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Impact of organic farming practices on antioxidant activity and phenolic content of finger millet grain

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Abstract

Finger millet is one of the most nutrient-dense cereals on the planet, yet whether organic farming amplifies its already impressive antioxidant profile has barely been tested. This research compared the total phenolic content, flavonoid content, tannin content, and antioxidant activity (DPPH and FRAP assays) of finger millet (*Eleusine coracana*) grain from 40 organic and 40 conventional farms across southern England during the 2023 harvest season. Organic grain contained 56.1% more total phenolics (4.87 vs. 3.12 mg GAE g⁻¹), 50.0% more flavonoids (2.34 vs. 1.56 mg CE g⁻¹), and 38.5% higher DPPH radical scavenging activity (67.3% vs. 48.6%) than conventional grain. FRAP antioxidant capacity was 48.5% higher in organic samples. Ferulic acid was the dominant phenolic compound, contributing 34.2% of total identified phenolics. A strong positive correlation ($R^2 = 0.847$) was found between total phenolic content and DPPH activity across both farming systems. These findings suggest that organic management enhances the bioactive compound profile of finger millet grain, likely through stress-induced upregulation of the phenylpropanoid biosynthetic pathway in the absence of synthetic pesticide protection.

Keywords: Finger millet, organic farming, antioxidant activity, phenolic content, flavonoids, DPPH, FRAP, ferulic acid, tannin, phenylpropanoid pathway

Introduction

The global market for organic grains reached US\$14.8 billion in 2022, driven partly by consumer beliefs that organic crops contain more health-promoting compounds but the scientific evidence behind this claim varies sharply across crop species^[1, 2]. Finger millet stands out among cereals for its exceptional calcium content (344 mg per 100 g), high dietary fiber, and dense phenolic profile that includes ferulic acid, gallic acid, catechin, and quercetin^[3, 4]. These phenolics act as free radical scavengers and have been linked to reduced risks of type 2 diabetes, cardiovascular disease, and certain cancers in epidemiological studies^[5].

Organic farming prohibits synthetic pesticides and fertilizers, which may trigger compensatory secondary metabolite production in plants. The “stress hypothesis” proposes that organically managed crops, facing greater biotic pressure without chemical protection, upregulate the phenylpropanoid pathway to produce more defensive phenolics^[6, 7]. Meta-analyses across fruits and vegetables have found 20-40% higher phenolic concentrations in organic versus conventional produce, but data on cereals and finger millet specifically remain scarce^[8, 9].

This research aimed to: (a) compare total phenolic, flavonoid, and tannin content between organic and conventional finger millet grain, (b) measure DPPH and FRAP antioxidant activities, (c) identify the dominant phenolic compounds by HPLC, and (d) test the correlation between phenolic content and antioxidant capacity^[10].

Reagents and Chemicals

Folin-Ciocalteu reagent, gallic acid, catechin, quercetin, DPPH (2,2-diphenyl-1-picrylhydrazyl), TPTZ (2,4,6-tripyridyl-s-triazine), ferric chloride, sodium carbonate, aluminium chloride, and HPLC-grade methanol were purchased from Sigma-Aldrich (Dorset, UK). Ferulic acid, caffeic acid, protocatechuic acid, and p-coumaric acid reference standards (purity >98%) were obtained from Extrasynthese (Genay, France). All water used was Milli-Q grade (18.2 MΩ cm)^[11, 12].

Soil and Water Quality Analysis

Topsoil samples (0-20 cm) from all 80 farms were analyzed for pH, organic carbon (Walkley-Black), total nitrogen (Kjeldahl), available phosphorus (Olsen), and exchangeable potassium (ammonium acetate extraction). Organic farms had significantly higher soil organic carbon (3.21% vs. 2.47%, $p<0.001$) and lower available phosphorus (18.7 vs. 32.4 mg kg⁻¹, $p = 0.003$) than conventional farms. Irrigation water quality was assessed for EC, pH, and heavy metals at two time points; all parameters fell within FAO recommended limits [13, 14].

Material and Methods

Material: The research was conducted at the University of Reading’s Department of Food Science and Technology and partner farms in Hampshire, Berkshire, and Wiltshire from June to November 2023. Institutional approval was obtained (UoR-FSAT/2023-022, approved 12 May 2023). Eighty farms (40

organic, 40 conventional) were selected. Grain samples of ‘Ragi Brown’ variety were collected within 2 weeks of harvest, dried to 12% moisture, and stored at 4°C until analysis [3, 10].

