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RESEARCH ARTICLE

# Enhancing plant growth, yield and nutritional quality of brinjal through Arka Microbial Consortium (AMC) applications

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**Abstract**

Brinjal (*Solanum melongena* L.) is the "poor man's vegetable" and prized for its affordability, nutritional value and medicinal uses. The Elavambadi brinjal (VRM-1) is a Geographical Indication (GI)-tagged variety from Tamil Nadu, India. It is known for its tender texture, fewer seeds and health benefits, particularly for managing diabetes and liver ailments. This study investigated the impact of the Arka Microbial Consortium (AMC), a carrier-based bio-fertilizer containing nitrogen-fixing, phosphorus, zinc solubilizing and plant growth-promoting microbes, on the growth, yield and quality of Elavambadi brinjal. The treatment $T_{5,}$ which combined soil drenching, rhizosphere soil and foliar application of AMC, resulted in the highest performance across multiple parameters. It recorded the maximum plant height, branching, stem diameter, fruit yield (8704.67 g/plant), ascorbic acid content (107.81 mg/100 g) and phenol content (90.49 mg Gallic Acid Equivalent (GAE)). Additionally, $T_5$ demonstrated superior cooking quality and reduced weight loss during frying (65.96 %) and baking (11.97 %). These results highlight AMC's ability to enhance nutrient uptake, plant growth and the synthesis of bioactive compounds. The findings emphasize that AMC is a potentially effective bio-fertilizer for improving brinjal production, enhancing nutritional quality and promoting sustainable agricultural practices.

**Keywords:** empirical model; global models; hydrological model; sensitivity; uncertainty

## Introduction

Brinjal (*Solanum melongena* L.) (2n=24) is widely known as the poor man's vegetable (1) due to its cheap source of vitamins and minerals. It is used as a principal component in the pharmaceutical industry for the treatment of diseases like high cholesterol, liver and skin diseases and throat problems (2, 3). Brinjal is the third most widely cultivated crop in the Solanaceae family after tomato and potato. It is grown in an area of about-1.87 million hectares with a total production of 56.62 million tons in 2020-21, with a productivity of 30.27 tonnes/ha (4). Elavambadi brinjal (VRM-1) or Mullu Katharikai is a Geographical Indication (GI) tagged cultivar of brinjal predominantly grown in the Vellore and Tiruvannamalai districts of Tamil Nadu, India, known for its tender texture, fewer seeds and slightly sweet taste (5). The Elavambadi brinjal is characterized by a typical purple hue, spines on the stem, calyx and leaves (6). In the Vellore district, the cultivation of Elavambadi brinjal spans approximately 1397 ha with an annual production of around 41100 tonnes. The unripe fruits of this variety are commonly used as cooked vegetables and are reputed for their health benefits. Notably, Elavambadi brinjal is considered beneficial for diabetic patients. Additionally, when the fruits are fried in sesame oil, they are believed to alleviate toothaches and serve as a remedy for individuals suffering from liver ailments (7).

Soil microorganisms enhance food production by influencing nutrient accumulation, organic matter decomposition, carbon dynamics and plant resilience to abiotic and biotic stresses. Microbial Consortia (MC), which consist of multiple microbial species or strains coexisting symbiotically, often exhibit superior performance compared to single-species inoculants (8). In brinjal cultivation, biofilm-based bio-fertilizers and plant growth-promoting rhizobacteria within MC have demonstrated potential benefits. These microbial consortia contribute to nutrient solubilisation from the soil's native reserves, enhance root growth by producing beneficial compounds such as siderophores, phytohormones and mitigate the effects of growth-inhibitory hormones, ultimately improving plant health and productivity. The current experiment aimed to maximize AMC efficiency in increasing the growth and yield of Elavambadi brinjal by testing different inoculation methods (9).

