

Are Organic Foods Safer or Healthier Than Conventional Alternatives?

A Systematic Review

Crystal Smith-Spangler, MD, MS; Margaret L. Brandeau, PhD; Grace E. Hunter, BA; J. Clay Bavinger, BA; Maren Pearson, BS; Paul J. Eschbach; Vandana Sundaram, MPH; Hau Liu, MD, MS, MBA, MPH; Patricia Schirmer, MD; Christopher Stave, MLS; Ingram Olkin, PhD; and Dena M. Bravata, MD, MS

Background: The health benefits of organic foods are unclear.

Purpose: To review evidence comparing the health effects of organic and conventional foods.

Data Sources: MEDLINE (January 1966 to May 2011), EMBASE, CAB Direct, Agricola, TOXNET, Cochrane Library (January 1966 to May 2009), and bibliographies of retrieved articles.

Study Selection: English-language reports of comparisons of organically and conventionally grown food or of populations consuming these foods.

Data Extraction: 2 independent investigators extracted data on methods, health outcomes, and nutrient and contaminant levels.

Data Synthesis: 17 studies in humans and 223 studies of nutrient and contaminant levels in foods met inclusion criteria. Only 3 of the human studies examined clinical outcomes, finding no significant differences between populations by food type for allergic outcomes (eczema, wheeze, atopic sensitization) or symptomatic *Campylobacter* infection. Two studies reported significantly lower urinary pesticide levels among children consuming organic versus conventional diets, but studies of biomarker and nutrient levels in serum, urine, breast milk, and semen in adults did not identify clinically meaningful differences. All estimates of differences in nutrient and contaminant levels in foods were highly heterogeneous except for

the estimate for phosphorus; phosphorus levels were significantly higher than in conventional produce, although this difference is not clinically significant. The risk for contamination with detectable pesticide residues was lower among organic than conventional produce (risk difference, 30% [CI, -37% to -23%]), but differences in risk for exceeding maximum allowed limits were small. *Escherichia coli* contamination risk did not differ between organic and conventional produce. Bacterial contamination of retail chicken and pork was common but unrelated to farming method. However, the risk for isolating bacteria resistant to 3 or more antibiotics was higher in conventional than in organic chicken and pork (risk difference, 33% [CI, 21% to 45%]).

Limitation: Studies were heterogeneous and limited in number, and publication bias may be present.

Conclusion: The published literature lacks strong evidence that organic foods are significantly more nutritious than conventional foods. Consumption of organic foods may reduce exposure to pesticide residues and antibiotic-resistant bacteria.

Primary Funding Source: None.

Ann Intern Med. 2012;157:348-366.

For author affiliations, see end of text.

www.annals.org

Between 1997 and 2010, U.S. sales of organic foods increased from \$3.6 to \$26.7 billion (1, 2). Although prices vary, consumers can pay up to twice as much for organic than conventional foods (3–5).

Organic certification requirements and farming practices vary worldwide, but organic foods are generally grown without synthetic pesticides or fertilizers or routine use of antibiotics or growth hormones (6, 7). Organic livestock are fed organically produced feed that is free of pesticides and animal byproducts and are provided access to the outdoors, direct sunlight, fresh air, and freedom of movement (7). In addition, organic regulations typically require that organic foods are processed without irradiation or chemical food additives and are not grown from genetically modified organisms (6, 8). The International Federation of Organic Agriculture Movements endorses the principles of “health, ecology, fairness, and care” (9).

Consumers purchase organic foods for different reasons, including concerns about the effects of conventional farming practices on the environment, human health, and animal welfare and perceptions that organic foods are tastier than their conventional alternatives (2, 10–13).

The purpose of this study is to comprehensively synthesize the published literature on the health, nutritional, and safety characteristics of organic and conventional foods. Previous reviews comparing the nutritional content of organic and conventional foods have summarized studies narratively (13–18), reported differences in nutrient levels without assessing the statistical significance of those differences or weighting outcomes by sample size (19–22), or considered only harms (23).

METHODS

Data Sources and Searches

With a professional librarian, we developed search strategies for 7 databases: MEDLINE (January 1966 to May 2011), EMBASE, CAB Direct, Agricola, TOXNET, and Cochrane Library (January 1966 to May 2009) with such terms as *organic*, *vegetable*, *fruit*, and *beef* (Supple-

See also:

Web-Only
Supplements

ment 1, available at www.annals.org) and reviewed bibliographies of retrieved articles.

Study Selection

Peer-reviewed, English-language studies, regardless of design, were eligible for inclusion if they reported a comparative evaluation of populations consuming diets of foods grown organically and conventionally or a comparative evaluation of nutrient levels or bacterial, fungal, or pesticide contamination of fruits, vegetables, grains, meats, poultry, milk (including raw milk), or eggs grown organically and conventionally. We excluded studies of processed foods, those that evaluated samples from livestock feces or gastrointestinal tracts, and those that did not report information about variance or results of statistical tests (24–34). Organic practices included biodynamic farming and were defined by investigators' stated adherence. Studies merely comparing the effects of organic and nonorganic fertilization practices were ineligible unless they specified that the produce receiving organic fertilizer was grown by using organic farming practices (28, 32, 33, 35–47). Similarly, we excluded studies of such foods as recombinant bovine somatotropin-free milk and grass-fed beef unless the food production was reported to be organic.

Data Extraction and Quality Assessment

One author abstracted data on study methods (for example, design; food tested; sample size; organic standard; testing methods; harvest season; and cultivar, breed, or population studied) and end points (Supplement 2, available at www.annals.org). At least 1 additional author verified all abstracted data; discrepancies were resolved with discussion. If 2 or more studies presented the same data from a single population or the same farm experiment, we included these data only once in our analyses.

We defined quality criteria a priori and evaluated the extent to which included human population studies specified the organic standard used, evaluated the amount of organic foods consumed in diets, linked reported outcomes with health outcomes, obtained institutional review board approval and participant consent, and were not funded by an organization with a financial interest in the study outcome. For the studies that directly evaluated the study foods, we evaluated the extent to which each study specified the organic standard used, used the same harvesting or processing method for both groups, reported sample size, used equal sample size in both groups, and were not funded by organizations with a financial interest in the study outcome. We also evaluated the extent to which the organic–conventional comparison pairs were of the same cultivar or breed, grown on neighboring farms, and harvested during the same season.

Data Synthesis and Analysis

We calculated summary effect sizes by using random-effects models for outcomes with at least 3 studies reporting data: summary risk differences (RDs) and summary prevalence rates for studies reporting the number of sam-

ples contaminated and summary standardized mean differences (SMDs) for studies reporting mean nutrient or harm levels. Differences were calculated as organic minus conventional (for example, a positive number indicates more contamination in organic). All RDs are absolute RDs.

We performed tests of homogeneity (Q statistic and I^2 statistic) on all summary effect sizes. Homogeneity was indicated if I^2 was less than 25% and P value for the Q statistic was greater than 0.010. If the 2 tests agreed, we report only the I^2 statistic; otherwise, we report results for both. We used funnel plots to assess publication bias (48). We qualitatively summarized studies not reporting information on variance and excluded studies not reporting any information on variance or statistical testing. All analyses were completed by using Comprehensive Meta-analysis, version 2 (Biostat, Englewood, New Jersey). Because of the large number of comparisons (22 for produce and 31 for meat, poultry, milk, and eggs), we report adjusted P values for summary estimates using the Sidak formula for multiple comparisons. For each reported summary effect size, we omitted 1 study at a time to assess the influence of each individual study on summary effects and omitted outliers that were more than 1 order of magnitude larger or smaller than others. We explored heterogeneity by conducting subgroup analyses by food type, organic standard used, testing method, and study design when at least 3 studies examined these subgroups.

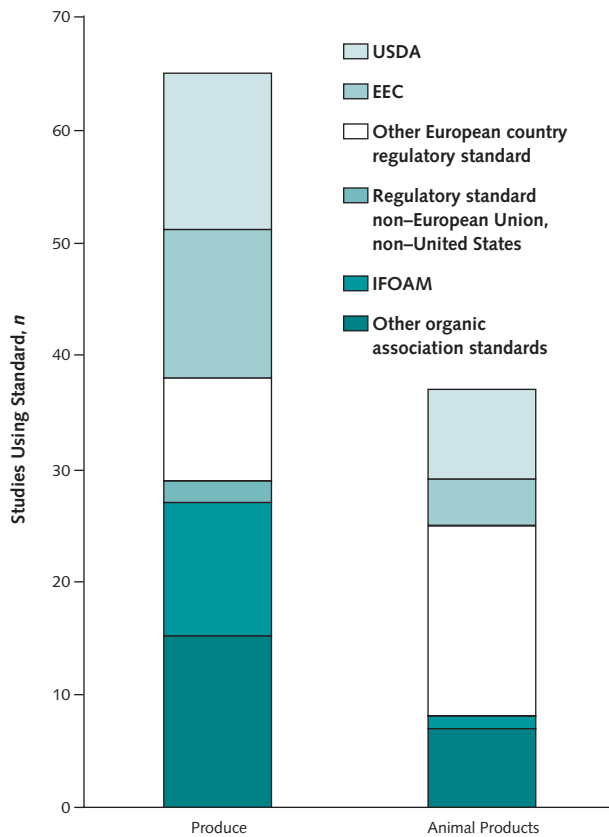
We limited our analyses of bacterial contamination to foodborne pathogens monitored by the Centers for Disease Control and Prevention's FoodNet (49) (for example, *Campylobacter*, *Listeria*, *Salmonella*, and *Escherichia coli*). However, given the potential for transfer of antibiotic resistance between species, we included all human pathogens (for example, *Staphylococcus aureus*) in the analyses of antibiotic resistance.

Studies frequently reported several results per outcome (for example, mean vitamin C level in years 1 and 2). To include such studies only once in our analyses, we combined the results within each study by using random-effects models and used this study-level summary effect in our overall summary calculation.

Similarly, several studies (50–53) reported multiple results for resistance to the same antibiotic by examining different bacteria (for example, *Salmonella* and *Campylobacter*). To include these studies only once in each effect size calculation, we used results for pathogens in the *Enterobacteriaceae* family (for example, *Salmonella*) for the main analyses and the alternate species (for example, *Campylobacter*) in sensitivity analysis.

Among the produce studies, several studies that otherwise could have been included in summary effect size calculations did not report sample sizes. To avoid discarding them, we assumed that they had a sample size of 3 (a common sample size among the smaller studies). In sensitivity analyses, we varied this to 10, the median sample size among studies. This alternate assumption did not change

Figure 1. Organic standards used for studies of produce and animal products.



Sixty-five produce studies and 37 studies of animal products reported the organic standard applied. EEC = European Economic Community; IFOAM = International Federation of Organic Agriculture Movements; USDA = U.S. Department of Agriculture.

conclusions, so we report the outcomes using a sample size of 3.

Role of the Funding Source

This study did not receive external funding.

RESULTS

Searches identified 5908 potentially relevant articles (Appendix Figure 1, available at www.annals.org). Two hundred thirty-seven studies met inclusion criteria: 17 evaluated health outcomes among human populations consuming organic and conventional foods (54–70); 223 compared organic and conventional fruits, vegetables, grains, meats, poultry, milk, or eggs directly (50–53, 57, 65, 69, 71–286) (3 reported on both human and food outcomes). Supplement 2 lists all studies reporting each outcome and studies included in each subgroup analysis.

Studies in Humans Consuming Organic and Conventional Foods

Seventeen articles describing 14 unique populations (13 806 participants) met inclusion criteria (Supplement

3, available at www.annals.org). Study designs varied: 6 randomized, controlled trials (56, 57, 62, 65, 66, 69), 2 prospective cohort studies (54, 61), 3 cross-sectional studies (55, 64, 68), 4 crossover studies (describing 2 populations) (59, 60, 63, 67), and 1 case–control study (70). Only 3 studies (61, 64, 70) examined clinical outcomes (for example, wheezing, allergic symptoms, or reported *Campylobacter* infections), and the remaining studies examined health markers (for example, serum lipid or vitamin levels).

In general, the included studies were of fair quality (Appendix Figure 2 [top panel], available at www.annals.org). Only 6 studies specified the organic standard used. Only 5 studies (54, 61, 64, 65, 68) evaluated participants who consumed a predominately organic diet; participants in the remaining studies consumed only certain organic foods (for example, apples [62], carrots [69], or meat or dairy products [68]). The sample sizes ranged from 6 to 6630, and duration ranged from 2 days to 2 years. Four studies were from the United States (55, 59, 60, 63), and all others were from Europe.

Studies in Pregnant Women and Children

One prospective cohort study (61) and 1 cross-sectional study (64) of pregnant women and their children reported no association between diet type and the development of eczema, wheezing, serum IgE levels, or other atopic outcomes among children. Exploratory subgroup analyses found that children who consumed dairy products of which more than 90% were organically produced had a lower risk for eczema at age 2 years than children who consumed dairy products of which less than 50% were organically produced (odds ratio, 0.64 [95% CI, 0.44 to 0.93]) (61).

Three other studies examined markers of pesticide or insecticide exposure in children. One cross-sectional study (55) and 1 crossover study (59) examined urinary organophosphate pesticide metabolites, finding significantly lower levels among children on organic diets than those on conventional diets. Although these studies suggest that consumption of organic fruits and vegetables may significantly reduce pesticide exposure in children, they were not designed to assess the link between the observed urinary pesticide levels and clinical harm. One crossover study comparing urinary insecticide levels among children spending 5 days on a conventional diet followed by 5 days on an organic diet found household use of insecticides—but not diet—to be a significant predictor of urinary insecticide levels (60).

Studies in Nonpregnant Adults

Eleven reports of 10 populations examined differences between adults consuming organic and conventional diets. Only 1 reported clinical outcomes: An exploratory case–control study (70) found consumption of organic meat in

Table 1. Summary of Benefits: SMD of Nutrient Levels Found in Organic Versus Conventional Fruits, Vegetables, and Grains*

Nutrient	Summary of All Identified Studies				Results of Meta-analysis										
	Studies, n	Comparisons, n	Comparisons Favor Organic, n†	Comparisons Favor Conventional, n‡	Studies, n§	Studies Describing Sample Size, n	Organic Sample Size, n	Conventional Sample Size, n	SMD (95% CI)	P Value¶	Heterogeneous (I ² Statistic)				
Ascorbic acid	Foods studied: banana, berries, broccoli, cabbage, carrots, celery, eggplant, grapes, leafy greens, lettuce, oranges, peaches, pears, peppers, plums, potatoes, strawberries, and tomatoes				41	113	23	12	31	28	1141	1306	0.50 (0.05 to 0.95)	0.48	Yes (80%)
β-Carotene	Foods studied: eggplant, plums, carrots, tomatoes, sweet peppers, kale, and orange				16	23	6	3	12	6	114	114	1.14 (−0.13 to 2.42)	0.83	Yes (91%)
α-Tocopherol	Foods studied: peaches, pears, plums, corn, cabbage, carrots, and olive oil				8	19	3	2	5	5	60	60	−0.09 (−0.70 to 0.53)	1.00	Yes (26%)
Potassium	Foods studied: carrots, celery, corn, oranges, grapes, potatoes, peppers, plums, onions, strawberries, and wheat				37	108	18	18	14	9	300	315	0.45 (−0.30 to 1.20)	1.00	Yes (87%)
Calcium	Foods studied: carrots, celery, corn, oranges, peppers, plums, strawberries, onions, potatoes, and wheat				36	105	18	7	15	11	484	500	0.61 (0.01 to 1.22)	0.68	Yes (84%)
Phosphorus	Foods studied: carrots, celery, corn, plums, onions, and potatoes				30	82	24	12	7	6	353	374	0.82 (0.44 to 1.20)	<0.001	No (0%)
Magnesium	Foods studied: potato, plums, onions, peas, carrots, celery, corn, cabbage, strawberries, peppers, tomato, orange, and wheat				34	86	23	6	13	10	352	362	0.65 (0.01 to 1.30)	0.66	Yes (81%)
Iron	Foods studied: potato, plums, onions, peas, corn, cabbage, carrots, strawberries, peppers, wheat, oats, and tomatoes				24	77	10	12	12	9	350	300	0.30 (−0.47 to 1.08)	1.00	Yes (90%)
Protein	Foods studied: wheat, banana, plum, tomato, soybeans, grape juice, and eggplant				27	63	7	34	14	8	93	108	−1.27 (−3.20 to 0.62)	1.00	Yes (83%)
Fiber	Foods studied: banana, eggplant, plums, wheat, grape juice, and oranges				8	11	2	5	7	3	73	90	−0.79 (−1.87 to 0.29)	0.97	Yes (83%)
Quercetin	Foods studied: plums, tomatoes, bell peppers, grapes, grape leaves, lettuce, strawberries, and black currants				13	50	16	2	11	6	156	156	2.45 (0.20 to 4.69)	0.52	Yes (94%)
Kaempferol	Foods studied: plums, black currants, grapes, lettuce, bok choy, collard greens, tomatoes, bell peppers, strawberries, and tomatoes				9	18	6	2	9	5	96	96	2.64 (0.41 to 4.86)	0.36	Yes (93%)
Total flavanols	Foods studied: apples, grape leaves, strawberries, chicory, and black currants				5	22	7	6	5	3	96	96	−0.19 (−1.68 to 1.31)	1.00	Yes (59%)
Total phenols	Foods studied: apples, peaches, pears, plums, bell peppers, berries, tomatoes, chicory, olive oil, grape leaves, oranges, strawberries, bok choy, lettuce, leafy greens, tomatoes, and wheat				34	102	36	12	22	19	401	401	1.03 (0.47 to 1.59)	0.007	Yes (67%)

SMD = standardized mean difference.

* All summary effect measures reported are results of random-effects models. Among studies examining nutritional content, studies with null findings tended to report results incompletely (hence, they were excluded from syntheses). The exception to this rule was among studies reporting on protein content of organic vs. conventional grain: Studies insufficiently reporting results (hence, they were excluded from summary effect calculation) tended to find significantly higher levels of protein in conventional vs. organic grains. In calculation of summary effect sizes, sensitivity analyses were performed, in which studies not reporting sample size were removed, and subgroup analyses were done by fresh vs. dry weight. Findings did not substantially change with the sensitivity analyses.

