Utilization of Eggshell Powder in Cereal Bars to Control Calcium Levels

Sana Imtiaz[1], Samina Kauser[1], Zain ul Abideen[2], Haniam Sahar Niazi[1], Aymen Mubashar[1], Emaan Shahid[1], Mehak Fatima[1], Muhammad Soban Mumtaz[3], Muhammad Abid [1] and Kashif Ameer [1,*]

[1]Institute of Food Science and Nutrition, University of Sargodha, Sargodha, Pakistan
[2]Institute of Nutrition, Mahidol University, Thailand
[3]School of Tea and Food Science, Anhui Agricultural University, China
*Corresponding author: kashifameer89@gmail.com

Abstract

The possibility of using eggshell powder, which is one of the richest sources of calcium that can be used within cereal bars. The nutrition source added to the cereal bars can supplement them with nutrients utilizing enhancing the overall nutrition value. The addition of eggshell powder to cereal bars may be useful in increasing the intake of calcium for a day which would be taken by adding it to cereal bars. Eggshell powder has advantages such as having high calcium content, being low-cost, and being environmentally sustainable. This chapter discusses the benefits and challenges of using eggshell powder in cereal bars, including effects on nutritional content, sensory properties, and potential health benefits. Further research is necessary to fully explore the potential of eggshell powder in cereal bars. The food industry can develop eggshell powder-fortified cereal bars as innovative, high-calcium products to answer the growing demand for healthier snack options.

Keywords: Eggshell powder, Calcium, Cereal bars, Nutritional value, Fortification, Food Applications

Cite this Article as: Imtiaz S, Kauser S, Abideen ZU, Niazi HS, Mubashar A, Shahid E, Fatima M, Mumtaz MS, Abid M and Ameer K, 2025. Utilization of eggshell powder in cereal bars to control calcium levels. In: Aadil RM, Salman M, Mehmood K and Saeed Z (eds), Gut Microbiota and Holistic Health: The Role of Prebiotics and Probiotics. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 241-246. https://doi.org/10.47278/book.HH/2025.322

A Publication of Unique Scientific Publishers

Chapter No: 25-032

Received: 09-Jan-2025
Revised: 10-March-2025
Accepted: 10-May-2025

Introduction

Cereal bars are a food product in the form of bars, which comprises cereals, dried fruits, and glucose syrup (Palazzolo, 2003). The global market for cereal bars has experienced a significant growth rate: consumption increased by 11% in 2007, with a total market value of USD 4 billion (Sharma et al., 2014). This surge in popularity can be attributed to the diverse appeal of cereal bars (de Saint Pol & Hébel, 2021; Djupegot et al., 2021; Nordman et al., 2021), which cater to various consumer groups, including individuals adhering to specific diets, athletes, those with health concerns, and consumers seeking convenient and energy-rich snacks (Zaveri& Drummond, 2009; Singh et al., 2022).

Cereal bars are considered healthier than their traditional chocolate counterparts and provide low-calorie alternatives (Brito et al., 2013). The addition of nuts, fruits, and cereals to these food products increases their appeal, as they are rich in bioactive compounds (Bucher et al., 2016; Huitink et al., 2020; Poquet et al., 2020). Also, consumer acceptance of cereal bars is determined by their perceived richness in fiber content (Aleksejeva et al., 2017; Curtain & Grafenauer, 2019).

Though the potential benefits of cereal and fruit and cereal bars cannot be denied, it would be inappropriate to label them as health foods because they belong to the category of sweet products (Pallavi et al., 2015). The commercially available cereal bars vary in nutritional content, and many of them are high in saturated fat and some high in sugar (Hawkes et al., 2013; Herforth et al., 2019). More sweets consumption leads to many diseases, including emotional disorders (Elfhag et al., 2008; Koenders& van Strien et al., 2011). With an increase in cereal bar consumption, lifestyle choices are also shifting. It is being sought after, as people look for something easy, functional, and healthy to eat (Kosicka-Gębska et al., 2024). Class-wise, Cereal bars are not categorized; so the classification of the product under different formats exists (Campos et al., 2011).

