ORIGINAL ARTICLE

Cultivation, nutritional, antinutritional, and mineral analysis of organic and non-organic *Momordica charantia*: Comparative study

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Abstract

Introduction: Organic agriculture is one among the different production methods that are supportive to the environment. The demand for organic food is increasing rapidly both in the developed as well as developing countries. **Aim:** To examine the morpho-physiological traits, nutrition and mineral composition of comparative cultivated organic and non-organic *Momordica charantia*. **Materials and Methods:** The experiment was carried out in randomized block design with 12 replications using organic and non-organic fertilizers and pesticides. The unripe fruits harvested; lyophilized and whole fruits were screened for nutritional, antinutritional, physico-chemical, and mineral (by inductively coupled plasma atomic emission spectroscopy) analysis. **Results:** The mean performances of all the traits were higher in organic fruits of MC (OMC) except the average weight of the fruits. Nutritional analysis revealed an elevated caloric value (332.62 kcal/100 g DW) in OMC fruits. Similarly, higher values for total bitters, vitamin C, and mineral contents (K, Ca, Mg, Fe, Na, Zn, Cu, and Mn) were also observed in OMC. In contrast, non-organic fruits of MC (NMC) contained a higher content of total ash, extractives, and toxic heavy metals (Pd, Cd - 2.23, 0.15 mg/100 g DW, respectively). **Conclusion:** The perception is proved by the scientific justification that organically grown foods or medicinal herbs are “better for you” in terms of nourishment, sustainability, better quality standards, and safety measures.

Key words: Antinutritional, minerals, *Momordica charantia*, non-organic, nutritional, organic

INTRODUCTION

Biological Diversity Act (2002) and rule (2004) enforced the noble thought of protecting our biodiversity, especially crude drugs from plant origin.[1] Therefore, it has become an essential criterion for all the herbal industries and those working on medicinal plants, to produce these crude drugs by cultivation in the fields. A series of food scares and the controversy surrounding genetically modified crops have prompted heated debate about the safety and integrity of our food and herbal medicines. Against this background, demand for organically grown food has been growing rapidly.[2] Increasing consciousness about conservation of the environment, as well as health hazards associated with agrochemicals and consumer’s preference to safe and hazard-free food, are the major factors that lead to the growing interest in alternate forms of agriculture in the world. Organic agriculture is one among the broad spectrum of productive methods that are supportive to the environment. The demand for organic food is steadily increasing both in the developed as well as developing countries with an annual average growth rate of 20-25%.[3] Until now, this perception that organically grown food is “better for you” appears to have been largely based on intuition rather than conclusive evidence. Therefore, the present study was designed to scientifically validate the

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perception in terms of growth pattern, nutrients, antinutrients, and minerals by taking *Momordica charantia* Linn. as an experimental model.

MATERIALS AND METHODS

The present investigation was carried out in the Department of Pharmaceutical Sciences, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur, situated in the center of the Indian peninsula 79° 7′ East longitude and 21° 7′ North latitude and is at a mean altitude of 310.5 meters above sea level. The average annual rainfall of the area is 1205 mm. The average maximum temperature of the city is 33.53°C and the average minimum temperature is 20.37°C and the relative humidity ranges from 20% to 70%.[4] Seeds were procured from Organic India Pvt. Ltd., Lucknow, India.

Experimental Land

The land for the organic treatment was selected and converted (period 2.5 years before 1st harvest) as per the recommendations of the National Centre for Organic Farming, India,[5] and the parallel area with marked buffer zone was selected for conventional treatment. The soil of experimental site was comprised of black clay soil with a pH of 6.8, rich in humus, potash, and trace elements (Cu, Fe, Mn, and Zn) (analyzed by "Soil Survey and Soil Analysis Department" Government of India, Nagpur, MS, India). Results are given in Table 1a, 1b, and 1c.