† The number of comparisons in which a statistically significant difference was identified with higher levels in the organic group.

‡ The number of comparisons with a statistically significant difference with higher levels in the conventional group.

§ Supplement 2 (available at www.annals.org) lists the studies included for each statistical analysis.

|| The difference between mean nutrient level in organic minus that in conventional divided by the pooled SD; thus, a positive (negative) number indicates higher (lower) nutrient levels in organic.

¶ All summary *P* values are adjusted *P* values.

the winter (but not organic meat in general) to be a risk factor for illness due to *Campylobacter* infection (odds ratio, 6.86 [CI, 1.49 to 31.69]).

The remaining studies examined differences in the serum, urine, breast milk, and semen of persons consuming organic and conventional diets. We found no studies comparing pesticide levels among adult consumers of organic versus conventional foods. Seven studies evaluated serum and urine antioxidant levels or immune system markers; 6 of these found no consistent differences in plasma or urine carotenoids, polyphenols, vitamins E and C content, low-density lipoprotein cholesterol, antioxidant activity, ability to protect against DNA damage, immune system markers, or semen quality between participants consuming organic and conventional diets (54, 57, 62, 65, 66, 69). All were randomized, controlled trials except the study of semen quality (a prospective cohort study) (54). One prospective

crossover study reported a statistically significant reduction in serum total homocysteine levels, phosphorus levels, and fat mass after 2 weeks on an organic Mediterranean diet compared with a conventional Mediterranean diet but did not describe the magnitude or clinical significance of these reductions (67). Another crossover study found that organic diets were associated with higher urinary excretion of quercetin and kaempferol but not other polyphenols and found no difference in 7 of 8 serum markers of antioxidation (56).

Two cross-sectional studies examined the breast milk of women from the Dutch KOALA (Child, Parent, and Health: Lifestyle and Genetic Constitution) Birth Cohort consuming predominantly organic versus conventional meat and dairy products (58, 68). They found no difference in the amount of total fatty acids in the breast milk of mothers who consumed meat and dairy products of which

Table 2. Summary of Harms: RD or SMD in Harms in Organic Versus Conventional Fruits, Vegetables, and Grains*

Harm	Summary of All Identified Studies			
	Studies, <i>n</i>	Comparisons, <i>n</i>	Comparisons Favor Organic, <i>n</i> †	Comparisons Favor Conventional, <i>n</i> ‡
Any detectable pesticide residue contamination**	22	NA		
<i>E. coli</i> contamination	5	NA		
DON contamination	9	NA		
OTA contamination	7	NA		
Cadmium level	15	77	21	1
Lead level	11	49	9	7
Mercury level	3	34	0	0
Arsenic level	2	16	0	0
DON level	10	29	9	0
OTA level	4	15	3	2

E. coli = *Escherichia coli*; DON = deoxynivalenol; NA = not applicable; OTA = ochratoxin A; RD = risk difference; SMD = standardized mean difference.

* All summary effect measures reported are results of random-effects models.

† The number of comparisons in which a statistically significant difference between organic and conventional was identified with lower levels in the organic group.

‡ The number of comparisons with a statistically significant difference with lower levels in the conventional group.

§ Supplement 2 (available at www.annals.org) lists the studies included for each statistical analysis.

|| RD is calculated as the risk for contamination in the organic group minus that in the conventional group; thus, a positive (negative) number indicates more (less) contamination in organic. All RDs are absolute RDs. SMD is the difference between mean contaminant level in organic minus that in conventional divided by the pooled SD; thus, a positive (negative) number indicates more (less) contamination in organic.

¶ All summary *P* values are adjusted *P* values.

** One of the studies included in the pesticide synthesis includes a data set (U.S. Department of Agriculture’s Pesticide Data Program) that oversamples products from sources with a history of violations. Hence, prevalence estimates may overstate prevalence of pesticide contamination in both organic and conventional products.

†† Result not robust to removal of 1 study at a time. Removal of 1 study (225) rendered results significant, suggesting higher contamination among organic produce (RD, 5.1% [95% CI, 2.92% to 7.18%]; *P* < 0.001; *I*² = 0%).

‡‡ For cadmium, lead, mercury, arsenic, DON, and OTA levels, these are the sample sizes instead of the number of contaminated samples divided by the total number of samples.

more than 90% were organically produced versus mothers who consumed meat and dairy products of which less than 50% were organically produced (58, 68). In subanalyses, they found higher levels of 2 beneficial fatty acids (conjugated linoleic acid and trans-vaccenic acid) in the breast milk of mothers consuming predominantly organic dairy and meat products versus mothers consuming conventional alternatives (58).

Studies of Nutrient and Contaminant Levels in Organic Versus Conventional Foods

Two hundred twenty-three studies of foods met inclusion criteria: 153 studies of fruits, vegetables, and grains and 71 studies of meats, poultry, milk, and eggs (1 study reported on both types of foods [189]) (Supplement 4, available at www.annals.org). Seventy percent (157 studies) were from Europe, and 21% (47 studies) were from the United States or Canada. Study methods varied: Among produce studies, 52% (80 studies) were on experimental farms in which potential confounders (for example, weather, geography, or plant cultivar) of the relationship between method of cultivation and nutrient levels were

controlled and 29% (44 studies) sampled food grown on commercial farms. Among animal product studies, 11% (8 studies) were conducted on experimental farms and 56% (40 studies) surveyed farms. Of the 37 milk studies included, 7 examined pasteurized milk and 30 examined raw milk (Supplement 4).

Forty-six percent (102 studies) of included studies specified the organic cultivation standard used (Appendix Figure 2 [bottom panel]). The most common standards were European Union or other European country-specific standards (43 studies), International Federation of Organic Agriculture Movements or other association standards (34 studies), and U.S. Department of Agriculture standards (22 studies). The most common standards among produce studies were from organic associations; country-specific European regulatory standards were most common among animal product studies (Figure 1).

Sixty-eight percent (151 studies) reported that harvesting or processing methods were the same for both groups; the remaining studies largely did not describe harvesting or processing methods (such as in studies that examined retail

Table 2—Continued

Results of Meta-analysis						
Studies, n§	Studies Describing Sample Size, n	Contaminated/Total Organic, n/N	Contaminated/Total Conventional, n/N	Difference (95% CI)	P Value¶	Heterogeneous (I ² Statistic)
Foods studied: variety of fruits and vegetables 9	9	253/3041	45 184/106 755	RD, -30% (-37% to -23%)	<0.001	Yes (94%)
Foods studied: apples, bell peppers, berries, bok choy, broccoli, cabbages, carrots, cucumber, leafy greens, lettuces, spring mix, scallions, spinach, summer squash, tomatoes, and zucchini 5	5	63/803	39/1454	RD, 2.4% (-1.5% to 6.3%)††	1.00	Yes (58%)
Foods studied: barley, buckwheat, corn, mixed grains, rice, rye, and wheat 9	9	267/393	310/347	RD, -23% (-37% to -8%)	0.043	Yes (89%)
Foods studied: baby multigrain, baby rice cereal, baby semolina, barley, buckwheat, corn, maize/tapioca, oats, rice, rye, spelt, and wheat 7	7	384/713	791/1641	RD, 11% (-3% to 24%)	0.93	Yes (92%)
Foods studied: beet, bell peppers, cucumber, greens, green beans, lentil, oats, potatoes, purple 11	9	568††	470††	amaranth, strawberries, tomatoes, and wheat SMD, -0.14 (-0.74 to 0.46)	1.00	Yes (87%)
Foods studied: cucumber, greens, potato, strawberries, tomato, and wheat 8	7	207††	354††	SMD, 0.38 (-0.16 to 0.92)	0.98	Yes (75%)
Foods studied: results not synthesized 0	NA	NA	NA	NA	NA	NA
Foods studied: results not synthesized 0	NA	NA	NA	NA	NA	NA
Foods studied: oats and wheat 8	8	278††	275††	SMD, -0.82 (-1.19 to -0.45)	<0.001	Yes (69%)
Foods studied: corn and wheat 4	4	198††	214††	SMD, -0.21 (-0.13 to 0.54)	1.00	Yes (62%)

samples). Eighty-seven percent (194 studies) reported sample size; however, definitions of a sample varied (for example, 1 sample is 10 apples from 1 tree vs. 10 apples from 1 row of trees). Sixty-five percent (146 studies) had equal sample sizes in both groups, and 91% (204 studies) were not funded by an organization with an overt interest in the outcome. Eighty-six percent (61 studies) of animal product studies sampled animal products from the same season. Among produce studies, 59% (90 studies) and 65% (100 studies) compared food pairs from neighboring farms or the same cultivar, respectively.

Vitamin and Nutrient Levels by Food Origin

Vitamins

We did not find significant differences in the vitamin content of organic and conventional plant or animal products (Supplement 5 [available at www.annals.org] and Table 1). Produce studies reported on ascorbic acid (31 studies), β -carotene (12 studies), and α -tocopherol (5 studies) content; milk studies reported on β -carotene (4 studies) and α -tocopherol levels (4 studies). Differences were heterogeneous and not significant. Few studies examined vitamin content in meats, but these found no difference in β -carotene in beef (272), α -tocopherol in pork (149) or beef (272), or vitamin A (retinol) in beef (272).

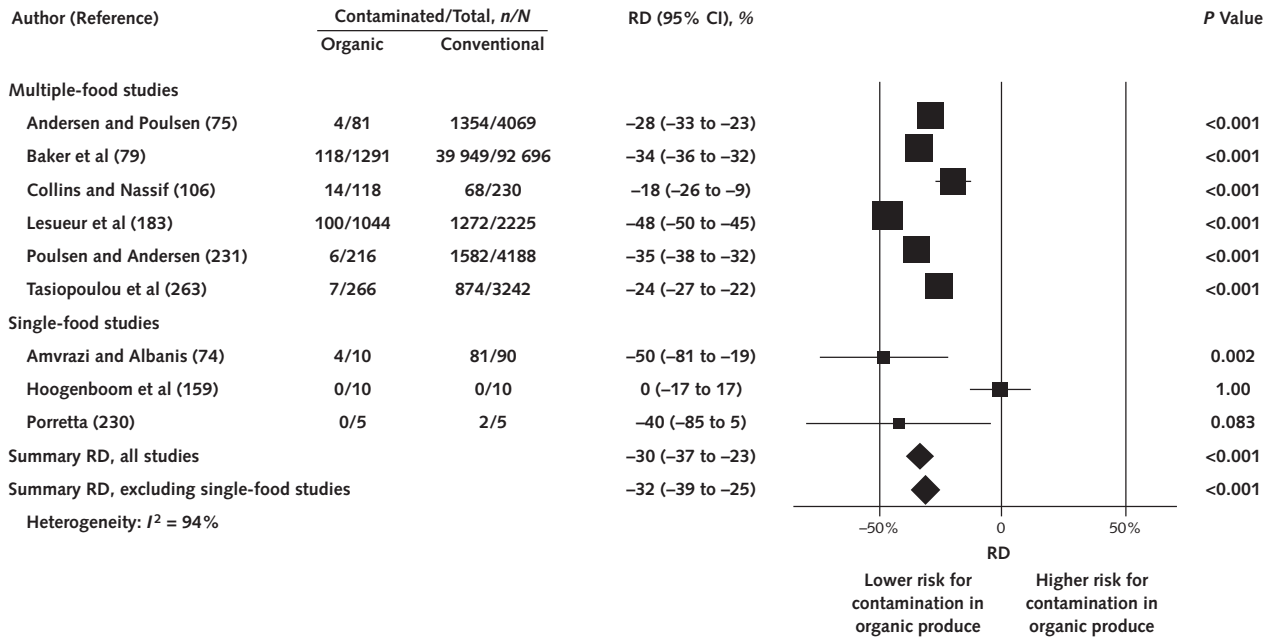
Nutrients

Summary SMDs were calculated for 11 other nutrients reported in studies of produce (Table 1). Only 2 nutrients were significantly higher in organic than conventional produce: phosphorus (SMD, 0.82 [CI, 0.44 to 1.20]; $P < 0.001$; 7 studies; median difference, 0.15

mg/kg [minimum difference, -18 mg/kg; maximum difference, 530 mg/kg]) and total phenols (SMD, 1.03 [CI, 0.47 to 1.59]; $P = 0.007$; 22 studies; median difference, 31.6 mg/kg [minimum difference, -1700 mg/kg; maximum difference, 10 480 mg/kg]). The result for phosphorus was homogenous ($I^2 = 0\%$), but removal of 1 study (227) reduced the summary effect size and rendered the effect size statistically insignificant (SMD, 0.63; $P = 0.064$). The finding for total phenols was heterogeneous ($I^2 = 67\%$) and became statistically insignificant when studies not reporting sample size (95, 175) were removed ($P = 0.064$). Too few studies of animal products reported on other nutrients for effect sizes to be calculated.

Few studies examined fatty acids in milk (Supplement 6, available at www.annals.org). These studies suggest that organic milk may contain significantly more beneficial ω -3 fatty acids (SMD, 11.17 [CI, 5.93 to 16.41]; $P < 0.001$; $I^2 = 98\%$; 5 studies; median difference, 0.5 g/100 g [minimum difference, 0.23 g/100 g; maximum difference, 4.5 g/100 g]) and vaccenic acid than conventional milk (SMD, 2.62 [CI, 1.04 to 4.19]; $P = 0.031$; $I^2 = 97\%$; 5 studies; median difference, 0.26 g/100 g [minimum difference, 0.11 g/100 g; maximum difference, 3.1 g/100 g]). All but 1 of these studies (212) tested raw milk samples. Results were robust to removal of 1 study at a time. Similarly, organic chicken contained higher levels of ω -3 fatty acids than conventional chicken (SMD, 5.48 [CI, 2.19 to 8.76]; $P = 0.031$; $I^2 = 90\%$; 3 studies; median difference, 1.99 g/100 g [minimum difference, 0.94 g/100 g; maximum difference, 17.9 g/100 g]). The differences between the remaining fatty acids examined in chicken and milk (Sup-

Figure 2. RD of detecting any pesticide residues in organic and conventional fruits, vegetables, and grains.



All studies sampled food from retail or wholesale settings except Hoogenboom and colleagues (159), which sampled directly from farms. Tasiopoulou and colleagues (263) did not specify the study design, but because the testing was part of a governmental monitoring program, we assume that samples were obtained from retail or wholesale settings, similar to the other government monitoring programs (75, 79, 231). We used a continuity correction of 0.5 (half a sample contaminated) for studies with 0 counts to allow RDs to be calculated. Removal of studies with 0 cells did not change results (see Appendix, available at www.annals.org). All RDs are absolute RDs. Summary *P* values are adjusted *P* values. Funnel plots did not suggest publication bias, and results were robust to removal of 1 study at a time. RD = risk difference.

plement 6) were heterogeneous and statistically insignificant. Several included studies reported that the season of sampling and brand of milk affected fatty acid levels at least as much as the farming method (93, 94, 123, 125).

We found no difference in the protein or fat content of organic and conventional milk (Supplement 5). Results were robust to removal of 1 study at a time. Too few studies examined the protein and fat content of meats to calculate summary effect sizes.

Contaminants

Pesticide Contamination

Detectable pesticide residues were found in 7% of organic produce samples (CI, 4% to 10%; 3041 samples) and 38% of conventional produce samples (CI, 32% to 45%; 106 755 samples) (9 studies) (Table 2). Studies of meats, poultry, eggs, and milk did not assess pesticide levels. Organic produce had 30% lower risk for contamination with any detectable pesticide residue than conventional produce (RD, -30% [CI, -37% to -23%]; *P* < 0.001; $I^2 = 94\%$; 9 studies) (Figure 2). This result was statistically heterogeneous, potentially because of the variable level of detection used among these studies.

Only 3 studies reported the prevalence of contamination exceeding maximum allowed limits; all were from the European Union (159, 183, 263). One study was small (10 samples per group) and did not detect any pesticide resi-

dues exceeding maximum allowed limits in either group (159). Differences in prevalence of contamination exceeding maximum allowed limits were small among the other 2 studies (6% [60 of 1048 studies] for organic vs. 2% [179 of 2237 studies] for conventional [183], and 1% [1 of 266 studies] for organic vs. 1% [36 of 324 studies] for conventional [263]).

Bacterial Contamination

Prevalence of *E. coli* contamination was 7% in organic produce (CI, 4% to 11%; 826 samples) and 6% in conventional produce (CI, 2% to 9%; 1454 samples)—not a statistically significant difference (Figure 3) (RD, 2.4% [CI, -1.5% to 6.2%]; *P* = 1.00; $I^2 = 58\%$), although only 5 studies examined this outcome. Four of these 5 studies found higher risk for contamination among organic produce. In sensitivity analyses, when we removed the 1 study (of lettuce) that found higher contamination among conventional produce, we found that organic produce had a 5% greater risk for contamination than conventional alternatives (RD, 5.1% [CI, 2.92% to 7.18%]; *P* < 0.001; $I^2 = 0\%$). No study detected *Salmonella* (90, 159, 205, 206, 214), enterohemorrhagic *E. coli* (90, 159, 205, 206, 214), or *Listeria* (214, 226) among produce samples.

Bacterial contamination is common among both organic and conventional animal products; however, differ-

ences in the prevalence of bacterial contamination between organic and conventional animal products were statistically insignificant (Figure 4). For chicken, 67% (CI, 42% to 93%) of organic samples and 64% (CI, 40% to 90%) of conventional samples were contaminated with *Campylobacter* and 35% (CI, 8% to 63%) of organic samples and 34% (CI, 16% to 52%) of conventional samples were contaminated with *Salmonella* (3 studies). Pork was commonly contaminated with *E. coli* (65% of organic and 49% of conventional samples) (201), *Salmonella* (median, 5.1%; range, 0% to 39%) (282), and *Listeria monocytogenes* (3% of organic and 4% of conventional samples) (152). No studies compared the contamination of organic and conventional beef with human pathogens.

