CHAPTER

5

From a Perspective of Nutrition: Importance of Organic Foods over Conventional Counterparts

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OUTLINE

1 INTRODUCTION

The production of organic foods, one of the most important branches of ecological agriculture, has developed rapidly all over the world. In addition to paying attention to sustainable organic production modes and protection of the environment, people have a strong interest in the quality of organic food. Focusing on the nutrition and safety differences of organic and conventional food, a wide range of research in the world has compared conventional and

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organic agricultural systems. The field of food quality has drawn much attention regarding differences between conventional and organic foods.

This chapter aims at assessing past research that focuses on the comparison of the nutrients and contaminants present between organically and conventionally produced agricultural foods.

2 BASIC NUTRITIONAL CONTENTS

2.1 Macronutrients

2.1.1 Fat and Fatty Acid

Many consumers choose organic foods because they are supposed to be more nutritious than conventional counterparts in the market.

Moreover, some studies have found that organic and conventional foods share some differences in fat content. Dalziel et al. (2015) reported that organic chicken meat had a lower content of 18:3 *n*-3, cis-monounsaturated fatty acids and a higher content of docosahexaenoic acid than conventional chicken meat. However, generally speaking, the difference between conventional and organic poultry regarding fat level is negligible. No evidence suggests that the fat profile of organic chicken is healthier than its conventional counterpart (Table 1).

Samman et al. (2009) reported that egg weight and albumen were similar between conventional and organic eggs. Meanwhile, significant variation was displayed between conventional and organic eggs regarding the ratio of yolk and yolk fat. Little difference was reported in the composition of fatty acid for organic and conventional eggs. However, organic egg yolk did show higher ratio in stearic as well as palmitic acids compared with conventional yolk ($P < 0.05$). No significant difference ($P > 0.05$) was observed for polyunsaturated or monounsaturated fatty acid contents (Tables 2 and 3).

TABLE 1 Contents of Fat and Fatty Acid in Conventional (C) or Organic (O) Ready-To-Eat Chicken (Shown in Least Square Means; mg/100 g Ready-to-Eat Chicken) (Dalziel et al., 2015)

	Breast meat (With Skin)		Leg meat (With Skin)	
Class of Fat and Fatty Acid	**C**	**O**	**C**	**O**
Total fat	5.6[bc]	4.9[cd]	13.8[a]	11.9[a]
14:0	25.9[b]	23.5[bc]	55.6[a]	59.7[a]
16:0	1201[b]	1070[bc]	2541[a]	2478[a]
16:1 cis-9	246[c]	176[cd]	552[a]	486[ab]
18:0	350[b]	363[b]	716[a]	790[a]
18:1 cis-9	2071[c]	1412[d]	4518[a]	3535[b]
18:2 cis-9,12 (*n*-6)	815[b]	910[b]	1975[a]	2415[a]
18:3 cis-6,9,12 (*n*-6)	5.0[b]	4.4[b]	12.1[a]	12.5[a]
18:3 cis-9,12,15 (*n*-3)	123[c]	76.8[c]	344[a]	230[b]
20:0	1.8[b]	2.8[b]	5.7[ab]	10.0[a]

TABLE 1 Contents of Fat and Fatty Acid in Conventional (C) or Organic (O) Ready-To-Eat Chicken (Shown in Least Square Means; mg/100 g Ready-to-Eat Chicken) (Dalziel et al., 2015)—cont'd

	Breast meat (With Skin)		Leg meat (With Skin)	
Class of Fat and Fatty Acid	**C**	**O**	**C**	**O**
20:1 cis-8	2.4[a]	1.9[a]	3.0[a]	4.4[a]
20:1 cis-11	5.6	5.4	4.7	11.5
20:2 cis-11,14 (*n*-6)	14.6[b]	13.2[bc]	21.2[a]	21.9[a]
20:3 cis-8,11,14 (*n*-6)	15.7[abc]	14.0[bc]	21.5[a]	19.8[ab]
20:4 cis-5,8,11,14 (*n*-6)	49.1[c]	70.8[bc]	87.3[ab]	105.6[a]
22:0	3.4[abc]	1.7[c]	5.5[ab]	5.9[a]
22:1 cis-13	2.5	1.0	4.7	6.2
22:2 cis-13,16 (*n*-6)	0.91	1.3	1.8	1.1
22:4 cis-7,10,13,16 (*n*-6)	11.2[b]	12.5[b]	18.9[a]	19.3[a]
EPA (*n*-3)[1]	9.0	10.6	12.1	18.9
DPA (*n*-3)[2]	17.1[b]	20.4[ab]	28.6[ab]	31.8[a]
DHA (*n*-3)[3]	12.2[b]	24.5[ab]	14.4[ab]	37.5[a]
24:0	2.6	1.8	5.7	2.1
24:1 cis-15	1.5	1.1	1.3	1.6
Total SFA[4]	1582[b]	1461[bc]	3323[a]	3343[a]
Total cis-MUFA[5]	2501[c]	1722[cd]	5439[a]	4325[ab]
Total cis-PUFA[6]	1074[b]	1159[bc]	2538[a]	2915[a]
Total *n*-6 PUFA	911[b]	1026[b]	2138[a]	2595[a]
Total *n*-3 PUFA	162[c]	132[cd]	399[a]	318[ab]
EPA + DHA	21.2	35.0	26.5	56.4
EPA + DPA + DHA	38.3[b]	55.4[ab]	55.2[ab]	88.2[a]

Numbers sharing same superscript within one row are meant to be significantly different ($P < 0.05$).
[1]EPA: 5,8,11,14,17-eicosapentaenoic acid (20:5, n-3); [2]DPA: 7,10,13,16,19-docosapentaenoic acid (22:5, n-3); [3]DHA: 4,7,10,13,16,19-docosahexaenoic acid (22:6 n-3); [4]SFA: saturated fatty acids[5]; MUFA, monounsaturated fatty acids; [6]PUFA, polyunsaturated fatty acids. (Reprinted with permission.)

TABLE 2 Components of Conventional and Organic Eggs (Samman et al., 2009)

Production Type	Egg Weight (g)	Yolk (g)	Albumen (g)	Yolk Fat (g/100 g)[1]
Conventional	61.70±3.70[a]	16.10±1.80[a]	38.3±3.58[a]	4.43±0.55[a]
Organic	59.62±4.17[a]	15.87±1.95[b]	37.3±2.61[a]	4.45±0.71[b]

Numbers sharing same superscript within one column are meant to be significantly different ($P<0.05$).
[1]Data for egg yolk fat are shown as means of conventional (n=48) and organic (n=36) samples. (Reprinted with permission.)

TABLE 3 Composition of Conventional and Organic Egg Fatty Acids (Samman et al., 2009)

Fatty Acid Class	Content of Fatty Acid (%)	
	Conventional	Organic
C14:0	0.36 ± 0.06^{a}	0.35 ± 0.04^{b}
C16:0	25.1 ± 1.07^{a}	25.5 ± 0.94^{a}
C16:1 (n-7)	3.23 ± 0.61	3.03 ± 0.77
C18:0	8.37 ± 0.59^{a}	8.77 ± 0.69^{a}
C18:1 (n-9)	46.7 ± 3.02	46.0 ± 3.19
C18:2 (n-6)	13.1 ± 3.14	13.1 ± 2.24
C18:3 (n-3)	0.51 ± 0.20^{a}	0.50 ± 0.15^{b}
C20:4 (n-6)	1.83 ± 0.16^{a}	1.88 ± 0.14^{b}
C22:6 (n-3)	0.85 ± 0.16^{a}	0.84 ± 0.17^{b}
Total saturated	33.8 ± 1.20^{a}	34.6 ± 1.10^{a}
Total monounsaturated	50.0 ± 3.35	49.0 ± 3.12
Total polyunsaturated	16.3 ± 3.50^{a}	16.4 ± 2.56^{b}
Total n-6	15.0 ± 3.23	15.0 ± 2.30
Total n-3	1.36 ± 0.33^{a}	1.34 ± 0.30^{b}

Numbers sharing same superscript within the same column have no significant difference ($P < 0.05$).
(Reprinted with permission.)

Högberg et al. (2003) reported that PUFA n-3 is capable of regulating the balance of energy by promoting thermogenesis, thus directing fatty acids toward fatty acid (FA) oxidation. The ratio of n-6/n-3 was quite high in both polar and neutral lipids from organic pig muscle. The organic feed resulted in higher concentration of PUFA n-6 in polar lipids of muscle together with higher n-6/n-3 ratio. The FA composition of the intramuscular porcine fats was proven to be influenced by organic feed composition (Table 4).

Letaief et al. (2016) reported that the system of agriculture had significant influence on the FA composition of juice ($P < 0.05$). Fruits produced on organic farms have higher concentrations of total FAs (Table 5). Florence et al. (2016) reported that, compared with organic milk, conventional milk contains a higher level of long chain FAs (C16:0-C18:3) and saturated FAs. Inversely, monounsaturated FAs, polyunsaturated FAs, and medium chain FAs (C8:0 -C15:0) were found in higher content in organic milk compared with their conventional counterparts (Table 6).

2.1.2 Carbohydrates

Past research has proven that differences in carbohydrates of organically and conventionally grown foods are inconsistent. Carillo et al. (2011) reported that, compared with organic potatoes, total carbohydrate and starch content were much higher in conventional potatoes ($P < 0.05$). One possible reason is the usually slow-released way of providing fertilizers for organic potatoes, thus limiting carbohydrate and starch synthesis (Table 7).

TABLE 4 Fatty Acid (FA) Composition (% Least Squares Mean) of Neutral and Polar Lipids from Conventional and Organic Pig Muscle (Högberg et al., 2003)

	Neutral Lipid		Polar Lipid	
Class of Fatty Acid	**Conventional**	**Organic**	**Conventional**	**Organic**
SAFA[1]	37.2	37.8	26.3	25.5
MUFA[2]	51.1	51.2	13.9	11.0
HUFA[3]	1.33	1.27	18.8	19.3
PUFA[4]	11.0	10.2	47.6	49.5
PUFA *n*-6	9.58	9.24	42.1	45.0
PUFA *n*-3	1.39	0.98	5.55	4.51
Trans[5]	0.72	0.62	0.62	0.63
PUFA *n*-6/ PUFA *n*-3	6.93	9.35	7.64	10.1

[1]SAFA, saturated FAs; [2]MUFA, monounsaturated FAs; [3]HUFA, highly polyunsaturated FAs (18 carbon atoms or more, except for 18:2 n-6 and 18:3 n-3); [4]PUFA, polyunsaturated FAs; [5]16:1 9 trans, 18:2 (9,12 trans), 18:1 trans. (Reprinted with permission.)

TABLE 5 Effect of System of Agriculture on the Composition of Fatty Acid of Maltaise Demi-Sanguine Juice (Letaief et al., 2016)

	Content of Fatty Acid (μg/mL)	
Fatty Acid Class	**Conventional**	**Organic**
C14:0	0.67	0.24
C16:0	9.47	23.5*
C16:1	1.82	3.86*
C18:0	1.25	1.95*
C18:1	12.0	31.4*
C18:2	15.5	49.6*
C18:3	11.8	23.4*
C18:4	0.73	1.27*
C19:0	1.04	1.01
C20:0	0.83	0.47
C20:1	1.14	0.82
C22:0	0.89	0.50*
C22:1	0.89	0.90
Saturated fatty acids	14.16	27.72*
Monounsaturated fatty acids	15.89	36.97*
Polyunsaturated fatty acids	28.02	74.36*
Total fatty acids	58.1	136.0*

* Values are significantly ($P < 0.05$) different in the same row. (Reprinted with permission.)

TABLE 6 Content of Fatty Acids in Organic and Conventional Milk Bases (Florence et al., 2016)

Fatty Acid Class	Relative Content of Fatty Acid (%)	
	Conventional	Organic
Short chain fatty acids (C4:0 to C6:0)	1.19±0.08	1.29±0.05
Medium chain fatty acids(C8:0 to C15:0)	18.81±0.11	19.69±0.09*
Long chain fatty acids (C16:0 to C18:3)	80.00±0.10*	79.02±0.12
Saturated fatty acids	70.31±0.10*	67.80±0.12
Monounsaturated fatty acids	27.49±0.09	29.77±0.12*
Polyunsaturated fatty acids	2.20±0.08	2.43±0.03*

* *Values are significantly different* ($P<0.05$) *in the same row. (Reprinted with permission.)*

TABLE 7 Composition of Raw Conventional and Organic Potato (Carillo et al., 2011)

Class	Content (g/100 g)	
	Conventional	Organic
Total carbohydrates	88.0±4.7*	77.8±3.0
Starch	81.8±4.9*	72.1±3.3
Sucrose	2.3±0.3	2.6±0.6
Glucose	2.2±0.2	1.3±0.8
Fructose	1.5±0.1	1.8±0.6
Lipids	0.3±0.0*	0.2±0.0
Total proteins	4.7±0.6	7.0±0.9*

* *Values are significantly different* ($P<0.05$) *in the same row. (Reprinted with permission.)*

According to Nunes-Damaceno et al. (2013), conventional kiwis showed a higher content of sugars than organic kiwis ($P < 0.05$). Thus, conventional kiwis were larger in size and weight, and had a sweeter taste than organic kiwis (Table 8).

Lombardo, Pandino, and Mauromicale reported that "early" potato tubers contained more dry matter in ORG-grown (grown with organic practice) tubers than in CONV-grown (grown with conventional practice) ones. "Early" potato ORG-grown tubers also contained more starch and total phenolics compared with CONV-grown tubers. In contrast, ORG-grown tubers contained less amounts of total soluble sugars, ascorbic acid, and nitrate than CONV-grown ones (Table 9).

