

Utilization of eggshell in food system as an alternative source of Calcium

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Abstract

Eggshell is a waste generated through food manufactures and hotel in tons, which is rich source of calcium and could be used as an alternative for enrichment of calcium in foods. First time this review on summary of nutritional composition, microbial quality, extraction of calcium, and application of eggshell are discussed. Extraction of calcium from eggshell plays crucial role in preservation of fruits and vegetables and act as firming agents.

Keywords: eggshell, calcium, microbial quality, pulse electric field.

Introduction

The normal functioning of human body can be regulating with the help of calcium which is most important macronutrients. Osteoporosis or bone loss is defect occurs due to the deficiency of calcium in diet which overcome with fortification of calcium with better absorption in small amount. Calcium supplements is a good solution for fortification supported by Bradauskiene, Montrimaite, & Moscenkova (2017). There are different kinds source like calcium phosphate, cattle bone powder, milk calcium, and calcium carbonate are used as sources for fortification in food to meet daily intake of calcium (Kato *et al.*, 2002). According to clinical guidelines, people unable to meet the dietary requirements of calcium through food. In the Asian region a

large population group are suffer under lactose intolerance which keep to meet the daily requirements of calcium though milk which boos the researcher to find alternative source of calcium to fulfil the dietary requirements (Flammini *et al.*, 2016). The cost of the calcium supplements is costly which prescribed by the doctor for the poor people to cure diseases or to meet dietary requirements (Silva & Nabavi, 2019). Ray *et al.* (2017) reported that chicken eggshell powder (CESP) is an alternative source of calcium for human consumption (Bradauskiene *et al.*, 2017).

A ton of eggshell generate as waste through food manufactures and egg-based product companies, poultry farms, hatcheries, restaurants, and homes which create environmental issues (Amu *et al.*, 2005; Phil and Zhihong, 2009). The shell membrane and eggshell are fall in category of non-edible by-products, and also a source for bioactive compounds (Abdulrahman *et al.*, 2014). The food processing industry is generating about 250000 tons of eggshell waste worldwide annually utilizing egg as ingredient in different product (Verma, Kumar, & Bansal, 2012). Only USA produces 150000 tons of waste annually (Abdullah *et al.*, 2018).

The aim of the review article to provide brief insight on utilization of calcium from the source of eggshell which fulfil normal physiological functions of an individual and its possible application in food industry.

Solubility of calcium extracted from eggshell

Calcium lactate and citrate are water soluble as like in milk, but calcium carbonate insoluble in water due to which it poorly absorbed (Szeleszczuk *et al.*, 2015). The calcium obtained from eggshell are readily dispersed in gastric juices compared to commercial supplements like Calcivit®, Calcigran®, and Coral Calcium® (Bradauskiene *et al.*, 2017).

Eggshell Composition

According to Dri *et al.* (2011), egg divided in three parts eggshells (9.5%), egg white (63%), and egg yolk (27.5%). It also reported that eggshell composed with 0.8% of magnesium carbonate, 0.8% of tricalcium phosphate, and 98.4% of calcium carbonate. The eggshell makes up with 98% of dry matter and 2 % of moisture in which 93 % of dry matter composed with ash and 5% of protein. This ash contains higher amount of calcium with minor amount of other minerals like boron, copper, iron, magnesium, molybdenum, sulphur, silicon and zinc (Schaafsma *et al.*, 2000). The mineral content present in eggshell from different countries of poultry sources are presented in **Table 1**.

The variation in the protein content of eggshell influences due to the structure of eggshell which is composition of protein polysaccharide, where 70% protein and 11% of polysaccharides are reported by Dupoirieux *et al.* (1955). Cartilage-protein-polysaccharides shows the presence of Hydroxyproline which is an amino acid (Baker and Balch, 1962), both chondroitin sulphates A and B are present in the matrix which account for 35% of total polysaccharides (Dupoirieux *et al.*, 1955). Other proteoglycans and proteins like osteopontin (OPN), ovalbumin, ovotransferrin, ovocleidin-17, ovocalyxin-32, and lysozyme, are reported in eggshell which some of this support modification of eggshell calcite crystal morphology and rate of precipitation (Pines *et al.*, 1995; Panheleux *et al.*, 1999). The eggshell

protein plays key role in protection egg content due to antimicrobial activity and also regulates mineralization (Rose and Hincke, 2009). It also composed with other organic matter like glycein, alanine, sialic acid, and uronic acid in higher concentration as compared to shell membrane (Nakano *et al.*, 2008).

