (3). As vinegar for manufacturing a pickled egg, unhulled rice, apples, lemon, or plum vinegar are usually used (4). This pickled egg has been traditionally used for the treatment of diabetes, osteoporosis, and other patients who are in a period of recovery (5). However, a solubilized calcium and other minerals such as magnesium, potassium, aluminum, manganese, iron, selenium, zinc, and their acid salts are very bitter and furthermore acrid to the taste, and the pickling solution is extremely unpalatable, in combination with the sour taste of acid (3).

Calcium is a major component of bone and teeth, and also a very important inorganic compound related with a major metabolism process in the human body such as enzyme activation, neuro-modulation, and muscle contraction. Thus, the health authority of Korea enforces the recommendation of a daily calcium intake but still it is not sufficient. It may be due to an increase of calcium requirement, changes of a calcium metabolism, and a decrease of a calcium absorption in humans (6). Calcium absorption rate is known to be dependent on various factors. Shin *et al*. (7) reported that an increase of dietary proteins from animal origins may accelerate a calcium excretion from body, resulting into a calcium shortage in humans. However, Jung and Choi (8) indicated that a 40% of dietary protein level increased the efficiency of calcium absorption, thereby providing a beneficial effect to a human bone density. Chang *et al*. (9) reported that a level of protein intake affected a calcium or bone metabolism differently.

During the manufacture of a pickled egg using vinegar an acidified pickled egg can be a very good source of natural calcium supplements but its information is very limited. In fact, among the egg shell produced in Korea, very limited amount is used for the calcium supplements in processed food or animal feed, and the majority of egg shell is abandoned. These egg shells, a major byproduct in the egg industry, are composed of 95% minerals, 3% protein, and 2% moisture. Of the minerals, $CaCO_3$, $MgCO_3$, and $Ca_3(PO_4)_2$ were 93.7, 1.3, and 0.8%, respectively (10).

Therefore, the present study was designed to investigate the physicochemical and sensory characteristics and calcium content of the pickled egg. Especially for the sensory characteristics, a plain yogurt, honey, and milk were used as carrier foods to mask the unpleasant sour taste for the development of a pickled egg-based beverage in the future.

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Materials and Methods

Materials Hen eggs were purchased from a local store in Daejeon, Korea and the general quality characteristic of the eggs was measured. Vinegar (apple-based, 6-7% acetic acid concentration) for a pickled egg manufacturing and other products for sensory analysis such as plain yogurt, honey, and milk were also purchased from a local store in Daejeon, Korea.

Manufacturing a pickled egg Raw shell eggs with similar weight (approximately 60-62 g/egg) were collected, washed with tap water and dried with a paper towel. Thirty eggs per batch were transferred into a glass container (5 L) and apple vinegar with 2-folds volume was added on the basis of total egg weight (v/w). The glass container was tightly sealed with wrap and placed on the dark for 7 and 14 days at room temperature (approximately 22±3°C) for a pickling process. The whole manufacturing of a pickled egg and analyses were performed twice.

Measurement of the egg quality Physical characteristics of the egg including the egg weight, egg shell color, albumen height, yolk color, and Haugh unit score were measured electronically by an automatic egg quality measurement system (QCM+ System, Technical Services and Supplies, York, UK). For the yolk color, egg yolk was separated from the albumen and placed on a small white bowl underneath of a QCC yolk colorimeter (Technical Services and Supplies). The instrument measured the ratio of red, green, and blue light reflected from the yolk when illuminated by a flashed white light and automatically compared these values with known percentages of the 1 to 15 colors of the Roche color fan score which are pre-programmed into the colorimeter. Eggshell breaking strength of each egg was determined by an egg shell force gauge (Model-II; Robotmation Co., Ltd., Tokyo, Japan). The eggs were placed horizontally in a cradle under a sensor load and the load applied a pressure to the eggs until the shell fractured. The force needed to fracture the eggs was automatically recorded in kg unit. Data from a replicate were averaged to give one value per replicate.

pH During the manufacturing of the pickled egg, pH was measured at day 0, 7, and 14 for the pickling solution, egg white and yolk. In detail, 1 g from each sample was added into 9 mL distilled water (DW) and homogenized for 30 sec at 20,000 rpm using a homogenizer (Ultraturrax T25; IKK, Staufen, Germany), centrifuged (920×g for 10 min), and measured the upper layer of the homogenate using a pH meter (Digi-Sense, Model 5985-80; Cole-Parmer Instrument Co., Chicago, IL, USA).