Antibiotic Resistance

The risk for isolating bacteria resistant to 3 or more antibiotics was 33% higher among conventional chicken and pork than organic alternatives (CI, 21% to 45%; $P < 0.001$; $I^2 = 62%$; 5 studies) (Figure 5 [top panel] and Supplement 7, available at www.annals.org). Results were robust to removal of 1 study at a time. Bacteria isolated from retail samples of organic chicken and pork had 35% lower risk for resistance to ampicillin (RD, -34.9% [CI, -56.2% to -13.6%]; $P = 0.031$; $I^2 = 90%$; 5 studies) (Figure 5 [bottom panel]), although removal of 1 study rendered results statistically insignificant. Although comparisons for most of the remaining antibiotics suggest greater resistance among bacteria isolated from conventional compared with organic products, differences were statistically insignificant (Supplement 8, available at www.annals.org). Few studies examined resistance to the same antibiotic on the same animal product, and effect sizes were heterogeneous.

Fungal Toxin and Heavy Metal Contamination

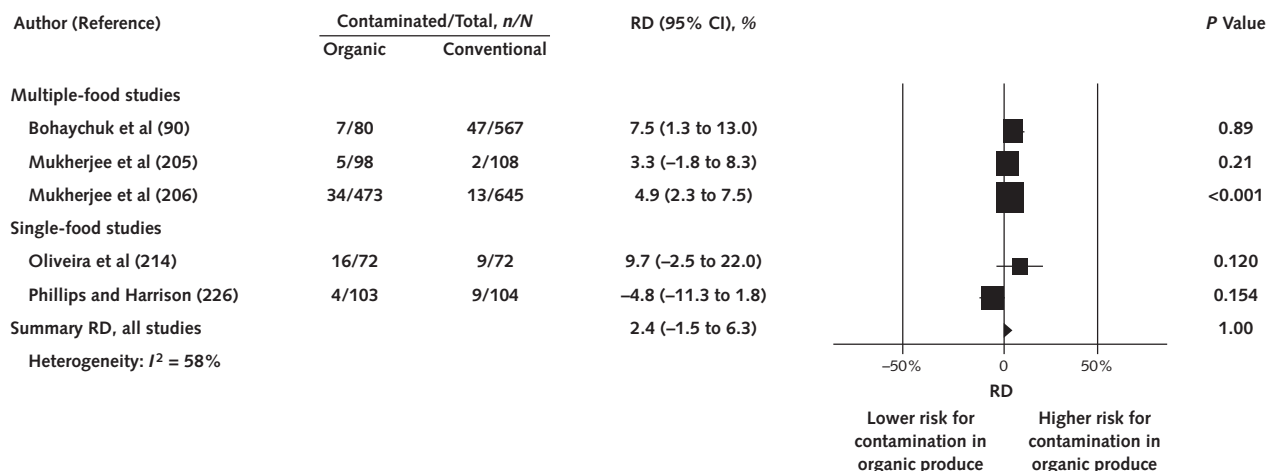
The included studies demonstrate mixed results about contamination of grains with fungal toxins. We found no difference in risk for contamination with or mean levels of ochratoxin A (Table 2). However, we found lower levels and lower risk for contamination with deoxynivalenol in organic grains than conventional alternatives (SMD, -0.82 [CI, -1.19 to -0.45]; $P < 0.001$; $I^2 = 69$; 8 studies; median difference, -34 $\mu\text{g}/\text{kg}$ [minimum difference, -426 $\mu\text{g}/\text{kg}$; maximum difference, 72 $\mu\text{g}/\text{kg}$] (RD, -23% [CI, -37% to -8%]; $P = 0.043$; $I^2 = 89$; 9 studies). Results were similar in subgroup analyses by grain type (Appendix, available at www.annals.org). Among studies of produce, no significant differences in cadmium or lead content were identified (Table 2). All results were heterogeneous.

Heterogeneity and Subgroup Analyses

To explore causes of heterogeneity, we conducted subgroup analyses by specific food, testing method (fresh vs. dry weight, and peeled and washed vs. unpeeled and unwashed), study design, and organic standard used. Results remained heterogeneous when analyzed by food: No significant differences were found in the ascorbic acid content of cabbage (3 studies), carrots (3 studies), potatoes (3 studies), or tomatoes (9 studies); β -carotene content of tomatoes (3 studies); or protein content of wheat (6 studies) when grown organically versus conventionally. Subgroup analyses by testing method, study design, and organic standard remained heterogeneous and did not change findings, although sample sizes were smaller, limiting our ability to detect significant differences.

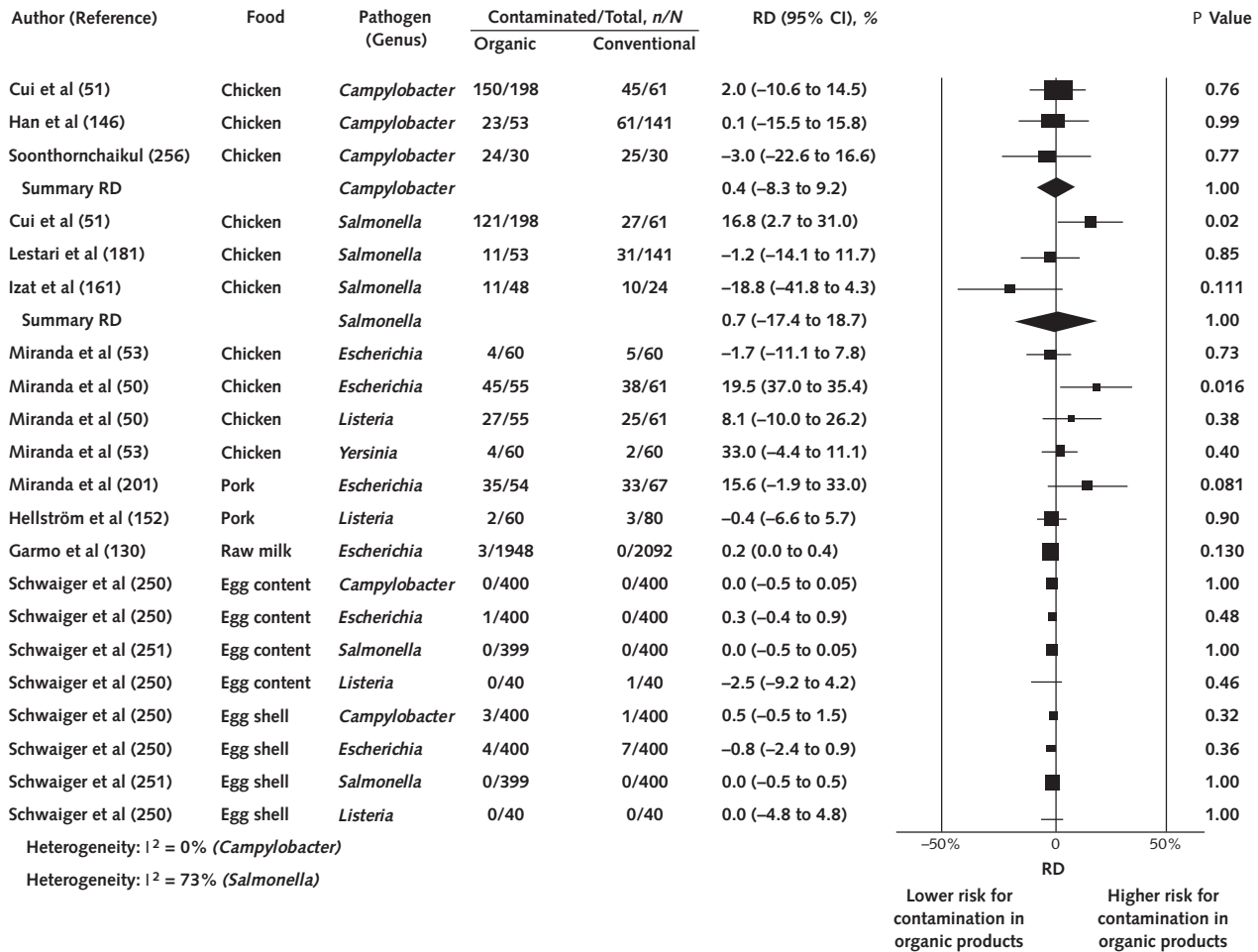
Only 1 data set reported peeling and washing produce before testing. However, the prevalence of contamination

Figure 3. RD of detecting *Escherichia coli* in organic and conventional fruits, vegetables, and grains.



All RDs are absolute RDs. Summary P value is an adjusted P value. Funnel plot did not suggest publication bias. Removal of 1 study (225) rendered results significant, suggesting higher contamination among organic produce (RD, 5.1% [95% CI, 2.92% to 7.18%]; $P < 0.001$; $I^2 = 0%$). All studies sampled foods directly from farms, except Bohaychuk and colleagues (90), which sampled produce purchased in retail settings. RD = risk difference.

Figure 4. RD for contamination of organic and conventional meat products with bacterial pathogens.



Meat samples were obtained from retail stores, milk samples were raw milk obtained from farms, and all egg samples were obtained directly from farms. Risk difference is calculated as the risk for contamination in the organic group minus that in the conventional group; thus, a positive (negative) number indicates more (less) contamination in organic products. All RDs are absolute RDs. Summary effect measures reported are results of random-effect models. $I^2 > 25\%$ suggests heterogeneity. Summary P values are adjusted P values. Funnel plots did not suggest publication bias, and results were robust to removal of 1 study at a time. All studies sampled products from retail or wholesale settings with 4 exceptions: Lestari and colleagues (181), Hellstrom and colleagues (152), Garmo and colleagues (130), and Schwaiger and colleagues (250, 251) sampled foods obtained directly from farms. Results for *Salmonella* in pork (282) are not reported in this figure because the authors reported only median prevalence of contamination. RD = risk difference.

in this study could not be compared with other studies because of use of different levels of detection (79). One study tested products for pesticide residues before and after peeling, finding that pesticide residues were undetectable in both organic and conventional samples once apples were peeled (203).

Reporting and Publication Bias

Among nutrient studies of produce, those with null findings tended to report results incompletely (hence, they could not be included in summary effect size calculations), suggesting publication bias (Table 1). For example, among the 34 studies that evaluated phenol levels in produce, only 36 of the 102 comparisons (35%) found higher levels in organic produce. However, only 24 of the 34 studies re-

ported sufficient data for analysis, and among these, we found significantly higher levels of total phenols among organic produce (Table 1). In addition, for total phenols and several other nutrients in produce, funnel plots were asymmetric, raising concern for publication bias. Similarly, funnel plots of analyses of fatty acids in milk suggested possible publication bias.

We adjusted P values to assign significance to differences between organic and conventional foods due to the multiple statistical comparisons. It may be reasonable to use a less stringent criterion for the interpretation of contaminant results because consumers may have a lower threshold in their desire to avoid harms. However, examination of unadjusted P values changes the conclusions for

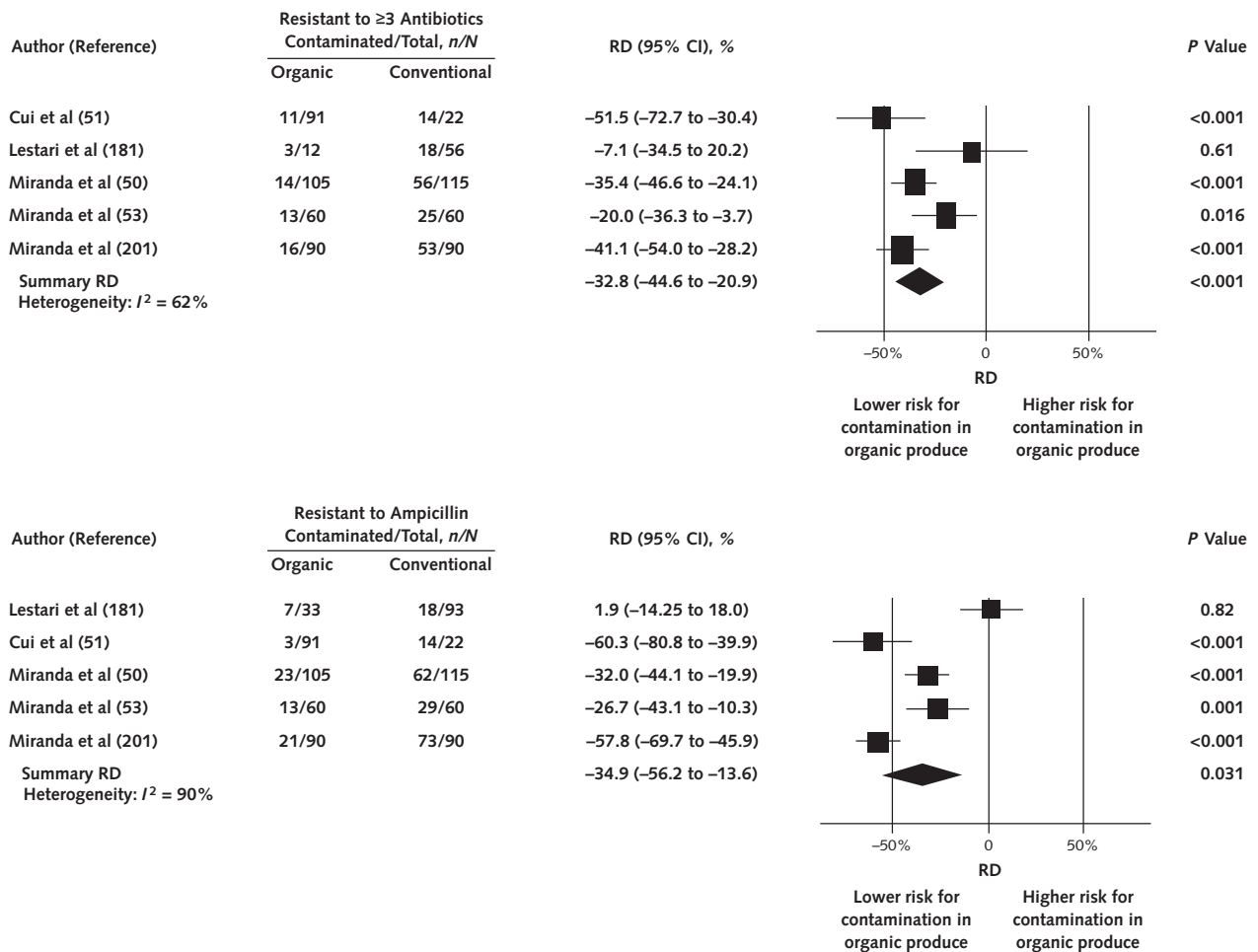
only a few outcomes: specifically, differences in contamination with bacteria resistant to cephalothin, sulfisoxazole, and tetracycline (Supplement 7).

DISCUSSION

Consumers purchase organic foods for many reasons. Despite the widespread perception that organically pro-

duced foods are more nutritious than conventional alternatives, we did not find robust evidence to support this perception. Of the nutrients evaluated, only 1 comparison, the phosphorus content of produce, demonstrated the superiority of organic foods (differences were statistically significant and homogenous), although removal of 1 study rendered this result statistically insignificant. Higher levels of phosphorus in organic produce than in conventional

Figure 5. RD for isolating antibiotic-resistant bacteria in selected analyses.



Risk difference is calculated as the risk for contamination in the organic group minus that in the conventional group; thus, a positive (negative) number indicates more (less) contamination in the organic group. All RDs are absolute RDs. Summary P values are adjusted P values. The number of antibiotics tested in the included studies ranged from 8 to 15 (median, 9.5). All summary effect measures reported are results of random-effects models. Funnel plots did not suggest publication bias. All studies sampled food purchased in retail settings except Lestari and colleagues (181), which sampled animal products obtained directly from farms. The top panel shows the difference in risk for detecting *Escherichia coli*, *Salmonella* species, and *Enterobacteriaceae* resistance to at least 3 antibiotics in organic vs. conventional chicken and pork. One study (50) examined drug resistance patterns for 3 organisms (*E. coli*, *Listeria*, and *Staphylococcus aureus*) identified on organic and conventional products. To avoid entering the same study twice in the analyses, we included only the resistance patterns reported for *E. coli*. However, in sensitivity analysis, we included the results for *Listeria* instead of *E. coli*. The results did not substantially change. Two studies (52, 53) reported antibiotic resistance patterns for different bacteria (*Enterobacteriaceae* [53] and *Enterococcus* species [52]) obtained from the same population of retail packaged chicken. To avoid entering the same chickens in the synthesis twice, we included *Enterobacteriaceae* results in the syntheses (reported above) because it is the family to which *E. coli* and *Salmonella* belong. In sensitivity analysis, we used the *Enterococcus* results, which did not substantially change findings. Results were robust to removal of 1 study at a time from summary effect estimate. The bottom panel shows the difference in risk for detecting *E. coli*, *Salmonella* species, and *Enterobacteriaceae* resistance to ampicillin in organic vs. conventional chicken and pork. The result was not robust to removal of 1 study at a time from summary effect estimate. RD = risk difference.

produce is consistent with previous reviews (19, 20), although it is unlikely to be clinically significant because near-total starvation is needed to produce dietary phosphorus deficiency (287).

We also found statistically higher levels of total phenols in organic produce, ω -3 fatty acids in organic milk and chicken, and vaccenic acid in organic chicken than in conventional products, although these results were highly heterogeneous and the number of studies examining fatty acids was small (≤ 5). Our finding of higher levels of these beneficial fatty acids in organic than in conventional milk is consistent with another recent meta-analysis of these outcomes (288). One study examining the breast milk of mothers consuming strictly organic diets found higher levels of trans-vaccenic acid (58), similar to our findings among organic dairy products. Otherwise, studies measuring nutrient levels among humans consuming organic and conventional diets did not find consistent differences.

Our study has 3 additional key findings. First, conventional produce has a 30% higher risk for pesticide contamination than organic produce. However, the clinical significance of this finding is unclear because the difference in risk for contamination with pesticide residue exceeding maximum allowed limits may be small. One study found that children switched to an organic diet for 5 days had significantly lower levels of pesticide residue in their urine (55), consistent with our findings among the food studies.

