



ORIGINAL RESEARCH

Analysis of Brown and White Chicken Eggshells for Content of Calcium Carbonate

Ogah CO*, Nwaeze KU and Adetifa OO

Department of Pharmaceutical Chemistry, Faculty of Pharmacy, University of Lagos, Lagos, Nigeria

Address for correspondence:

Dr. Celina O. Ogah
Department of Pharmaceutical Chemistry, Faculty of Pharmacy, University of Lagos, Lagos, Nigeria
Email: onotsec@yahoo.com

To cite this article: Ogah CO, Nwaeze KU and Adetifa OO. Analysis of Brown and White Chicken Eggshells for Content of Calcium Carbonate. Journal of Basic and Social Pharmacy Research, 2021;2(2):27-34
ISSN: 2705-3245

ABSTRACT

Background: An eggshell is the hard outer covering of an egg that serves to protect it from damage, microbial contamination and desiccation. The major component of the eggshell is calcium carbonate, which provides it with hardness and strength. Calcium carbonate content of eggshells contributes to the overall quality of the egg and eggs are an essential component of human and animal nutrition. Eggshells containing high calcium carbonate can also be processed and used as calcium supplement for bone and teeth health in vulnerable populations.

Objectives: This study determined the calcium carbonate content of brown and white chicken eggshells sourced from Lagos markets and the effect of boiling on same.

Materials and method: Eggs were sourced randomly from three markets in Lagos metropolis and the shells were washed and dried. The dry shells were pulverized and analyzed for calcium carbonate using the back titration method. Each sample (0.5 g) was reacted with excess 1.0 M HCl and the excess acid titrated with 0.1 M NaOH. The calcium carbonate content of each sample was calculated from the difference between the total number of moles of HCl used and that titrated as excess.

Results: The results show that the eggshells studied have high calcium carbonate content and brown eggshells contained higher levels of calcium carbonate (95%) than white eggshells (91%). Boiling did not significantly reduce the calcium carbonate content of both brown and white eggshells. Eggshells from the three markets were similar in their content of calcium carbonate.

Conclusion: This study shows that brown eggshells have a higher calcium carbonate content than white eggshells and boiling of eggs does not significantly reduce the calcium carbonate content of the shells.

Keywords: Eggshells, Calcium Carbonate, Back titration

INTRODUCTION

Eggs are laid by female animals of many different species such as insects, reptiles, amphibians, fish, birds and mammals. Some eggs have gelatinous or soft covering while others are hard-shelled. The most popular choice for human consumption is avian egg

due to its nutritional benefits for a healthy life. Avian eggs contain high-quality protein, essential vitamins and minerals that form part of a healthy diet. The nutritional value of an egg is dependent on its quality, which in turn, is partly determined by the shell integrity^{1,2}.

An eggshell is the outer covering of a hard-shelled egg that provides protection for the albumen and yolk. The shell consists of thousands of tiny pores which makes it a semi-permeable membrane for passage of air and moisture. There is also an outer cuticle that keeps out bacteria and dust³. Thus, the structure and composition of the avian eggshell serves to protect the egg against damage, microbial contamination and desiccation. The eggshell also provides calcium for embryogenesis and regulates gas and water exchange for the growing embryo. An eggshell is usually 10% of the total weight of an egg and is made up of 92-97% calcium carbonate^{4,5}, which gives it strength and hardness. Minor components of an eggshell include magnesium and phosphorus, and traces of sodium, potassium, zinc, manganese, iron and copper^{6,7}. The disposal of eggshells and hatchery waste has become a global environmental pollution problem due to large quantities generated annually. As at 2012, global annual production of chicken eggs stood at 66.4 million tonnes (66.4 billion kilogrammes)⁸. Therefore, studies on the chemical composition of eggshells and their creative use can provide health, economic and environmental benefits.

Among avian eggs, chicken eggs are most popular for human consumption, hence the shells are most readily available. Chickens are raised usually as a source of meat or eggs for food. Those for meat are usually called broilers while the ones for eggs are the layers. On the average, a laying hen produces one egg per day, starting from the age of 21 weeks⁸. Chicken eggs are available and relatively affordable source of protein and other nutrients for a healthy diet. They come mainly in brown and white shell colour, the main difference being in the species and breed of the laying hen. In general, chicken breed with white ear lobes lays white eggs, whereas chickens with red ear lobes lay brown eggs. There is however, no significant link between shell color and nutritional value¹. Regional preferences play an important role in determining the

breed/colour produced for sale to the consuming public.

