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This is a final project report submitted to the Organic Farming Research Foundation.

General topic: Nutritional content of organic and conventionally produced vegetables.

Project Title:

Are organic vegetables more nutritious?

Fresh and postharvest assessment of nutritional quality of organically- and conventionally-grown lettuce and other salad greens.

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Project period: 2003 - 2006

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1. Summary.

This project was funded by Organic Farming Research Foundation (OFRF) during 2003 and 2004, with project activities extending into 2005 and 2006. This final report, submitted in 2007, is still, in fact, a report of an ongoing effort to understand whether organic vegetables are more nutritious than conventionally grown vegetables, and, if they are, to understand the factors that contribute to those differences. This work is continuing under a grant from the USDA-Integrated Organic Program.

Our project was primarily conducted at the Kansas State University, K-State Horticulture Research and Extension Center at Olathe, Kansas. At this site in 2002, under a USDA-funded project, “High tunnels for the Central Great Plains: Profitable, season extending horticultural production systems,” we established replicated organic and conventional plots in open fields and high tunnels. Our OFRF project complemented the production system research being conducted under the USDA project, and allowed us to address the question of whether organically-produced vegetables are more nutritious than their conventional counterparts. We proposed to focus largely on leafy green vegetables and the influences of organic and conventional fertilization on a range of minerals, vitamins and phytochemicals important to human health.

Early in the process of addressing this seemingly simple question, we realized that what we were asking was actually quite complex. This is because organic production can encompass a huge array of environments (varying in climate, soils, nutrients, moisture, pests, etc.). Furthermore, our results might vary depending on crop and cultivar, stage of growth, and nutrient evaluated. Thus our results would not provide a comprehensive answer to the question, but rather, would pertain to the environment at our trial site and to the crop and nutrient studied. Furthermore, our trials were to be conducted on plots established on certifiable organic ground in the previous year, so our organically and conventionally managed soils would be in transition. We also realized that for practical reasons, we would need to restrict the broad array of nutrients we had initially proposed to analyze. We chose to focus primarily on phytochemicals, particularly flavonoids, a class of phenolic compounds recognized as making an important contribution to antioxidant levels in fruit and vegetables.

Results of our project include trials conducted on lettuce, pac choi and collards in the summer of 2003, in which we extensively analyzed flavonoids in fresh crops and which included a postharvest study of total phenolics in lettuce. In the summer of 2004, trials focused on the antioxidant contents of pac choi, lettuce and spinach. In the summer of 2005, we conducted a consumer taste analysis study of lettuce, spinach, arugula, mustard greens, onion, cucumber and tomato. None of these studies showed consistent enhancement of phytochemical levels or taste superiority of organic versus conventional produce. However they did reveal various intriguing

differences, including a tendency for phytochemical or antioxidant levels to be higher in organic production plots, and for these levels to be higher in field-grown than high tunnel-grown crops. The results of our trials indicated the need for more systematic study of the influence of organic production methods on crop health, focusing on fertilizer rates and sources, season effects and on the influences of stress factors, such as diseases and pests on the levels of phytochemicals.

While the results of our studies were inconclusive, this OFRF project did much to help build an ongoing research program at Kansas State University to address this issue. Our research site is now in its fifth season, and differences between soil quality in organic and conventional plots are increasingly marked. Results of our OFRF project were reported in five peer-reviewed journal articles, which not only served to make a contribution to the scientific literature of this poorly studied subject, but also enabled us to successfully compete for a USDA-Integrated Organic Program grant entitled, “Effects of organic fertility management on crop health and phytochemical content of vegetables under open field and high tunnel production,” which will run through mid-2010. Finally, Xin Zhao, the primary investigator on this OFRF grant, received her Ph.D. in 2006 and has recently joined the faculty in the Horticultural Sciences Department of the University of Florida as an Assistant Professor of sustainable and organic crop production and physiology.