Cereal bars- even so many are rather of dubious nutritional value. Still primarily based on an ingredient listing of some sort (Svetlana Aleksejeva et al., 2017). Furthermore, milk, a high nutrient group, is also experiencing declining consumption rates due to common issues of lactose intolerance, milk allergies, an unfavorable fat content profile (Ray et al., 2017), and a wide-ranging increase in veganism (National Institutes of Health, 2013. All over the world, there is considerable variation in calcium intake by humans, with average intake values in many areas substantially below the Recommended Dietary Allowance of the United States (Prentice, 1994). Plant-based calcium sources, such as cereals, nuts, green leafy vegetables, and pulses, have limited bioavailability due to the presence of inhibitors (National Institutes of Health, 2013). Consumers are increasingly prioritizing health, expecting the food they consume to be natural, health-promoting, and sustainable (Stapleton et al., Stewart et al., 2020). These expectations also extend to cereal bars, prompting manufacturers to reformulate and improve these products (Kosicka-Gębska et al., 2022). The use of eggshells as a supplement in diet has proved to be an inexpensive means of dealing with the hazards posed by calcium deficiency (Mahima et al., 2024).

As of now, according to the International Osteoporosis Foundation, there is an increased possibility of osteoporotic fractures as 1 in 5

males and 1 in 3 females above the age of 50 years are projected to be affected globally (Ray et al., 2017). Calcium is one of the important minerals in the skeletal, circulatory system, endocrine, and nervous systems as shown in Figure 1 (Cormick&Belizán, et al., 2019). Lack of calcium in the body leads to various bone-related problems, such as rickets, fractures, osteopenia, and osteoporosis (Office of Dietary Supplements, 2021). Osteoporosis is considered a public health issue worldwide (Shlisky et al., 2022), and risk factors include advancing age, inactivity, smoking, and family history (National Osteoporosis Foundation, 2021). Even though the use of eggshell powder as a calcium supplement may have potential benefits, there is a huge gap in the literature, with very few studies conducted on the use of eggshell powder in cereal bars.

The objective of this chapter is to bridge the gap in research on the use of eggshell powder as a calcium fortification in cereal bars. Though eggshells are rich in calcium, the use of eggshells in cereal bars is under-explored. This chapter explores the possibility of using eggshell powder to increase the calcium content in cereal bars so that the risk of developing calcium deficiency can be decreased. This study will focus the attention of food manufacturers, producers, and scientists on the benefits of including eggshell powder in cereal bar production.

1. Eggshell Powder as Calcium Supplement

Eggshell powder obtained from chicken eggs is of high quality, and economical, and can be applied to every age group as an ideal calcium supplement for calcium fortification (Mahima et al., 2024). Research studies show that calcium is absorbed from the eggshell powder just like the one taken from calcium carbonate in rats (Brun et al., 2013). Eggshells are comprised of intricate and complicated substances to defend not only an embryo but, also provide developing organisms with essential nutrients. The basic component of eggshells consists of calcium carbonate, comprising 90% - 95% of solid eggshell matter (Rovenský et al., 2003; Adeyeye, 2009). Besides calcium carbonate, the other minerals present in eggshells include potassium, magnesium, sodium, phosphorus, iron, sulfur, iodine, manganese, cobalt, copper, zinc, molybdenum, chromium, and, fluorine percentages are shown in Table 1 (Al-Awwal et al., 2015).

