Organic and Inorganic of 10 Varieties Vegetables and Fruits Commonly Consumed in Thailand: Comparison of Minerals, Polyphenol content, and Antioxidant activity

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ABSTRACT: At present the attention to plants (fruits and vegetables) rich in natural bioactive compounds is increasing due to their functional properties associated with prevention or reduction a number of risks of chronic non-communicable diseases. Currently, organic plants are very popular to consumers due to their absence of pesticide residues and good sources of bioactive compounds. However, there are a few reports comparing the amount of nutrient and bioactive compounds between organic and inorganic plants. Therefore, the objective in this study was to determine and compare minerals (magnesium, potassium, iron, zinc and copper), bioactive compounds; polyphenol, and antioxidant activity (Oxygen Radical Absorbance Capacity) between organic and inorganic plants of 5 varieties of vegetables (kale, cabbage, carrot, tomato and yardlong bean) and 5 varieties of fruits (pineapple, ripe papaya, rambutan, long-kong and watermelon). Results showed that the amounts of mineral contents (magnesium, iron, zinc and copper) were not significantly different between organic and inorganic fruits and vegetables. Except potassium contents in all 10 varieties of organic fruits and vegetables were significantly higher than those of inorganic plants, whereas other nutrients, particularly, polyphenol and antioxidant activity (Oxygen Radical Absorbance Capacity) in organic fruits and vegetables were slightly higher than those of inorganic plants.

Keyword: organic, inorganic fruits and vegetables, minerals, polyphenol

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INTRODUCTION

Currently, people are highly interested in improving their health, fruits and vegetables that are rich in natural antioxidants are receiving greater attention, since evidence shows that consuming such foods are associated with preventing or delaying the onset of non-communicable diseases (NCDs) and with maintaining a healthy weight (1). Several bioactive compounds found in fruits and vegetables, such as vitamin C, polyphenol, carotenoids, and flavonoids show a strong inverse correlation with many chronic diseases, including cancer, hypertension, diabetes, cardiovascular disease, and neurological disorders (2-4). Consumers, however, are also becoming more aware of the adverse health effects of toxic residues in fruits and vegetables that are used during their cultivation, such as chemical fertilizers, herbicides, and pesticides. Consequently, the demand for organic fruits and vegetables is increasing among consumers, health educators, farmers, and food retailers. Consumers, especially, believe that organically grown fruits and vegetables are free of pesticide residues and are of better quality, healthier, and more nutritious compared to conventionally grown produce.

It is hypothesized that since organic fruits and vegetables are grown without the use of insecticides or some chemical pesticides, the plants protect themselves against the environment by increasing their own protective or chemical substances in order to defend against free radical reactive oxygen species in the environment, ultra violet light, as well as insect pests, diseases, and bacteria that could damage or destroy cells (5, 6). A study by de Castro and others (2014) showed that plants grown in organic systems were more exposed to the environment and therefore needed to increase the amount of polyphenol and antioxidant capacity (7). Roghelia and Patel (2015) demonstrated that vegetables grown without fertilizer had higher amounts of flavonoids and total phenol compounds (6). However, conflicting evidence exists between studies. Some studies have found no significant differences in nutrient content and bioactive compound values between organically and conventionally grown fruits and vegetables, since nutrient quality and bioactive nutrient content can be affected by geographic location, local soil, climactic conditions, seasonality, and maturity at time of harvest, and post-harvest storage practices (8).

In Thailand, no data are available comparing nutrient content and bioactive compounds between organic and inorganic fruits and vegetables. Therefore, the aims of this study were to compare and determine the minerals, polyphenol, and antioxidant activity on fresh organic and inorganic vegetables and fruits.

