Breeding for Nutrition in Organic Seed Systems
Philipp Simon, Jim Myers, Walter Goldstein, Micaela Colley
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http://www.extension.org/organic_production

Breeding for Nutrition: Prospects and Challenges for Plant Breeders
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Department of Horticulture
University of Wisconsin-Madison

Plants and People, Vegetables and Vitamins

- Domestication of plants and animals was one of the most significant human achievements
  - Modern humans are dependent on domesticated plants
- Humans domesticated crops, then crops domesticated humans
  - Jacob Bronowski

Crop Plants Feed the World
Domestication of staple food crops fed first civilizations
Rice, wheat, corn, and potatoes are major sources of calories for humans today

Vegetables, fruits, and staple crops also provide vitamins and minerals

Phytonutrients

What are phytonutrients?

- Nutrients and promoters of health found in plants
  - Macronutrients (carbohydrate, oil, protein) sometimes not included in this definition
  - Vitamins, provitamins, and minerals
  - Clear function and targeted intake levels
  - Other biologically active health-enhancing compounds
    - Long list of complex molecules abundant in horticultural crops, e.g. lycopene in tomatoes, sulphoraphane in broccoli, anthocyanins in strawberries, thiosulfinates in garlic & onion, resveratrol in blueberries
Nutritional status of the U.S. and the Globe – Malnutrition on both sides

- Dietary Guidelines Advisory Committee (2004) identified inadequate, or shortfall, intake for at least half of the U.S. population
- Two vitamins - A and C
  - Likely vitamin E and folate also
- Three minerals - Ca, Mg, and K; also fiber
- Intake shortfalls for a nation with 33.8% obese adults, 17% obese children/adolescents
- Globally, 13% undernutrition, 30% Fe, 2% VAD
- 4% to 5% global obesity rate

Food Sources of Nutrients in the U.S. Diet

Contributions of Crop Plants to Nutrients in the U.S. Diet, 2000 (% total)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Total Contribution from Plants</th>
<th>Vegetables &amp; Potatoes</th>
<th>Fruits</th>
<th>Cereals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>**** &gt; 50%</td>
<td>*** &gt; 40%</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>** &gt; 30%</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>* &gt; 20%</td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin A</td>
<td>***</td>
<td>**</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Vitamin C</td>
<td>****</td>
<td>****</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>K, Vitamin B6,</td>
<td>***</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Cu, Folate</td>
<td>****</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe, Vitamin B12</td>
<td>****</td>
<td>***</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Fiber</td>
<td>****</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
</tbody>
</table>

Vegetables and fruits contribute significantly to human health

Foods Contributing to U.S. Nutrient Intake

Cereals

Some carotenes are vitamin A precursors

All vitamin A ultimately comes from plants

** => 40%

Analysis can be expensive, but data is important to

Cooperation w/ nutritionists/physicians more essential

** => 50%

***

Improve well

100+ million deficient, several million die annually

Vitamin A deficiency is a global health problem

** => 30%

***

Provitamin A carotenoids

Improve less well

Is genetic improvement the best approach?

**

- Table 7.
- Table 5.

- Collards, frozen, chopped, boiled, drained
- Watermelon, raw
- Spinach, canned, drained solids
- Spinach, frozen, chopped or leaf, boiled, drained
- Catsup
- Vegetables, mixed, frozen, boiled, drained
- Lettuce, cos or romaine, raw
- Carrots, frozen, boiled, drained
- Carrots, raw
- Sweet potato, baked in skin
- Carrots, boiled, drained
- Carrots, raw
- Lettuce, iceberg (includes crisphead, **)
- Sweet potato, boiled, drained
- Tomatoes, red, ripe, raw
- Melons, cantaloupe, raw
- Peppers, sweet, green, raw
- Peppers, red, bell, raw
- Broccoli, boiled, drained, without salt
- Strawberries, raw
- Fruit punch
- Oranges, raw, all commercial varieties
- Apple juice, canned or bottled, unsweetened, undiluted
- Cranberry juice cocktail, bottled
- Cranberry
- Broccoli
- Tomatoes, red, ripe, raw
- Sweet potato, boiled, drained
- Cranberry
- Carrots, raw
- Spinach, raw
- Tomatoes, red, ripe, raw
- Vegetables and fruits contribute significantly to human health