Gąstoł et al. (2011) reported that higher total sugars were noted for organic than conventional beetroot (8.4% versus 5.9%). As seen in Table 10, no significant difference was observed for total sugar content for the other fruit or vegetables tested.

In addition, there are also some studies comparing the quality of organic and conventional crops. No significant correlations with starch content were found between potatoes grown in organic and conventional fields (Skrabule et al., 2013).

TABLE 8 Physicochemical Parameters of Conventional and Organic Kiwis (Nunes-Damaceno et al., 2013)

Property	Conventional	Organic
Sugars (g/100 g)		
Fructose	4.36±0.19	3.64±0.27*
Glucose	4.60±0.29	3.83± 0.20*
Saccharose	0.89±0.20	0.91±0.06
Organic acids (mg/100 g)		
Oxalic	23.00±9.59	25.68±7.13
Quinic	849.05±118.11	877.10±46.7
Malic	244.33±78.20	244.11± 35.90
Citric	1053.19±39.87	1151.78±47.46*
Titratable acidity (as % citric acid)	1.41±0.06	1.43±0.05
Phenols (mg tannic acid/100 g)	4.65± 0.34	4.40±0.27
Vitamin C (mg/100 g)	74.14±7.75	74.28±3.82

* *Values are significantly different* ($P < 0.05$) *in the same row. (Reprinted with permission.)*

TABLE 9 Physicochemical Parameters of Conventional and Organic "Early" Potato Tuber (Lombardo et al., 2012)

Property	Conventional	Organic
Dry matter (DM, %)	20.3±1.2[a]	22.2±1.1[b]
Ash (g/100 g)	4.6±0.3[a]	4.2±0.1[b]
Total soluble sugars (g/100 g)	2.5±0.2[a]	1.9±0.1[b]
Glucose (g/100 g)	0.59±0.04[a]	0.42±0.03[b]
Fructose (g/100 g)	0.24±0.02[a]	0.18±0.01[b]
Sucrose (g/100 g)	1.70±0.13[a]	1.26±0.10[b]
Starch (g/100 g)	63.2±3.2[a]	66.9±5.4[b]

In each row, different letters indicate significant differences ($P < 0.05$). (Reprinted with permission.)

2.1.3 Proteins

Lombardo, Pandino, and Mauromicale reported the protein content of organically and conventionally grown tubers. Results showed the total protein (g/100 g) in organic and conventional tubers was 9.3±0.5 and 9.3±0.7, respectively, and there was no significant difference (Lombardo et al., 2012).

Gąstoł et al. (2011) reported that conventional beetroot juice had a significantly higher protein-N level (0.21%) than organic juice (0.162%). As seen in Table 11, no significant difference in protein-N level was reported for the other fruits or vegetables tested.

TABLE 10 Total Sugar Content of Juices Made from Organically/Conventionally Produced Vegetables and Fruit

	Total Sugars (%)	
Species	**Conventional**	**Organic**
Apple	9.0	7.9
Pear	6.7	6.9
Blackcurrant	7.5	7.7
Carrot	7.1	5.6
Beetroot	5.9	8.4
Celery	0.6	1.3

TABLE 11 Protein Nitrogen Content of Juices Made from Organically and Conventionally Produced Fruits and Vegetables

	Protein-N (%)	
Species	**Conventional**	**Organic**
Apple	0.03	0.02
Pear	0.03	0.04
Blackcurrant	0.05	0.05
Carrot	0.12	0.09
Beetroot	0.21	0.16
Celery	0.15	0.19

Data were extracted from Gąstoł, M., Domagała-Świątkiewicz, I., Krośniak, M., 2011. Organic versus conventional—a comparative study on quality and nutritional value of fruit and vegetable juices. Biol. Agri. Horticult., 27 (3–4), 310–319.

One research group studied the protein composition of milk produced in both conventional and organic pastures in Poland, comparatively. The results they collected showed the farming system had no significant effect in protein concentrations of milk, although they did notice that a significant difference existed between organic and conventional milk regarding the composition of protein fraction during the late pasturing seasons. Protein in cow milk depends on many factors including season of the year, feeding levels, the breed and diet habit of the cattle, their health conditions, stage of lactation, and specific genetic characters (Kuczyńska et al., 2012).

A 21-year field experiment focusing on conventional and organic wheat qualities also showed that neither amino acid composition nor protein content was affected by the farming systems (Mäder et al., 2007).

Although most studies did not report significant differences in the content of protein in conventional and organic foods, there are exceptions to the results. Kaur et al. reported that protein content of rice flour from organic farms was significantly lower ($P < 0.05$) compared to their counterparts harvested from conventional farms (Kaur et al., 2015).

2.2 Micronutrients

2.2.1 Minerals

There are some studies giving scientific evidence that organic foods have higher levels of trace metals, which are beneficial for human beings compared with their conventional counterparts, in general. Moreover, they also showed a lower level of heavy metals, which might potentially cause adverse effects to our health. Küçükyılmaz et al. (2012) reported that the different breeding systems for hens of organic and conventional farms could significantly affect the phosphorous and zinc concentration of the eggs ($P < 0.01$). The phosphorous and zinc concentration of the egg was lower in conventional eggs compared to organic eggs. However, no significant difference was observed for ash content or the concentration of calcium, magnesium, iron, and copper contents between conventional and organic eggs ($P > 0.05$). Generally speaking, part of these scientific reports provided evidence that organic eggs were healthier and could provide more nutrition for consumers compared with their conventional counterparts (Table 12).

Ryan, Derrick, and Dann reported that only slight variations were observed for grains regarding the concentration of minerals including potassium, magnesium, nitrogen, calcium, sulfur, and iron. Also, organic grains displayed higher levels of copper and zinc and lower levels of phosphorous and manganese compared with their conventional counterparts. As seen in Table 13, despite all the predictions, organic grains did not show significantly higher levels of minerals compared with their conventional counterparts (Ryan et al., 2004).

Giannenas et al. (2009) reported that, in egg yolks, selenium concentration was much lower in conventional eggs compared to their organic counterparts. However, zinc contents of organic eggs were significantly lower compared with the conventional counterparts. No significant difference was observed regarding manganese, cobalt, copper, molybdenum, vanadium, nickel, titanium, arsenic, and chromium concentrations in egg yolks of organic and conventional eggs. As for the egg white part, the concentration of trace elements displayed no significant difference between conventional and organic eggs (Table 14).

However, Kristensen et al. (2008) reported that no proven trend was observed for the differences in the content of elements of food products produced organically or conventionally. Actually, the differences caused by the year of harvest were shown to be more obvious than those caused by different cultivation systems. Therefore, this study stood against the theory that organic food products contain higher level of trace elements compared with their conventional counterparts (Table 15).

TABLE 12 Mineral Concentration of Organic and Conventional Eggs Based on their Edible Parts (Dry Weight Basis) (Küçükyılmaz et al., 2012)

Minerals (mg/kg)	Conventional	Organic
Ca	2633	2460
P	9800[a]	5778[b]
Mg	533	578
Fe	95.4	81.2
Zn	60.0[a]	41.6[b]
Cu	12.8	11.6

[a,b]Numbers with different superscripts are significantly ($P < 0.05$) different in the same row. (Reprinted with permission.)

TABLE 13 Grain Mineral Concentrations from Organic and Conventional Wheat Crops at Ardlethan (1991, 1992, and 1993) (Ryan et al., 2004)

	1991		1992		1993	
Element	**Conventional**	**Organic**	**Conventional**	**Organic**	**Conventional**	**Organic**
N(g/kg)	25	23	20	21	22	22
P(g/kg)	3.0[a]	3.1[b]	3.8[a]	2.8[b]	3.1[a]	2.9[b]
K (g/kg)	4.1	4.5	2.8	3.0	3.5	3.9
Mg(g/kg)	0.72	0.78	0.46	0.46	0.50	0.55
Ca(g/kg)	0.41	0.49	0.35	0.41	0.35	0.40
S (g/kg)	1.8	1.6	1.2	1.3	1.4	1.4
Fe(mg/kg)	33	29	19	18	21	20
Mn(mg/kg)	43	33	53	30	49	29
Zn(mg/kg)	15[a]	20[b]	16[a]	20[b]	16[a]	21[b]
Cu(mg/kg)	4.4[a]	5.1[b]	2.7[a]	3.7[b]	2.4[a]	3.8[b]

In each year, different letters indicate significant differences between organic and conventional wheat crops ($P<0.05$).

TABLE 14 Concentration of Trace Elements in Egg Albumen and Yolk of Organic and Conventional Products (Giannenas et al., 2009)

	Egg Yolk (ng/g)		Egg Albumen (ng/g)	
Element	**Conventional**	**Organic**	**Conventional**	**Organic**
Se	313±16[b]	410±26[a]	62±4.4	54.5±4.6
Zn	20676±923[b]	18225±857[a]	1003±54	1029±96
Mn	836±79	797±44	33±3.5	35±4.7
Co	4.6±0.5	4.6±0.4	1.36±0.2	1.14±0.2
Cu	1357±111	1233±104	212±24	189±28
Mo	260±14	246±16	26±1.3	19.5±3.8
V	12.5±0.4	13.2±0.8	13.2±0.2	13.6±0.3
Cr	66.2±8	82.9±11	48.2±5.2	48.2±3.4
Ni	63.3±5.6	58.4±3.6	64.2±4.2	56.3±4.3
Tl	1.4±0.2	1.5±0.2	0.72±0.2	0.51±0.1
As	13.9±1.8	12.5±2.6	5.4±0.5	4.4±0.2
Cd	1.4±0.2	1.6±0.2	0.6±0.2	0.8±0.2

Numbers with different superscript are significantly ($P<0.05$) different with respect to row for yolk or albumen. (Reprinted with permission.)

TABLE 15 Concentration of Elements (Both Major and Trace Elements) in the Dry Part of Vegetables and Fruits Grown in Organic and Conventional Agricultural Systems and Harvested in Different Years (2001, 2002). Data displayed as means of triplicate analysis (Kristensen et al., 2008)

		Carrot		Kale		Pea		Potato		Apple	
Element		**C**	**O**	**C**	**O**	**C**	**O**	**C**	**O**	**C**	**O**
Ca (g/kg)	2001	3.0	2.9	14.8*	15.2	1.7	1.9	0.3	0.3	0.3	0.3
	2002	2.9	2.7	17.6	20.7	1.9	1.9	0.2	0.2	0.3	0.3
Mg (g/kg)	2001	0.7	0.7	1.0	1.2	1.3*	1.4	0.6*	0.8	0.3	0.3
	2002	0.9	1.0	1.0	1.1	1.5	1.6	0.9	0.9	0.3	0.3
P (g/kg)	2001	2.1	2.2	3.7	4.0	4.6	4.7	1.9	2.2	0.5*	0.5
	2002	2.6	2.2	3.5	3.5	5.8	5.4	2.1	2.0	0.6	0.6
K (g/kg)	2001	22.2	18.9	13.8*	14.3	10.2*	10.3	8.9*	10.4	5.6*	5.0
	2002	28.3	17.0	19.2	17.0	13.5	12.9	15.3	14.9	7.2	6.5
Na (mg/kg)	2001	1540	2142	610	744	102*	111	109*	160	67.3	78.9
	2002	1638	3220	558	745	132	140	450	497	50.6	87.9
Cu (mg/kg)	2001	3.2	3.3	2.7	3.1	6.6	7.5	4.1	3.9	2.0	1.9
	2002	4.2	3.7	2.7	2.8	6.8	7.0	4.7	4.5	2.0	1.7
Fe (mg/kg)	2001	30.3	29.2	90.7*	104	57.4	54.5	17.1	19.1	14.7*	14.6
	2002	42.2	39.7	70.0	64.0	62.3	58.0	14.5	13.0	7.5	7.5
Mn (mg/kg)	2001	8.2b*	6.7a	21.5	18.5	12.2*	14.9	5.6	6.3	2.1	2.0
	2002	10.0	8.2	38.7	29.2	17.0	17.3	6.6	6.2	3.1	2.3
Zn (mg/kg)	2001	10.5	9.2	11.9	12.5	31.0	29.7	10.7	11.0	1.5	1.9
	2002	10.7	12.2	10.3	10.8	31.2	36.6	11.0	9.0	1.1	4.0
Mo (μg/kg)	2001	66.4	144	1190b*	2115a	1940b	3177a	147b*	282a	22.0	24.9
	2002	98.1	92.9	465	1670	1870	2913	363	524	56.0	43.8
Cd (μg/kg)	2001	339	289	99.8*	132	16.9*	18.1	67.7b*	44.6a	5.2	4.6
	2002	509	333	268	264	23.2	30.9	58.6	36.5	–	–
Co (μg/kg)	2001	8.9	10.2	35.8*	35.1	74.8	142	–	–	–	–
	2002	23.9	17.9	117	89.4	124	113	–	17.7	–	–
V (μg/kg)	2001	42.3	40.5	112	125	16.7	13.2	–	–	–	–
	2002	65.2	58.6	68.3	40.7	–	–	–	–	–	–

C, conventional; O, organic. *Difference between the content of different harvest year are independent of farming system ($P < 0.05$).
**Different letters in the same row suggest significant difference between organic and conventional farming system independent of harvest year ($P < 0.05$).*

