Agric Res J **60** (1) : 113-120, *February* 2023
DOI No. 10.5958/2395-146X.2023.00018.2

INFLUENCE OF ORGANIC, INTEGRATED AND CONVENTIONAL PRODUCTION SYSTEMS ON CONCENTRATION OF PHYTONUTRIENTS IN CEREALS AND LEGUMES

Manisha Verma[1] , Neerja Singla[2]* , C S Aulakh[3] and Rohini Jain[2]

[1]Dr. Ram Manohar Lohia Hospital, New Delhi-110001
[2]Department of Food and Nutrition; [3]School of Organic Farming,
Punjab Agricultural University, Ludhiana - 141004, Punjab

ABSTRACT

Bioactive components, antioxidant capacity and vitamin concentrations were studied in wheat (*Triticum aestivum* L.), Basmati rice (*Oryza sativa* L.), soybean [*Glycine max*L.] and chickpea (*Cicer arietinum* L.) under organic, integrated and conventional production systems. The total phenolic contents in organically grown rice, wheat, chickpea and soybean were 166.68±1.37, 17.74±0.95, 77.55±0.70 and 335.96±0.83 mg GAE/100g, respectively. The total flavonoid contents ranged from 20.04 to ± 0.35 to 411.78±0.48 mg RE/100g in the given crops under organic production system and were significantly (p≤0.05) higher than integrated and conventional systems. Similar trend was found for total antioxidant capacity as measured by DPPH (1,1diphenyl-picrylhydrazyl) radical scavenging activity, FRAP (ferric reducing antioxidant power), ABTS [2,2'-azino-bis (3-ethylbenz-thiazoline-6-sulfonic-acid)] radical scavenging activity and RPA (reducing power assay). Among vitamins, the vitamin C content in all the crops was higher under organic management than the conventional one. Antioxidant capacity was correlated significantly with total phenolic and flavonoid contents. The investigation infers that organic production system contributes significantly in enhancing the bioactive compounds and antioxidant activity in cereals and legumes.

Keywords: Antioxidant capacity, Bioactive compound, Conventional system, Integrated system, Organic system

Cereals and legumes play a predominant role in developing countries as they constitute major portion of diet of people in these countries. Cereal grains are optimal source of energy, carbohydrates, protein, dietary fibre and have an important position in nutrition all over the world due to their ubiquitous consumption. Soluble fibre reduces the risk of cardiovascular diseases and diabetes while, insoluble fibre promotes positive status of gut, and phenolic compounds are known to possess antioxidant activity, thus influence greatly the human health (Liu, 2007). Legumes are rich in protein with good amino acid profile especially for vegetarians and also a good source of micronutrients as well as antioxidants and bioactive components such as polyphenols.

Bioactive compounds, such as phenolic acids and lignins, play an important role in prevention of various chronic diseases (Fardet *et al*., 2008). Phytochemicals,including polyphenols and flavonoids, are widely distributed in the plant kingdom as secondary metabolites and known to possess antioxidant properties and free radical scavenging capabilities. They are also known to play an important role in prevention of various non-communicable diseases such as cancer, diabetes and cardiovascular diseases (Arts and Hollman, 2005). Among bioactive components, the phenolic compounds present in cereals are in both free and bound form. Ferulic acid, p-coumarin acid, and caffeic acid are the major phenolic compounds, which exist in free soluble conjugate and insoluble bound form as dietary fibre in rice. Polyphenols including flavonoids, phenolic acids and procyanidins are present in legumes, which possess hypo-cholesterolemic, anti-atherogenic, anti-carcinogenic and hypoglycemic characteristics and function as free radical scavengers, reducing agents and metal chelators (Cardador-Martínez *et al*., 2002). Bioactive compound genistein (isoflavones) present mainly in soybean has anti-carcinogenic, -inflammatory, -microbial, -oxidative effects and helps in reducing the risk of cardiovascular diseases, cancer, Alzheimer's disease and osteoporosis (Wei *et al*., 2002). Genotype, climate, soil and crop management practices affect the concentration of phytochemicals in crop produce.

Intensive agricultural practices has led to various climatic changes creating more soil, air and water pollution along with biodiversity loss. A potential solution to these issues is to adopt management practices that increase the level of provision of ecosystem services such as soil fertility and biological regulation (Duru *et*

*Corresponding author : singlaneerja@pau.edu
Date of receipt: 22.12.2021, Date of acceptance: 13.02.2023

al., 2015). Organic agriculture is being promoted as an alternative sustainable production system in several countries of the world including India (Diwedi *et al.,* 2018). In India, the area under organic farming has increased significantly (0.3 % of cultivated area in 2004-05 to 1.3 % in 2018-19) and the demand for organic products among consumers is also increasing day by day due to awareness, availability and affordability. It is also claimed that foods produced by organic methods taste better and contain a better balance of vitamins and minerals than conventionally grown foods (Saini and Pandey, 2009). The available literature on phenolic compounds is mostly related to fruits, vegetables, wines and tea. However, these phytochemicals are also abundantly present in whole grain cereals and legumes, but the information on differences in their contents with varied crop production systems is meager. Therefore, the present study was carried out to assess the bioactive compounds and total antioxidant capacity of the cereals and legumes grown under organic, integrated and conventional production systems.