Contributions of Crop Plants to Nutrients in the U.S. Diet, 2000 (% total)

<table>
<thead>
<tr>
<th>TOTAL CONTRIBUTION FROM PLANTS</th>
<th>VEGETABLES &amp; POTATOES</th>
<th>FRUITS</th>
<th>CEREALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>**=50%</td>
<td>**=50%</td>
<td>**=50%</td>
</tr>
<tr>
<td>Protein</td>
<td>***=30%</td>
<td></td>
<td>**=20%</td>
</tr>
<tr>
<td>Fat</td>
<td></td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Vitamin A</td>
<td>***=20%</td>
<td>**=10%</td>
<td>**=10%</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>***=20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K, Vitamin B&lt;sub&gt;2&lt;/sub&gt;</td>
<td>***=20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu, Folate</td>
<td>***=10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe, Vitamin B&lt;sub&gt;12&lt;/sub&gt;</td>
<td>***=10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiber</td>
<td>***=10%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Vegetables and fruits contribute significantly to human health

What nutrients should be targeted for genetic improvement?

- Improve well-characterized phytonutrient levels (e.g. vitamins, provitamins, minerals)?
  - Analysis can be expensive, but data is important to consumers
- Improve less well-characterized phytonutrients?
  - Analysis often more complicated
  - Cooperation w/ nutritionists/physicians more essential
  - Public opinion may change by the time you develop a product
- Is genetic improvement the best approach?
  - Horticultural approaches to improve garlic
  - Food scientists have also developed fortified foods

Considerations for Improving Nutritional Value of Crops: Provitamin A Carotenones

- Carotenes occur in all green leaves and are essential for photosynthesis in plants
- Some carotenes are vitamin A precursors
  - Provitamin A carotenoids
- All vitamin A ultimately comes from plants
- An essential nutrient
- Vitamin A deficiency is a global health problem
  - 100+ million deficient, several million die annually
- Little overt deficiency in the U.S. but much suboptimal intake
What can be done to make fruits and vegetables better sources of vitamin A?

- Improve the productivity of crops that provide vitamin A
- Improve yield for growers
- Improve postharvest longterm storage
- Identify crop varieties already in production that are better sources of vitamin A
- Genetically increase provitamin A carotene content
- Encourage consumers to increase intake
  - Flavor
  - Convenience

Crop germplasm varies widely in nutrient content


Agronomic crops for which genetic improvement of phytonutrients is being undertaken.
Breeding for Nutrient Content in Agronomic Crops

- **QPM – Quality Protein Maize**
  - CIMMYT since the 1970’s, to improve maize lysine content
- **HarvestPlus**
  - High provitamin A carotenoid maize, cassava, sw. potato
  - High Fe beans, pearl millet
  - High Zn rice, wheat
- **Cooking oil quality, fiber, starch quality**

Horticultural crops for which genetic variation exists and improvement of phytonutrients has been undertaken

Carotene content varies among vegetable and fruit cultivars
Horticultural crops with genetics known and some breeding for essential phytonutrients

- Carotenoids: tomato, pepper, carrots, squash, pumpkin, melon, watermelon, cucumber, cauliflower, broccoli, kale, sweet potato, potato, sweet corn, citrus, mango, papaya
- Vitamin C: tomato, onion, potato, citrus, apple, strawberry
- B Vitamins: beets (folate), peas (thiamin), tomato, pepper
- Vitamin E: brassicas, carrot
- Protein: bean, potato
- Calcium: bean

