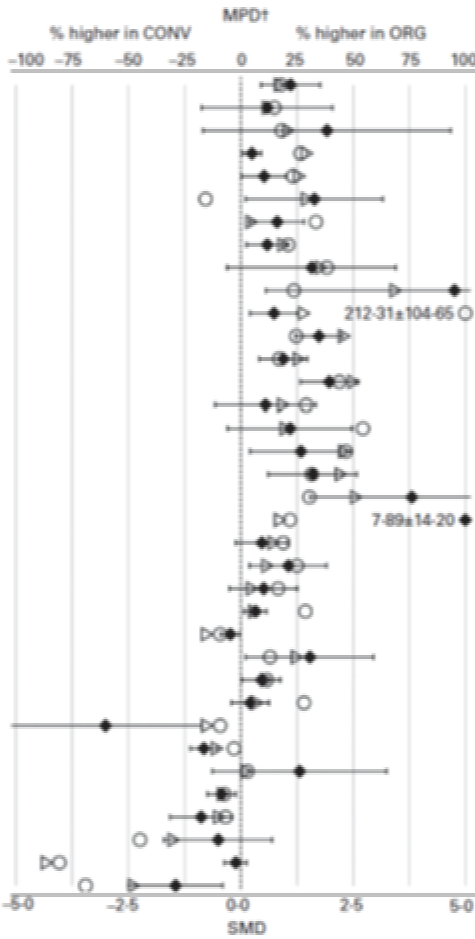
5.4. Effect of Organic farming on the nutritional value of plants for humans

Theoretically organic crops should perform just as well as conventional crops in terms of biomass when adequate nutrients and pest protection are provided. However, available capital, labour, machinery and variable soil and climatic conditions make it more challenging to produce crops organically in some places than in others. In general, literature reviews and meta-analyses have shown organic yields to be 60–100% that of conventional systems. In a metareview of 316 crops in 66 studies, Seufert *et al.* (2017) show that average yields from organic farms are globally 20% lower than from conventional farms. Similar results were found by de Ponti *et al.* (2012). Although yield themselves are lower: a study by Knorr and Vogtmann (1983) indicates that storage losses might be lower in organically grown compared to conventionally grown crops. For example, postharvest storage losses of the following organically grown crops were significantly reduced: potatoes with 17.7%, carrots 18.0%, turnips 15.7% and beets 29.4%. Thus, although the yield at harvest of organically grown crops is lower, lower storage loss of organically grown crops can result in a higher final yield and starch content after storage.

Before we address effects of organic crops on human health, it should be noted that organic farming is not a clear cut "treatment" with a clearly defined control "conventional farming". There are many differences between countries, regions and individual farmers for both types of agronomic practices. Nevertheless, on a policy level organic practices and regulations do not differ substantially between countries (Seufert *et al.* 2017). In general, organic regulations define organic mainly in terms of 'natural' vs. 'artificial' substances that are allowed, or not permitted, as inputs. Of course, this has effects on cultivation itself, but the interpretation of organic as "chemical-free" farming, is largely a void of broader environmental principles. That is, organic as "chemical-free" farming does not fully incorporate the original ideas of organic theoreticians. It was originally conceived as a holistic farming system aimed primarily at improving soil health, and secondarily would lead to long term improvements in animal, human, and societal health (William A. Albrecht (1888–1974) among others). The narrow focus of organic regulations on "chemical-free" farming can be explained by the interest of organic consumers who predominantly buy organic because they believe it is healthier and more nutritious due to the absence of harmful substances. Note however that "chemical-free" farming is not equivalent to sustainable farming. Current regulations lack emphasis on environmental best practices and do not centralise soil health. As can be derived from the previous paragraphs, mineral uptake is mainly determined by soil fertility. Although soil fertility is not thoroughly targeted by regulations on organic farming, most organic farmers are aware of the importance of soil fertility for the health of their crop and take cultivation measures accordingly. As reviewed by Reganold and Wachter (2016) many studies have found that organic farming systems consistently have greater soil carbon levels, better soil quality and less soil erosion and lower N input compared with conventional systems.

In summary, policy pushes organic farming towards "chemical-free" farming although many organic farmers have a more holistic view and want to create a healthy sustainable agricultural ecosystem. It is therefore surprising to read in the meta-analyses articles Dangour *et al.* (2009), Smith-Spangler *et al.* (2012), Hoefkens *et al.* (2009) that there are no significant composition differences between organic and conventional crops. However, diving deeper in literature reveals that quantitative reviews and meta-analyses greatly disagree. As other studies (Brandt and Mølgaard 2001; Worthington 2001; Smith-Spangler *et al.* 2012; Baraski *et al.* 2014) did find significant increase in nutrient content. The most recent study by Baranski *et al* (2014) point out that the main reason for the inability of previous studies to detect composition differences was probably the limited number of datasets available or included in analyses by these authors, which would have decreased the statistical power of the meta-analyses. Other reasons for the disagreements can be traced to whether nutrient content was measured on a dry matter or fresh weight basis. Organic foods are generally higher in dry matter content, therefore it is very likely that the actual consumed fresh weight is higher in nutrient content. However, when measured on a dry weight basis differences will not be detected. Another factor that makes it hard to relate organic practices to human health effects is the fact that human nutritionists have not reached a consensus on what the actual beneficial phytochemicals in fruit and vegetables are (see Chapter 2).