TABLE 16 Summary of Vitamins in Organic and Conventional Foods

References	Samples	Vitamins Analyzed	Key Results
Bergamo et al. (2003)	Dairy products	Fat-soluble vitamin: retinol, TH, β-carotene	The organic products had significantly higher levels of TH and β-carotene compared with conventional dairy products, but the retinol content in organic milk was not significantly different from that found in conventional products
Lombardi-Boccia et al. (2004)	Yellow plums	Ascorbic acid α-, γ-tocopherols β-carotene	Organic plums have higher concentrations of α-, γ-tocopherols, ascorbic acid, as well as β- carotene compared with conventional products
Ellis et al. (2007)	Organic and conventional milk	vitamin A, β-carotene, vitamin E	Conventional milks showed higher vitamin A contents compared with organic milks. However, β-carotene and vitamin E contents did not display any significant difference between organic and conventional milk.
Wunderlich et al. (2008)	Broccoli	Vitamin C	No significant difference was observed for vitamin C between conventional and organic broccoli, but the significant changes due to seasonal reasons have been observed.
Koh et al. (2008)	Marinara pasta sauce	Carotenoids, vitamin C	Vitamin C concentration did not show any significant difference between organic and conventional sauces studied.
Cardoso et al. (2011)	Fruits (acerola, strawberries, persimmons)	Vitamin C, carotenoids	There was no evidence supporting that organic fruits have superior nutritional value.
Navarro et al. (2011)	Mandarin juice	Carotenoids, vitamin C	Organic juice contained significantly higher vitamin C and carotenoids than conventional samples.
Koh et al. (2012)	27 Varieties of spinach	Vitamin C	No significant difference was reported between the spinaches on vitamin C contents.
Lombardo et al. (2012)	Potato	Ascorbic acid	Ascorbic acid level in conventionally grown potatoes was 23% higher than that in organic potatoes.
Skrabule et al. (2013)	Potato	Vitamin C, vitamin B_1, vitamin B_2	The concentration of vitamin B_1 of potatoes harvested from organic farms was higher than conventional samples.
Tõnutare et al. (2014)	Strawberry	Ascorbic acid vitamin E	There is no evidence supporting that organically harvested strawberries have more bioactive compounds compared with conventional strawberries.
Kazimierczak et al. (2015)	Rosemary peppermint lemon balm sage	Vitamin C carotenoids	Organic medicinal plants contained significantly higher vitamin C than the conventional plants, but conventional medicinal plants had significantly higher amounts of carotenoids compared to the organic counterparts.

TABLE 16 Summary of Vitamins in Organic and Conventional Foods—cont'd

References	Samples	Vitamins Analyzed	Key Results
Khalil and Hassan (2015)	Strawberries and oranges (conventional and organic samples, 50 each kind)	Ascorbic acid β-carotene	Organic strawberries had higher level of β- carotene as well as ascorbic acid compared with conventionally grown ones. Same for oranges.
Assumpção et al. (2016)	Grape seed oils	Carotenoids tocopherol	No differences were found for grape seed oil between conventional and organic products. The difference of the species of the grapes, however, did cause variations.

Note: Ascorbic acid (AA); vitamin A (retinol); vitamin E (tocopherol).

2.2.2 Vitamins

The reports of vitamins in organic foods are primarily about organic fruits, vegetables, and eggs. For fat-soluble vitamins, some studies are mainly about dairy products and egg products. A large number of studies of vitamins in organic foods are about vitamin C (ascorbic acid) and carotenoids. Table 16 summarizes some of the major studies on the variation of vitamin content in recent years.

Furthermore, a previous report on kiwis indicates that no significant differences ($P > 0.05$) were found for phenols and vitamin C compositions. In addition, conventional kiwis had lower organic acids contents than organic kiwis (Nunes-Damaceno et al., 2013) (Table 8).

Based on Table 16 reports on the variation in the content of vitamins in conventional food products and their organic counterparts, 43% of studies (six reports) reported that no significant difference existed between these two agricultural systems, 29% of the studies (four reports) suggested that vitamin contents of organic food products were higher than those of their conventional counterparts, 21% of the studies (three reports) suggested that there were differences between different types of vitamins, and only one study (7%) suggested that vitamin content in conventional foods was higher than organic foods.

Apart from farming system, vitamin contents could be affected by time of year and yield, etc. For instance, there is an increase of the vitamin content of milk during the summer, and it is also affected by feeding level. Meanwhile, high yield pastures showed a lower level of β-carotene and vitamin E in their milk products (Ellis et al., 2007).

3 ANTIOXIDANTS

In addition to vitamin E and vitamin C, minerals such as selenium, magnesium, and zinc found in many fruits and vegetables also contain significant amounts of phytochemicals with antioxidant activities (Fu et al., 2015a,b). There are many studies on antioxidants in organic foods, and the main antioxidants (carotenoids, anthocyanins, phenolic acids, and flavonoid) and related foods are shown in Table 17.

Some of the major studies and key results on the difference in antioxidant content and antioxidant activities between organic and common foods are reported in the following section.

TABLE 17 Antioxidants in Organic Food

Antioxidants Category	Antioxidant-Rich Foods
Carotenes, carotenoids	Carrot, sweet potato, pumpkin
Lutein	Carrot, corn, pumpkin
Licopene	Tomato, red hearts grapefruit
Resveratrol	Grape, peanut
Procyanidins (OPC)	Grape, pomegranate, peanut
Anthocyanins	Grape, blueberry
Ellagic acid	Strawberry, pomegranate
Chlorogenic acid	Cabbage
Caffeoylquinic acid	Potato, carrot
Hydroxycinnamic acids	Orange
Tannins	Grape, pomegranate
Kaempferol, naringenin	Tomato
Punicalagin	Pomegranate
Isoflavone	Soybean
Myricetin	Onion, beetroot
Quercetin	Tomato, onion, eggplant
Catechin	Grape, green tea
Epicatechin	Grape

As shown in Table 18, based on 47 studies on the difference in the antioxidant amounts in organic foods and conventional foods, 43% studies (20 reports) showed that antioxidants in organic foods were higher than those in conventional foods, 34% of the studies (16 reports) showed that there were no significant difference between the two agricultural systems, and only two reports (4%) showed that antioxidants content in conventional foods was higher than organic foods. Others (9 reports, 19%) suggested that the different antioxidants or food raw materials could result in various experimental results, whereas most of the experimental results indicated that antioxidant activities of organic food were higher than conventional food.

Many studies found higher levels of antioxidants in organic products than in conventionally grown food, yet there is no certain rule for the effects of cooking on the total polyphenol content and antioxidant capacity (Ismail et al., 2004; Lombard et al., 2005; Turkmen et al., 2005).

Faller evaluated the antioxidant activity and amounts of polyphenol of vegetables after cooking (boiling, microwaving, and steaming) for both organic and conventional products, and results showed organic vegetables were more affected than conventional vegetables (Faller and Fialho, 2009).

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods

References	Samples	Method Design	Antioxidants Analysed	Key Results
Weibel et al. (2000)	5 pairs of organic/ integrated apple	Phenolic compounds: HPLC analysis with diode-array-detection and post-column-derivatisation	Total flavanols, total cinnamon acids, total phloretin glycosiders, total quercetin-glycosides	Phenols (mainly flavanols) contents were lower in conventional apples compared to organic apples.
Mikkonen et al. (2001)	Black currant cultivars (10 organic, 5 conventional)	Flavonols: HPLC	Quercetin, myricetin, and kaempferol	The flavonols content varied widely among the cultivars. No difference was displayed for flavonols content between organic black currant and their conventional counterparts when the cultivar is same.
Carbonaro et al. (2002)	Peaches and pears	Total polyphenol content: spectrophotometry PPO activity: spectrophotometry Ascorbic, citric acids, tocopherol: HPLC	Polyphenol content, PPO activity, ascorbic acid, citric acids, tocopherol	Polyphenol content, PPO activity, ascorbic acid, and α-tocopherol were higher in organic peaches as well as pears when compared with their conventional samples.
Asami et al. (2003)	Marionberry, strawberry, and corn	Processing treatments: freeze/ air-drying, freezing. a Ascorbic Acid: HPLC Total Phenolics: Folin-Ciocalteu assay	Total phenolics; Ascorbic acid	Higher amounts of total phenolic matters were found in organic foods compared to conventional products. Higher levels of total phenolics can be obtained through freeze-drying other than air-drying.
Lombardi-Boccia et al. (2004)	Yellow plums	Total polyphenols: Folin-Ciocalteu reagent Phenolic Acids, flavonols: RP-HPLC β-carotene, ascorbic acid, citric acid, and malic acid: HPLC	Total polyphenols, protocatecuic, caffeic, ferulic, trans-p-coumaric acids VE, flavonols, β-carotene, ascorbic acid, citric acid, and malic acid	Conventional plums contain more quercetin and total polyphenols, whilst organic plums have more kaempferol and myrecitin.

Continued

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
Dimberg et al. (2005)	Oats	Avenanthramides (AVA), hydroxycinnamic acid (HCA), ruxinic acid (TASE): HPLC	AVA; HCA; TASE	Significant difference was observed between different years, different cultivars, and nitrogen rate of avenanthramides concentration in the oat grains. However, no difference was observed for cropping system. The hydroxycinnamic acid showed differences for cultivar and years but was not affected by cropping system or nitrogen rates.
Young et al. (2005)	Leaf lettuce collards pac choi	Phenolics: HPLC total phenolic content: Folin-Ciocalteu Assay	Phenolic acids including gallic acids and caffeic acids, glycoside or aglycone flavonoids including apigenin, luteolin, kaempferol, and quercetin.	No significant difference was shown for phenolics concentrations between conventional and organic lettuce and collard samples, but organic pac choi has significantly higher phenolic content compared with conventional pac choi.
Chassy et al. (2006)	Tomatoes bell peppers	Total phenolics analysis by modified phosphomolybdic phosphotungstic acid reagents; Flavonoid analysis by Liquid chromatographic	Ascorbic acid, ctotal phenolics, flavonoid aglycones quercetins, kaempferols, luteolins	Organic tomatoes have higher levels of phenolic and flavonoid compared with conventional tomatoes. Variability between different years was significant among tomatoes varieties. On the other hand, bell peppers were less affected by the farming system and did not show difference in chopping system.

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
Olsson et al. (2006)	Strawberry strawberry extracts	Antioxidants content: HPLC	Flavonols, ellagic acid, anthocyanins	The antioxidant levels in the organic strawberries were higher compared to the conventionally ones, although not always significantly. Organic strawberries extract showed higher antiproliferative activity compared with conventional strawberries.
Tarozzi et al. (2006)	Red oranges	Total phenolics: Folin Ciocalteau assay; total anthocyanins: spectrophotometric; total antioxidant activity: ABTS•+ test	Total phenolics, total anthocyanins, total antioxidant activity	Organic orange displayed significantly higher concentrations of total anthocyanins and phenolics, as well as ascorbic acid compared with conventional oranges, whereas the extract of organic oranges displayed higher total antioxidant activity compared with conventional oranges.
Vian et al. (2006)	Grapes harvested at different growing phases	Total content of anthocyanin and composition: HPLC	Anthocyanin: malvidin, delphinidin, malvidin glucosides petunidin, acylated	Total anthocyanins contents during ripening phase of conventional grapes were much higher compared with organic ones.
Dani et al. (2007)	Purple and white grape juices	Total phenol content: Folin–Ciocalteau's colorimetric method; phenolic compounds: HPLC analysis; antioxidant activity: DPPH radical scavenging	Phenolic compounds: trans-Resveratrol, anthocyanins, procyanidins; Total phenol content; antioxidant activity	Organic grape juice displayed higher content of total polyphenols as well as resveratrol compared with conventional juice. Higher level of total polyphenol and higher in vitro antioxidant activity was observed for

Continued

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
				purple juices compared with white juices, which was positively correlated with total polyphenol concentration.
Hoikkala et al. (2007)	Skimmed Finnish cow milk	Phytoestrogens: HPLC-diode array detector/ fluorescence detector	Daidzein, genistein, formononetin, biochanin A, O-DMA, equol contents	Organic milk contained higher equol than conventional milk. Formononetin and daidzein was detected in organic samples but not in conventional milk. No genistein, biochanin A, or O-DMA was detected in either milk samples.
Mitchell et al. (2007)	Tomatoes	Ten years study of comparative study of the influence of farming system on tomatoes flavonoids content	Quercetin, kaempferol, naringenin, kaempferol and other flavonoids	Flavonoid of highest amount was quercetin in both conventional and organic tomatoes. The increasing rate for kaempferol as well as quercetin was lower in conventional farms compared with those in organic farms.
Wang et al. (2008)	Blueberries	Total phenolics content: Folin-Ciocalteu reagent total anthocyanins: pH differential method anthocyanins and phenolic compounds separation and determination: HPLC Analysis antioxidant activity: Oxygen radical absorbance capacity assay	ORAC values, total phenolics, total anthocyanins	The organic blueberry displayed higher concentration of total phenolic compounds and anthocyanins, and higher antioxidant activity compared with conventional counterparts.