MATERIALS AND METHODS

Wheat (PBW 725), Basmati rice (Punjab Basmati 3), soybean (SL 744) and chickpea (GPF 2) grains were taken from a long term field experiment. The experiment, initiated during 2004-05, consisted of three crop management systems- organic (nutrition and pest management as per organic standards), integrated (50% nutrition through organic sources and 50% through chemical fertilizers, and integrated pest management) and conventional (Chemical nutrition and pest management) and four cropping systems- Basmati rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L., soybean [*Glycine max* (L.) Merill] – wheat, basmati rice – chickpea (*Cicer arietinum* L.) and clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] – wheat. The experimental site has semi-arid and sub-tropical type of climate. The recommended nutrient supply of 40 kg N to basmati rice, 31 kg N and 60 kg P_2O_5 to soybean, 20 kg N and 47.5 kg P_2O_5 to clusterbean, 125 kg N and 62.5 kg P_2O_5 to wheat, and 15 kg N and 20 kg P_2O_5 to chickpea was made through chemical fertilizers to the conventional crops. Farmyard manure (FYM), having 1% N on dry-weight basis, was used to supply the recommended nitrogen to organic crops. The pest management under organic management was done by using Tricho-cards and neem-based biopesticides. Under integrated management system, the 50% nitrogen requirement of crops was met through FYM and 50% of the recommended NPK fertilizers were used along with integrated pest management. .

The grain samples were cleaned to remove extraneous material and milled into flour and stored. The wheat grains were milled using laboratory mill, model KT-3303 with No.2 burr having rpm 3500±100. Basmati was cleaned and milled on a Satake mill for getting polished grains which were grounded for further analysis. The homogenous powder of all the grains was prepared by grinding and the samples were packed and kept under ambient storage for further analysis. For the estimation of bioactive compounds and total antioxidant activity, the chemicals- Gallic acid (GA), Folin-Ciocalteu (FC), Rutin, 2,4,6-Tris (2-pyridyl)-s-triazine (TPTZ), 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2'-azino-bis (3-ethylbenz-thiazoline-6-sulfonic-acid) (ABTS), 2,6-dichloropheno lindo phenol and β-carotene standard from Sigma were used. Other chemicals and reagents used in analysis were of analytic grade (AR).

Extract preparation for estimation of total phenols, flavonoids and antioxidant capacity

About 2g of sample was mixed with 80% methanol (ethanol: water, 80:20.v/v) and acidified to pH 2.0 with 6N HCl and incubated in shaking water bath at room temperature for 30 minutes and repeated twice. Following incubation, supernatants were pooled and centrifuged at 6,000 rpm for 15 min and filtered through Whatman No.1 filter paper, and volume was made up to 50 ml with solvent. Supernatants, considered to be extracts, were stored at -20°C for estimation of total phenolic content (TPC), total flavonoid content (TFC) and total antioxidant capacity (TAC).

Estimation of total phenolic content (TPC)

Known quantity of aliquot of sample was taken and volume made to 1.5 ml with distilled water (D/W). To this 0.5 ml FC reagent and 10 ml 7.5% Na_2CO_3 were added and incubated at 37°C for 60 minutes. Absorbance was read at 750 nm using a spectrophotometer against blank. Standard curve was constructed using concentration of gallic acid ranging from 5 to 20 µg. Total phenolic contents were expressed as mg of gallic acid equivalent (GAE)/100 g extract (Singleton *et al*., 1999).

Estimation of total flavonoids content (TFC)

Rutin standard was used to estimate the TFC using a calibration curve. Known aliquot was taken and volume made to 5 ml with D/W, and 0.3 ml 5% $NaNO_2$, 0.6 ml 10% $AlCl_3$ and 2 ml 1 N NaOH weres added to it, mixed and volume made to 10 ml with 2.1 ml D/W. The absorbance was read at 510 nm against blank and flavanoid contents were expressed as mg of rutin equivalent (RE)/100 g extract (Zhishen *et al*., 1999).

Estimation of DPPH radical scavenging activity

It was determined by using method described by Brand-Williams *et al*. (1995) as modified by Tadhani *et al.* (2009). Sample aliquots were taken and volume

made to 1ml using methanol. To it 3 ml DPPH reagent was added and incubated for 20 min at 37°C. The absorbance was read at 517 nm against methanol as blank. The Trolox standard was prepared in the range of 5-20 µg and the concentration of DPPH was calculated from trolox standard curve and expressed as mg trolox equivalents (TE)/100 g extract.

