INTERNATIONAL JOURNAL OF FOOD SCIENCES and NUTRITION

http://informahealthcare.com/ijf
ISSN: 0963-7486 (print), 1465-3478 (electronic)

Int J Food Sci Nutr, 2013; 64(6): 740–743
 DOI: 10.3109/09637486.2013.787399

informa healthcare

RESEARCH ARTICLE

Chicken eggshell as suitable calcium source at home

Lucas R. Brun[1,2], Maela Lupo[1,2], Damián A. Delorenzi[1], Verónica E. Di Loreto[1], and Alfredo Rigalli[1,2,3]

[1]Bone Biology Laboratory, School of Medicine, Rosario National University, Rosario, Argentina, [2]National Council of Scientific and Technical Research (CONICET), Argentina, and [3]Rosario National University Research Council, Rosario, Argentina

Abstract

Aim: Taken into consideration that the deficiency of calcium (Ca) in the diet is a common problem, the aim of this work was to study the chicken eggshell as Ca source at home. It was evaluated: (1) different mechanisms to process eggshells and find an easy way to determine the required amount of Ca at home and; (2) the flavor and the texture for eggshell fortified food. *Methods*: Chemical and mechanical methods of eggshell processing were evaluated. Changes in flavor and texture were evaluated in volunteers coordinated by a professional chef. *Results*: A single eggshell contains 2.07 ± 0.18 g of Ca; therefore half an eggshell could provide the amount of Ca needed by adult human beings per day. The best way to use chicken eggshell as Ca dietary supplement is powdered to add to bread, pizza or spaghetti as there were small changes in texture and no changes in flavor.

Keywords

Calcium, calcium dietary supplement, eggshell

History

Received 8 January 2013
Revised 5 March 2013
Accepted 15 March 2013
Published online 22 April 2013

Introduction

Deficiency of calcium (Ca) in the diet is a common problem. Ca intake from dairy products is an appropriate way to fulfill Ca requirements. However, people do not usually consume them in the amounts established by clinical guidelines. Supplementation with tablets is costly and sometimes involves difficulties of adherence to treatment. Chicken eggshell is a source of Ca, which is available at home that can be used as Ca supplementation.

Some works have reported results about the use of eggshells as Ca supplement. It has been demonstrated that for ovariectomized rats eggshells are an effective Ca source with no significant differences regarding body weight gain, food intake or food efficiency (Omi & Ezawa, 1998). The addition of vitamin D improves bone mineral density of the lumbar spine and the proximal tibia in rats treated with calcium carbonate ($CaCO_3$) or eggshell (Hirasawa et al., 2001). In piglets, there were no differences in Ca absorption from $CaCO_3$ and eggshells in casein-based diets and soy protein isolate-based diets (Schaafsma & Beelen, 1999). Moreover, it has been demonstrated that eggshell proteins improve Ca absorption. The total Ca transport across Caco-2 monolayers showed an increase of 64% in the presence of soluble eggshell matrix proteins (Daengprok et al., 2003).

There are few papers describing the use of chicken eggshells as Ca supplement in human beings. Schaafsma & Pakan (1999) showed an increase in lumbar spine, total proximal femur and trochanter bone mineral density in osteoporotic postmenopausal women who received eggshell powder with vitamin D_3 and magnesium supplementation. Another paper (Schaafsma et al., 2002) reported an increase in bone mineral density in the femoral neck, but not in the lumbar spine, compared with a group having $CaCO_3$ as a Ca dietary supplement.

The aim of this work was to study the chicken eggshell as a Ca source at home. It was evaluated: (1) different mechanisms to process eggshells and find an easy way to determine the required amount at home and; (2) the flavor and texture for eggshell fortified food. Additionally, as complementary information, the mineral content of the chicken eggshell and Ca absorption was also analyzed.