MATERIALS AND METHODS

Ten varieties of organically and inorganically grown fruits and vegetables were selected based on common consumption in Thailand. Each sample variety weighed at least 3 kilograms and was collected during July 2016-July 2017. Three representative samples of inorganic vegetables and fruits were purchased from traditional distribution module trade centers in Thailand, locally known as Talaad Thai and Talaad Simummuang, as well as Ratchaburi province. Certified organic samples were obtained from the Health Society Company, which is an organic farm network that has received the certification standard for organic produce (IFOAM certified) and the participation guarantee system (PGS) mainly from Chachoengsao, Chiang Mai, Suphanburi, Chiang Rai, Chanthaburi, and Yasothon province.

Five varieties of vegetables (cabbage, *Brassica oleracea var.capitata*; carrot, *Daucus carota subsp. Sativus*; Kale, *Brassica albroglabra*; tomato, *Solanum lycopersicum*; yardlong bean, *Vigna unguiculata ssp. Sesquipedalis*) and five varieties of fruits (pineapple, *Ananas comosus*; papaya, *Carica papaya;* long-kong, *Lansium parasiticum*; rambutan, *Nephelium Lappaceum*; watermelon, *Citrullus lanatus,*) were selected for this study because these are normally consumed in Thailand.

Sample preparation

Upon arrival at the laboratory, three sets of the same variety of fruit or vegetable from the trade centers (Talaad Thai, Talaad Simummuang, Ratchaburi province) and from the Health Society Company were individually washed with tap water to eliminate any contaminants and rinsed again with deionized distilled water. The edible portion of each vegetable or fruit set was prepared and homogenized separately (Ace homogenizer, NISSEI, Ltd, Tokyo, Japan) in a dark room at 25°C. Approximately 300 g of each homogenized sample were pooled to obtain a single sample. Consequently, a total of three representative composite samples were obtained for each variety of vegetable and fruit. Individual samples from the three representative samples of the same variety (inorganic and certified organic) were then analyzed in duplicate. Moisture content was determined immediately after the samples were homogenized and pooled. The homogenized samples were divided into two portions and stored in acid-washed polyethylene bottles. One bottle was used to determine antioxidant content (total polyphenol and Oxygen Radical Absorbance Capacity activity). The second bottle was used for mineral analysis (magnesium, potassium, zinc, iron, and copper).

Determination of moisture and minerals content

Moisture was determined by drying in a hot air oven at 100 ± 5°C until constant weight according to Association of Analytical Communities (AOAC) method 950.46 (9). Mineral content was measured by digesting with wet ashing according to AOAC method 984.15 (9) and analyzed by inductively coupled plasma-optical emission spectrometer (ICP-OES, PerkinElmer Optima 4200 DV, Waltham, MA, USA).

Determination of total polyphenol content

Total polyphenol content was determined by the Folin-Ciocalteau assay (10). Briefly, 2 g of homogenized sample were extracted by constant shaking at room temperature with 20 ml of 50% dimethyformamide (Sigma-Aldrich, St, Louis, MO, USA) in 0.1 M acetate buffer for 16 h. After extraction, samples were centrifuged (20 min, 25°C 3000 rpm) and supernatants were collected. The supernatants were diluted to appropriate volume with deionized water. The diluted samples were added to 96-well, followed by 10% Folin–Ciocalteau (Merck, Darmstadt, Germany) and 0.5 M sodium hydroxide (Merck, Darmstadt, Germany) to each well and mixed. Absorbance was measured at 750 nm using automated microplate reader (TECAN Micro plate reader, Grodig, Austria) after standing for 15 min at 25°C. Gallic acid (Sigma–Aldrich, St. Louis, MO, USA) was used as the standard with concentrations ranging from 0.00-80.00 ppm. The total polyphenol content was reported in milligram Gallic acid equivalents per 100 g (mg GAE/100 g).