Estimation of ABTS radical scavenging activity

Aliquots were taken and volume made upto 1ml with ethanol, 3 ml of ABTS reagent was added and incubated for 10 min at 37°C. The absorbance was read at 734 nm against ethanol as blank. Standard curve was constructed using trolox in the range of 1.0-4.0 µg and antioxidant capacity was calculated from trolox standard curve and expressed as mg trolox equivalents (TE)/100 g extract (Re *et al*., 1999).

Estimation of FRAP (Ferric reducing antioxidant power)

It was estimated by using method given by Benzie and Strain (1999) and modified by Tadhani *et al*. (2009). Aliquots of samples were taken and volume up to 0.3 ml was made with distilled water, added 1.8 ml of FRAP working reagent and incubated at 37°C for 10 minutes. The blue coloured complex was read at 593 nm against blank. Trolox in the range of 0.5-2.0 µg was used for construction of standard curve, antioxidant capacity was calculated and expressed as mg trolox equivalents (TE)/100 g extract.

Estimation of RPA (Reducing power assay)

Sample extract was taken and volume was made up to 1 ml with D/W, 2.5 ml of 0.2 M phosphate buffer (pH 6.6) and 2.5 ml of 1% potassium ferricyanide were added and incubated at 50°C for 20 min. Following incubation, 2.5 ml of 10% trichloroacetic acid was added and centrifuged at 3000 rpm for 10 min, 2.5 ml of the supernatant was taken and mixed with 2.5 ml of D/W and 0.5 ml of 0.1% ferric chloride and incubated at 37 °C for 20 min. The absorbance was read at 700 nm and trolox in the range 10-40 µg was used to construct standard curve. The antioxidant capacity was calculated from trolox standard curve and expressed as mg trolox equivalents (TE)/100 g extract (Oyaizu, 1986).

Estimation of vitamin C

Two g of the fresh sample was mixed with 20 ml of 6% metaphosphoric acid to make slurry and was filtered. Three separating funnels (50 ml) were labeled as A, B and C and 5 ml of filtrate was pipetted to funnel A, 0.1 ml of standard ascorbic acid solution into funnel C and 5 ml acetate buffer was added, followed by 2 ml of dye solution and 10 ml of Xylene solution and Xylene layer was transferred into a test tube and absorbance was read in a spectrophotometer at 500 nm (AOAC, 2000).The funnel B was treated as dye blank.

Estimation of β-carotene

Eight g sample was taken in 150 ml glass stoppered Erlenmeyer flask, added 40 ml water saturated butanol (WSB) and kept overnight (16-18 hrs) at room temperature under dark for complete extraction of β-carotene. Next day, the contents were filtered and absorbance was measured at 440 nm. Calibration curve was made from known amounts of pure β-carotene ranging from 0.25 to 1.5 µg/ml (AACC, 1995).

From the data obtained, the mean values and standard deviations were computed. One-way analysis of variance (ANOVA) (Tukey's test) was employed to compare the total phenolic, flavonoids, antioxidant capacity and vitamin content. Pearson's correlation was used to assess the linear association between total phenolic, flavonoid content and antioxidant capacities. The statistical procedures were performed using SPSS (version 16.0) (SPSS, 2007).

RESULTS AND DISCUSSION

Total phenols and flavonoids

Organically grown cereals and legumes had significantly ($p \leq 0.05$) higher phenols and flavonoids as compared to integrated and conventional system (Table 1). Among cereals, total phenols in organically grown rice and wheat were 166.68 and 17.74 mg GAE/100g, respectively. However, conventionally grown rice and wheat had 163.0 and 10.25 mg RE/100g total phenols, respectively. Total flavonoid content of organically grown rice and wheat was 23.29 and 160.74 mg RE/100 g, whereas conventionally grown rice and wheat had 21.78 and 119.49 mg RE/100g, respectively. Kumari *et al*. (2017) also reported significantly higher total phenols and flavonoids content of organic rice compared to conventional. Zhu *et al.* (2011) also reported significantly higher phenols and flavonoid ranging from 13.98 to 16.75 mg GAE/g in organic defatted wheat germ compared to the inorganic. Kesarwani *et al.* (2014) reported significantly higher total phenols (167.4 mg GAE/100g) and flavonoids (19.4 mg QAE/g) in organic rice varieties.

Among legumes also, the similar trend was observed. Organically grown chickpea and soybean had significantly ($p \leq 0.05$) higher concentration of total phenols and flavonoids than conventionally grown legumes. Total phenolic content in organic chickpea and soybean was 77.55 and 335.96 mg GAE/100g respectively, whereas conventional chickpea and soybean had 70.18 and 191.63 mg GAE/100g. Organic chickpea had flavonoid 411.78 mg RE/100g, whereas

Table 1. Total phenols and flavonoids content in cereals and legumes under different production systems

