CHEMICAL ENGINEERING TRANSACTIONS
VOL. 101, 2023
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Paolo Ciambelli, Luca Di Palma

ISBN 979-12-81206-00-7; ISSN 2283-9216
DOI: 10.3303/CET2310104

Analysis of Quality and Shelf Life of Quail Eggs (Coturnix Coturnix Japonica) in Sauce of Beta Vulgaris "Beterraga”

Ángela E. Estrada Cadillo[a], Roberto H. Tirado Malaver[a*], Fredesvindo Fernández Herrera[a], Edson M. Caro Degollar[a], Ángel Campos Julca[a], Roberto Tirado-Lara[b], Rubén Paredes Martínez[a]

[a]Universidad Nacional José Faustino Sánchez Carrión, Huacho, Perú
[b]Universidad Nacional Pedro Ruíz Gallo, Lambayeque, Perú.
hugotiradomalaver@gmail.com

To increase the shelf life of quail eggs and maintain their quality, a good preserving medium must be available. Therefore, the objective of this research was to determine the effect of Beta vulgaris "Beterraga" sauce as a preserving liquid on the shelf life, sensory acceptability and quality of quail eggs. A complete randomized design was used, which consisted of 5 treatments which were the formulations where the Beta vulgaris pulp was incorporated in 5 levels (0, 25, 50, 50, 75 and 100%) of a variable matrix which was completed with treated water. Acceptability was evaluated using a consumer panel, and the stability of pH and color of egg white, yolk and whole egg during storage was determined. Accelerated tests were used to determine shelf life and the data were processed through analysis of variance and Duncan's test. The results indicated that T4 (75% Beta vulgaris) presented the highest acceptability compared to the other formulas, its pH stabilized after 11 days, the color also stabilized from cream-gray to red and finally to purple, the shelf life reached with the F4 formulation was 360 days. Therefore, the use of 75% of Beta vulgaris as a preserving liquid allows maintaining the external and internal quality and microbial load of the quail egg for a longer storage period at different temperatures, improving its diffusion and commercialization throughout the nation.

1. Introduction

Quail eggs (*Coturnix coturnix* japonica) are considered one of the most consumed foods in the world, as they are a natural source of proteins, minerals, vitamins, phospholipids and low cholesterol content, necessary for human nutrition (Matos et al., 2023). However, chicken eggs are more widely consumed worldwide, although the high cost of this food makes consumption difficult in low-income areas (Petek et al., 2022). Quail eggs, on the other hand, due to their chemical composition in the albumin, are not harmful for people with allergies (Mokhtarzadeh et al., 2022) and contains a rich source of immune enzymes and its low price makes it more affordable (Cufadar et al., 2022).
However, eggs are a perishable food and as such have a limited shelf life, as processes occur that alter the chemical, physical and functional properties of the food (Pires et al., 2019). Once the cooked egg is obtained, the metabolic process is accelerated and this can cause a deterioration in the internal quality and it is also susceptible to the invasion of microorganisms that produce mucus and bad odors, implying risks to public health (Soares et al., 2021).
Therefore, the loss of quality of the cooked egg is imminent due to microbial activity and biological composition, since the yolk has lipids and is susceptible to oxidation due to its polyunsaturated fatty acid content, which consequently causes undesirable flavor (Araújo et al., 2019). In view of this fact, the use of canning liquid is an option to maintain the stable chemical characteristics of the quail egg, and the beterraga sauce can be used as a key raw material in the formulation of the canned egg. In addition, its compatibility with acetic acid would solve one of the main problems of the canning industry, bacterial growth, which can be solved by developing an acidic canning product (pH < 4.5) that prevents bacterial germination and growth (Hoover, 2022). It should be noted that the use of Beta *vulgaris* (beterraga) as the main input for canning quail eggs is due to its antioxidant activity