Table 1a: Soil properties

Soil contents	Observed values	Standard values	Remarks
pH	6.8	-	Neutral
Salt (EC) Mscm^{-1}	0.34	-	Common
Carbon (% w/w)	1.237	-	Very high
Nitrogen (kg/hec.)	325	-	Normal
Phosphorus (kg/hec.)	18.687	-	Normal
Potassium (kg/hec.)	895.1	-	Very high
Copper (ppm)	2.36	0.2	Very high
Iron (ppm)	8.36	4.5	Very high
Manganese (ppm)	11.65	2.0	Very high
Zinc (ppm)	1.73	0.65	Very high

Analyzed by Soil Survey and Soil Analysis Department, Nagpur District, Maharashtra, India. (Repot No. 30S20120033001, 30M20120020001)

Table 1b: Standard limit of macronutrients

Remark	Organic carbon (%)	Nitrogen (kg/hec.)	Phosphorous (kg/hec.)	Potassium (kg/hec.)
Very less	Up to 0.2	<141	<7.0	<100
Less	0.21-0.40	141-280	8.0-14	101-150
Normal	0.41-0.60	281-420	15-21	151-200
Normal high	0.61-0.80	421-560	22-28	201-250
High	0.81-1.00	561-800	29-35	251-300
Very high	>1.00	>801	>36	>301

Data provided by Soil Survey and Soil Analysis Department, Nagpur District, Maharashtra, India

Table 1c: Standard limit of salt

Remark	Salt (EC) Dsm^{-1}
Common	<1.00
Harmful to crop	1.01-2.00
Harmful to salt susceptible minerals	2.01-3.00
Dangerous to crop	>3.00

Data provided by Soil Survey and Soil Analysis Department, Nagpur District, Maharashtra, India

Manures

Organic manure was prepared using a mixture of protein rich materials including animal manures, fresh green grass, leaves, and shoots of leguminous plants or trees (*Cassia* species), and carbon-rich materials including wood chips, dry leaves, and grasses in a proportion of 60% protein and 40% carbonaceous. The heap was made by a layering method, of about 2 m wide at the base, 0.5 m high and 3 m long, comprised first stiff/hard layer of woody stems as a base, later the carbonaceous layer about 10 cm deep, alternating with the loose proteinaceous layer which was about 15 cm deep. The animal dung was made into slurry using cow urine and watered onto the carbon layer. Very little amount of hydrated lime and rock powder were sprinkled over the pile. Heap was turned regularly after about 6 weeks and brown, crumbly humus was ready in 3 months.[6] Non-organic fertilizer, *viz*., urea granules (N), superphosphate (P_2O_5), and potash (K_2O) per hectare were applied according to the treatment schedule.

Pesticides

Organic insecticide and fungicide

Fully dried *Azadirachta indica* L. (neem) seeds of about 500 g were pulverized and macerated for 24 h in 10 L of Milli Q (MQ) water (BioAGE Direct Ultra, Punjab, India). Filtrate was utilized as potent insecticide. Fresh *Allium sativum* L. (garlic) paste was prepared and about 250 g paste was fermented for about 15 days in 05 L of MQ water. The fermented filtrate was diluted again with 5 L of MQ water and sprinkled over organic crop as fungicide.[7]

Non-organic insecticide and fungicide

Monocrotophos 36% (Monocil, Insecticide India Ltd. India) as an insecticide and Zineb 75% W.P. (Indofil Z-78, Indofil

Industries Ltd, Mumbai, India) as a fungicide were purchased from the local market and utilized in a ratio of 3:2 in MQ water, respectively, as per product manual.[8]

Cultivation and harvesting

All the seeds were sown in their favorable season with the implementation of good agricultural practices by adopting the randomized block design in twelve replicates of each treatment in the year 2013. Two different treatments were utilized, organic, and non-organic (in terms of fertilizer and insecticide/fungicide). About 5 m^3/acre organic (biodynamic manure) was utilized for the organic crop. Non-organic manure (urea, superphosphate, and potash) was utilized in a ratio of 50:25:00, respectively.[8] Half of the N and entire P were applied at basal stare and the remaining of N was applied in two splits at vegetative and flowering stage. About 10 L/acre of each organic and non-organic pesticide were sprayed. Unripe fruits of organic and non-organic *M. charantia* (OMC and NMC) were harvested at different day intervals and on the 100^{th} day after germination whole climber was harvested.[9] The four different morpho-physiological traits (climber height [inches], secondary branches, number of flowers, and number of fruits) were observed till harvesting (pre-harvesting), and seven traits (climber height [inches], secondary branches, number of flowers, number of fruits, weight of fruits, roots length [inches], and secondary roots) were examined after harvesting (post-harvest: p.h.) using statistical package PAST (version 2.03). The plant was botanically authenticated from the Department of Botany, Rashtrasant Tukadoji Maharaj, Nagpur University, Nagpur. Voucher specimen (9787) has been deposited for future reference. The whole fruits were cut into small pieces and later converted to hard brittle masses by lyophilization (Lyodel-00-12, Chennai, India). The material was pulverized, again lyophilized and stored in air tight containers for further use.