Second, we found no difference in the risk for contamination of produce or animal products with pathogenic bacteria. Both organic and conventional animal products were commonly contaminated with *Salmonella* and *Campylobacter* species. The reported rates of contamination are consistent with published contamination rates of U.S. retail meat samples (289–291). However, with removal of 1 study, results suggested that organic produce has a higher risk for contamination with *E. coli*, a finding that was both homogeneous and statistically significant. Similarly, an exploratory case-control study suggested that human consumption of organic meat in the winter is associated with symptomatic *Campylobacter* infection (70). These preliminary findings need to be confirmed with additional research. A recent U.S. study found that produce from organic farms using manure for fertilization was at significantly higher risk for contamination with *E. coli* than was produce from organic farms not using animal waste (odds ratio, 13.2 [CI, 2.6 to 61.2]) (292).

Third, we found that conventional chicken and pork have a higher risk for contamination with bacteria resistant to 3 or more antibiotics than were organic alternatives. This increased prevalence of antibiotic resistance may be related to the routine use of antibiotics in conventional animal husbandry. However, the extent to which antibiotic use for livestock contributes to antibiotic-resistant pathogens in humans continues to be debated (293) because inappropriate use of antibiotics in humans is the major cause of antibiotic-resistant infections in humans. A previ-

ous review (23) reported that ciprofloxacin-resistant *Campylobacter* was more common among conventional than organic chickens, a finding that our study did not detect. Unlike the previous study, most of our included studies were done after bans on fluoroquinolone use and we excluded fecal samples. As a precaution, the European Union banned the use of some antibiotics in animal feed for growth promotion in 2006 (294), and the United States banned the use of enrofloxacin in 2005 (295).

Finally, there have been no long-term studies of health outcomes of populations consuming predominantly organic versus conventionally produced food controlling for socioeconomic factors; such studies would be expensive to conduct. Only 3 short observational studies examined a very limited set of clinical outcomes: 2 studies evaluating allergic outcomes of a cohort of children consuming organic versus conventional diets in Europe found no association between diet and allergic outcomes (61, 64).

Our results should be interpreted with caution because summary effect estimates were highly heterogeneous. Three potential sources of heterogeneity are study methods (for example, measurement and sampling methods, study design, or organic standard used), physical factors (for example, season, weather, soil type, ripeness, cultivar, or storage practices [14, 111, 165, 171, 296]), and variation within organic practices.

For example, heterogeneity among studies of pesticide contamination likely reflects variation in the sensitivity of testing methods and differences in pesticide contamination by food type and country of origin (75, 297). To explore causes of heterogeneity, we conducted subgroup analyses by study design, assay method (fresh vs. dry weight), and organic standard used in the study; however, these sub-analyses did not reduce observed heterogeneity.

Too few studies for any 1 outcome reported information about physical factors to conduct subgroup analyses, although many studies controlled for these factors (for example, 86% of meat studies specified sampling both production systems during the same season and approximately 60% of comparison produce pairs were of the same cultivar and harvested from neighboring farms). Many studies noted that season of sampling and brand of milk were important determinants of nutrient and fatty acid levels (93, 94, 123, 125) because organic and conventional cows may have similar diets in the winter but different diets in the summer when grass is available for organic cows.

Finally, variation within organic practices (even if certified under the same standard) may also explain heterogeneity. A review of organic practices concluded that “variation within organic and conventional farming systems is likely as large as differences between the two systems” (298). For example, the use and handling of manure fertilizers (a risk factor for bacterial contamination) varies among organic farms (292).

Our study has several additional limitations. First, produce studies, most of which were experimental field stud-

ies, may not reflect real-world organic practices. Subgroup analyses by study design did not change conclusions, although sample sizes were small. Additionally, studies with null findings frequently failed to adequately report results, potentially biasing our study to find differences where none exist. Finally, milk results should be interpreted with caution because most milk studies examined raw rather than pasteurized milk.

In summary, our comprehensive review of the published literature on the comparative health outcomes, nutrition, and safety of organic and conventional foods identified limited evidence for the superiority of organic foods. The evidence does not suggest marked health benefits from consuming organic versus conventional foods, although organic produce may reduce exposure to pesticide residues and organic chicken and pork may reduce exposure to antibiotic-resistant bacteria.

From Veterans Affairs Palo Alto Health Care System, Palo Alto, California; Division of General Medical Disciplines and Lane Medical Library, Stanford School of Medicine, Stanford, California; and Center for Health Policy/Center for Primary Care Outcomes Research, Department of Management Science & Engineering, and Department of Statistics, Stanford University, Stanford, California.

Note: As the corresponding author and guarantor of the manuscript, Crystal Smith-Spangler, MD, MS, takes full responsibility for the work as a whole, including the study design, access to data, and decision to submit the manuscript for publication.

Acknowledgment: The authors thank the staff of DocXpress at Lane Medical Library for document retrieval.

Financial Support: Ms. Pearson was supported by a Stanford Undergraduate Research Grant.

Potential Conflicts of Interest: None disclosed. Forms can be viewed at www.acponline.org/authors/icmje/ConflictOfInterestForms.do?msNum=M12-0192.

Requests for Single Reprints: Crystal Smith-Spangler, MD, MS, Stanford Center for Health Policy and Center for Primary Care and Outcomes Research, 117 Encina Commons, Stanford University, Stanford, CA 94305-6019; e-mail, csmithsp@stanford.edu.

Current author addresses and author contributions are available at www.annals.org.

References

- Dimitri C, Oberholtzer L. Marketing U.S. Organic Foods: Recent Trends From Farms to Consumers. U.S. Department of Agriculture Economic Research Service, Economic Information Bulletin no. EIB-58. September 2009. Accessed at www.ers.usda.gov/Publications/EIB58/ on 14 July 2012.
- Organic Trade Association. U.S. organic industry valued at nearly \$29 billion in 2010. Accessed at www.organicnewsroom.com/2011/04/us_organic_industry_valued_at.html on 15 July 2012.
- Martin A, Severson K. Sticker shock in the organic aisles. *New York Times*. 18 April 2008. Accessed at www.nytimes.com/2008/04/18/business/18organic.html on 14 July 2012.

- U.S. Department of Agriculture Economic Research Service. Data Products: Organic Prices. 2009. Accessed at www.ers.usda.gov/Data/OrganicPrices/ on 23 November 2009.
- Winter CK, Davis SF. Organic foods. *J Food Sci*. 2006;71:R117-24.
- International Federation of Organic Agriculture Movements (IFOAM). The IFOAM Norms for Organic Production and Processing Version 2005. Bonn, Germany: IFOAM; 2006. Accessed at http://shop.ifoam.org/bookstore/download_preview/IFOAM_NORMS_2005_intro.pdf on 18 June 2012.
- National Archives and Records Administration. Electronic Code of Federal Regulations, Title 7: Agriculture, Part 205—National Organic Program, Subpart C—Organic Production and Handling Requirements. Washington, DC: U.S. Government Printing Office; 2010. Accessed at <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&trgn=div5&view=text&node=7:3.1.1.9.32&idno=7#7:3.1.1.9.32.3> on 18 June 2012.
- Commission of European Communities. Council Regulation (EC) No. 834/2007. Brussels, Belgium: Commission of European Communities; 2007. Accessed at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:189:0001:0023:EN:PDF> on 18 June 2012.
- International Federation of Organic Agriculture Movements (IFOAM). The Principles of Organic Agriculture. Bonn, Germany: IFOAM; 2009. Accessed at www.ifoam.org/about_ifoam/principles/index.html on 12 May 2012.
- Williams PR, Hammitt JK. A comparison of organic and conventional fresh produce buyers in the Boston area. *Risk Anal*. 2000;20:735-46. [PMID: 11110219]
- Williams PR, Hammitt JK. Perceived risks of conventional and organic produce: pesticides, pathogens, and natural toxins. *Risk Anal*. 2001;21:319-30. [PMID: 11414540]
- Jolly DA, Schutz HG, Diaz-Knauf KV, Johal J. Organic foods: consumer attitudes and use. *Food Technol*. 1989;43:60-6.
- Woese K, Lange D, Boess C, Bögl KW. A comparison of organically and conventionally grown foods—results of a review of the relevant literature. *J Sci Food Agric*. 1997;74:281-93.
- Magkos F, Arvaniti F, Zampelas A. Organic food: nutritious food or food for thought? A review of the evidence. *Int J Food Sci Nutr*. 2003;54:357-71. [PMID: 12907407]
- Bourn 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;42:1-34. [PMID: 11833635]
- Heaton S. Organic farming, food quality and human health. A review of the evidence. Bristol, UK: British Soil Assoc; 2001. Accessed at www.soilassociation.org/LinkClick.aspx?fileticket=cY8kfP3Q%2BgA%3D&tabid=388 on 12 July 2012.
- Huber M, Rembialkowska E, Średnicka D, Bügel S, van de Vijver LPL. Organic food and impact on human health: assessing the status quo and prospects of research. *NJAS—Wageningen Journal of Life Sciences*. 2011;58:103-9.
- Lairon D. Nutritional quality and safety of organic food. A review. *Agronomy for Sustainable Development*. 2010;30:33-41.
- Worthington V. Nutritional quality of organic versus conventional fruits, vegetables, and grains. *J Altern Complement Med*. 2001;7:161-73. [PMID: 11327522]
- Dangour AD, Dodhia SK, Hayter A, Allen E, Lock K, Uauy R. Nutritional quality of organic foods: a systematic review. *Am J Clin Nutr*. 2009;90:680-5. [PMID: 19640946]
- Benbrook C, Zhao X, Yanez J, Davies N, Andrews P. New evidence confirms nutritional superiority of plant-based organic foods. Boulder, CO: The Organic Center; March 2008. Accessed at www.organic-center.org/science.nutri.php?action=view&report_id=126 on 18 June 2012.
- Brandt K, Leifert C, Sanderson R, Seal CJ. Agroecosystem management and nutritional quality of plant foods: the case of organic fruits and vegetables. *Critical Review in Plant Sciences*. 2011;30:177-97.
- Young I, Rajić A, Wilhelm BJ, Waddell L, Parker S, McEwen SA. Comparison of the prevalence of bacterial enteropathogens, potentially zoonotic bacteria and bacterial resistance to antimicrobials in organic and conventional poultry, swine and beef production: a systematic review and meta-analysis. *Epidemiol Infect*. 2009;137:1217-32. [PMID: 19379542]
- Champeil A, Fourbet JF, Dore T, Rossignol L. Influence of cropping system on Fusarium head blight and mycotoxin levels in winter wheat. *Crop Prot*. 2004;23:531-7.
- Stalenga J. Applicability of different indices to evaluate nutrient status of winter wheat in the organic system. *J Plant Nutr*. 2007;30:351-65.

26. Forster MP, Rodríguez Rodríguez E, Martín JD, Díaz Romero C. Statistical differentiation of bananas according to their mineral composition. *J Agric Food Chem*. 2002;50:6130-5. [PMID: 12358491]
27. Petterson BD, von Wistinghausen E, Brinton WF, Woods End Agricultural Institute. *Organic, Biodynamic and Conventional Cropping Systems: A Long Term Comparison*. Mt. Vernon, ME: Woods End Agricultural Institute; 1988.
28. Nilsson T. Yield, storage ability, quality and chemical composition of carrot, cabbage and leek at conventional and organic fertilizing. *Acta Hort*. 1979;209-23.
29. Krejčířová L, Capouchová I, Petr J, Bicanová E, Kvapil R. Protein composition and quality of winter wheat from organic and conventional farming. *Žemdirbystė-Agriculture*. 2006;93:285-96.
30. Fernandes ALT, Rodrigues GP, Testezlaf R. Mineral and organomineral fertirrigation in relation to quality of greenhouse-cultivated melon. *Scientia Agricola*. 2003;60:149-54.
31. Petr J, Škerik J, Psota V, Langer I. Quality of malting barley grown under different cultivation systems. *Monatsschrift für Brauwissenschaft*. 2000;53:90-4.
32. Singh SR. Effect of organic farming system on yield and quality of Brinjal (*Solanum melongena* L) var Pusa Purple Cluster under mid-hill conditions of Himachal Pradesh. *Haryana Journal of Horticultural Sciences*. 2004;33:265-6.
33. Kannan P, Saravanan A, Balaji T. Organic farming on tomato yield and quality. *Crop Research-Hisar*. 2006;32:196-200.
34. Daoud HG, Tomoskozi-Farkas R, Kapitany J. Antioxidant content of bio and conventional spice red pepper (*Capsicum annum* L) as determined by HPLC. *Acta Agronomica Hungarica*. 2006;54:133-40.
35. Anttonen MJ, Karjalainen RO. High-performance liquid chromatography analysis of black currant (*Ribes nigrum* L.) fruit phenolics grown either conventionally or organically. *J Agric Food Chem*. 2006;54:7530-8. [PMID: 17002418]
36. De Pascale S, Tamburrino R, Maggio A, Barbieri G, Fogliano V, Pernice R. Effects of nitrogen fertilization on the nutritional value of organically and conventionally grown tomatoes. *Acta Hort*. 2006;700:107-10.
37. Sousa C, Pereira DM, Pereira JA, Bento A, Rodrigues MA, Dopico-García S, et al. Multivariate analysis of tronchuda cabbage (*Brassica oleracea* L. var. *costata* DC) phenolics: influence of fertilizers. *J Agric Food Chem*. 2008;56:2231-9. [PMID: 18290619]
38. Polat E, Demir H, Onus AN. Comparison of some yield and quality criteria in organically and conventionally-grown lettuce. *African Journal of Biotechnology*. 2008;7:1235-9.
39. Bahadur A, Singh J, Singh KP, Upadhyay AK, Mathura R. Effect of organic amendments and biofertilizer on growth, yield and quality attributes of Chinese cabbage (*Brassica pekinensis*). *The Indian Journal of Agricultural Sciences*. 2006;76:596-8.
40. Zahradník A, Petříková K. Effect of alternative organic fertilizers on the nutritional value and yield of head cabbage. *Horticultural Science*. 2007;34:65-71.
41. Pimpini F, Giardini L, Borin M, Gianquinto G. Effects of poultry manure and mineral fertilizers on the quality of crops. *The Journal of Agricultural Science*. 1992;118:215-21.
42. Saleha A. Studies on the effects of organic vs. inorganic form of nitrogen on the quality of okra. *Journal of Maharashtra Agricultural Universities*. 1992;17:133-4.
43. Srikumar TS, Ockerman PA. The effects of fertilization and manuring on the content of some nutrients in potato (var. Provita). *Food Chem*. 1990;37:47-60.
44. 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. [PMID: 2852803]
45. Vogtmann H, Matthies K, Kehres B, Meier-Ploeger A. Enhanced food quality: effects of composts on the quality of plant foods. *Compost Sci Util*. 1993;1:82-100.
46. Lazcano C, Revilla P, Malvar RA, Domínguez J. Yield and fruit quality of four sweet corn hybrids (*Zea mays*) under conventional and integrated fertilization with vermicompost. *J Sci Food Agric*. 2011;91:1244-53. [PMID: 21328364]
47. Citak S, Sonmez S. Mineral contents of organically and conventionally grown spinach (*Spinacea oleracea* L.) during two successive seasons. *J Agric Food Chem*. 2009;57:7892-8. [PMID: 19685878]
48. Sutton AJ, Duval SJ, Tweedie RL, Abrams KR, Jones DR. Empirical assessment of effect of publication bias on meta-analyses. *BMJ*. 2000;320:1574-7. [PMID: 10845965]
49. Centers for Disease Control and Prevention. FoodNet—Foodborne Diseases Active Surveillance Network. Atlanta: Centers for Disease Control and Prevention; 2011. Accessed at www.cdc.gov/foodnet on 23 April 2011.
50. Miranda JM, Vázquez BI, Fente CA, Calo-Mata P, Cepeda A, Franco CM. Comparison of antimicrobial resistance in *Escherichia coli*, *Staphylococcus aureus*, and *Listeria monocytogenes* strains isolated from organic and conventional poultry meat. *J Food Prot*. 2008;71:2537-42. [PMID: 19244911]
51. Cui S, Ge B, Zheng J, Meng J. Prevalence and antimicrobial resistance of *Campylobacter* spp. and *Salmonella* serovars in organic chickens from Maryland retail stores. *Appl Environ Microbiol*. 2005;71:4108-11. [PMID: 16000828]
52. Miranda JM, Guarddon M, Mondragon A, Vázquez BI, Fente CA, Cepeda A, et al. Antimicrobial resistance in *Enterococcus* spp. strains isolated from organic chicken, conventional chicken, and turkey meat: a comparative survey. *J Food Prot*. 2007;70:1021-4. [PMID: 17477278]
53. Miranda JM, Guarddon M, Vázquez BI, Fente CA, Barros-Velazquez J, Cepeda A, et al. Antimicrobial resistance in *Enterobacteriaceae* strains isolated from organic chicken, conventional chicken and conventional turkey meat: a comparative survey. *Food Control*. 2008;19:412-6.
54. Juhler RK, Larsen SB, Meyer O, Jensen ND, Spanò M, Giwercman A, et al. Human semen quality in relation to dietary pesticide exposure and organic diet. *Arch Environ Contam Toxicol*. 1999;37:415-23. [PMID: 10473800]
55. Curl CL, Fenske RA, Elgethun K. Organophosphorus pesticide exposure of urban and suburban preschool children with organic and conventional diets. *Environ Health Perspect*. 2003;111:377-82. [PMID: 12611667]
56. Grønder-Pedersen L, Rasmussen SE, Bügel S, Jørgensen LV, Dragsted LO, Gundersen V, et al. Effect of diets based on foods from conventional versus organic production on intake and excretion of flavonoids and markers of antioxidative defense in humans. *J Agric Food Chem*. 2003;51:5671-6. [PMID: 12952417]
57. Caris-Veyrat C, Amiot MJ, Tyssandier V, Grasselly D, Buret M, Mikolajczak M, et al. Influence of organic versus conventional agricultural practice on the antioxidant microconstituent content of tomatoes and derived purees; consequences on antioxidant plasma status in humans. *J Agric Food Chem*. 2004;52:6503-9. [PMID: 15479014]
58. Rist L, Mueller A, Barthel C, Snijders B, Jansen M, Simões-Wüst AP, et al. Influence of organic diet on the amount of conjugated linoleic acids in breast milk of lactating women in the Netherlands. *Br J Nutr*. 2007;97:735-43. [PMID: 17349086]
59. Lu C, Toepel K, Irish R, Fenske RA, Barr DB, Bravo R. Organic diets significantly lower children's dietary exposure to organophosphorus pesticides. *Environ Health Perspect*. 2006;114:260-3. [PMID: 16451864]
60. Lu C, Barr DB, Pearson MA, Walker LA, Bravo R. The attribution of urban and suburban children's exposure to synthetic pyrethroid insecticides: a longitudinal assessment. *J Expo Sci Environ Epidemiol*. 2009;19:69-78. [PMID: 18766203]
61. Kummeling I, Thijs C, Huber M, van de Vijver LP, Snijders BE, Penders J, et al. Consumption of organic foods and risk of atopic disease during the first 2 years of life in the Netherlands. *Br J Nutr*. 2008;99:598-605. [PMID: 17761012]
62. Briviba K, Stracke BA, Rüfer CE, Watzl B, Weibel FP, Bub A. Effect of consumption of organically and conventionally produced apples on antioxidant activity and DNA damage in humans. *J Agric Food Chem*. 2007;55:7716-21. [PMID: 17696483]
63. Lu C, Barr DB, Pearson MA, Waller LA. Dietary intake and its contribution to longitudinal organophosphorus pesticide exposure in urban/suburban children. *Environ Health Perspect*. 2008;116:537-42. [PMID: 18414640]
64. Fløistrup H, Swartz J, Bergström A, Alm JS, Scheynius A, van Hage M, et al; Parsifal Study Group. Allergic disease and sensitization in Steiner school children. *J Allergy Clin Immunol*. 2006;117:59-66. [PMID: 16387585]
65. Soltoft M, Bysted A, Madsen KH, Mark AB, Bügel SG, Nielsen J, et al. Effects of organic and conventional growth systems on the content of carotenoids in carrot roots, and on intake and plasma status of carotenoids in humans. *J Sci Food Agric*. 2011;91:767-75. [PMID: 21213256]
66. Stracke BA, Rüfer CE, Bub A, Seifert S, Weibel FP, Kunz C, et al. No effect of the farming system (organic/conventional) on the bioavailability of apple (*Malus domestica* Bork., cultivar Golden Delicious) polyphenols in healthy men: a comparative study. *Eur J Nutr*. 2010;49:301-10. [PMID: 20033417]