Low calcium carbonate content of chicken eggshells can weaken the shells and lead to breakage before hatching or getting to the market, thereby reducing chicken and egg production rates⁹. On the average, 4 g of calcium per day is required by the laying hen for adequate eggshell quality¹⁰. Vitamin D is also required for proper utilization of calcium. Poor quality feeds or inadequate consumption by the laying hens (as in very hot environment) can lead to low body weight of laying hens, low egg production rate and small egg size, in addition to poor egg and eggshell quality¹. One reliable method of monitoring the strength of eggs is by determining the calcium carbonate content of the eggshells.

Calcium carbonate is a chemical compound with the formula CaCO_3 and molecular mass of 100.1 g/mol. It is the main component of eggshells and is also found in nature as limestone, usually in rocks. In addition to uses in food and cosmetic industries, it is used pharmaceutically as excipient in solid dosage forms, as antacid and as a source of dietary calcium supplement. It is also a component of some household cleaning products and toothpastes¹¹. Calcium carbonate from eggshells has more stability and bioavailability than one from synthetic sources and does not contain potentially toxic elements like aluminium, cadmium and mercury⁴. Like other carbonates, calcium carbonate reacts with acids to form elemental calcium with the release of carbon dioxide. This reaction forms the basis for its determination by titrimetric method of analysis. This study determined the calcium carbonate content of brown and white eggshells and assessed the effect of boiling on same.

MATERIALS AND METHODS

Collection and Preparation of Samples

Brown and white eggs were purchased randomly from three markets (Agege, Ikeja and Mushin, code-named A, B and C

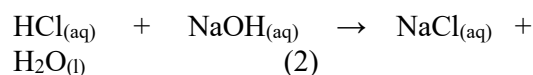
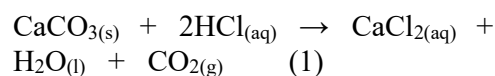
respectively) in the Lagos metropolis. The eggs were washed under tap water and ten each of the brown and white eggs from each of the three markets were weighed and used raw; another ten each were boiled. The brown raw eggs were cracked into a beaker and the shells were washed with distilled water. The thin membranes were carefully removed from the inside surface of the shells which were then wiped with a paper towel, weighed and dried in an oven for 1 hour at 40°C. The dry shells were ground into powder using a small size blender and the powder was stored in a labelled bottle until use. The procedure was repeated for the white raw eggshells.

The boiled brown and white eggs were cooled in water at room temperature, the shells were carefully peeled off the eggs and the membranes removed. The clean brown and white shells were prepared separately following the same procedure as described for the raw eggshells.

Determination of Calcium Carbonate content

The calcium carbonate content of each sample was determined using the standard acid-base back titration method^{5,12}. To 0.5 g of each sample in a beaker, 0.5 mL of ethanol was added as a wetting agent followed by addition of 10 mL of 1.0 M HCl. The beaker was swirled and the mixture heated on a hot plate until all solid was dissolved and bubbling had stopped. The beaker was cooled in a bowl of water at room temperature and the solution filtered using a filter paper into a conical flask. Distilled water, 10 mL was used to rinse the beaker into the filter, 3 drops of phenolphthalein indicator were added to the filtrate which was then titrated with standard 0.1 M Sodium Hydroxide solution to the

first persistent faint-pink color. The volume of titrant used was recorded, the procedure was repeated for two more determinations and the average volume calculated. The calcium carbonate content of each sample was calculated from the difference between the total number of moles of HCl used and that titrated as excess, based on the following equations of reactions:



Statistical Analysis

Weights of calcium carbonate in the samples were expressed as mean \pm standard deviation. Comparison of calcium carbonate content of brown and white eggs and of raw and boiled eggs were done using Student t-test (on Microsoft Excel) with statistical difference at $p \leq 0.05$. One Way Analysis of Variance (ANOVA) was used to compare calcium carbonate content of eggs from the three markets using Minitab.

RESULTS

Samples from the three markets A, B and C were analyzed for calcium carbonate content. The results for raw and boiled samples as well as the weight of the raw eggs are presented in Table 1 for brown eggshells and in Table 2 for white eggshells. Figure 1 is a column display of the difference between the calcium carbonate content of raw brown and white eggshells while Figure 2 shows a comparison between the two after boiling. In Figure 3, the similarity between the calcium carbonate content of eggshells from the three markets is displayed.