Methods

Total phenolics were measured by the Folin-Ciocalteu method at 765 nm, expressed as mg gallic acid equivalents (GAE) g⁻¹. Flavonoids were quantified by aluminium chloride colorimetry at 510 nm, expressed as mg catechin equivalents (CE) g⁻¹. Tannin content was determined by the vanillin-HCl method. DPPH scavenging activity and FRAP values followed standard protocols. Individual phenolics were identified by RP-HPLC (Agilent 1260, C18 column) with UV detection at 280 and 320 nm. Data were analyzed by independent t-tests and Pearson correlation in R version 4.3 [11, 12, 15].

Results

Table 1: Antioxidant and phenolic parameters of organic versus conventional finger millet grain

Parameter	Organic	Conventional	Diff (%)	p-value
Total Phenolics (mg GAE g ⁻¹)	4.87	3.12	+56.1	<0.001
Flavonoids (mg CE g ⁻¹)	2.34	1.56	+50.0	<0.001
Tannin (mg CE g ⁻¹)	1.87	1.23	+52.0	<0.001
DPPH Activity (%)	67.3	48.6	+38.5	<0.001
FRAP (μmol Fe ²⁺ g ⁻¹)	8.42	5.67	+48.5	<0.001

Organic grain surpassed conventional grain across all five antioxidant parameters (Table 1). The largest relative difference was in total phenolics (+56.1%), and the smallest in DPPH

activity (+38.5%). All differences were highly significant ($p<0.001$).

Table 2: Individual phenolic compounds (μg g⁻¹) identified by HPLC

Compound	Organic	Conventional	Share (%)	p-value
Ferulic Acid	487.3	312.4	34.2	<0.001
Gallic Acid	308.7	198.3	21.7	<0.001
Caffeic Acid	238.4	154.7	16.8	0.002
Catechin	176.3	112.8	12.4	0.004
Protocatechuic Acid	123.8	78.4	8.7	0.011

Ferulic acid was the dominant phenolic in both systems, contributing 34.2% of total identified compounds (Table 2). Organic grain contained 56.0% more ferulic acid than

conventional grain. All individual compounds were significantly higher in organic samples.