Viscosity Egg yolk and white was separated and approximately 100 g of each yolk and white was weighed. Then DW was added at 4 times the weight and measured the viscosity using a rotary viscometer (VT-03F; Rion Co., Tokyo, Japan) at room temperature. Used spindle was No. 4 and the measurement was done for 3 times with 2 min-intervals at 62.5 rpm.

Inhibition of a lipid oxidation for a pickled egg Meat homogenate was prepared to investigate the effect of a pickled egg for an inhibition of a lipid oxidation. Pork loin was purchased from a local market and ground through a 9-mm plate. An equal amount of egg yolk and white from a pickled egg was mixed with a glass bar by hand for 30 sec. To 5 g of ground pork loin, 15 mL of DW and a mixture of prepared pickled egg (1 and 2 mL) were added. The mixture of fresh egg yolk and white was also prepared and 1 mL was added for a control. The sample mixture was, then, homogenized with a homogenizer (DIAX 900; Heidolph Co., Ltd., Schwabach, Germany) at 20,000 rpm for 1 min. The homogenate was placed in an incubator set at 37°C for the acceleration of a lipid oxidation development and the 2-thiobarbituric acid reactive substances (TBARS) value was measured (11) at day 0, 3, and 6 of incubation. Each meat homogenate mixture (1 mL) was transferred to a glass test tube (15-mL) and mixed with 2 mL of 20 mM 2-thiobarbituric acid in a 15% trichloroacetic acid solution, heated in boiling water, and centrifuged for 15 min at 980×g using a centrifuge (UNION 5KR; Hanil Science Industrial Co., Ltd., Incheon, Korea). The absorbance of the supernatant was measured at 532 nm using a spectrophotometer (UV 1600 PC; Shimadzu, Tokyo, Japan). The concentration (mg malondialdehyde/kg meat sample on the basis of wet weight) was calculated by using a standard curve.

Calcium content of a pickled egg Pickled eggs (totally 30) were separated into egg yolk and white and individually homogenized. These samples were measured their calcium contents (12). In detail, each 0.1 g of egg yolk, white, and pickling solution were mixed with 65% suprapure nitric acid (Merck KGaA, Darmstadt, Germany) and pretreated using a microwave digestion system (MARS 5; CEM Co., Matthews, NC, USA) at conditions of 1,200 W, 150 psi, and 150°C for 30 min. The pretreated sample (5 mL) was then mixed with DW (5 mL) and measured using an Optima 4300 DV inductively coupled plasma-optical emission spectrometer (ICP-OES; Perkin-Elmer, Norwalk, NJ, USA). Each sample was analyzed in duplicate on the conditions indicated in Table 1. To develop a standard curve 100 μg/mL of a Quality Control Standard 21 (Perkin-Elmer) was used and WinLab 32 Instrument Control software (Perkin-Elmer) was used for a data analysis.

Table 1. Conditions of the inductively coupled plasma-optical emission spectrometer (ICP-OES) for measuring the calcium contents in the pickled egg

Item	Condition
Radiofrequency power (W)	1,300
Gas flows (L/min)	
Plasma	15.0
Auxiliary	0.2
Nebulizer	0.8
Nebulizer type	Cross-flow
Peristaltic pump speed (mL/min)	1.5
Equilibrium time (sec)	15

Table 2. General egg quality for manufacturing a pickled egg

Egg weight (g)	Shell color	AH	HU	Yolk color	Shell strength (kg)
62.03±2.034[1)]	37.40±3.646	1.60±0.932	27.8±13.261	8.00±0.707	3.31±0.376

[1)]Mean±SD (n=25); AH, albumen height (mm); HU, Haugh unit.