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
Lamperi et al. (2008)	Apples	Apple peel and pulp of four cultivars were tested. Total polyphenols: Folin-Ciocalteau method, polyphenols analysis: HPLC-DAD antioxidant property: free radical DPPH scavenging activity	Total polyphenols contents Polyphenols composition antioxidant property	Production method did not significantly contribute to the polyphenol content. Apple peels of both cultivars of organic fruits showed higher radical scavenging properties than corresponding integrated ones. In pulp, more similar radical scavenging properties were found.
Wang et al. (2008)	Blueberry	Total anthocyanin contents: pH differential method, spectrophotometer Total soluble phenolics: Folin-Ciocalteu reagent analysis Anthocyanins and phenolic compounds: HPLC antioxidant capacity: Oxygen radical absorbance capacity assay	Total anthocyanin contents, total soluble phenolics, anthocyanins compounds, phenolic compounds, ORAC value	Organic blueberries showed higher concentration in total anthocyanins, total phenolics, and higher antioxidant activity compared with conventional counterparts.
Juroszek et al. (2009)	Tomatoes	Antioxidant activity: ARP and ILP methods carotene and lycopene: HPLC total soluble phenolics: Folin-Ciocalteu reagent method	Antioxidant activity. ascorbic acid, β-carotene, total phenolics and lycopene contents	Organic and conventional tomatoes displayed no significant difference on the amounts of bioactive compounds with antioxidant activity.
Mulero et al. (2009)	Red wines	Phenolic compounds: HPLC-DAD. Antioxidant activity: DPPH radical method.	Anthocyanins, flavonols, hydroxycinnamic acids, antioxidant activity	There was no proved significant difference between wines produced conventionally and organically.

Continued

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
Singh et al. (2009)	Freeze-dried eggplant pulp samples	Phenolic compounds: HPLC/MS/MS antioxidant capacity of eggplant extracts: LDL migration and lag-time of LDL oxidation	Phenolic acids: N-caffeoylputrescine, 5-caffeoylquinic acid and 3-acetyl-5-caffeoylquinic acid Favonols including quercetin-3-rhamnoside, quercetin-3-glucoside and myricetin-3-galactoside	Antioxidant activity and phenolic compounds concentrations of the conventional backbell variety were equal to or slightly higher than organic samples. The antioxidant activity of the organic product was significantly stronger than the conventional samples.
Stracke et al. (2009)	Apples	Polyphenol content: HPLC Analysis; antioxidant capacity: Ferric reducing antioxidant power, oxygen radical antioxidant capacity as well as Trolox equivalent antioxidant capacity assay.	Polyphenol content; antioxidant capacity;	For year 2005 and 2006, organic apples displayed stronger antioxidant capacity than their conventional counterparts. Higher level of polyphenol was reported for year 2005 in organically harvested apples. However, no statistical difference was observed for year 2004 and year 2006. Variations between different years in antioxidant capacity and the concentration of polyphenol content were more significant compared with the farming systems.
Stracke et al. (2009)	Carrots	Double-blind, randomised intervention study. Carotenoids: HPLC; lipophilic antioxidant activity: Trolox equivalent antioxidative capacity (TEAC) assay	Carotenoids; lipophilic antioxidant activity; Total antioxidants in plasma.	The results showed no significant difference in total carotenoid amounts between organic carrots and conventional counterparts.

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
Faller and Fialho (2010)	6 vegetables (potato, broccoli, onion, carrot, tomato, white cabbage); 6 fruits (banana, orange, papaya, mango, apple, tangerine)	Hydrolysable as well as soluble polyphenols: Folin-Ciocalteu reagent antioxidant capacity: DPPH radical method.	Hydrolysable and soluble polyphenols; antioxidant capacity	Organic fruits displayed higher level of hydrolysable polyphenol compared to conventional products. Peels of the fruits also contained more polyphenols compared to pulp. Antioxidant capacity as well as polyphenol content was shown to be different between conventional and organic vegetables. Generally speaking, organic fruits and vegetables have slightly higher or almost same antioxidant capacity and polyphenol content compared to conventional products.
Luthria et al. (2010)	Eggplants (n=32)	Phenolic quantification: Folin–Ciocalteu assay; Phenolic compounds: HPLC, LC–MS	Total phenolics;5-caffeoylquinic acid content	There were significant variations in phenolic compound content between different plants in various samples, except that eggplants displayed same phenolic acid content for organic and conventional farming systems.
Mulero et al. (2010)	Grapes and wines	Phenolic content: HPLC-DAD analysis; phenolic compounds: UV–vis spectra chromatograph	Phenolic content; total phenolic compounds (anthocyanins, flavonols, hydroxycinnamic acids)	The total phenolic compounds level 1 month before harvest as well as the antioxidant activity was higher for organic grapes than conventional

Continued

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
				counterparts; Such difference was not displayed at the time of harvesting.
Reganold et al. (2010)	Strawberry (13 conventional and 13 organic)	Total phenolics: Folin-Ciocalteu phenol reagent method. Antioxidant activity of lipophilic as well as hydrophilic fractions: the end-point 2,9-azino-bis-(3-ethylbenzthiazoline-6-sulfonic acid) / hydrogen peroxide/ peroxidase. anthocyanins: UV visible spectrophotometer	Phytochemical composition, shelf life, organoleptic properties; soil DNA	Organic strawberries displayed significantly higher level of phenolics and ascorbic acid, as well as stronger antioxidant activity.
Søltoft et al. (2010)	Onions carrots potatoes	Flavonoids and phenolic acids contents: HPLC and ultraviolet quantification flavonoids and phenolic acids structure: MS analysis	Flavonoids phenolic acids	There was no significant difference for phenolic acids and flavonoids concentrations between organic and conventional products.
Fonseca Maciel et al. (2011)	Biodynamic, organic and conventional mangoes in three maturation stages	Total phenolic compounds content: Folin-Ciocalteau reagent method; flavonoids content: 510 nm spectrophotometer; antioxidant activity: DPPH radical reduction	Total phenolic compounds; flavonoids content; antioxidant activity	Mangoes (biodynamic ones) had strongest antioxidant activity among ripe and mature-green products; Organic mangoes displayed highest antioxidant activity in nonripened fruits. Organic mangoes contained most phenolic compounds no matter which maturation stage they are at.

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
Gąstoł et al. (2011)	Fruit and vegetable (apple, pear, blackcurrant, carrot, beetroot, celery) juices	Total polyphenol content: Folin-Ciocalteu method, total antioxidant activity: Ferric antioxidant reducing power assay	Total polyphenol contents, total antioxidant activity	Organic juice displayed similar level of ascorbic acid and polyphenols with conventional juices. Their antioxidant activity was slightly stronger compared to conventional counterparts.
Kalinova and Vrchotova (2011)	Buckwheat	3 species (Spacinska, Pyra, and Jana), Flavonoids content: HPLC-DAD	Flavonoids: rutin, epicatechin, catechin, epicatechin gallate	Organic goat milk contained more epicatechin as well as rutin and gallate. The difference was influenced by the agricultural system in the year of study.
Vrček et al. (2011)	Wines	Total phenolic matters and antioxidant activity: ABTS and DPPH free radical methodphenolic compounds: HPLC	Antioxidant capacity, TPI, polyphenols: chlorogenic acid, catechin, ferulic acid, flavonols, trans-resveratrol	Compared with conventional wines, organic wines showed higher phytochemical content as well as stronger antioxidant capacity.
Bunea et al. (2012)	Grapes of nine varieties	Carotenoids: HPLC-PDA chromatogram; Total phenolic content: Folin-Ciocâlteu method; Antioxidant activity: DPPH scavenging activity assay.	Arotenoids (Main components: β-carotene as well as lutein), total polyphenolic matters, antioxidant activity.	Significant difference existed in total phenolic content for all grape species tested. Stronger antioxidant activity was observed for organic grapes compared with conventional grapes in stage of ripening.
Lv et al. (2012)	Cinnamon and peppermint	Total phenolic content: Folin-Ciocalteu reagent RDSC: spectrophotometric and electron spin resonance (ESR) spectrometry	Total phenolic content RDSC HOSC and ORAC phenolic compounds	Individual phenolic compound didn't show significant difference among conventional and organic products. Cinnamon and peppermint extracts

Continued

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
		methods inhibit DPPH• and $ABTS^{\bullet +}$ HOSC and ORAC: fluorescein assay Phenolic compounds: HPLC		exhibited strong anti-inflammatory as well as anti-proliferative characters among all the samples tested.
Picchi et al. (2012)	2 different genotypes of green cauliflowers (Magnifico and Emeraude)	Ascorbic acid: HPLC; total polyphenol content: Folin–Ciocalteu assay; thiol groups: spectrophotometry; total carotenoids: spectrophotometry; antioxidant capacity: DPPH radical quenching and O_2^- radical scavenging method	Ascorbic acid; total polyphenol content; thiol groups; total carotenoids:; antioxidant capacity	Magnifico genotype: phytochemical production, ascorbic acid, and polyphenols significantly increased under organic management. Emeraude genotype: phytochemical production, glucosinolates, and ascorbic acid decreased under organic management. For cauliflower, the quality was identified genotype no matter what the cultivation system was like for all the parameters tested.
Vallverdu-Queralt et al. (2012)	Tomato juices (5 organic and 6 conventional)	Antioxidant activity: ABTS+ radical decolourisation assay; Phenolic compounds: HPLC–ESI-MS/MS.	Hydrophilic antioxidant capacity, total phenolic content, flavonol contents (kaempferol-3-Orutinoside, kaempferol-3-O-glucoside, quercetin, rutin), the content of flavanones (naringenin-7-O-glucoside, naringenin), as well as the content of hydroxycinnamic acids (ferulic-Ohexoside, caffeic-O-hexoside, chlorogenic, caffeic, cryptochlorogenic, dicaffeoylquinic acids)	According to the study, organic tomatoes contain significantly higher concentration of total phenolics and have stronger antioxidant activity.

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
Hallmann et al. (2013)	Tomato juice	Polyphenols: HPLC	Dry matter, vitamin C, carotenoids, polyphenols (gallic acid, p-coumaric acid, chlorogenic acid, quercetin-3-O-glucoside, quercetin-3-O-rutinoside, quercetin and kaempferol)	According to the study, more total phenolic acid, chlorogenic acid, beta-carotene, rutin, p-coumaric acid, gallic acid, quercetin-3-O-glucoside, total flavonoids, and quercetin was found in organic tomato juice compared with conventional tomato juice.
Lo Scalzo et al. (2013)	Green cauliflower	Total Polyphenol Content: HPLC-DAD; total Carotenoids: spectrophotometry; antioxidant capacity: DPPH radical quenching and O2 – radical scavenging method	Total Polyphenol Content; Thiols; Total Carotenoids; antioxidant capacity	More polyphenols, volatiles, carotenoids, and stronger antioxidant capacity was observed for organic cauliflowers. However, for phytochemicals or the antioxidant potential, no significant increase was reported. Organic farming system might be preferable for particular cauliflower genotypes.
Koh et al. (2013)	Tomatoes	10 different farming systems were investigated	α-tomatine concentrations in dried tomatoes harvested from organic and conventional farming systems were comparatively studied over 10 years (from 1994 to 2004)	Organic tomatoes contained more α-tomatine compared with conventional ones over 10 years. Variability caused due to different years was significant for the level of α-tomatine in tomatoes, suggesting that environment, influence a lot on α-tomatine content of tomatoes.

Continued

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
Ornelas-Paz et al. (2013)	Organic strawberry fruits harvested at six different ripening stages	Total anthocyanins content (TAC): pH-differential method total phenolic content (TPC): Folin–Ciocalteu reagent phenolic compounds identification and quantification: HPLC-DAD–MS	TAC, TPC, twenty eight phenolic compounds	The organic fruit presented higher content of anthocyanins and total phenolic compounds than those of strawberries.
Tassoni et al. (2013)	Conventional, organic and biodynamic red and white grape berries of different species and red and white wines	Total polyphenols: Folin-Ciocalteu method total anthocyanins: spectrophotometric analysis polyphenols: HPLC – DAD antioxidant activity: DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging capacity	Biogenic amines, total polyphenols, anthocyanins, polyphenols, antioxidant activity	There was no significant variation among samples collected from different wine factories. Compared with white grapes and wines, red grapes and wines contain more anthocyanins have stronger antioxidant activity. As for polyphenols, the contents were similar between red and white grapes and wines.
Barański et al. (2014)	Crops and crop-based foods(n=98)	Review study based on more than 300 peer-reviewed publications	Phenolic acids, polyphenolics, stilbenes, flavanones, flavones, flavonols as well as anthocyanins	The antioxidants concentrations were higher in organic food products.
Kazimierczak et al. (2014)	Beetroots (raw) and fermented beetroot juice	Phenolic compounds: HPLC Betacyanins: HPLC Cancer cell apoptosis studies: cell line AGS – gastric adenocarcinoma stomach cancer	Phenolics: Chlorogenic acid, Caffeic acid, Ferulic acid, Kaempferol Flavonoids, Myricetin, Luteolin, Quercetin	Conventional beetroots displayed significantly higher amount in total phenolic acids compared with the organic counterparts. The flavonoids level was similar in organic and conventional beetroots. Organically

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
				fermented juice displayed stronger anticancer activity compared to conventional ones.
Garaguso and Nardini (2015)	Red wines	Total polyphenols: Folin–Ciocalteu method total flavonoids content: spectrophotometer phenolics: HPLC total antioxidant activity: Ferric Reducing Antioxidant Power (FRAP) assay	Total polyphenol contents, total flavonoid contents and total phenolics total antioxidant activity	Flavonoids and polyphenols contents were slightly higher in organic wines compared with their conventional counterparts, but the differences were not statistical significance. Antioxidant activity was also observed to be slightly higher in organic samples. The phenolic acids profile was quite similar in both groups of wines.
Granato et al. (2015)	Purple grape juices (biodynamic, organic, and conventional)	Chemical compounds and antioxidant activity: electronic tongue, spectrophotometric measurements coupled with chemometrics total phenolic content of juices: Folin–Ciocalteu reagent	Total phenolic content of juices ferric-reducing antioxidant power (FRAP) copper chelating activity	The grape juices, organic and conventional ones, showed no significant difference according to instrumental data of physicochemical parameters including total phenolic matters, o-diphenols amount, and antioxidant activity. Compared with conventional juices, the activity of copper chelating of organic products is higher than conventional ones.