Nutritional and Physic-chemical Analysis

Moisture content

Moisture content was measured using hot air oven (Bio Technics BT3-29, India) following official methods of Association of Official Analytical Chemists.[10] A vacuum desiccating chamber (containing silica gel with cobalt chloride) was used to dry the samples till constant weight. The results for moisture content were expressed as (g/100 g on dry weight basis-DW) using following formula:

$$\% \text{ Moisture} = 1 - (\text{Weight}_{\text{dry sample}}/\text{Weight}_{\text{wet sample}}) \times 100 \quad (1)$$

Lipid content

Determination of lipid content was performed by simple Soxhlation method till the decolorization of siphoning back.[11] Petroleum ether was used for the extraction, whereas percentage of lipid was obtained following the equation:

$$\% \text{ Lipid} = \text{Weight}_{(\text{extraction flask + extract})} - \text{Weight}_{(\text{extraction flask})}/\text{Weight}_{\text{sample}} \times 100 \quad (2)$$

Protein content

The total nitrogen content in the sample was determined as per Kjeldahl method using Kjeldahl distillation assembly.[12] A nitrogen-to-protein conversion factor of 6.25 was used for the determination of protein present in the samples.

Ash contents

A dry ashing method was used to determine the ash content.[10] The samples were incinerated in a muffle furnace (Yorco, YSPL-532 York, New Delhi, India) at 550°C. The remaining inorganic material was cooled, weighed and further used for the determination of acid insoluble ash.

Carbohydrate and caloric values

The total carbohydrate content (g/100 g) in the samples was calculated by difference method. The caloric value was calculated by sum of the percentages of proteins and carbohydrates multiplied by a factor of 4 (kcal/100 g) and total lipids multiplied by a factor of 9 (kcal/100 g).[13]

Vitamin C content

Vitamin C content was determined by 2, 6-dichlorophenol-1, 2-indophenol method.[14] Briefly, 2 g dried plant material was extracted with 4% oxalic acid and the volume was made up to 100 ml. It was centrifuged at 10,000 rpm for 10 min. The supernatant liquid (5 ml) was quickly titrated to the end-point (change from blue to a permanent pink) with the standardized dichlorophenol indophenol solution. The titrations were repeated in triplicates, and the blank was determined following the above procedure using 5 ml of oxalic acid instead of the supernatant. Ascorbic acid 100 ppm (5 ml) was used as standard. Ascorbic acid content was calculated using the formula:

$$\text{Ascorbic acid (g/100 g)} = (0.5 \text{ mg} \times \text{titer vol against test} \times 100 \text{ ml/titer vol. against std.} \times 5 \text{ ml} \times \text{weight of sample}) \times 100 \quad (3)$$

Total bitters

About 5 g coarse powder was refluxed with ethanol (95%) till the marc became completely tasteless. The mixture was filtered; filtrate was dried and dissolved in 60 ml of hot MQ water. The aqueous mixture was defatted by fractionation with 25, 20, and 15 ml of petroleum ether (60-80°C). Finally, aqueous portion was fractionated with 25, 20, and 15 ml of ethyl acetate. The ethyl acetate fractions were combined, dried, and weighed (total bitters were expressed as g/100 g).[15]

Antinutritional Analysis (Phytate and Oxalate Contents)

Phytate of each sample was determined according to the method described by Maga.[16] The titration method was used to determine the oxalate content according to the methods of day and underwood.[17]