Determination of Oxygen Radical Absorbance Capacity (ORAC)

Antioxidant capacity was determined using the Oxygen Radical Absorbance Capacity method. This assay was followed using the method of Huang and others (2002) (11). The assay was performed using the Spectrofluorometer (Perkin-Elmer LS 55 Luminescence

Spectrofluorometer, Perkin Elmer, Waltham, Ma, USA) with an excitation wavelength of 493 nm and an emission wavelength of 515 nm. A 500 µl volume of blank (pH 7.2 buffer solution (Potassium 0.75 M and Sodium 0.75 M)), standard or extract, 3 ml of 500 nM fluorescein solution and 500 µl of 2,2'-Azobis [2-amidinopropane] dihydrochloride solution (AAPH), were directly placed in each tube and mixed well. The antioxidant capacity (ORAC) was calculated using a standard curve of Trolox (TE) and results were expressed as Trolox equivalents (TE) in µmol per 100g fresh weight (µmol TE/100g fresh weight). All assays were done in duplicate analysis for sample and quality control sample. It is generally recommended to use more than one method for determining antioxidant activity in food, since the antioxidants may respond in a different manner to different radical or oxidant sources. However, in the present study, antioxidant activity and polyphenol contents were determined through Oxygen Radical Absorbance Capacity and Folin-Ciocalteu methods, as they are the only two tools to obtain data for a comparison between both extraction methods.

Statistical analysis

Data were expressed as mean ± standard deviation of duplicated analysis. Non-parametric of Mann-Whitney U-test was applied to compare mean of nutrient content and bioactive compounds of fruit and vegetable as same variety. The Statistical Package for Social Science for Windows version 19 (IBM Corporation, New York, USA) was used to analyse the data. Statistical significance was determined at a level of $p \leq 0.05$.

RESULTS AND DISCUSSION

Moisture and Mineral Content

The moisture content of 10 varieties of vegetables and fruits were showed in Table 1. Moisture content of the same variety of fresh vegetables and fruits grown under different systems (organic and inorganic) showed no significant differences between systems (Table 1).

For mineral analysis, both organic and inorganic vegetables and fruits were good sources of macro-minerals (potassium and magnesium) but not micro minerals (iron, zinc, and copper) (Table 1). Organic Chinese kale, carrot, tomato, and yardlong bean had the highest potassium content among the vegetable samples. Among 5 different varieties of fruits, 4 varieties of organic fruits, namely, pineapple, papaya, rambutan, and long-kong were higher in potassium than their inorganic counterparts, except for organic watermelon. Among 5 different varieties of vegetables, potassium content was significantly higher in organic Chinese kale, carrot, and tomato as compared to inorganic vegetables of the same variety ($p \leq 0.05$). Comparison between inorganic vegetables in the present study with other publications found that potassium content in Chinese kale, carrot, tomato and yardlong bean was lower than those reported by United States Department of Agriculture (2015) and Indian food Composition Tables (2017) (12, 13). Moreover, no significant differences in other minerals (iron, zinc, copper, and magnesium) were observed between the two different growing systems. Whereas, in 2001 Worthington has reviewed from the 1240 publications indicated that plants were grown by organic system had higher minerals content than conventional ones but it was difficult to explain because several factors can impact on the amount of mineral contents in plants such as weather conditions, growing method, planting season, environment and post-harvest processing (14).

