

Is Organic Produce Nutritionally Superior to Conventional?

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*A comment-enabled version of this can be found on my blog at <http://wp.me/pH6F5-1/>
An HTML (and, effectively, the most up to date) version can be read at: <http://tinyurl.com/organic-nutrition>*

One reason that consumers feel that organic food is better than “conventional” and worth a premium price is that it is supposed to be more nutritious. What is meant by “more nutritious.”? What specific nutrients are being referred to? Are there nutrients that conventional food has more of, but that are considered harmful? When I looked into it, there appears to be no real scientific support for the claim that organic food is nutritionally superior to conventional, or even that different. In this entry I will look at what the latest science has to say on the matter.

The article is broken up into two parts. The first goes over Vitamin C and Nitrates, which are the two items that come up most often when discussing the differences between organic and convention -- organic claimed to be higher in Vitamin C and lower in nitrates and therefore better. The second part looks at the actual systematic reviews that have been done on this very question from the most recent in 2009 to an earlier one in 2000. There is also an appendix in which I thought it would be interesting to talk a bit about the most frequent studies referenced by the reviews (basically, what did the reviewers review).

Notes on a couple of nutrients

Vitamin C

While in general there seems to be no difference between organic and conventional, my reading is that there *might* be a slight trend toward some fruits and vegetables having a higher ascorbic acid (Vitamin C) content, however this conclusion is not supported by the most recent and, arguably, thorough review. Regardless, in the case of Vitamin C, the [recommended daily intake](#) is about about 75-90 mg for an adult. [1 cup of the orange slices has about 95mg](#) ¹(USDA DB 2010). I have seen some references put a single orange around 75mg. So if you have an orange and some peppers or tomatoes in a day, you will be well above the amount your body can hold in any case and will just release it in your urine. So it would not seem to matter much, even if organic produce does have a trend toward slightly higher Vitamin C.

Nitrates

Even in more recent studies, conventional produce tends to have a higher nitrate content (generally due to differences in fertilizers), which proponents of organic food consider to be a major win. It seems that they are holding on to pre-2000 notions on the safety of dietary nitrate content. In [1945 there were 2 cases of methemoglobinemia](#) (“blue baby syndrome”) in small infants which they traced to very high concentrations of nitrate in rural well water. This led to

¹USDA. “USDA National Nutrient Database for Standard Reference, Release 22”. <http://www.ars.usda.gov/SP2UserFiles/Place/12354500/Data/SR22/nutrlist/sr22w401.pdf> Visited August 18, 2010

limits on drinking water levels of [10 ppm](#) ²(EPA 2009). Additionally, In the 1970s it was believed that dietary nitrate was a potential carcinogen, but this conclusion was not able to be supported by the science done since then.

Research starting around 1994 demonstrated that dietary nitrate is actually quite beneficial in helping to fight disease pathogens in the mouth and gut. This is because it acts as an [alternative source of nitric oxide](#) ³, an important product in our bodies to help prevent stroke and ulcers (Lundberg 2008). Fascinatingly, its not our own bodies that does the conversion from nitrate to nitrite and nitric oxide, but rather [symbiotic bacteria living in our mouths](#) ⁴ and stomach (sounds gross, but is good!)(Duncan 1995). It seems in fact, that dietary nitrate presents no real health hazard to children or adults. There is also an entire book devoted to this question entitled [Nitrate and Man: Toxic, Harmless or Beneficial](#) by J. L'hirondel.

So it appears to be only infants < 6 months of age where there is any concern about nitrate levels, due to fears about [methemoglobinemia](#) (Greer 2005 ⁵), and that is really only related to contaminated well water used for formula and some very high nitrate-level foods (beets, green beans, squash carrots). Those foods have high nitrates on their own, switching to organic certainly would have no effect in this case, and the recommendation for small infants is to simply avoid them.