Table 1: Weight of Eggs and Calcium Carbonate Content of Brown Eggshells

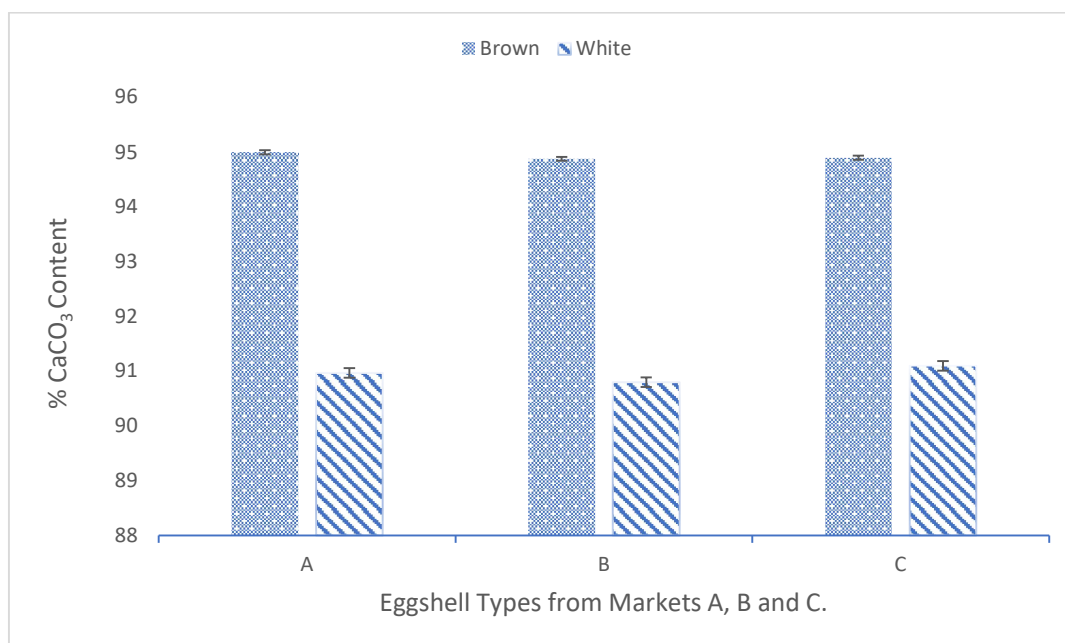
Sample Code	Sample Type	*Weight/Egg (g)	*Weight of CaCO ₃ /Sample (g)
A	Raw	69.25 ± 2.05	0.4750 ± 0.034
	Boiled		0.4719 ± 0.005
B	Raw	68.00 ± 1.85	0.4744 ± 0.028
	Boiled		0.4720 ± 0.006
C	Raw	65.80 ± 2.26	0.4745 ± 0.032
	Boiled		0.4722 ± 0.015

*Presented as Mean ± Standard Deviation (n = 3)

Table 2: Weight of Eggs and Calcium Carbonate Content of White Eggshells

Sample Code	Sample Type	*Weight/Egg (g)	*Weight of CaCO ₃ /Sample (g)
A	Raw	63.85 ± 1.65	0.4549 ± 0.061
	Boiled		0.4417 ± 0.008
B	Raw	64.50 ± 2.05	0.4540 ± 0.053
	Boiled		0.4410 ± 0.015
C	Raw	65.20 ± 1.80	0.4555 ± 0.044
	Boiled		0.4422 ± 0.007

*Presented as Mean ± Standard Deviation (n = 3)

