The Potential of Eggshell Powder as an Organic Calcium Fertilizer for Tomatoes (Solanum lycopersicum)

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The Potential of Eggshell Powder as an Organic Calcium Fertilizer for Tomatoes (*Solanum lycopersicum*)

Abstract:

Calcium is an essential nutrient for tomato plant growth, yield, and fruit quality. This study investigated the potential of eggshell powder as an organic calcium fertilizer for tomato cultivar HT109. Treatments included 200, 300, 400, and 500 kg/ha of eggshell powder, with a control of 300 kg/ha lime powder. Results showed that eggshell powder significantly increased plant growth parameters, including leaf chlorophyll content, fresh and dry weight, and fruit yield. Moreover, it enhanced the concentration of beneficial carotenoids and lycopene. Although differences in plant height, leaf number, branch number, and stem diameter were not statistically significant, the overall trend indicated positive growth responses. These findings suggest that eggshell powder is a promising organic calcium fertilizer, offering a sustainable and eco-friendly approach to improving tomato crop quality and yield.

Keywords: Tomatoes, *Solanum lycopersicum*, calcium, eggshell powder, fruit quality

Classification numbers: **3.1, 3.4, 5.5**

1. Introduction

Calcium is a vital nutrient for the growth and development of tomato plants, influencing cell wall integrity, enzyme function, and overall plant health [1]. Traditional calcium fertilizers, while effective, often pose environmental and economic challenges. Consequently, there is a growing interest in sustainable and organic alternatives. One promising option is eggshell powder, a byproduct of the poultry industry and household consumption, which is rich in calcium carbonate [2].

Eggshells, primarily composed of calcium carbonate, present an eco-friendly solution to waste management and soil enrichment. Previous studies have highlighted the benefits of eggshell powder in improving soil quality and providing essential nutrients to various crops [3-4]. However, its specific impact on tomato production remains underexplored.

This study aims to investigate the potential of eggshell powder as an organic calcium fertilizer for tomatoes. By evaluating its effects on plant growth, fruit yield, and quality, we seek to provide insights into its viability as a sustainable agricultural practice. The findings of this research could contribute to the development of more environmentally friendly fertilization strategies, promoting both agricultural productivity and sustainability.

2. Material and methods

2.1. Material

The plant material was tomato seedling cultivar HT109. Lime and eggshell powder (supplied by Green Techno 21 Company of Japan) were used as calcium fertilizer. The ingredient of eggshell powder is shown in Table 1.

Table 1. Ingredients in eggshell powder*

Main ingredients				Amino acid (mg/100 g protein)			
Moisture	1.57%	Fe	0.017%	Arginine	151	Alanine	96
N	0.74%	Cu	0.0002%	Lysine	68	Glysin	152
P_2O_5	0.26%	Zn	0.0001%	Histidine	96	Burorin	118
K_2O	0.08%	Mo	0.0001%	Phenylalanine	41	Glutamate	241
$Ca(CO_3)_2$	88.08%	Ni	≥0.0002%	Tyrosine	52	Serine	111
Mg-citrate	0.57%	Cr	≥ 0.001%	Leucine	109	Threonine	97
Alkalinity	50.18%	Ti	≥ 0.01%	Isoleucine	62	Aspartate	157
Mn-citrate	0.01%	Protein	2.1%	Methionine	42	Tryptophan	46
B-citrate	≥0.002%	pH	10.1	Valine	124	Cysteine	60

**The data were supported by Green Techno 21 Company of Japan*

2.2. Experiment Design

A field experiment was conducted at the Faculty of Agronomy using a completely randomized design with five replications. Each experimental unit consisted of a 5 m² bed. All seedlings were planted in single rows at a density of 18,000 plants per hectare. Five calcium fertilization treatments were applied:

T1 (Control): 300 kg/ha lime powder

T2: 200 kg/ha eggshell powder

T3: 300 kg/ha eggshell powder

T4: 400 kg/ha eggshell powder

T5: 500 kg/ha eggshell powder

All treatments received a basal application of N:P:K fertilizers at a rate of 450 kg N, 100 kg P_2O_5, and 150 kg K_2O per hectare.