2. Introduction.

Increasing demand for organically grown fresh produce has stimulated interest by both consumers and producers about the relative nutritional values of organically and conventionally grown produce. Recent research reports and review articles have presented mixed findings on nutritional value and quality attributes of organically and conventionally grown foods but have identified certain areas of consistency, and have also made recommendations for future research approaches (Worthington, 2001; Bourn and Prescott, 2002; Heaton, 2002; Williams, 2002; Magkos et al., 2003). A consistent finding has been that conventionally grown lettuce, spinach and leafy greens tend to have a higher content of undesirable nitrate than organically grown greens. Recommended future areas for investigation from these reviews included a) assessment of plant secondary metabolite levels in organic and conventionally grown produce, b) postharvest comparisons of organically and conventionally grown produce; and c) inclusion of whole farm comparisons to complement on-station or pot studies.

In 2003, we began investigations to assess selected nutrients, secondary metabolites and sensory quality attributes of lettuce, spinach, pac choi and other vegetables produced in the field and high tunnels under conventional and organic production regimes in Kansas. Our work has included assessments of crops produced at different times of the year, both on-station and on organic and conventional farms, and also included comparisons of postharvest changes in order

to assess potential advantages of locally-grown, fresh produce over that shipped in from distant production sites.

The overall goal of the project was to investigate the effects of selected organic and conventional open-field and high tunnel production systems on fresh and postharvest nutritional value and quality attributes of lettuce, spinach and other selected leafy green vegetables. On-station comparisons were to be complemented by evaluations of crops produced on organic and conventional farms. The effects of production season and cultivar were to be assessed through spring, summer and winter production. The project was to take place over two years, with the second year's focus of activities refined on the basis of results from the first year.

This report highlights results of studies conducted under our project that have been published in peer-reviewed journals. When undertaking the work, we found that we were unable to satisfactorily complete work proposed for some of the project's objectives. We also found that opportunities led us to conduct some relevant work not anticipated in the project proposal.

3. Objectives.

Objective One: Survey levels of selected nutrients and secondary compounds in productive cultivars of loose-leaf lettuce, spinach and other leafy green vegetables grown organically and conventionally during different production seasons (spring, summer, fall and/or winter). Compounds to be assessed (depending on previous reports by species) will include ascorbic acid, dehydroascorbic acid, folic acid, β -carotene, nitrate, chlorogenic acid and salicylic acid.

Objective two: Evaluate selected quality attributes of loose-leaf lettuce, spinach and leafy green vegetables grown organically and conventionally, including color, texture, and various hedonic and objective attributes.

Objective three: Evaluate selected above-mentioned attributes on limited numbers of promising species and cultivars produced on organic and conventional farms.

Objective four: Perform fresh and postharvest comparisons of selected above-mentioned attributes on limited numbers of promising species and cultivars produced under organic and conventional production systems on-station and on-farm.

4. Materials and Methods.

Trial site description. Organic and conventional plots were established in 20' x 32' high tunnels and adjacent open fields on Kennebec silt loam soils at the K-State Horticulture Research and Extension Center, Olathe, Kansas, during the spring of 2002. Since then plots have been continually managed organically or conventionally, using recommended management practices for either system (though to accentuate differences, we have not added organic matter to the

conventional plots). Because our research plots were established on land which had previously been managed organically, they qualified for organic certification at the beginning of our experiments. Differences between the organic and conventional plots in protected environments (high tunnels) and open fields have developed in response to our management regimes (which have so far varied principally with respect to fertilizer, insect control and cropping sequences – cover crops being regularly grown in the organic plots). We thus have four distinct production environments, two organic and two conventional (each replicated 3 times), to compare the effects of organic and conventional production systems on crop production and quality parameters.

In 2003 and 2007 our organic plots were certified organic. In the intervening years, we did not certify our plots but maintained compliance with USDA NOP guidelines.

Trials and treatments.

Spring and summer, 2003. (Detailed in Young et al., 2005 and Zhao et al., 2007a) Lettuce (cultivars Red Sails and Kalura), collard (cv. Top Bunch) and pac choi (cv. Mei Qing Choi) were grown in open field and high tunnel plots under organic and conventional fertilization applied at recommended rates according to soil tests. Organic plots received a cattle manure/alfalfa compost and supplemental fertigation with fish emulsion, while conventional plots were fertilized with comparable rates of pre-plant 13-13-13 supplemented by fertigation with calcium nitrate. Pest control (particularly of flea beetles on pac choi) was done using Pyganic in the organic plots and Pounce 3.0 EC in conventional plots. Leaf samples were extracted and analyzed for total phenolics and selected individual flavonoids, either fresh or following a period of postharvest storage (in the case of lettuce).