Microbial parameters of eggshell

The eggshell, membrane and yolk are primary parts of eggs which contaminated by array of microorganisms with wide range of pathogens. *Listeria monocytogenes*, *Escherichia coli*, *Yersinia enterocolitica*, *salmonella*, and *campylobacter jejuni* are most responsible for contamination in vital parts of eggs (Ricke *et al.*, 2001; Board and Tranter, 1995). The *staphylococci* most contaminated microorganisms grow on surface of eggshell. The physical conditions like storage environment, dirty shells and cracked eggs are possible reason behind contamination of microorganisms which allows penetration of *Salmonella enteritidis* (Abdullah, 2010). Chaemsanit *et al.* (2015) investigated the pathogenic and aerobic bacteria from table eggshells which collected from the market as well as from farm storage. Author observed the presence of *Staphylococcus* (a gram's positive bacteria), *Salmonella* and *Escherichia coli* (a pathogenic bacteria) present on the surface of eggshell.

Calcium extraction from eggshell

There are various methods used for calcium extraction such as soaking, neutral or calcination by using ultra high temperature. Garnjanagoonchorn and Changpuak (2007) explain simple method for extraction of calcium from eggshell by using hydrochloric acids, in which clean eggshell powder incubate with acid for 3h until there is no gas bubble formation. The mixture is stirred after every 30 min of intervals. Further, supernatant was collected by using centrifugation and allowed

to heat supernatant for 110-120°C until dry crystals of calcium chloride is obtained.

Pulse electric field treatment (PEF) assisted extraction

Lin *et al.* (2012) used pulse electric field treatment (PEF) for extraction of calcium malate and promote in vitro absorption of calcium. PEF is an environment friendly, energy saving and effective method. In this eggshell powder treated with malic acid at flow of 25 ml/ min with the frequency of 1000–3000 Hz, at 15 kV/cm electric field intensity which further flowed by centrifugation. The major disadvantage of chemical method is heavy pollution, high energy consumption, and complicated operation with low extraction rate.

Ultrasound assisted extraction of calcium from eggshell

Liew *et al.* (2015) extracted calcium from chicken eggshells (CS) and duck eggshells (DS) by using ultrasound processing (horn-type ultrasonic generator) which prepared biobased calcium carbonate (CaCO₃) nanoparticles. In these process author used dried eggshell and deep in the acetone and dichloromethane (DCM) solution which further followed by filtration. Theses treatment helps to remove the impurities from the eggshell powder. Further, ultrasonication irradiated treatment given to eggshell powder in distilled water for 5 to 20min to extract calcium efficiently.

Application of eggshell as nonedible and edible

Non edible application

The non-edible application of eggshell powder is fertilizers, paper making industries, bone graft material.

Fertilizer

In preparation of fertilizer, the clean eggshell is boiled in water for 10 min and

then dried overnight. Before pulverizing it can be dried at 200°C for 10 min and then it can pulverized to get granular form. These powders used for the treatment of blossom end root disease occurs in plant due to deficiency of calcium. It is observed that the different concentration of eggshell powder into soil results in nourishment of soil by improving pH and calcium content which prevent plant to suffer from BER disease. This used in the preservation of tomato plant and berry (Gaonkar *et al.*, 2007).

Paper Preparation

For production of paper, trees are cutting down from the ancient time which ultimately effect on the ecosystem of world. The paper and pulp industry generate landfill waste, utilize larger amount of water, energy which generates larger amount of waste and pollutants, which can be overcome with production of composite paper by using eggshell (Kang and Paulapuro. 2006). The eggshell powder was mixed with recycle paper in the proportion of 20:80, which gives mechanical strength to paper. It could be used in food packaging material due to its strength because it prevents tearing or breaking of material (Abdullah *et al.*, 2018).