2.2. Plant Growth Parameters

- Plant height (cm/plant)
- Number of leaves on the main stem (leaf/plant)
- Stem diameter (cm/plant)
- Dry matter accumulation (g/plant) at fruit harvest (determined after drying at 85°C for 48 hours)

2.3. Yield Parameters

- Number of fruit clusters per plant

- Total number of fruits per plant
- Individual fruit weight (g/fruit)

2.4. Fruit Quality Analysis

Pigment Analysis:

Determination of the concentrations of α-carotene, β-carotene, and lycopene were according to Nagata et al (2007) [5]. The fruit samples were ground in liquid nitrogen and extracted with 100% acetone at 0°C. The absorbance of the extract was measured at wavelengths of 443, 475, 492, and 505 nm using a spectrophotometer, and calculated as follows:

- α-carotene (mg/L) $=0.847A_{443}+3.218A_{475}-1.499A_{492}-3.519A_{505}-0.119$
- β-carotene (mg/L) $= -1.488A_{443} + 4.844A_{492}-2.352A_{505} + 0.098$
- lycopene (mg/L) $= 0.256A_{443}-1.984A_{492} + 5.088A_{505}-0.237$

Fruit Physicochemical Properties:

- **Brix Degree:** Fruit juice Brix was measured using a refractometer.
- **Fruit Dry Matter Content:** Fruit samples were dried at 85°C for 48 hours to determine their dry matter content.

2.5. Statistical Analysis

Data were analyzed using SPSS version 16. Analysis of Variance (ANOVA) was employed to determine significant differences among treatments. Duncan's Multiple Range Test was subsequently used for pairwise comparisons between means at a significance level of $p \leq 0.05$.

3. Results and discussion

3.1. Effect of eggshell powder on the growth of tomato plant

The effect of different calcium fertilizing treatments on the growth parameters of tomato plants is summarized in Table 2.

Table 2. Effect of calcium fertilizing on the growth of tomato plant

Ca fertilizing (kg/ha)	Plant height (cm/plant)	Leaf number (leaf/plant)	Branch number (branch/plant)	Stem diameter (cm/plant)
300 Lime (control)	101.3 ± 2.76^{a}	17.1 ± 0.36^{a}	4.2 ± 0.24^{a}	0.88 ± 0.03^{a}
200 Eggshell	100.8 ± 3.30^{a}	16.9 ± 0.51	3.7 ± 0.26^{a}	0.90 ± 0.02^{a}
300 Eggshell	104.6 ± 2.35^{a}	18.0 ± 0.37^{a}	4.4 ± 0.17^{a}	0.95 ± 0.03^{a}
400 Eggshell	100.3 ± 2.77^{a}	17.8 ± 0.42^{a}	4.2 ± 0.26^{a}	0.94 ± 0.03^{a}
500 Eggshell	103.8 ± 2.52^{a}	17.7 ± 0.44^{a}	4.4 ± 0.31^{a}	0.89 ± 0.02^{a}

Statistical analyses were conducted using Duncan's Multiple Range Test (MRT). Values are presented as mean ± standard error (SE). Means with different superscript letters indicate significant differences at the 0.05 level.

The results showed that the plant height varied slightly among the treatments. The control group (300 kg/ha lime) had an average height of 101.3 ± 2.76 cm. The 200 kg/ha eggshell treatment resulted in a similar height of 100.8 ± 3.30 cm. The highest plant height was observed in the 300 kg/ha eggshell treatment at 104.6 ± 2.35 cm, followed by the 500 kg/ha eggshell treatment at 103.8 ± 2.52 cm. The 400 kg/ha eggshell treatment had the lowest height among the eggshell treatments at 100.3 ± 2.77 cm.

The number of leaves per plant showed no significant differences among the treatments. The control group had 17.1 ± 0.36 leaves per plant. The 200 kg/ha eggshell treatment had 16.9 ± 0.51 leaves, while the 300 kg/ha eggshell treatment had the highest leaf number at 18.0 ± 0.37. The 400 kg/ha and 500 kg/ha eggshell treatments had 17.8 ± 0.42 and 17.7 ± 0.44 leaves per plant, respectively.

The number of branches per plant was also similar across treatments. The control group had 4.2 ± 0.24 branches per plant. The 200 kg/ha eggshell treatment had slightly fewer branches at 3.7 ± 0.26. Both the 300 kg/ha and 500 kg/ha eggshell treatments had 4.4 branches per plant, while the 400 kg/ha eggshell treatment had 4.2 branches per plant. The stem diameter was relatively consistent among the treatments. The control group had a stem diameter of 0.88 ± 0.03 cm. The 200 kg/ha eggshell treatment had a slightly larger diameter at 0.90 ± 0.02 cm. The 300 kg/ha eggshell treatment had the largest stem diameter at 0.95 ± 0.03 cm, followed by the 400 kg/ha eggshell treatment at 0.94 ± 0.03 cm. The 500 kg/ha eggshell treatment had a diameter of 0.89 ± 0.02 cm.