67. De Lorenzo A, Noce A, Bigioni M, Calabrese V, Della Rocca DG, Di Daniele N, et al. The effects of Italian Mediterranean organic diet (IMOD) on health status. *Curr Pharm Des*. 2010;16:814-24. [PMID: 20388092]
68. Mueller A, Thijs C, Rist L, Simões-Wüst AP, Huber M, Steinhart H. Trans fatty acids in human milk are an indicator of different maternal dietary sources containing trans fatty acids. *Lipids*. 2010;45:245-51. [PMID: 20148367]
69. Stracke BA, Rüfer CE, Bub A, Briviba K, Seifert S, Kunz C, et al. Bioavailability and nutritional effects of carotenoids from organically and conventionally produced carrots in healthy men. *Br J Nutr*. 2009;101:1664-72. [PMID: 19021920]
70. Gillespie IA, O'Brien SJ, Adak GK, Tam CC, Frost JA, Bolton FJ, et al; *Campylobacter Sentinel Surveillance Scheme Collaborators*. Point source outbreaks of *Campylobacter jejuni* infection—are they more common than we think and what might cause them? *Epidemiol Infect*. 2003;130:367-75. [PMID: 12825720]
71. Acharya T, Bhatnagar V. Quality assessment of organic and conventional Nagpur mandarins (*Citrus reticulata*). *Indian Journal of Nutrition and Dietetics*. 2007;44:403-6.
72. Aldrich HT, Salandanan K, Kendall P, Bunning M, Stonaker F, Külen O, et al. Cultivar choice provides options for local production of organic and conventionally produced tomatoes with higher quality and antioxidant content. *J Sci Food Agric*. 2010;90:2548-55. [PMID: 20718027]
73. Amodio ML, Colelli G, Hasey JK, Kader AA. A comparative study of composition and postharvest performance of organically and conventionally grown kiwifruits. *J Sci Food Agric*. 2007;87:1228-36.
74. Amvrazi EG, Albanis TA. Pesticide residue assessment in different types of olive oil and preliminary exposure assessment of Greek consumers to the pesticide residues detected. *Food Chem*. 2009;113:253-61.
75. Andersen JH, Poulsen ME. Results from the monitoring of pesticide residues in fruit and vegetables on the Danish market, 1998-99. *Food Addit Contam*. 2001;18:906-31. [PMID: 11569771]
76. Angood KM, Wood JD, Nute GR, Whittington FM, Hughes SI, Sheard PR. A comparison of organic and conventionally-produced lamb purchased from three major UK supermarkets: price, eating quality and fatty acid composition. *Meat Sci*. 2008;78:176-84. [PMID: 22062268]
77. Asami DK, Hong YJ, Barrett DM, Mitchell AE. Comparison of the total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry, and corn grown using conventional, organic, and sustainable agricultural practices. *J Agric Food Chem*. 2003;51:1237-41. [PMID: 12590461]
78. Bacchi MA, de Nadai Fernandes EA, Tsai SM, Santos LGC. Conventional and organic potatoes: assessment of elemental composition using k_0 -INAA. *Journal of Radioanalytical Nuclear Chemistry*. 2003;259:421-4.
79. Baker BP, Benbrook CM, Groth E 3rd, Lutz Benbrook K. Pesticide residues in conventional, integrated pest management (IPM)-grown and organic foods: insights from three US data sets. *Food Addit Contam*. 2002;19:427-46. [PMID: 12028642]
80. Barrett DM, Weakley C, Diaz JV, Watnik M. Qualitative and nutritional differences in processing tomatoes grown under commercial organic and conventional production systems. *J Food Sci*. 2007;72:C441-51. [PMID: 18034702]
81. Bavec M, Turinek M, Grobelnik-Mlakar S, Slatnar A, Bavec F. Influence of industrial and alternative farming systems on contents of sugars, organic acids, total phenolic content, and the antioxidant activity of red beet (*Beta vulgaris* L. ssp. *vulgaris* Rote Kugel). *J Agric Food Chem*. 2010;58:11825-31. [PMID: 20964342]
82. Beltran-Gonzalez F, Perez-Lopez AJ, Lopez-Nicolas JM, Carbonell-Barrachina AA. Effects of agricultural practices on instrumental colour, mineral content, carotenoid composition, and sensory quality of mandarin orange juice, cv. Hernandina. *J Sci Food Agric*. 2008;88:1731-8.
83. Bennedsgaard TW, Thamsborg SM, Aarestrup FM, Enevoldsen C, Vaarst M, Christoffersen AB. Resistance to penicillin of *Staphylococcus aureus* isolates from cows with high somatic cell counts in organic and conventional dairy herds in Denmark. *Acta Vet Scand*. 2006;48:24. [PMID: 17125515]
84. Baretta B, De Domenico R, Gaiaschi A, Ballabio C, Galli CL, Gigliotti C, et al. Ochratoxin A in cereal-based baby foods: occurrence and safety evaluation. *Food Addit Contam*. 2002;19:70-5. [PMID: 11817376]
85. Bergamo P, Fedele E, Iannibelli L, Marzillo G. Fat-soluble vitamin contents and fatty acid composition in organic and conventional Italian dairy products. *Food Chem*. 2003;82:625-31.
86. Bernhoft A, Clasen PE, Kristoffersen AB, Torp M. Less *Fusarium* infestation and mycotoxin contamination in organic than in conventional cereals. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess*. 2010;27:842-52. [PMID: 20425661]
87. Bicanova E, Capouchova I, Krejcirova L, Petr J, Erhartova D. The effect of growth structure on organic winter wheat quality. *Zemdirbyste/Agriculture*. 2006;93:297-305.
88. Biffi R, Munari M, Dioguardi L, Ballabio C, Cattaneo A, Galli CL, et al. Ochratoxin A in conventional and organic cereal derivatives: a survey of the Italian market, 2001-02. *Food Addit Contam*. 2004;21:586-91. [PMID: 15204537]
89. Blanco-Penedo I, López-Alonso M, Miranda M, Hernández J, Prieto F, Shore RF. Non-essential and essential trace element concentrations in meat from cattle reared under organic, intensive or conventional production systems. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess*. 2010;27:36-42. [PMID: 19750401]
90. Bohaychuk VM, Bradbury RW, Dimock R, Fehr M, Gensler GE, King RK, et al. A microbiological survey of selected Alberta-grown fresh produce from farmers' markets in Alberta, Canada. *J Food Prot*. 2009;72:415-20. [PMID: 19350990]
91. Bombyk RA, Bykowski AL, Draper CE, Savelkoul EJ, Sullivan LR, Wyckoff TJ. Comparison of types and antimicrobial susceptibility of *Staphylococcus* from conventional and organic dairies in west-central Minnesota, USA. *J Appl Microbiol*. 2008;104:1726-31. [PMID: 18179539]
92. Butler G, Collomb M, Rehberger B, Sanderson R, Eyre M, Leifert C. Conjugated linoleic acid isomer concentrations in milk from high- and low-input management dairy systems. *J Sci Food Agric*. 2009;89:697-705.
93. Butler G, Nielsen JH, Slots T, Seal C, Eyer MD, Sanderson R, et al. Fatty acid and fat-soluble antioxidant concentrations in milk from high- and low-input conventional and organic systems: seasonal variation. *J Sci Food Agric*. 2008;88:1431-41.
94. Butler G, Stergiadis S, Seal C, Eyre M, Leifert C. Fat composition of organic and conventional retail milk in northeast England. *J Dairy Sci*. 2011;94:24-36. [PMID: 21183013]
95. Carbanaro M, Mattered M. Polyphenoloxidase activity and polyphenol levels in organically and conventionally grown peach (*Prunus persica* L., cv. Regina binca) and pear (*Pyrus communis* L., cv. Williams). *Food Chem*. 2001;72:419-24.
96. Carbonaro M, Mattered M, Nicoli S, Bergamo P, Cappelloni M. Modulation of antioxidant compounds in organic vs conventional fruit (peach, *Prunus persica* L., and pear, *Pyrus communis* L.). *J Agric Food Chem*. 2002;50:5458-62. [PMID: 12207491]
97. Carcea M, Salvatorelli S, Turfani V, Mellara F. Influence of growing conditions on the technological performance of bread wheat (*Triticum aestivum* L.). *International Journal of Food Science and Technology*. 2006;41:102-7.
98. Castellini C, Mugnai C, Dal Bosco A. Effect of organic production system on broiler carcass and meat quality. *Meat Sci*. 2002;60:219-25. [PMID: 22063392]
99. Cayuela JA, Vidueira JM, Albi MA, Gutierrez F. Influence of the ecological cultivation of strawberries (*Fragaria X Ananassa* cv. chandler) on the quality of the fruit and on their capacity for conservation. *J Agric Food Chem*. 1997;45:1736-40.
100. Champagne ET, Bett-Garber KL, Grimm CC, McClung AM. Effects of organic fertility management on physicochemical properties and sensory quality of diverse rice cultivars. *Cereal Chemistry*. 2007;84:320-7.
101. Chang PT, Salomon M. Metals in grains sold under various labels—organic, natural conventional. *J Food Qual*. 1978;1:373-7.
102. Chassy AW, Bui L, Renaud EN, Van Horn M, Mitchell AE. Three-year comparison of the content of antioxidant microconstituents and several quality characteristics in organic and conventionally managed tomatoes and bell peppers. *J Agric Food Chem*. 2006;54:8244-52. [PMID: 17032035]
103. Cirillo T, Ritieni A, Visone M, Cocchieri RA. Evaluation of conventional and organic Italian foodstuffs for deoxynivalenol and fumonisins B(1) and B(2). *J Agric Food Chem*. 2003;51:8128-31. [PMID: 14690407]
104. Clarke RP, Merrow SB. Nutrient composition of tomatoes homegrown under different cultural procedures. *Ecol Food Nutr*. 1979;8:37-46.
105. Colla G, Mitchell JP, Poudel DD, Temple SR. Changes of tomato yield and fruit elemental composition in conventional, low input, and organic systems. *J Sustain Agric*. 2002;20:53-67.
106. Collins M, Nassif W. Pesticide residues in organically and conventionally grown fruit and vegetables in New South Wales, 1990-91. *Food Australia*. 1993;45:429-31.

107. Collomb M, Bisig W, Butikofer U, Sieber R, Bregy M, Etter L. Fatty acid composition of mountain milk from Switzerland: comparison of organic and integrated farming systems. *Int Dairy J*. 2008;18:976-82.
108. Coorevits A, De Jonghe V, Vandroemme J, Reekmans R, Heyman J, Messens W, et al. Comparative analysis of the diversity of aerobic spore-forming bacteria in raw milk from organic and conventional dairy farms. *Syst Appl Microbiol*. 2008;31:126-40. [PMID: 18406093]
109. Corrales M, Fernandez A, Vizoso Pinto MG, Butz P, Franz CM, Schuele E, et al. Characterization of phenolic content, in vitro biological activity, and pesticide loads of extracts from white grape skins from organic and conventional cultivars. *Food Chem Toxicol*. 2010;48:3471-6. [PMID: 20870004]
110. Cuuubonn J, Foltys V, Hasszók P, Kačániová M, Ubrezziová I, Kráčmar S. The raw milk quality from organic and conventional agriculture. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*. 2008;56:25-30.
111. Czerwiecki L, Czajkowska D, Witkowska-Gwiazdowska A. On ochratoxin A and fungal flora in Polish cereals from conventional and ecological farms. Part 2: occurrence of ochratoxin A and fungi in cereals in 1998. *Food Addit Contam*. 2002;19:1051-7. [PMID: 12456276]
112. Dahl L, Opsahl JA, Meltzer HM, Julshamn K. Iodine concentration in Norwegian milk and dairy products. *Br J Nutr*. 2003;90:679-85. [PMID: 13129475]
113. D'Amico DJ, Donnelly CW. Microbiological quality of raw milk used for small-scale artisan cheese production in Vermont: effect of farm characteristics and practices. *J Dairy Sci*. 2010;93:134-47. [PMID: 20059912]
114. Dani C, Oliboni LS, Agostini F, Funchal C, Serafini L, Henriques JA, et al. Phenolic content of grapevine leaves (*Vitis labrusca* var. Bordo) and its neuroprotective effect against peroxide damage. *Toxicol In Vitro*. 2010;24:148-53. [PMID: 19699291]
115. Dani C, Oliboni LS, Vanderlinde R, Bonatto D, Salvador M, Henriques JA. Phenolic content and antioxidant activities of white and purple juices manufactured with organically- or conventionally-produced grapes. *Food Chem Toxicol*. 2007;45:2574-80. [PMID: 17683842]
116. Danilchenko H. Effect of growing method on the quality of pumpkins and pumpkin products. *Folia Horticulturae*. 2002;14:103-12.
117. DeEll JR, Prange RK. Postharvest physiological disorders, diseases and mineral concentrations of organically and conventionally grown McIntosh and Cortland apples. *Canadian Journal of Plant Science*. 1993;73:223-30.
118. del Amor FM. Yield and fruit quality response of sweet pepper to organic and mineral fertilization. *Renewable Agriculture and Food Systems*. 2007;22:233-8.
119. D'Evoli L, Tarozzi A, Hrelia P, Lucarini M, Cocchiola M, Gabrielli P, et al. Influence of cultivation system on bioactive molecules synthesis in strawberries: spin-off on antioxidant and antiproliferative activity. *J Food Sci*. 2010;75:C94-9. [PMID: 20492158]
120. do Amarante CVT, Steffens CA, Mafra AL, Albuquerque JA. Yield and fruit quality of apple from conventional and organic production systems. *Pesqui Agropecu Bras*. 2008;43:333-40.
121. Döll S, Valenta H, Kircheim U, Dänicke S, Flachowsky G. *Fusarium* mycotoxins in conventionally and organically grown grain from Thuringia/Germany. *Mycotoxin Research*. 2000;16:38-41.
122. Edwards SG. *Fusarium* mycotoxin content of UK organic and conventional wheat. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess*. 2009;26:496-506. [PMID: 19680924]
123. Ellis K. Studies of the composition of milk produced on organic and conventional dairy farms. *Organic Studies Centre Technical Bulletin Issue 8*. 2006. Accessed at www.organicstudiescornwall.co.uk/pdf_docs/bulletins/Bulletin%208.pdf on 14 July 2012.
124. Ellis KA, Innocent G, Grove-White D, Cripps P, McLean WG, Howard CV, et al. Comparing the fatty acid composition of organic and conventional milk. *J Dairy Sci*. 2006;89:1938-50. [PMID: 16702257]
125. Ellis KA, Monteiro A, Innocent GT, Grove-White D, Cripps P, McLean WG, et al. Investigation of the vitamins A and E and beta-carotene content in milk from UK organic and conventional dairy farms. *J Dairy Res*. 2007;74:484-91. [PMID: 17922933]
126. Euroala M, Hietaniemi V, Kontturi M, Tuuri H, Pihlava JM, Saastamoinen M, et al. Cadmium contents of oats (*Avena sativa* L.) in official variety, organic cultivation, and nitrogen fertilization trials during 1997-1999. *J Agric Food Chem*. 2003;51:2608-14. [PMID: 12696945]
127. Fjellkner-Modig S, Bengtsson H, Stegmark R, Nystrom S. The influence of organic and integrated production on nutritional, sensory and agricultural aspects of vegetable raw materials for food production. *Acta Agriculturae Scandinavica. Section B, Soil and Plant Science*. 2000;50:102-13.
128. Forster MP, Rodríguez Rodríguez E, Díaz Romero C. Differential characteristics in the chemical composition of bananas from Tenerife (Canary Islands) and Ecuador. *J Agric Food Chem*. 2002;50:7586-92. [PMID: 12475275]
129. Gabryszuk M, Soniewski K, Sakowski T. Macro- and microelements in milk and hair of cows from conventional vs organic farms. *Animal Science Papers and Reports*. 2008;26:199-209.
130. Garmo RT, Waage S, Sviland S, Henriksen BI, Østerås O, Reksen O. Reproductive performance, udder health, and antibiotic resistance in mastitis bacteria isolated from Norwegian Red cows in conventional and organic farming. *Acta Vet Scand*. 2010;52:11. [PMID: 20141638]
131. Ghidini S, Zanardi E, Battaglia A, Varisco G, Ferretti E, Campanini G, et al. Comparison of contaminant and residue levels in organic and conventional milk and meat products from northern Italy. *Food Addit Contam*. 2005;22:9-14. [PMID: 15895606]
132. Giannenas I, Nisianakis P, Gavriil A, Kontopidis G, Kyriazakis I. Trace mineral content of conventional, organic and courtyard eggs analysed by inductively coupled plasma mass spectrometry (ICP-MS). *Food Chem*. 2009;114:706-11.
133. González L, Juan C, Soriano JM, Moltó JC, Mañes J. Occurrence and daily intake of ochratoxin A of organic and non-organic rice and rice products. *Int J Food Microbiol*. 2006;107:223-7. [PMID: 16316704]
134. Gonzalez M, Miglirona KS, Aizpún de Moreno JE, Moreno VJ. Evaluation of conventionally and organically produced vegetables for high lipophilic organochlorine pesticide (OCP) residues. *Food Chem Toxicol*. 2005;43:261-9. [PMID: 15621339]
135. Griesshaber D, Kuhn F, Berger U, Oehme M. Comparison of trichothecene contaminations in wheat cultivated by three different farming systems in Switzerland: biodynamic, bioorganic and conventional. *Mitt Lebensmittelunters Hyg*. 2004;95:251-60.
136. Gundersen V, Bechmann IE, Behrens A, Stürup S. Comparative investigation of concentrations of major and trace elements in organic and conventional Danish agricultural crops. 1. Onions (*Allium cepa* Hysam) and peas (*Pisum sativum* ping pong). *J Agric Food Chem*. 2000;48:6094-102. [PMID: 11312781]
137. Gutierrez F, Arnaud T, Albi MA. Influence of ecological cultivation on virgin olive oil quality. *Journal of the American Oil Chemists' Society*. 1999;76:617-21.
138. Hajslová J, Schulzová V, Slanina P, Janné K, Hellenäs KE, Andersson CH. Quality of organically and conventionally grown potatoes: four-year study of micronutrients, metals, secondary metabolites, enzymic browning and organoleptic properties. *Food Addit Contam*. 2005;22:514-34. [PMID: 16019825]
139. Hakala MA, Lapveteläinen AT, Huopalahti R, Kallio HP, Tahvonen R. Effects of varieties and cultivation conditions on the composition of strawberries. *J Food Compos Anal*. 2003;16:67-80.
140. Häkkinen SH, Törrönen AR. Content of flavonols and selected phenolic acids in strawberries and *Vaccinium* species: influence of cultivar, cultivation site and technique. *Food Res Int*. 2000;33:517-24.
141. Halbert LW, Kaneene JB, Linz J, Mansfield LS, Wilson D, Ruegg PL, et al. Genetic mechanisms contributing to reduced tetracycline susceptibility of *Campylobacter* isolated from organic and conventional dairy farms in the mid-western and northeastern United States. *J Food Prot*. 2006;69:482-8. [PMID: 16541675]
142. Halbert LW, Kaneene JB, Ruegg PL, Warnick LD, Wells SJ, Mansfield LS, et al. Evaluation of antimicrobial susceptibility patterns in *Campylobacter* spp isolated from dairy cattle and farms managed organically and conventionally in the midwestern and northeastern United States. *J Am Vet Med Assoc*. 2006;228:1074-81. [PMID: 16579787]
143. Hallmann E, Rembiałkowska E. Comparison of the nutritive quality of tomato fruits from organic and conventional production in Poland. Presented at the 3rd International Congress of the European Integrated Project Quality Low Input Food (QLIF) Congress: Improving Sustainability in Organic and Low Input Food Production Systems, University of Hohenheim, Germany, 20-23 March 2007. Accessed at <http://orgprints.org/9944> on 12 July 2012.
144. Hamouz K, Lachman J, Dvůrák P, Pivec V. The effect of ecological growing on the potatoes yield and quality. *Plant, Soil and Environment*. 2005;51:397-402.