Progress in Improving Carotene Content of Carrot in the U.S. Crop

- Result of classical plant breeding
- Carrot varieties of 1950’s – 60 ppm
- Carrot varieties of 1970’s – 90 ppm
- Carrot varieties of 1990’s – 130 ppm
  - 1/2 of a carrot (50g) contains enough provitamin A to provide adult vitamin A requirements if fully absorbed
  - Concomitant flavor, convenience improvement essential to deliver higher nutritional content

An example of improving nutritional value of horticultural crops

Breeding for higher content of provitamin A carotenoids in orange carrots

U.S. Carrot and Carotene Production, 1975 ($472M, 2005$$) and 2005 ($650M)

<table>
<thead>
<tr>
<th>Year</th>
<th>Carotene content</th>
<th>Per capita availability</th>
<th>Est. % of total vitamin A available</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>90</td>
<td>3.7 kg</td>
<td>14 %</td>
</tr>
<tr>
<td>2005</td>
<td>130</td>
<td>5.6 kg</td>
<td>21 %</td>
</tr>
</tbody>
</table>
Carrot Impact

One square meter of carrots (~2500) in 1 year
Enough provitamin A for 10 adults for a year

One of very few crops with increased nutritional value per unit weight, as compared to 1950 (Davis et al., 2004)

Plant breeders have made progress improving crop nutritional value in several crops

- Genetic improvement of phytonutrients content can be undertaken with simple tools for pigments
- Lab analysis necessary for most nutrients
- Growers realize no economic value from high-carotene crops
- Marketers cannot easily label high nutrient content
- Improving flavor can increase consumption, and indirectly increase nutrient intake
- Critically important to “obesity epidemic”

A team approach is essential to improve crop nutritional content

- Breeders
- Growers
- Marketers
- Nutritionists and health professionals
- Government and non-government groups
- Educators

Progress in Breeding for Crop Production
Farm Values of Nearly All Crops Have Increased

Nutritional Values of Few Crops Have Increased

Nutritious Crops Make for a Healthy Economy

- Greater consumption of healthier foods improves human health and has positive economic benefits to U.S. agriculture.
- Genetic selection for nutrients that ameliorate "obesity diseases" is expected to reduce health care costs and consequently have an economic benefit (Cordain et al. 2005).
- Healthier foods have the potential to alleviate both the incidence and severity of these diseases, as well as obesity which is a causal factor for many chronic diseases (Heber and Bowerman, 2001).
- Consumer adoption of the recommendations of the 2005 Dietary Guidelines for Americans would significantly alter food demand and production with positive economic impact (Buzby et al. 2006).
- To realize improved nutritional value of crops in the marketplace, improved economic value for the grower, and culinary quality for consumers must also be realized.

Future Issues Will Influence Progress

- What crops, nutrients, tools?
- Production, consumption, germplasm, breeding
- Value to grower, labeling
- Team approach necessary in any case
Domestication of plants and animals was one of the most significant human achievements.

- Modern humans are dependent on domesticated plants.

Responsibility of agricultural scientists to increase food quantity and improve food quality.

Complex solutions requiring teamwork including international cooperation.

http://www.ars.usda.gov/mwa/madison/vcru
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Breeding Tomatoes for increased Flavonoids

Jim Myers
Department of Horticulture

Phenolics and Flavonoids

- Phenolics
  - caffeic acids
  - chlorogenic acids
  - cinnamic acids
  - benzoic acids
- Flavonoids
  - flavones
  - flavonols
  - proanthocyanidins
  - anthocyanins

Phenolics and Flavonoids II

- Biological activity
  - Pathogen defense
  - Environmental stress
  - Feeding deterrent
  - Attractants (flowers, ripe fruit)
Relationship of Phenolics & Flavonoids & to Health

- Effects
  - Anti-allergic
  - Anti-inflammatory
  - Anti-microbial
  - Anti-cancer activity
  - Anti-oxidants
- Possible human health benefits
  - Anti-carcinogens
  - Improved cardiovascular function

New research indicates that flavonoids have only minor activity as antioxidants in vivo – however – they may induce other antioxidant systems. ([Lotito & Frei 2006 Free Radical Biol & Med])

Why modify nutritional characteristics of Tomatoes?