Mineral Analysis

The total 12 minerals, i.e., Na, K, Ca, Mg, Fe, Zn, Cu, Mn, Pb, Cd, As, and Hg were determined with an inductively coupled plasma atomic emission spectroscopy (ICP-AES). About 0.5 g (dry mass) of plant sample was weighed into the digestion vessel. Then, 5 ml of concentrated HNO_3 and 1 ml of 30% H_2O_2 were added to each sample. Samples were allowed to digest overnight (16 h) in a fume hood at room temperature. After 16 h, the entire digest was filtered through a Whatman number 1 filter paper into 25 ml volumetric flasks and made up to the mark with MQ water.[18]

Working conditions: Instrument ICP-AES (ARCOS, Spectro, Germany). R.F. Generator: Maximum of 1.6 KW, 27.12 MHz. Plasma: Radial plasma having capability to analyze aqueous solutions with high dissolved solid content even up to 30% (w/w). Aqueous solutions can be acidic, basic, or neutral. Spectrometer: Wavelength Range: 130-770 nm, Resolution: Approximately 9 pico meters, having capability to scan full spectrum to have qualitative information about the content of the sample. Detector: Charge coupled devices. The results for mineral contents were expressed as mg/100 g DW.

Statistical Analysis

Statistical analysis was conducted using statistical package PAST (version 2.03) for morpho-physiological traits and GraphPad Prism version 5.02 (for Windows) for proximate, antinutritional, and mineral analysis. All the determinations were carried out in triplicate, and data were expressed as mean ± (n = 3) standard deviation.

RESULTS AND DISCUSSIONS

Morpho-physiological Characteristics and their Mean Performance

The mean performance and range (pre-harvest and post-harvest - p.h.) for 7 different morpho-physiological traits of 12 karela replicates (organically and non-organically grown) are given in Tables 2 and 3. All the traits including climber height (inches) [Figure 1] roots length (inches), number of secondary branches, number of secondary roots, number of flowers, and number of fruits were found to acquire higher mean values of 106.30, 8.15, 27, 16.17, 2.75, and 2.5 (p.h. 100th day), respectively, in OMC. Similarly in OMC, weight of individual fruit ranged

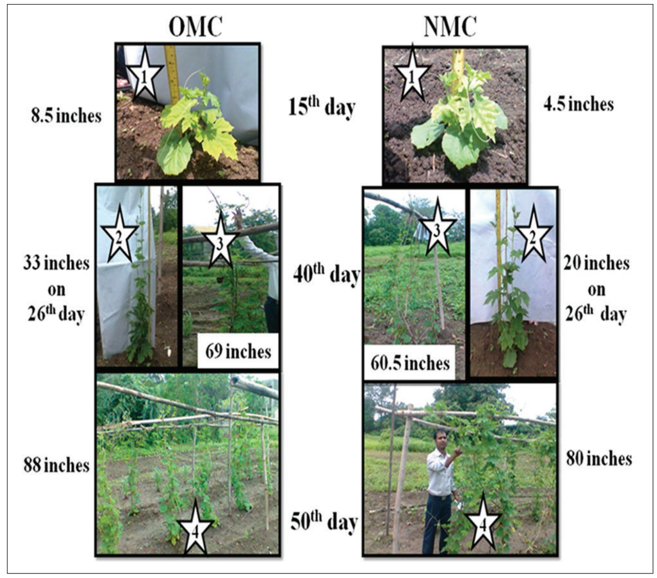

Figure 1: The performance of *Momordica charantia* climber in terms of trait (height)

from 0.00 to 23.52 g (100th day) with a mean value of 6.64, while in NMC it ranged from 0.00 to 26.30 g (100th day) with a mean value of 3.09 g. Among 12 karela replicates, under organic and non-organic conditions, the OMC showed 3 days early flowers initiation and exhibited higher mean performance in all the morpho-physiological traits except only less average yield of fruits (8847.66 g/12 replicates), while NMC given higher average yield of fruits (9838.26 g/12 replicates). OMC showed early germination, flowering buds, secondary branches, and sustain life which may be attributed to the presence of plenty of "beneficial soil microbes" in organic manure which helps in "soil regeneration" and "fertility improvement" and protect them from degradation while also promoting growth in plants. [19]