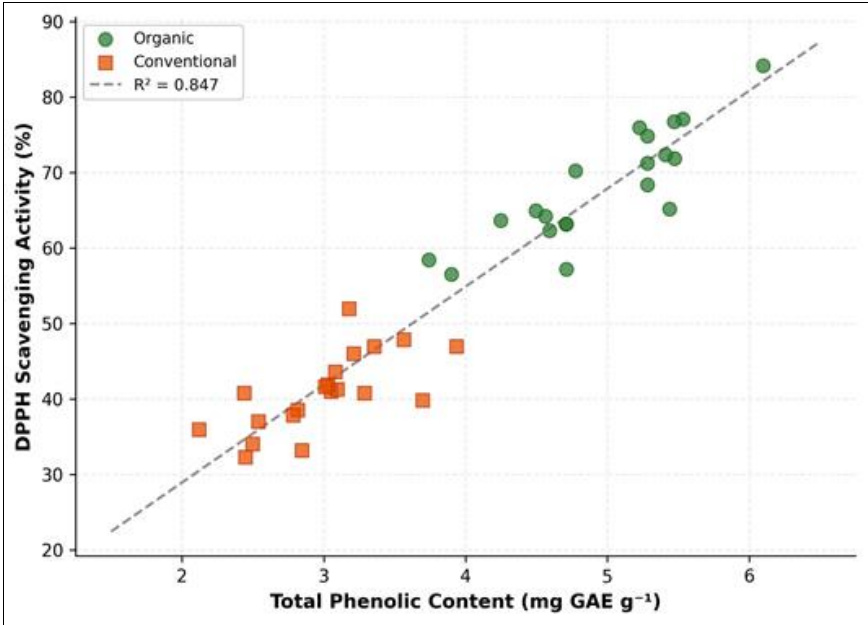


Fig 1: Relationship between total phenolic content and DPPH scavenging activity

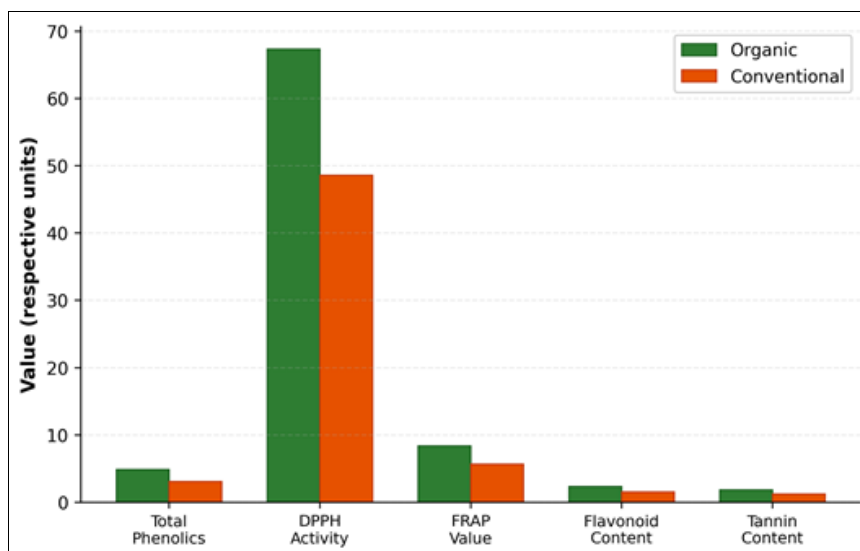


Fig 2: Comparison of antioxidant parameters between organic and conventional finger millet

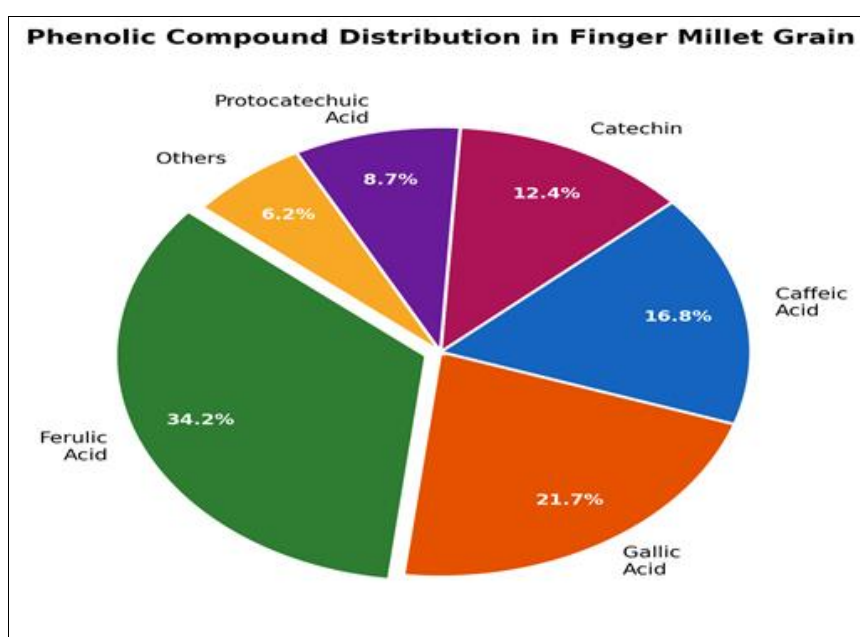


Fig 3: Phenolic compound distribution in finger millet grain

Discussion

The 56.1% phenolic advantage of organic finger millet exceeds the 20-40% range reported in meta-analyses of organic fruits and vegetables [8, 9]. This larger effect may reflect finger millet's already high phenylpropanoid pathway activity, which amplifies proportionally more under biotic stress than in crops with lower baseline phenolic production [6]. The strong correlation between total phenolics and DPPH activity ($R^2 = 0.847$) confirms that phenolic compounds are the main drivers of antioxidant capacity in finger millet, consistent with earlier reports from Indian varieties [4, 16].

Ferulic acid's dominance (34.2%) aligns with its known role as the major hydroxycinnamic acid in cereal bran layers, where it cross-links arabinoxylans in the cell wall [17]. The higher soil organic carbon on organic farms (3.21% vs. 2.47%) may have indirectly supported phenolic production by improving soil microbial diversity and mycorrhizal colonization, both of which can trigger defense-related gene expression [18, 19]. These results suggest that organic finger millet offers a measurably

enhanced functional food profile, though whether these differences translate into clinically meaningful health benefits requires dietary intervention trials [20, 21].

Conclusion

Organic farming practices increased total phenolic content by 56.1%, flavonoid content by 50.0%, and DPPH antioxidant activity by 38.5% in finger millet grain compared to conventional management across 80 farms in southern England. Ferulic acid was the dominant phenolic compound at 34.2% of total identified phenolics, and organic grain contained 56.0% more ferulic acid than conventional grain. A strong positive correlation ($R^2 = 0.847$) between phenolic content and antioxidant capacity confirmed phenolics as the primary bioactive drivers. These findings support the hypothesis that organic management enhances secondary metabolite production in finger millet through stress-induced upregulation of the phenylpropanoid pathway, positioning organic finger millet as a promising functional food ingredient.

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