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Enhancing functional properties and nutraceutical value in finger millet using organic foliar nutrition

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Abstract

In recent years, the importance of organic foliar nutrition has increased. Foliar application of organic foliar nutrition or biostimulants could be a possible solution to develop plant stress tolerance to achieve nutritional security. Hence, this trial was conducted to study the influence of organic liquid formulations on the biochemical properties and nutraceutical value of finger millet. The five organic liquid formulations, *viz.*, panchagavya (PG 3%), fish amino acid (FAA 0.5%), jeervamrut (JA3%), groundnut oil cake extract (GOC 1%) and seaweed extract (SWE 0.5%), were used in this study. Results revealed that application of FAA (0.5%) improved the quality attributes such as carbohydrate (73.5%) and protein content (7.82%). The application of SWE (0.5%) promoted the fat (1.54%), fibre (11.28%), and phytic acid content (642.8 mg/100 g) in finger millet. The application of SWE (0.5%) recorded more antioxidant activity (1130.7 µg/g). Further, the foliar application of SWE (0.5%) exhibited a significantly high value of phosphorus (298.2 mg/100 g), potassium (14.29 mg/100 g), calcium (356.6 mg/100 g), magnesium (6.258 mg/100 g), iron (4.396 mg/100 g), zinc (0.213 mg/100 g). Similarly, a foliar application of FAA (0.5%) recorded more value of phosphorus (294.3 mg/100 g), potassium (14.26 mg/100 g), calcium (347.7 mg/100 g), magnesium (6.212 mg/100 g), iron (4.314 mg/100 g), zinc (0.211 mg/100 g), which is on par with each other. SWE (0.5%) expressed a high value of total chlorophyll content in leaves (1.651 mg/g), relative water content (RWC) in leaves (75.66%), polyphenol compound (2.452%) in grain and tannins (1.594%) in grain and low value of proline content (2.045%) in leaves compared to other organic sources. The results revealed that applying FAA (0.5%) and SWE (0.5%) improved the biochemical properties and nutraceutical value of finger millet. Further, the results showed that the foliar application of organic liquid formulations. SWE and FAA applications improve the nutritional properties and nutraceutical values of finger millet.

1. Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn) is grown extensively in tropical and subtropical regions, even in drought-prone, saline, and sodic environments. Its grain contains more nutrients than other cereal grains and can combat malnutrition and hidden hunger (Maharajan *et al.,* 2021; Ayushi Joshi *et al.,* 2024). Finger millet is valued for its high nutraceutical content; hence it is recognized as one of the significant small millets globally (Sood *et al.,* 2017). It is rich in carbohydrates, fiber, and amino acids, and it contains important minerals while being gluten-free. Diet plays a significant role in public health initiatives to ensure optimal health throughout life, thereby reducing the risk of early chronic diseases and supporting healthier aging. When compared to other cereals, finger millet boasts the highest levels of calcium and iron (Sharat Dhruthi *et al.,* 2022). Various research has shown that finger millet promotes natural weight loss, boosts bone strength, helps in diabetes prevention, fights signs of aging, assists in blood pressure regulation, provides protection against diseases, and improves hemoglobin levels. Apart from its use in human diets, finger millet serves as feed for livestock and poultry. Additionally, when malted, it is a beneficial option for individuals with diabetes and children. Eleusinian is a major and healthy source of protein present in finger millet and has a lot of biological value. Arginine, lysine, methionine, tryptophan, and lecithin are the main amino acids present in this protein that help in improving insulin sensitivity, decreasing blood pressure, and lowering the chance of heart disease, *etc.* (Mounika and Hymavathi, 2021). Nowadays, consumers are increasingly focused on health and are more inclined to choose healthier and more nutritious foods (Sushree *et al.,* 2023; Sirisha Kurella *et al.,* 2022).

Rising expenses for chemical fertilizers, along with their harmful impacts on soil quality, the ecosystem, and human well-being, have forced farmers to seek alternative sources of nutrition (Manish Chauhan *et al.,* 2024). In recent years, the importance of organic liquid formulations or biostimulants has increased. Foliar application of organic liquid formulations or biostimulants could be a possible solution to develop salt tolerance in plants to achieve nutritional security. Because, it has properties like fertilizer, improving nutrient intake, biopesticide, and growth-promoting substances and it promotes growth, yield, and immunity to the plant under various stresses (Gao *et al.,* 2023). Further, it helps to reduce the dependence