Continued

TABLE 18 Overview of Antioxidants and Antioxidant Activity in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Antioxidants Analysed	Key Results
Khalil and Hassan (2015)	Oranges and strawberries (50 each for both organic and conventional samples)	Ascorbic acid and β-carotene: HPLC; total phenol content: Optical density measured at 750 nm, calculated from a standard curve of tannic acid.	Ascorbic acid β-carotene total phenol content	Organic oranges and strawberries had higher ascorbic acid and β-carotene content than conventionally grown ones. Total phenol content was significantly higher in conventional oranges compared to its organic production, but total phenol content was significantly higher in organic strawberries than the conventional ones.
Cano-Lamadrid et al. (2016)	Pomegranate juices	Antioxidant activity: DPPH, ABTS+, and FRAP; TPC: Foli-Ciocalteu colorimetric method; Phenolic compounds identification and quantification: HPLC-DAD; Ames test: residual AFB1 mutagenicity	Antioxidant activity; TPC; Punicalagin, ellagic acid contents; antimutagenic potential	The punicalagin contents and the antimutagenicity capacity were higher in conventional pomegranate juice than in organic counterparts, but the total contents of phenolics was similar.
Letaief et al. (2016)	Maltaise demi-sanguine citrus juice (freshly pressed)	Total phenolics: Folin–Ciocalteu method; total flavonoids contents: mg (+)-catechin equivalents (CE) per gram of dry weight through the calibration curve; phenolic compounds: RP-HPLC; antioxidant capacity: DPPH radical-scavenging assay	Total phenolic matters, flavonoids amount, antioxidant capacity	Maltaise demi-sanguine citrus juice showed higher phenolic acids and flavonoid amount in conventional products, as well as antioxidant activity.

Total polyphenol content (TPC).

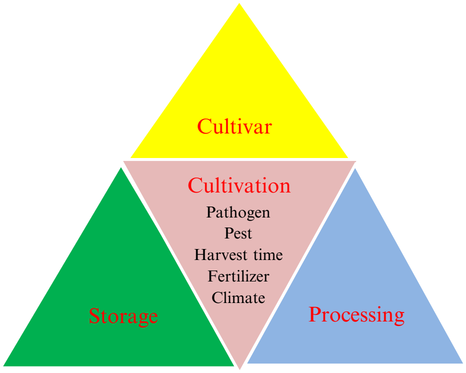

FIG. 1 Key factors affect the antioxidant content in organic plants. *Adapted from Vallejo et al., 2003.*

High temperature environment can cause changes in flavonoids and polyphenols, resulting in the subsequent change in their antioxidant capacity as well (Vallejo et al., 2003). Key factors affecting the antioxidants content in organic plants are shown in Fig. 1. We also need to conduct comprehensive and quantitative analysis of the quality of food and soil at different farms, adopting different agricultural practices at different times.

4 SAFETY

Although some scientists reported that organic foods contain higher amount of some nutrients, other reports found no significant difference between organic and conventional foods. One of the key reasons causing this debatable result is that it is hard to make the comparison with strict controlled equivalent conditions between organic and conventional counterparts. However, for chemical safety, many studies have proven that organic foods had a lower amount of pesticide residue and suffered from lower risk level of antimicrobial resistance. In another word, organic foods have unique advantages in chemical safety.

4.1 Pesticides

Organic agriculture is commonly referred to those that banned the usage of synthetic pesticides or fertilizers. The general term "pesticides" includes herbicides, fungicides, insecticides, and other related molecules. The trace amount of pesticides left in products is referred to as "residues". To protect the environment's biodiversity and human health, harmful chemical insecticides and herbicides are prohibited in organic agriculture. Maximum residue level (MRL) is defined as the highest amount of one kind of pesticide residue legally allowed in foods or feeds (Good Agricultural Practice).

It should be pointed out that organic food is not completely without synthetic pesticides. The possible causes of synthetic pesticide residues include illegal labeling of organic food or mishandle in organic food operations, for example, unauthorized use of pesticides, or mishandling in organic food transport, processing, and storage. The more likely reason is due to the general

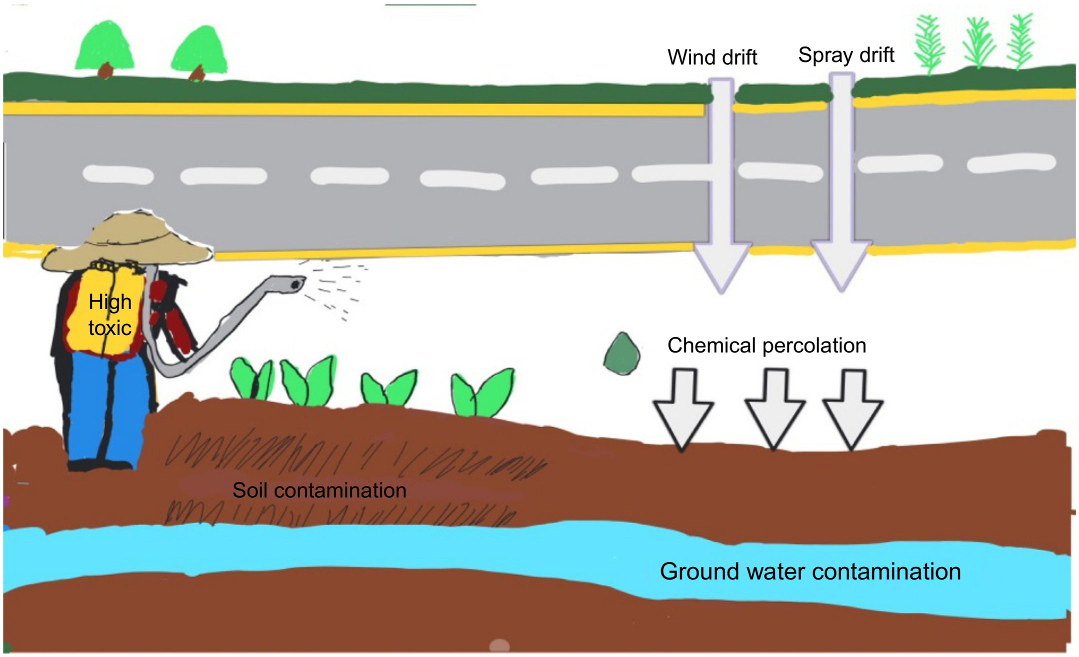

FIG. 2 Possible causes of pesticides contamination in organic foods. *Adapted from Tasiopoulou, S., Chiodini, A.M., Vellere, F., Visentin, S., 2007. Results of the monitoring program of pesticide residues in organic food of plant origin in Lombardy (Italy). J. Environ. Sci. Health B 42(7), 835–841.*

environmental pollution, such as the wind, irrigation water, or the original planting of soil residues of pesticides. As shown in Fig. 2, cross-contamination from wind or conventional neighborhood farms might be another reason of such residues (Tasiopoulou et al., 2007).

For example, the last organochlorine pesticides, such as DDT, although it has been banned for many years, residues are still detected in organic and conventional crops. Forty percent of the pesticide residue detected in the organic samples from the PDP data set were organochlorines. Due to unavoidable contamination, the USDA national standards allow, in organic crops, 5% of the applicable US Environmental Protection Agency (EPA) pesticide tolerance level for conventional crops (Chen, 2005).

Although organic food products might be grown, harvested, and processed properly according to all the rules, they might still be contaminated by pesticides or other synthetic chemicals as well, just like conventional foods (Magkos et al., 2006). The USDA carried out continuous tests for pesticide residue in organic foods since 1993, which is a part of pesticide Data Program led by the Agricultural Marketing Service. In the past few years, this program has expanded the range of organic samples and has also issued a report on the level of pesticides residues for both domestic and imported organic products. The program also discussed how these products possibly became contaminated although they were organically produced (Benbrook, 2010).

According to the pilot study pesticide residue testing of organic product, most of the pesticides allowed for use in organic farms are naturally derived from natural extracts of plants (e.g., pyrethroids) or microorganisms (e.g., *Bacillus thuringiensis*) (Yu and Yang, 2017; Yu et al., 2017; Yu et al., 2018). Standards of organic farming prohibit the use of most synthetic chemicals, including pesticides that are commonly applied in conventional agriculture, and this has to be implemented for at least 3 years before the harvest of organic products. Artificial pest control chemicals allowed in organic farms are few, such as copper hydroxide, insecticidal soaps, elemental sulfur, as well as horticultural oil (USDA, 2012).

Organic agriculture allows the use of botanical pesticides. Although there is no evidence that the use of botanical pesticides can bring harm, the safety of botanical pesticides also needs long-term evaluation.

Currently when pesticide residue meets the general safety regulation, in many scenarios, there is no further specific requirement on the detailed quantification of the amount. Perhaps in the future, with the reduction of the use of synthetic pesticides in the production of more and more conventional foods, the residue level will become a factor that is less considered by consumers when making decisions in supermarkets when they are shopping for food (Bourn and Prescott, 2002).

Because many consumers choose organic food products that cost more compared with their conventional counterparts due to supposedly lower pesticides residue levels, more analytical studies supporting such claims have drawn much interest. As shown in Table 19, based on 22 studies in recent years on the difference in the pesticide residues between conventional and organic food products, 59% studies (13 researches) showed pesticides residues in organic foods were lower than conventional foods, whereas 41% of the studies (9 reports) showed no significant difference between the two agricultural systems.

TABLE 19 Overview of Pesticide Residue Comparisons in Organic and Conventional Food

References	Samples	Analytical Method	Pesticides Residues	Key Results
Moore et al. (2000)	Baby food (applesauce, pears, winter squash, carrots)	Multi-residue analyses Organochlorine residues: GC Botanical pesticides: HPLC	Organochlorines including aldrin, cis-chlordane, dieldrin, p,p′-DDD, p,p′-DDT, p, p′-DDE, heptachlor, hexachlorobenzene; five botanical chemicals including nicotine, pesticides pyrethrin II, pyrethrinI, warfarin, rotenone)	Because no residues were found in the baby foods, there was no apparent distinction between the traditional commercial and the organic baby foods.
Baker et al. (2002)	Conventional, organic, and integrated pest management (IPM) / no detectable residues (NDR) foods	Raw data were obtained from USDA, California Department of Pesticide Regulation (DPR), and Consumers Union (CU). Data pairs test	Detectable pesticide residues, Frequency of pesticide residues	Compared to IPM or conventionally-grown foods, organically produced foods have less pesticide residues.

Continued

TABLE 19 Overview of Pesticide Residue Comparisons in Organic and Conventional Food—cont'd

References	Samples	Analytical Method	Pesticides Residues	Key Results
Poulsen and Andersen (2003)	4404 samples of mainly fresh conventionally and organically (216) grown fruit and vegetables	Pesticides residues: GC, HPLC, spectrophotometric methods	130 pesticides (including isomers and degradation products)	Residues were detected in 6 fruit and vegetables in 216 organic samples (2.8%), all below the MRL. A total of 151 of all conventional samples (4%) had residues exceeding the EU or national MRL. Residues below the MRLs were found in 1276 (38%) conventional samples.
Tsatsakis et al. (2003)	Olive oils	Fenthion and dimethoate pesticides residues: liquid-liquid and solid-phase extractions, GC-MS analysis	Fenthion dimethoate	According to the olive oils tested, all samples displayed level of residue below the maximum residue levels set by the Codex Alimentarius. Organic olive oils showed lower level of residue compared with conventional ones.
Chen (2005)	Organic vegetables and fruits	Summary of data analysis	Pesticide residues	According to the results, organic product displayed less and lower concentrations of pesticides compared to conventional ones.
Ghidini et al. (2005)	Milk products meat products	Organochlorine pesticides: multi-residue method, GC-ECD analysis	24 organochlorine pesticides	Organic and conventional products did not display significant difference for the residue of organochlorine. Almost organochlorine compounds in all the samples were not detected.