Second in per capita consumption (after potatoes) in the U.S.

They possess compounds with health benefits:

- Carotenoids:
  - Lipophilic
  - Antioxidants
  - Prevent prostate cancer (lycopene)
  - Pro-vitamin A (beta-carotene, other carotenoids)
  - Vitamin C

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  - Vitamin C

Increasing Flavonoids in Tomatoes

- Tomatoes relatively low in flavonoids
- Two approaches to increasing:
  - Transgenes
  - Introgress from related wild species

Tomatoes have excellent genetic resources

- Genetic stocks collection
- Extensive collection of wild relatives
- Genomics resources widely available
- Used as a model system for studying fruit development

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What about “black” and “purple” heirloom tomatoes?

- Genotype of the “purple” tomatoes: \( y \) or \( Y \) & \( gf \)
- \( Gf \) (Green flesh) prevents complete chlorophyll breakdown, producing brown pigment

Plant and fruit characteristics of high anthocyanin tomatoes

- Change to open plant canopy
- Foliage and stems more intensely pigmented
- Light induced expression
- Only skin deep

Tomato Flavonoids and Anthocyanin Quantities

<table>
<thead>
<tr>
<th>Partition</th>
<th>Lactic Acid Equivalents, mg/g FW</th>
<th>Total Anthocyanins, mg/100g FW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legend</td>
<td>Ethyl Acetate</td>
<td>Methanol</td>
</tr>
<tr>
<td>( r )</td>
<td>35.49 a</td>
<td>53.33 a</td>
</tr>
<tr>
<td>Aft/aw</td>
<td>36.95 a</td>
<td>51.85 a</td>
</tr>
<tr>
<td>ss Aft/aw</td>
<td>626.39 c</td>
<td>663.86 c</td>
</tr>
</tbody>
</table>

**Legend**

a-c letters indicate significant difference (\( P<0.05 \)) within a column, determined by Fishers' LSD

Antioxidant Capacity of Ethyl Acetate and Methanol fractions

<table>
<thead>
<tr>
<th>ORAC, ( \mu M ) Trolox equivalence</th>
<th>Ethyl Acetate</th>
<th>Methanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>500.00</td>
<td>500.00</td>
<td>500.00</td>
</tr>
<tr>
<td>1000.00</td>
<td>1000.00</td>
<td>1000.00</td>
</tr>
<tr>
<td>1500.00</td>
<td>1500.00</td>
<td>1500.00</td>
</tr>
<tr>
<td>2000.00</td>
<td>2000.00</td>
<td>2000.00</td>
</tr>
</tbody>
</table>

**Legend**

Aft/atv/aw tomatoes

Phenylalanine + 3X Malonyl CoA

\[ \text{C4H, 4CL, CH5, Aft, atv, Aft/atv/aw, Aft/atv} \]

Petunindin

Unexpected phenotype in \( Aft/atv/aa \) and \( Aft/atv/aw \)
**Flavonols in Aft/atu/aw tomatoes (greenhouse)**

![Graph showing flavonol levels in different tomato varieties](image)

Means not sharing a letter significantly different, LSD test, p≤0.05. Error bars = one standard error, 3 biological replicates.

**Fruits with anthocyanin are much more resistant to decay than normal tomato fruit**

![Image of tomatoes with anthocyanin](image)

**Appearance of detached fruit after 35 days in field**

**Need to investigate “feral” tomatoes**

![Image of tomatoes](image)

**Acknowledgements**

- Carl Jones
- Peter Mes
- Peter Boches
- Deborah Kean
- Brian Yorgey
- Ron Wrolstad
- Balz Frei & LPI
- Baggett-Frazier Endowment

**Breeding Corn for Nutritional Value;**

- Protein, Carotenoids, Taste.
- What our Experience has been.