Methods

Evaluation of the mineral content

This evaluation was carried out to know the mineral content – particularly Ca concentration – of the chicken eggshell used. Mineral content of white chicken free-running eggshells ($n = 8$) and battery eggshells ($n = 8$) was measured as the weight of the ashes obtained by incineration at 550 °C. Organic matter plus water content was calculated as the difference between chicken eggshell weight and ashes.

The percentage of Ca and strontium (Sr) was determined by atomic absorption spectroscopy (Arolab MK II, Buenos Aires, Argentina). Phosphate (P) was spectrophotometrically measured at 340 nm with a commercial kit (UV fosfatemia, Wiener Lab, Rosario, Argentina) with a Perkin Elmer Lambda 11 spectrophotometer (Perkin Elmer Corporation, Norwalk, CT). Fluoride (F) was measured by direct potentiometry with an ion selective electrode (Orion 94-09, Orion Research, Cambridge, MA) after an isothermal distillation. Sodium (Na) and potassium (K) were measured by flame photometry (Crudo Caamaño, Ionometer NANII, Buenos Aires, Argentina). Sulfate content was determined by a precipitation with ^{133}Ba and measured in a solid scintillator (Alfanuclear, Buenos Aires, Argentina). Carbonate was measured through the quantity of CO_2 produced by a known mass of eggshell after treatment with hydrochloric acid (Chapol, 1955).

Correspondence: Lucas R. Brun, Cátedra de Química Biológica, Facultad de Ciencias Médicas, Santa Fe 3100, (2000) Rosario, Argentina. Tel: 54-341-155786840. E-mail: lbrun@unr.edu.ar

Ca absorption

Ca absorption from eggshell was compared with Ca absorption from calcium carbonate. Seven-week old male Sprague–Dawley rats (200 ± 30 g body weight) provided by the School of Medicine, Rosario National University, were fed with a balanced food for rodents according to the American Institute of Nutrition report (AIN-93) (Reeves et al., 1993) and water *ad libitum*. All experiments were carried out according to the international rules of animal care (Canadian Council on Animal Care Guidelines, 1998).

Rats were divided into two groups which received rat chow containing 0.9 g Ca/100 g diet (0.9%) from calcium carbonate ($CaCO_3$ group; $n = 6$) or chicken eggshell powder (eggshell group; $n = 6$).

Rats were placed in individual metabolic cages and fed with the diet described above for 3 d before the experiment. The amount of food eaten during 24 h was measured and 24-h feces excretion were collected and incinerated at 550 °C. The amount of Ca was determined in food and feces by an atomic absorption spectroscopy (Arolab MK II, Buenos Aires, Argentina) and 24-h Ca intake and 24-h fecal Ca excretion were calculated. The percentage of Ca absorption (%Ca) for each animal was calculated as %Ca = (24-h Ca intake − 24-h fecal Ca excretion) × 100/24-h Ca intake.

Chemical and mechanical methods of chicken eggshell processing

Chicken eggshells were processed using three different ways:

(1) Dry eggshells were mechanically processed using a mixer mill (Retsch GmbH, MM200, Haan, Germany) for 20 min at a frequency of $30\,s^{-1}$ as a standard method.

(2) Dry eggshells were powdered using a rolling pin, a common instrument available at home, and after that, a small sieve was used to separate the particles of larger size and obtain a fine powder.
Chicken eggshell powder obtained in 1 and 2 were examined using a light microscope (Leitz, Wetzlar, Germany). Digital images ($n = 16$/group) were obtained at a 4× magnification (Olympus SP-350, Tokyo, Japan) and the size (diameter) of the eggshells particles were analyzed with ImageJ 1.40 (National Institutes of Health, Maryland, MD). From each image the 10 largest particles were measured and the five largest particles were selected for a statistical analysis.

