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Seafood Waste as a Nutrient-Dense Source for Calcium Supplements in India: A Minireview

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Calcium is an important mineral that is essential for human health, particularly bone health. Marine biological calcium is a plentiful supply with a complicated active structure that is well accepted. India has a long coastline, and seafood is an important element of its cuisine, culture and economy. However, seafood processing generates a significant amount of waste, which causes environmental issues and creates waste management challenges. Simultaneously, calcium deficiency is a serious public health problem in India, impacting people of all ages. This article presents a solution to both of these issues at the same time by extracting calcium supplements from seafood trash. The article investigates and assesses the viability of using discarded seafood shells as a source of calcium supplements and the provision of a low-cost and long-term solution.

Keywords

Calcium, Seafood waste, Processing, Calcium Supplement, Calcium deficiency

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Introduction

Calcium is one of the most fundamentally important and necessary minerals for the human body, accounting for 98% of the human skeletal system (Ross *et al.*, 2011). Calcium is a vital element that is commonly thought to influence bone health and human metabolism. Calcium deficiency can lead to osteoporosis, rickets, epilepsy, and anemia. Calcium enters the circulation via diet or calcium supplements and dynamic equilibrium between blood and bone calcium is maintained (Shojaeian *et al.*, 2019). An inappropriate diet can reduce calcium bioavailability. Calcium deficiency gets increasingly adverse with age. Osteoporosis has become a pandemic as a result of chronic calcium deficiency (Weaver *et al.*, 2019). Calcium deficiency and disorders associated with calcium deficiency continue to affect an increasing number of people. On the recommendations of medical professionals, many people have boosted their calcium intake by taking calcium supplements. This calcium supplement comes mainly from the sources like calcium carbonate minerals, shells of marine organisms and calcium-rich bones of the animals. But it is important to note that there may be a presence of heavy metals and other toxic compounds in the natural calcium carbonate minerals as stated by Ross *et al.* (2000). Animal bones may be a source of prion transmission. Calcium supplements derived from marine sources have gained popularity in recent years due to their enormous reserves, excellent safety, and biological activity. The use of marine biological calcium, as an abundant source of calcium, is an important strategy to boost the utilization rate of biological resources.

India: Chronic Calcium Deficiency

The daily calcium intake from dietary sources has been steadily falling in India. The data show that over the past ten years, the calcium concentration in g/CU/day has significantly decreased in the Indian population leading to severe calcium deficiency and increasing the risk of osteomalacia and osteoporosis. Kerala and Maharashtra had the lowest consumption of calcium according to the study by Singh *et al.* (2021). Recommended Dietary Allowance (RDA) of calcium is 600 g/CU/day. Harinarayan *et al.* (2021) compared statistics for various Indian states as distribution percentages of households and percent of RDA (Table 1).

Table:1 Distribution of percent RDA of different population age groups of India

	Age group	Percentage Population	States of India	RDA of calcium
Children	Adolescent boys & girls	70%–85%	All over India	<50%
	1–3 years	<15%	Kerala, Karnataka, AP, Maharashtra, Gujarat, MP, Orissa,	>70%
		25%–30%	TN, WB and UP	
	4–6 years, 10–12 years	10%–12%	All over India	>70%.
Adults	Sedentary men	51-65%	TN, Gujarat	>70%
		25%–35%	AP, Maharashtra and Orissa	
	Moderately active men	35%–42%	All states except Gujarat (50.8%), Maharashtra and WB (21%).	>70%

	Non-pregnant women	35%–45%	All over India except Gujarat (55%) and WB (27%)	>70%
	Pregnant women	<10%	all states except Kerala (21%)	<50%
			all states except for Maharashtra (97%) and MP (96%).	