145. Hamouz K, Lachman J, Pivec V, Vokal B. Influence of environmental conditions and way of cultivation on the polyphenol and ascorbic acid content in potato tubers. *Rostlinna Vyroba*. 1999;45:293-8.
146. Han F, Lestari SI, Pu S, Ge B. Prevalence and antimicrobial resistance among *Campylobacter* spp. in Louisiana retail chickens after the enrofloxacin ban. *Foodborne Pathog Dis*. 2009;6:163-71. [PMID: 19099357]
147. Hanell U, L-Baekström G, Svensson G. Quality studies on wheat grown in different cropping systems: a holistic perspective. *Acta Agriculturae Scandinavica*. Section B, Soil and Plant Science. 2004;54:254-63.
148. Hansen H. Comparison of chemical composition and taste of biodynamically and conventionally grown vegetables. *Plant Foods Hum Nutr*. 1981;30:203-11.
149. Hansen LL, Claudi-Magnussen C, Jensen SK, Andersen HJ. Effect of organic pig production systems on performance and meat quality. *Meat Sci*. 2006;74:605-15. [PMID: 22063213]
150. Harcz P, De Temmerman L, De Voghel S, Waegeneers N, Wilmart O, Vromman V, et al. Contaminants in organically and conventionally produced winter wheat (*Triticum aestivum*) in Belgium. *Food Addit Contam*. 2007;24:713-20. [PMID: 17613056]
151. Heimler D, Isolani L, Vignolini P, Romani A. Polyphenol content and antiradical activity of *Cichorium intybus* L. from biodynamic and conventional farming. *Food Chem*. 2009;114:765-70.
152. Hellström S, Laukkanen R, Siekkinen KM, Ranta J, Majjala R, Korkeala H. *Listeria monocytogenes* contamination in pork can originate from farms. *J Food Prot*. 2010;73:641-8. [PMID: 20377951]
153. Hermansen JE, Badsberg JH, Kristensen T, Gundersen V. Major and trace elements in organically or conventionally produced milk. *J Dairy Res*. 2005;72:362-8. [PMID: 16174368]
154. Hietaniemi V, Kontturi M, Ramo S, Euroala M, Kangas A, Niskanen M, et al. Contents of trichothecenes in oats during official variety, organic cultivation and nitrogen fertilization trials in Finland. *Agricultural and Food Science*. 2004;13:54-67.
155. Hildermann I, Messmer M, Dubois D, Boller T, Wiemken A, Mäder P. Nutrient use efficiency and arbuscular mycorrhizal root colonisation of winter wheat cultivars in different farming systems of the DOK long-term trial. *J Sci Food Agric*. 2010;90:2027-38. [PMID: 20582996]
156. Högberg A, Pickova J, Andersson K, Lundström K. Fatty acid composition and tocopherol content of muscle in pigs fed organic and conventional feed with different n6/n3 ratios, respectively. *Food Chem*. 2003;80:177-86.
157. Hogstad S, Risvik E, Steinholt K. Sensory quality and chemical composition in carrots: a multivariate study. *Acta Agriculturae Scandinavica*. Section B, Soil and Plant Science. 1997;47:253-64.
158. Hoikkala A, Mustonen E, Saastamoinen I, Jokela T, Taponen J, Saloniemi H, et al. High levels of equol in organic skimmed Finnish cow milk. *Mol Nutr Food Res*. 2007;51:782-6. [PMID: 17576638]
159. Hoogenboom LA, Bokhorst JG, Northolt MD, van de Vijver LP, Broex NJ, Mevius DJ, et al. Contaminants and microorganisms in Dutch organic food products: a comparison with conventional products. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess*. 2008;25:1195-207. [PMID: 18608495]
160. Husak RL, Sebranek JG, Bregendahl K. A survey of commercially available broilers marketed as organic, free-range, and conventional broilers for cooked meat yields, meat composition, and relative value. *Poult Sci*. 2008;87:2367-76. [PMID: 18931189]
161. Izat AL, Kopek JM, McGinnis JD. Research note: incidence, number, and serotypes of Salmonella on frozen broiler chickens at retail. *Poult Sci*. 1991;70:1438-40. [PMID: 1886849]
162. Jahan K, Paterson A. Lipid composition of retailed organic, free-range and conventional chicken breasts. *International Journal of Food Science and Technology*. 2007;42:251-62.
163. Jahan K, Paterson A, Spickett CM. Fatty acid composition, antioxidants and lipid oxidation in chicken breasts from different production regimes. *International Journal of Food Science and Technology*. 2004;39:443-53.
164. Jørgensen K, Jacobsen JS. Occurrence of ochratoxin A in Danish wheat and rye, 1992-99. *Food Addit Contam*. 2002;19:1184-9. [PMID: 12623679]
165. Jorhem L, Slanina P. Does organic farming reduce the content of Cd and certain other trace metals in plant foods? A pilot study. *Journal of the Science of Food and Agriculture*. 2000;80:43-8.
166. Juan C, Molto JC, Lino CM, Manes J. Determination of ochratoxin A in organic and non-organic cereals and cereal products from Spain and Portugal. *Food Chem*. 2008;107:525-30.
167. Juroszek P, Lumpkin HM, Yang RY, Ledesma DR, Ma CH. Fruit quality and bioactive compounds with antioxidant activity of tomatoes grown on-farm: comparison of organic and conventional management systems. *J Agric Food Chem*. 2009;57:1188-94. [PMID: 19178281]
168. Kahu K, Janes H, Luik A, Klaas L. Yield and fruit quality of organically cultivated blackcurrant cultivars. *Acta Agriculturae Scandinavica*. Section B, Soil and Plant Science. 2009;59:63-9.
169. Karavoltos S, Sakellari A, Dimopoulos M, Dasenakis M, Scoullou M. Cadmium content in foodstuffs from the Greek market. *Food Addit Contam*. 2002;19:954-62. [PMID: 12443557]
170. Krejcirova L, Capouchova I, Petr J, Bicanova E, Famera O. The effect of organic and conventional growing systems on quality and storage protein composition of winter wheat. *Plant, Soil and Environment*. 2007;53:499-505.
171. Kristensen M, Østergaard LF, Halekoh U, Jørgensen H, Lauridsen C, Brandt K, et al. Effect of plant cultivation methods on content of major and trace elements in foodstuffs and retention in rats. *J Sci Food Agric*. 2008;88:2161-72.
172. La Torre A, Leandri A, Lolletti D. Comparison of health status between organic and conventional products. *Commun Agric Appl Biol Sci*. 2005;70:351-63. [PMID: 16637200]
173. Lairon D, Spitz N, Termine E, Ribaud P, Lafont H, Hauton J. Effect of organic and mineral nitrogen fertilization on yield and nutritive value of butterhead lettuce. *Qualitas Plantarum-Plant Food for Human Nutrition*. 1984;34:97-108.
174. Lamperi L, Chiuminatto U, Cincinelli A, Galvan P, Giordani E, Lepri L, et al. Polyphenol levels and free radical scavenging activities of four apple cultivars from integrated and organic farming in different Italian areas. *J Agric Food Chem*. 2008;56:6536-46. [PMID: 18642842]
175. Langenkämper G, Zörb C, Seifert M, Mäder P, Fretzdorff B, Betsche T. Nutritional quality of organic and conventional wheat. *Journal of Applied Botany and Food Quality*. 2006;80:150-4.
176. Larsen MK, Nielsen JH, Butler G, Leifert C, Slots T, Kristiansen GH, et al. Milk quality as affected by feeding regimens in a country with climatic variation. *J Dairy Sci*. 2010;93:2863-73. [PMID: 20630203]
177. Laukkanen R, Martínez PO, Siekkinen KM, Ranta J, Majjala R, Korkeala H. Transmission of *Yersinia pseudotuberculosis* in the pork production chain from farm to slaughterhouse. *Appl Environ Microbiol*. 2008;74:5444-50. [PMID: 18641149]
178. L-Baekström G, Hanell U, Svensson G. Baking quality of winter wheat grown in different cultivating systems, 1992-2001: a holistic approach. *J Sustain Agric*. 2004;24:53-79.
179. Leclerc J, Miller ML, Joliet E, Rocquelin G. Vitamin and mineral contents of carrot and celery grown under mineral or organic fertilization. *Biological Agriculture and Horticulture*. 1991;7:339-48.
180. Lehesranta SJ, Koistinen KM, Massat N, et al. Effects of agricultural production systems and their components on protein profiles of potato tubers. *Proteomics*. 2007;7:597-604. [PMID: 17309105]
181. Lestari SI, Han F, Wang F, Ge B. Prevalence and antimicrobial resistance of *Salmonella* serovars in conventional and organic chickens from Louisiana retail stores. *J Food Prot*. 2009;72:1165-72. [PMID: 19610326]
182. Lester GE, Manthey JA, Buslig BS. Organic vs conventionally grown Rio Red whole grapefruit and juice: comparison of production inputs, market quality, consumer acceptance, and human health-bioactive compounds. *J Agric Food Chem*. 2007;55:4474-80. [PMID: 17474757]
183. Lesueur C, Gartner M, Knittl P, List P, Wimmer S, Sieler V, et al. Pesticide residues in fruit and vegetable samples: analytical results of 2 year's pesticide investigations. *Ernährung/Nutrition*. 2007;31:247-59.
184. Lindén A, Andersson K, Oskarsson A. Cadmium in organic and conventional pig production. *Arch Environ Contam Toxicol*. 2001;40:425-31. [PMID: 11443376]
185. Lombardi-Boccia G, Lucarini M, Lanzi S, Aguzzi A, Cappelloni M. Nutrients and antioxidant molecules in yellow plums (*Prunus domestica* L.) from conventional and organic productions: a comparative study. *J Agric Food Chem*. 2004;52:90-4. [PMID: 14709018]
186. Lu C, Bravo R, Caltabiano LM, Irish RM, Weerasekera G, Barr DB. The presence of dialkylphosphates in fresh fruit juices: implication for organophosphorus pesticide exposure and risk assessments. *J Toxicol Environ Health A*. 2005;68:209-27. [PMID: 15762180]
187. Mäder P, Hahn D, Dubois D, Gunst L, Alfvöldi T, Bergmann H, et al. Wheat quality in organic and conventional farming: results of a 21 year field experiment. *J Sci Food Agric*. 2007;87:1826-35.

