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A Waste-to-Wealth Approach: Preparation of Fish Scale-Derived Calcium Powder and Assessment of Its Impact on the Growth of *Trigonella foenum-graecum L.*

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ABSTRACT:

Fish scales are an abundant fish-processing by-product and a good natural source of collagen, and hydroxyapatite. The study was done to prepare calcium powder from fish scales using a simple boiling and sun-drying method without using chemicals and to test its effect on fenugreek (*Trigonella foenum-graecumL.*) growth.The calcium content of the powder was tested, and a 0.5 g sample contained 22.44% calcium.Twenty grams of fish-scale calcium powder was mixed with soil, and fenugreek seeds were grown under the same conditions as an untreated group.The treated soil produced better plant growth,including taller plants,more leaves,larger leaves,and stronger overall growth.The study shows that fish-scale calcium powder can be prepared by using an environmentally friendly method and could be used as an affordable organic soil additive to improve plant growth..

Keywords :

Fish scales, Calcium powder, Fenugreek, Organic fertilizer, Sustainable agriculture, Fish-processing waste.

Introduction:

The growth of the global fishing and seafood-processing industries has produced large amounts of organic waste, including fish scales, bones, skin, and fins. Among these waste materials, fish scales are often thrown away even though they hold useful materials such as collagen and calcium phosphate. Poor disposal of fish-processing waste causes pollution and creates serious waste problems. Therefore, turning fish waste into useful products has received a lot of attention as an environmentally friendly way to use waste while helping to protect the environment and save resources.

The use of fish-scale calcium powder offers an environmentally friendly way to reuse fish-processing waste while providing a cheap source of calcium for farming. Earlier studies have shown that fish scales can be made into-calcium-rich powders or hydroxyapatite for use in biomedical engineering, water purification, and agriculture. However, few studies have examined the direct use of simply prepared fish-scale calcium powder as a natural soil additive for improving plant growth.

Fish scales are a natural source of hydroxyapatite, a calcium phosphate mineral that has a large amount of calcium needed for plant growth. Calcium plays a vital role in keeping cell walls strong, maintaining cell membranes, supporting root growth, controlling enzyme activity, and moving nutrients through plants. Calcium deficiency harms plant growth, causing poor root development, smaller leaves, and lower crop yield (White & Broadley, 2003; Hepler, 2005). Although chemical calcium fertilizers are commonly used to treat calcium deficiency, their repeated use-increases production costs and may cause environmental harm. Therefore, finding sustainable and environmentally friendly alternatives has become more important.

Calcium fertilizers, such as calcium nitrate, gypsum, and agricultural lime, are often used to improve soil fertility. However, producing these fertilizers needs a lot of energy and increases farming costs**,** especially for small farmers. Sustainable agriculture supports the use of natural, low-cost, and environmentally friendly sources of nutrients**.** Fish-scale calcium powder is a useful organic option because it reuses waste that contains nutrients and turns it into a useful farm product while reducing the need for chemical fertilizers**.**

Trigonella foenum-graecum L. (fenugreek) is an important legume crop widely grown for its food, health, and cooking uses. Because it germinates quickly, has a short growing period, and responds to nutrient levels, fenugreek is a useful plant for testing the effects of nutrient-rich soil additives. Enough calcium can improve seed germination, root growth, leaf development, and overall plant growth.

This study uses fish waste to make a useful product by preparing calcium powder from fish scales through a simple method without chemicals. The method includes boiling, sun-drying, and grinding. The calcium powder was tested for its calcium content and its effect on the growth of *Trigonella foenum-graecum* in treated and untreated soils. By turning fish-processing waste into a useful farm product, this study aims to support proper waste handling, reduce pollution, and study whether fish-scale calcium powder can be used as an environmentally friendly fertilizer to help plants grow better.