TABLE 19 Overview of Pesticide Residue Comparisons in Organic and Conventional Food—cont'd

References	Samples	Analytical Method	Pesticides Residues	Key Results
Pussemier et al. (2006)	Conventionally and organically produced food	Data summarizes in the U.S. and in Europe on the database (94000 samples in the American database)	Pesticides	Compared with conventional products, organic ones contain lower level of pesticides residue. IPM products contain residue at levels between the above two.
Rekha et al. (2006)	Wheat rice	Pesticide residues extraction and analysis: HPLC, GC	Organochlorine, carbamates, organophosphorous, pyrethrites	Organochlorine residue was detected in 2 out of 10 organic farms products. These farms converted from conventional to organic just a few years ago. Wheat and rice grown conventionally contain noticeable level of pesticides residue.
Dani et al. (2007)	White and purple grape juices	Methyl-parathion calibration curve to express AChE activity in ppm of methyl-parathion.	Organophosphorus and carbamate pesticide	No carbamate or organophosphorus was detected in the grape juice tested.
Harcz et al. (2007)	Winter wheat	Data from the Pesticide Residue Monitoring Program achieved in 2002–2004 by the FASFC	28 pesticides in 2003 and 29 pesticides in 2004; chlorpyriphos-methyl, dichlorvos, pirimiphos-methyl	Commonly used pesticides were regularly detected in conventional cereal samples. On the other hand, they were not detected in organic samples.
Lesueur et al. (2007)	Fruit and vegetable samples (n=3300)	Pesticide residues: GC/MS	Insecticide, fungicide, acaricide, herbicide. inhibitor	90% of the organic farming products were below the LOD. The conventional products with detectable pesticide residues were 62 % in 2004 and 54 % in 2005. A significant

Continued

TABLE 19 Overview of Pesticide Residue Comparisons in Organic and Conventional Food—cont'd

References	Samples	Analytical Method	Pesticides Residues	Key Results
				amount of conventional samples showed multi-residues.
Tasiopoulou et al. (2007)	3508 samples of plant (266 organic samples) (citrus fruits, legumes, vegetables, potatoes, processed products, cereals, and fruit other than citrus)	Pesticides monitoring program	Organophosphorus, organochlorine, synthetic pyrethroids, benzylate, carbamate	The results displayed 10 times greater contamination in conventional products than organic products. Most of organic farming products did not contain pesticides residue or contain nondetectable level of pesticides. Only limited amount of samples were tested with residues, but at levels way below the MRLs.
Hoogenboom et al. (2008)	Wheat lettuce carrots potatoes	Pesticides extraction dispersive solid-phase extraction (dispersive-SPE) quantitative and confirmatory analysis: GC/MS	Organophosphates, organochlorines, pyrethroids	Nonpolar pesticides were detected in neither organic nor conventional samples with amount above the limits. Conventional lettuce was detected with residue.
Hoefkens et al. (2009)	Potatoes carrot tomato lettuce	Meta-analyses data from peer-reviewed papers, reports and databases	Pesticide residues	The chloropropham residue in conventional potatoes is higher than that in organic potatoes. However, chlorothalonil residue displayed higher amount in organic potatoes compared with conventional samples. The iprodione amount was higher in conventional lettuces, tomatoes

TABLE 19 Overview of Pesticide Residue Comparisons in Organic and Conventional Food—cont'd

References	Samples	Analytical Method	Pesticides Residues	Key Results
				carrots. The pesticides residues in conventional vegetables are below the MRL.
Mir et al. (2009)	Pulp and peel from conventional and organic beet samples	Pesticide and herbicide residues: layer chromatography	Carbamates, organochlorides, organophosphates, herbicides	Presence of pesticides was not observed in the organic beet. There were pesticides in different beet parts in conventional beet, but pesticides was not observed in the conventional cooked beet probably the thermal treatment lead to the leaching of pesticides.
Fernandes et al. (2011)	Strawberries produced from organic farming and integrated pest management (IPM)	GC equipped with various detection modules including GC-ECD, GC-MS, and GC- MS/MS	14 organochlorine pesticides and their metabolites	β-endosulfan as well as lindane were detected with amount above the MRLs set for organic and IPM farming systems. Other organochlorine pesticides were found below the MRL.
Almeida-González et al. (2012)	Commercially available brands of cheese (54 conventional, 7 organic)	Organochlorine pesticides residues: GC/MS	22 organochlorine pesticides and the metabolites	A number of cheese brands were detected with nonquantitative amounts of residues. The organic cheese had lower concentrations than conventional samples.
Luzardo et al. (2012)	Milk (16 conventional and 10 organic)	Solid-phase extraction and gel permeation chromatography cleanup, organochlorine pesticides: GC/MS	Organochlorine pesticides and metabolites: diphenyl-aliphatic (methoxychlor, p, p-DDT, o,p-DDE, o, p-DDT, p,p-DDD, p, p-DDE, and o,p-DDD);	Hexachlorobenzene and trans-chlordane were present in almost all type of milk, but the daily intake estimated was way lower than the tolerable daily

Continued

TABLE 19 Overview of Pesticide Residue Comparisons in Organic and Conventional Food—cont'd

References	Samples	Analytical Method	Pesticides Residues	Key Results
			hexachlorobenzene (HCB); the four isomers of hexachlorocyclohexane (α-, β-, γ- lindane), δ-HCH); the cyclodienes dieldrin, endrin, aldrin, heptachlor (and cis-, trans-epoxides) and chlordane (cis-, trans-isomers); and endosulfan (α-, β-isomers)	intake. The organochlorine pesticides residues of both types of milk were of quite low amount, suggesting that organic milks contain fewer residues than conventional ones.
Lima et al. (2013)	Broccoli subjected to two sanitation treatments (chlorine, ozone)	Pesticide residues: thin layer chromatography	Organochlorine and other pesticide residues	No difference was shown between organic and conventional broccolis, because analyzed pesticides were not detectable.
Barański et al. (2014)	Crops, vegetables and fruits (n=98)	Review work based on over 300 publications	Pesticide residues	The occurrence frequency of pesticide residues was higher in conventional products such as vegetables and fruits than in organic products. One the other hand, the level of contamination was quite similar among different organic products.
de Souza Araújo et al. (2014)	Lettuce, peppers, and tomatoes	Pesticide extraction and purification: QuEChERS method Multi-residue analysis: LC-MS/MS, CG-MS/MS, UPLC MS/MS	Pesticide residues	No pesticide residue was found in the lettuce samples. Residues were, however, detected in pepper (conventional) and tomatoes (organic).
Yu et al. (2017)	10 pairs of organic and conventional vegetables (cabbage, pakchoi, Chinese	Pyrethroids residue extraction and preconcentration: magnetic solid phase	Pyrethroids residue: Beta-cyfluthrin, Decamethrin,	Four kinds of conventional vegetables and two kinds of organic

TABLE 19 Overview of Pesticide Residue Comparisons in Organic and Conventional Food—cont'd

References	Samples	Analytical Method	Pesticides Residues	Key Results
	kale, rape, Chinese chive, lettuce, amaranth, broccoli, cauliflower and Chinese cabbage)	extraction using the polystyrene-coated magnetic nanoparticles Residue analysis: HPLC	Fenvalerate, Permethrin, Bifenthrin	vegetables were detected with trace amount of pyrethroids residue while no violation was observed. Both the organic and conventional vegetables are safe because the pyrethroids residue detected in products were far more lower than the limitations.

Limit of detection: LOD; Maximum Residue Limit: MRL; QuEChERS: Quick, Easy, Cheap, Effective, Rugged, Safe; chromatography-tandem mass spectrometry: LC-MS/MS; gas chromatography-tandem mass spectrometry: CG-MS/MS; ultra-performance liquid chromatography: UPLC MS/MS.

TABLE 20 Antibiotics Category in Conventional Livestock Production

Antibiotics Categories	Antibiotics Uses	Antibiotics Property
Therapeutic treatment	To treat and cure diseased animals	High doses, therapeutic doses
Metaphylaxis	To medicating sick animals as well as surrounding healthy animals	Therapeutic doses
Prophylaxis	For healthy animals to prevent bacterial infections from occurring	Doses at low enough level, nontherapeutic levels
Growth promotion	For food animals to promote growth	Nontherapeutic levels

4.2 Antibiotics

With the development of animal husbandry, the use of veterinary drugs has increased significantly. Due to the broad antibacterial spectrum, some antibiotics are widely used as feed additives for the treatment of animal diseases and to promote animal growth. However, unreasonable use of antibiotics in animal-derived food in the presence of residues may endanger people's health, and many researchers are quite concerned about this. Tables 20 and 21 list commonly used antibiotics in the food supply chain.

As shown in Tables 20 and 21, the usage of antibiotics in conventional pastures is extremely common (McEwen and Fedorka-Cray, 2002; Bowling, 2009). In fact, in the United States, around 88% of growing swine receive antibiotics in their feed to prevent disease and promote growth (FDA, 2009). Organic livestock production may provide one of the simplest and most effective ways to reduce the proliferation of antibiotic-resistant bacteria, because the National

Organic Standards banned the usage of any antibiotics in organic farms and pastures (National Organic Program Regulations, 2016).

For antibiotics in organic food, in 1997, Smith studied conventional, natural, and organic beef samples (more than 60 muscle and adipose samples each, over 30 liver samples and over 20 kidney tissue samples), and revealed no violated antibiotics residues detected (Smith et al., 1997).

In recent years, the study of antibiotics in organic foods has been shown in Table 22 and Table 23.

From all the previously discussed studies, it can be determined that organic food resistance to antibiotics and sensitivity were stronger than conventional food; furthermore, the antibiotic residues data of organic food are still limited and conflicting, and definite conclusions rely on further reports.

TABLE 21 Commonly Used Veterinary Antibiotics

Antibiotics Category	Commonly Used Drugs
Tetracyclines	Tetracycline, oxytetracycline, minocycline, chlortetracycline,
Macrolides	Erythromycin, tylosin, tilmicosin
Quinolones	Ciprofloxacin, danofloxacin
Aminoglycosides	Amikacin, gentamicin, neomycin
β-lactams	Ampicillin, penicillin, desfuroylceftiofur
Sulfonamides	Sulfathia-zole, sulfamethazine, sulfadimethoxine
Streptogramins	Virginiamycin

TABLE 22 Overview of Antibiotic Resistance Comparisons in Organic and Conventional Food

References	Samples	Method Design	Indicator Analyzed	Key Results
Cui et al. (2005)	Organic and conventional chicken meat	Salmonella isolates genomic DNA fingerprinting profiles: pulsed field gel electrophoresis, antimicrobial resistance: agar dilution and the sensititre system	Antimicrobial resistance of campylobacter and salmonella	All of the conventional chicken samples tested contain *Salmonella enterica serovar* and *Typhimurium* with resistance to over five kinds of antimicrobials, but 79% isolates prepared from organic chicken samples could be killed by these antimicrobials.
Miranda et al. (2007)	Chicken	Antimicrobial susceptibility tests: disk diffusion method using Mueller-Hinton agar plates	Antimicrobial resistance to Enterococcus	According to the obtained data showing resistance, organic chicken isolates displayed less resistance to antibiotics compared with conventional counterparts. Both organic and conventional

TABLE 22 Overview of Antibiotic Resistance Comparisons in Organic and Conventional Food—cont'd

References	Samples	Method Design	Indicator Analyzed	Key Results
				chicken isolates were found to contain multi drug resistant strains, but such strains were found to exist in higher frequency in conventional chichen isolates compared with organic counterparts.
Hoogenboom et al. (2008)	Food products: pigs, broilers	Susceptibility of the isolates: broth micro-dilution method, minimum inhibitory concentrations (MICs)	Antibiotic resistance occurrence rate of *E. coli, Campylobacter and E. faecium.*	Faeces of organically raised pigs displayed lower occurrence rate for antibiotic resistant bacteria, except for *Campylobacter* in broilers.
Miranda et al. (2008a)	Chicken	Antimicrobial susceptibility testing: Mueller–Hinton agar plates using the agar disk diffusion method.	Antimicrobial resistance in Enterobacteriaceae	Organic chicken meat isolates showed lower level of resistance compared with conventional counterparts for multiple drugs including chloramphenicol, ampicillin, doxycycline, gentamicin, ciprofloxacin as well as sulfisoxazole. Strains with multi drug resistance were more frequently detected in conventional chicken isolates compared with organic counterparts. Generally, organic agricultural system promoted the decrease of occurrence rate of antibiotic resistant strains.
Miranda et al. (2008b)	Organic (n=54) and conventional (n=67) pork meat	Antimicrobial resistance: agar disk diffusion assay		Compared with conventional pork isolates, organic pork isolates displayed lower occurrence rate of antimicrobial resistance for ampicillin, sulfisoxazole as well as doxycycline. Multi-drug resistant *E coli* strains existed at significant higher rate in conventional pork compared to organic pork.
Miranda et al. (2008c)	Organic (n=55) and conventional (n=61) poultry meat	Antimicrobial tests: agar disk diffusion on Mueller-Hinton agar plates.	Antimicrobial resistance in *E.coli, Listeria monocytogenes and staphylococcus aureus.*	Organic poultry meat displayed lower occurrence rate for intestinal bacteria in antimicrobial resistance. As for multi-drug resistant strains, conventional poultry

Continued

TABLE 22 Overview of Antibiotic Resistance Comparisons in Organic and Conventional Food—cont'd

References	Samples	Method Design	Indicator Analyzed	Key Results
				showed significantly higher rates of existence in conventional poultry meat compared with organic poultry meat.
Lestari et al. (2009)	Salmonella isolates from conventional and organic chicken carcasses	Antimicrobial susceptibility testing: 15 antimicrobials, National antimicrobial resistance monitoring system.	Antimicrobial resistance of salmonella	Isolates from conventional chicken meat were susceptible to less antimicrobials compared with isolates from organic chicken meat tested.
Young et al. (2009)	Poultry swine beef	Systematic review and meta-analysis methodology of 38 published articles	Antimicrobials resistance	Isolated bacteria displayed higher antimicrobials resistance in conventional animal products
Kilonzon-Nthenge et al. (2015)	Chicken	Antimicrobial susceptibility: antimicrobial susceptibility test disc for antibiotics	*Enterococci* isolates antimicrobial resistance	Antimicrobial resistant *enterococci* isolates were detected in organic and conventional chicken meat. But the antimicrobial resistant *enterococci* exist at a lower rate in organic chicken compared with conventional chicken.