Production System	Total Phenols (mg GAE/100g)	Flavonoids (mg RE/100g)
Rice		
Organic	166.68^{b}±1.37	23.29^{c} ± 0.39
Integrated	156.30^{a}±1.97	20.04^{a} ± 0.35
Conventional	163.0 $^{a\ b}$±2.72	21.78^{b} ± 0.06
Wheat		
Organic	17.74 ^{c} ±0.95	160.74^{c} ± 0.25
Integrated	14.56^{b}±0.84	132.40^{b} ± 0.26
Conventional	10.25^{a} ±0.04	119.49^{a} ± 0.64
Chickpea		
Organic	77.55 ^{c} ±0.70	411.78 ^{c} ±0.48
Integrated	73.03^{b}±0.47	391.96^{b}±0.76
Conventional	70.18 ^{a} ±0.54	327.96 ^{a} ±1.18
Soybean		
Organic	335.96 ^{c} ±0.83	116.29 ^{c} ±0.89
Integrated	210.22^{b}±0.51	98.55^{b}±0.54
Conventional	191.63 ^{a}±0.62	86.92 ^{a} ±0.23

Values are mean ± SD
Values followed with different superscripts are significantly different (p<0.05) using Tukey's test

conventional chickpea had 327.96 mg RE/100g. Flavonoid contents of organic and conventional soybean were 116.29 and 86.92 mg RE/100g, respectively. Kaur (2018) reported total phenols and flavonoids content in inorganically grown chickpea as 70 mg GAE/100g and 354.48 mg RE/100g, respectively.

Polyphenol quantity and quality in plant foods can vary significantly according to different intrinsic and extrinsic factors such as plant genetics and cultivators, soil composition and growing conditions, maturity state and post-harvest conditions. Among the crops, the highest total phenolic content was found in soybean followed by rice, chickpea and wheat and total flavonoids were the highest in chickpea followed by wheat, soybean and rice under organic production system. Firstly, easy and rapid bioavailability of nitrogenous fertilizers under conventional management systems accelerates plant development and growth, thereby limiting the production of secondary metabolites, such as phenolics and flavonoids. Secondly, stress imposed by lack of utilization of pesticides causes the plants to activate their own defense system, eventually resulting in enhanced production of defensive compounds (Faller and Fialho, 2009).

Total antioxidant capacity

Total antioxidant capacity of cereals and legumes was determined using 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity (DPPH), ferric reducing antioxidant power (FRAP), 2,2'-azino-bis-3-ethylbenz-thiazoline-6-sulfonic acid (ABTS) and reducing power assay (RPA) method, as more than one test is required to have accuracy in measuring the antioxidant capacities. The results (Fig. 1-4) indicated that total antioxidant capacity by different methods was significantly (p≤0.05) higher in organically grown crops than integrated and conventional, using 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity, assay is based on the stable DPPH free radical. Antioxidant capacity as determined by DPPH in organically grown rice, wheat, chickpea and soybean was 416.9, 1393.5, 1503.4 and 463.5 mg TE/100 g, respectively, which was higher than conventional crops (Fig. 1). Kaur (2018) reported antioxidant capacity by DPPH in inorganic wheat and chickpea as 1142.64 and 1256.96 mg TE/100 g, respectively.

The ABTS assay is another commonly used method to measure the relative radical scavenging activity of hydrogen-donating and chain-breaking antioxidants in plant extracts (Verstraeten *et al*., 2003). Antioxidant capacity by ABTS was 72.0, 26.8, 42.9 and 116.7 mg TE/100g in organically grown rice, wheat, chickpea and soybean respectively, whereas inorganic rice, wheat, chickpea and soybean had 64.1, 15.6, 37.8, 97.8 mg TE/100g (Fig 2). Kaur (2018) reported 12.17 and 34.38 mg TE/100g antioxidant capacity by ABTS among inorganic wheat and chickpea respectively. The FRAP assay is a reliable method for assessing the antioxidant capacity of polyphenols. FRAP assay is based on the ability of the extract to reduce the ferric tripyridyltriazine (Fe3+–TPTZ) complex to ferrous tripyridyltriazine (Fe2+–TPTZ). In the presence of antioxidant compounds the Fe(II)–TPTZ complex turns blue, which exert their action by donating a hydrogen atom to break the free radical chain (Kathirvel *et al*., 2012).

Total antioxidant capacity by FRAP was highest in soybean (210.7 mg TE/100), followed by chickpea (157.9 mg TE/100g), rice (198.2 mg TE/100g) and wheat (99.2 mg TE/100g) respectively under organic production system, whereas the corresponding values for conventional soybean, chickpea, rice and wheat were 184.6, 137.9, 175.9 and 82.3 mg TE/100, respectively. Kaur (2018) reported antioxidant capacity by FRAP in inorganic wheat and chickpea crops as 86.19 and 142.31 mg TE/100g respectively. In the RPA assay, Fe3+ reduction is an indicator of electron-donating activity. The solution changes from yellow to different shades of blue and green depending on the power of a compound to reduce the free radicals (Singh and Bag, 2013). Higher antioxidant capacity by RPA was found in organically grown rice, wheat, chickpea and soybean, the values being 715.1, 712.3, 975.9 and