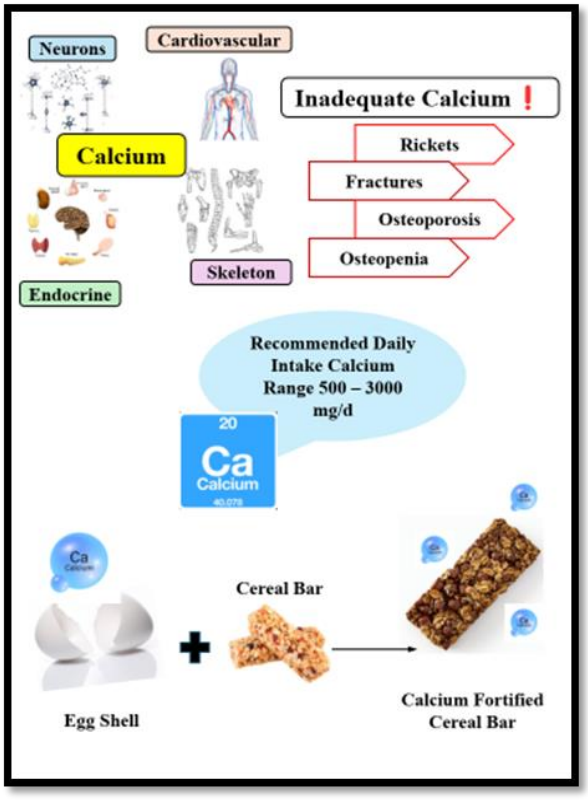

Fig. 1: Role of Calcium in Human Body, Inadequate Calcium Outcomes, Daily Dose Range of Calcium and Calcium Fortified Cereal Bars (Cormick & Belizán, et al., 2019; Shlisky et al., 2022).

Table 1: Mineral Content with nutritional values in Egg shells (Al-Awwal et al., 2015; Purevjav & Jargalsaikhan 2024).

Mineral Content in Egg Shell	Nutritional Value
Calcium	72.6 - 85.7%
Magnesium	2.7 - 4.7%
Phosphorus	7.0 - 18.1%
Sulfur	0.5 -5.2%
Potassium	0.6 – 0.4%
Iodine	2.6 – 3%

2. Dietary Reference Intake Values for Calcium

The National Academy of Medicine/ Institute of Medicine (NAM/IOM) published Dietary Reference Intake (DRI) values for calcium in North America (Canada and the United States) in 2011 (Anderson et al., 2016). These values of calcium were based on the effect of calcium intake on the health of bones, as evidence for the consequences of calcium intake on cardiovascular disease, cancer, autoimmune disorders, and diabetes was too inconsistent to inform nutritional needs (Prentice et al., 2013). However, future calcium panels may want to add some of the emerging data on calcium to include dietary reference intakes, while future panels may need to consider the inclusion of diet-related components in the effects (Shlisky et al., 2022). The wide changes in persistent calcium intakes all around the world and the noticeable ability of the human body to adapt to a wide range of calcium intakes cause a threat that increasing calcium intake may not have as great a population health benefit as might be expected (Kanis, 1994). Current needs are designed to optimize bone gains at the growth and developmental stages of childhood and adolescence and preserve the skeleton in later life, especially during postmenopausal periods in women (Ross et al., 2011). Needs are high in adolescents to support the period of rapid growth and decline in adults (Ross et al., 2011). The standard requirements established by the European Food Safety Authority (EFSA) in 2015 are relatively less than those recommended by the Institute of Medicine/National Academy of Medicine as shown in Table 2, and the European Food Safety Authority emphasized the inconsistency of the available evidence to support causal relationships between calcium intake and health outcomes, including bone health (European Food Safety Authority, n.d.). Some developing countries have population-specific calcium recommendations, and many organizations have Dietary Reference Values for calcium that were established some time ago (ICMR-National Institute of Nutrition, 2020). Calcium dietary requirements are affected by various factors that include diet, physical activity, and population variations (Shlisky et al., 2022).

3. Food Applications of Eggshell Powder

Eggshell powder has been successfully added to different food products such as bakery items to enhance their calcium level. Chocolate cakes supplemented with 6% eggshell powder showed maximum physical, chemical, and sensory properties (Mahima et al., 2024).