## Materials and Methods

The experiment was carried out in the Instructional Farm Area (Latitude: 12.967886°, Longitude: 79.162115°), Department of Horticulture and Food Science, Vellore Institute of Technology, Vellore to study the effect of Arka Microbial Consortium (AMC) in seedling growth, yield and quality parameters of Elavambadi brinjal (VRM-1). The nursery-raising method was adopted to raise healthy, disease-free seedlings of brinjal. The media consisted of cocopeat and vermicompost (7:3 ratio). The seedlings were ready for transplanting at 35 days after sowing. The main field was cultivated to a fine tilth and well-decomposed farmyard manure was incorporated @ 20 tonnes /ha. Brinjal seedlings were transplanted at a spacing of 60 cm (between plants) x 75 cm (between rows) on the tops of the ridges. Brinjal cultivation was carried out following the recommended fertilization protocol. Farmyard manure (FYM) and chemical fertilizers were applied at 125 kg N, 50 kg $P_2O_5$ and 70 kg $K_2O$ per hectare. The full dose of phosphorus, along with 20 % of both nitrogen and potassium, was incorporated as a basal application. The remaining 80 % of nitrogen and potassium was administered in two equal split doses at 20 and 40 days after transplanting, following weeding and hoeing. The treatment details include $T_1$: Seedling dipping with AMC, $T_2$: Soil drenching with AMC, $T_3$: rhizosphere soil application of AMC, $T_4$: Foliar application of AMC, $T_5$: Soil drenching + Rhizosphere soil + foliar application of AMC, $T_6$: Seedling dipping + Soil drenching + Rhizosphere soil + foliar application of AMC and $T_7$: Control (no application of AMC). For seedling dipping, AMC was mixed with water @ 20 g $L^{-1}$ and the roots of the seedlings were dipped in AMC for 15 min before transplanting. For soil drenching, AMC was mixed with water @ 20 g $L^{-1}$ and applied in the soil after 10 days of transplanting. For rhizosphere application, 20 g of AMC was applied to each plant equally near the root zone. For foliar application, AMC solution was prepared @ 10g $L^{-1}$ of water and sprayed 15 days after flowering. The experiment was carried out in a Randomized Block Design (RBD) with seven treatments replicated thrice. Ten healthy plants from each treatment and replication were selected randomly and tagged for recording the observations.

The plant height was measured from the ground level to the top of the inflorescence at the time of maturity and their mean value was taken for analysis of this character at 30, 60 and 90 days after transplanting (DAT). The total number of branches in each of the ten tagged plants was counted and their mean value was taken as the number of branches per plant at 30, 60 and 90 DAT. Stem diameter was measured with the help of a vernier calliper at 30, 60 and 90 days after transplanting. Days to first flowering were recorded by calculating the number of days taken from the date of transplanting till plants in the plot start flowering. The number of fruits from each plant in the population was counted and the mean was taken. For fruit yield per plant, fruits harvested from the tagged plants were weighed and the mean was taken and expressed in grams. The lengths of twenty fruits from the tagged population were measured in cm from the attachment end (stalk end) to the tip (stylar end) and the mean values were calculated as fruit length. After recording the fruit length, the same fruits were also used for measuring the fruit girth. Fruit girth was measured at the widest diameter of the fruit. Average fruit weight was calculated by dividing the total fruit yield by a total number of fruits harvested.

The ascorbic acid content was determined using a volumetric titration method. A 5 mL aliquot of the standard solution was placed in a 100 mL conical flask, followed by the addition of 10 mL of 4 % oxalic acid. The solution was titrated against a dye solution until a stable pink endpoint was achieved ($V_1$), with the volume of dye consumed corresponding to the ascorbic acid content. For sample analysis, 1 g of plant material was weighed, homogenized in 4 % oxalic acid and filtered using Whatman No.1 filter paper. The final volume was adjusted to 100 mL. The ascorbic acid concentration was calculated and expressed in milligrams per 100 g of fruit pulp.

$$\text{Ascorbic acid content (mg/100 g)} = \frac{0.5\text{ mg} \times V2 \times 100\text{mL} \times 100}{V1\text{ mL} \times 5\text{ mL} \times \text{weight of sample}}$$

The total phenolic content (TPC) of the brinjal extracts was determined calorimetrically following the method described with some modifications (10). A five-gram sample was pulverized and extracted in 80 % acetone the volume was made up to 50 mL. The extract was then filtered using Whatman's No. 1 filter paper and centrifuged for 15 min at 4000 rpm. 0.15 mL aliquot of the supernatant was mixed with 0.15 mL of 0.25 N Folin-Ciocalteu reagent, 2.4 mL of distilled water in a glass test tube properly mixed and incubated for 3 min. 0.3 mL of 1N sodium carbonate was added and the mixture was incubated at room temperature for 2 hr under dark conditions. Absorbance was measured using a UV spectrophotometer at 760 nm with distilled water as the blank. A gallic acid standard was prepared and the total phenolic content of the brinjal fruit extract was expressed as mg GAE $g^{-1}$ fresh weight of brinjal (11, 12).