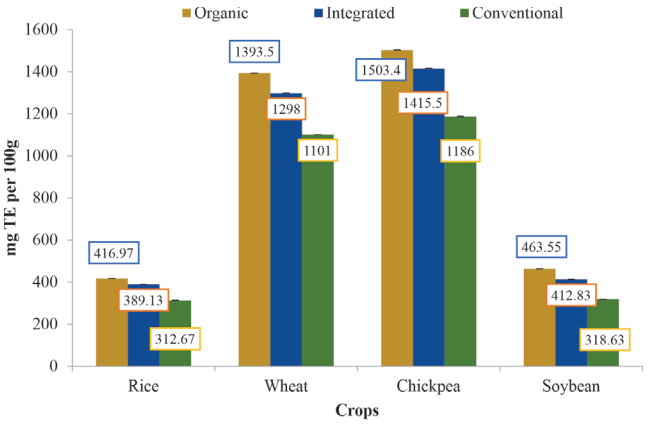

Fig. 1. Total Antioxidant Capacity (TAC) measured by DPPH

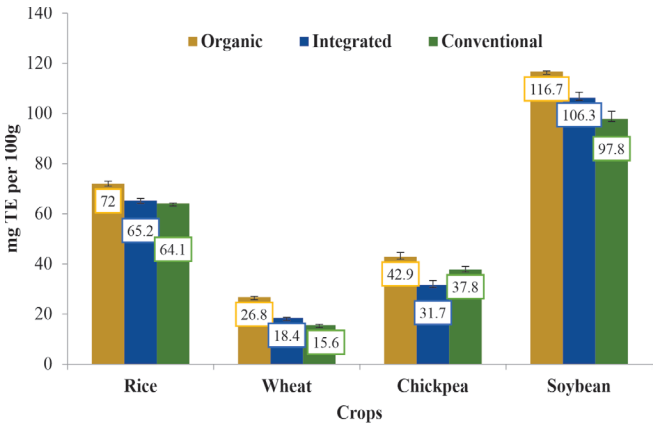

Fig. 2. Total Antioxidant Capacity (TAC) measured by ABTS

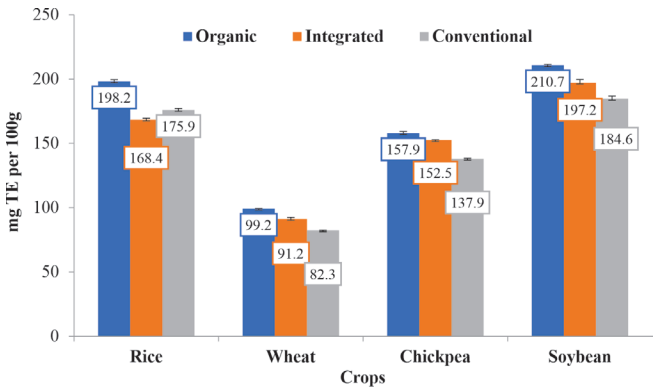

Fig. 3. Total Antioxidant Capacity (TAC) measured by FRAP

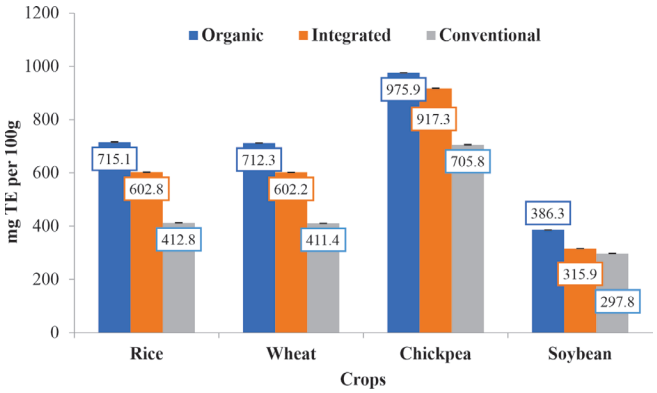

Fig. 4. Total Antioxidant Capacity (TAC) measured by RPA

386.3 mg TE/100g, respectively. Kaur (2018) reported 424.87 and 618.72 mg TE/100 antioxidant capacity by RPA in inorganic wheat and chickpea, respectively. Shen *et al.* (2009) reported significantly higher antioxidant capacity by ABTS and DPPH in organically grown wheat variety as compared to inorganic sample. Kesarwani *et al*. (2014) also found higher antioxidant capacity as determined by ABTS, FRAP and DPPH in organically grown rice varieties as compared to the inorganic varieties. Plants grown under organic system show higher antioxidant potential as compared to conventional system. Secondary metabolites are produced by plants to protect themselves against insect-pest attack, disease and damage. When plant is subjected to higher level of stress, it accumulates higher levels of antioxidants. In crops grown under organic production system there is exclusion of insecticides, fungicides that put a greater influence on the plants' own natural protection system resulting in accumulation of high levels of these secondary metabolites (Kasote *et al*., 2015).