3DSHU5HFHLYHG0DUFK5HYLVHG-XQH$FFHSWHG-XO\
3OHDVHFLWHWKLVDUWLFOHDV(VWUDGD&DGLOOR$7LUDGR0DODYHU5+)HUQDQGH]+HUUHUD)&DUR'HJROODU(0&DPSRV-XOFD$7LUDGR/DUD5
3DUHGHV0DUWLQH]5$QDOVLVRI4XDOLWDQG6KHOI/LIHRI4XDLO(JJV&RWXUQL[&RWXUQL[-DSRQLFDLQ6DXFHRI%HWD9XOJDULV%HWHUUDJD´
&KHPLFDO(QJLQHHULQJ7UDQVDFWLRQV2,&(7

produced by betalain, which is a compound used as a natural colorant and food preservative (Popescu et al., 2023). On the other hand, Derelioğlu and Turgay (2022) indicate that there are other preservation methods that extend the shelf life of quail eggs, such methods include additives or the use of coatings to maintain the internal quality of the egg during storage for extended periods, however, it increases the costs of canning and are not usually as effective as vegetable sauce-based preserves. For these reasons, the objective of this research was to determine the effect of *Beta vulgaris* "Beterraga" sauce as a preserving liquid on the shelf life, sensory acceptability and quality of quail eggs.

2. Materials and Methods

This research was conducted during the months of April and July 2021, in Barranca, Lima, Peru.

2.1 Preparation of raw materials

The treatments developed in the present investigation were established based on the levels of the variable matrix for the percentages of *Beta Vulgaris* and treated water of the preserving liquid as detailed in Table 1.

Table 1: Fixed and variable matrix of ingredients for each formulation of the canning liquid

Ingredients		Treatments (%)				
		T1	T2	T3	T4	T5
Fixed matrix	Acetic acid	4.5	4.5	4.5	4.5	4.5
	Salt	4	4	4	4	4
	sodium benzoate	0.5	0.5	0.5	0.5	0.5
	Total sub (A)	9	9	9	9	9
Variable matrix	Agua	100	75	50	25	0
	Beta vulgaris pulp	0	25	50	75	100
	Total sub (B)	91	91	91	91	91
Total (A+B)		100	100	100	100	100

2.2 Statistical application

A completely randomized design was used in the research, with 5 treatments combining 5 levels of *Beta vulgaris* pulp percentage to evaluate its effect on the sensory acceptability, physicochemical characteristics and shelf life of preserved quail eggs.

2.3 Procedures

The process can be seen in the following stages: Stage 1 consists of receiving the quail egg, followed by cooking it for 10 minutes after boiling, then cooling it in drinking water and then stored at 5ºC while the canned products were being prepared. Eggs were heated to 25°C in a water bath and peeled by hand. Stage 2 began with the preparation of the canning liquid, having an acidic condition based on acetic acid so that the canning liquid reaches a pH equilibrium of less than 4.6 to avoid the germination of bacterial spores. They were formulated taking into account a fixed matrix for each of the canned products under test, in which 4.5% acetic acid and a sodium benzoate concentration of 0.5% were considered in each formulation. For canning, the peeled hard-boiled eggs were placed in 300 g transparent glass jars and were added to the liquid in a ratio of 60/40 as according to Acosta et al. (2014).

2.4 Experimental Variables

The analysis of the variables was determined by means of control indicators such as: sensory acceptability, pH stability and egg color. With respect to the sensory acceptability analysis, 34 regular consumers voluntarily tasters who evaluated the attributes: aroma, color, appearance and to express their opinion using a 9-point hedonic test (acceptability) according to Fernandez et al. (2018): “I like it very much” (9) to “I dislike it very much” (1). Likewise, the storage conditions and evaluation times for canned quail eggs in *Beta vulgaris* sauce using temperature-controlled (40, 45 y 50 °C) in six times as recommended by Acosta et al. (2014). The determination of color stability in quail eggs was evaluated with a portable colorimeter calibrated with standard white plate (Y=85.4, x=0.3173, y= 0.3240), each sample was measured three times. The color values were expressed as L* (brightness), value a* (redness or greening) and value b* (yellowness or blueness), as proposed by Cho et al. (2016).

3. Results and Discussion

3.1 Sensory acceptability analysis of canned quail eggs in *Beta vulgaris* sauce

Results of the sensory acceptability analysis of the five formulations of canned quail eggs in beterraga sauce (*Beta vulgaris*) are shown in Table 2, which presents significant differences among treatments, with the treatment T4 (75% de *Beta vulgaris*) statistically superior to the other treatments, reaching a mean acceptability of 8.18 points compared to T2 (25% *Beta vulgaris*) which reported the lowest average with 3.71 points based on the 9-point hedonic scale. This demonstrates that increasing the percentage of Beta vulgaris pulp to 75% increases the shelf life of the product while maintaining the physicochemical characteristics of the quail egg. The results are close to those reported by Gunathilaka et al. (2021) stated that the most suitable pickling solutions are obtained with a level of 80% in pickling solutions as the governing liquid in canned quail eggs and also in agreement with Hoover (2022) who found high acceptability values in pickling solutions of 20% pickled marinated in vinegar for canning quail eggs.