Nutritional and Physico-chemical Analysis

The dried whole fruit of OMC contained a higher content of protein, lipid, and crude fibers 14.67, 7.90, and 15.24% DW, respectively. The protein content of OMC and NMC was comparable to that of other leafy vegetables, where the protein content ranged from 8% to 30% of dry weight basis.[20] The caloric value (332.62 kcal/100 g DW) and vitamin C content (8.21% DW) were higher in OMC. Results are given in Table 4, indicating the enrichment of energy source and vitamin contents in the organic crop. The higher carbohydrate content in OMC (50.97% DW) was the highest calorie contributor as the total lipid and protein contents did not considerably affect the determination of energy produced, results have been given in Table 4. Vitamin C is an important factor in photosynthesis and is also considered as an enzyme cofactor (including synthesis of ethylene, gibberellins, and anthocyanins) and in control of cell growth.[21]

The higher total bitters were also recorded in OMC (1.58% DW) which may attribute to an improved and stronger nervous and digestive system, activate digestive hormones and have

Table 2: Range, mean, standard error, variance, and standard deviation for seven morpho-physiological traits (pre- and post-harvest) in 12 karela replicates under organic cultivation

Traits of OMC	Days after germination	Range		Mean	Standard error	Variance	Standard deviation
		Min	Max				
Pre-harvest							
Height (inches)	15th day	1.5	8.5	5.08	0.37	30.34	0.52
	20th day	4	24	15.13	1.32	37.58	1.87
	30th day	13	45	30.67	2.03	23.42	2.88
	40th day	30	69	59.38	2.04	12.33	2.89
Secondary branch	20th day	0	15	8.33	1.1	39.07	1.55
	30th day	8	22	17.58	0.98	27.37	1.39
	40th day	11	24	19.25	0.83	15.62	1.17
	50th day	12	30	22.58	1.61	22.75	2.28
Number of flowers	30th day	0	6	3.25	0.34	60.53	0.48
	40th day	0	8	4.58	0.65	58.46	0.92
	50th day	0	2	1	0.38	76.08	0.54
	60th day	0	5	1.91	0.34	81.28	0.48
	80th day	0	5	2.5	0.66	74.18	0.94
Number of fruits	30th day	0	2	0.75	0.23	116.24	0.33
	40th day	0	2	0.75	0.23	106.36	0.32
	50th day	0	3	1.66	0.3	132.61	0.42
	60th day	1	5	2.16	0.16	149.52	0.22
	80th day	1	7	3	0.45	199.57	0.64
Post-harvest							
Weight of fruits (g)	30th day	1.33	74.16	32.39	5.33	56.24	7.53
	40th day	6.6	135.72	36	2.79	29.72	3.95
	50th day	4.96	104.83	39.24	4.35	44.73	6.15
	60th day	4.28	101.44	41.19	4.61	88.6	6.52
	80th day	3.17	99.22	38.56	4.23	76.43	5.82
	100th day	0	23.52	6.64	4.1	112.5	5.23
Height (inches)	100th day	74	161	106.3	0.21	18.1	0.85
Secondary branch	100th day	15	40	27	1.89	22.93	2.68
Number of flowers	100th day	1	4	2.75	0.57	52.38	0.73
Number of fruits	100th day	1	8	2.5	0.36	94.59	0.51
Roots length (inches)	100th day	3.5	11	8.15	0.52	22.5	0.74
Secondary roots	100th day	14	18	16.17	1.37	29.57	1.94

where OMC: Organically cultivated *Momordica charantia*

a broad effect on the entire physiology, tone, and function of the whole body.[22] NMC showed the higher amount of total ash (9.08% DW) and water-soluble extractives (40.99% DW) which may be a primary indicator of high heavy metal content and other inorganic salts, shown in Table 4.