## Results and Discussion

### Plant growth parameters

The growth performance of brinjal was significantly influenced by the different treatments of the AMC (Table 1). Among all treatments, $T_5$ (Soil drenching + Rhizosphere soil + Foliar application of AMC) exhibited the highest plant growth, with the maximum plant height observed at 30 days after transplanting (DAT) (27.70 cm), 60 DAT (51.67 cm) and 90 DAT (71.28 cm). This was followed by $T_6$ (Seedling dipping + Soil drenching + Rhizosphere soil + Foliar application of AMC), with plant heights of 25.91 cm, 42.08 cm and 60.34 cm at 30, 60 and 90 DAT, respectively. The least growth was observed in $T_1$ (Seedling dipping with AMC), with a plant height of 13.99 cm at 30 DAT and 52.85 cm at 90 DAT.

The number of branches per plant was highest in $T_5$ at 30 DAT (5.33), 60 DAT (7.67) and 90 DAT (10.43), followed by $T_7$ (Control) with values of 4.52 (30 DAT), 7.71 (60 DAT) and 9.57 (90 DAT). T4 (Foliar Application of AMC) showed the least number of branches, particularly at 30 DAT (3.43). $T_1$ displayed fewer branches at 60 DAT (5.52) and 90 DAT (5.05). This indicates that multiple applications of AMC through various

**Table 1.** Effect of AMC on morphological traits of brinjal

| | Plant height (30 DAT) (cm) | Plant height (60 DAT) (cm) | Plant height (90 DAT) (cm) | Number of branches (30 DAT) | Number of branches (60 DAT) | Number of branches (90 DAT) | Stem diameter (30 DAT) (cm) | Stem diameter (60 DAT) (cm) | Stem diameter (90 DAT) (cm) |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 13.99$^{d}$ | 33.75$^{d}$ | 52.85$^{d}$ | 3.66$^{cd}$ | 5.05$^{d}$ | 5.52$^{d}$ | 1.30$^{d}$ | 2.60$^{d}$ | 3.66$^{c}$ |
| $T_2$ | 18.63$^{c}$ | 31.64$^{e}$ | 57.69$^{bc}$ | 4.38$^{bc}$ | 6.15$^{c}$ | 9.57$^{ab}$ | 1.40$^{cd}$ | 2.39$^{d}$ | 3.30$^{c}$ |
| $T_3$ | 15.32$^{d}$ | 24.83$^{f}$ | 54.48$^{cd}$ | 3.44$^{d}$ | 6.29$^{c}$ | 7.22$^{c}$ | 1.74$^{bcd}$ | 3.38$^{bc}$ | 2.79$^{d}$ |
| $T_4$ | 18.76$^{c}$ | 40.19$^{c}$ | 58.03$^{bc}$ | 3.43$^{d}$ | 6.76$^{b}$ | 5.95$^{d}$ | 1.91$^{abc}$ | 3.11$^{c}$ | 3.23$^{cd}$ |
| $T_5$ | 27.70$^{a}$ | 51.67$^{a}$ | 71.28$^{a}$ | 5.33$^{a}$ | 7.67$^{a}$ | 10.43$^{a}$ | 2.45$^{a}$ | 4.53$^{a}$ | 5.54$^{a}$ |
| $T_6$ | 25.91$^{ab}$ | 42.08$^{b}$ | 60.34$^{b}$ | 4.50$^{b}$ | 6.15$^{c}$ | 9.38$^{b}$ | 1.25$^{d}$ | 3.47$^{bc}$ | 4.88$^{b}$ |
| $T_7$ | 24.18$^{b}$ | 41.97$^{bc}$ | 57.06$^{bc}$ | 4.52$^{b}$ | 7.71$^{a}$ | 7.33$^{c}$ | 2.03$^{ab}$ | 3.64$^{bc}$ | 4.70$^{b}$ |
| S. Em. | 0.64 | 0.59 | 1.19 | 0.23 | 0.09 | 0.30 | 0.19 | 0.17$^{b}$ | 0.15 |
| S. Ed. | 0.91 | 0.83 | 1.69 | 0.33 | 0.13 | 0.43 | 0.27 | 0.23 | 0.22 |
| C.D. $_{0.05}$ | 1.98* | 1.82** | 3.68** | 0.72* | 0.28** | 0.93** | 0.60** | 0.51** | 0.47** |
| CV (%) | 5.41 | 2.69 | 3.52 | 9.72 | 2.40 | 6.62 | 19.61 | 8.77 | 6.59 |

*- statistically significant differences (p≤0.05); **- statistically significant differences (p≤0.01) (Duncan's multiple range test)

methods (soil drenching, rhizosphere and foliar treatments) positively impacted plant branching.