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on chemical fertilizers. The use of biostimulants like seaweed extract (SWE), fish amino acid (FAA), panchagavya (PG), jeevamrut (JA), *etc.,* enhance the performance of various crop plants. Liquid extracts derived from seaweeds have recently become significant as foliar sprays for a variety of crops, including different grasses, cereals, flowers, and vegetables. SWE is rich in both major and minor nutrients, amino acids, vitamins, and growth-promoting substances like cytokinins, auxin, and abscisic acid, and they have been shown to enhance plant growth and yield, improve tolerance to environmental stress, boost nutrient absorption from the soil, and increase antioxidant properties. FAA is a liquid organic fertilizer produced from fish waste, which is highly beneficial for both plants and microorganisms due to its diverse range of nutrients and amino acids. Applying FAA as a foliar spray or through soil drenching can optimize nutrient uptake while reducing runoff or leaching, supplying sufficient nitrogen to plants to produce chlorophyll, thereby supporting their health (Ajmal Siddique *et al.,* 2023). Both SWE and FAA assist plants in managing photoperiodism and photosynthesis, promoting carbon and nitrogen metabolism, improving nutrient accessibility, and enhancing crop yield and quality. PG and JA offer nutritional benefits and biocontrol properties for crop plants due to their substantial nutrient content, beneficial microbial populations, growth promoters, and biocontrol agents (Bishal Chakraborty and Indrajit Sarkar, 2019). Groundnut oil cake is an important source of vegetable protein, and the extract of groundnut oil cake provides a good number of amino acids (Asghar *et al.,* 2014). The use of groundnut oil cake extracts enables them to absorb water rapidly and reactivate their metabolism and germination processes, which may explain the enhancement of seed quality traits related to germination and the potential for crop vigor (Manonmani *et al.,* 2023).

The use of liquid organic nutrient sources has gained acceptance in stress conditions, to avoid excessive fertilizer usage and to increase nutrient absorption. Most of the research was on the use of organics in soil and less research was done on their effect on foliar organic liquid formulations application on the biochemical changes and nutraceutical value of finger millet under sodic soil. Hence, the current study is proposed to evaluate the effect of salinity on nutraceutical content and to study the effect of various organic liquid formulation applications regarding the enhancement of nutritional properties, nutraceutical value, and yield of finger millet.

2. Materials and Methods

2.1 Authentication of plant material

Dr. R. Ramasubbu, Associate Professor, Department of Biology, Gandhigram Rural Institute, Gandhigram, Dindigul, conducted the entire botanical authentication and identification of the plant specimen. The Voucher Specimen is Catalogued and stored at the GUD Herbarium.

2.2 Experiment details

Field experiments were conducted at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu, India during the summer of 2023 and 2024. In recent years, the use of organic liquid formulations through foliar applications has gained attention to achieving nutritional security. Hence, five commonly available organic liquid formulations, *viz.,* panchagavya (PG 3%), jeevamrut (JA 3%), groundnut oil cake extract (GOC 1%), fish amino acid (FAA 0.5%), and seaweed extract (SWE 0.5%) were used for this study as organic foliar nutrition. The nutrient content of organic liquid formulations is presented in Table 1. The foliar spray was done at four critical stages, *viz.,* tillering, flowering, milky stage, and grain filling stage. In treatment numbers seven to ten, two organic sources were sprayed at alternate at different growth stages. The soil was clay loam in texture, pH 9.3, electrical conductivity of 0.67 dS/m, exchangeable sodium percentage 26, and low organic carbon content of 3.73 g/kg. The available nutrient status was nitrogen 169.87 kg/ha, and phosphorus 10.987 kg/ha status was low with medium available potassium 183.7 kg/ha. A plot without organic nutrient spray was maintained as control. In each plot yield, nutritional properties, and mineral contents of finger millet grain were measured. Then the statistical analysis was done for each treatment to calculate means, standard errors, and critical differences, as shown in the tables.

Table 1: Nutritional composition of organic nutrient sources used for this experiment

S. No.	Nutritional composition	Panchagavya	Groundnut cake	Fish amino acids	Jeevamirdham	Seaweed extract
1.	Total nitrogen (%)	0.22	7.32	1.51	1.05	0.18
2.	Total phosphorus (%)	0.20	3.07	0.21	0.12	0.48
3.	Total potassium (%)	0.23	2.29	1.64	0.08	1.89
4.	Sodium (ppm)	90.1	0.01	0.01	0.05	0.13
5.	Zinc (ppm)	0.26	6.15	3.13	82.4	11.8
6.	Manganese (ppm)	0.28	34.1	0.54	46.3	13.1
7.	Copper (ppm)	1.99	11.4	0.15	51.0	15.6
8.	Iron (ppm)	9.17	7.38	15.8	318	256
9.	Calcium (ppm)	25.0	1.85	15.0	100	1100

Note: 1. Panchagavya is an organic formulation made from five cow-derived products: Milk, curd, ghee, urine and dung. It is traditionally used in agriculture to promote plant growth and improve soil fertility. 2. Jeevamrutham is a fermented organic fertilizer made from cow dung, cow urine, jaggery, pulse flour and soil. It enhances microbial activity in the soil and supports plant growth in natural farming.