Sensory evaluation After dipping it into apple vinegar (solution) the pickled egg's shell was removed at day 7 and 14 and the egg yolk and white was separated. Then an equal amount of yolk and white was mixed with a glass bar by hand for 30 sec and used for a sensory evaluation. For a carrier material to overcome the sour taste of a pickled egg, plain yogurt, honey, and milk were tested to make a beverage-type food with a 0, 20, 40, and 80% concentration of the pickled egg mix. Ten semi-trained panelists, who were composed of graduate student and staff including 6 females and 4 males and had experiences in a sensory analysis for raw and cooked eggs, were selected. The sensory panelists were provided a sample individually in a sample cup (approximately 20 g). Drinking water was given to eliminate remaining taste after they evaluated each sensory attribute. The evaluated sensory parameters were color, odor, taste, intensity of a sour taste, and overall acceptance by using a 9-point hedonic scale (1, very unpleasant; 9, very pleasant).

Statistical analysis The data was collected and analyzed by SAS software (Version 8.02; SAS Institute, Cary, NC, USA). A general linear model (GLM) procedure was performed and mean values and a standard deviation were reported. Duncan's multiple range tests was used to compare the mean values and $p<0.05$ was considered as statistically significant.

Results and Discussion

Physicochemical characteristics The general quality of hen egg for manufacturing a pickled egg is shown in Table 2. The egg weight, shell color, Haugh unit, and yolk color were 62.03 g, 37.4%, 27.8, and 8.0 (Roche color pan score), respectively. The egg shell strength was 3.31 kg. The albumen height and Haugh unit of the fresh eggs are more than 9 mm and 65, respectively. According to the albumen height and Haugh unit, the eggs purchased from the local market and used for the preparation of a pickling showed a relatively poor quality initially. Albumen quality could be determined not only by egg freshness but also by other factors such as a hen's age and genotype and dietary ingredients (13,14). Also, Silversides and Villeneuve (15) reported that an egg's size is known to affect the albumen height and Haugh unit.

Figure 1 shows the weight changes of an egg as a function of immersion time during pickled egg manufacturing. The egg weight was increased to 46.9 and 53.3% from the initial egg weight after 7 and 14 days, respectively ($p<0.05$). It is clear that the apple vinegar solution penetrated through the egg shell by solubilizing it and enlarged the volume of the egg inside. As Yang (5) and Han (16) reported, the egg white and yolk may be coagulated from this acidic condition.

Generally, the pH value of a fresh egg ranges 7.6-8.5 but it can reach over 9.6 by increase of a storage temperature and time (17). The pH changes of a pickled egg are shown in Fig. 2. The pH of the egg white was changed from 10.24 at day 0 to 4.84 and 4.99 after 7 and 14 days of a pickling, respectively, which showed a significant decrease by a penetration of the acidic pickling solution. There was no difference found in the pH of the egg white between day 7 and 14. The pH of the egg yolk was also decreased from 6.56 to 4.61 at day 7 and maintained this value thereafter. On the other hand, the pH of the pickling solution was increased from the original 2.91 to 3.57 at the time of an immersion then increased continuously to 5.01 until day 14. This change of the pH values confirmed the results

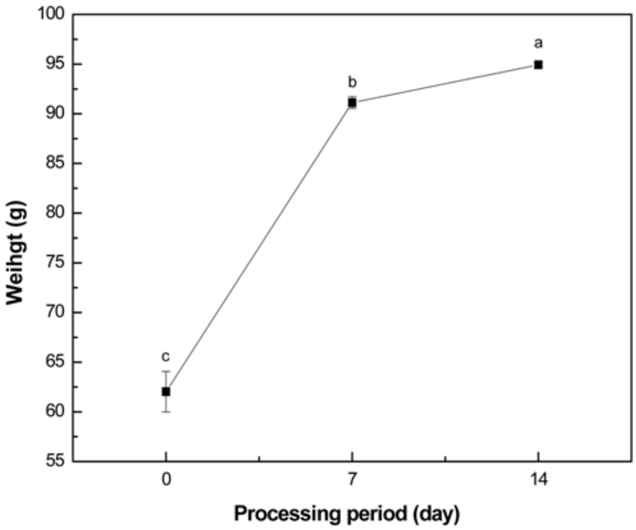

Fig. 1. Weight change of the pickled egg during a manufacturing (g/egg).