Note that these aren't just obscure arguments in scientific journals, it has in fact been picked up by the media [mainstream media](#) (Minkel 2004 ⁶) and [blogs](#) (pponline ⁷). So it makes sense for earlier reviews (such as Worthington's) to have called out nitrate as being exceptional, but there is currently no real reason that I can discern for lower nitrate levels in organic to make it any "safer", especially given the amounts already present. Finally, the European Food Safety Authority (similar to FDA) put out a [finding in 2008](#) that affirms the safety of leafy fruits and vegetables, considering their nitrate content with no link with cancer and some potential positive side effects (EFSA 2008 ⁸).

²EPA. "Drinking Water Contaminants". May 2009. Visited August 25, 2009. Available at <http://water.epa.gov/drink/contaminants/index.cfm>

³Lundberg JO, Weitzberg E, Gladwin MT. The nitrate-nitrite-nitric oxide pathway in physiology and therapeutics. *Nat Rev Drug Discov.* 2008 Feb;7(2):156-67. Review. PubMed PMID: 18167491

⁴Duncan, C. "Chemical generation of nitric oxide in the mouth from the enterosalivary circulation of dietary nitrate". *Nature Medicine.* 1(6):1 June 1995. pp546-551

⁵Greer, FR. "Infant Methemoglobinemia: The Role of Dietary Nitrate in Food and Water". *Pediatric.* Vol. 116 No. 3 September 2005, pp. 784-786 (doi:10.1542/peds.2005-1497)

⁶Minkel, JR. *Scientific American.* "Bad Rap for Nitrate?". September 6, 2004. Visited August 23, 2010. Available <http://www.scientificamerican.com/article.cfm?id=bad-rap-for-nitrate>

⁷Editors. *Peak Performance Online.* "Sports nutrition: Is dietary nitrate the key to enhanced endurance performance?". Visited August 23, 2010. Available <http://www.pponline.co.uk/encyc/sports-nutrition-is-dietary-nitrate-the-key-to-enhanced-endurance-performance-41930>

⁸European Food Safety Authority. "Nitrate in vegetables - Scientific Opinion of the Panel on Contaminants in the Food chain". Published 5 June 2008. Visited 4 Sept 2010. Available at <http://tinyurl.com/efsa-nitrate>

What the Science Says

Looking over the history of the studies in this area, I think it may be interesting to actually approach this in reverse chronological order, starting from the most recent and comprehensive review down to one in 2000 that actually seems much less systematic in its approach.

2009 - Dangour, American Journal of Clinical Nutrition

The most recent review is "[Nutritional quality of organic foods: a systematic review](#)" by Dangour et al, published September of 2009 in the American Journal of Clinical Nutrition. The study was sponsored by the UK Food Standards Agency (equivalent to US FDA). Their primary finding was that (Dangour 2009 ⁹):

There is no evidence of a difference in nutrient quality between organically and conventionally produced foodstuffs. The small differences in nutrient content detected are biologically plausible and mostly relate to differences in production methods.

I hunted down the full text and found a [preview](#) (so reader should note that I cannot say for certain that it represents the final published version). All additional details come from that document¹⁰. For the statistically inclined, they have [made the raw data available](#) (Food Standards Agency 2010 ¹¹). Now, that's open science for you!. In the full text we find the specific nutrients:

Analysis of satisfactory quality-crop studies found no evidence of a difference in 8 of the 11 nutrient categories (vitamin C, phenolic compounds, magnesium, potassium, calcium, zinc, copper, and total soluble solids)

Looking more into the paper, it mentions that Phosphorous and "titratable acidity" went to organic and Nitrogen content went to conventional.

Their study filtered through more than 52,000 articles (covering the years 1958 to 2008) to find 162 studies purporting to compare organic and conventional foods (both food and livestock), to arrive at 55 that actually met the standards of the systematic review.

Those standards were:

"The quality of research and reporting in this area is extremely variable. Each study included in the review was graded for quality based on 5 criteria addressing key components of study design: a clear definition of the organic

⁹Dangour, AD et al. "Nutritional quality of organic foods: a systematic review". Am J Clin Nutr. 2009 Sep;90(3):680-5. Epub 2009 Jul 29. Review. PubMed PMID: 19640946.