2.3 Biochemical parameters

2.3.1 Carbohydrate content

The major carbohydrate distributed in plants are mono, di, oligo and polysachharides. The total carbohydrate content was determined by following formula. Carbohydrate (%) = 100 – (Moisture (%) + Ash (%) + Crude protein (%) + Crude fat (%)) (James, 1995).

2.3.2 Protein content

The Kjeldahl method was used to determine crude protein according to the AOAC (2002) protocol. A 2 g sample was digested with 20 ml of concentrated H_2SO_4 and a Kjeldahl catalyst (composed of 9 parts H_2SO_4 and 1-part $CuSO_4$) in a digestion chamber until the solution became clear. A blank test was conducted without the inclusion of the sample. Following digestion, the Kjeldahl distillation method was employed to assess the nitrogen content.Then, the nitrogen value was multiplied with 6.25 to get crude protein value.

2.3.3 Fibre content

Crude fiber is a non-degradable part of carbohydrates, which is determined by using diluted alkali and acid. The remaining substances are categorized as crude fiber (Sadasivam and Manickam, 1996).

2.3.4 Ash content

The ash content was assessed using the AOAC method (AOAC, 2002). Initially, the silica crucible was heated in a muffle furnace, then allowed to cool in a desiccator, and its initial weight was recorded. A 5 g sample was then placed in a muffle furnace and heated to 550°C for 6 h., after which it was cooled in the desiccator, and the weight of the ash was measured.

2.3.5 Fat content

The Soxhlet extraction method was used to estimate the fat content. The determination of crude fat was carried out according to the methods established by the Association of Official Analytical Chemists (AOAC, 2002). Initially, the weight of the flask was measured after being heated in a hot air oven at 105°C overnight, then cooled in a desiccator. A5 g sample was extracted with petroleum ether using a Soxhlet apparatus for approximately 6 h.

2.3.6 Chlorophyll content

Chlorophyll is extracted using 80% acetone, and the absorption readings are taken at 663 and 645 nm with a spectrophotometer (Aminot and Rey, 2002).

2.3.7 Relative water content

The relative water content of a leaf indicates its hydration level (actual water content) in relation to its maximum water storage capability when fully turgid. This measurement was obtained by assessing the fresh weight, dry weight, and turgid weight of the leaf (Smart and Bingham, 1974).

2.3.8 Proline content

Proline is estimated by ninhydrin and sulfo salicylic acid method. The extracted proline is made to react with ninhydrin in acid condition (pH 1.0) to form the chromophore (red colour) and them the proline is estimated by colorimetric method (520 nm) (Bates *et al.,* 1973).

2.4 Mineral nutrients

2.4.1 Calcium content

Grain samples were processed using a 9:4 blend of nitric acid and perchloric acid. The sample is then filtered with Whatman number 1 filter paper. Portions of this solution can be utilized for the measurement of calcium in addition to magnesium and for calcium analysis. The calcium content was estimated by Versenate Titration method (Govindaraju *et al.,* 2001).

2.4.2 Magnesium content

Grain samples were processed using a 9:4 combination of nitric acid and perchloric acid. The sample is then filtered with Whatman number 1 filter paper. Portions of this solution can be utilized for measuring calcium plus magnesium as well as for estimating calcium. The magnesium content was estimated by the difference between the value of calcium plus magnesium and calcium estimation in the Versenate titration method (Govindaraju *et al.,* 2001).

2.4.3 Phosphorus content

Grain samples were treated with a 9:4 mixture of nitric acid and perchloric acid. The sample is then filtered using Whatman number 1 filter paper. Portions of this solution can be utilized for measuring phosphorus through a colorimetric approach. (Govindaraju *et al.,* 2001).

2.4.4 Potassium content

Grain samples were treated with a 9:4 mixture of nitric acid and perchloric acid. The sample is then filtered using Whatman number 1 filter paper. Aliquots of this solution can be used for the determination of phosphorus content by flame photometric method (Govindaraju *et al.,* 2001).