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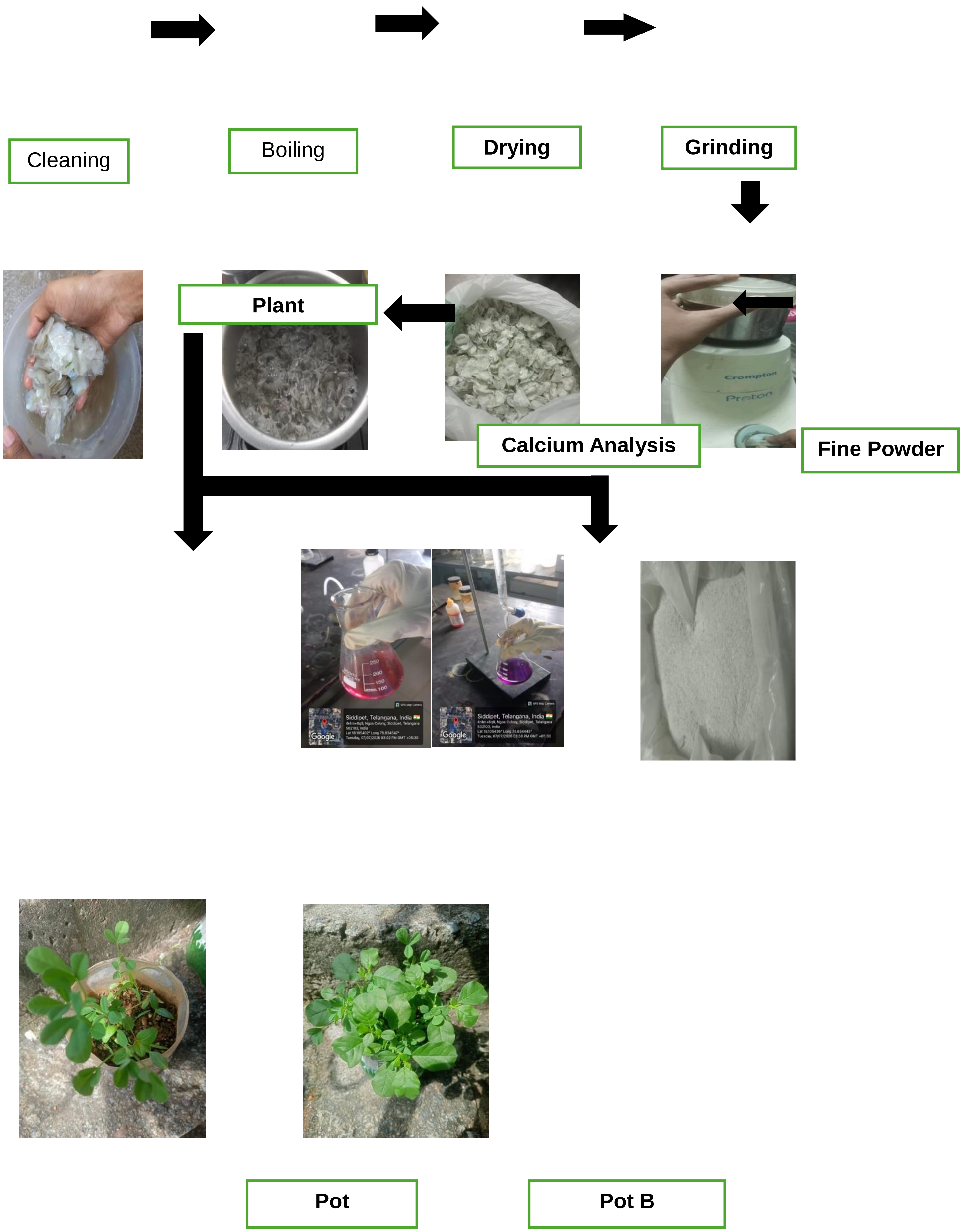
Cleaning
Boiling
Drying
Grinding
Plant
Calcium Analysis
Fine Powder
Pot
Pot B

Materials and methods

The materials used in this study included fresh fish scales collected from a local fish market as the raw material for calcium powder preparation and healthy seeds of ***Trigonella foenum-graecumL.*** (fenugreek) for evaluating plant growth. Garden soil was used as the planting medium, and plastic pots were usedto raise the experimental plants. Throughout the studydistilled water was used. The required chemicals and reagents for calcium estimation include disodium ethylenediamine tetra acetic acid (EDTA), sodium hydroxide (NaOH), hydrochloric acid (HCl), Nitric acid (HNO_3)and murexide indicator. Laboratory glassware and equipment such as beakers, conical flasks, burettes, pipettes, measuring cylinders, volumetric flasks, an analytical balance, a mixer grinder, a sieve, a glass rod, and a measuring scale were also used during the study.

Collection of Raw materials

The Fresh raw fish scales were collected from a local fish market. The scales weremoved to the laboratory in clean polyethylene bags and thoroughly washed primarily with tap water followed by distilled water to remove adhering flesh, mucus, blood, and other impurities and allowed to drain water through a sieve.