**Figure 1: Calcium Carbonate Content of Raw Brown eggshells Compared to Raw White Eggshells.**

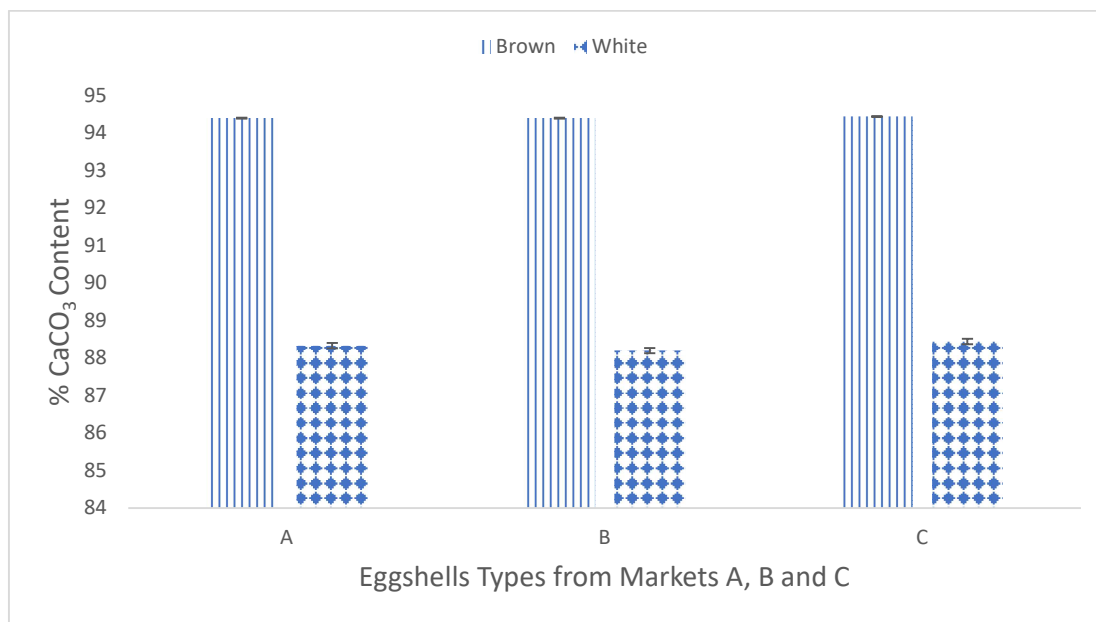


Figure 2: Calcium Carbonate Content of Boiled Brown Eggshells Compared to Boiled White Eggshells.

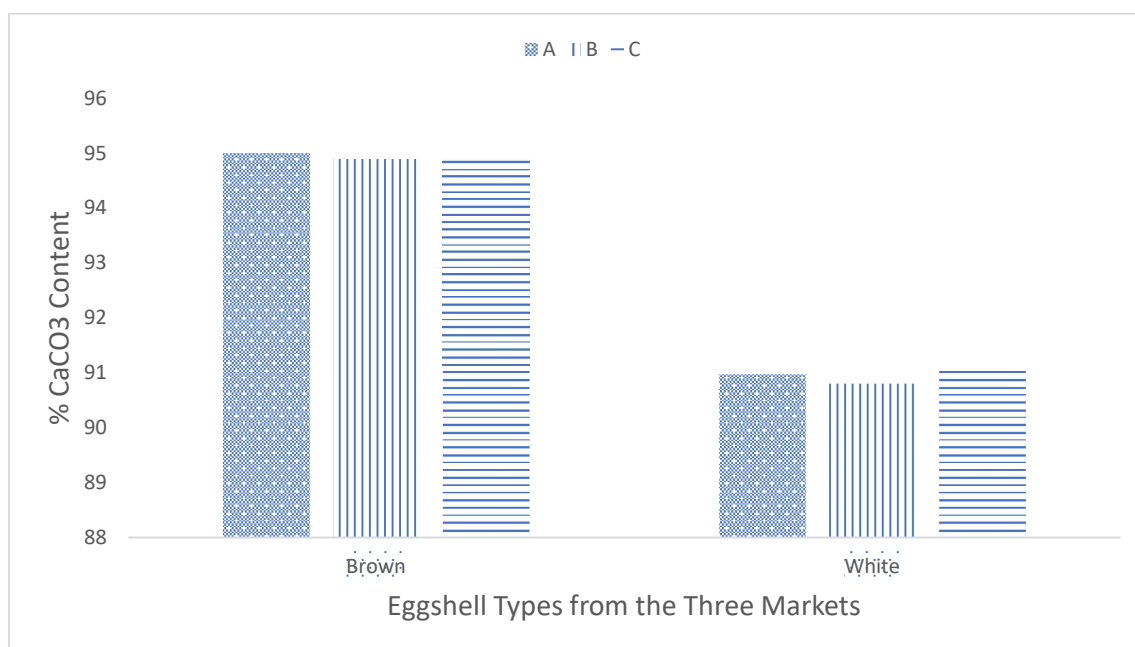


Figure 3: Comparison Between the Three Markets in Terms of Calcium Carbonate of Raw Brown and White Eggshells.