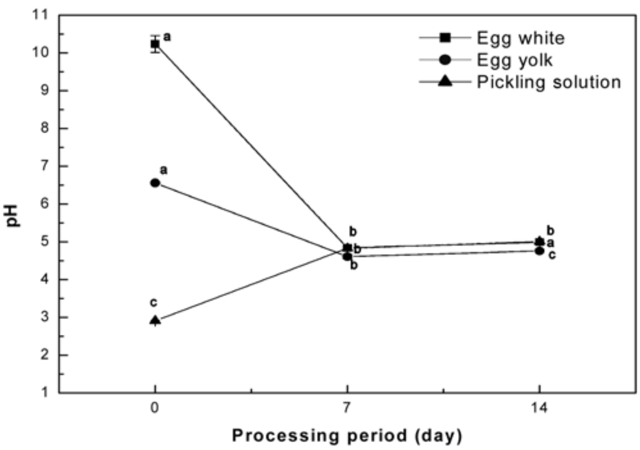

Fig. 2. pH changes for the pickled egg white, yolk, and pickling solution during a manufacturing.

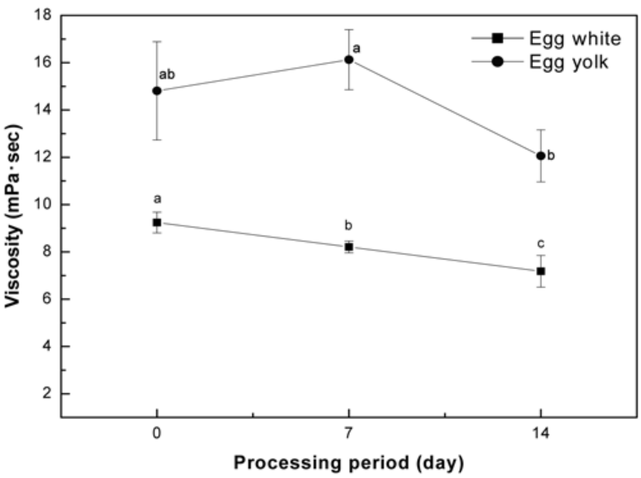

Fig. 3. Viscosity changes for the pickled egg white and yolk during a manufacturing.

from Yang (5) who reported that the picking solution penetrated into the inner part of the egg and that the egg white and yolk are acidified and the pickling solution was alkalized.

The viscosity of an egg is a major criterion to judge its freshness and the functionality of a fresh egg. Figure 3 shows the viscosity changes of the egg yolk and white after an immersion the eggs into pickling solution during storage. The viscosity of the egg white at day 0 (9.24 mPa · sec) decreased at day 7 (8.21 mPa · sec) and 14 (7.18 mPa · sec) after immersion of egg, however, that of egg yolk at day 0 (14.81 mPa · sec) increased during the first 7 days (16.13 mPa · sec) and decreased again at day 14 (12.06 mPa · sec). It is well known that egg proteins such as ovomucin play a key role in the viscosity of egg white (18) and an increased storage time degrades these proteins, thereby resulting in a decrease of the viscosity. Heat or acid treatment of egg white may reduce its fluidity and coagulate by conformational changes of a protein. Egg yolk is generally composed of 50% water, 35% lipid, and 15% protein (19). Because of the difference of molecular weight and isoelectric point of protein between egg yolk and white (20), even if they showed a similar pH decrease, they may have different changes in their viscosity. Yang (5) manufactured pickled quail eggs and investigated the changes of the viscosity during storage for 5, 10, and 15 days at 20°C. The viscosity of the quail egg white was 1.5 cp higher than the yolk but during storage no difference was found in the viscosity. Forsythe and Berquist (21) suggested that eggs from different birds differ in the pattern of their viscosity change.