188. Mäder P, Pfiffner L, Niggli U, Plochberger K, Balzer U, Balzer F, et al. Effect of three farming systems (bio-dynamic, bio-organic, conventional) on yield and quality of beetroot (*Beta vulgaris* L. var. esculenta L.) in a seven year crop rotation. *Acta Hort.* 1993;339:11-31.
189. Malmauret L, Parent-Massin D, Hardy JL, Verger P. Contaminants in organic and conventional foodstuffs in France. *Food Addit Contam.* 2002;19:524-32. [PMID: 12042017]
190. Mansour SA, Belal MH, Abou-Arab AA, Ashour HM, Gad MF. Evaluation of some pollutant levels in conventionally and organically farmed potato tubers and their risks to human health. *Food Chem Toxicol.* 2009;47:615-24. [PMID: 19138717]
191. Mansour SA, Belal MH, Abou-Arab AA, Gad MF. Monitoring of pesticides and heavy metals in cucumber fruits produced from different farming systems. *Chemosphere.* 2009;75:601-9. [PMID: 19237184]
192. Martino G, Ponzelli V, Grotta L. Healthier fat content through organic production. *World Poultry.* 2008;24:33-4.
193. Masamba KG, Nguyen M. Determination and comparison of vitamin C, calcium and potassium in four selected conventionally and organically grown fruits and vegetables. *African Journal of Biotechnology.* 2008;7:2915-9.
194. Mason H, Navabi A, Frick B, O'Donovan J, Niziol D, Spaner D. Does growing Canadian Western Hard Red Spring wheat under organic management alter its breadmaking quality? *Renewable Agriculture and Food Systems.* 2007;22:157-67.
195. Mazzoncini M, Belloni P, Risaliti R, Antichi D. Organic vs conventional winter wheat quality and organoleptic bread test. Improving Sustainability in Organic and Low Input Food Production Systems. Presented at the 3rd International Congress of the European Integrated Project Quality Low Input Food (QLIF) Congress: Improving Sustainability in Organic and Low Input Food Production Systems, University of Hohenheim, Germany, 20–23 March 2007. Accessed at <http://orgrprints.org/9753> on 14 July 2012.
196. Meier Ploeger A, Duden R, Vogtmann H. Quality of food plants grown with compost from biogenic waste. *Agric Ecosyst Environ.* 1989;27:483-91.
197. Mercadante AZ, Rodriguez-Amaya DB. Carotenoid composition of a leafy vegetable in relation to some agricultural variables. *J Agric Food Chem.* 1991;39:1094-7.
198. Messens W, Grijspeerd K, De Reu K, De Ketelaere B, Mertens K, Bamelis F, et al. Eggshell penetration of various types of hens' eggs by *Salmonella enterica* serovar Enteritidis. *J Food Prot.* 2007;70:623-8. [PMID: 17388050]
199. Mikkonen TP, Määttä KR, Hukkanen AT, Kokko HI, Törrönen AR, Kärenlampi SO, et al. Flavonol content varies among black currant cultivars. *J Agric Food Chem.* 2001;49:3274-7. [PMID: 11453762]
200. Millet S, Hesta M, Seynaeve M, Ongena E, De Smet S, Debraekeleer J, et al. Performance, meat and carcass traits of fattening pigs with organic versus conventional housing and nutrition. *Livestock Production Science.* 2004;87:109-19.
201. Miranda JM, Vazquez BI, Fente CA, Barros-Velazquez J, Cepeda A, Abuin CMF. Antimicrobial resistance in *Escherichia coli* strains isolated from organic and conventional pork meat: a comparative survey. *European Food Research and Technology.* 2008;226:371-5.
202. Mitchell AE, Hong YJ, Koh E, Barrett DM, Bryant DE, Denison RF, et al. Ten-year comparison of the influence of organic and conventional crop management practices on the content of flavonoids in tomatoes. *J Agric Food Chem.* 2007;55:6154-9. [PMID: 17590007]
203. Mladenova R, Shtereva D. Pesticide residues in apples grown under a conventional and integrated pest management system. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess.* 2009;26:854-8. [PMID: 19680960]
204. Moreira MDR, Roura SI, del Valle CED. Quality of Swiss chard produced by conventional and organic methods. *Lebensmittel Wissenschaft Und Technologie—Food and Science Technology.* 2003;36:135-41.
205. Mukherjee A, Speh D, Dyck E, Diez-Gonzalez F. Preharvest evaluation of coliforms, *Escherichia coli*, *Salmonella*, and *Escherichia coli* O157:H7 in organic and conventional produce grown by Minnesota farmers. *J Food Prot.* 2004;67:894-900. [PMID: 15151224]
206. Mukherjee A, Speh D, Jones AT, Buesing KM, Diez-Gonzalez F. Longitudinal microbiological survey of fresh produce grown by farmers in the upper midwest. *J Food Prot.* 2006;69:1928-36. [PMID: 16924919]
207. Nakamura YN, Fujita M, Nakamura Y, Gotoh T. Comparison of nutritional composition and histological changes of the soybean seeds cultivated by conventional and organic farming systems after long-term storage—preliminary study. *Journal of the Faculty of Agriculture Kyushu University.* 2007;52:1-10.
208. Ninfali P, Bacchiocca M, Biagiotti E, Esposto S, Servili M, Rosati A, et al. A 3-year study on quality, nutritional and organoleptic evaluation of organic and conventional extra-virgin olive oils. *Journal of the American Oil Chemists' Society.* 2008;85:151-8.
209. Nitika, Punia D, Khetarpaul N. Physico-chemical characteristics, nutrient composition and consumer acceptability of wheat varieties grown under organic and inorganic farming conditions. *Int J Food Sci Nutr.* 2008;59:224-45. [PMID: 17852472]
210. Nowak B, Mueffling TV, Caspari K, Hartung J. Validation of a method for the detection of virulent *Yersinia enterocolitica* and their distribution in slaughter pigs from conventional and alternative housing systems. *Vet Microbiol.* 2006;117:219-28. [PMID: 16837145]
211. Nyanjage MO, Wainwright H, Bishop CFH, Cullum FJ. A comparative study on the ripening and mineral content of organically and conventionally grown Cavendish bananas. *Biological Agriculture and Horticulture.* 2001;18:221-34.
212. O'Donnell AM, Spatny KP, Vicini JL, Bauman DE. Survey of the fatty acid composition of retail milk differing in label claims based on production management practices. *J Dairy Sci.* 2010;93:1918-25. [PMID: 20412905]
213. Ogbadu GH, Easmon JP. Influence of inorganic and organic fertilizers on the chemical composition of three eggplant cultivars. *Tropical Science.* 1989;29:237-46.
214. Oliveira M, Usall J, Viñas I, Anguera M, Gatiús F, Abadías M. Microbiological quality of fresh lettuce from organic and conventional production. *Food Microbiol.* 2010;27:679-84. [PMID: 20510788]
215. Olivo CJ, Beck LI, Mossate Gabbi A, Santini Charão P, Sobczak MF, Gomez Uberty LF, et al. Composition and somatic cell count of milk in conventional and agro-ecological farms: a comparative study in Depressao Central, Rio Grande do Sul state, Brazil. *Livestock Research for Rural Development.* 2005;17, Article 72. Accessed at www.lrrd.org/lrrd17/6/oliv17072.htm on 14 July 2012.
216. Olsson IM, Jonsson S, Oskarsson A. Cadmium and zinc in kidney, liver, muscle and mammary tissue from dairy cows in conventional and organic farming. *J Environ Monit.* 2001;3:531-8. [PMID: 11695124]
217. Olsson ME, Andersson CS, Oredsson S, Berglund RH, Gustavsson KE. Antioxidant levels and inhibition of cancer cell proliferation in vitro by extracts from organically and conventionally cultivated strawberries. *J Agric Food Chem.* 2006;54:1248-55. [PMID: 16478244]
218. Olsson V, Andersson K, Hansson I, Lundström K. Differences in meat quality between organically and conventionally produced pigs. *Meat Sci.* 2003;64:287-97. [PMID: 22063015]
219. Ottesen AR, White JR, Skaltsas DN, Newell MJ, Walsh CS. Impact of organic and conventional management on the phyllosphere microbial ecology of an apple crop. *J Food Prot.* 2009;72:2321-5. [PMID: 19903395]
220. Peck GM. Orchard Productivity and Apple Fruit Quality of Organic, Conventional, and Integrated Farm Management Systems. Pullman, WA: Washington State University; 2004. Accessed at <http://ecommons.library.cornell.edu/bitstream/1813/2720/1/Peck%202004%20WSU%20MS%20Thesis.pdf> on 18 June 2012.
221. Pérez-López AJ, del Amor FM, Serrano-Martínez A, Fortea MI, Nunez-Delgado E. Influence of agricultural practices on the quality of sweet pepper fruits as affected by the maturity stage. *J Sci Food Agric.* 2007;87:2075-80.
222. Pérez-López AJ, López-Nicolás JM, Carbonell-Barrachina AA. Effects of organic farming on minerals contents and aroma composition of Clemenules mandarin juice. *European Food Research and Technology.* 2007;225:255-60.
223. Pérez-López AJ, López-Nicolás JM, Núñez-Delgado E, Del Amor FM, Carbonell-Barrachina AA. Effects of agricultural practices on color, carotenoids composition, and minerals contents of sweet peppers, cv. Almuden. *J Agric Food Chem.* 2007;55:8158-64. [PMID: 17822289]
224. Perkowski J, Wiwart M, Busko M, Laskowska M, Berthiller F, Kandler W, et al. Fusarium toxins and total fungal biomass indicators in naturally contaminated wheat samples from north-eastern Poland in 2003. *Food Addit Contam.* 2007;24:1292-8. [PMID: 17852394]
225. Petr J. Quality of triticale from ecological and intensive farming. *Scientia Agriculturae Bohemica.* 2006;37:95-103.
226. Phillips CA, Harrison MA. Comparison of the microflora on organically and conventionally grown spring mix from a California processor. *J Food Prot.* 2005;68:1143-6. [PMID: 15954699]

227. Pieper JR, Barrett DM. Effects of organic and conventional production systems on quality and nutritional parameters of processing tomatoes. *J Sci Food Agric*. 2009;89:177-94.
228. Pla M. A comparison of the carcass traits and meat quality of conventionally and organically produced rabbits. *Livestock Science*. 2008;115:1-12.
229. Pla M, Ramirez JA, Diaz I, Hernandez P, Arino B. Prediction of fatty acid content in rabbit meat and discrimination between conventional and organic production systems by NIRS methodology. *Food Chem*. 2007;100:165-70.
230. Porretta S. Qualitative comparison between commercial "traditional" and "organic" tomato products using multivariate statistical analysis. *Acta Hort*. 1994;376:259-70.
231. Poulsen ME, Andersen JH. Results from the monitoring of pesticide residues in fruit and vegetables on the Danish market, 2000-01. *Food Addit Contam*. 2003;20:742-57. [PMID: 13129791]
232. Pozzo L, Cavallarin L, Nucera D, Antoniazzi S, Schiavone A. A survey of ochratoxin A contamination in feeds and sera from organic and standard swine farms in northwest Italy. *J Sci Food Agric*. 2010;90:1467-72. [PMID: 20549798]
233. Prandini A, Sigolo S, Piva G. Conjugated linoleic acid (CLA) and fatty acid composition of milk, curd and Grana Padano cheese in conventional and organic farming systems. *J Dairy Res*. 2009;76:278-82. [PMID: 19445826]
234. Procida G, Pertoldi Marletta G, Cecon L. Heavy metal content of some vegetables farmed by both conventional and organic methods. *Italian Journal of Food Science*. 1998;27:181-9.
235. Pussemier L, Piérard JY, Anselme M, Tangni EK, Motte JC, Larondelle Y. Development and application of analytical methods for the determination of mycotoxins in organic and conventional wheat. *Food Addit Contam*. 2006;23:1208-18. [PMID: 17071524]
236. Raigon MD, Palomares G, Ortiz-Perez M, Ordone I. Ca, K, Fe, P and Na content in different varietal types of dry bean using two growing systems: organic and conventional. Reports of Bean Improvement Cooperative and National Dry Bean Council Research Conference. Annual Report. 2003;46:109-10.
237. Raigón MD, Rodríguez-Burruezo A, Prohens J. Effects of organic and conventional cultivation methods on composition of eggplant fruits. *J Agric Food Chem*. 2010;58:6833-40. [PMID: 20443597]
238. Reganold JP, Glover JD, Andrews PK, Hinman HR. Sustainability of three apple production systems. *Nature*. 2001;410:926-30. [PMID: 11309616]
239. Rembialkowska E. [A comparison of selected parameters of potatoes health quality from ecologically oriented and conventional farms]. *Rocz Panstw Zakl Hig*. 1998;49:159-67. [PMID: 9847674]
240. Rodriguez J, Rios D, Rodriguez E, Diaz C. Physico-chemical changes during ripening of conventionally, ecologically and hydroponically cultivated Tyrlain (TY 10016) tomatoes. *International Journal of Agricultural Research*. 2006;1:452-61.
241. Roesch M, Doherr MG, Blum JW. Management, feeding, production, reproduction and udder health on organic and conventional Swiss dairy farms. *Schweiz Arch Tierheilkd*. 2006;148:387-95. [PMID: 16933702]
242. Roesch M, Perreten V, Doherr MG, Schaeren W, Schällibaum M, Blum JW. Comparison of antibiotic resistance of udder pathogens in dairy cows kept on organic and on conventional farms. *J Dairy Sci*. 2006;89:989-97. [PMID: 16507693]
243. Rossi F, Bertuzzi T, Comizzoli S, Turconi G, Roggi C, Paganì M, et al. Preliminary survey on composition and quality of conventional and organic wheat. *Italian Journal of Food Science*. 2006;18:355-66.
244. Rossi F, Godani F, Bertuzzi T, Trevisan M, Ferrari F, Gatti S. Health-promoting substances and heavy metal content in tomatoes grown with different farming techniques. *Eur J Nutr*. 2008;47:266-72. [PMID: 18604621]
245. Ruimy R, Brisabois A, Bernede C, Skurnik D, Barnat S, Arlet G, et al. Organic and conventional fruits and vegetables contain equivalent counts of Gram-negative bacteria expressing resistance to antibacterial agents. *Environ Microbiol*. 2010;12:608-15. [PMID: 19919536]
246. Ryan MH, Derrick JW, Dann PR. Grain mineral concentrations and yield of wheat grown under organic and conventional management. *J Sci Food Agric*. 2004;84:207-16.
247. Sablani SS, Andrews PK, Davies NM, Walters T, Saez H, Syamaladevi RM, et al. Effect of thermal treatments on phytochemicals in conventionally and organically grown berries. *J Sci Food Agric*. 2010;90:769-78. [PMID: 20355111]
248. Sato K, Bennedsgaard TW, Bartlett PC, Erskine RJ, Kaneene JB. Comparison of antimicrobial susceptibility of *Staphylococcus aureus* isolated from bulk tank milk in organic and conventional dairy herds in the midwestern United States and Denmark. *J Food Prot*. 2004;67:1104-10. [PMID: 15222534]
249. Schollenberger M, Jara HT, Suchy S, Drochner W, Müller HM. Fusarium toxins in wheat flour collected in an area in southwest Germany. *Int J Food Microbiol*. 2002;72:85-9. [PMID: 11843417]
250. Schwaiger K, Schmied EM, Bauer J. Comparative analysis of antibiotic resistance characteristics of Gram-negative bacteria isolated from laying hens and eggs in conventional and organic keeping systems in Bavaria, Germany. *Zoonoses Public Health*. 2008;55:331-41. [PMID: 18667026]
251. Schwaiger K, Schmied EM, Bauer J. Comparative analysis on antibiotic resistance characteristics of *Listeria* spp. and *Enterococcus* spp. isolated from laying hens and eggs in conventional and organic keeping systems in Bavaria, Germany. *Zoonoses Public Health*. 2010;57:171-80. [PMID: 19486494]
252. Shier NW, Kelman J, Dunson JW. A comparison of crude protein, moisture, ash and crop yield between organic and conventionally grown wheat. *Nutrition Reports International*. 1984;30:71-6.
253. Skaug MA. Analysis of Norwegian milk and infant formulas for ochratoxin A. *Food Addit Contam*. 1999;16:75-8. [PMID: 10435076]
254. Slots T, Butler G, Leifert C, Kristensen T, Skibsted LH, Nielsen JH. Potentials to differentiate milk composition by different feeding strategies. *J Dairy Sci*. 2009;92:2057-66. [PMID: 19389964]
255. Slots T, Sorensen J, Nielsen JH. Tocopherol, carotenoids and fatty acid composition in organic and conventional milk. *Milchwissenschaft*. 2008;63:352-5.
256. Soonthornchaikul N, Garelick H, Jones H, Jacobs J, Ball D, Choudhury M. Resistance to three antimicrobial agents of *Campylobacter* isolated from organically- and intensively-reared chickens purchased from retail outlets. *Int J Antimicrob Agents*. 2006;27:125-30. [PMID: 16417991]
257. Sousa C, Valentão P, Rangel J, Lopes G, Pereira JA, Ferreres F, et al. Influence of two fertilization regimens on the amounts of organic acids and phenolic compounds of tronchuda cabbage (*Brassica oleracea* L. Var. *costata* DC). *J Agric Food Chem*. 2005;53:9128-32. [PMID: 16277412]
258. Srikumar TS, Ockerman PA. The effects of organic and inorganic fertilization on the content of trace elements in cereal grains. *Food Chem*. 1991;42:225-30.
259. Stracke BA, Eitel J, Watzl B, Mäder P, Rüfer CE. Influence of the production method on phytochemical concentrations in whole wheat (*Triticum aestivum* L.): a comparative study. *J Agric Food Chem*. 2009;57:10116-21. [PMID: 19817369]
260. Stracke BA, Rüfer CE, Weibel FP, Bub A, Watzl B. Three-year comparison of the polyphenol contents and antioxidant capacities in organically and conventionally produced apples (*Malus domestica* Bork. Cultivar 'Golden Delicious'). *J Agric Food Chem*. 2009;57:4598-605. [PMID: 19388640]
261. Tarozzi A, Hrelia S, Angeloni C, Morroni F, Biagi P, Guardigli M, et al. Antioxidant effectiveness of organically and non-organically grown red oranges in cell culture systems. *Eur J Nutr*. 2006;45:152-8. [PMID: 16096701]
262. Tarozzi A, Marchesi A, Cantelli-Forti G, Hrelia P. Cold-storage affects antioxidant properties of apples in Caco-2 cells. *J Nutr*. 2004;134:1105-9. [PMID: 15113953]
263. Tasiopoulou S, Chiodini AM, Vellere F, Visentin S. Results of the monitoring program of pesticide residues in organic food of plant origin in Lombardy (Italy). *J Environ Sci Health B*. 2007;42:835-41. [PMID: 17763041]
264. Tikofsky LL, Barlow JW, Santisteban C, Schukken YH. A comparison of antimicrobial susceptibility patterns for *Staphylococcus aureus* in organic and conventional dairy herds. *Microb Drug Resist*. 2003;9 Suppl 1:S39-45. [PMID: 14633366]
265. Toledo P, Andren A, Bjorck L. Composition of raw milk from sustainable production systems. *International Dairy Journal*. 2002;12:75-80.
266. Tran thi Ngoc S, Vu van T, Luu Hong M, Hiraoka H. Effect of organic and bio-fertilizer on quality, grain yield and soil properties of soybean under rice based cropping system. Omonrice. 2001;55-61. Accessed at <http://wenku.baidu.com/view/80b49684ec3a87c24028c4be.html> on 14 July 2012.
267. Tsatsakis AM, Tsakiris IN, Tzatzarakis MN, Agourakis ZB, Tutudaki M, Alegakis AK. Three-year study of fenthion and dimethoate pesticides in olive oil from organic and conventional cultivation. *Food Addit Contam*. 2003;20:553-9. [PMID: 12881128]
268. Tsiplakou E, Kotrotsios V, Hadjigeorgiou I, Zervas G. Differences in sheep and goats milk fatty acid profile between conventional and organic farming systems. *J Dairy Res*. 2010;77:343-9. [PMID: 20482951]