2.4.5 Copper, zinc and iron content

Grain samples were treated with a 9:4 mixture of nitric acid and perchloric acid. The sample is then filtered using Whatman number 1 filter paper. Aliquots of this solution can be used for the determination of Fe, Zn and Cu. Then the sample was fed in atomic absorption spectro photo meter to record copper, zinc and iron content (Govindaraju *et al.,* 2001).

2.5 Antioxidant and antinutritional factors

2.5.1 Phytic acid

Phytic acid is chemically known as myoinositol 1,2,3,4,5,6-hexakis dihydrogen phosphate. It is the primary storage form of phosphorus, making up 1-5% of the weight in cereals, legumes, oilseeds, and nuts. The phytic acid contents of all the samples were estimated by the method of Gao *et al.* (2007) using sodium phytate.

2.5.2 Total polyphenols

Phenolic compounds are water soluble and form complex with protein by hydrogen bonding. Total polyphenol extraction was made by colorimetric methods as explained by Chethan and Malleshi (2007).

2.5.3 Tannin content

Tannins are polyphenolic compound which are divided into 2 main groups, the hydrolysable tannins and condensed tannins. The total tannins were estimated by the method of Price *et al.* (1978).

2.5.4 Antioxidant activity

Antioxidant activities of polyphenol extract were tested through DPPH free radical scavenging activity by the method of De Ancos *et al.* (2002).

2.6 Statistical analysis

Standard error of the means (SEM) was worked out for each factor and interactions. Wherever the results were significant, the critical difference (CD) was worked out at 5 per cent level of significance.

3. Results

3.1 Biochemical properties

Biochemical properties such as total chlorophyll content, relative water content (RWC), polyphenolic compounds, proline content, and tannins increase photosynthetic efficiency and promote defensive mechanisms for stress tolerance. The plant biochemical properties such as total chlorophyll content, relative water content, proline content, polyphenol compound, and tannins were significantly altered by the organic liquid formulations (Table 2). The results indicated that SWE (0.5%) expressed a high value of total chlorophyll content in leaves (1.651 mg/g), (RWC) in leaves (75.66%), polyphenol compound (2.452%) in grain and tannins (1.594%) in grain and low value of proline content (2.045%) in leaves compared to other organic sources. Similarly, a foliar application of FAA (0.5%) recorded more value of total chlorophyll content in leaves (1.564 mg/g), (RWC) in leaves (73.93%), polyphenol compound (2.364%) in grain and tannins (1.553%) in grain and low value of proline content (2.125%) in leaves. The lowest value of total chlorophyll content of 1.250 mg/g, RWC of 69.62%, polyphenol compound of 1.221% and tannins 0.331%, and high value of proline content of 3.512 mg/g, was recorded in the control.

Table 2: Effect of organic liquid formulations on biochemical properties in leaves

Treatment Details	Total chlorophyll (mg/g)	RWC (%)	Proline (mg/g)	Polyphenolic compound (%)	Tannins (%)
Control	1.250	69.62	3.512	1.221	0.331
PG (3%)	1.489	72.15	3.257	1.358	1.412
JA (3%)	1.365	74.66	3.125	1.425	0.495
GOC (1%)	1.357	71.44	3.415	1.315	0.411
FAA (0.5%)	1.564	73.93	2.125	2.364	1.553
SWE (0.5%)	1.651	75.66	2.045	2.452	1.594
PG (3%) + GOC (1%)	1.341	72.16	3.269	1.489	1.324
PG (3%) + FAA (0.5%)	1.411	72.58	2.687	1.348	1.325
PG (3%) + SWE (0.5%)	1.428	73.97	2.498	1.971	1.458
JA (3%) + GOC (1%)	1.321	71.82	2.315	1.752	1.344
JA (3%) + FAA (0.5%)	1.416	74.35	2.201	2.105	1.498
JA (3%) + SWE (0.5%)	1.525	75.18	2.168	2.134	1.450
SED	0.113	1.781	0.561	0.442	0.473
CD =0.05 %	0.227	3.561	1.122	0.884	0.947

Note: 1. Panchagavya is an organic formulation made from five cow-derived products: Milk, curd, ghee, urine and dung. It is traditionally used in agriculture to promote plant growth and improve soil fertility. 2. Jeevamrutham is a fermented organic fertilizer made from cow dung, cow urine, jaggery, pulse flour and soil. It enhances microbial activity in the soil and supports plant growth in natural farming.