(3) Also chicken eggshell powder described in 1 and 2 was dissolved in vinegar, lemon or orange juice as acid solutions, all of which are available at home. Twenty-five different kinds of commercial vinegars, six lemon juices and six orange juices were analyzed. The volume of these solvents needed to dissolve a whole eggshell was determined by incubation with 2-fold serial dilutions of the original solvent. The dissolution volume was determined based on the highest dilution which produced a complete dissolution in 48 h of incubation at room temperature Percentage of acetic acid in vinegars was measured by titration with NaOH using a pH meter (Hanna HI 9017, Woonsocket, RI) in order to compare different kinds and brands of commercial vinegars.

Additionally, several common containers available at home have been evaluated as measure devices to obtain the required amount of eggshell at home without the use of scales.

Chicken eggshell addition to food

Chicken eggshell powder was sterilized in an automatic sterilizer autoclave (Microclave SL 9000, Buenos Aires, Argentina) for 15 min at 134 °C before adding to food.

White chicken eggshell powder – obtained using a mixer mill or a rolling pin plus a sieve – was used to prepare bread, pizza, spaghetti, rice with vegetables, breaded fried meat, stew and corn flour. Foods were supplemented with 500 mg of Ca per person from white chicken eggshell.

The organoleptic features (flavor and texture) of the different dishes were subjectively evaluated by a group of volunteers ($n = 10$) using a hedonic scale coordinated by a professional chef. The score considered was: * Important changes that make food unacceptable; ** Moderate changes; *** Minimal changes; **** No changes. Each food was evaluated in the morning on different days. Volunteers were members of the laboratory who were not involved in the project between 25 and 50 years of age. All have good health without oral or nasal pathologies and normal appetite. None previously rejected the food to evaluate. All of them provided written informed consent. The project was approved by the Bioethics Committee of the School of Medicine of the National University of Rosario, Santa Fe, Argentina, and has been performed in accordance with the ethical standards (Declaration of Helsinki).

Statistical analysis

Data are expressed as mean ± SD. Statistical analyses were performed with the software GraphPad Prism 2.0 (GraphPad Software, San Diego, CA) and differences were considered significant if $p < 0.05$ (unpaired Student's *t*-test).

Results

Evaluation of mineral content

Since there were no differences between free-running and battery eggshells the results are shown together. Eggshell weight was 5.43 ± 0.79 g ($n = 16$). Mineral composition was: organic matter = 16.1 ± 4.6 g/100 g chicken eggshell and inorganic matter = 83.9 ± 5.0 g/100 g chicken eggshell. Mineral content is shown in Table 1 as gram (g) of each mineral and organic matter per 100 g chicken eggshell (mean ± SD). It should be noted that a complete eggshell contains 2.07 ± 0.18 g of Ca (381 ± 89 mg Ca/g eggshell); therefore, half of an eggshell provides 100% of the adult Ca daily requirement. These data were used to prepare the diet for Ca absorption experiments and eggshell powder-fortified food.

Ca absorption

Calcium absorption from a diet containing chicken eggshell powder (45.59% ± 14.43%) was not different from a diet where $CaCO_3$ (39.88% ± 16.07%) was used as calcium supplement (unpaired Student's *t*-test, $p > 0.05$). Body weight gain and food intake were not different in both groups.

Chemical and mechanical methods of chicken eggshell processing

A rolling pin and then a small sieve were evaluated as mechanical methods available at home compared with a mixer mill as the standard method. As expected particle size of the powder was smaller with the laboratory instrument: mixer mill = 0.14 ± 0.07 mm versus rolling pin + sieve = 0.45 ± 0.25 mm; (Figure 1) (unpaired Student's *t*-test, $p < 0.05$).

Additionally, it was found that the dissolution of a whole eggshell was achieved with 108.6 ± 15.8 ml of 100% vinegar in 48 h of incubation at room temperature. The acetic acid concentration of the commercial vinegars was titrated ($n = 25$) and 4.5 ± 0.6% was obtained. No differences were found from the different kinds of vinegars: alcohol, wine, apples and rice.

Table 1. Organic and inorganic content of chicken eggshell (g/100 g eggshell).