As a bone grafting material

In vivo studies show that eggshells can be used as an alternative source for bone substitute materials (Dupoirieux *et al.*, 1995). Preliminary studies show that no inflammatory or toxicity effects of this natural material with addition to its biocompatibility, and also protein present in eggshell having interest in, cell proliferation, osteointegration, and important steps of bone regeneration (Dupoirieux *et al.*, 2001). Neunzehn *et al.* (2015) observed the combination of eggshell and hyaluronan showed high potential as basic component for bone regeneration and tissue engineering. Authors noted improvement in the osteogene activity with addition of hyaluronan to eggshell.

Edible application

Bread

Bread is breakfast cereal product which can be used as an efficient delivery system by fortification with healthy nutrient like calcium, omega oil etc to overcome many deficiency (Marpalle *et al.*, 2014a; 2014b; 2015). The fat, protein, carbohydrates, and minerals are basic nutrient of bread (Ameh *et al.*, 2013). To avoid multiple deficiency which occurs due to lack of calcium, is overcome with fortification of calcium in bread by contributing in balance of body calcium (Das *et al.*, 2013). Alsuhaibani (2018) incorporated 2% of eggshell powder to develop calcium enriched bread. Author observed lower dough weakening index (BU) and higher dough stability, dough development time, and mixing time compared to control sample of bread. The calcium of eggshell improves the negative charge proteins which present in dough formation, where three-dimensional network is developed between negatively charged proteins. These produce more homogeneous matrix and restructuring of gluten network due to calcium results in stiffness (Daengprok *et al.*, 2003). The nutritional properties of bread with fortification of calcium is positively influence, but negatively influence with sensory characteristics (Alsuhaibani, 2018).

Cakes

Cakes being a popular flour-based bakery product intrigues a lot of consumers because of different varieties, taste and low price. Because of intense competition and higher demand for healthy food, efforts are made to improve the nutritional content and composition of cakes. Therefore, cakes can be fortified or enriched with calcium by using eggshell as source. Ray *et al.* (2017) utilize 3%, 6%, and 9% of eggshell powder as fortification of calcium in cake preparation.

Biscuits

A biscuit is popular snack having sweet/salty, small, and flat characteristics which falls under baked products, which consume all age of people and eaten with tea. Soft wheat is basic ingredient in preparation of biscuit. The demand for baked process foods increases with increase in urbanization due to local bakery, longer shelf life, texture, low cost and variation in taste. Wesley & Renitta, (2018) used 0.8% (optimized) eggshell powder in the biscuit formulation which received higher rating in sensory compared to control in terms of color, texture, aroma, appearance, and overall acceptability. It also improves nutritional quality with increasing calcium concentration.

Preservation of fruits and vegetables

Calcium chloride extracted from the eggshell act as firming agent in the preservation of fresh cut fruit like musk melon, guava, and papaya (Thakur *et al.*, 2019). Calcium chloride helps in keeping the firmness of the fruits intact, it stabilizes the membrane system and forms Ca-pectates leading to the enhanced firmness of fresh produce. Calcium delays the aging of fruits as it is harmful to the enzymes produced by fungal attacks (Thakur *et al.*, 2019). The retention of firmness in fresh cut produce fruits and vegetable is due to cross-connected polymer network and pectic substances which control physiological properties and delays senescence (Poovaiah, 1986). The calcium chloride triggers the osmoregulatory process in microbes which result in suppression of microbes and enhancement of shelf life of fruits and vegetables (Yaganza *et al.* 2009).

Safe utilization of eggshell

The utilization of eggshell for the production of calcium need to be contamination free. The mostly *Salmonella enteritidis* may developed during uncooked egg products which grow internally as well as outer surface of eggshells which spreads infection (Guard-

Petter, 2001). The heating method like cooking or pasteurization is an effective method to eliminate the infectious agent (Davis *et al.*, 2008). Alternative method for cleaning of eggshell and eliminate the contamination by treating eggshell with domestic bleaching agent like sodium hypochlorite (Geovana *et al.*, 2011).

Conclusion & Future Scope

Calcium extracted from the eggshell could be used as supplement with breakfast bakery product which act as delivery medium. The extraction of calcium by using chemical method is major method observed though literature till date expect the application of pulse electric field treatment (PEF). Still there is lack in the recent novel technologies like nonthermal as well thermal pre-treatment on the effective extraction of calcium from the eggshell, which can overcome to chemical extraction method. Pasteurization is effective method for preservation of eggshell powder from various microorganism. Eggshell powder could be cheapest source for calcium which can be utilized for functional food.

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