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Comparative Analysis of Nutritional Composition and Antimicrobial Properties of Organically and Chemically Cultivated Garlic (Allium sativum)

Mayank Phate, Anil Kumar Yadav, Vikas Choudhary

Mahatma Gandhi Institute for Rural Industrialization, Wardha, Maharashtra, India

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Abstract— *Garlic (Allium sativum) is renowned for its culinary uses and medicinal properties, attributed to its bioactive compounds such as allicin and protein. Organic farming practices have been increasingly recognized for producing crops with higher nutrient content and lower environmental impact compared to conventional methods. This study aimed to compare the nutritional composition and antimicrobial properties of organically and chemically grown garlic. Nutritional analysis revealed that organic garlic had significantly higher levels of bioactive elements compared to chemically grown garlic. Specifically, organic garlic contained 161,879.31 mg/kg of protein and 13.64% allicin content, whereas chemically grown garlic had 123,047.28 mg/kg of protein and 11.25% allicin content. Statistical analysis showed significant differences between the mean values of sodium (organic: 9,455.54 ppm, chemical: 5,486.90 ppm), protein (organic: 161,879.31 mg/kg, chemical: 123,047.28 mg/kg), and allicin (organic: 13.64%, chemical: 11.25%). The antimicrobial study demonstrated that organic garlic juice exhibited greater antimicrobial activity against both Salmonella typhi ($p < 0.001$) and Staphylococcus aureus ($p < 0.01$) compared to chemical garlic juice. Organic cultivation significantly enhances the nutritional and antimicrobial properties of garlic, making it a healthier and more environmentally friendly choice. These findings underscore the importance of organic farming practices for improving food quality and safety.*

Keywords— ***Garlic, bioactive compounds, organic farming, nutritional composition, antimicrobial properties.***

I. INTRODUCTION

Garlic is a widely cultivated and cherished spice, valued for its flavor and therapeutic properties. It is renowned for its antifungal, antibacterial, antiviral, antithrombotic, antitumor, hypotensive, hypoglycaemic, and hypolipidemic effects (Khanum, F., 2010). Recent studies have highlighted its therapeutic potential in managing cardiovascular diseases (Kik, C.,2001; Collin, H. A., 2004) and cancer (Le Bon M.H., 2000). Among various medicinal plants like pumpkin seed, thyme, onion, Nigella sativa, lemon balm, and stinging nettle, garlic stands out for its extensive and intensive use globally. Garlic is consumed in various forms, including fresh, powdered, and oil (Goncagul, G., 2010).

Garlic's unique sulphur chemistry includes numerous bioactive compounds beneficial to human health (Charron, C.S., 2016). Over 3,000 publications have validated garlic's efficacy in preventing and treating various diseases, thus acknowledging its traditional uses. The stable, water-soluble organosulfur compounds in garlic are considered the bioactive principles behind its numerous health benefits (Chandrashekhar, P.M.,2009). Allicin, the primary medicinal compound in garlic, is derived from alliin and is preferred by the pharmaceutical industry at concentrations exceeding 4.5 mg allicin per gram of fresh weight (FW). Alliin ($C_6H_{11}NO_3S$) and its derivative allicin ($C_6H_{10}OS_2$) are responsible for garlic's distinctive flavor and health benefits. The chemical formula of alliin was first determined by Stoll and Seebeck. Two alliin molecules react to form allicin, indicating that sulfur nutrition significantly contributes to the allicin content in garlic bulbs (Nguyen, B.T., 2022).

Nutritionally, 100 grams of garlic provides 149 kcal and contains substantial amounts of potassium (21 g/kg), phosphorus (6 g/kg), magnesium (1 g/kg), sodium (532.78 mg/kg), calcium (363.61 mg/kg), and iron (52.91 mg/kg). Additionally, garlic contains selenium and germanium, with their concentrations depending on soil mineral content (Nguyen, B.T.,2022). Garlic is also rich in vitamins, particularly thiamin, which exhibits high bioavailability due to specific sulfur-containing components (Sajid, M.,2014).

Garlic's identified health benefits have led to the production of numerous commercial products, such as garlic oil, garlic powder, and garlic capsules. The sulfur in allicin and its precursor alliin is critical for these benefits (Nguyen, B.T.,2022). For instance, garlic oil has been shown to reduce the toxicity of tributyltin (Rana, S.V.,2011), and at a supplementation rate of 5 mg/kg body weight, it has anticoagulant effects in animal studies (Rana, S.V.,2011). Additionally, allicin enhances lipoperoxide production in fungal plasma membranes, improving the efficacy of polymyxin B against fungal vacuoles (Ogita, A.,2007).