¹⁰Danger AD. <http://civileats.com/wp-content/uploads/2009/07/Preview-of-ajcn28041-1..6>".pdf. Ahead of print preview July 2009. Visited 7/23/2010.

¹¹Food Standards Agency. Report details. "Systematic review of differences in nutrient content of organically and conventionally produced food". http://www.foodbase.org.uk/results.php?f_report_id=497. Published 5/12/2010. Visited 7/23/2010

production methods, including the name of the organic certification body; specification of the cultivar of crop or breed of livestock; a statement of which nutrient or other nutritionally relevant substance was analyzed; a description of the laboratory analytic methods used; and a statement of the methods used for statistical analyses. Studies were defined as being of satisfactory quality if they met all 5 criteria. We did not grade further the quality of organic certifying bodies or analytic methods used”

One would think that all systematic reviews on this topic would follow similar standards, but that is not the case. It is possible that the lack of specific certification body filtered out quite a bit of them because “organic” is not a concrete term, but rather is defined in practice by whichever certification bodies have been approved by the national governments. Their criteria could be more or less “strict” for different parts of the definition of “organic” and, for the case of the US, might not be the same “organic” recognized by the USDA (which simply means they [cannot use the official labelling](#) (USDA 2010 ¹²).

Not surprisingly, the UK Soil Association (organic food lobby) was [none too pleased with the study](#). Their primary complaint was that it did not cover herbicide/pesticide content. The study was explicitly about nutritional content, so it is a rather strange complaint (Soil Association 2009 ¹³). They attempt to discredit even the nutritional part by listing out the differences that were found in the study. However, the figures are misleading because the standard error is sometimes more than the difference! But the Soil Association doesn't mention that. For instance, they show copper has having an 8.6% difference (in favor of organic). But if you look at the data in the Dangour study, the standard error is 11.5, making the difference meaningless. They do however make a fair point that organic food is not just about nutritional content (clearly or pesticides, but about the whole lifecycle of production. This precludes “conventional” farmers from making use of the techniques that they feel will best optimize production without actually attempting to have organic certification, which I highly doubt is the case in the real world.

So it seems that the most recent, and certainly the most rigorous, systematic review finds no real nutritional difference between organic and conventional food. That study stretches back to studies in the 50s and has a very clear definition of its entry criteria.

2006 - Györéné, Orv Hetil

This study, “[[A comparison of chemical composition and nutritional value of organically and conventionally grown plant derived foods](#)]”, is actually in Hungarian but PubMed has an English version of its abstract. It has only been cited a single time (in a study by the Organic Center's Charles Benbrook, which is my main reason for still including it here). That said, it is listed in PubMed, but I cannot tell if it is peer-reviewed or not. Part of the conclusions (Györéné 2006 ¹⁴):

¹National Organic Program (NOP). USDA. “NOP Regulations: Subpart D - Labels, Labeling, and Market Information”. Updated February 4, 2010. Visited August 18, 2010. Available at <<http://tinyurl.com/2dups22>>

¹Soil Association. “Soil Association response to the Food Standards Agency's Organic Review”. Published 7/29/2009. Visited 7/23/2010. Available at <<http://tinyurl.com/mtjked>>

¹Györéné KG, Varga A, Lugasi A. [A comparison of chemical composition and nutritional value of organically and conventionally grown plant derived foods]. Orv Hetil. 2006 Oct 9;147(43):2081-90. Review. Hungarian. PubMed PMID: 17297755.

“Organic crops contain a significantly higher amount of certain antioxidants (vitamin C, polyphenols and flavonoids) and minerals, as well as have higher dry matter content than conventional ones.”

“Orv Hetil” appears to translation to something like “Health Weekly”.

So the results of this study are the organic crops are actually more nutritious. However, I don't have a way of determining what studies they looked at, what criteria they used, or whether it was peer-reviewed.