Spring and summer, 2004. (Detailed in Zhao et al., 2007c). Pac choi (cv. Mei Qing Choi), spinach (cv. Tyee) and lettuce (cvs. Red Sails and Green Forest) were grown in open field and high tunnel plots under organic or conventional fertilization applied at recommended rates. Organic fertility was applied as cattle manure/alfalfa compost, applied at twice the rate of total nitrogen compared to the conventional fertilizer in order to provide plants with roughly similar levels of available nitrogen. One trial examined the effects of rates of fertilizer application on antioxidant levels in pac choi and another trial examined the effect of stage of growth (baby versus full head) on antioxidant levels in pac choi, spinach and lettuce. Antioxidant levels were assessed using the oxygen radical absorbance capacity (ORAC) assay, with hydrophilic, lipophilic and total ORAC levels analyzed.

Spring and summer, 2005. (Detailed in Zhao et al., 2007b). Lettuce (cv. New Red Fire), spinach (cv. 7-Green), arugula (cv. Arugula), mustard green (cv. Red Giant), tomato (cv. Florida 91), cucumber (cv. Tasty Jade) and onion (cv. Candy) were grown in open field and high tunnel plots under organic and conventional fertilization applied at recommended rates. Organic fertility

was applied at twice the rate of nitrogen compared to the conventional fertilizer treatments in provide comparable levels of available nitrogen to crops. Crops were watered and diseases and pests controlled as necessary. At harvest, samples were taken for consumer sensory analysis to determine if differences between organic and conventional vegetables could be detected and whether either type was preferred. This analysis was conducted under controlled conditions at the Sensory Analysis Center at Kansas State University.

Results of all trials were statistically analyzed using SAS

5. Project Results.

Spring and summer, 2003. (Detailed in Young et al., 2005 and Zhao et al., 2007a). We did not find differences in individual flavonoids and phenolic acids between organic and conventional lettuce, collards, and pac choi but we did find that organically produced pac choi was significantly higher in total phenolics than conventionally produced pac choi. Due to differential efficacy of organic and conventional pest control treatments, the organic pac choi was also more affected by insect feeding (predominantly flea beetle) than was the conventional (figure 1). It was not possible to tell whether elevated total phenolics in pac choi were in response to differences in soil fertility between the organic and conventional systems, or to differences in extent of insect attack between the two systems, or to a combination of the two.

While there were not consistent significant effects of organic and conventional production environments on lettuce phenolics, we did find consistently higher total and individual phenolic levels in the red leaf lettuce cultivar Red Sails than in the green romaine cultivar Kalura. Phenolic levels were also generally lower in high tunnels than in the open field, particularly in Red Sails. Total phenolic levels increased during postharvest storage of lettuce at 4°C for 16 days, and relative differences in levels occurring because of genotype or production environment (high tunnels vs. open field) were maintained (figures 2 and 3). The increase in total phenolics during storage was probably a reflection of declining quality (browning, etc.) during storage.

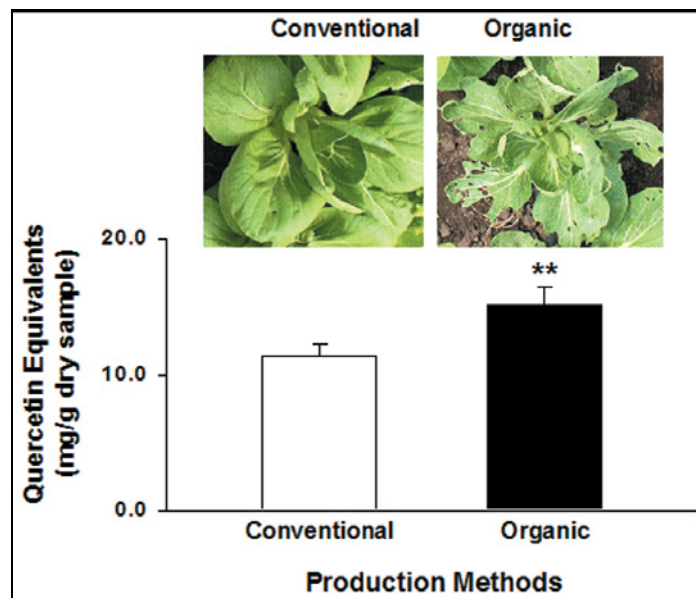


Figure 1. Total phenolic contents as measure by Folin-Ciocalteu assay in conventionally and organically grown pac choi. Photos above illustrate differential insect attack in the two systems. Total phenolic levels are presented as means of six samples \pm SEM of six samples per group.