Antinutritional Analysis

Similarly, the antinutritional factors, *viz*., oxalate (12.83 g/100 g) and phytate (0.28 g/100 g) were found to be higher in NMC, results demonstrated in Table 4. Phytic acid strongly binds to metallic cations of Ca, Fe, K, Mg, Mn, and Zn making them insoluble and thus unavailable as nutritional factors.[23]

It is reported that organic acids and amino acids (such as citric acid, tartaric acid, oxalic acid, succinic acid, aspartic acid, and glutamic acid) excreted by the roots of plant formed soluble complexes with heavy metals and increased the mobility of heavy metals in soil.[24]

Table 3: Range, mean, standard error, variance, and standard deviation for seven morpho-physiological traits (pre- and post-harvest) in 12 karela replicates under non-organic cultivation

Traits of NMC	Days after germination	Range		Mean	Standard error	Variance	Standard deviation
		Min	Max				
Pre-harvest							
Height (inches)	15th day	1.5	4.5	3.37	0.08	13.45	0.11
	20th day	1.5	15	9.37	0.19	19.85	0.28
	30th day	16	40	29.63	0.18	11.59	0.25
	40th day	32	60.5	55.45	0.13	6.33	0.19
Secondary branch	20th day	0	10	4.58	0.25	36.3	0.35
	30th day	3	15	7.41	0.14	14.14	0.2
	40th day	8	28	17.66	0.1	8.04	0.14
	50th day	20	32	24.66	0.17	11.82	0.24
Number of flowers	30th day	0	2	0.66	0.1	25.84	0.15
	40th day	0	6	3.16	0.18	32.99	0.26
	50th day	0	4	2.5	0.14	35.7	0.2
	60th day	0	2	1	0.11	30.17	0.15
	80th day	0	8	3.75	0.19	38.93	0.28
Number of fruits	30th day	0	2	0.66	0.1	35.85	0.15
	40th day	0	2	0.75	0.1	33.7	0.14
	50th day	0	5	2.33	0.13	42.32	0.18
	60th day	1	5	2.16	8.37	32.2	0.11
	80th day	1	8	3.41	0.17	58.86	0.24
Post-harvest							
Weight of fruits (g)	30th day	6.01	57.53	25.46	0.67	36.43	0.94
	40th day	5.25	83.56	32.05	0.4	23.37	0.56
	50th day	1.97	123.71	36.67	0.65	79	0.93
	60th day	3.4	91.99	29.54	0.67	56.05	0.96
	80th day	2.39	88.77	26.34	0.72	62.3	0.85
	100th day	0	26.3	3.09	0.53	48.92	0.94
Height (inches)	100th day	61	190	97.58	0.51	17.9	0.72
Secondary branch	100th day	23	36	26.33	0.18	11.77	0.25
Number of flowers	100th day	1	7	2.66	0.17	37.89	0.34
Number of fruits	100th day	1	7	2	0.14	39.13	0.2
Roots length (inches)	100th day	6	10	8	9.55	11.35	0.13
Secondary roots	100th day	9	26	16	0.16	14.37	0.23

Where NMC: Non-organically cultivated *Momordica charantia*

Mineral Analysis

Plants are the first step of a metal's pathway from the soil to heterotrophic organisms such as animals and humans, so the macronutrient and micronutrient (trace elements and minerals) in their edible parts makes a major contribution to human intake.[25]

Organic fruits were found to contain higher contents of all the 8 minerals examined such as K, Ca, Mg, Fe, Na, Zn, Cu, and Mn (281.43, 192.28, 116.91, 21.96, 9.98, 5.991, 1.49, and 1.17 mg/100 g DW, respectively). Results are given in Table 5. The high content of potassium compared to sodium leads to a very low Na/K ratio, which is favorable from nutritional point of view, as diets with low Na/K ratio are associated with lower incidence of hypertension.[26] Followed by calcium, which was found to be the second most abundant mineral element in the OMC. Therefore, OMC can be considered as an appropriate dietary source of calcium to maintain the biological role of nerve transmission, muscle contraction, glandular secretion as well as mediating vascular contraction and vasodilation.[27]

Table 4: Nutritional, physico-chemical, and antinutritional contents of OMC and NMC