	Mean	SD
Organic matter	16.1	4.6
Inorganic matter	83.9	5.0
Calcium	38.2	3.5
Carbonate	44.3	3.2
Sodium	0.51	0.09
Phosphate	0.44	0.06
Sulfate	0.32	0.07
Potassium	0.14	0.05
Strontium	0.14	0.02
Fluoride	1.8×10^{-6}	1.1×10^{-6}

Table 2. Qualitative analyses of the organoleptic features.

	Mixer mill		*Rolling pin + sieve*	
Food	Flavor	Texture	Flavor	Texture
Breaded fried meat	****	****	****	***
Bread	****	****	****	***
Pizza	****	****	****	***
Spaghetti	****	****	****	***
Stew	****	***	****	**
Rise with vegetables	****	***	****	**
Corn flour	****	**	****	*

*Important changes that make food unacceptable; ** Moderate changes; *** Minimal changes; **** No changes.

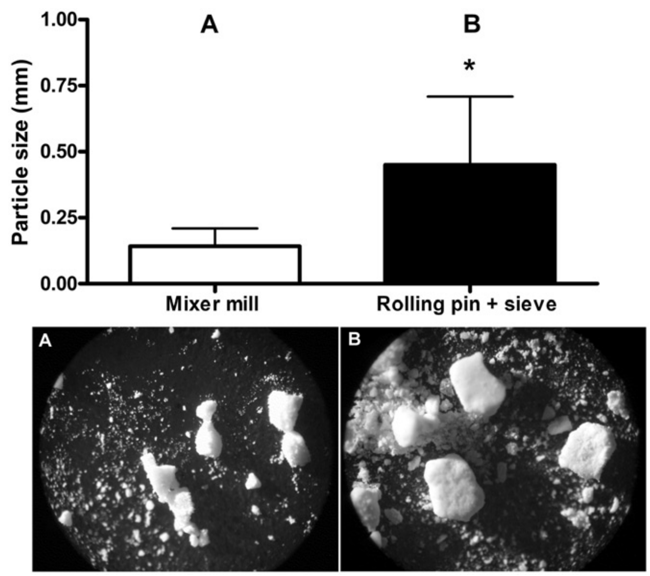

Figure 1. Eggshell particle size (mm) produced by a mixer mill (A) and a rolling pin plus a sieve (B) [mean ± SD]. In the lower panel there are representative pictures of each group (4× magnification). *Indicates significant differences (unpaired Student's *t*-test, $p < 0.05$).

Balsamic vinegar was not different from other vinegars. Regarding the use of fruit juices, the dissolution of a complete eggshell could be achieved with approximately 120 ml of lemon juice or 800 ml of orange juice in 48 h of incubation at room temperature.

Several common containers as spoons, teaspoons, plastic cups, coffee cups, tea cups, metal bottle-caps and plastic bottle-caps have been tested to be use at home to easily determine the amount of eggshell without scales. We found that the simplest way to determine the amount of required eggshell is the plastic bottle screw cap. This is an usual container and has similar sizes worldwide. A cap of a plastic bottle of soft drink can contain approximately 5 g of chicken eggshell powder, which is equivalent to a complete eggshell, which can provide 100% of Ca daily requirements for two adults.

Chicken eggshell addition to food

Although the particle size that can be obtained at home was greater than those achieved in a laboratory, we were interested to know if the size of the particles affects the flavor and/or texture of eggshell powder-fortified food. The chicken eggshell powder (sample 1 and 2) was added to different food items and the flavor and texture was evaluated by a group of volunteers ($n = 10$) coordinated by a professional chef (Table 2).