TABLE 23 Overview of Antibiotic Residues Comparisons in Organic and Conventional Food

References	Samples	Method Design	Antibiotics Analysed	Key Results
Blanco-Penedo et al. (2009)	Calves carcasses from organic (244), intensive (2596), and conventional (3021) farms	Data from the Official Inspector's Veterinary Record Book. data classification: SEUROP system (grades from S: superior to P: poor), visual fatness score (5 grades from 1: lean to 5: fat)	Drug residues	For drug residues, only one positive animal from an intensive farm was detected.
Bowling (2009)	Beef samples: USDA certified organic beefs; conventional beefs; ground beefs from market. Sample	Veterinary drug residues: UPLC-MS	Anti-inflammatory drug residues, antibiotic drugs,	Residues exceeding US tolerance limit were detected in 6 samples: including 2 samples from USDA certified

TABLE 23 Overview of Antibiotic Residues Comparisons in Organic and Conventional Food—cont'd

References	Samples	Method Design	Antibiotics Analysed	Key Results
	number were 100 each kind of product		nonsteroidal and β-agonist drugs	organic and 1 sample from conventional product.
Hu et al. (2010)	Organic vegetable in northern China	LC-MS-MS	Antibiotic residues concentrations	There was not any significant geographical difference for antibiotic distribution between manure and soil. Water transport may contribute more to antibiotics transfer, so as passive absorption of vegetables.
Guarddon et al. (2015)	Conventional (83) and organic (68) meat or vegetable-based baby foods	Tetracycline residues: receptor assay, plate reader at 450 nm	Tetracycline residues	The tetracycline residue contents were detected to exist at higher amount in organic baby foods compared with conventional baby foods.

Liquid chromatography coupled with triple-quadrupole mass spectrometry: UPLC-MS; Liquid chromatography coupled with tandem mass spectrometry: LC-MS-MS.

4.3 Heavy Metal Content

Because some farm characteristics might be different in the two agricultural systems, generally speaking, organic farms take locations with higher population density as well as busier traffic, whereas conventional farms are mostly located in rural areas with a smaller population and less traffic. However, until now, no clear evidence was found supporting this conclusion (Harcz et al., 2007).

Heavy metals pollutants are mainly introduced from the soil before harvest and during the packaging, transportation, and preparation of food products (Pussemier et al., 2006). Other causes of contamination include contamination related to the production system such as the usage of old instruments with degraded or broken materials, for example, kitchen utensils including teapot made from ceramics containing Pb.

As shown in Table 24, based on the 22 reports in recent years on the differences in the heavy metals concentration between conventional and organic foods, 45% of the studies (10 reports) showed there were no significant difference of heavy metals concentration between conventional foods and organic foods, 23% studies (5 reports) showed heavy metal in organic foods were lower than in conventional foods, and others (6 articles, 27%) suggested that the different metal or raw materials could result in various experimental results, whereas most of the experimental results indicated that most of the heavy metal concentrations in the tested food are below the statutory limit.

TABLE 24 Overview of Heavy Metals in Organic and Conventional Foods

References	Products Tested	Metals Analysis Method	Key Results
Jorhem and Slanina (2000)	Rye carrots potatoes	Concentrations of Cd, Pb, Cr, Zn: AAS	There was no significant difference in lead, caladium, chromium, and zinc concentrations detected between the cultivation systems.
Lindén et al. (2001)	Kidney and liver of pig	Cd: graphite furnace atomic absorption spectrometry	Organic pig kidneys were detected to have significantly higher levels of chromium compared to the conventional ones, but the pig livers did not show significant difference between organic and conventional pigs. The composition and Cd levels in individual components differed between the feed.
Karavoltsos et al. (2002)	93 different kinds of food and beverages	Cd: AAS	Cadmium content of organic food samples showed significantly lower contents compared with conventional samples.
Malmauret et al. (2002)	15 kinds of foodstuffs including meats, eggs, cereals, milks and vegetables (192 samples: 98 conventional, 94 organic products)	Pb, Cd, As, Hg: ETAAS	For lead, organic carrots, and buckwheat as well as conventional wheat exceeded the maximum levels set. The differences were not significant between organic and conventional samples.
Eurola et al. (2003)	3 types of oats trials: official variety, organic and conventional cultivation, nitrogen fertilization trials	Cadmium contents: ETAAS	The Cd concentrations were generally well below the permitted maximum level. No significant differences were found between the organic and the conventional cultivations.
Ghidini et al. (2005)	Milk and meat products	Pb, Cd: AAS	The difference was not significant between the conventional and organic milks and meats. No samples were tested to be above the legal limit set by EU.
Zagorska and Ciprovica (2005)	9 pair of organic and conventional milk	Cd, Pb, Cu, Zn: AAS	No significant difference was found between conventional and organic milks in heavy metals levels.
Harcz et al. (2007)	Winter wheat (over 200 samples for caladium and lead, and over 150 samples for mercury)	Mercury: mercury analyser AMA245, Cd and Pb contents: ICP-MS	The concentrations of caladium and mercury showed no significant difference, but lead content were higher in organic cereals compared with conventional counterparts.
Hoogenboom et al. (2008)	Food products (wheat, lettuce, carrots, potatoes, pigs, laying hens, broilers)	Cd, Pb, As, Hg: AAS	Organic products showed equal contents of heavy metals. No difference was observed between conventional and organic product.

TABLE 24 Overview of Heavy Metals in Organic and Conventional Foods—cont'd

References	Products Tested	Metals Analysis Method	Key Results
Gabryszuk et al. (2008)	Milk	Toxic elements Cd, Pb, Hg, As, Al: inductively coupled plasma atomic emission spectroscopy	Caladium and lead contents of milks were detected with highest concentration with samples collected from conventional farms. However, content of mercury was low for conventional milks. As for aluminum and arsenic, no significant difference was found between the two kinds of farms. The contents of toxics were below the admissible level.
Karavoltsos et al. (2008)	Over 50 different kinds of organic and conventional food products and beverages bought from Greek local markets	Cadmium and lead determinations: graphite furnace AAS	According to the results, "uncertified" organic food products have higher amount of caladium and lead compared to certified organic foods and conventional foods.
Giannenas et al. (2009)	Courtyard, conventional, and organic eggs	Trace minerals: ICP-MS	Albumens of courtyard eggs were highest in chromium and zinc. As for amounts of selenium, manganese, cobalt, copper, molybdenum, vanadium, nickel, titanium, arsenate, and caladium, organic and conventional eggs contain similar amounts. Yolks contain higher amounts of trace elements compared with albumens.
Hoefkens et al. (2009)	Potatoes, carrot, tomato, and lettuce	Cd, Pb Meta-analyses data from peer-reviewed papers, reports and databases	There was no significant variation for the heavy metals Cd and Pb between conventional and organic vegetables such as potatoes.
Blanco-Penedo et al. (2010)	Beef	Low concentrations elements: ICP–MS; higher concentrations elements: ICP–OES	Cd concentration was low, and As, Hg, and Pb contents were all below the detection limits in most of the samples tested (over 70%). No significant difference was reported between different farms.
Tomza-Marciniak et al. (2011)	Serum of cattle from organic and conventional farm	Pb, Zn, Fe, Cu, Cr, Ni, As, Al: inductively coupled plasma atomic emission spectrometry	Organic cattle were found of significantly lower serum concentrations of heavy metals compared with conventional farm raised cattle.
Xie et al. (2011)	Chinese shrimp	Cd, Cu, Pb, Zn: AAS	For all the shrimp samples tested, the amount of copper, zinc, caladium, and lead were below the maximum residue levels permitted. The conventional shrimp samples were significantly higher in heavy metal contents compared the organic shrimps.

Continued

TABLE 24 Overview of Heavy Metals in Organic and Conventional Foods—cont'd

References	Products Tested	Metals Analysis Method	Key Results
Vrček et al. (2011)	Wines	Element Pb, As, Cr, Ni, Co, Mo, Cd, Tl, Zn, Se, Sn concentrations: multi-element ICP-MS analysis	There was no obvious trend in the metal contents of the wines. All of the wines were below the safe limits.
Vrček and Vinković Vrček (2012)	Wheat flours	Toxic metals Al, As, Cd, Pb contents: ICP-MS	Data showed that toxic metal amounts in conventional samples were higher compared to organic wheat flours. Both samples never exceeded the Commission Regulation (EC 466/2001/EC).
Barański et al. (2014)	98 relevant crops and foods	Meta-analyses based on 343 peer-reviewed publications	Crops grown organically have lower concentrations of Cd than the conventional crops across regions and production seasons. No significant difference was reported for As and Pb amounts between conventional and organic crops.
de Souza Araújo et al. (2014)	Lettuce, peppers, and tomatoes	Heavy metals Cd, Ni, Pb: AAS	The composition of heavy metals under study varied among all the vegetables: lead and caladium contents displayed no significant difference between conventional and organic lettuces. However, organic lettuces contained significantly higher amount of nickel compared to the conventional samples lettuces. Twice as much as nickel was detected in conventional peppers compared to organic ones. No significant difference was observed between the two kinds of tomatoes.
Ilić et al. (2014)	Tomato	Zn, Pb, Cu, Cr, Ni, Co, Cd: AAS	Significantly higher amounts of lead, zinc, copper, and nickel were found in conventional tomatoes whereas the farming practice had no significant influence on caladium, cobalt, and chromium amounts in cultivars. Contaminants levels were lower than the maximum limits.
Vrček et al. (2014)	Wheat flours	Al, As, Cd, Pb contents: ICP-MS	Four toxic metals were detected to exist in higher levels in conventional flours compared with organic samples, but both agricultural samples never exceeded the Commission Regulation (EC 1881/2006).

AAS: atomic absorption spectrophotometer; ICP-MS: Inductively Coupled Plasma Mass Spectrometry; ETAAS: electrothermal atomic absorption; inductively coupled plasma atomic emission spectrometry: ICP–OES.

4.4 Mycotoxin

Mycotoxins mainly refer to mold-derived toxic metabolites in contaminated food, which can be through feed or food into humans and animals, causing acute and chronic toxicity of human and animal, even damage the body's liver, kidneys, nerve tissue, hematopoietic tissue, and skin tissue (Yu et al., 2019).

More than 300 mycotoxins were studied, and results of commonly detected mycotoxins are displayed in Table 25. Most mycotoxins are low molecular stable compounds, and they have some characteristics as shown in Table 26.

In addition to these characteristics, cereals are usually contaminated with various molds, such as *Aspergillus, Fusarium,* as well as *Penicillium.* These molds produce secondary metabolites called mycotoxins. Some of the mycotoxins are highly dangerous. They have strong heat resistance and thus could be transferred to various processed food products from plants and animals along the production chain (Vrček et al., 2014).

As shown in Table 27, according to the 22 studies showing the difference in the mycotoxin contamination in both conventional and organic food products, 59% studies (13 articles) showed that there was no significant difference between the two agricultural systems, 27% of the studies (6 articles) showed that the amounts of mycotoxin in organic foods were higher compared to those in conventional foods, and only 14% of the studies (3 articles) suggested that mycotoxin in conventional foods were higher than organic foods.

TABLE 25 Main Categories of Mycotoxins in Food

Mycotoxins	Main Source	Main Properties
Aflatoxin	Corn, peanut	Toxicity, teratogenic, carcinogenic, mutagenic
Zearalenone (ZEN/ ZON)	Corn	Estrogen-like effect, resistant to heat treatment
Ochratoxin	Corn, nut, coffee	Carcinogenic, teratogenic, mutagenic
Trichothecenes (T2)	Corn, wheat, barley, oats	Carcinogenic, teratogenic, mutagenic
Deoxynivalenol (DON)	Corn, wheat, barley, Oats	Most common fusarium mycotoxin, resistant to heat treatment
Fumonisins	Corn, sorghum	Carcinogenic, FB1 is the most common pollution
Islanditoxin	Rice	Carcinogenic, liver injury
Patulin	Apple, pear, tomato, hawthorn, fruit product	Toxicity, optimum temperature: 20-25°C, optimum pH: 3-6.5
Citrinin	Rice, barley, monascus products	Nephrotoxicity

TABLE 26 Mycotoxins Characteristics

Specificity: different molecular structure can greatly affect toxicity
Synergy: various of mycotoxins can increase the toxicity
High efficiency: very low concentration (mg/L or μg/L) can produce significant toxicity

TABLE 27 Summary of Mycotoxins in Organic and Conventional Foods Comparison Studies

References	Samples	Method Design	Mycotoxins Analyzed	Key Results
Ghidini et al. (2005)	Milk	Aflatoxin M_1 determination: immune enzymatic tests using ELISA technique	AFM_1	The AFM_1 concentrations in some but not all organic milk samples were higher than those detected in conventional milk samples. However, the difference might be caused by many factors. Organic production system is just one of them.
Piemontese et al. (2005)	100 conventional and 69 organic fruity foodstuffs samples	Patulin determination: HPLC	Patulin	The organic fruit products showed higher occurrence rate of patulin as compared with conventional fruit samples.
Schollenberger et al. (2005)	Bread (n=101)	Deoxynivalenol content: GC-MS	Deoxynivalenol	The median DON levels were higher in conventional breads compared with organic counterparts.
Anselme et al. (2006)	Beers	Mycotoxin analysis: HPLC	Ochratoxin A, deoxynivalenol	Organic beers were more frequently detected to contain OTA and DON contamination compared with conventional beers while no violation was reported for all samples tested no matter organic or conventional. The variation caused by batch difference was more obvious than that of brand, suggesting that raw material might bring in much variation for beers.
González et al. (2006)	Organic (n=20) and nonorganic (n=64) rice and rice products	OTA extraction: accelerated solvent extraction (ASE) OTA analysis: LC-FLD	OTA	The OTA occurrence rate in organic rice and related products of rice is higher than conventional rice and related products.
Ariño et al. (2007)	Corn	Fumonisins determination: LC-FLD	Fumonisins B_1 and B_2	The difference in fumonisin concentrations between conventional and organic corns was not significant, and the fumonisin levels in samples were far below the maximum residue levels set in EU regulation, which means no violation was reported.