The stem diameter, a key indicator of plant robustness, was also highest in $T_5$, with values of 2.45 cm (30 DAT), 4.53 cm (60 DAT) and 5.54 cm (90 DAT). This was followed by $T_7$ (Control), which exhibited a diameter of 2.03 cm (30 DAT), 3.64 cm (60 DAT) and $T_6$ at 90 DAT (4.88 cm). $T_6$ showed the lowest stem diameter at 30 DAT (1.25 cm), while $T_2$ (Soil drenching with AMC) showed reduced stem growth at 60 DAT (2.39 cm) and $T_3$ showed the lowest at 90 DAT (2.79 cm). The increased stem diameter in $T_5$ may be attributed to the synergistic effect of AMC treatments that promote nutrient absorption and stimulate cellular growth in plants.

## Flowering and fruit characteristics

The timing of flowering varied significantly across treatments. $T_7$ (Control) exhibited the earliest flowering at 50 DAT, followed by $T_3$ (54.76 DAT), while the delayed flowering was observed in $T_5$ (68.10 DAT) (Table 2). The delayed flowering period may be perceived as a disadvantage, but it is indicative of a robust physiological response to multiple AMC applications, potentially contributing to improved fruit development later in the growth cycle.

Arka Microbial Consortium significantly enhanced the yield of numerous vegetable crops such as radish, lettuce and basil (13-15). In terms of fruit characteristics, $T_5$ demonstrated the maximum fruit length (7.09 cm), fruit diameter (4.30 cm), fruit weight (75.90 g) and fruit yield (8704.67 g/plant). These values were significantly higher than other treatments, indicating that the combined application of AMC via soil drenching, rhizosphere soil application and foliar spraying strongly impacted fruit quality and yield. $T_6$ showed a moderate yield (4388.60 g/plant), while $T_1$ (Seedling dipping with AMC) had the lowest fruit weight (41.43 g) and fruit yield (1202.75 g/plant). This suggests that the AMC application through multiple routes is essential for achieving higher fruit production.

## Nutrient content and cooking quality

The treatments exhibited significant variations in ascorbic acid content, with $T_5$ attaining the highest value of 107.81 mg/100 g, indicating superior antioxidant properties (Fig. 1). This result suggests that the Arka Microbial Consortium (AMC) enhances nutrient uptake, as evidenced by the increased ascorbic acid content in treatments such as $T_5$ and $T_4$. In contrast, T6 had the lowest ascorbic acid content (74.19 mg/100 g). This demonstrates the potential of AMC in enhancing the nutritional quality of brinjal by increasing its ascorbic acid content, which is important for human health due to its antioxidant properties. Research demonstrated that the application of bio-fertilizers on brinjal resulted in an increase in ascorbic acid content from 75 mg/100 g to 105 mg/100 g, closely aligning with the highest recorded value of 107.81 mg/100 g in $T_5$ in the present study. This demonstrates the comparable or superior efficacy of AMC in enhancing nutritional quality (16).

The phenol content of the brinjal was significantly influenced by AMC (Fig. 2). $T_5$ exhibited the highest phenol content at 90.49 mg GAE, followed by $T_4$ at 69.57 mg GAE, indicating a substantial enhancement in the synthesis of bioactive compounds. This elevated phenol level underscores the functional improvement of the brinjal attributed to the microbial consortium. Conversely, treatments such as $T_7$ recorded the lowest phenol content at 43.31 mg GAE, demonstrating the varying effects of AMC on different treatments. This enhancement in phenolic content is crucial for the nutritional and medicinal value of brinjal. The AMC treatment (particularly $T_5$) positions brinjal as a more phenolic-dense and functionally improved vegetable compared to black