3.2 Nutritional properties

The result indicated that foliar application of organic liquid formulations significantly altered the quality attributes of finger millet. The nutritional properties were recorded in the control, whereas the application of foliar organic nutrition provided more values of nutritional properties (Table 3). The highest quality attributed carbohydrate of 73.50 g/100 g, the protein content of 7.82%, and fibre (11.28%), was recorded by applying FAA (0.3%), whereas the highest fat (1.54%), ash content (3.14%), and phytic acid (642.8 mg/100g) were found in SWE (0.5%) applied plots. Interestingly, the alternate application of FAA (0.3%) alone and its combination with JA (0.5%) also recorded more value of carbohydrate content (72.25 g/100 g) and protein content (7.70%). Foliar application of FAA (0.3%) and PG (0.5%) registered more fibre content of 11.02%. It was noticed that the lowest value of carbohydrate (70.11 g/100 g), protein (6.74%), fat (1.19%), fibre (10.34%), and phytic acid content (631.6 mg/100 g) was recorded in the control.

3.3 Mineral content

The organic liquid formulations positively improved the mineral values in grain (Table 4). The results indicated that SWE (0.5%) expressed a high value of calcium and iron compared to other organic sources. The foliar application of SWE (0.5%) exhibited a significantly high value of phosphorus (298.2 mg/100 g), potassium (14.29 mg/100 g), calcium (356.6 mg/100 g), magnesium (6.258 mg/100 g), iron (4.396 mg/100 g), and zinc (0.213 mg/100 g). Similarly, a foliar application of FAA (0.5%) recorded more values of phosphorus (294.3 mg/100 g), zinc (0.211 mg/100 g), and calcium (347.7 mg/100 g). The highest value of copper, (0.129 mg/100 g) was recorded in FAA (0.5%), but it did not exhibit a significant difference. The SWE

(0.5%) expressed a high value of iron compared to other organic sources. The foliar application of SWE (0.5%) exhibited a significantly high value of iron (4.396 mg/100 g). Similarly, an alternate foliar application of JA (0.5%) and SWE 0.5% recorded more value iron content of 4.381 mg/100 g and 344.5 mg/100 g, respectively. The lowest value of iron, 3.641 mg/100 g, was recorded in the control. The lowest value of mineral nutrients, *viz*., phosphorus, potassium, calcium, magnesium, iron, zinc, and copper, were recorded in control.

Table 3: Efficacy of organic liquid formulations on the proximate compounds of finger millet

Treatment details	Carbohydrates (g/100 g)	Protein (%)	Fat (%)	Dietary fibre (%)	Ash content (%)	Energy (kcal)
Control	70.11	6.74	1.19	10.34	2.79	283.8
PG (3%)	70.85	6.91	1.28	11.15	2.88	292.5
JA (3%)	72.35	7.74	1.43	10.67	3.03	307.8
GOC (1%)	71.30	7.33	1.20	10.91	2.80	284.7
FAA (0.5%)	73.50	7.82	1.45	11.28	3.05	309.2
SWE (0.5%)	73.15	7.62	1.54	11.26	3.14	318.6
PG (3%) + GOC (1%)	71.95	6.95	1.34	10.92	2.94	298.4
PG (3%) + FAA (0.5%)	71.40	7.15	1.36	11.16	2.96	300.9
PG (3%) + SWE (0.5%)	72.85	7.21	1.32	10.65	2.92	296.4
JA (3%) + GOC (1%)	71.55	7.51	1.45	10.63	3.05	309.8
JA (3%) + FAA (0.5%)	72.75	7.70	1.42	10.90	3.02	306.0
JA (3%) + SWE (0.5%)	71.05	7.39	1.36	11.02	2.96	300.1
SED	0.3524	0.165	0.031	0.247	0.1044	10.44
CD = 0.05 %	0.7308	0.343	0.064	0.512	0.2089	20.89

Note: 1. Panchagavya is an organic formulation made from five cow-derived products: Milk, curd, ghee, urine and dung. It is traditionally used in agriculture to promote plant growth and improve soil fertility. 2. Jeevamrutham is a fermented organic fertilizer made from cow dung, cow urine, jaggery, pulse flour and soil. It enhances microbial activity in the soil and supports plant growth in natural farming.

Table 4: Efficacy of organic foliar nutrition on the mineral nutrients of finger millet