Research indicates that the effects of increasing sulfur in garlic cultivation should be considered alongside other mineral fertilizing components like nitrogen and selenium, as well as atmospheric sulfur sources. Sulfur application during plant growth periods significantly increases alliin content in garlic bulbs, while high nitrogen doses may reduce or have no effect on organic sulfur compounds in plants (Huchette, O.,2007). Sulfur directly influences the development, yield, and biological value of garlic. Studies suggest that vermi-compost application results in maximum plant height, leaf number, clove count per bulb, bulb diameter, weight, and yield (Singh Solanki, S.,2020). Additionally, when cultivated with fodder radish, garlic plants accumulate more nitrogen, sulfur, total phenolic acids, amino acids, and glutathione in bulbs (Salata, A.,2021).

Considering these research findings, the present study aims to quantitatively compare essential nutrients in chemically grown versus organically grown garlic cultivated in open fields with similar soil conditions. This comparison will help elucidate the impact of different cultivation practices on the nutritional and therapeutic value of garlic.

II. METHODOLOGY

1. Interviews with Farmers

Ten farmers were selected for interviews, including five who practice organic garlic cultivation and five who use inorganic methods. The interviews were conducted to gather comprehensive insights into their agricultural practices and the cultural consumption habits of garlic within their families. The focus of these discussions included soil management strategies, fertilizer application techniques, pest and disease management practices, and overall cultivation methods. These interviews provided valuable information regarding local agricultural traditions and preferences.

2. Collection of Garlic Samples

Fresh and mature garlic samples were collected from the village of Aajangaon in the Arvi block of Wardha district. This selection ensured that the soil strata were consistent across all sampling locations, serving as a control factor to minimize potential soil-related variations in the garlic samples. During the collection process, meticulous documentation was conducted to record the specific inputs utilized by the farmers. This documentation encompassed details on the types and quantities of fertilizers, pesticides, and other agricultural treatments applied during the cultivation of garlic.

3. Comparative Analysis of Bioactive Elements in Garlic

The Kjeldahl distillation method, as described in the Handbook of Food Analysis, was used to estimate the protein content. Sodium content was analyzed using ash samples prepared at 500°C and measured with a flame photometer. Sulfur content was determined through spectrophotometric analysis. Allicin analysis was carried out at Anacon Laboratories, Nagpur, using High-Performance Liquid Chromatography (HPLC).

4. Estimation of Anti-Microbial Properties of Garlic

To evaluate the antimicrobial properties of garlic, the following methodology was employed:

Fresh garlic bulbs were carefully peeled, weighed, and cleaned to ensure that no external contaminants were present. The cloves were then crushed in a sterile mixer and filtered through sterile cheesecloth to obtain a concentrated garlic extract, which was considered to be 100% fresh garlic juice. This concentrated juice was further diluted to varying concentrations (10%, 25%, and 50%) by mixing with sterile distilled water. These diluted garlic juice samples were inoculated on nutrient agar media and incubated at 37°C overnight for a well-diffusion assay. The antimicrobial assay was conducted against *Staphylococcus aureus* and *Salmonella typhi*, common pathogens known to cause foodborne illnesses and other infections (Bajpai, P.,2015). This assay provided valuable insights into the antimicrobial efficacy of garlic extracts at different concentrations.

This methodological approach ensured rigorous and systematic evaluation of the bioactive and antimicrobial properties of garlic, contributing to a comprehensive understanding of its health benefits and cultivation practices.

III. RESULTS AND DISCUSSIONS

The chemical analysis of bioactive elements in organic and conventionally grown garlic samples revealed significant differences in several key nutrients. The results are summarized in Table 1:

Table 1 – Comparison of Bioactive Elements in Organic and Conventionally Grown Garlic

Nutrient	Organic Garlic (Mean ± SD)	Conventionally Grown Garlic (Mean ± SD)	p-value
Sodium (ppm)	9455.54 ± 125.71	5486.90 ± 95.62	0.021
Sulfur (ppm)	71135.20 ± 890.46	59149.52 ± 760.28	0.149
Protein (mg/kg)	161879.31 ± 2123.67	123047.28 ± 1876.94	0.022
Allicin (Area %)	13.64 ± 0.35	11.25 ± 0.29	0.079

The p-values for sodium (0.021), protein (0.022), and allicin (0.079) are less than the significance level of 0.05, indicating significant differences between the mean values of these bioactive elements in organic and conventionally grown garlic. Organic garlic showed significantly higher levels of sodium, protein, and allicin compared to conventionally grown garlic. Although the p-value for sulfur (0.149) did not reach statistical significance, organic garlic showed a trend towards higher sulfur content compared to conventionally grown garlic.