Inhibition effect of a pickled egg on lipid oxidation A ground pork homogenate was used to investigate the inhibition effect of a pickled egg against a lipid oxidation during storage at 37°C. When 1 mL pickling solution or 1 mL pickled egg (yolk:white=1:1) of the 7th day pickled egg mixture was added into a meat homogenate, the TBARS values of the meat homogenate showed no difference during storage for 6 days (Table 3). However, after storage for 6 days at 37°C, the TBARS value of the meat homogenate containing the fresh egg showed the highest value followed by that containing 2 mL of the pickled egg mixture and 1 mL of the pickling solution. The results of a relatively higher TBARS value in the homogenate with 2 mL of pickled egg than that of 1 mL of pickled egg or pickling solution may be due to the higher content of egg yolk lipid. The addition of the 14th day pickled egg resulted in a strong inhibition of a lipid oxidation in the meat homogenate system at 3 and 6 days of a storage (Table 4). When compared with the 7th day of pickled egg, the addition of the 14th day of pickled egg showed slightly higher TBARS value. It can be explained by the results of Rhee *et al*. (22), who reported that a lowering of a meat pH can accelerate a lipid oxidation in

Table 3. 2-Thiobarbituric acid reactive substances (TBARS) values of the meat homogenate with the addition of the 7th day pickled egg during a storage at 37°C

Sample	Storage (day)		
	0	3	6
Pickled egg (1 mL)	$0.36^{a}\pm0.034^{1)}$	$0.38^{ay}\pm0.041$	$0.37^{bz}\pm0.000$
Pickled egg (2 mL)	$0.35^{c}\pm0.032$	$0.50^{bx}\pm0.043$	$0.63^{ay}\pm0.013$
Fresh egg (1 mL)	$0.42^{c}\pm0.035$	$0.52^{bx}\pm0.135$	$0.73^{ax}\pm0.018$
Pickling solution (1 mL)	0.42±0.030	$0.40^{y}\pm0.032$	$0.40^{z}\pm0.044$

1)Mean±SD; a-c, x-zmeans within the same row and column, respectively, with the same superscript were not significantly different (p<0.05).

Table 4. 2-Thiobarbituric acid reactive substances (TBARS) values of the meat homogenate with the addition of the 14th day pickled egg during a storage at 37°C

Sample	Storage (day)		
	0	3	6
Pickled egg (1 mL)	$0.42^{bz}\pm0.035^{1)}$	$0.47^{aby}\pm0.015$	$0.54^{ay}\pm0.045$
Pickled egg (2 mL)	$0.58^{bx}\pm0.015$	$0.69^{ax}\pm0.037$	$0.67^{ax}\pm0.030$
Fresh egg (1 mL)	$0.47^{by}\pm0.032$	$0.94^{aw}\pm0.036$	$0.96^{aw}\pm0.080$
Pickling solution (1 mL)	$0.37^{az}\pm0.011$	$0.27^{bz}\pm0.035$	$0.35^{az}\pm0.078$

1)Mean±SD; a-c, x-zmeans within the same row and column, respectively, with the same superscript were not significantly different (p<0.05).

Table 5. Calcium content (ppm) of the pickled egg during a manufacturing

	Day 0	Day 7	Day 14
Egg white	30.23^{c}±0.500	$9,015.81^{a}$±0.715	$8,426.05^{b}$±0.050
Egg yolk	$1,381.10^{c}$±0.760[1)]	$2,653.00^{a}$±0.529	$2,630.70^{b}$±0.404
Pickling solution	$-^{c}$	$9,549.66^{b}$±0.557	$10,082.68^{a}$±0.246

[1)]Mean±SD; $^{a-c}$means within the same row with the same superscript were not significantly different (p<0.05).

stored meat, resulting in an increase of TBARS values. Kim *et al*. (23) also reported that the pH of raw ground pork inoculated with *Lactobacillus casei* decreased because *L. casei* produced lactic acid during its growth and this pH decrease contributed to have the higher TBARS values. However, the pH decrease by the addition of pickled egg did not increase lipid oxidation in meat homogenate in the present study. Therefore, other factors, partially by opening the antioxidative system from the denaturation of the proteins, may be the reason of the inhibition of lipid oxidation. A further research is needed to identify the stimulation of the antioxidative system of a pickled egg during manufacturing process.