Antioxidant capacity measured by different assays like DPPH, ABTS, FRAP and RPA is important to evaluate the extracts of various parts of plant to cover the range of different endogenous compounds. Antioxidants consist of a wide range of reducing agents, nucleophiles and polyphenols which vary in terms of their redox potential, localization, solubility, specificity and mechanism of action. Folin and FRAP method measures only the activity of hydrophilic antioxidants, whereas the activity of both hydrophilic and lipophilic antioxidants is measured by ABTS assay. The activity of antioxidants soluble in organic solvents, especially alcohols is detected by DPPH assay only. So, the evaluation of overall antioxidant capacity based on one chemical reaction is somewhat unrealistic. For this reason, multiple assays are being used to evaluate the overall antioxidant capacity (Sahid *et al*., 2015).

Association between total phenolics, flavonoid content and antioxidant capacity

TPC and TFC were found to be positively correlated with antioxidant activity measured by DPPH, ABTS, FRAP and RPA in all the crops (Table 2). DPPH assay was positively correlated with ABTS ($r = 0.887$, $P \leq 0.01$), FRAP ($r = 0.982$, $P \leq 0.01$) and RPA ($r = 0.999$, P

Table 2. Correlation coefficient between TPC, TFC and antioxidant capacity

			Rice			
Compounds	**TPC**	**TFC**	**DPPH**	**ABTS**	**FRAP**	**RPA**
TPC	1	0.789*	NS	NS	0.739*	NS
TFC		1	NS	0.711**	0.864**	NS
DPPH			1	0.780*	NS	0.993**
ABTS				1	0.904**	0.846**
FRAP					1	NS
RPA						1
Wheat						
TPC	1	0.909**	0.938**	0.887**	0.954**	0.945**
TFC		1	0.916**	0.997**	0.967**	0.933**
DPPH			1	0.887**	0.982**	0.999**
ABTS				1	0.946**	0.907**
FRAP					1	0.989**
RPA						1
Chickpea						
TPC	1	0.878**	0.896**	NS	0.876**	0.870**
TFC		1	0.998**	NS	0.996**	0.999**
DPPH			1	NS	0.997**	0.998**
ABTS				1	NS	NS
FRAP					1	0.996**
RPA						1
Soybean						
TPC	1	0.957**	0.842**	0.922**	0.924**	0.997**
TFC		1	0.956**	0.965**	0.986**	0.973**
DPPH			1	0.948**	0.970**	0.880**
ABTS				1	0.967**	0. 948**
FRAP					1	0.947**
RPA						1

**Correlation significant at 0.01 level; *Correlation significant at 0.05 level; NS, non-significant

≤ 0.01) in wheat. There was a non-significant correlation between DPPH assay and FRAP in rice, whereas DPPH was found to be positively correlated with ABTS (r = 0.780, P ≤ 0.05) and RPA (r = 0.993, P ≤ 0.01). DPPH assay of soybean was found to be positively correlated with ABTS (r = 0.948, P ≤ 0.01), FRAP (r = 0.970, P ≤ 0.01) and RPA (r =0.880, P ≤ 0.01). Non-significant correlation was found between ABTS, FRAP and RPA assay of chickpea, whereas DPPH assay was found positively correlated with FRAP (r = 0.997, P ≤ 0.01) and RPA (r = 0.998, P ≤ 0.01) in chickpea. Sahid *et al.* (2015) showed significant correlations (r^2 values of 0.851–0.982) between antioxidant activities measured by different methods ((DPPH, ABTS, RPA and FRAP) and bioactive compounds (TPC and TFC) of *E. coccinea* extracts.

Vitamins

Vitamin C and β-carotene content varied significantly (p≤0.05) among all the three production systems (Table 3). Wheat, rice, chickpea and soybean under organic production system had higher vitamin C content as compared to integrated and conventional systems. Vitamin C content of organic, integrated and conventionally grown rice was 0.96 mg, 0.68 mg and 0.74 mg per 100g, respectively. Conventionally grown wheat, chickpea and soybean had vitamin C content of 0.12, 0.23 and 0.38 mg per 100g, respectively which was lower than organically grown crops. The quality attributes such as vitamin C, oxalate and nitrate content as well as nutrient uptake were the highest for bio-organic composite manure-treated plants whereas the beta-carotene content was the highest for the

Table 3. Vitamin content of cereals and legumes under different production systems