Preparation of Fish Scale-Derived Calcium Powder

The cleaned fish scales were boiledfor 30–45 minutes in distilled water to remove residual organic matter and reduce smell. After boiling, the scales were rinsed with distilled water and spread on clean sheets for sun drying until completely free of moisture (5-6 days).By using mixer grinderthe dried scales were ground into a fine powder. The prepared fish scale-derived calcium powder was stored in airtight containers at room temperature until further analysis and use.

Estimation of Calcium Content

The calcium content of the fish scale calcium powder was estimated by the EDTA complexometric titration method using Murexide indicator at pH 12. The procedure was carried out according to the standard method described in Vogel's Textbook of Quantitative Chemical Analysis **(Jeffery et al., 1989)**.

Approximately 0.5 g of the finely powdered fish scale sample was accurately weighed using an analytical balance and transferred into a clean beaker. To dissolve the calcium-containing minerals present in the sample Dilute hydrochloric acid (HCl) was added gradually to it. The mixture was continuously stirred until complete dissolution was obtained . The solution was filtered through Whatman No. 1 filter paper to remove any insoluble residue and transferred to a volumetric flask. The filtrate was then diluted to a known volume using distilled water to obtain the sample solution.

A measured aliquot of the prepared sample solution was transferred into a conical flaskand deionised water were added to the flaskto provide sufficient liquid volume to observe the colour change without diluting the indicator too much. To adjust the pH of the solution to approximately 12Sodium hydroxide (NaOH) solution was added, which provides the optimum alkaline conditions required for the selective determination of calcium. A small quantity of murexide indicator was then added. In the presence of calcium ions, the indicator formed a pink-coloured complex with calcium.

The sample solution was titrated with a standardised EDTA solution delivered from a burette while continuously swirling the flask. During titration, EDTA formed a stable 1:1 complex with calcium ions present in the solution. The endpoint of the titration was identified by a distinct colour change of the indicator from pink to purple (or violet), indicating that all free calcium ions had reacted completely with EDTA.

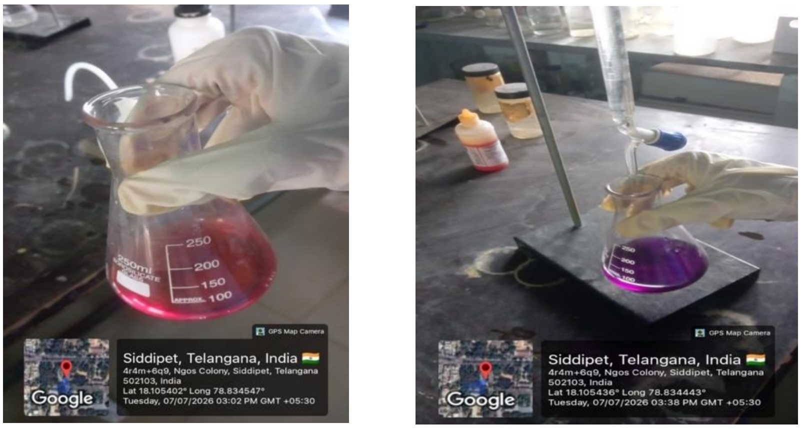

Fig.a & b respectively (a). Before titrating with EDTA

(b). After titrating with EDTA

The volume of EDTA consumed during titration was recorded, and the calcium content was calculated based on the concentration and volume of EDTA used. The analysis was carried out in triplicate to ensure accuracy and reproducibility, and the average value was reported as the calcium content of the fish scale-derived calcium powder.

Calculations

$$\% \text{ Calcium} = \frac{V \times 0.02 \times 40.08 \times DF}{W \times 1000} \times 100$$

V = Average volume of 0.02N EDTA consumed from the burette (mL)

0.02 = The normality of EDTA titrant

40.08 = Atomic weight of calcium

DF = Dilution factor

W = Initial weight of the fish scale powder used for the digestion

1000 = conversion factor (mg to g)

100 = conversion to percentage

$$\% \text{ Calcium} = \frac{14\times0.02\times40.08\times10}{0.5\times1000}\times 100$$

$$= \frac{112.224}{500}\times 100$$

$$= 112.224 \div 500 = 0.224448$$

$$= 0.224448\times100=22.4448$$

$$\boxed{\% \text{ Calcium} = 22.44\%}$$

The obtained calcium content in fish scale powder is 22.44%.