Treatment details	Phosphorus (mg/100 g)	Potassium (mg/100 g)	Calcium (mg/100 g)	Magnesium (mg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)	Copper (mg/100 g)
Control	257.1	13.03	315.5	6.168	3.641	0.183	0.980
PG (3%)	273.4	13.90	340.7	6.218	4.233	0.197	0.114
JA (3%)	276.2	14.11	337.4	6.127	4.209	0.190	0.112
GOC (1%)	271.1	13.05	334.8	6.215	4.175	0.185	0.109
FAA (0.5%)	294.3	14.26	347.7	6.212	4.314	0.211	0.129
SWE (0.5%)	298.2	14.29	356.6	6.258	4.396	0.213	0.127
PG (3%) + GOC (1%)	271.4	13.96	335.5	6.201	4.112	0.199	0.110
PG (3%) + FAA (0.5%)	277.7	13.92	330.4	6.203	4.056	0.210	0.121
PG (3%) + SWE (0.5%)	279.5	14.10	325.6	6.190	4.254	0.209	0.128
JA (3%) + GOC (1%)	268.9	13.97	336.2	6.200	4.260	0.207	0.118
JA (3%) + FAA (0.5%)	273.4	14.28	327.8	6.138	4.351	0.198	0.123
JA (3%) + SWE (0.5%)	288.9	14.22	344.5	6.237	4.381	0.210	0.128
SED	11.30	0.441	11.03	0.041	0.212	0.011	0.250
CD =0.05 %	22.62	0.882	22.06	NS*	0.422	0.023	0.501

***Non-significant**

Note: 1. Panchagavya is an organic formulation made from five cow-derived products: Milk, curd, ghee, urine and dung. It is traditionally used in agriculture to promote plant growth and improve soil fertility. 2. Jeevamrutham is a fermented organic fertilizer made from cow dung, cow urine, jaggery, pulse flour and soil. It enhances microbial activity in the soil and supports plant growth in natural farming.

3.4 Antioxidant and antinutritional properties

Antioxidants are essential for maintaining food quality and promoting human health. (Table 5). Managing oxidative stress processes could prove essential for preventing and treating various diseases. The results indicated that SWE (0.5%) expressed a high value of calcium and iron compared to other organic sources. The foliar application of SWE (0.5%) and FAA (0.5%) exhibited a significantly high value of total antioxidant activity. Similarly, a foliar application of PG (3%) along with SWE (0.5%) or JA along with SWE (0.5%) recorded more values of the total antioxidant activity. The SWE (0.5%) expressed a high value of total antioxidant activity of 1130.7 µg/g compared to other organic sources. Similarly, foliar application of JA (0.5%) and SWE 0.5% recorded more value total antioxidant activity of 1119.8 µg/g. The lowest value of 859.1 µg/g was recorded in control. Phytic acid content was slightly altered from 631.6 mg/100 g to 642.8 mg/100 g by organic foliar nutrition. Tannin content was altered from 1.331-1.594 % and polyphenol content was altered from 1.221-2.452 mg GAE/ 100 g by organic foliar nutrition. The application of liquid organic sources reduced the antinutritional values significantly. The low value of phytic acid, tannin content, and polyphenol (631.6 mg/100 g, 1.331% and 1.221mg GAE/ 100 g, respectively) were found in SWE (0.5%) followed by FAA 0.5% applied plots (640.7 mg/100g, 1.411% and 1.315 mg GAE/ 100 g, respectively). The more value of phytic acid (642.4 mg/100 g), tannin content (1.594%), and polyphenol (2.452 mg GAE/100 g) were recorded in control.

Table 5: Efficacy of organic foliar nutrition on the antioxidant and antinutritional factors of finger millet

Treatment details	Total antioxidant activity (µg/g)	Antinutritional properties		
		Phytic acid (mg/100 g)	Tannins (%)	Polyphenol (mg GAE/ 100 g)
Control	859.1	642.4	1.594	2.452
PG (3%)	947.2	640.0	1.553	2.364
JA (3%)	993.2	642.2	1.495	1.425
GOC (1%)	904.3	642.8	1.412	1.358
FAA (0.5%)	1119	640.7	1.411	1.315
SWE (0.5%)	1130	631.6	1.331	1.221
PG (3%) + GOC (1%)	936.4	637.2	1.324	1.489
PG (3%) + FAA (0.5%)	990.3	630.8	1.325	1.348
PG (3%) + SWE (0.5%)	1010	640.3	1.458	1.971
JA (3%) + GOC (1%)	967.3	641.2	1.344	1.752
JA (3%) + FAA (0.5%)	982.3	641.3	1.498	2.105
JA (3%) + SWE (0.5%)	1022	642.1	1.450	2.134
SED	66.49	14.70	0.473	0.442
CD =0.05 %	122.9	NS*	0.947	0.884

*Non-significant

Note: 1. Panchagavya is an organic formulation made from five cow-derived products: Milk, curd, ghee, urine and dung. It is traditionally used in agriculture to promote plant growth and improve soil fertility. 2. Jeevamrutham is a fermented organic fertilizer made from cow dung, cow urine, jaggery, pulse flour and soil. It enhances microbial activity in the soil and supports plant growth in natural farming.