Similarly, pieces of bread made with eggshell powder and oyster shell powder showed better water absorption, dough development, and dough stability (Alsuhaibani, 2018). Eggshell powder has been investigated as a source of calcium in different foodstuffs. A study on butter cake revealed that supplementation with eggshell powder at a 10% inclusion level is viable (Salem et al., 2012). Another study reported that supplementation of biscuits with eggshell powder up to 6% did not have an impact on flavor (Hassan, 2015). White bread was also studied, and results have shown that it can be enriched up to 2% by eggshell powder without impacting acceptability (Platon et al., 2020). Eggshells are considered one source of waste recycling because of the high content of eggshell carbonate present within them (Messens et al., 2007; Dudusola, 2010).

Table 2: Daily Calcium Intake dose in milligrams per day for each human age group

Human Age Group	IOM/NAM Upper Limit (Shlisky et al., 2022)	EFSA Upper Limit (Gomes &Ashorn, 2022)	RDA in Asians (Nair & Augustine, 2018; Mahima et al., 2024)
Infants (0-6 months)	1000 mg/day	No established limit	500mg/day
Children (1-8 years)	1000-2500 mg/day	No established limit	600mg/day
Adolescents (9-18 years)	3000 mg/day	No established limit	600mg/day
Adults (19-50 years)	2500 mg/day	2000 mg/day	600mg/day
Adults (>50 years)	2000 mg/day	2500mg/day	600mg/day

Note: IOM/NAM (Institute of Medicine/National Academy of Medicine); EFSA (European Food Safety Authority); RDA (Recommended Daily Allowance).

4. Preparation of Eggshell Powder

Eggshell powder is prepared through several processes like cooking, cleaning, oven drying, and pulverization. The eggshells are sterilized by cooking for 10 minutes and then oven-dried at 200°C for 10 minutes. The dried eggshells are then ground into fine powder (Chakraborty &Gaonkar, 2016). The purchased eggs were cleaned, dried, and evaluated for quality through candling and sink tests. Eggshells were obtained, washed, and autoclaved at 121°C for 15 minutes. The eggshells were then dried, ground, and sieved to obtain small-sized particles. Microbial analysis was conducted to confirm the inactivation of Salmonella species, despite the pre-processing heat treatment being sufficient to inactivate them (Mahima et al., 2024). The nutrients in eggshell powder are shown in Table 3. The flowline of eggshell powder is illustrated in Figure 2.

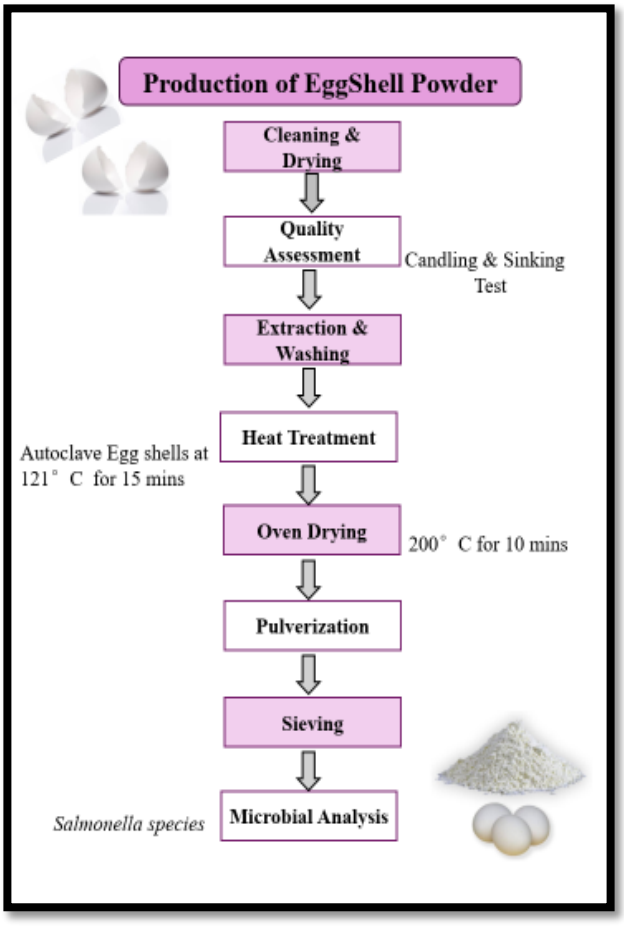

Fig. 2: Flowline of Production of Eggshell Powder (Chakraborty & Gaonkar, 2016; Mahima et al., 2024).