Experimental Design

A pot experiment was conducted to evaluate the effect of fish scale-derived calcium powder on the growth performance of ***Trigonella foenum-graecumL.***(fenugreek) under controlled conditions. The experiment was done using plastic pots. Each pot was filled with an equal quantity(1Kg) garden soil, free fromplant debris, and other foreign materials.

The present study consisted of two experimental treatments:

- **Pot A(Control):** Garden soil without the addition of fish scale-derived calcium powder.
- **Pot B(Treatment):** Garden soil mixed with **20 g of fish scale-derived calcium powder**.

The fish scale-derived calcium powder evenly mixed with the soil in the treatment pot to ensure uniform distribution before sowing the seeds. The control pot received no calcium amendment and served as the reference for comparison

Sowing of Seeds

Healthy, disease-free, and uniformly sized seeds of ***Trigonella foenum-graecum*** (fenugreek) were selected for the experiment to ensure uniform germination and growth. Before sowing, the prepared pots containing untreated soil (control) and soil mixed with fish scale-derived calcium powder (treatment) were lightly moistened with distilled water to provide favourable conditions for seed germination.

Seeds were sown in each pot at a uniform depth of approximately 1–2 cm below the soil surface. Adequate spacing was maintained between the seeds to minimize competition for nutrients, water, and sunlight during plant growth. After sowing, the seeds were gently covered with a thin layer of soil.

The pots were maintained under identical environmental conditions throughout the experimental period. Equal quantities of water were given to maintain optimum soil moisture without causing water logging. No additional fertilizers, growth regulators, or chemical amendments were applied during the experiment so that the effect of the fish scale-derived calcium powder could be evaluated independently. The pots were regularly inspected for weed growth, pest infestation, and disease symptoms, and appropriate care was taken to maintain healthy growing conditions. All environmental factors, including light exposure and watering schedule, were kept as consistent as possible for both treatments to ensure reliable comparison.

Result and Discussion

Calcium Content of Fish Scale-Derived Calcium Powder

The fish scales were successfully processed into a fine calcium-rich powder using a simple boiling, sun-drying, and grinding method. The calcium content of the prepared powder was determined by EDTA complexometric titration. The analysis revealed that the fish scale-derived powder contained **22.44% calcium**, confirming that the processed fish scales are a natural source of calcium. The prepared powder was later used as a soil amendment to evaluate its influence on the growth of ***Trigonella foenum-graecumL.***

Effect of Fish Scale-Derived Calcium Powder on the Growth of *Trigonella foenum-graecum L.*

The growth performance of ***Trigonella foenum-graecumL.*** (fenugreek) was evaluated after one month by comparing plants grown in untreated soil (control) and soil mixed with fish scale-derived calcium powder. The observations are presented in **Table 1.**

Table.1Effect of fish scale-derived calcium powder on the growth of *Trigonella foenum-graecum L.*

Parameter	Pot A(Control)	Pot B(Treated)
Observation Period	1 month	1month
Germination	14 plants	20 plants
Plant Height (cm)	9.5	10
Number of Leaves per Plant	18	21
Leaf size	Smaller	Broader

Stem	Narrow(thin) and weak	Broad(thick) and strong
Plant Vigour	Moderate	High

The results demonstrated that soil treated with fish scale-derived calcium powder containing **22.44% calcium** supported better growth of *Trigonella foenum-graecum L.* than the untreated control. Seed germination was noticeably higher in the treated pot, where **20 seedlings** emerged compared with **14 seedlings** in the control, standing for an approximate **42.9% increase in germination**.

Plant height was also greater in the treated plants, reaching an average of **10.0 cm**, whereas the control plants reached an average height of **9.5 cm** after one month. This corresponds to an approximate **5.3% increase in plant height** in response to the application of fish scale-derived calcium powder.

The number of leaves per plant increased from **18 leaves** in the control to **21 leaves** in the treated plants, standing for an approximate **16.7% increase in leaf production**. Besides these quantitative improvements, qualitative differences were also observed between the two treatments. Plants grown in the treated soil developed **broader leaves**, **thicker and stronger stems**, and shown**higher plant vigour** than those grown in untreated soil. In contrast, plants in the control pot produced comparatively smaller leaves, thinner stems, and only moderate vigour.