Table 2: Multiple comparison of means by Tukey at 5% for the sensory acceptability of canned quail eggs

Treatment	% *Beta vulgaris*	Means
T4	75	8.18 ± 0.76 a
T5	100	6.41 ± 0.70 b
T3	50	5.18 ± 0.90 c
T1	0	4.68 ± 1.18 c
T2	25	3.71 ± 1.03 d

Table 3, indicates that T4 presented the best acceptability results when stored at high temperatures (40, 45 and 50°C) presents acceptability with a mean of 5.5 (I slightly like it) stored up to 60 days at a temperature of 40ºC, while at 45ºC the acceptability reaches up to 40 days of storage. While storage at 50ºC acceptability reaches 20 days. This indicates that the 75% *Beta vulgaris* formulation maintains the physicochemical characteristics of the quail egg despite the temperature increase. The results indicate that quail egg quality is directly influenced by storage temperature and time, which will determine the shelf life of the *Beta vulgaris* sauce. The results are in agreement with the findings of Brasil et al. (2019) who indicate that temperature influences the loss of internal and external egg quality due to its natural physiological process during the storage period, therefore, the appropriate preserving liquid will allow maintaining the quality properties of quail egg for longer and at different storage temperatures. Also corroborated by Pires et al. (2015) who indicate that the internal and external quality of canned quail eggs is strongly influenced by storage temperature and time.

Table 3: Average acceptability of canned quail eggs in Beta vulgaris sauce during storage at different temperatures.

Time (days)	Mean acceptability		
	40°C	45°C	50°C
0	8. 18	8. 18	8. 18
5	-	-	7. 32
10	-	7. 26	7. 09
15	7. 15	-	6. 38
20	-	7. 03	5. 82
25	-	-	5. 12
30	6. 88	6. 26	4. 29
40	-	5. 68	-
45	6. 18	-	-
50	-	5. 18	-
60	5. 50	4. 59	-
75	5. 06	-	-
90	4. 41	-	-

Likewise, considering a limit value of 6 points on the hedonic scale, which represents an acceptability of "I like it slightly" and for a standard storage temperature of 25°C, the expected shelf life is determined using the Arrhenius equation with the following according to Fernandez et al. (2019). From equation (1) of reaction kinetics of order 0, the shelf life of the quail egg preserve was estimated according to the proposal of Fernandez et al (2019).

For this purpose, the minimum acceptability value classified as "I slightly like" was considered (A = 6) given that the product continues to be pleasing to consumers, in addition, the initial experimental acceptability value obtained in treatment 4 (8.18 points) and the reaction kinetic constant for a constant temperature of 25°C (K_{25} = - 0.00604 dia^{-1}), the lifetime was determined.

$$A = Ao \pm K_{25}t \quad (1)$$

$$6 = 8.18 - 0.0604 \times t \quad (2)$$

$$t = 360{,}17 \text{ days} \quad (3)$$

The results indicate that the T4 treatment (75% *Beta vulgaris*) had a significant effect on the shelf life of canned foods, because the pickling of Beta vulgaris allowed maintaining the external and internal quality of the quail egg for up to 360 days with a high sensory acceptability. This may be due to the increase in viscosity due to the pectin content that the beterraga can provide, generating a sensation of greater viscosity that is less acceptable for the preserving liquid (Ohlmaier et al., 2021). The results are similar to those observed by Hoover (2022) who indicates that the vegetable-based preserving liquid maintains its acceptability for a longer time despite the increase in temperature and that the addition of acetic acid favors its acceptability. Likewise, the results are corroborated by Gunathilaka et al. (2021) who found that the use of pickle-based preserving liquid maintained the physicochemical characteristics and shelf life of quail egg preserves for up to 380 days. In fact, Brasil et al. (2019) indicate that canning eggs at room temperature for long periods of storage causes changes in internal quality, while the appropriate canning liquid allows the quality and microbial load of the egg to be maintained.