**p<0.01 versus the conventional sample (from Young et al., 2005)

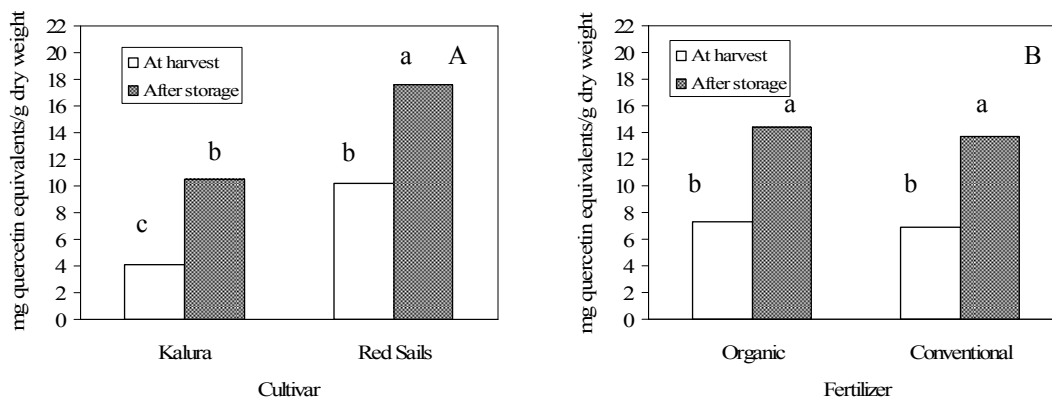


Figure 2. Changes in total phenolics in romaine lettuce cv. Kalura and loose leaf lettuce cv. Red Sails (A), and in these lettuce cultivars grown organically or conventionally (B), after storage at 4°C for 16 days. Differences among treatment combinations indicated by different letters are significant at the 0.05 level. (from Zhao et al., 2007a)

Spring and summer, 2004. (Detailed in Zhao et al., 2007c). An experiment was conducted to assess the influence of rates of nitrogen fertilization on antioxidant levels in

pac choi grown on organic and conventional plots in open field and high tunnels. Hydrophilic and total antioxidant (ORAC) levels were significantly higher in field plots than in high tunnels, while levels of lipophilic antioxidants were higher in organic plots.

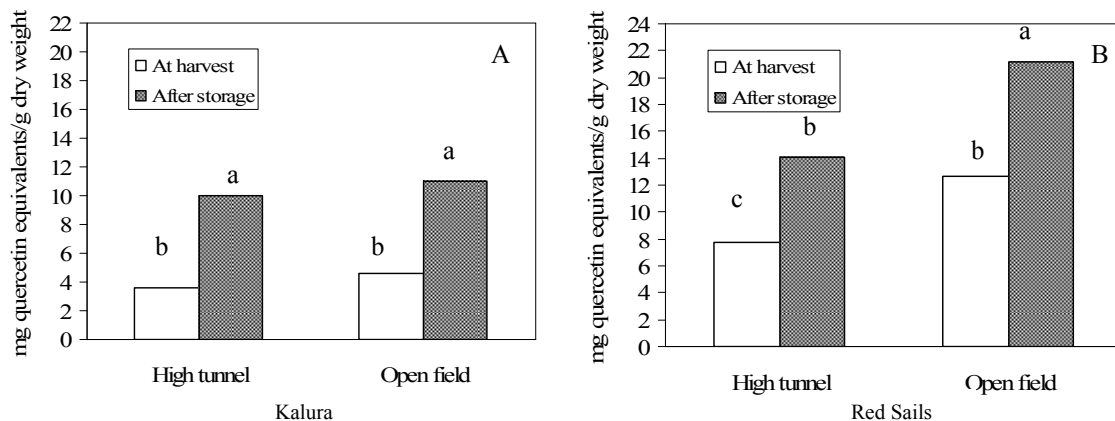


Figure 3. Change in total phenolics in romaine lettuce cv. Kalura (A) and loose leaf lettuce cv. Red Sails (B) grown in high tunnel and open field environments after storage at 4°C for 16 days. Differences among treatment combinations indicated by different letters are significant at the 0.05 level. (from Zhao et al., 2007a)