Calcium content Calcium content was measured for the pickled egg white, egg yolk, and pickling solution during a manufacturing (Table 5). At day 0 of a pickling, the calcium content was 30, 1,381, and 0 mg/L in the egg white, yolk, and pickling solution, respectively. However, the calcium content of the egg white was 3.4 and 3.2 times higher than those of the egg yolk after 7 and 14 days of a pickling, respectively. This value is 280-300 times higher than fresh egg white and 1.9 times higher than the fresh egg yolk. Also, in the pickling solution 9,550 and 10,083 mg/L of calcium was found at day 7 and 14, respectively. Egg shell is mainly composed of calcium carbonate thus it is a very good natural calcium source. Therefore, a certain portion of the egg processing industry separates the egg shell followed by a washing and drying for a natural calcium enrichment source as a powdered form (7). However, because an egg shell is insoluble, it is hard to apply it to a liquid- or paste-type food even after manufacturing a powdered form (24). Pickling solution, a byproduct of manufacturing a pickled egg, therefore, can be a good source for a calcium-enriched food.

Lee and Kim (25) measured the blood calcium level of female Sprague-Dawley mouse after a supplementation of calcium with different solutions for 9 hr with 1-hr interval and reported that the calcium level in the blood was the highest in the mouse with a supplementation of calcium with rice hull vinegar followed by vacuum packed brewed vinegar, aerobic packed brewed vinegar, precipitate calcium carbonate, and egg shell calcium. They demonstrated that calcium availability is not dependent on the amount of calcium intake but the ionization of calcium, and the mixing with brewed vinegar showed the higher ionization effect (25). Therefore ionization of calcium during the manufacturing of a pickled egg may help the calcium absorption rate in the human body.

Daily required calcium intake in Korea is 900 and 700 mg for the male ages 10 and 20, respectively (26). For a female, the required value is 800, 700, and 800 mg for teen-ages, ages 20-40, and over ages 50, respectively. Use of picked egg as a calcium supplement will be beneficial. Furthermore, an egg white from a pickled egg may be used for a food processing as ordinary additives for foaming, gelling, and binding abilities in the confectionary and processed meat industries as well as egg-based foods such

Table 6. Sensory characteristics of the 7th day pickled egg with honey, milk, and plain yogurt

% Additive	Color	Aroma	Taste	Sour taste	Overall acceptability
		Pickled egg with honey			
0	6.3^{a}±1.28[1)]	5.5±1.31	5.6±1.51	5.3±0.89	5.5±1.41
20	5.6^{a}±1.06	5.0±1.31	4.8±1.04	5.4±1.30	5.0±1.07
40	5.6^{a}±0.92	5.0±1.41	5.1±1.46	5.8±1.28	5.3±1.49
80	4.5^{b}±0.53	5.3±1.28	5.4±1.51	5.3±1.49	5.1±1.46
		Pickled egg with milk			
0	5.1±1.73	4.3^{b}±0.89	4.9±1.13	6.0±1.20	4.9±0.99
20	5.4±0.92	4.8^{ab}±1.16	5.3±0.89	5.4±0.92	5.0±0.76
40	6.3±1.388	5.0^{ab}±1.69	5.9±1.25	5.3±1.16	5.8±1.16
80	4.6±1.69	6.0^{a}±1.31	5.9±1.55	4.6±1.77	5.4±1.19
		Pickled egg with plain yogurt			
0	4.9±1.46	5.3±0.89	4.9^{b}±1.55	6.1±1.64	5.1^{b}±1.36
20	5.6±0.52	5.0±1.20	5.4^{ab}±0.92	5.4±0.92	5.1^{b}±0.99
40	5.9±1.25	5.0±0.93	5.5^{ab}±0.93	5.6±1.19	5.3^{b}±0.89
80	4.8±1.75	5.8±0.89	6.4^{a}±0.92	5.6±1.06	6.5^{a}±0.93

[1)]Mean±SD; $^{a-b}$means within the same column with the same superscript were not significantly different (p<0.05).