The enhanced growth characteristics seen in the treated plants show that the fish scale-derived calcium powder served as an effective natural soil amendment during the experimental period.,

Table 2. Percentage improvement in growth parameters

GrowthParameter	Control	Treated	Percentage increase
Germination	14 plants	20 plants	42.9%
Plant Height (cm)	9.5	10	5.3%
Numberof Leaves per Plant	18	21	16.7%


Pot A (Control) **Pot B (Treated)**

Overall,the combined findings show that fish scale-derived calcium powder holding 22.44% calcium effectively enhanced seed germination, vegetative growth, stem development, and overall plant vigour of ***Trigonella foenum-graecumL.***under the conditions of the present study.

Discussion

The present study proved that the application of fish scale-derived calcium powder positively influenced the growth of ***Trigonella foenum-graecumL.*** Plants grown in the treated soil exhibited improved germination, slightly greater plant height, increased leaf production, broader leaves, stronger stems, and better overall vigour compared with plants grown in untreated soil. These findings show that fish scale-derived calcium powder can serve as a beneficial natural source of calcium for plant growth.

The higher germination isseen in the treated soil may be related to the role of calcium in supporting membrane integrity, regulating enzyme activity, and promoting early root development. Calcium is an essential plant macronutrient that plays a critical role during seed germination and seedling establishment by stabilizing cell membranes and easing normal cellular metabolism **(Hepler, 2005; White & Broadley, 2003)**.

Although the increase in plant height was relatively small, the treated plants showed more uniform and healthier growth than the control plants. Calcium contributes to cell elongation, cell wall formation, and meristematic tissue development, which collectively support vegetative growth **(Marschner, 2012).** The observed increase in plant height suggests that the calcium supplied through fish scale-derived powder enhanced the physiological processes responsible for plant development.

An increase in the number of leaves was also seen in the treated plants. Leaf production is directly associated with photosynthetic capacity and biomass accumulation. Calcium promotes leaf expansion by strengthening cell walls and keeping structural stability, thereby supporting healthy leaf development **(Taiz et al., 2018)**. The broader leaves recorded in the treated plants further show improved vegetative growth and increased photosynthetic surface area.

The treated plants also developed thicker and stronger stems than the control plants. Calcium is a structural part of the middle lamella of plant cell walls, where calcium pectate provides rigidity and mechanical strength.

Adequate calcium availability therefore contributes to stronger stems and improved plant architecture **(White & Broadley, 2003)**.

The positive growth response seen in the present study is also consistent with the mineral composition of fish scales. Fish scales are primarily composed of hydroxyapatite, a calcium phosphate mineral that can gradually release calcium into the soil. Earlier studies have reported that fish-processing wastes are rich sources of calcium and phosphorus and have potential applications as sustainable biofertilizers and soil amendments **(Ikoma et al., 2003; Ooi et al., 2007)**. The calcium content of **22.44%** determined in the present study further supports the suitability of fish scale-derived powder as a natural calcium source.

Overall, the results support the concept of converting fish-processing waste into a value-added agricultural product. The use of fish scale-derived calcium powder not only improves plant growth but also contributes to sustainable waste management by reducing the environmental burden associated with fish-processing residues. The findings therefore highlight the potential of fish scale-derived calcium powder as an eco-friendly alternative to conventional calcium fertilizers in sustainable agriculture.

Conclusion

The present study proves that fish scale waste can be effectively transformed into a value-added calcium-rich material through a simple, environmentally friendly, and chemical-free preparation method. The findings support the concept of waste valorization by converting an abundant fish-processing by-product into a useful agricultural resource. The prepared fish scale-derived calcium powder showed promise as a natural soil amendment for promoting the growth of ***Trigonella foenum-graecum L.***, showing its potential application in sustainable agriculture.

The use of fish scale-derived calcium powder offers a dual environmental benefit by reducing the accumulation of fish-processing waste and offering an eco-friendly alternative to conventional calcium fertilizers. This approach aligns with the principles of the circular economy by encouraging resource recovery and the efficient use of biological waste.

Although the present investigation was conducted under controlled pot conditions, the encouraging findings provide a foundation for future research. Further studies should evaluate different application rates, assess the long-term effects on soil health and nutrient availability, investigate its performance under field conditions using various crop species, and characterize the prepared calcium powder using advanced analytical techniques. Such studies will help show the practical feasibility of fish scale-derived calcium powder as a sustainable agricultural input and further strengthen its potential for large-scale utilization..

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