Discussion

As expected, we found that a chicken eggshell has a high Ca content: 381 ± 89 mg Ca/g eggshell, consistent with Schaafsma et al., who found from 385 to 401 mg Ca/g eggshell depending on the eggshell origin (Schaafsma et al., 2000). This means that half of an eggshell can provide the amount of Ca needed per day in adult human beings, considering that the Ca recommendations vary with age and gender (Ross et al., 2011). In addition, Ca absorption was not different from $CaCO_3$, indicating that the bioavailability of Ca from eggshell is similar to that of Ca carbonate. Therefore, chicken eggshell can be considered as a possible calcium dietary supplement taking into account that the absorption study was made in rats. Moreover, eggshell contains not only Ca but also other elements, such as Sr and F which – despite the low concentration – may contribute to Sr and F requirements and have a positive effect on bone and dental metabolism (Meunier et al., 2004; Vestergaard et al., 2008). The levels of others elements (Na, K, P) are low, especially when compared with daily requirements. We did not measure Cu, Fe, Cr, B, Zn, Se, Pb, Al, Cd and Hg, but very low content of them has been determined by others (Schaafsma et al., 2000).

Although the particle size that can be obtained at home was larger than those that can be achieved in a laboratory, it was found that the chicken eggshell powder obtained at home using a rolling pin and a sieve could be used as foods supplements in several food items. The best dishes to add chicken eggshell powder were breaded fried meat, bread, pizza and spaghetti where small changes in texture without changes in flavor were detected. Other dishes display some detectable changes in texture but this effect was reduced when the size of the particles was smaller. Although, several drink items such as orange juices fortified with Ca are commercially available, this paper provides methods that are cheaper and easier to prepare at home. In Argentina, the price of one Ca tablet of 1000 mg of Ca is around USD 0.30, hence the monthly cost is USD 9. The volume of lemon or orange juice needed to dissolve a complete eggshell makes these methods not very useful and more expensive than Ca tablets, while vinegar would be effective and cheap. However, the use of lemon or orange juice would be effective if Ca and vitamin C is required.

Additionally, it is an environmentally friendly technique which could contribute to decreased waste disposal. In Argentina, egg consumption per person per year increased from 126 eggs per person in 2002 to 233 in 2011 (Argentina Chamber of Poultry Producers, 2011). As a consequence, eggshell accounts for approximately 45 000 tons per year for waste disposal. There are other countries with higher egg consumption: 250–300 eggs per person per year in Hungary, Spain, France, USA and Russia and 300–350 eggs per person per year in Denmark, Japan, Paraguay, Mexico, the Netherlands, China among others (WATT Executive Guide to World Poultry Trends, 2011).

A risk factor for human salmonellosis (*Salmonella enteritidis*) is the consumption of undercooked eggs (Guard-Petter, 2001), as eggs can become contaminated internally and on the outer shell surface. Despite the fact that pasteurization was predicted to be effective for reducing *S. enteritidis*, not all the eggs go through this procedure before consumption. Therefore, the way to avoid Salmonella contamination is to store the eggs in the fridge and effectively eliminate the infectious agent from eggs through several cooking methods. It was demonstrated that hard-cook (63 °C–15 min), soft-cook (63 °C–5 min), over-easy (82.5 °C–5 min) and poaching (64.3 °C–5 min) cooking methods are all useful to eliminate *S. enteritidis* from eggs. However, sunny-side-up (58.9 °C) and scrambled egg (63 °C–2 min) cooking methods are not safe (Davis et al., 2008). Another way to avoid Salmonella is to thoroughly wash eggshells under running tap water, scrub with a domestic sponge, and then immerse eggshells in a solution of 10 drops of sodium hypochlorite (domestic bleaching agent) per liter of tap water. Rinse, dry with paper towels and use the eggshells. Therefore, it is important to emphasize the necessity to avoid the contamination with *S. enteritidis.*

Conclusions

It is concluded that eggshell is an appropriate and cheap source of Ca for human nutrition easily prepared at home. Eggshell obtained with a rolling pin plus a sieve did not produce important changes in flavor and texture in different foods evaluated in this paper. Also, eggshell powder dissolved in vinegar, lemon and orange juice can be useful.

Acknowledgements

We thank Nicolas Dri and Hilda Moreno for their technical assistance.