3.2 Effect of storage time on quail egg pH

The results in Table 4, indicates that Treatment 4 showed variation in quail egg pH stability with respect to storage time. The albumen pH shows a high initial value of 7.7±0.10 with a decreasing trend until day 11 with the lowest value at pH 4.1±0.10, this is due to its immersion in an acidic Beta vulgaris sauce preserving liquid and the incorporation of acetic acid. On the other hand, the pH of the yolk shows slightly more acidic values of 6.36±0.06, while the pH of the whole egg started with values of 7.23 ±0.15 and gradually acidified to an average of 4.0±0.1. This was achieved over a period of 11 days at room temperature (23 ±4°C). These results indicate that the *Beta vulgaris* sauce as a preserving liquid has a favorable effect on the physicochemical characteristics of the quail egg preserves, since it was able to favorably increase the acidity of the eggs, allowing to achieve pH values of 4.0 ±0.1 in the egg after 11 days of storage, which allows it to be considered as an acid canned product, preventing the germination of pathogenic agents in the product. The variation of the initial pH is due to the proportion of the canning formulation. The results are corroborated by Gunathilaka et al. (2021) found that canned quail eggs in pickle sauce show a decreasing trend in pH by the seventh day, indicating that the acidic condition of the canning liquid is absorbed through the white to the yolk reaching an equilibrium concentration within 3 to 6 days, indicating that there is a relationship between the canning liquid and the pH of the whole egg.

Table 4: pH stability of egg white, yolk and whole egg during storage time

Time (days)	pH		
	Albumen	Yolk	Whole egg
0	7.70±0.10	6.37±0.06	7.20±0.15
1	6.40±0.10	5.47±0.15	6.03±0.12
2	6.10±0.17	5.10±0.10	5.87±0.21
3	5.60±0.30	4.83±0.06	5.30±0.10
4	5.00±0.10	4.33±0.15	4.80±0.10
5	4.87±0.12	4.23±0.06	4.67±0.15
6	4.50±0.10	4.17±0.15	4.53±0.06
7	4.23±0.15	4.07±0.15	4.20±0.10
8	4.10±0.10	4.03±0.06	4.17±0.06
9	4.17±0.06	4.03±0.12	4.13±0.06
10	4.13±0.12	3.97±0.06	4.07±0.06
11	4.10±0.10	3.93±0.06	4.00±0.10

3.3 Quail egg color during storage

Tables 5 show the results of the color during storage of quail eggs of formulation F4 (Treatment 4), which show changes in the color of the white and yolk. As for the color of the whole eggs, the main change was in the white, going from gray to purple, which was achieved in 6 days when the purple intensified and stabilized, since after 6 days there were no noticeable changes in the color. The favorable effect on the physicochemical

characteristics of the canned eggs also includes the coloring effect of the canning liquid, by generating noticeable changes in the values of the coordinates L*, a* y b* the CIELAB color space for the quail egg white and yolk, showing mainly a decrease in the coordinate L* that I pass 79 to 28 in the whole egg, for coordinate a* the change was made from - 2 to 33 and for coordinate b* the change came from 15 a -10 which refers a change from gray to red. The results resemble those found by Ondrušíková et al. (2018) who evaluating the effect of different storage times on quail egg quality characteristics, found that there was a change in quail egg color without affecting the internal quality of the preserved egg. Therefore, the use of beterraga as a preserving sauce allowed to extend the shelf life of quail eggs due to the antioxidant, antimicrobial and other bioactivities presented by the natural pigment betalain from beterraga whose properties proved to maintain the internal quality of quail eggs according Calva et al. (2022).

Table 5: Color changes in canned whole eggs with Beta vulgaris sauce during storage

Time (days)	Sample	Parameters			Color
		L*	a*	b*	
0		79	-2	15	
1		76	12	6	
3		36	49	-23	
6		28	33	-10	

4. Conclusions

The treatment T4 (75% *Beta vulgaris*) as a canning liquid has a favorable effect on the sensory acceptability of canned quail eggs, increasing its acceptability to 8.18 points compared to the canned product without the *Beta vulgaris* sauce, which only achieved an average of 5 points, 75% Beta vulgaris has a preservative effect by raising and maintaining sensory acceptability levels allowing an increase in the shelf life of canned quail eggs for up to 360 days. As for the effect of storage time on the pH of quail eggs, the 75% treatment of beterraga as a preserving liquid has an acidifying and coloring effect on the physicochemical characteristics of preserved

quail eggs by reducing the pH to 4.0±0.1 in 11 days and pigmenting the quail eggs in red tones. Therefore, the use of 75% of beterraga as a preserving liquid allows maintaining the external and internal quality and microbial load of the quail egg for a longer storage period at different temperatures, improving its diffusion and commercialization throughout the nation.