**Table 2.** Effect of AMC on flowering and fruiting attributes of brinjal

| | Days to first flowering | Fruit length (cm) | Fruit diameter (cm) | Fruit weight (cm) | Number of fruits per plant | Fruit yield per plant (g) |
|---|---|---|---|---|---|---|
| $T_1$ | 55.76$^{de}$ | 5.18$^{c}$ | 3.70$^{b}$ | 47.14$^{cd}$ | 24.00$^{d}$ | 1202.75$^{e}$ |
| $T_2$ | 59.71$^{bc}$ | 5.26$^{c}$ | 2.80$^{d}$ | 50.29$^{bc}$ | 34.00$^{c}$ | 2235.26$^{d}$ |
| $T_3$ | 54.76$^{e}$ | 6.41$^{b}$ | 3.18$^{c}$ | 41.43$^{e}$ | 48.33$^{b}$ | 3401.02$^{c}$ |
| $T_4$ | 57.90$^{cd}$ | 6.19$^{b}$ | 3.80$^{b}$ | 52.48$^{b}$ | 28.33$^{d}$ | 2484.31$^{d}$ |
| $T_5$ | 68.10$^{a}$ | 7.09$^{a}$ | 4.30$^{a}$ | 75.90$^{a}$ | 76.67$^{a}$ | 8704.65$^{a}$ |
| $T_6$ | 61.76$^{b}$ | 6.20$^{b}$ | 3.23$^{c}$ | 53.81$^{b}$ | 38.00$^{c}$ | 4388.60$^{b}$ |
| $T_7$ | 50.19$^{f}$ | 5.37$^{c}$ | 2.61$^{d}$ | 46.43$^{d}$ | 36.33$^{c}$ | 2541.05$^{d}$ |
| S. Em. | 0.84 | 0.17 | 0.12 | 1.22 | 1.74 | 142.05 |
| S. Ed. | 1.19 | 0.23 | 0.16 | 1.72 | 2.47 | 200.89 |
| C.D. $_{0.05}$ | 2.58** | 0.51** | 0.36** | 3.75** | 5.37** | 437.71** |
| CV (%) | 2.49 | 4.84 | 5.99 | 4.02 | 7.40 | 6.90 |

*- statistically significant differences (p≤0.05); **- statistically significant differences (p≤0.01) (Duncan's multiple range test)

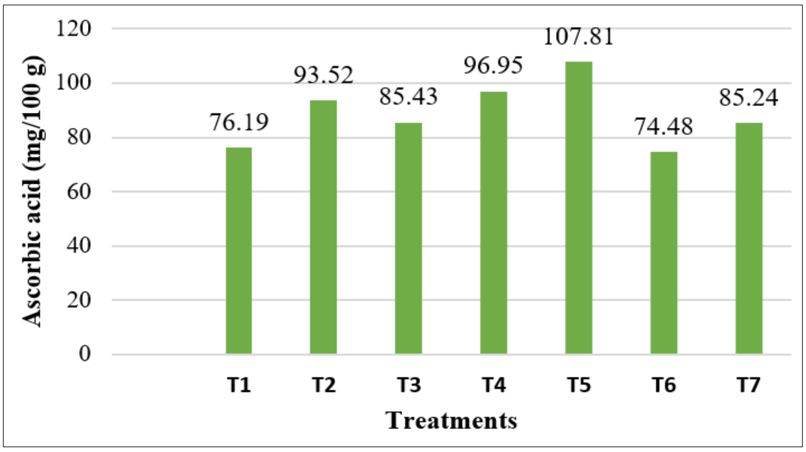


**Fig. 1.** Effect of AMC on ascorbic acid content of brinjal.

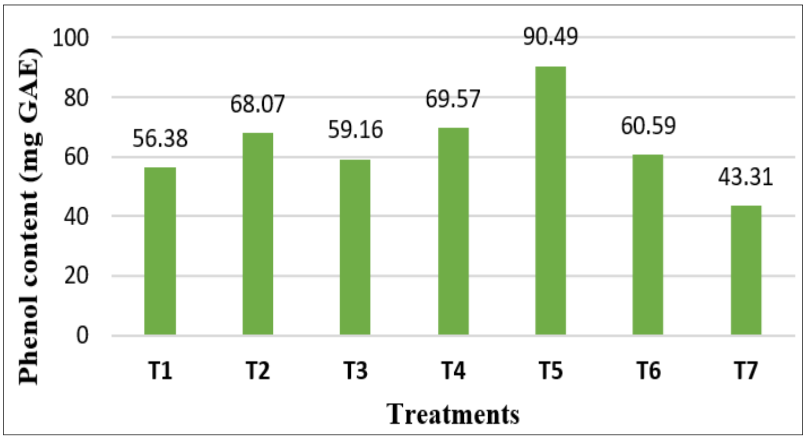


**Fig. 2**. Effect of AMC on the phenol content of brinjal.

beans, especially after cooking. While black beans are still nutritionally valuable, the enhanced phenolic levels and likely stability of AMC-treated brinjal under appropriate cooking conditions (17).