4. Discussion

SWE can be used for both agricultural and horticultural crops. Foliar application or soil drenching of organic foliar nutrients could maximize uptake and minimize runoff or leaching, providing just enough nitrogen to the plant to produce chlorophyll to maintain plant health. The use of SWE can advance growth, production, and resistance to biotic and abiotic stress conditions, and increase chlorophyll content and photosynthetic rate (Moses and Maria, 2020). The application of FAA regulates phototropism, photosynthesis, nutrient access, absorption, and utilization efficiency in plants (Ajmal Siddique *et al.,* 2023). Enhancing the nutraceutical properties, antioxidant effectiveness, and mineral content in finger millet is crucial for improving human health. The application of FAA and SWE increases the carbohydrate, protein, fat, fibre, and phytic acid of finger millet grain. This might be due to the increasing availability and uptake of minerals from organic sources, and the increased availability of nitrogen is an integral part of nitrogen of protein (Bishal Chakraborty and Indrajit Sarkar, 2019). According to Somdutt *et al.* (2023), the use of PG and JA notably enhanced the absorption of nutrients, total sugars, protein content, carbohydrates, and vitamin C levels in tomatoes. Enhancing the nutritional quality of food is an essential method for increasing the quality of our diets and providing overall health benefits (Riddhi Verma *et al.,* 2024). The presence of polysaccharides, polyunsaturated fatty acids, plant nutrients, proteins, polyphenols, osmolytes, and phytohormones in SWE and FAA produce several advantages for plants (Khan *et al.,* 2022; Song Yang *et al.,* 2023). The effectiveness of SWE as a biostimulant in the enhancement of carbohydrate, fiber, and protein content in tomatos was also documented by Vinothkumar *et al.* (2024).

Diets that incorporate finger millet led to notably reduced plasma glucose levels due to the greater fiber content found in finger millet (Lakshmi and Sumathi, 2002). A diet rich in finger millet components results in reduced lipid peroxidation, which decreases arteriosclerosis, thereby offering significant protection against strokes or heart attacks (Kumar *et al.,* 2016). Additionally, finger millet contains a combination of soluble and insoluble dietary fibers, or roughage, that resist digestion, contributing to the prevention of gastrointestinal issues, colon cancer, coronary heart disease, and diabetes (Anderson *et al.,* 2009; Flieger *et al.,* 2021). Because of its high cellulose content, the insoluble fiber found in finger millet helps to add bulk to the stool, acts as a laxative to enhance bowel movement, and aids in preventing constipation by retaining water in the feces and encouraging peristalsis. Beyond the fibers, the polyphenols can assist in alleviating peptic inflammation and demonstrate anti-ulcer properties (Chethan and Malleshi, 2007). For individuals experiencing protein-energy malnutrition, it serves as a fantastic source of carbohydrates (80%) and protein (7-9%), containing essential amino acids such as valine, methionine, and tryptophan, which are typically rare in vegetarian diets. Finger millet is low in fat, making it suitable for individuals with obesity. Integrating finger millet bran into the diet has been shown to help prevent obesity induced by high-fat diets and enhance the presence of beneficial gut microbiota in animal studies (Murtaza *et al.,* 2014).

Finger millet is rich in vital nutrients and is effective in herbal remedies to address various health issues. The application of organic nutrients via foliar methods increases the mineral content in finger millet. A similar outcome was noted with the use of SWE by Layek *et al.* (2018) and Murtic *et al.* (2018). The application of digested organic liquid manures like PG and JA increased mineral nutrients like calcium and iron (Czech *et al.,* 2022; Golijan and Seèanski, 2021). Minerals form an important part of a balanced diet, and a lack of them can negatively impact health. Zinc is important for activating specific enzymes and zinc-containing organic compounds are used as astringents and anti-fungal agents. Additionally, it supports wound healing and the metabolism of nucleic acids and insulin. Copper is an essential component of the diet as it plays a crucial role in the proper utilization of iron (Bwai *et al.,* 2014). Finger millet is rich in minerals like calcium, phosphorus, potassium, and iron, along with vitamins. Finger millet contains the highest calcium levels among cereals, boasting up to ten times more calcium than brown rice, wheat, or maize, and three times more than milk. Including finger millet in the diet during pregnancy and lactation can offer considerable advantages for the bone health of both mothers and children and can help prevent osteoporosis. Calcium plays a crucial role in giving structure and stability to the body, as well as facilitating muscular contractions, vascular functions, and nerve signal transmission (Agarwal *et al.,* 2023). Additionally, it is abundant in iron and fiber, making finger millet more nutritious than many of the other commonly consumed cereals (Kumar *et al.,* 2016). The consumption of dietary calcium and magnesium has been proposed to lower the risk of type 2 diabetes (Pittas *et al.,* 2006).