269. Turgut C, Ornek H, Cutright TJ. Determination of pesticide residues in Turkey's table grapes: the effect of integrated pest management, organic farming, and conventional farming. *Environ Monit Assess*. 2011;173:315-23. [PMID: 20213057]
270. Vanova M, Klem K, Misa P, Matusinsky P, Hajslova J, Lancova K. The content of *Fusarium* mycotoxins, grain yield and quality of winter wheat cultivars under organic and conventional cropping systems. *Plant Soil Environment*. 2008;54:395-402.
271. Vicini J, Etherton T, Kris-Etherton P, Ballam J, Denham S, Staub R, et al. Survey of retail milk composition as affected by label claims regarding farm-management practices. *J Am Diet Assoc*. 2008;108:1198-203. [PMID: 18589029]
272. Walshe BE, Sheehan EM, Delahunty CM, Morrissey PA, Kerry JP. Composition, sensory and shelf life stability analyses of *Longissimus dorsi* muscle from steers reared under organic and conventional production systems. *Meat Sci*. 2006;73:319-25. [PMID: 22062304]
273. Wang SY, Chen CT, Sciarappa W, Wang CY, Camp MJ. Fruit quality, antioxidant capacity, and flavonoid content of organically and conventionally grown blueberries. *J Agric Food Chem*. 2008;56:5788-94. [PMID: 18590274]
274. Warman PR, Havard KA. Yield, vitamin and mineral contents of organically and conventionally grown carrots and cabbage. *Agric Ecosyst Environ*. 1997;61:155-62.
275. Warman PR, Havard KA. Yield, vitamin and mineral content of four vegetables grown with either composted manure or conventional fertilizer. *Journal of Vegetable Crop Production*. 1996;2:13-25.
276. Warman PR, Havard KA. Yield, vitamin and mineral contents of organically and conventionally grown potatoes and sweet corn. *Agric Ecosyst Environ*. 1998;68:207-16.
277. Wszelaki AL, Delwiche JF, Walker SD, Liggett RE, Scheerens JC, Kleinhenz MD. Sensory quality and mineral and glycoalkaloid concentrations in organically and conventionally grown redskin potatoes (*Solanum tuberosum*). *J Sci Food Agric*. 2005;85:720-6.
278. Wunderlich SM, Feldman C, Kane S, Hazhin T. Nutritional quality of organic, conventional, and seasonally grown broccoli using vitamin C as a marker. *Int J Food Sci Nutr*. 2008;59:34-45. [PMID: 17852499]
279. Young JE, Zhao X, Carey EE, Welti R, Yang SS, Wang W. Phytochemical phenolics in organically grown vegetables. *Mol Nutr Food Res*. 2005;49:1136-42. [PMID: 16302198]
280. Zhao X, Carey EE, Young JE, Wang W, Iwamoto T. Influences of organic fertilization, high tunnel environment, and postharvest storage on phenolic compounds in lettuce. *HortScience*. 2007;42:71-6. Accessed at <http://hortsci.ashspublications.org/content/42/1/71.full.pdf> on 14 July 2012.
281. Zhao X, Nichols JR, Williams KA, Wang WQ, Carey EE. Comparison of phenolic acids in organically and conventionally grown pac choy (*Brassica rapa* L. *chinensis*). *J Sci Food Agric*. 2009;89:940-6.
282. Zheng DM, Bonde M, Sorensen JT. Associations between the proportion of *Salmonella* seropositive slaughter pigs and the presence of herd level risk factors for introduction and transmission of *Salmonella* in 34 Danish organic, outdoor (non-organic) and indoor finishing-pig farms. *Livestock Science*. 2007;106:189-99.
283. Zörb C, Betsche T, Langenkämper G. Search for diagnostic proteins to prove authenticity of organic wheat grains (*Triticum aestivum* L.). *J Agric Food Chem*. 2009;57:2932-7. [PMID: 19253955]
284. Zörb C, Niehaus K, Barsch A, Betsche T, Langenkämper G. Levels of compounds and metabolites in wheat ears and grains in organic and conventional agriculture. *J Agric Food Chem*. 2009;57:9555-62. [PMID: 20560625]
285. Zuchowski J, Jonczyk K, Pecio L, Oleszek W. Phenolic acid concentrations in organically and conventionally cultivated spring and winter wheat. *J Sci Food Agric*. 2011;91:1089-95. [PMID: 21308690]
286. Molkenin J, Giesemann A. Differentiation of organically and conventionally produced milk by stable isotope and fatty acid analysis. *Anal Bioanal Chem*. 2007;388:297-305. [PMID: 17393158]
287. Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board, Institute of Medicine. Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D, and fluoride. Washington, DC: National Academies Pr; 1997. Accessed at www.nap.edu/openbook.php?record_id=5776&page=R2 on 26 April 2011.
288. Palupi E, Jayanegara A, Ploeger A, Kahl J. Comparison of nutritional quality between conventional and organic dairy products: a meta-analysis. *J Sci Food Agric*. 2012. [PMID: 22430502]
289. Zhao C, Ge B, De Villena J, Sudler R, Yeh E, Zhao S, et al. Prevalence of *Campylobacter* spp., *Escherichia coli*, and *Salmonella* serovars in retail chicken, turkey, pork, and beef from the Greater Washington, D.C., area. *Appl Environ Microbiol*. 2001;67:5431-6. [PMID: 11722889]
290. Bokanyi RP Jr, Stephens JF, Foster DN. Isolation and characterization of *Salmonella* from broiler carcasses or parts. *Poult Sci*. 1990;69:592-8. [PMID: 2356175]
291. M'ikanatha NM, Sandt CH, Localio AR, Tewari D, Rankin SC, Whichard JM, et al. Multidrug-resistant *Salmonella* isolates from retail chicken meat compared with human clinical isolates. *Foodborne Pathog Dis*. 2010;7:929-34. [PMID: 20443729]
292. Mukherjee A, Speh D, Diez-Gonzalez F. Association of farm management practices with risk of *Escherichia coli* contamination in pre-harvest produce grown in Minnesota and Wisconsin. *Int J Food Microbiol*. 2007;120:296-302. [PMID: 17997496]
293. Mathews KH. Antimicrobial Drug Use and Veterinary Costs in U.S. Livestock Production. Agricultural Information Bulletin No. (AIB-766). Washington, DC: U.S. Department of Agriculture; 2001. Accessed at www.ers.usda.gov/publications/aib766/aib766.pdf on 18 June 2012.
294. European Food Safety Authority (EFSA). Antimicrobial Resistance: EFSA's Role. 2011. Accessed at www.efsa.europa.eu/en/topics/topic/amr.htm on 18 June 2012.
295. Nelson JM, Chiller TM, Powers JH, Angulo FJ. Fluoroquinolone-resistant *Campylobacter* species and the withdrawal of fluoroquinolones from use in poultry: a public health success story. *Clin Infect Dis*. 2007;44:977-80. [PMID: 17342653]
296. Harker FR. Organic food claims cannot be substantiated through testing of samples intercepted in the marketplace: a horticulturalist's opinion. *Food Quality and Preference*. 2004;15:91-5.
297. Food and Drug Administration. Pesticide Monitoring Program—FY 2008. Washington, DC: U.S. Food and Drug Administration; 2008. Accessed at www.fda.gov/downloads/Food/FoodSafety/FoodContaminantsAdulteration/Pesticides/ResidueMonitoringReports/UCM230537.pdf on 18 June 2012.
298. Knoblauch WA, Brown R, Braster M. Organic field crop production: a review of the economic literature. Ithaca, NY: Agriculture Experimental Research, Department of Agricultural Economics, Cornell University; 1990. Accessed at <http://dyson.cornell.edu/research/researchpdf/rb/1990/Cornell-Dyson-rb9010.pdf> on 14 July 2012.

Current Author Addresses: Dr. Smith-Spangler: Division of General Medical Disciplines, Stanford University, 1265 Welch Road, Medical School Office Building, MC 5411, Stanford, CA 94305.

Dr. Brandeau: Department of Management Science and Engineering, Huang Engineering Center, Room 262, Stanford University, Stanford, CA 94205-4026.

Ms. Hunter, Mr. Bavinger, Ms. Pearson, Mr. Eschbach, Ms. Sundaram, and Drs. Liu and Bravata: Center for Health Policy, Stanford University, 117 Encina Commons, Stanford, CA 94305-6019.

Dr. Schirmer: Veterans Affairs Palo Alto Health Care System, 3801 Miranda Avenue (132), Palo Alto, CA 94304.

Mr. Stave: Lane Medical Library, 300 Pasteur Drive, L-109, Stanford, CA 94305-5123.

Dr. Olkin: Department of Statistics, Sequoia Hall, 390 Serra Mall, Stanford University, Stanford, CA 94305-4065.

Author Contributions: Conception and design: C. Smith-Spangler, J.C. Bavinger, M. Pearson, V. Sundaram, D.M. Bravata, I. Olkin.

Analysis and interpretation of the data: C. Smith-Spangler, M.L. Brandeau, G.E. Hunter, J.C. Bavinger, M. Pearson, P.J. Eschbach, V. Sundaram, P. Schirmer, D.M. Bravata, I. Olkin.

Drafting of the article: C. Smith-Spangler, M.L. Brandeau, J.C. Bavinger, V. Sundaram, P. Schirmer, D.M. Bravata.

Critical revision of the article for important intellectual content: C. Smith-Spangler, M.L. Brandeau, V. Sundaram, H. Liu, D.M. Bravata, I. Olkin.

Final approval of the article: C. Smith-Spangler, M.L. Brandeau, J.C. Bavinger, P.J. Eschbach, V. Sundaram, H. Liu, P. Schirmer, D.M. Bravata, I. Olkin.

Provision of study materials or patients: C. Smith-Spangler, D.M. Bravata.

Statistical expertise: C. Smith-Spangler, D.M. Bravata, I. Olkin.

Administrative, technical, or logistic support: G.E. Hunter, M. Pearson, C. Stave.

Collection and assembly of data: C. Smith-Spangler, M.L. Brandeau, G.E. Hunter, J.C. Bavinger, M. Pearson, P.J. Eschbach, V. Sundaram, H. Liu, P. Schirmer, C. Stave, D.M. Bravata.

APPENDIX: SUPPLEMENTAL INFORMATION ABOUT STATISTICAL ANALYSES AND OUTCOMES THAT COULD NOT BE SYNTHESIZED

Continuity Correction

In an effort to include all eligible studies, a continuity correction was applied for studies with 0 events in 1 or more groups. In practice, we applied the continuity correction in 2 analyses: contamination with any pesticide residues (Figure 2) and contamination of chicken or pork with bacteria resistant to ciprofloxacin.

Among the 9 pesticide contamination studies, 2 had 0 events (Figure 2). These were small, single-food studies. Removal of the small studies with 0 events did not substantially change results (Figure 2).

Among the contamination of chicken or pork with bacteria resistant to ciprofloxacin, removal of the 2 studies with 0 events (146, 256) did not substantially change results, although only 3 studies remained for analysis (RD, -4% [CI, -25% to 17%]; $P = 1.00$, $I^2 = 93\%$).

Results were not synthesized if the number of studies was less than 3 after those studies with 0 events were removed. This

was the case with pesticide residues exceeding maximum allowed limits (we report a range); contamination of milk with *S. aureus* resistant to erythromycin, oxacillin, and tetracycline; and contamination of chicken and pork with bacteria resistant to doxycycline and gentamicin.

Other Nutrients in Produce

Too few studies evaluated selenium, manganese, zinc, and vitamins B, D, and K to be synthesized (Supplement 2).

Other Nutrients in Animal Products

Only 3 studies (110, 129, 153) evaluated the calcium content of milk: 2 studies (129, 153) reported no difference by farming method and the other (110) reported significantly higher levels of calcium in organically produced milk ($P < 0.010$). Two studies evaluated the lutein and zeaxanthin content of milk (93, 255), finding significantly higher levels of both antioxidants in organic than conventional milk. Two studies examined the zinc content of eggs (132) and beef products (216), finding significantly less zinc in organic egg yolks and beef kidney and significantly more zinc in beef muscle than their conventional counterparts.

Two studies compared protein content of chicken: 1 study found significantly more protein in organic than conventional chicken (160) and the other found no difference (192).

Botanical Pesticides in Produce

Two studies (95, 172) tested for 2 botanical pesticides allowed in organic cultivation: Neither pesticide was detectable in organic or conventional produce samples.

Antibiotic Resistance of Bacteria in Produce

Only 1 study examined the prevalence of antibiotic resistance in bacteria in produce, finding no difference between organic and conventional produce (245).

Subgroup Analyses of Deoxynivalenol and Ochratoxin A in Produce

In subgroup analyses, we found a higher risk for ochratoxin A (OTA) contamination in organically grown rice (84, 133, 166) (RD, 35% [CI, 17% to 53%]; $P < 0.001$; $I^2 = 22$) but not in wheat (84, 111, 164, 166, 189, 235) compared with conventional alternatives.

Seven studies examined deoxynivalenol levels in wheat (135, 150, 224, 235, 243, 249, 270), finding significantly lower levels of deoxynivalenol in organic wheat (SMD, -0.94 [CI, -1.27 to -0.62]; $P < 0.001$; $I^2 = 63$), although 1 large study, which did not report sufficient detail to be included in summary effect size calculations, found no significant differences in deoxynivalenol concentrations (122).

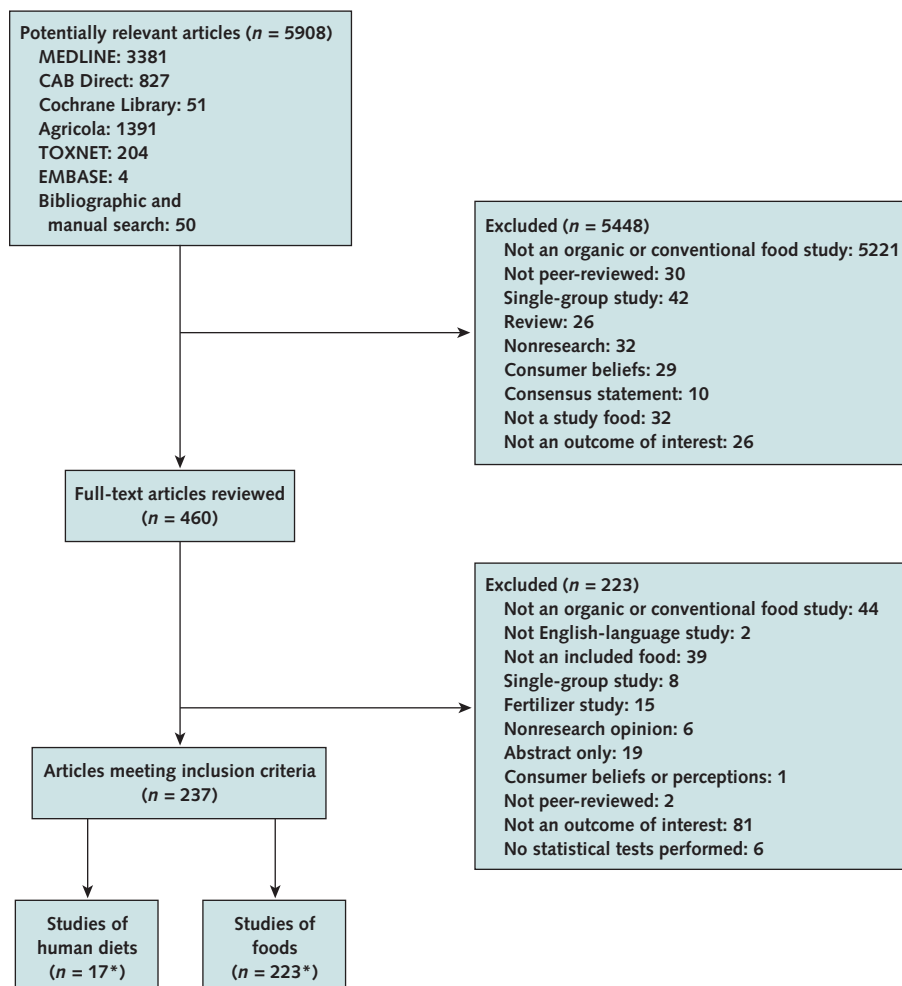
Other Fungal Toxin Results in Milk and Meats

Two studies evaluated mycotoxin contamination of milk: 1 study found significantly higher levels of aflatoxin in organic than conventional milk (131), whereas another study found no difference in OTA contamination (253). One study found that OTA contamination of porcine serum samples was significantly higher among organic than conventional samples (1.32 vs. 0.16 $\mu\text{g}/\text{kg}$; $P < 0.001$) (232).

Two studies evaluated mycotoxin contamination of milk: 1 study found significantly higher levels of aflatoxin in organic than conventional milk (131), whereas another study found no difference in OTA contamination (253). One study found

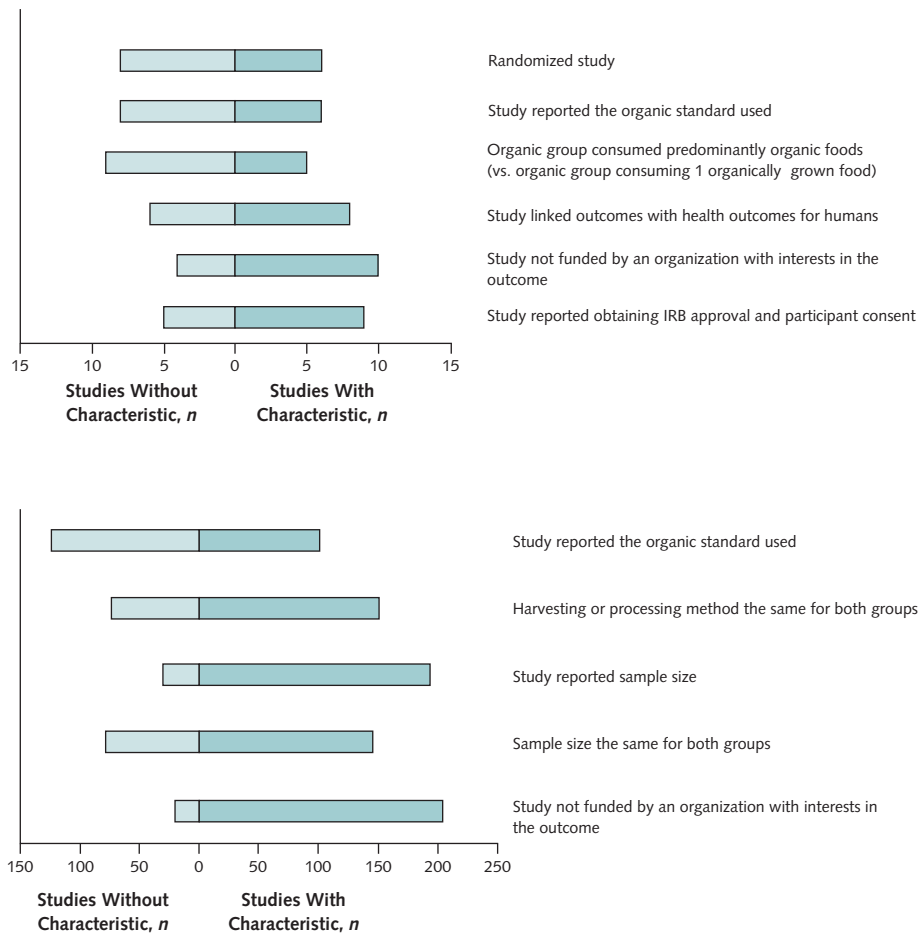
that OTA contamination of porcine serum samples was significantly higher among organic than conventional samples (1.32 vs. 0.16 $\mu\text{g}/\text{kg}$; $P < 0.001$) (232).

Appendix Figure 1. Summary of evidence search and selection.



* Three studies reported on human diets and on the foods themselves.

Appendix Figure 2. Selected characteristics of included studies.



The top panel presents the characteristics of the included human studies. Seventeen publications compared the human health effects of consuming organic vs. conventional food. Three publications report data from the same population and are counted only once in the figure. Hence, the number of studies sums to 14. The bottom panel presents the characteristics of the 223 included studies of food. IRB = institutional review board.