Declaration of interest

The authors declare that they have no conflict of interest.

This work was funded by a grant of Department of Science, Technology and Innovation of the Province of Santa Fe, Argentina.

References

Argentina Chamber of Poultry Producers. 2011. Global egg consumption increases in 2011. Available at: http://www.capia.com.ar/. Accessed on 03 December 2012.

Canadian Council on Animal Care Guidelines. 1998. Guide to the care and use of experimental animal. 2nd ed. Ottawa, ON, Canada: Canadian Council on Animal Care.

Chapol L. 1955. Micro method for the continuous and simultaneous determination of oxygen and carbon dioxide using a modified Warburg apparatus. Bull Soc Chim Biol (Paris) 37:171–180.

Daengprok W, Garnjanagoonchorn W, Naivikul O, Pornsinlpatip P, Issigonis K, Mine Y. 2003. Chicken egg shell matrix proteins enhance calcium transport in the human intestinal epithelial cells, Caco-2. J Agric Food Chem 51:6056–6061.

Davis AL, Curtis PA, Conner DE, McKee SR, Kerth LK. 2008. Validation of cooking methods using shell eggs inoculated with Salmonella serotypes Enteritidis and Heidelberg. Poult Sci 87: 1637–1642.

Guard-Petter J. 2001. The chicken, the egg and Salmonella enteritidis. Environ Microbiol 3:421–430.

Hirasawa T, Omi N, Ezawa I. 2001. Effect of 1alpha-hydroxyvitamin D3 and egg-shell calcium on bone metabolism in ovariectomized osteoporotic model rats. J Bone Miner Metab 19:84–88.

Meunier PJ, Roux C, Seeman E, Ortolani S, Badurski JE, Spector TD, Cannata J, et al. 2004. The effects of strontium ranelate on the risk of vertebral fracture in women with postmenopausal osteoporosis. N Engl J Med 350:459–468.

Omi N, Ezawa I. 1998. Effect of egg-shell Ca on preventing of bone loss after ovariectomy. J Home Econ Jpn 49:227–282.

Reeves PG, Nielsen FH, Fahey Jr GC. 1993. AIN-93 purified diets for laboratory rodents: final report of the American Institute of Nutrition ad hoc writing committee on the reformulation of the AIN-76A rodent diet. J Nutr 123:1939–1951.

Ross AC, Manson JE, Abrams SA. 2011. The 2011 report on dietary reference intakes for calcium and vitamin D from the Institute of Medicine: what clinicians need to know. J Clin Endocrinol Metab 96: 53–58.

Schaafsma A, Beelen GM. 1999. Eggshell powder, a comparable or better source of calcium than purified calcium carbonate: piglet studies. J Sci Food Agric 79:1596–1600.

Schaafsma A, Pakan I. 1999. Short-term effects of a chicken egg shell powder enriched dairy-based products on bone mineral density in persons with osteoporosis or osteopenia. Bratisl Lek Listy 100: 651–656.

Schaafsma A, Pakan I, Hofstede GJ, Muskiet FA, Van Der Veer E, De Vries PJ. 2000. Mineral, amino acid, and hormonal composition of chicken eggshell powder and the evaluation of its use in human nutrition. Poult Sci 79:1833–1838.

Schaafsma A, van Doormaal JJ, Muskiet FA, Hofstede GJ, Pakan I, van der Veer E. 2002. Positive effects of a chicken egg shell powder-enriched vitamin-mineral supplement on femoral neck bone mineral density in healthy late post-menopausal Dutch women. Br J Nutr 87: 267–275.

Vestergaard P, Jorgensen NR, Schwarz P, Mosekilde L. 2008. Effects of treatment with fluoride on bone mineral density and fracture risk: a meta-analysis. Osteoporos Int 19:257–268.

WATT Executive Guide to World Poultry Trends. 2011. Global egg consumption increases in 2011. Available at: http://www.wattagnet.com/. Accessed on 3 December 2012.