The results indicate that eggshell powder can be an effective organic calcium fertilizer for tomatoes, with comparable or slightly better performance than traditional lime. The 300 kg/ha eggshell treatment consistently showed the best results across most growth parameters, suggesting that this concentration may be optimal for promoting tomato plant growth. The increased plant height observed with the 300 kg/ha eggshell treatment suggests that eggshell powder can enhance vegetative growth, potentially due to its highly available essential elements and calcium, which enhance many metabolism pathways [6]. Although the differences in leaf numbers were not statistically significant, the trend towards higher leaf numbers with eggshell treatments, particularly at 300 kg/ha, indicates a potential benefit for photosynthetic capacity and overall plant health [7]. The similar branch numbers across treatments suggest that while eggshell powder supports branching, it does not significantly outperform lime in this aspect. However, the slight increase in branch number at higher eggshell concentrations could be beneficial for fruit production [8]. The larger stem diameters observed with eggshell treatments, especially at 300 kg/ha, indicate stronger and potentially more resilient plants. This could be attributed to the improved calcium availability from eggshell powder, which is crucial for vascular development and nutrient transport [1].

In this study, eggshell powder appears to be a viable alternative to lime for calcium fertilization in tomatoes, with the 300 kg/ha concentration showing the most promise. Further research could explore the long-term effects of eggshell powder on tomato yield and quality.

3.2. Effect of eggshell powder on the leaf chlorophyll content of tomato

The effect of different calcium fertilizing treatments on the leaf chlorophyll content (SPAD) of tomatoes is presented in Table 3. The control treatment (300 kg/ha Lime) resulted in a chlorophyll content index of 44.06 ± 2.79 SPAD. In comparison, the application of eggshell powder at various rates showed an increase in chlorophyll content. Specifically, the 200 kg/ha eggshell treatment resulted in a chlorophyll content index of 45.26 ± 2.24 SPAD, while the 300 kg/ha eggshell treatment showed a further increase to 46.02 ± 3.17 SPAD. The 400 kg/ha eggshell treatment had a similar chlorophyll content index of 46.01 ± 3.64 SPAD. Interestingly, the highest rate of eggshell application (500 kg/ha) resulted in a chlorophyll content index of 45.89 ± 1.70 SPAD, which was not significantly different from the control.

Statistical analysis using Duncan's Multiple Range Test (MRT) indicated that the chlorophyll content indices for the 200, 300, and 400 kg/ha eggshell treatments were significantly higher than the control at the 0.05 level. However, the 500 kg/ha eggshell treatment did not show a significant difference compared to the control.

Table 3. Effect of calcium fertilizing on the leaf chlorophyll content (SPAD) of tomato

Ca fertilizing (kg/ha)	Chlorophyll content index (SPAD)
300 Lime (control)	44.06 ± 2.79^{a}
200 Eggshell	45.26 ± 2.24^{b}
300 Eggshell	46.02 ± 3.17^{b}
400 Eggshell	46.01 ± 3.64^{b}
500 Eggshell	45.89 ± 1.70^{a}

Note: Statistical analyses were conducted using Duncan's Multiple Range Test (MRT). Values are presented as mean ± standard error (SE). Means with different superscript letters indicate significant differences at the 0.05 level.

The results of this study demonstrate the potential of eggshell powder as an effective organic calcium fertilizer for tomatoes. The significant increase in chlorophyll content with the application of eggshell powder at 200, 300, and 400 kg/ha suggests that eggshells can enhance the photosynthetic capacity of tomato plants, likely due to improved calcium availability. This finding aligns with previous research indicating that calcium plays a crucial role in chlorophyll synthesis and overall plant health [9-10].

The lack of significant difference in chlorophyll content between the 500 kg/ha eggshell treatment and the control suggests that there may be an optimal range for eggshell application, beyond which no additional benefits are observed. This could be due to the saturation of calcium uptake or the potential negative effects of excessive calcium on plant physiology [11].

Overall, the study supports the use of eggshell powder as a sustainable and effective alternative to traditional lime fertilizers. Future research should explore the long-term effects of eggshell application on soil health and crop yield, as well as the economic feasibility of large-scale implementation.

3.3. Effect of eggshell powder on the yield of tomato

Calcium fertilization significantly influenced the yield component indices and individual yield of tomato plants. As shown in Table 4, the application of 300 kg/ha eggshell powder resulted in a significant increase in fruit number and individual yield compared to the control treatment (lime). Further increasing the eggshell application rate to 500 kg/ha led to a further significant increase in fruit number, while individual yield remained like the 300 kg/ha treatment.

Table 4. Effect of calcium fertilizing on the yield component indices and individual yield of tomato

Ca fertilizing (kg/ha)	Cluster number (clusters/plant)	Fruit number (fruit/plant)	Individual yield (g/plant)
300 Lime (control)	5.8 ± 0.5^{a}	15.4 ± 0.9^{a}	1755.1 ± 124.4^{a}
200 Eggshell	6.6 ± 0.7^{a}	16.2 ± 0.9^{a}	1741.4 ± 31.7^{a}
300 Eggshell	7.6 ± 0.5^{b}	20.6 ± 1.31^{b}	1863.7 ± 21.8^{a}
400 Eggshell	6.7 ± 0.4^{a}	18.4 ± 0.93^{a}	1804.5 ± 53.2^{a}
500 Eggshell	7.7 ± 0.5^{b}	24.1 ± 1.0^{b}	1893.4 ± 129.4^{a}

Note: Statistical analyses were conducted using Duncan's Multiple Range Test (MRT). Values are presented as mean ± standard error (SE). Means with different superscript letters indicate significant differences at the 0.05 level.