The addition of organic fertilizers boosts antioxidant activity (Figure 3) and the presence of bioactive compounds (Ibrahim *et al.,* 2013; Alejandro Moreno *et al.,* 2016). Pandey *et al.* (2016) and Salehi *et al.* (2019) also identified the positive impact of applying organic manure on secondary metabolic pathways that increase antioxidant activity. Numerous phytochemicals serve as dietary antioxidants, protecting against oxidative damage and helping to maintain a healthy physiological balance. Finger millet is considered an excellent type of millet due to its great nutritional content and health benefits. Compared to major cereals, finger millet offers greater nutritional advantages in terms of protein, carbohydrates, and energy content. Millets, which are food that varies by region, are abundant in phytochemicals such as dietary fiber and antioxidants and have gained attention as a dietary choice in the fight against diabetes (Geetha *et al.,* 2020). Millets possess antioxidative benefits because they contain phenolic compounds that have been demonstrated to offer protection against cardiovascular diseases (Kumari *et al.,* 2019). A diet incorporating 55% finger millet led to an increase in the activity of antioxidant enzymes, including catalase, glutathione peroxidase, and glutathione reductase in rats, highlighting its protective effects (Hegde *et al.,* 2005).

Finger millet grains, especially the seed coat, are rich in various phenolic compounds, predominantly derivatives of benzoic acid, which are known to possess antioxidant properties valued by consumers for their numerous health advantages, such as the decreased likelihood of cancer, cardiovascular issues, neurodegenerative disorders, infections, ageing, and diabetes (Gunashree *et al.,* 2014). Due to the presence of various compounds, finger millet may help reduce excessive cellular oxidation, thereby offering protection against various types of cancers that affect the human population. Research has shown that ferulic acid can inhibit induced carcinogenesis in both the tongues and colons, and breast cancer cells of rats (Kawabata *et al.,* 2000; Choi and Park, 2015, suggested that this main component of bound phenolic acid in finger millet may function as a natural bioactive chemotherapeutic agent in the fight against cancer. The phenolic compounds, tannins, and phytate found in millet may help decrease the onset and advancement of cancer in various tissues (Chandrasekara and Shahidi, 2011). The existence of specific anti-nutritional components in whole-finger millet fractions, such as tannins, phenolics, and phytates, could contribute to a reduced glycemic response by lowering starch digestibility and absorption (Kumari and Sumathi, 2002).

The polyphenols found in the outer layer of millet seeds contribute to their antioxidant and antiaspirin effects. The high levels of phytic acid in millets, particularly in finger millets (ragi), decrease carbohydrate digestibility and help lower blood glucose levels after meals. Consequently, finger millet represents a viable dietary option for those with diabetes (Agarwal *et al.,* 2023). Finger millet is known for their free radical scavenging abilities, anti-protein glycation, anti-cataract properties, and antimicrobial effects (Ramwant, 2014). Anti-nutritional components, which diminish the nutritional quality of foods, can be lowered through conventional food preparation methods like fermentation, cooking, soaking, and puffing. These food processing techniques decrease anti-nutritional components, enhance protein digestibility, and boost the biological value of cereal grains (Handa *et al.,* 2017).

5. Conclusion

Finger millet is valued for its high nutraceutical content; hence it is recognized as one of the significant small millets globally . Finger millet promotes natural weight loss, boosts bone strength, helps in diabetes prevention, fights signs of aging, assists in blood pressure regulation, provides protection against diseases, and improves hemoglobin levels. The present studies were performed to investigate the influence of different organics foliar nutrition on the improvement of functional properties and nutraceutical value in finger millet. The findings indicated that the applications of SWE and FAA expressed their superiority by improving all the functional properties and nutraceutical value of finger millet in sodic soil. The findings indicate that organic foliar nutrition improves the biochemical properties such as chlorophyll content, relative water content, proline content, polyphenol and tannin concentration in leaves. The presence of more value of carbohydrates, protein, fibre, fat, and ash proved its superiority by the presence of the high nutritional value and health benefit of finger millet. The results indicated that the addition of organic nutrition through foliar improves the mineral content (P, K, Ca, Mg, Zn, and Fe) in finger millet, which is essential to alleviate the nutritional disorder or mall nutrition in children. Further increased antioxidant in finger millet . In summary, the study suggests that foliar application of organic nutritional sources could be a possible solution to change the biochemical properties to enhance the nutraceutical value of finger millet.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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