There was a significant difference in hydrophilic ORAC levels between organic and conventional pac choi from high tunnels and open field plots, with higher antioxidant levels in organic pac choi from the open field than from the high tunnels. There were no significant effects of fertilizer rates on antioxidant levels, though there were intriguing trends. Organic plots at lower fertilizer rates tended to have higher antioxidant levels, and antioxidant levels in pac choi tended to be lowest from conventional plots fertilized at the highest rates (figure 4). As with our 2003 study, there was more severe insect attack in the organic than the conventional pac choi, making it difficult to attribute increased antioxidant levels (in this case) to organic fertilization or to stress related to insect feeding. There were also significant yield differences between organic and conventional and open field and high tunnel plots, with yields higher in the tunnels and in conventional plots.

The second trial conducted in 2004 looked at the influence of growth stage on antioxidant levels in spinach, pac choi and two lettuce cultivars grown in organic and conventional plots in high tunnels and open field. Hydrophilic, lipophilic, and total ORAC values from this trial are presented in Table 1. We did not see significant effects of organic production environment on antioxidant levels or yields of crops, but we did find significant differences among crops (not surprisingly) and significant effects of growth stage. Spinach showed the highest ORAC, followed by pac choi, red leaf lettuce and romaine lettuce. Spinach had significantly lower

ORAC in high tunnels relative to the open field, but other crops did not. The ORAC values of spinach from the open field and pac choi from high tunnels were significantly higher when harvested at the mature “head” stage than at the baby stage. The differential response of the crops to the high tunnel and open field environment is interesting. It should be mentioned that following the first harvest (baby stage), a severe thunderstorm removed poly from all of our high tunnels, so they spent the rest of the season (4 weeks) growing in what was essentially an open field environment.