DISCUSSION

In this study, brown and white eggshells were analyzed for calcium carbonate content. The effect of heat on the calcium carbonate content was also determined by analyzing the shells of boiled eggs using

same methods. Titrimetric analysis is the most commonly used method for determination of calcium carbonate and the back titration was used in this study because calcium carbonate is insoluble in water, making direct titration unsuitable.

The weight of eggs used in this study ranged from 63 to 69 g, the white eggs being in the lower range. Eggs in this weight range are classified as large. Egg weight is affected by factors such as age and breed of the laying hen, environment and nutrition¹³.

Results of this study showed that brown eggshells had a higher percent of calcium carbonate than white eggshells and the difference was significant ($p < 0.05$). While raw brown eggshells had an average content of 95% calcium carbonate, the average for raw white eggshells was 91%. The difference in colour between brown and white eggshells is pigmentation. However, the difference in calcium carbonate content can be attributed to breed: the breeds that lay brown eggs are bigger, consume more feeds and therefore deposit more calcium carbonate in their eggshells^{3,14}.

Boiling reduced the calcium carbonate content of the eggshells for both brown and white eggs. The percent reduction was higher for white eggshell (2.6 - 2.8) than for brown eggshell (0.5 - 0.6). The effect was, however, not significant in both eggshell types ($p > 0.05$). Eggshells from the three markets used in the study were similar as there was no significant difference in their calcium carbonate content for both brown and white. Calcium carbonate content of eggshells has been reported to be in the range of 92 -97%, though values as low as 82% and 78% for brown and white eggshells respectively, have been published^{2,7,12}. Variations occur based on regional poultry practices, breed of the laying hen, nutritional and environmental factors.

Low content of calcium carbonate in eggshells may be due to inadequate nutrition, low quality feeds, age of the laying hen or environmental factors such as hot weather^{15,16}. The resulting low strength of the shells can cause egg breakage, leading to economic losses. Egg breakage has been found to reach up to 10% of total egg production⁹. Weakened eggshell resulting from low calcium carbonate content also makes the egg susceptible to microbial contamination and desiccation, thus

diminishing overall internal quality of the egg and putting the health of the consumer at risk^{2,8}. Annual per capita consumption of eggs ranges from 2 kg to 19 kg depending on the country's wealth¹⁷. Considering the fact that eggs are widely consumed for nutritional purposes and as part of solution to the problem of malnutrition in many parts of the developing world, poor quality eggs could constitute a public health problem.

The high concentration of calcium carbonate in eggshells can be utilized in a variety of ways, including use as pharmaceutical excipients, in toothpastes, in agriculture to reduce soil acidity, and as a source of dietary calcium supplement in the treatment of osteoporosis^{4,11,18-20}. A study has shown that addition of heat-treated eggshell powder to locally prepared food is a good method of increasing dietary intake of calcium in humans²¹. It has also been reported that *in-vitro* dissolution of calcium from eggshells was better than from precipitated calcium carbonate²². Therefore, calcium carbonate obtained from eggshells, in addition to industrial and pharmaceutical uses can be of dietary benefit, especially in low-income communities.

Quantitative determination of calcium carbonate levels in the shells of eggs consumed in our locality can lead to creative use of the huge number of eggshells disposed daily from hatcheries, food industries and homes, and serve as a solution to environmental pollution caused by this category of waste.

CONCLUSION

This study shows that chicken eggshells are a very rich source of calcium carbonate. Brown eggshells have a higher calcium carbonate content (95%) than white eggshells (91%). Boiling of eggs did not significantly reduce the calcium carbonate content of the shells. The study also shows that eggs from different markets in the Lagos metropolis are similar in the calcium carbonate content of their shells.

ACKNOWLEDGEMENTS

None.

The authors declare that there is no conflict of interest associated with this study. No external funding was received for the study.