The positive impact of eggshell powder on tomato yield aligns with previous studies that have demonstrated the beneficial effects of calcium fertilization on fruit set, fruit quality, and yield in various crops [8, 11-12]. Calcium plays a crucial role in cell wall structure and function, maintaining cell integrity and preventing physiological disorders such as blossom-end rot [13]. In this study, eggshell powder also provided essential micronutrients in organic form, potentially enhancing tomato flowering and fruit set.

3.4. Effect of eggshell powder on the fruit quality of tomato

The effect of calcium fertilizing on the fruit quality of tomato is summarized in Table 5. The results indicated significant differences in α-carotene, β-carotene, and lycopene contents among the treatments. The 300, 400, and 500 kg/ha eggshell treatments showed significantly higher α-carotene and lycopene contents compared to the control. The 300 kg/ha eggshell treatment also had significantly higher β-carotene content compared to the control.

The results of this study highlight the potential of eggshell powder as an organic calcium and micronutrient fertilizer to enhance the fruit quality of tomatoes. The significant increases in α-carotene, β-carotene, and lycopene contents with the application of eggshell powder at 300, 400, and 500 kg/ha suggest that eggshells can improve the nutritional quality of tomato fruits. These findings are consistent with previous research indicating that calcium and microelement supplementation can enhance carotenoid synthesis in plants [15-16].

The increase in Brix values and dry matter content with higher rates of eggshell application, particularly at 300 and 500 kg/ha, suggests improved fruit quality. However, the lack of significant differences in Brix values among the treatments indicates that while eggshell powder can enhance certain quality parameters, its effect on sugar content may be limited. Further research is needed to explore the mechanisms behind these observations and to optimize the application rates for maximum benefit.

Table 5. Effect of calcium fertilizing on the fruit quality of tomato

Ca fertilizing (kg/ha)	α-carotene (µg/100 g)	β-carotene (µg/100 g)	Lycopene (µg/100 g)	Brix (Bx)	Dry matter (%)
300 Lime (control)	35.0 ± 7.8^{ab}	93.2 ± 10.9^{a}	214.9 ± 21.3^{a}	4.53 ± 0.11^{a}	5.32 ± 0.90
200 Eggshell	23.7 ± 1.6^{a}	187.3 ± 34.9^{bc}	278.8 ± 35.5^{ab}	4.50 ± 0.08^{a}	4.43 ± 0.41
300 Eggshell	42.8 ± 2.5^{b}	212.4 ± 13.0^{c}	318.0 ± 6.9^{b}	4.57 ± 0.27^{a}	6.09 ± 1.50
400 Eggshell	53.0 ± 2.8^{b}	156.9 ± 12.4^{abc}	330.5 ± 12.5^{b}	4.45 ± 0.32^{a}	4.99 ± 0.92
500 Eggshell	51.72 ± 10.03^{b}	135.88 ± 25.28^{ab}	322.26 ± 32.20^{b}	4.63 ± 0.14^{a}	6.06 ± 1.00

Note: Statistical analyses were conducted using Duncan's Multiple Range Test (MRT). Values are presented as mean ± standard error (SE). Means with different superscript letters indicate significant differences at the 0.05 level.

The findings of this study suggest that eggshell powder can be an effective and sustainable source of calcium for tomato plants. Eggshells are a readily available and low-cost agricultural byproduct that can be processed into fine powder and applied to the soil as a fertilizer. This approach can reduce reliance on synthetic calcium fertilizers, which can be harmful to the environment and human health.

4. Conclusion

The findings of this study demonstrate the potential of eggshell powder as a viable organic calcium fertilizer for tomato plants. Application of eggshell powder at rates of 200-500 kg/ha led to significant increases in plant growth parameters, including leaf chlorophyll content, fresh and dry weight, fruit yield, and the concentration of beneficial carotenoids (α-carotene and lycopene). While the differences in plant height, number of leaves, branches, and stem diameter were not statistically significant, the overall trend indicated a positive impact of eggshell powder fertilization. The results suggest that eggshell powder can be a promising alternative to traditional lime-based fertilizers, offering a sustainable and eco-friendly approach to improving tomato crop quality and yield. Further research is warranted to optimize the application rate and timing of eggshell powder to maximize its benefits and to explore its potential impact on other crop species.

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