2003 - Magkos, International Journal of Food Science And Nutrition

This study, [“Organic food: nutritious food or food for thought? A review of the evidence”](#) acknowledges (as do most) that quality studies in this area can be few and far between especially as you look at earlier studies. Their findings (Magkos 2003¹⁵):

“In spite of these limitations, however, some differences can be identified. Although there is little evidence that organic and conventional foods differ in respect to the concentrations of the various micronutrients (vitamins, minerals and trace elements), there seems to be a slight trend towards higher ascorbic acid content in organically grown leafy vegetables and potatoes. There is also a trend towards lower protein concentration but of higher quality in some organic vegetables and cereal crops. “

I managed to track down what appears to the full text by searching for the first few words of the abstract. It is hosted on docstoc.com, so I won't link to it here as I am not certain of the legality of documents uploaded there.

So the only real finding other than that organic and conventional are virtually identical is another case of the trend toward finding slightly higher ascorbic acid/Vitamin C content in organic food. It strikes me as being a well done study without obvious bias. The authors go item by item and provide overview of the findings.

2002 - Bourn, Critical Reviews in Food Science and Nutrition

This particular review (entitled [“A comparison of the nutritional value, sensory qualities, and food safety of organically and conventionally produced foods”](#)) was interesting in that it actually separated out the different types of studies and discussed them as units. For instance, the studies which looked only at fertilizer usage versus those that made retail purchases of “organic” and “conventional” products. 41 key studies were discussed and put into tables, but there are actually over 200 references. Part of their

¹⁵Magkos F, Arvaniti F, Zampelas A. Organic food: nutritious food or food for thought? A review of the evidence. Int J Food Sci Nutr. 2003 Sep;54(5):357-71.Review. PubMed PMID: 12907407.

results (Bourn 2002 ¹⁶):

With the possible exception of nitrate content, there is no strong evidence that organic and conventional foods differ in concentrations of various nutrients.

Google Scholar [also identified the full text article](#) (available as of July of 2010), which is where I found the information about how the study was done and the number of them. The review is a good read, especially as it goes into detail into the study design (or lack of) as well as tests of significance (or lack of) employed by the researchers. One thing that becomes quite clear from reading this study is the true variability and complexity in looking at the nutritional effects of the organic production process.

In the end, as you can see from the quote, there is no real difference between organic and conventional especially if you look at studies in their own context.

2001 - Worthington, Journal of Complementary and Alternative Medicine

This was an earlier “systematic” review performed by Virginia Worthington, a chiropractor from Washington DC. The review was entitled “[Nutritional quality of organic versus conventional fruits, vegetables, and grains](#)” and ended up using 41 studies (Worthington 2001 ¹⁷, Full Text ¹⁸).

The results:

Organic crops contained significantly more vitamin C, iron, magnesium, and phosphorus and significantly less nitrates than conventional crops. There were nonsignificant trends showing less protein but of a better quality and a higher content of nutritionally significant minerals with lower amounts of some heavy metals in organic crops compared to conventional ones.

I mention her profession because this is an alert to look closer at the study, and how it has been reviewed. By definition, a chiropractor who practices traditional chiropractic must ignore the majority of the science of illness in favor of the non-scientific idea of “[subluxations](#)” and “innate intelligence” as a basis for illness (Ernst 2008 ¹⁹). So while her personal views do not actually make this study invalid, they lead to the reasonable suggestion that it may possibly cherry pick or otherwise perform improper analysis in the goal of coming up with a desired outcome. And if you read the article, she does seem to indicate that there was not much concern for how good a study was, rather they were just matched up. In any case, this is the earliest of the reviews and

¹⁶Bourn D, Prescott J. A comparison of the nutritional value, sensory qualities, and food safety of organically and conventionally produced foods. Crit Rev Food Sci Nutr. 2002 Jan;42(1):1-34. Review. PubMed PMID: 11833635.

¹⁷Worthington V. Nutritional quality of organic versus conventional fruits, vegetables, and grains. J Altern Complement Med. 2001 Apr;7(2):161-73. PubMed PMID: 11327522.