REFERENCES

1. Roberts JR. Factors Affecting Egg Internal Quality and Eggshell Quality in Laying Hens. *Poultry Science*, 2004; 41:161-177.
2. Butcher GD and Miles RD. Concepts of Eggshell Quality [Online]. University of Florida IFAS Extension, 2018. <http://edis.ifas.ufl.edu/vm013> [Accessed: 5th May 2020].
3. Lavelin I, Meiri N and Pines M. New Insight in Eggshell Formation. *Poultry Science*, 2000; 79:1014-1017.
4. Murakami FS, Rodrigues PO, Teixeira de Campos CM and Silva MAS. Physicochemical Study of CaCO₃ from Eggshells. *Food Science and Technology*, 2007; 27(3):30-35.
5. Kristl M, Jurak S, Brus M, Sem V. and Kristl J. Evaluation of Calcium Carbonate in Eggshells Using Thermal Analysis. *Journal of Thermal Analysis and Calorimetry*, 2019; 138: 2751–2758.
6. Arias JL and Fernandez MS. Role of Extracellular Matrix Molecules in Shell Formation and Structure. *World's Poultry Science Journal*, 2001; 57:349-357.
7. Hunton P. Research on Eggshell Structure and Quality: An Historical Overview. *Brazilian Journal of Poultry Science*, 2005; 7(2):67-71.
8. Zaheer, K. An Updated Review on Chicken Eggs: Production, Consumption, Management Aspects and Nutritional Benefits to Human Health. *Food and Nutrition Sciences*, 2015; 6(13):1208-1220.
9. Carter TC. Why Do Eggs Crack? *World's Poultry Science Journal*, 2019; 26(2):549-561.
10. Butcher GD and Miles RD. Chicken Eggs: Nutritional and Economical Values. *Poultry Science*, 2003; 102:200-220.
11. Dafal GB and Khare NK. Formulation and Evaluation of Toothpaste by Using Eggshells. *World Journal of Pharmaceutical Research*, 2017; 6(2):534-543.
12. UK Essays. Experiment on Calcium Carbonate Composition of Eggshells [Online] <https://www.ukessays.com/essays/chemistry/calcium-carbonate.php?vref=1> [Accessed: 18th June 2020].
13. Travel A; Bain M: Effect of Hen Age, Moulting, Laying Environment and Egg Storage on Egg Quality. In: Nys Y, Bain M, Immerseel FV, Eds. *Improving the Safety and Quality of Eggs and Egg Products: Egg Chemistry, Production and Consumption*. Cambridge: Woodhead Publishing; 2011: 300-329.
14. Fernandez MS, Moya A, Lopez L and Arias JL. Secretion Pattern, Ultrastructural Localization and Function of Extracellular Matrix Molecules Involved in Eggshell Formation. *Matrix Biol*, 2001; 19:793–803.
15. Sykes AH and Fahatan, ARA. Effect of Change in Environmental Temperature on Heat Tolerance in Laying Fowl. *Poultry Science*, 1986; 27:307-316.
16. Lukić, M., Pavlovski, Z. and Krbić, Z. Adequate Calcium Nutrition and Quality of Egg Shell and Bones in Layers-Innovative Approach. *Biotechnology in Animal Husbandry*, 2011; 27:485-497.
17. Food and Agriculture Organization of the United Nations (FAO). *World Egg Day*, 2012. http://www.fao.org/ag/againfo/home/en/news_archive/World_Egg_Day_2012.html [Accessed: 26th August 2020].
18. King`ori AM. A Review of the Uses of Poultry Eggshells and Shell Membranes. *International Journal of Poultry Science*, 2011; 10:908-912.

19. Rovenský J, Stancíková M, Masaryk P, Svík K, and Istok, R. Eggshell calcium in the prevention and treatment of osteoporosis. *International Journal of Clinical Pharmacology Research*, 2003; 23(2-3):83-92.
20. Brun LR, Lupo M, Delorenzi DA, Di Loreto VE and Rigalli A. Chicken eggshell as suitable calcium source at home. *International Journal of Food Sciences and Nutrition*, 2013; 64(6):740-743.
21. Bartter J, Diffey H, Yeung YH, O'Leary F, Häsler B, Maulaga W *et al.* Use of Chicken Eggshell to Improve Dietary Calcium Intake in Rural Sub-Saharan Africa. *Maternal and Child Nutrition*, 2018; 14(S3):1-10.
22. Szeleszczuk L, Pisklak DM, Kuras M and Wawer I. In Vitro Dissolution of Calcium Carbonate from the Chicken Eggshell: A Study of Calcium Bioavailability. *International Journal of Food Properties*, 2015; 18(12):2791-2799.