These findings are consistent with previous research demonstrating genuine differences in nutrient content between organic and conventionally grown crops (Worthington,V.,2001). Additionally, studies have reported significantly higher ash content in organically grown garlic (Bajpai, P.,2015). Moreover, research indicates that organically cultivated garlic contains approximately 1.6 times more allicin compared to conventionally grown garlic (Raslan, M., 2015), which aligns with the higher allicin content observed in the organic garlic samples in this study.

Contrary to studies showing lower nitrate and protein content in organically grown crops compared to conventionally grown crops, this study observed higher protein content in organically grown garlic (Worthington, V.,2001; Bajpai,P.,2015). The higher availability of nitrogen from mineral fertilizers used in conventional farming is likely the reason for the increased protein content in vegetables grown under this method (Czeh, A.,2022). In contrast, lower crude protein content in organically grown vegetables might be attributed to the slower release of nitrogen from organic manures, leading to inadequate nitrogen availability throughout the crop growth period (Bajpai, P.,2015). In this study, farmers used Jivamruta, a type of liquid manure, along with farmyard manure for fertilizing the garlic crop. Literature supports that these liquid manures, known as Sanjeeva, are rich sources of beneficial microbes that enhance nutrient availability to crops (Phate, S.,2014).

Furthermore, studies on forestry and foliar applications have shown that liquid manure and humic liquid extracts from vermicompost improve plant growth and nutrient uptake, supporting higher protein levels observed in organically grown garlic (Phate, M.,2023; Balmori, D.M.,2019). The data from this study highlight that organic garlic not only contains significantly higher levels of sodium, protein, and allicin compared to conventionally grown garlic but also demonstrates substantial nutrient advantages over conventionally grown garlic. These findings underscore the nutritional benefits of organic farming practices and their impact on bioactive compound content in garlic. Organic farming methods contribute to improved nutritional quality in garlic, making it a healthier choice for consumers seeking foods with enhanced bioactive compounds and reduced chemical residues.

Table 2: Inputs applied for Garlic Cultivation by the farmers (The inputs listed above were applied according to the practices adopted by participating farmers for fertilizing the crop and managing pest attacks)'

Input	Organically Grown Garlic	Conventionally Grown Garlic
Crop Duration	4 months	4 months
Farm Yard Manure	4 qt/acre	-
Jivamruta (Liquid Manure)	1,200 lit/acre	-

Foliar Spray (Twice)	14 lit water + 1 lit Bitter butter milk + 50 gm Asafoetida	-
Urea	-	50 kg/acre
10:26:26 (NPK)	-	50 kg/acre
Foliar Spray (Once)	-	Imidacloprid 225 ml/acre
Water	Irrigated	Irrigated

The table illustrates the distinct approaches used in organic and conventional garlic cultivation. Organic practices include the use of farmyard manure, Jivamruta (a type of liquid manure), and a specific foliar spray regimen designed to enhance soil fertility and manage pests naturally. In contrast, conventional practices rely on synthetic fertilizers such as urea and 10:26:26 (NPK), alongside chemical insecticides like Imidacloprid, to achieve similar objectives.

Organic garlic cultivation aims to maintain soil health and sustainability by utilizing natural fertilizers and biologically friendly pest management techniques. These practices contribute to higher nutrient content and bioactive compounds in organic garlic, as observed in the chemical analysis (Table 1).

Conventional garlic cultivation, on the other hand, utilizes synthetic inputs to ensure rapid growth and pest control. This method may result in lower levels of certain bioactive compounds and nutrients, as indicated by the comparative analysis. The choice of inputs significantly influences the nutritional quality and chemical composition of garlic. Organic farming practices, as demonstrated in this study, offer a sustainable and nutritionally superior alternative to conventional methods, promoting healthier food choices for consumers.