TABLE 27 Summary of Mycotoxins in Organic and Conventional Foods Comparison Studies—cont'd

References	Samples	Method Design	Mycotoxins Analyzed	Key Results
Harcz et al. (2007)	Winter wheat	Analysis of the databases in Belgium	DON, Zea	The levels of mycotoxin were higher of the conventional cereals, but there was no significant difference between the conventional and organic cereal samples.
Hoogenboom et al. (2008)	Wheat (n=71)	Mycotoxins: LC-MS/MS Zearalenone: HPLC and fluorescence detection	Aflatoxin B_1, ochratoxin A, deoxynivalenol, T-2, fumonisins B_1 and B_2, zearalenone, and HT-2 toxins.	No significant difference was detected between conventional and organic wheats. However, a possible trend was observed that organic cereals might contain less mycotoxins compared with conventional wheats.
Juan et al. (2008)	Cereals and cereal products (n=83)	OTA extraction: matrix solid phase dispersion (MSPD) OTA analysis: LC-FLD	OTA	A higher incidence of OTA as well as higher amount detected was observed in organic cereals compared with conventional counterparts.
Edwards (2009a)	Barley	Trichothecenes: GC/MS	Deoxynivalenol, nivalenol, diacetoxyscirpenol, neosolaniol, fusarenone X, 3-acetyl DON, 15-acetyl DON, HT-2 toxin, T-2 toxin, and T-2 triol	No significant difference was found in the mycotoxins amounts between organic and conventional barleys.
Edwards (2009b)	Wheat	Trichothecenes: GC/MS zearalenone: HPLC	DON, nivalenol, 3-acetyl-DON, 15-acetyl-DON, fusarenone X, T2 toxin, HT2 toxin, diacetoxyscirpenol, neosolaniol and T-2 triol	No significant differences were found in mycotoxins concentration of organic and conventional samples.
Bernhoft et al. (2010)	Barley, oats, and wheat (n=602)	Trichothecene analysis: GC–MS Zearalenone analysis: HPLC Moniliformin analysis: HPLC	Trichothecene (HT-2, T-2, DON, NIV), ZON, Moniliformin	Fusarium infestation and mycotoxins levels were significantly lower in all cereal samples grown organically than conventionally.

Continued

TABLE 27 Summary of Mycotoxins in Organic and Conventional Foods Comparison Studies—cont'd

References	Samples	Method Design	Mycotoxins Analyzed	Key Results
Pattono et al. (2011)	Organic (n=63) and conventional (n=20) milk	Ochratoxin A: HPLC	OTA	Three organic samples (4.8%) were positive for OTA, but the amount of OTA detected was considerably lower than the maximum limit. No conventional sample resulted positive.
Malissiova et al. (2013)	Ewe and goat milk	AFM_1sample screening: ELISA AFM_1analysis: HPLC-FLD	AFM_1	Organic milks were not proved to contain less AFM1 than conventional samples. Actually higher level of contaminants is possible compared to conventional milks.
Kuzdraliński et al. (2013)	Oats	Mycotoxin determination: ELISA NIV, HT-2 and DAS toxins: GC–ECD and GC–MS	DON, T-2, HT-2, DAS, NIV, and aflatoxins(B_1, B_2, G_1 and G_2)	Mycotoxins concentration was a little higher in conventional oats compared with organic samples, but the number of mycotoxin-positive samples was higher in organic farming in comparison to conventional.
Serrano et al. (2013)	Pasta	Fusarium mycotoxins: Ultra-Turrax extraction followed byMS/MS QqQ	ENs, BEA and FUS	There were higher frequencies of fusarium contamination in organic pasta than in conventional samples, but the concentration levels were variable of both types of pasta.
Blajet-Kosicka et al. (2014)	Conventional (n = 42) and organic (n = 75) rye grain and rye products	Mycotoxins analyses: LC-MS/MS	DON, NIV, 3ADON, T-2, HT-2, MAS, DAS, ZEN	Conventional samples were more contaminated with DON and ZEN than the organic samples.
Vrček et al. (2014)	Wheat flours	Mycotoxin analyses: HPLC with fluorescence detection	ZON, OTA	Mycotoxins were no significant difference between conventional and organic wheat flours samples.
Armorini et al. (2015)	Flour	AFB_1 analysis: HPLC–FD	AFB_1	No significant difference in AFB1 pollution in conventional and organic samples. Except in one case, the AFB1 levels never exceed the legal limit.
Ruiz et al. (2015)	Maize	Mycotoxins: commercial kit Veratox, competitive direct ELISA (CD-ELISA)	Fumonisin and deoxynivalenol	No significant difference was reported in maize samples between conventional and organic farms.

TABLE 27 Summary of Mycotoxins in Organic and Conventional Foods Comparison Studies—cont'd

References	Samples	Method Design	Mycotoxins Analyzed	Key Results
Armorini et al. (2016)	Conventional (n = 36) and organic (n = 22) milk products	Aflatoxin M_1 extraction: immunoaffinity column extraction/clean-up, aflatoxin M_1 analyze: HPLC-FD	AFM_1	No statistically significant differences were observed in the concentration of AFM_1 in the two categories of product. No sample exceeded the AFM_1 legal limit for milk.
Sifuenteset al. (2016)	Pasteurized and raw milk samples	Aflatoxin M_1 determination: ELISA	AFM_1	Among the organic and conventional samples, no significant difference was found to exist. None of the samples contaminated with aflatoxin M_1 was detected to violate Brazilian laws.

ELISA: Enzyme-linked immunosorbent assay, GC–ECD: gas chromatography coupled to electron capture detector, GC-MS: gas chromatography-mass spectrometry, LC-FLD/LC–FD: liquid chromatography coupled to fluorescence detection, HPLC–FD: high performance liquid chromatography coupled with fluorescence detection, LC-MS/MS QqQ: liquid chromatography coupled to triple quadrupole mass spectrometer detector, MAS: monoacetoxyscirpenol, AF:aflatoxin, ZEN/ZON: zearalenone, OTA: ochratoxin A, FUS: fusaproliferin, DON: deoxynivalenol, NIV: nivalenol, ENs: enniatins, 3ADON: 3-acetyldeoxynivalenol, T-2: T-2 toxin, HT-2: HT-2 toxin, DAS: diacetoxyscirpenol, BEA: beauvericin.

Some results could be observed in which the occurrence rate of mycotoxins in organic food is higher than in conventional samples. This may be true because organic production involves practices such as using nonsynthetic fungicides, fertilizers, and pesticides, and strict prohibition of using genetically modified products, thus causing a higher possibility of the growth of fungi, producing more mycotoxins (González et al., 2006).

4.5 Nitrates and Nitrites

The content of nitrates is an important parameter for evaluating the quality of vegetable agricultural products. Nitrates are actually nontoxic. However, the metabolites of nitrates might cause adverse effect on the health of consumers. According to some researchers' publications, nitrate actually plays an important role in helping us defend gastroenteritis (Santamaria, 2006).

The nitrate content in vegetables depends on numerous variables such as the time of the year, the temperature, the farming practices, sunshine, and also pest management (Dich et al., 1996; Yang et al., 2014). Because modern intensive agriculture requires the usage of many fertilizers containing nitrogen as well as manure of livestock, our drinking water, fruits, and vegetables have a higher possibility to be contaminated by more nitrates compared to the past (Santamaria, 2006). Lower occurrence rate of nitrites in organic farms might be attributed to special farming practices such as the denitrification for soils (Reeve et al., 2010).

TABLE 28 Summary of Comparison of Nitrate in Organic and Conventional Foods

References	Samples	Method Design	Key Results
Joice et al. (2005)	Milk ($n = 45$)	Nitrate: Ion chromatography	Nitrate levels in raw milk were no significant difference between the production systems.
Hoogenboom et al. (2008)	Lettuce, carrots and potatoes	Nitrate: SKALAR hydrazinium reduction method	Nitrate levels in organic lettuce were much lower than those in conventional products. Nitrate levels in organic carrots and organic potatoes showed a large variation.
Lima et al. (2009)	Chinese cabbage and maize	Nitrate content: compact ion meter	Higher concentration of nitrate was found in organic samples than conventional samples.
Gąstoł et al. (2011)	Fruit and vegetable (apple, pear, blackcurrant, carrot, beetroot celery) juices	Nitrate content: FIA method	Nitrates content were lower in organic vegetable juices than in conventional ones, while the species was an important factor influencing nitrate level. The nitrate concentrations determined were very low. No differences were found between conventional and organic fruit juices.
Kalinova and Vrchotova (2011)	Buckwheat	Nitrate content: HPLC	The nitrate content was higher in conventional buckwheat compared with the organic samples.
Gorenjak et al. (2012)	Various varieties and different types of cultivation for lettuce and dandelion	Nitrate/nitrite concentration: EN 12014-7 1998 standard protocol, using continuous flow (CF) analyser	No major differences were recorded between the dandelion samples, the nitrate content were very low. The mean nitrate contents in organic lettuce were considerably lower than those in conventional lettuce.
Koh et al. (2012)	Spinach	Nitrate Analysis: HPLC	Mean levels of nitrate were significantly higher in conventional spinaches compared to organic samples.
Lombardo et al. (2012)	Potato	Nitrate content: ion selective electrode method	The nitrate content in the organic tubers was 34% less than in the conventional products.
Nuñez et al. (2012)	Meat	Nitrite and nitrate residue: ENO-20 HPLC system equipped with a reverse phase column	No differences were of nitrite concentrations between conventional and organic meats, while some organic

TABLE 28 Summary of Comparison of Nitrate in Organic and Conventional Foods—cont'd

References	Samples	Method Design	Key Results
			products studied in certain cities contained lower amount of nitrate.
Aires et al. (2013)	6 kinds of baby-leaf salads (red and green lettuces, rucola, corn salad, watercress, and chard)	Nitrate and nitrite contents: spectrophotometric method on foodstuff after zinc reduction and Griess reaction	The nitrates average levels were significantly higher in conventional produce. There were no significant differences of nitrite content. The nitrate and nitrite detected in samples are within the legal limits (EU).
Laursen et al. (2013)	Potato from three cropping systems: conventional, organic with animal manure, and organic with green manures	Nitrate content: ion chromatography	There were no significant differences between systems, locations, or harvest years.
Ilić et al. (2014)	Tomato	Nitrates analysis: Serbian standard, colorimetric procedure according to SRPS EN 12014-2	The nitrate contents of tomatoes were influenced greatly by cultivar. Lower nitrate contents were observed in organic products compared to conventional ones.
Nuñez De González et al. (2015)	Vegetables (broccoli, cabbage, celery, lettuce, and spinach)	Nitrate and nitrite concentrations: HPLC	There was no difference in the average nitrite contents of conventional vegetables compared to organic vegetables. Significant difference of nitrate contents was reported between some organic and conventional vegetables
Rossetto et al. (2015)	Raw and cooked vegetables (broccoli, collard greens, carrots and beets)	Nitrate content: nitrate card	Nitrate contents showed significant difference between conventional and organic broccolis, carrots, and collard greens. Organic beets contain lower nitrate compared with its conventional counterpart.

According to Table 28, based on 14 studies in recent years on the difference between the contents of nitrate and nitrite in organic and conventional food products, 43% studies (6 articles) showed that there was no significant difference between the two agricultural systems, 36% of the studies (5 articles) suggested that nitrate or nitrite contents in organic foods were lower than conventional foods, 14% of the studies (2 articles) suggested that the species was an important factor influencing nitrate level, and only one study (7%) suggested that nitrate contents in organic foods were higher than in conventional counterparts. Results showed that organic foods had certain advantages in the nitrite content.

5 CONCLUSION

Whether or not the nutrition value of organic food is superior to conventional food has been a controversial issue. In this chapter, recent research was reviewed and analyzed. Although the existing research data could not draw a definitive conclusion, the results showed some trends. In the study of carbohydrates and proteins, products from different sources did not show significant differences. However, at least some published papers indicated that organic foods have shown advantages in some studies of fatty acid composition. In addition, organic foods usually contain more vitamins, some trace elements, and antioxidants (such as polyphenols, flavonoids or lycopene, etc.) than conventional foods. However, because many of these reports did not control the equivalent soil, water, and fertilizer, etc., further experiments should be conducted for comparing the nutrients between organic and conventional foods.

From the chemical safety perspective, pesticides, heavy metal residues, and nitrates remain at a very low level under the legal limit in most of the organic foods. Furthermore, antimicrobial resistance in organic food was lower than conventional counterparts. However, many reports indicate that no significant difference was found in mycotoxin content between conventional foods and organic counterparts.

In this study, we also found that the quality of organic foods was related to various aspects of the food production process, such as planting or breeding environment, maturity or harvest period, package, processing, and storage. Therefore, it is essential to take into account these factors when we study the quality difference of food under different patterns.

In the future, as there are few studies on the role and utilization of nutrient in organic food, more research on human epidemiology and animal testing can be done on organic food, and it may be possible to provide further evidence on whether organic food contains more of certain nutrients than conventional counterparts.

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