Table 7. Sensory characteristics of the 14th day pickled egg with honey, milk, and plain yogurt

% Additive	Color	Aroma	Taste	Sour taste	Overall acceptability
			Pickled egg with honey		
0	6.6^{a}±1.30[1)]	5.9±0.99	4.9^{b}±0.64	6.4^{a}±1.19	5.0^{b}±0.93
20	5.9^{a}±1.36	4.9±1.25	5.4^{b}±0.74	5.9^{ab}±1.46	5.0^{b}±0.93
40	4.5^{b}±0.76	4.9±1.25	5.9^{ab}±1.36	4.8^{bc}±1.39	5.4^{b}±1.06
80	4.1^{b}±0.64	4.8±1.67	6.9^{a}±1.13	4.0^{c}±1.51	6.4^{a}±0.92
			Pickled egg with milk		
0	5.6±1.69	4.4±1.30	4.9±0.64	5.5^{a}±1.77	4.4±1.06
20	6.3±1.39	5.8±1.16	5.3±0.71	5.0^{ab}±1.41	5.3±1.16
40	5.8±0.46	5.6±1.06	5.8±1.28	4.4^{ab}±0.74	5.6±1.41
80	5.4±0.92	5.5±1.60	5.6±1.30	3.9^{b}±0.83	5.1±1.55
			Pickled egg with plain yogurt		
0	5.1±1.96	5.0±1.41	5.1±1.46	6.5^{a}±1.51	4.9±1.13
20	5.9±1.46	5.9±0.83	5.4±1.19	5.4^{ab}±1.19	5.4±1.19
40	5.6±0.74	5.8±0.71	6.3±1.04	4.6^{bc}±1.30	5.6±1.19
80	5.5±1.07	6.0±1.69	6.5±1.41	3.8^{c}±1.04	5.9±1.46

[1)]Mean±SD; [a-b]means within the same column with the same superscript were not significantly different ($p<0.05$).

as mayonnaise. An egg yolk from a pickled egg can also be used in the same manner in a conventional processing with a flavor, color, viscosity, emulsion capacity, and others (27) with a calcium enhancing function.

Sensory analysis Table 6 shows the sensory characteristics of the 7th day pickled egg with honey, milk, and plain yogurt. Color of the pickled egg with 80% of honey showed a significantly lower score compared with the rest of the treatments ($p<0.05$). However, taste, intensity of the sourness, and overall acceptance of the pickled egg were not affected by the inclusion of honey at any concentration. Similar to this, the inclusion of milk at a 0, 20, 40, and 80% of concentration did not change the color, taste, intensity of the sourness, and overall acceptance of the pickled egg. On the contrary, the pickled egg with plain yogurt at a 80% concentration revealed a significantly improved taste and resulted in a better overall acceptance at the same concentration ($p<0.05$). From the result, plain yogurt was the best additive to improve the sensory quality for the 7th day pickled egg.

Pickled egg with honey with 40 and 80% concentrations showed significantly lower color scores (Table 7). However, the addition of honey significantly decreased the intensity of the sourness and increased the taste and overall acceptance. Overall acceptance of the 14th day pickled egg was not affected by the addition of milk and yogurt at any concentration, while the intensity of the sourness was significantly decreased ($p<0.05$) with an increase of the addition of those additives. These result showed a difference from the 7th day pickled egg and only plain yogurt at an 80% concentration improved its acceptance as shown in Table 6. This result may be due to the fact that, with a longer dipping period in vinegar, the 14th day pickled egg was sourer than that of the 7th day pickled egg ($p<0.05$) and the honey (80% addition in the pickled egg) whose sweet taste strongly reduced the sourness and improved the acceptance. Siebert (28) and Da Conceicao Neta *et al.* (29) reported that a sour taste is the aspect of a flavor most commonly associated with acids, although other taste characteristics such as a bitterness, saltiness, and astringency may coexist. This was in agreement with the comment of one of our panelists, who reported that there was a bitterness and saltiness in the 14th day pickled egg with a low concentration of additives and in itself alone.

Pickled egg dipped in apple vinegar for both 7 and 14 days could be a good source for the development of a calcium-enriched food and beverage with an antioxidative activity. Plain yogurt and honey would be potent additives to reduce the unpleasant sour taste and increase the overall acceptance.

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