Walter Goldstein, Research Director

**Mandaamin Institute**

**The Need for Quality as well as Quantity**

- Conventional breeding has emphasized increasing grain yield.
- This caused a progressive increase in starch and decrease in the protein content of the grain.
- The protein content and quality of corn is important to produce balanced rations for organic livestock production in light of the role that corn plays in livestock feed and the high price of organic protein.
- Listening sessions with organic farmers have indicated a keen interest in improving the nutritional value of corn, including its protein content and quality, and vitamin content, as well as improving its taste.
Analysis of native corn 2011 by NIRS spectroscopy at MFAI

<table>
<thead>
<tr>
<th>no samples</th>
<th>protein</th>
<th>oil</th>
<th>starch</th>
<th>density</th>
<th>lysine</th>
<th>methionine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hopi Flour</td>
<td>14</td>
<td>14.9</td>
<td>4.1</td>
<td>63</td>
<td>1.09</td>
<td>0.40</td>
</tr>
<tr>
<td>Hopi Mixed</td>
<td>4</td>
<td>14.2</td>
<td>3.6</td>
<td>66</td>
<td>1.07</td>
<td>0.34</td>
</tr>
<tr>
<td>Hopi Mex. June</td>
<td>12</td>
<td>12.6</td>
<td>5.1</td>
<td>67</td>
<td>1.24</td>
<td>0.36</td>
</tr>
<tr>
<td>Flour other Tribes</td>
<td>11</td>
<td>14.4</td>
<td>5.2</td>
<td>62</td>
<td>1.12</td>
<td>0.41</td>
</tr>
<tr>
<td>Corn Belt Dent</td>
<td>4</td>
<td>7.5</td>
<td>--</td>
<td>73</td>
<td>--</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Multi-aleurone corn from the Amazon with more minerals, protein and possibly more B vitamins and phytosteroids.

Methionine and Lysine

• Methionine and lysine are generally regarded as being primary limiting amino acids for humans, hogs, poultry, and dairy cattle.
• For poultry, the sulfur-containing amino acid methionine is commonly regarded as being the first limiting amino acid for overall health and egg production, and lysine the second.
• Corn is the major ingredient of poultry food but it is naturally low in the sulfur-containing amino acids methionine, cysteine, and cystine, and in lysine.
• This deficiency is commonly made up by combining corn with soybean meal and supplementing with synthetic DL methionine.

Synthetic methionine

• Organic egg production has quadrupled since 2003.
• Neither synthetic methionine, nutrient deficiencies, nor confinement are consistent with the ideals of organic farming.
• Due to national restrictions on its use, organic poultry producers will start to reduce the use of synthetic methionine in poultry feed and replace it after 2015 (Federal Register, 2010).

Breeding High Methionine Corn

• We developed a quick, cheap, non-destructive test NIRS for measuring methionine and lysine.
• We are breeding high methionine and lysine in hard endosperm and soft endosperm breeding sources.
• Hard endosperm sources are high protein corns; methionine will be more subject to fluctuations in protein content.
• Soft endosperm corn has a higher % lysine and methionine in its protein.
• Feeding trials with broilers and layers have shown it can replace synthetic methionine.
• Some soft types (floury-2) are associated with lower seed weight and yield but others are not.
• There probably will be a yield penalty but possibly more protein harvested per hectare.

Protein and amino acid information for corn analyzed in 2007 with high performance liquid chromatography.