Production System	Vitamin C (mg/100g)	β-carotene (µg/100g)
Rice		
Organic	0.96 [b] ±0.02	1.33[a] ±0.35
Integrated	0.68 [a] ±0.83	0.89 [a b]±0.04
Conventional	0.74 [a] ±0.12	0.44 [b] ±011
Wheat		
Organic	0.63 [b] ±0.06	3.03 [a] ±0.08
Integrated	0.08 [a] ±0.03	3.94[b]±0.11
Conventional	0.12 [a] ±0.04	4.07[b]±0.12
Chickpea		
Organic	0.89[b]±0.08	173.33[b]±6.71
Integrated	0.39 [a] ±0.06	111.22 [a] ±0.97
Conventional	0.23 [a] ±0.08	106.64 [a] ±0.51
Soybean		
Organic	0.61[a]±0.05	7.31[b]±0.93
Integrated	0.85[a]±0.06	5.83 [ab]±0.49
Conventional	0.38[a]±0.06	4.74 [a] ±0.61

Values are mean ± SD; Values followed with different superscripts are significantly different (p<0.05) using Tukey's test

recommended practices (Vipitha and Geethakumari, 2015). Kumpulainen (2001) reported higher vitamin C content in organically grown vegetables. Vitamin C was higher in organically grown broccoli than inorganic broccoli as reported by Kane *et al*. (2008). Pappachan (2016) reported that organic cauliflower, tomato, brinjal and okra contained vitamin C as 55.56, 28.33, 15.4 and 13.16 mg/100 g, where as their inorganic counter parts contained only 48.46, 20.66, 10.48 and 10.5 mg/100 g of vitamin C, respectively, indicating significantly (p≤ 0.01) higher vitamin C content in organic vegetables. Kaur (2018) reported vitamin C content of 0.05 and 0.11 mg in inorganic wheat and chickpea, respectively. The reason for higher vitamin C content in organically grown crops might be that the amount of nitrogen in the fertilizers affects the amount of vitamin C and nitrates, as well as quality and quantity of protein in the crops. When a plant contains more nitrogen as in the case of inorganic cultivation, it results in protein production and reduction of carbohydrate production. Since vitamin C is made from carbohydrates, so its synthesis is affected. β-carotene of organically grown rice, chickpea and soybean was significantly (p≤0.05) higher as compared to conventional crops whereas β-carotene content of conventional wheat was higher as compared to organic wheat. The values being 1.33, 3.03,173.33 and 7.31 µg/100g β-carotene in organically grown rice, wheat, chickpea and soybean, respectively. Conventionally grown rice, wheat, chickpea and soybean had 0.44, 4.07, 106.64, 4.74 µg/100g β-carotene, respectively. The differences in carotene content might be due to the genetic differences. Lawanprasert *et al*. (2007) reported higher β-carotene in organic rice as compared to inorganic rice. Pappachan (2016) reported that organically cultivated vegetables like tomato, brinjal and okra contained significantly (p≤ 0.01) higher amount of β-carotene i.e, 122.6, 10.23 and 5.83 µg/100 g, whereas inorganically cultivated vegetables contained lower amount of β-carotene (114, 8.66 and 3.26 µg/100 g, respectively).

The results indicate that vitamin C, total phenols, flavonoids and antioxidant capacity in organically raised crops were higher than the integrated and conventional ones. β-carotene content in rice, chickpea and soybean was significantly (p≤0.05) higher under organic production system, whereas in wheat it was higher under conventional system. TPC and TFC were positively correlated with antioxidant activity as measured by DPPH, ABTS, FRAP and RPA in all the crops. Therefore, it may be concluded that conversion from conventional to organic production system, in the long term, can result in positive changes in phytochemicals content. However, multi-location comparison of production systems in terms of bio-active components, antioxidants and vitamins are essential to determine the influence of environmental factors.

Authors' contribution

Conceptualization of research and designing of experiments (NS, CSA); Execution of field/ lab experiments (MV, RJ); Collection of data and interpretation of results (MV, NS, CSA); Preparation of manuscript (MV, NS, CSA).

LITERATURE CITED

AACC 1955. *Approved Methods of American Association of Cereal Chemists,* Methods, pp: 14–50. The Association St. Paul, MMN.

AOAC 2000. Official Methods of Analysis. *The Association of Official Analytical Chemists*, Gaithersburg, Maryland, USA. 2200p.

Arts I C W and Hollman P C H 2005. Polyphenols and disease risk in epidemiologic studies. *Amer J of Clin Nutr* **81**: 317–25.

Benzie I F and Strain J J 1999. Ferric acid reducing/ antioxidant power assay: Direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration. *Methods Enzymology* **299**: 15–27.

Brand-Williams W , Cuvelier M E and Berset C L W T 1995. Use of a free radical method to evaluate antioxidant activity. *J Food Sci Technol* **28:** 25–30.

Diwedi A , Jat R A and Reddy K K 2018. Organic manures and nutrient solubilizers for organic cultivation of summer groundnut (*Arachis hypogaea*) in black calcareous soil. *Indian J of Agron* **63:** 237-40

Duru M , Therond O , Martin G *et al.*2015. How to implement biodiversity-based agriculture to enhance ecosystem services: a review. *Agron Sust Dev* **35:** 1259–81.

Faller A L K and Fialho E 2009. The antioxidant capacity and polyphenol content of organic and conventional retail vegetables after domestic cooking. *Food Res Int* 42: 210-15.