Polyphenol Content

Fruits and vegetables also supply phytochemicals that are beneficial in protecting the human body against damage induced by reactive species. They also act as anti-inflammatory agents through other protective mechanisms (15). Polyphenol compounds are a large group of phytochemicals that have a high ability to act as antioxidants by free radical scavenging and acting as metal ion chelating agents for preventing the progression of chronic diseases, such as cancer, arteriosclerosis, coronary heart disease (CVD), and hypertension (16, 17). In addition, Scalbert and others (2003) suggested that antioxidants, such as polyphenol, are the most fruitful and abundant bioactive compounds (18). The consumption of polyphenols may reach 1 g/day in the diet, approximately 10 times higher than vitamin C intake. The polyphenol content of organic and inorganic vegetables and fruits are shown in Table 2. The highest values of total polyphenol were inorganic and organic yardlong bean, followed by organic Chinese kale, and organic cabbage. The lowest values were in carrot and tomato for organic and inorganic cultivation systems. The highest values of total polyphenol in fruit samples were found in inorganic pineapple and long-kong, while the lowest was found in watermelon. In comparing polyphenol content between organic and inorganic carrots in the present study, it was found that polyphenol content was higher than reported by de Pereira and others (2016) who found polyphenol around 5.40 and 4.64 mg GAE/100g fresh weight for organic and inorganic carrots, respectively (19). Overall, among 5 varieties of vegetables and fruits, polyphenol content was slightly higher in organic samples than inorganic samples, although the differences were not significant. This finding agrees with a previous report by Faller and Fialho (2010) which suggested that organic plants induced more polyphenol synthesis and had the greatest accumulation of polyphenol in plant tissues (20). Winter and Davis (2006) suggested that organic plants could result in higher polyphenol because the use of synthetic fertilizers in the absence of synthetic pesticides could result in higher exposure of the plant to stressful situations thus leading to an enhancement of natural defence substances, such as higher phenolic compounds and higher antioxidant capacity (21).

Antioxidant activity (ORAC) content

Antioxidants neutralize free radical mechanisms and act by preventing them from causing damage to cells. ORAC assay is a proven method to determine the antioxidant capacity. For ten varieties of selected vegetables and fruits, the results of an antioxidant activity analysis determined by the ORAC method showed inconsistencies in the ORAC values. Some types of vegetables that were cultivated by the organic system showed a significantly higher activity than those of inorganic cultivation, particularly organic cabbage and organic tomato, respectively, ($p \leq 0.05$) whereas other types showed lower activity (Table 2). For 5 varieties of fruits, the results of ORAC activity showed no significant difference between the different growing systems. However, at least three organic varieties of selected fruits in this study, namely, organic papaya, rambutan, and long-kong, showed higher ORAC activity than inorganic ones, whereas activity was higher in inorganic pineapple and watermelon. Comparison of antioxidant capacity between the two different cultivars showed that the antioxidant capacity in the samples was not significantly different ($p \leq 0.05$). A comparison of the ORAC activity value of inorganic fruits and vegetables in this study and that by the USDA (2016) showed that ORAC activity values of inorganic Chinese kale, cabbage, carrot, tomato, pineapple, papaya, and watermelon in the USDA database were reported to be lower than those of the present study (Table 2) (12). Unfortunately, no data on ORAC activity values of organic fruits and vegetables have been reported or available to compare with the present study.

Table 1 Moisture and mineral contents of organic and inorganic vegetables and fruits per 100 g of wet weight[1]