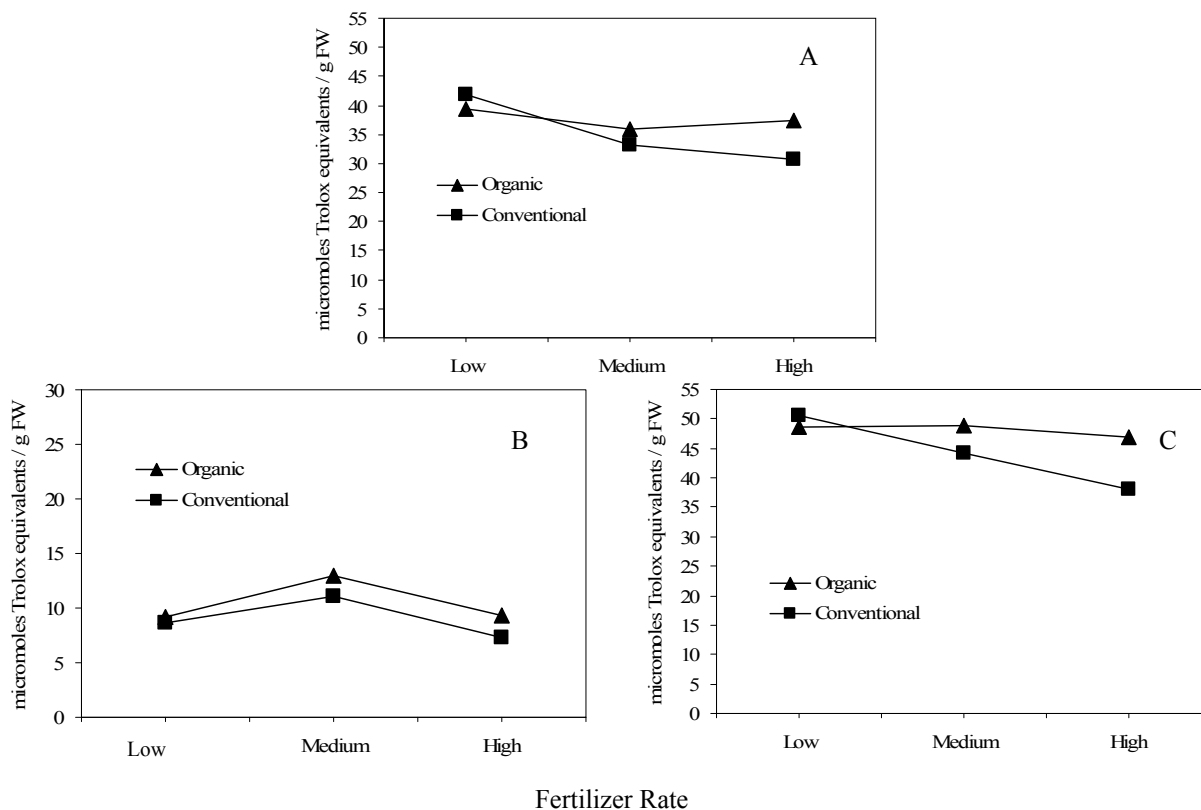


Figure 4. Hydrophilic ORAC (A), lipophilic ORAC (B), and total ORAC (C) values of pac choi grown under three application rates of organic and conventional fertilizers in the late spring trial 2004, at Olathe, Kansas. Low, medium, and high rates corresponded to 0 kg N/ha, 156 kg N/ha, and 314 kg N/ha, respectively, for organic fertilization and 0 kg N/ha, 78 kg N/ha, and 156 kg N/ha, respectively, for conventional fertilization. (From Zhao et al., 2007c)

Spring and summer, 2005. (Detailed in Zhao et al., 2007b). Results of consumer sensory analysis of organically and conventionally produced crops from high tunnels are presented in Tables 2 and 3. Overall, our organically and conventionally grown vegetables did not show significant differences in consumer liking or consumer-perceived sensory quality. The only exception was

tomato where conventionally produced tomatoes were rated as having significantly stronger flavor than organic tomatoes. However, there was no difference in preference between organic and conventional tomatoes. Conventional tomatoes were also scored marginally significantly higher on ripeness. Consumer panelists on our tests considered organic produce to be healthier (72%) and more environmentally friendly (51%) than conventional produce, while 28% considered organic produce to have better taste. Covariance analysis indicated that consumer demographics affected sensory comparisons of organic and conventional lettuce and cucumbers. For lettuce, consumers younger than 25 significantly preferred the conventional sample, whereas others expressed similar liking for both organic and conventional. For cucumber, the interaction of gender by growing method was marginally significant ($p=0.06$). Male consumers tended to favor conventionally grown cucumber ($p=0.19$) while females preferred organic ($p=0.15$). Curiously, consumers who believed that organic produce had better taste (based on our demographic questionnaire) actually tended to score conventional cucumbers higher in overall liking ($p=0.12$), while organic cucumbers tended to be liked more by consumers who did not initially believe organic produce tasted better ($p=0.13$).

Table 1. Hydrophilic, lipophilic, and total ORAC values (micromoles Trolox equivalents/g FW) of different types of leafy vegetables at two growth stages under high tunnel and open field environments in the late summer trial 2004, at Olathe, Kansas. (From Zhao et al., 2007c)

ORAC	Vegetable	High tunnel		Open field	
		Baby size	Mature head	Baby size	Mature head
Hydrophilic	pac choi	36.6b	75.8a	49.5ab	47.2ab
	spinach	71.7c	74.8c	158.6b	197.2a
	red leaf lettuce	9.2a	13.6a	8.9a	11.9a
	romaine lettuce	4.4a	4.7a	3.2a	4.6a
Lipophilic	pac choi	4.2	10.1	11.5	13.3
	spinach	8.3	10.3	7.4	8.8
	red leaf lettuce	2.9	4.1	2.8	3.7
	romaine lettuce	2.7	3.5	4.6	5.1
Total	pac choi	39.6b	85.9a	61.0ab	60.5ab
	spinach	87.4c	87.4c	166.9b	206.0a
	red leaf lettuce	12.0a	17.7a	11.8a	15.0a
	romaine lettuce	7.0a	8.3a	7.9a	9.8a

Data in rows followed by the same letters are not significantly different at $P \leq 0.05$.