Nevertheless, Baranski *et al* (2014) was the most recent study and did a thorough meta-analysis on the effects of organic farming and found that there are potential nutritional benefits of higher concentrations of antioxidant/(poly)phenolics in organic crops, lower risks associated with potentially harmful pesticide residues and lower Cd levels (Figure 5.10). This meta-analysis detected furthermore significantly higher concentrations of total carbohydrates and significantly lower concentrations of proteins, amino acids and fibre in organic crops/crop-based compound foods. Aside from lower N (protein), NO_2^- and NO_3^- levels, most macro and micro elements were unchanged by organic farming. There was, however, a small elevation in Mg, Mo and Zn in organic farming. Lowering levels of NO_2^- is generally regarded as healthy. Higher levels of Mg and Zn might also contribute to increased health. As expected and discussed, both in §5.3.1 and the beginning of this paragraph, differences in location, practices, cultivars etc., caused that data heterogeneity in this study was extremely high (Figure 5.10).



Parameters	Unweighted meta-analysis *n*	Ln ratio‡	*P**	Weighted meta-analysis *n*	*P**	Heterogeneity§
Antioxidant activity	160	4·74	<0·001	66	0·001	Yes (96 %)
FRAP	14	4·73	0·013	5	0·436	Yes (90 %)
ORAC	8	4·76	0·011	4	0·176	Yes (95 %)
TEAC	22	4·80	<0·001	7	0·030	Yes (26 %)
Phenolic compounds	129	4·74	<0·001	58	0·051	Yes (93 %)
Flavonoids (total)	20	4·54	0·282	8	0·039	Yes (89 %)
Phenolic acids (total)	9	4·85	0·008	3	0·012	Yes (86 %)
Phenolic acids‖¶	153	4·72	0·002	89	0·015	Yes (97 %)
Chlorogenic acid	24	4·84	0·009	14	0·103	Yes (98 %)
Flavanones‖¶	75	4·73	0·100	54	0·027	Yes (100 %)
Stilbenes	8	5·42	0·005	4	0·008	No (1 %)
Flavones and flavonols‖	194	4·78	<0·001	134	<0·001	Yes (97 %)
Flavones‖	27	4·72	0·063	23	0·001	Yes (85 %)
Flavonols‖¶	168	4·81	<0·001	111	<0·001	Yes (98 %)
Quercetin	23	4·79	0·028	17	0·341	Yes (95 %)
Rutin	12	4·93	0·013	9	0·127	Yes (96 %)
Kaempferol	14	4·90	0·006	13	0·023	Yes (94 %)
Anthocyanins (total)	20	4·82	<0·001	10	0·002	Yes (82 %)
Anthocyanins‖	53	4·79	0·004	22	0·001	Yes (99 %)
Carotenoids (total)	15	4·78	0·005	4	0·271	Yes (100 %)
Carotenoids‖¶	163	4·71	<0·001	82	0·126	Yes (98 %)
Xanthophylls¶	66	4·78	<0·001	33	0·018	Yes (97 %)
Lutein	21	4·74	0·019	13	0·203	Yes (90 %)
L-Ascorbic acid	65	4·73	0·005	30	0·018	Yes (76 %)
Vitamin E	25	4·56	0·300	15	0·046	No (0 %)
Carbohydrates (total)	60	4·71	0·003	16	0·037	Yes (98 %)
Carbohydrates‖¶	111	4·68	0·001	53	0·049	Yes (93 %)
Sugars (reducing)	20	4·78	0·034	3	0·360	No (0 %)
Protein (total)	87	4·53	<0·001	26	0·007	Yes (99 %)
Amino acids‖¶	332	4·58	0·001	117	<0·001	Yes (91 %)
DM¶	129	4·63	0·001	24	0·191	Yes (99 %)
Fibre	19	4·54	0·010	15	0·017	Yes (42 %)
N	88	4·55	0·001	35	0·015	Yes (97 %)
Nitrate¶	79	4·33	0·001	29	0·429	Yes (99 %)
Nitrite	15	4·17	<0·001	7	0·419	No (0 %)
Cd	62	4·25	<0·001	25	0·008	Yes (98 %)

Figure 5.10: Results of the standard unweighted and weighted meta-analyses for antioxidant activity, plant secondary metabolites with antioxidant activity, macronutrients, nitrogen compounds and cadmium (data reported for all crops and crop-based foods included in the same analysis). MPD, mean percentage difference; CONV, conventional food samples; ORG, organic food samples; n, number of data points included in the meta-analyses; FRAP, ferric reducing antioxidant potential; ORAC, oxygen radical absorbance capacity; TEAC, Trolox equivalent antioxidant capacity; SMD, standardised mean difference. Values are standardised mean differences, with 95 % confidence intervals represented by horizontal bars. * P value < 0.05 indicates a significant difference between ORG and CONV.†Numerical values for MPD; ‡Ln ratio = Ln(ORG/CONV £ 100 %). §Hetero-geneity and the I^2 statistic. || Data reported for different compounds within the same chemical group were included in the same meta-analyses. ¶ Outlying data points (where the MPD between ORG and CONV was more than fifty times greater than the mean value including the outliers) were removed. w, MPD calculated using data included in the standard unweighted meta-analysis; ¡, MPD calculated using data included in the standard weighted meta-analysis; ® SMD.

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