English name	Moisture (g)	Fe (mg)	Zn (mg)	Cu (mg)	Mg (mg)	K (mg)
Vegetables						
Chinese kale (organic)	88.87 ± 2.74[a]	0.55 ± 0.18[a]	0.34 ± 0.10[a]	0.11 ± 0.04[a]	26.19 ± 4.07[a]	389.27 ± 24.78[a]
Chinese kale (inorganic)	92.20 ± 1.25[a]	0.46 ± 0.04[a]	0.30 ± 0.11[a]	0.11 ± 0.04[a]	28.03 ± 2.86[a]	326.02 ± 24.31[b]
Cabbage (organic)	94.22 ± 1.88[a]	0.44 ± 0.05[a]	0.27 ± 0.01[a]	0.01 ± 0.00[a]	13.94 ± 0.22[a]	161.22 ± 5.94[a]
Cabbage (inorganic)	92.84 ± 0.62[a]	0.31 ± 0.05[b]	0.19 ± 0.01[b]	0.01 ± 0.00[a]	10.44 ± 0.33[a]	202.14 ± 34.79[a]
Carrot (organic)	90.33 ± 2.17[a]	0.19 ± 0.02[a]	0.22 ± 0.03[a]	0.05 ± 0.01[a]	9.77 ± 0.65[a]	309.75 ± 56.39[a]
Carrot (inorganic)	91.50 ± 0.84[a]	0.16 ± 0.02[b]	0.11 ± 0.02[b]	0.04 ± 0.004[a]	6.28 ± 0.26[b]	163.75 ± 21.94[b]
Tomato (organic)	93.95 ±0.19[a]	0.18 ± 0.01[a]	0.03 ± 0.00[a]	0.01 ± 0.01[a]	7.85 ± 0.09[a]	208.99 ± 9.00[a]
Tomato (inorganic)	93.68 ± 0.40[a]	0.21 ± 0.06[a]	0.08 ± 0.01[b]	0.17 ± 0.023[a]	7.31 ± 0.30[a]	154.53 ± 9.69[b]
Yardlong bean (organic)	91.55 ± 2.15[a]	0.49 ± 0.05[a]	0.42 ± 0.08[a]	0.10 ± 0.01[a]	24.02 ± 0.35[a]	223.57 ± 48.43[a]
Yardlong bean (inorganic)	90.31 ± 0.58[a]	0.55 ± 0.02[a]	0.38 ± 0.06[a]	0.08 ± 0.02[a]	25.37 ± 0.82[a]	188.72 ± 10.94[a]
Fruits						
Papaya (organic)	87.95 ± 0.84[a]	0.17 ± 0.05[a]	0.04 ± 0.01[a]	ND	8.17 ± 2.34[a]	202.73 ± 25.87[a]
Papaya (inorganic)	87.93 ± 0.51[a]	0.17 ± 0.03[a]	0.04 ± 0.02[a]	ND	7.92 ± 0.58[a]	161.57 ± 20.64[a]
Pineapple (organic)	84.81 ± 7.20[a]	0.20 ± 0.07[a]	0.10 ± 0.03[a]	0.05 ± 0.00[a]	16.00 ± 1.86[a]	208.27 ± 20.22[a]
Pineapple (inorganic)	84.08 ± 3.99[a]	0.16 ± 0.02[a]	0.14 ± 0.00[b]	0.05 ± 0.00[a]	20.22 ± 4.35[a]	167.02 ± 12.34[a]
Rambutan (organic)	79.28 ± 1.42[a]	0.25 ± 0.02[a]	0.52 ± 0.02[a]	0.40 ± 0.05[a]	14.31 ± 0.60[a]	121.67 ± 6.04[a]
Rambutan (inorganic)	82.01 ± 2.07[a]	0.26 ± 0.03[a]	0.43 ± 0.22[a]	0.33 ± 0.05[a]	13.81 ± 2.71[a]	83.75 ± 33.27[a]

[1]Data are showed as mean ± SD of each mineral contents in edible portion of each fresh organic and inorganic vegetables and fruits derived from duplicate analysis (n=6). Mean values within the same column and variety with different superscript letters show significant differences between organic and inorganic growing systems at $p \leq 0.05$, by independent-samples Mann-Whitney U-test.

Table 1 Continued (per 100g fresh weight)

English name	Moisture (g)	Fe (mg)	Zn (mg)	Cu (mg)	Mg (mg)	K (mg)
Fruits						
Long-kong (organic)	81.38 ± 0.41^{a}	0.22 ± 0.04^{a}	0.14 ± 0.00^{a}	0.07 ± 0.01^{a}	12.57 ± 0.74^{a}	271.80 ± 8.80^{a}
Long-kong (inorganic)	81.56 ± 0.49^{a}	0.19 ± 0.01^{a}	0.12 ± 0.01^{a}	0.09 ± 0.01^{a}	13.36 ± 0.36^{a}	255.51 ± 54.10^{a}
Watermelon (organic)	91.12 ± 0.70^{a}	0.13 ± 0.01^{a}	0.07 ± 0.01^{a}	0.07 ± 0.00^{a}	4.60 ± 0.41^{a}	67.23 ± 3.72^{a}
Watermelon (inorganic)	91.04 ± 0.32^{a}	0.14 ± 0.04^{a}	0.06 ± 0.01^{a}	0.07 ± 0.01^{a}	7.15 ± 2.21^{a}	112.19 ± 16.49^{b}