6. Conclusions and Discussion.

While our project did not generate the comprehensive array of results we anticipated in our initial proposal, including analysis of a number of vitamins and assessment of various crops in replicated trials at Olathe and at organic and conventional farms in our region, we are pleased with progress and findings made under the project. We focused on selected phytochemicals, particularly the flavonoids, a class of phenolic compounds considered to be among the important constituents of fruit and vegetables that contribute to human health. Along with various vitamins, flavonoids are among the major antioxidants in fruit and vegetables. We studied antioxidants as well. We also conducted a lettuce postharvest study, and a consumer sensory analysis of a number of crops grown at our trial site.

Table 2. Mean rating scores (least square means from the model) from a consumer panel comparing organically and conventionally grown leafy greens.^a (From Zhao et al., 2007b)

Vegetable	Production method	Overall liking^b	Flavor intensity^c	Bitterness intensity^c
Lettuce	Organic	5.0	4.5	4.4
	Conventional	5.4	4.2	3.9
	P-value (n=100)	0.11	0.16	0.10
Spinach	Organic	6.3	3.8	2.3
	Conventional	6.3	3.7	2.2
	P-value (n=100)	0.94	0.72	0.75
Arugula	Organic	2.9	6.3	5.5
	Conventional	2.8	6.5	5.7
	P-value (n=100)	0.70	0.15	0.37
Mustard green	Organic	2.7	6.6	5.3
	Conventional	3.0	6.5	5.2
	P-value (n=100)	0.42	0.70	0.56

^aSamples were scored by 100 consumers.

^bOn a 9-point hedonic scale, i.e., 9 = like extremely, 1 = dislike extremely.

^cOn a 7-point scale, i.e., 7 = extremely strong or bitter, 1 = barely any flavor or not bitter at all.

Table 3. Mean rating scores (least square means from the model) from a consumer panel comparing organically and conventionally grown tomatoes, cucumbers, and onions^a (From Zhao et al., 2007b)

Vegetable	Production method	Overall liking^b	Flavor intensity^c	Other attribute^d
Tomato	Organic	7.0	4.6	4.7
	Conventional	7.0	5.0	5.0
	P-value (n=106)	0.90	0.02	0.06
Cucumber	Organic	7.1	4.1	2.3
	Conventional	7.0	4.0	2.2
	P-value (n=106)	0.73	0.59	0.66
Onion	Organic	6.7	5.7	3.6
	Conventional	6.7	5.9	3.5
	P-value (n=106)	0.82	0.41	0.65

^aSamples were scored by 106 consumers.

^bOn a 9-point hedonic scale, i.e., 9 = like extremely, 1 = dislike extremely.

^cOn a 7-point scale, i.e., 7 = extremely strong, ripe, bitter, sweet, 1 = barely any flavor, not at all ripe, bitter, sweet.

^dOther attribute: tomato = ripeness; cucumber = bitterness; onion = sweetness.

Consideration of trial results to date should be made with the recognition that during the period studied, our organic and conventional plots were actually undergoing transition, with organic plots receiving regular compost applications and conventional plots receiving only synthetic fertilizers at recommended rates. In studies conducted in 2003 and 2004, pac choi and lettuce were the crops studied most. There was a tendency for total and individual phenolics (in 2003) and antioxidants (in 2004) to be elevated in organically grown or field grown pac choi. There were indications that this elevation in pac choi grown under organic conditions was related to nitrogen fertilization and form (see figure 4) but differences in insect damage between organic and conventional crops made it difficult to distinguish between these two possible factors responsible for elevated phenolic and antioxidant levels. This is an area of ongoing study, and we are excited about the possibility of determining the extent to which soil fertility and other biotic and abiotic stress factors might contribute to enhanced nutritional value of organically grown produce. There is increasing evidence that organic production systems can increase phytochemical content (Mitchell et al., 2007).