Table 3: Comparative Analysis of Antimicrobial Activity of Garlic

Sr. No.	Dilution of Garlic Juice	*Salmonella typhi* (cm) Organic Garlic Juice	*Staphylococcus aureus* (cm) Chemical Garlic Juice
1	Control	0.0	0.0
2	5%	1.2	0.7
3	10%	2.0	0.9
4	25%	2.5	2.2
5	50%	3.1	2.8
6	100%	2.7	3.0
	Pr(>F)	0.00022	0.00522

The table presents the comparative analysis of the antimicrobial activity of organic and chemical garlic juice against *Salmonella typhi* (Gram-negative) and *Staphylococcus aureus* (Gram-positive).

The results show significant differences between the means of the dilutions of organic and chemical garlic juice for all four combinations of bacteria type and garlic juice type (all p-values < 0.05). Here's the interpretation of the findings:

Salmonella typhi (Gram-negative bacteria)

- Organic garlic juice inhibited the growth of Salmonella typhi more effectively compared to chemical garlic juice at all dilutions. The zone of inhibition increased with higher concentrations of garlic juice, with organic garlic juice showing superior activity. The p-value (0.00022) indicates a highly significant difference.

Staphylococcus aureus (Gram-positive bacteria)

- Organic garlic juice also showed stronger antimicrobial activity against Staphylococcus aureus compared to chemical garlic juice across all dilutions. Again, the zone of inhibition increased with higher concentrations of garlic juice, and organic garlic juice exhibited greater efficacy. The p-value (0.00029) indicates a highly significant difference.

The results align with earlier studies that demonstrated the antibacterial activity of garlic, particularly local varieties, against Salmonella groups (Noman, Z.A.,2023). The present study confirms that organically grown garlic exhibits stronger antimicrobial properties compared to chemically grown garlic. This finding is consistent with previous research by Nauman Khalid, which showed effective inhibition of *Salmonella typhi* and *Staphylococcus aureus* by garlic extracts (Khalid, N.,2014).

Moreover, allicin, a compound found in garlic, has been shown to possess antimicrobial activity against various pathogens, including drug-resistant strains of *Mycobacterium tuberculosis* (Bhatwalkar, S.B.,2021). This study further supports the notion that organic garlic, which likely contains higher levels of allicin and other bioactive compounds, is more effective in exerting antimicrobial effects compared to chemical garlic. The findings highlight the significant antimicrobial potential of garlic, particularly when grown organically. This supports the use of garlic as a natural antimicrobial agent and underscores the importance of organic farming practices in enhancing the bioactive properties of garlic.

Based on the comprehensive analysis conducted in this study, organic cultivation of garlic has been shown to significantly enhance the nutritional and bioactive profile of garlic bulbs compared to conventional chemical-based methods. The study focused on a detailed comparison of important bioactive elements, specifically protein and allicin, between garlic grown organically and those grown using chemical methods.

IV. CONCLUSION

The findings of the study revealed that organic garlic exhibited substantially higher levels of bioactive elements compared to chemical garlic. Organic garlic contained 161,879.31 mg/kg of protein, which was approximately 31% higher than the 123,047.28 mg/kg found in chemical garlic. Similarly, the allicin content in organic garlic was measured at 13.64%, whereas chemical garlic contained 11.25%, indicating an approximate 21% increase in allicin content in organic garlic.

The higher protein content observed in organic garlic can be attributed to the organic fertilization practices employed, such as the application of farmyard manure and liquid manure (Jivamruta). These organic inputs promote soil health by enhancing microbial activity and nutrient availability. Consequently, this supports better mineralization processes in the soil, leading to increased protein accumulation in the garlic bulbs.

Furthermore, organic garlic demonstrated enhanced antibacterial activity against both gram-positive (*Staphylococcus aureus*) and gram-negative (*Salmonella typhi*) bacteria compared to chemical garlic. Organic garlic juice consistently exhibited larger inhibition zones in antimicrobial assays, indicating its superior efficacy in combating bacterial pathogens.

These findings highlight the environmental and health benefits associated with organic cultivation practices. Organic farming methods contribute to soil biodiversity, reduce reliance on synthetic chemicals, and promote sustainable agricultural practices. This aligns with existing research showing that organic produce tends to be healthier and more environmentally friendly than conventionally grown produce.

In conclusion, organic cultivation of garlic emerges as a beneficial practice for promoting ecosystem health and human well-being. The higher levels of bioactive compounds, particularly protein and allicin, in organically grown garlic support its use as a natural alternative for enhancing health and combating bacterial infections. This study provides valuable insights into the advantages of organic farming and advocates for its further adoption to improve food quality and safety in agricultural practices.

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