¹⁸Google Scholar found full text at http://journeytoforever.org/farm_library/worthington-organic.pdf, which is where I base my comments that are not in the abstract alone. Visited 7/25/2010

¹⁹Ernst E. Chiropractic: a critical evaluation. J Pain Symptom Manage. 2008 May;35(5):544-62. Epub 2008 Feb 14. Review. PubMed PMID: 18280103.

so did not have as good of studies to work with.

This one obviously found that trend for Vitamin C (and some others) in organic, as well as higher nitrate levels in conventional.

Conclusion

There does not appear to be any meaningful difference in nutrient content between organically-certified and “conventionally” grown produce. There is a possible trend toward higher Vitamin C content in organic, but for the levels found it would make no practical difference. The variance between any given two items of produce is so high that your specific organic fruit or vegetable is as likely to have less Vitamin C (or others) as any conventional one compared between themselves. Based on the scientific evidence, I see no reason to choose organically certified produce over conventional for purposes of obtaining higher nutrient content. This says nothing about other value/safety arguments that one might make (such as synthetic pesticide or sustainability), which I have not yet looked at, but plan to in a future article.

Appendix: Meta-meta review

For the reviews where I could get full text, or otherwise determine the the studies in use, I have created a table which has the reference, year and which reviewers used it. It is available as [web page](#) or as a [CSV](#). It also includes a column for whether or not it found positive differences in organic, but I have not filled that out.

What I found intriguing is that there are only 4 studies that all of the reviews (except Gyorene, for which I could not find any full text version) agree was of high enough quality (or at least, met their criteria). A spattering more are in 2 studies, and the rest are in a single one, even for where the years overlap.

Just looking at these few studies you see that lack of meaningful trend. One might find organic higher for a given nutrient, and another will find organic lower for the same nutrient. Sometimes the same study had switches between the years the study was run.

The 4 that all “agree” on (though if you read Bourn, he references some more to point that they are frequently referenced but weren’t necessarily great studies):

- **Clarke RP, [Merrow SB. Nutrient composition of tomatoes homegrown under different cultural procedures.](#) Ecol Food Nutr 1979;8:37–46.**
 - Long-term tomato study
 - 1 year higher Vitamin C in organic, others higher in conventional (but not statistically sig. difference)
- **Wolfson JL, Shearer G. Amino acid composition of grain protein of maize grown with and without pesticides and standard commercial fertilizers. Agron J 1981;73: 611–613.**
 - Proteins in maize
 - From Bourn, protein and most amino acids lower in organic
- **Shier NW, Kelman J, Dunson JW. [A comparison of Crude protein, moisture, ash and crop yield between organic and conventionally grown wheat.](#) Nutr Rep Int 1984;30:337–349.**
 - Found no difference in protein or moisture, difference in ash at a lower temperature
 - Conventional higher yield of grain
- **Smith B. [Organic foods vs. supermarket foods: element levels.](#) J Appl Nutr 1993;45:35–39.**
 - Of interest, Smith is actually from a company called Doctor’s Data, which is high on the list of Stephen Barrett’s “[QuackWatch](#)” and in fact they are [currently suing him](#) for calling them out on their invalid analysis of urine and the like. This does not mean their analysis is fruits are incorrect, and at the time they may have been totally legitimate. Small world I suppose.
 - Raw levels are not noted, neither are statistical significance levels (so “90% more” could mean almost anything). As an example of how you could choose to read the results to support whatever conclusion you want:
 - Organic potatoes had 10% more lead, but wheat 65% less, but sweet corn equal

- Organic potatoes had 70% more mercury, but wheat 40% less, and sweet corn 80% more
- Somehow they managed to calculate both as being less “on average” in organic, and all the “good” nutrients more in organic

There are some more that at least 3 considered:

- **Petterson BD. A comparison between the conventional and biodynamic farming systems as indicated by yields and quality. In: Lockeretz W, ed. Environmentally Sound Agriculture. New York: Praeger, 1983:87–94. (Not in Dangour)**
 - Biodynamic potatoes had higher protein, Vitamin C (from Bourn)
 - Wheat and Barley had lower protein
 - [Biodynamics](#) is...interesting... and includes ideas from the “spiritual science of anthroposophy” (which is also what Waldorf education is based on) of Rudolf Steiner. What is strange is that one of their **tenets** is that holistically/biodynamically grown produce is more healthy and nutritious. Making it a tenet does not make it true.
 - “The concept of dynamic practice—those practices associated with non-physical forces in nature like vitality, life force, ki, subtle energy and related concepts—is a commonality that also underlies many systems of alternative and complementary medicine. It is this latter aspect of biodynamics which gives rise to the characterization of biodynamics as a spiritual or mystical approach to alternative agriculture. See the following table for a brief summary of biological and dynamic farming practices.”
- **Termine E, Lairon D, Taupier-Letage B, Gautier S, Lafont R, Lafont H. Yield and content in nitrates, minerals and ascorbic acid of leeks and turnips grown under mineral or organic nitrogen fertilizations. Plant Foods Hum Nutr 1987;37:321–32. (Not in Dangour, all details from Bourn)**
 - Vitamin C higher in produce fertilized with manure versus woodchip compost
 - No consistent trends for organic versus conventional in either vegetable
- **Vogtmann H, Temperli AT, Kunsch U, Eichenberger M, Ott P. [Accumulation of nitrates in leafy vegetables grown under contrasting agricultural systems](#). Biol Agric Hort 1984;2:51–68. (Not in Dangour)**
 - Found no real difference in ascorbic acid or minerals
 - Organic had lower nitrate levels
- **Stopes C, Woodward L, Forde G, Vogtmann H. The nitrate content of vegetable and salad crops offered to the consumer as from “organic” or “conventional” production systems. Biol Agric Hort 1988;5:215–221. (Not in Magkos)**
 - (From Bourn) - no difference and generally wide variance
- **Starling, W. and Richards, M.C., Quality of organically grown wheat and barley, Aspects Appl. Biology, 1990; 25: 193-8. (Not in Worthington)**
 - (From Bourn) - Barley higher N in organic, wheat lower N and protein
- **LeClerc J, Miller ML, Joliet E, Rocquelin G. Vitamin and mineral contents of**

carrot and celeriac grown under mineral or organic fertilization. Biol Agric Hort 1991;7:339–348. (Not in Magkos)

- (From Bourn) - Higher beta-carotene in carrots
- (From Bourn) - [Celeriac](#) lower Nitrate and zinc, higher P and vitamin C
- **Warman PR, Havard KA. [Yield, vitamin and mineral content of four vegetables grown with either composted manure or conventional fertilizer](#). J Vegetable Crop Production 1996;2:13–25. (Not in Bourn)**
 - This is actually a combination of the results of the next 2 (not a distinct study)
 - Main finding across them: “Given the number of factors evaluated each year for each of the four crops, there were relatively few differences in the yield, vitamin and mineral content of the vegetables grown using the two different production systems. We believe this was related to the proper use of fertility amendments and pest control practices. When quality compost is analyzed prior to use, vegetables can be provided with approximately the same amount of essential nutrients from compost as from inorganic fertilizers.”
- **Warman PR, Havard KA. [Yield vitamin and mineral contents of organically and conventionally grown carrots and cabbage](#). Agric Ecosys Environ 1997;61:155–162. (Not in Magkos)**
 - Three year study
 - Vitamin yield no different
 - Other minor differences in leaves
- **Warman, P.R. and Havard, K.A., [Yield, vitamin and mineral contents of organically and conventionally grown potatoes and sweet corn](#), Agric. Ecosys. Environ., 1998; 68: 207-16. (Not in Worthington)**
 - Three year growing of potatoes and sweet corn
 - Vitamin C and E no different in corn
 - Phosphorous, Magnesium, Manganese higher in the organic potato tubers (as I read it), but others went to conventional (or were same)