A general tendency of crops produced in high tunnels to have lower phenolic or antioxidant levels compared to open field was also observed and was probably attributable to reduced ultraviolet light in tunnels. This was clearly noted in the difference in the intensity of red pigmentation of red lettuce in the field and high tunnel. In many areas, high tunnels are a valuable tool for organic farmers, improving crop yields and quality while reducing many

disease and pest problems relative to the open field. Further studies will help to determine whether and how nutritional quality of crops produced in high tunnels can be optimized.

Our initial consumer sensory analysis of organic and conventional crops did not reveal striking differences among the crops produced during one season. However, given high consumer interest in this subject, we will continue to study relationships between freshness, taste and nutritional quality in future work, including both fresh and postharvest comparisons.

One area of proposed study that we did not complete was to systematically conduct on-farm studies to gather similar information about variation in the production environment (soils, and other factors) on the nutritional quality of organically and conventionally grown produce. This is an area of continued interest since we recognize that the results from our research station may not be widely applicable. Nevertheless, given the very large gaps in our understanding of the factors that may contribute to enhanced nutritional value of crops, we feel that it is wise at this point to focus a continuing concerted effort on the study of “whether organic vegetables are more nutritious” at the K-State Horticulture Research and Extension Center, where our organic and conventional plots in open field and high tunnels provide a valuable research tool for a significant ongoing multidisciplinary research effort. Thanks to initial results (reported here), continuing studies are being supported under a three-year grant from the USDA Integrated Organic Program which began in June of 2007, entitled “Effects of organic fertility management on crop health and phytochemical content of vegetables under open field and high tunnel production.” Under this project we are taking a multidisciplinary approach to attempting to understand the effects of organic nitrogen fertility on crop health—including reaction to diseases and pests—and on nutritional quality, particularly focusing on phytochemicals such as flavonoids which may contribute to crop health while also contributing to the health of humans that consume crops high in these compounds.

7. Outreach.

The high tunnel plots at the K-State Research and Extension Center, Olathe were/are frequently used for field days and training events. Research methods, results and their implications are discussed with visitors and trainees.

On the professional scientific front, our project had a significant outreach component, resulting in five peer-reviewed journal articles and numerous presentations at professional meetings, particularly at the American Society for Horticultural Science (ASHS). At each presentation and in the publications, the support of the OFRF was recognized. It is safe to say that our project has helped contribute to an increasingly active organic working group within the ASHS, as we have been able to continually report results from this project each of the past few years at ASHS meetings.

Presentations made at scientific meetings under the project are as follows:

- Zhao, X., E. Carey, and T. Iwamoto. 2006. Antioxidant capacities of leafy vegetables as affected by fertilization, cultivation, environment, and growth stage. 27th International Horticultural Congress, Seoul, Korea, 2006. Oral presentation.
- Zhao, X., E. Carey, E. Chambers IV, and Z. Matta. 2006. Consumer sensory analysis of organically and conventionally grown vegetables. 27th International Horticultural Congress, Seoul, Korea, 2006. Oral presentation.
- Zhao, X., E. Carey, and T. Iwamoto. 2006. Fertilizer source and high tunnel production environment affect antioxidant levels of pac choi (*Brassica rapa* L.). American Society for Horticultural Science Annual Conference, New Orleans, LA, 2006.
- Zhao, X., E. Carey, J. Nechols, K. Williams, and W. Wang. 2005. Influences of fertilizer source and insecticide application on phenolic compounds in pac choi (*Brassica rapa* L.). HortScience 40:1092. Poster. 2nd place award in graduate student poster competition.
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- Zhao, X., E.E. Carey, and M. Hall. 2003. Influence of protected environment and fertilizer sources on growth and quality of lettuce and leafy greens during summer production on Kansas. HortScience 38: 749.

In addition to the publications referred to previously in this report, an additional publication was produced under this project. This is a literature review paper (Zhao et al., 2006) which extensively covered the literature related to the influence of organic production on phytochemical content in fruit and vegetables.

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- Young, J.E., X. Zhao, E. Carey, R. Welti, S. Yang, and W. Wang. 2005. Phytochemical Phenolics in Organically-grown Vegetables. *Mol. Nutr. Food Res.* 49: 1136-1142.