Analysis	OMC	NMC
Proximate analysis (g/100 g DW)		
Protein	14.67±1.57	13.44±2.18
Lipids	7.90±0.40	6.40±0.42
Carbohydrate	50.97±2.14	50.76±2.42
Moisture	5.11±0.19	6.99±0.42
Crude fiber	15.24±1.16	13.31±0.94
Energy (kcal/100 g)	332.62	314.40
Ash contents		
Total ash	6.09±1.87	9.08±1.12
Acid insoluble ash	1.02±0.05	1.89±0.16
Physico-chemical properties (g/100 g DW)		
Vitamin C	8.25±0.60	8.02±0.04
Total bitters	1.58±0.30	0.65±0.09
Water-soluble extractive value	36.16±0.81	40.99±0.10
Antinutritional contents (g/100 g DW)		
Oxalates	7.70±0.33	12.83±0.14
Phytates	0.18±0.07	0.28±0.11

Each value represents the mean±SD of three determinations (n=3) on dried weight of whole fruit (DW) basis. Where OMC: Organically cultivated *Momordica charantia* and NMC: Non-organically cultivated *Momordica charantia*

Table 5: Mineral Composition of OMC and NMC

Elements	OMC (mg/100 g)	NMC (mg/100 g)
Calcium	192.28±0.57	175.23±0.48
Sodium	9.98±0.11	7.72±0.04
Potassium	281.43±0.41	245.11±0.68
Magnesium	116.91±0.87	105.57±0.51
Iron	21.96±0.04	17.83±0.04
Zinc	5.99±0.05	4.58±0.34
Manganese	1.17±0.03	1.02±0.02
Copper	1.49±0.04	1.40±0.06
Lead	1.66±0.02	2.23±0.06
Cadmium	ND	0.15±0.01
Arsenic	ND	ND
Mercury	ND	ND

Each value represents the mean±SD of three determinations (n=3) on dried weight of whole fruit (DW) basis. Where OMC: Organically cultivated *Momordica charantia* and NMC: Non-organically cultivated *Momordica charantia,* ND means <0.01 ppm

Iron is an essential trace element and iron deficiency is a common nutritional problem affecting many people all over the world. Our body continually loses iron through everyday process such as urination, defecation, sweating, sloughing off skin cells, and bleeding (particularly menstrual cycle and pregnancy in women). To compensate for these losses and to maintain an adequate supply of iron, we should consume approximately 18 mg of iron daily.[28] A higher bioavailability of the dietary iron can be achieved by increasing the content of food components enhancing iron absorption (ascorbic acid) or by decreasing the content of inhibitors (e.g. phytates, oxalates, and tannins).[29] The optimum amount of iron observed in karela indicated that the plant could be a good source of dietary iron to overcome nutritional deficiency of iron if supplemented in the diet. Copper and zinc are the essential trace elements that are needed only in minute amounts by the human body for important biochemical functions. The levels of zinc and copper are closely interrelated. Zinc stimulates the synthesis of metallothionein, which has a higher affinity for copper and hinders copper systemic absorption within the intestinal cells.[30] Excessive ratio of zinc to copper (>16) from dietary sources causes imbalance in their bioavailability and has been linked to increased risk of cardiovascular disorders.[31] The recommended zinc/copper ratio in human tissues is four to six.[32,33] OMC with its zinc/copper ratio of four (4.02) compared to NMC (3.27), represents a potential food source to counter copper-zinc imbalances.

Dried whole fruits were also examined for the detection of toxic heavy metals such as Pb, Cd, As, and Hg. Heavy metals such as Cd and Pb are non-essential elements for plants. If higher amounts are accumulated in the plants, heavy metals will adversely affect the absorption and transport of essential elements, disturb the metabolism and have an impact on growth and reproduction.[34] A high level of Pb also causes inhibition of enzyme activities, water imbalance, alterations in membrane permeability and disturbs mineral nutrition.[35] Plants exposed to high levels of Cd causes reduction in photosynthesis, water uptake, and nutrient uptake.[36] OMC showed the presence of Pb only (1.66 mg/100 g DW) while NMC contained Pb and Cd (2.23 and 0.15 mg/100 g DW, respectively) that signifies the lower concentration of minerals in NMC, depicted in Table 5. This study is an attempt to set a milestone in justifying the importance of organic over non-organic medicinal plant species through the differences in their morpho-physiological traits, nutritional, antinutritional, and heavy metal contents. Conclusive evidences generated from this research study on *M. charantia,* proved the perception that organically grown foods or medicinal herbs are 'better for you' in terms of nourishment, sustainability, better quality standards, and safety measures.

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