Seafood Waste: Significant Source of Calcium

Modern seafood processing practices generate a considerable volume of waste products, such as skin, heads, tails, shells, scales, backbones, and so on. These waste items often consist of various high-value goods that remain untapped due to a lack of adequate management. The main components found in marine sources are calcium carbonate and calcium polyhydroxy phosphate, but they can be hard for the body to absorb and may cause digestive issues, according to Li et al. (2018). To improve calcium absorption rates, marine sources are commonly crushed or vacuum-heated. Studies have shown that calcium derived from marine sources has benefits that surpass those of calcium carbonate supplements or other foods rich in calcium. Regular intake of marine calcium supplements can prevent calcium deficiency. However, relying solely on marine species for calcium absorption may not be enough to address calcium deficiency-related illnesses. For the treatment of conditions like calcium deficiency, it may be necessary to increase the dosage of calcium supplements or medication.

Crustacean shells

Crustacean processing and consumption account for 30-40% of marine resource waste (Kandra *et al.*,2012). Crustacean shells such as shrimp, lobster and crab are primarily made up of calcium carbonate ($CaCO_3$), chitin and protein (Gbenebor *et al.,* 2016). Chitin is a complex carbohydrate that serves as the shell's structural component. Chitin is made up of long chains of sugar molecule N-acetylglucosamine but chitin does not provide a significant supply of calcium. Crustacean shells also contain minerals such as calcium carbonate, which offers a significant amount of calcium.

Fishbones

The term "fishbone" is used to describe the central appendage found in the body of a fish. This appendage accounts for approximately 10-15% of the fish's total body weight, according to Pateiro *et al.* (2020). The tissue in fishbone is primarily made up of an organic extracellular matrix that is coated in hydroxyapatite, which is a compound composed of calcium, phosphate, and hydroxide ions ($Ca_5(PO_4)_3OH$). Another good source of calcium is shark cartilage. To provide an example, the calcium present in the jaw cartilage of gummy sharks is mainly found in the form of hydroxy calcium phosphate crystal [$Ca_{10}(PO4)_6(OH)_2$], as stated by Patwardhan *et al.* (2001). In general, calcium extraction from fish bone includes removing protein and fat through heating, treating with alkali and organic solvents or enzymatic hydrolysis, and superfine crushing to create fishbone powder.

Cuttlebone

Cuttlefish, which are marine organisms related to squid and octopus, features a distinctive internal shell known as the cuttlebone. Cuttlefish processing in India for export or domestic consumption only uses the body, including the meat and the head; therefore, the cuttlebone is classified as a byproduct of the processing waste. The cuttlebone is a lightweight, porous structure made mostly of calcium carbonate, making it a possible source of calcium. As a rich source of calcium and other essential components, researchers have found potential uses of cuttlebone in the pharmaceutical industry towards innovations like biomaterials, hydroxyapatite, chitin and antacid drugs from cuttlebone (Henggu, 2021). Cuttlebone is frequently used as a calcium supplement for pet birds, offering a natural calcium supply for bone health.

Marine calcium supplements

Marketed as a natural and bioavailable type of calcium, marine calcium supplements are made from marine sources like crustacean shells, fishbones, cuttlebones and fish scales. Calcium comes in a variety of forms, each with a different bioavailability. Marine calcium comes in the form of calcium citrate or calcium carbonate may be found in supplements containing marine calcium. Marine calcium supplements are most frequently available in the form of calcium carbonate, which is frequently generated from marine sources. Since it needs stomach acid for proper absorption, it is typically well absorbed when taken with meals. Another popular form is calcium citrate, which is more readily absorbed and may be taken with or without food.

1. Organic acid Calcium

Calcium citrate, calcium gluconate, l-calcium lactate, calcium formate, calcium acetate and calcium propionate are examples of organic acid calcium. They have better bioavailability, solubility and absorption rates compared to calcium carbonate. Additionally, they are not as affected by changes in gastric pH (Reid et al., 2015). Fishbones, cuttlebones, shrimp shells, crab shells and other shells are the most common marine sources of calcium organic acids. Calcium absorption should be facilitated by appropriate techniques such as calcination, enzymatic hydrolysis, and fermentation methods.