[1]Data are showed as mean ± SD of each mineral contents in edible portion of each fresh organic and inorganic vegetables and fruits derived from duplicate analysis (n=6). Mean values within the same column and variety with different superscript letters show significant differences between organic and inorganic growing systems at $p \leq 0.05$, by independent-samples Mann-Whitney U-test.

Table 2 Antioxidant contents of organic and inorganic vegetables and fruits per 100 g of wet weight[1]

English name	Total polyphenol (mg GAE)	Antioxidant activity ORAC (µmoles TE)
Vegetables		
Chinese kale (organic)	90.81 ± 13.84[a]	2523.39 ± 133.14[a]
Chinese kale (inorganic)	62.83 ± 9.96[b]	2598.19 ± 133.14[a]
Cabbage (organic)	87.45 ± 1.33[a]	2638.33 ± 107.88[a]
Cabbage (inorganic)	33.12 ± 4.45[a]	584.88 ± 11.65[b]
Carrot (organic)	18.95 ± 0.87[a]	443.59 ± 18.88[a]
Carrot (inorganic)	16.18 ± 0.94[a]	531.48 ± 17.83[a]
Tomato (organic)	15.60 ± 0.12[a]	2600.80 ± 70.11[a]
Tomato (inorganic)	16.10 ± 5.22[a]	1482.65 ± 73.47[b]
Yardlong bean (organic)	138.30 ± 7.39[a]	3762.78 ± 130.67[a]
Yardlong bean (inorganic)	167.18 ± 7.27[a]	3614.53 ± 663.11[a]
Fruits		
Papaya (organic)	42.55 ± 1.03[a]	1106.73 ± 62.22[a]
Papaya (inorganic)	47.77 ± 2.15[a]	584.88 ± 11.65[a]
Pineapple (organic)	52.23 ± 4.53[a]	757.96 ± 42.82[a]
Pineapple (inorganic)	79.20 ± 10.74[a]	1060.06 ± 280.34[a]
Rambutan (organic)	44.10 ± 1.85[a]	518.80 ± 22.56[a]
Rambutan (inorganic)	40.85 ± 5.77[a]	415.99 ± 54.72[a]
Long-kong (organic)	64.45 ± 1.91[a]	582.74 ± 11.24[a]
Long-kong (inorganic)	59.43 ± 9.26[a]	571.56 ± 80.21[a]
Watermelon (organic)	15.57 ± 4.39[a]	197.11 ± 15.52[a]
Watermelon (inorganic)	15.57 ± 1.79[a]	244.58 ± 5.87[a]

[1]Data are showed as mean ± SD of total polyphenol and antioxidant activity in edible portion of each fresh organic and inorganic vegetables and fruits derived from duplicate analysis (n=6). Mean values within the same column and variety with different superscript letters show significant differences between organic and inorganic growing systems at $p \leq 0.05$, by independent-samples

CONCLUSIONS

It was found that overall there was almost no significant difference in mineral content (both in micro and macro elements) between fruit and vegetable samples grown in organic or inorganic systems, except for potassium content in organic Chinese kale, carrot and tomato which were higher than those of inorganic ones. For antioxidant contents, polyphenol, and Oxygen Radical Absorbance Capacity in most of fruits and vegetables in this study showed no significant differences between the two different growing systems. Nevertheless, the results of this study may be used as a guideline for purchasing organic vegetables and fruits by consumers and for generating a new database on organic vegetables and fruits for inclusion in the Thai food database.

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