5. Eggshell Calcium Fortified Cereal Bars

To our knowledge, no other research and studies have conducted or investigated calcium-fortified whole grain cereal bars as a non-dairy source of calcium (Lee et al., 2015). Daily intake of two calcium-fortified cereal bars raised calcium intake by 350 mg in healthy women. Cereal bars have significant potential to increase calcium intake, which is supported by increasing sales of $3.7 billion in the US for 2012, supported by consumer interests in health and convenience (Mintel, 2013). Replacing energy-dense snacks with cereal bars may have contributed to the lack of weight gain. Previous studies have also shown that non-dairy calcium-fortified foods, such as ready-to-eat breakfast cereals, could raise calcium intakes by 50 ± 4 mg SEM/d (Song et al., 2006). The calcium-fortified cereal bars did not raise average energy intake or cause significant weight changes. The 6g/d of dietary fiber from the cereal bars may have augmented satiety, as supported by previous research (Slavin, 2008). Therefore, the objective of this research work was to establish the effect of calcium-fortified whole grain-based cereal bars on the dietary intake of calcium in women (Lee et al., 2015). Regulatory Framework for Eggshell Waste Utilization The world production of eggshell waste was estimated to be about 2.3 million tons in 2018 (Hincke et al., 2012; Ahmed et al., 2019).

Eggshell waste is an excellent source of bioactive compounds, and therefore research has gained more investment toward the development of value-added products from eggshell derivatives with commercial applicability (Cordeiro & Hincke, 2011). A huge number of patents have been filed for various applications in generating value-added products from eggshell waste. Over the past two decades, a very exponential rise in patent filings has been reported (Ahmed et al., 2021). In 2012, the Seventh Framework Program and the European Commission supported a 2-year project, "Shellbrane," to separate the eggshell and membrane of the eggshell to transform the waste of the shell of the egg into useful source materials

(Shellbrane, 2019). Similarly, in Canada, funded projects have been undertaken to utilize waste protein from eggshells as potential medical and healthcare spinoffs (Cordeiro & Hincke, 2011; Poultry Innovations Conference, 2013) and to formulate eggshell powder as a functional food ingredient (Canadian Food Innovators, 2015).

The utilization of eggshell biowaste is expected to provide environmental advantages and improve the economic sustainability of egg producers (Ahmed et al., 2021).

Table 3: Nutrients in Egg shell powder with Nutritional values (Youngcheng et al., 2013).

Nutrients in Eggshell Powder	Nutritional Value
Ash	94.61%
Calcium	34.12%
Protein	3.92%
Moisture	0.46%
Potassium	0.03%
Magnesium	0.29%
Sodium	0.05%
Phosphorus	0.04%
Zinc	<1 ppm
Copper	<1 ppm
Fat	0.35%
Iron	22 ppm

6. Future Direction

Further research is suggested for the recovery of calcium as calcium ions which can be utilized in milk products and other solid food products like cereal bars (Jony et al., 2021). Furthermore, studies on the nutritional and sensory characteristics of eggshell powder-enriched cereal bars would help to understand their potential as a calcium supplement. Moreover, research is required to identify the innovations consumers expect in cereal bars (Klerks et al., 2022).

Conclusion

In conclusion, the available literature reveals a significant knowledge gap regarding eggshell powder as a calcium source in fortified cereal bars. Despite its potential, there is a lack of scientific research exploring this application. Existing evidence suggests eggshell powder could be valuable in developing calcium-rich cereal bars. Its use in various food products demonstrates versatility and potential for incorporation into different formulations. Using eggshell powder can support effective waste management and mitigate the lack of calcium. Further studies should be carried out for the potentiality and viability of using eggshell powder in fortified cereal bars as a way of enhancing public health with environmental sustainability.

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