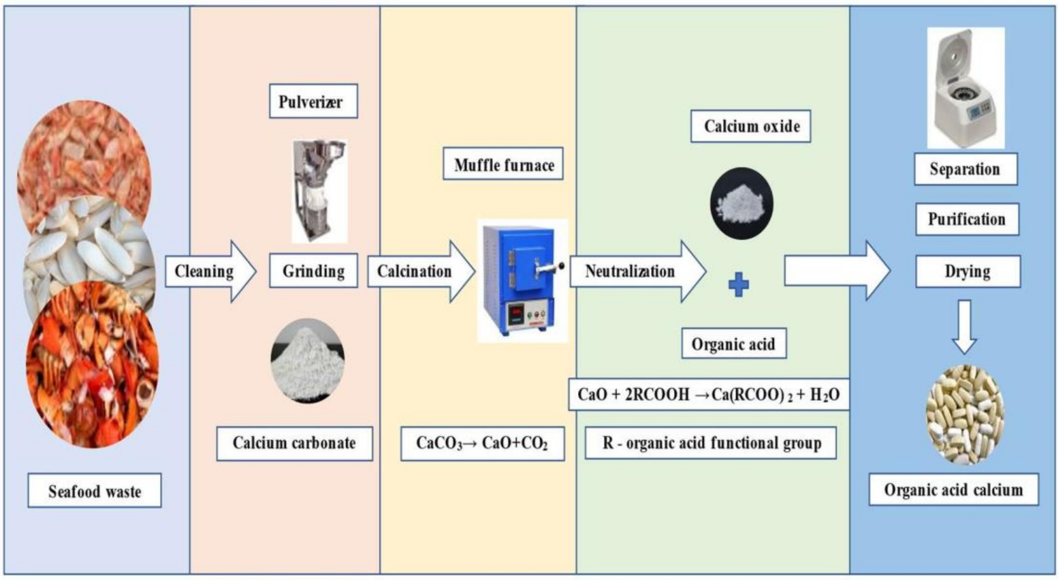

Fig. 1: Extraction of Organic Acid Calcium from Seafood Waste (Source: Xu *et al.*, 2021)

2. Seafood waste as a food additive

Shrimp and crab shells, which are high in calcium, can also be used to make food flocculants (Jun *et al.*, 2019). The calcium additives from marine organisms may be safer due to their natural origin. Calcium carbonate, calcium sulfate, calcium silicate and calcium lactate are calcium-containing food additives derived from aquatic organisms. Biological calcium derived from marine processing waste can still be utilized in food processing. For example, to improve the gel performance of fish surimi, fish bones can be added (Zhu *et al.*, 2014).

3. Development of new materials from marine calcium sources

Table:2 New Materials from marine calcium sources

New material	Seafood waste	Properties	References
Calcium-rich biochar	Crab shells	Remove dyes and phosphorus from wastewater	Dai *et al.* (2018)
hydroxyapatite	Cuttlefish bones	Bioceramic-based human bone scaffold	Henggu (2021)
Acid-insoluble calcium silicate hydrates	Oyster shells	Remove organic pollutants and heavy metal ions	You *et al.* (2016)
Porous scaffolds	oyster shells, clamshells, cuttlefish bones, and salmon bones	Bone tissue growth and vascularization	Brennan *et al.* (2015)
Hydroxy apatite (Ca10(PO4)6 (OH)2, HAp)-calcium phosphate	Codfish bones	Sunscreen formulation	Teixeira et al. (2017)

Conclusion and Future Prospective

In conclusion, seafood waste generation can be leveraged to address chronic calcium deficiency in India. Marine processing waste, which is often considered unnecessary, holds immense potential as a plentiful and cost-effective source of calcium. Calcium derived from marine species exhibits high bioavailability and biological function. By repurposing byproducts from marine creatures, we can enhance the value of additional calcium while mitigating the risk of pollution.

Developing calcium supplements from calcium-rich waste material not only alleviates the burden on waste management but also offers a more affordable alternative to conventional supplements for the calcium-deficient population. Future research should focus on maximizing the utilization of proteins, collagen, chitin, calcium, and other nutrients present in aquatic organisms.

To achieve commercial viability in various applications, further research is needed to explore the conversion of marine calcium into health foods, novel compounds, or food additives. This would contribute to both addressing calcium deficiency and reducing waste, ultimately promoting sustainability in the seafood industry.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

Conflict of interest

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