Fardet A , Edmond R E and Remesy C 2008. Is the *in vitro* antioxidant potential of whole-grain cereals and cereal products well reflected in vivo. *J Cer Sci* **48**: 258–76.

Kane S , Faldman H and Hazhin T 2008. Nutritional quality of organic, conventional, and seasonally grown broccoli using vitamin C as a marker. *Int J Food Scie Nutr* **59**: 35–45.

Kasote D M, Katyare S S, Hegde M V and Bae H 2015. Significance of Antioxidant Potential of Plants and its Relevance to Therapeutic Applications. *Int J Biol Scie* **11**:982-91.

Kathirvel A and Sujatha V 2012. Phytochemical studies, antioxidant activities and identification of active compounds using GC–MS of *Dryopteris cochleata*leaves. *Arabian J Chem* **8**:234-38.

Kaur G 2018. *Formulation and nutritional evaluation of cereal-pulse based extruded snacks supplemented with dehydrated herbs*. *Ph.D. Thesis*, Punjab Agricultural University, Ludhiana, Punjab.

Kesarwani A , Chiang Y and Chen S S 2014. Distribution of phenolic compounds and antioxidative activities of rice kernel and their relationships with agronomic practices. *The Scientific World J* **45**: 1093–99.

Kumari A , Kannojiya G , Kumar A and Gaur K A 2017. Assay of anti-oxidative activity of seed extracts derived from rice (*Oryza sativa* L.) varieties. *Int J Curr Microbiol Appl Scie* **6**: 2659–66.

Kumpulainen J 2001. Nutritional and toxicological quality comparison between organic and conventionally grown food stuffs. *Proc Int Fert Soc* **472**: 1–20.

Lawanprasert A , Kunket K , Arayarangsarit L and Prasertsak A 2007. Comparison between conventional and organic paddy fields in irrigated rice ecosystem. *J Food Sci Technol* **37**: 217–21.

Liu R H 2007. Whole grain phytochemicals and health. *J Cereal Sci* **46**: 207–19.

Oyaizu M 1986. Studies on products of browning reaction: antioxidative activities of products of browning reaction prepared from glucosamine. *Japanese J Nutr Diet* **44**: 307–15.

Pappachan A 2016. *Nutritional and organoleptic evaluation of organic vegetables* Ph.D.Thesis, Punjab Agricultural University, Ludhiana, Punjab.

Re R , Pellegrini N , Proteggente A , Pannala A , Yang M and Rice-Evans C 1999. Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology Medicine* **26**: 1231–37.

SPSS Inc. 2007. SPSS for Windows, Version 16.0. Chicago, SPSS Inc.

Sahid A S , Kamaria A S , Lim L B and Ahmad N 2015. Phytochemical screening, antioxidant and antimicrobial activities of leaves, stems and rhizomes of *Etlingera coccinea* (Blume). *Int J Pharmacog Phytochem Res* **7**: 873–83.

Saini S K and Pandey S T 2009. Organic farming: Development and strategies in Indian perspective. *Indian J Agron* **54**: 193-99.

Shen Y , Jin L , Xiao P , Lu Y and Bao J. 2009. Total phenolics, flavonoids, antioxidant capacity in rice grain and their relations to grain color, size and weight. *J Cereal Sci* **49**: 106–11.

Singh K L and Bag G 2013. Phytochemical analysis and determination of total phenolics content in water extracts of three species of *Hedychium*. *International J Pharm Tech Res* **5**: 1516–21.

Singleton V L , Orthofer R and Lamulea-Raventos R M 1999. Colorimetry of total phenolics with phosphomolybdic phototungstic acid reagents. *Amer J Enology Viticulture* **16**: 144–58.

Tadhani M B , Patel V H and Subhash R 2009. (In) *vitro* antioxidant activities of *Stevia rebaudiana* leaves and callus. *J Food Compost Anal* **20:** 323–29.

Verstraeten S V, Keen C L, Schmitz H H , Fraga C G and Oteiza P I 2003. Flavan-3-ols and procyanidins protect liposomes against lipid oxidation and disruption of the bilayer structure. *Free Radical Biology and Medicine* **34**: 84–92.

Vipitha V P and Geethakumari V L 2015. Bio-organic composite manures for sustainable yield and quality of Amaranth (*Amaranthus tricolor*). *Indian Journal of Agronomy* **60** (3): 471-75.

Wei H , Zhang X , Wang Y and Lebwohl M 2002. Inhibition of ultraviolet light-induced oxidative events in the skin and internal organs of hairless mice by isoflavonegenistein. *Cancer Letter* **185**: 21–29.

Zhishen J , Mengcheng T and Jianming W 1999. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. *Food Chem* **64**: 555–59.

Zhu K X , Lian C X , Guo X N , Peng W and Zhou H M 2011. Antioxidant activities and total phenolic contents of various extracts from defatted wheat germ. *Food Chem* **126**: 1122–26.