References

Acosta O., Gao X., Sullivan E., Padilla, O. 2014, Pickled Egg Production: Effect of Brine Acetic Acid Concentration and Packing Conditions on Acidification Rate, Journal of Food Protection, 788-795.

Angalet S., Wilson H., Fry J., 1976, Acceptability of pickled quail eggs, Journal of Food Science, 41, 449-450.

Araújo S., Noleto R.A., Martins J.M.S., Ulhoa C.J. 2019, Effect of vitamin E in ovo feeding to broiler embryos on hatchability, chick quality, oxidative state, and performance, Poultry Science, 98 (9), 3652-3661.

Brasil R., Cruz F., Oliveira F., Freitas B., Filho V., 2019, Physical-Chemical and Sensorial Quality of Eggs Coated With Copaiba Oil Biofilm and Stored At Room Temperature for Different Periods, Brazilian Journal of Poultry Science, 21(4), 001-006.

Calva, S. J., Jiménez-Fernández, M., Lugo-Cervantes, E., 2022. Betalains and their applications in food: The current state of processing, stability and future opportunities in the industry. Food chemistry. Molecular sciences, 4, 100089.

Cho S., Lee J., Park H., Sung H., Choi Y., Moon D., 2016, Image analysis to evaluate the browning degree of banana (*Musa spp*.) peel, Food Chemistry, 194, 1028-1033.

Cufadar Y., Curabay B., Gökmen S., Bahtiyarca Y., Sevim B., 2022, The Effect of Organic Copper Levels in Breeding Japanese Quail (*Coturnix coturnix* Japonica) Diets on Performance, Egg Quality, Incubation Parameters and Blood Parameters, Journal of the Hellenic Veterinary Medical Society, 73(3), 4619–4626.

Derelioğlu E., Turgay Ö., 2022. Effect of chitosan coatings on quality and shelf-life of chicken and quail eggs. African Journal of Food Science, 16(3), 63-70

Fernández I., García E., Fuentes A., 2019, Aplicación de las escalas de punto ideal o Just-About-Right (JAR) en análisis sensorial de alimentos, Universitat Politècnica de València, 1-10.

Gunathilaka M., Prabashwari T., Cyril H., Himali S., 2021, Assessment of different pickling solutions on quality characteristics of pickled quail (*Coturnix coturnix* japonica) eggs, Journal of Agriculture and Value Addition, 4(2), 26–43

Hoover A, 2022, Physical and Microbiological Characteristics of Pickled Eggs from Japanese Quail (*Coturnix coturnix* japonica) of the Pharaoh Variety, Clemson University, All Theses, 3786.

Matos J., Furtado D., Ribeiro N., Marques J., Leite P., Santos S., Oliveira A., Silva R., 2023, Productive performance, egg quality and the morphometry of the organs of Japanese quails (*Cotournix cotournix* japônica) kept at different temperaturas, Food Science and Technology, 43, e117822

Mokhtarzadeh S., Nobakht A., Mehmannavaz Y., Palangi V., Eseceli H., Lackner M., 2022, Impacts of Continuous and Intermittent Use of Bovine Colostrum on Laying Japanese Quails: Egg Performance and Traits, Blood Biochemical and Antioxidant Status, Animals, 12(20), 2811.

Ohlmaier F., Carvajal E., López Y., Islas M., Lara C., Marquez A., Sanchez A., Rascon A., 2021, Ferulated Pectins from Sugar Beet Bioethanol Solids: Extraction, Macromolecular Characteristics, and Enzymatic Gelling Properties, Sustainability, 13(19), 10723.

Ondrušíková S., Šárka N., Pytel R., Cwiková O., Kumbár V., 2018, Effect of different storage times on Japanese quail egg quality characteristics, Potravinarstvo Slovak Journal of Food Sciences, 12(1), 560-565

Petek M., Çavuşoğlu E., Odabaşi F., Yeşilbağ D., 2022, Comparison of Egg Quality Characteristics of Different Quail Lines, Journal of Research in Vetenary Medicine, 41(1), 27-31.

Popescu, V., Blaga, A.C., Caşcaval, D., Popescu, 2023. A. Beta vulgaris L.—A Source with a Great Potential in the Extraction of Natural Dyes Intended for the Sustainable Dyeing of Wool. Plants, 12, 1933. https://doi.org/10.3390/plants12101933