The frying process revealed substantial differences in weight loss among the treatments (Fig. 3). $T_5$ exhibited the lowest weight loss of 65.96 %, indicating superior retention of structural integrity and moisture, whereas $T_7$ demonstrated the highest weight loss of 81.73 %. These variations may be attributed to differences in the cell wall composition influenced by the microbial activity of AMC. The reduced weight loss in treatments such as $T_5$ resulted in improved cooking quality, which is essential for consumer satisfaction and nutritional value. Their research indicates a weight loss by frying resulted in a lower loss of phenolic compounds compared to grilling, indicating that frying may help retain more of the brinjal's nutritional value despite some weight loss (18), compared to research findings of 65.96 % in $T_5$, suggesting that AMC might offer enhanced retention of structural integrity and moisture during cooking.

Baking-induced weight loss exhibited significant variation, with $T_5$ demonstrating a minimum weight loss of 11.97 %, while $T_7$ recorded a maximum weight loss of 40.13 % (Fig. 3). The minimal weight loss observed in treatments such as $T_5$ and $T_2$ can be attributed to the enhanced water retention capacity and improved cellular structure, potentially facilitated by the application of AMC. This observation underscores the role of AMC in preserving the structural integrity of the brinjal during cooking. The present study recorded a baking-induced weight loss of 15 %, whereas the study about baking resulted in a significant loss of phenolic compounds, with a reported degradation of 61.4 % after the baking process, indicates the

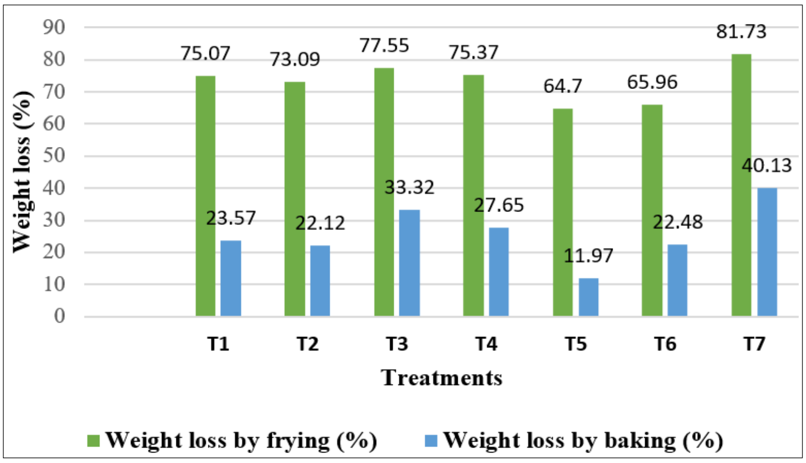


**Fig. 3**. Effect of AMC on cooking quality of brinjal.

loss of weight, which was higher compared to the present study (18).

## Conclusion

The application of Arka Microbial Consortium (AMC) through different treatment methods significantly influenced the growth, development and yield of plants, with $T_5$ (Soil drenching + Rhizosphere soil + Foliar application of AMC) providing the best results. The study demonstrated that AMC enhanced plant height, branching, stem diameter and fruit yield, while improving the nutritional composition, particularly ascorbic acid and phenol content. Furthermore, AMC treatments contributed to better post-harvest quality by reducing weight loss during frying and baking. These findings suggest that AMC can be an effective tool for improving the growth, productivity and quality of crops, offering potential benefits for sustainable agriculture.

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## Authors' contributions

UD and SPB conceptualized the research work. RKS and MD conducted the field experiment. MB, SSP and GA conducted the nutritional quality assessment. UD and SPB prepared the first draft. All the authors reviewed and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** The authors do not have any conflict of interest to declare.

**Ethical issues:** None

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