<table>
<thead>
<tr>
<th>Component</th>
<th>Normal Corn</th>
<th>hard kernel methionine corn</th>
<th>floury-2 methionine corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>9.5</td>
<td>13.1</td>
<td>12.8</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.21</td>
<td>0.31</td>
<td>0.33</td>
</tr>
<tr>
<td>Total Sulfur Amino Acids</td>
<td>0.43</td>
<td>0.58</td>
<td>0.57</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.30</td>
<td>0.36</td>
<td>0.46</td>
</tr>
<tr>
<td>number of samples tested</td>
<td>1903</td>
<td>28</td>
<td>16</td>
</tr>
</tbody>
</table>
Reliability: Results from 3 farms that grew the floury-2 hybrid in 2008.

<table>
<thead>
<tr>
<th>Farm</th>
<th>Protein %</th>
<th>Lysine %</th>
<th>Methionine %</th>
<th>Cysteine %</th>
<th>Oil %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm 1</td>
<td>10.2</td>
<td>0.40</td>
<td>0.27</td>
<td>0.21</td>
<td>5.7</td>
</tr>
<tr>
<td>Farm 2</td>
<td>10.2</td>
<td>0.40</td>
<td>0.27</td>
<td>0.21</td>
<td>5.7</td>
</tr>
<tr>
<td>Farm 3</td>
<td>9.9</td>
<td>0.41</td>
<td>0.26</td>
<td>0.19</td>
<td>6.0</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>10.1</strong></td>
<td><strong>0.40</strong></td>
<td><strong>0.27</strong></td>
<td><strong>0.20</strong></td>
<td><strong>5.8</strong></td>
</tr>
</tbody>
</table>

Results of developing an NIRS calibration for grain amino acids:

<table>
<thead>
<tr>
<th>Range (µmol)</th>
<th>Omega Infratec Spectra</th>
<th>Total Spectra</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>LYS</td>
<td>0.26-0.53</td>
<td>0.837</td>
<td>0.842</td>
</tr>
<tr>
<td>MET</td>
<td>0.14-0.39</td>
<td>0.746</td>
<td>0.730</td>
</tr>
<tr>
<td>CY3</td>
<td>0.14-0.37</td>
<td>0.783</td>
<td>0.787</td>
</tr>
</tbody>
</table>

Kovalenko et al. 2006 proposed using R² or RPD (Relative Predictive Determinant) to test whether values are calculated values or true predicted values.

Feeding trials to Chickens

- Soft-kernelled corn bred by the MFAI program replaced the need for synthetic methionine in trials with broilers by Organic Valley (Levendoski, 2006) and with layers by the University of Minnesota (Jacob et al., 2008).
- Palatability of the soft kernelled cultivars in both sets of trials was very high.
- Feed had to be restricted to avoid feeding frenzies.
- In the future, larger trials may be carried out with a team of organic poultry companies called the Methionine Task Force.

Tradeoffs between protein and yield

- High methionine corns are generally high protein corns.
- Selection for high protein can easily result in reduced endosperm and seed size.
- It is possible to select for corn that produces high protein without a reduction in endosperm size.
- Select should target alterations in N physiology and greater utilization of N from soil organic matter.
- Selection on the basis of a high concentration of methionine and lysine in the grain must be coupled with estimates of yields of constituents on a per acre basis.

**Goal:** Cultivars should produce very high yields of protein and essential amino acids on a per acre basis and have high percentages of those constituents.

Yields in 2009 of new hard endosperm hybrids

- HM hybrids were grown on 9 organic and 9 conventional sites and compared with many different normal, non-gmo hybrids.
- Relative to normal hybrids (100%) the HM hybrids in the USTN trials appeared to have averaged higher yields on organic sites (87%) than on conventional sites (81%).
- The best yielding HM hybrids on all organic sites were HM-11 and HM-2. They yielded 94% and 91% as high as the average for all the elite hybrids tested.
- The best yielding HM hybrids on conventional sites were HM-1 and HM-6 which yielded 88% as high as the average elite hybrids tested.
- The HM hybrids did not appear to differ from normal hybrids in lodging and showed a normal range in grain moisture content.
Quality 2009

- To evaluate differences in grain quality, on one site a subset of hybrids were grown next to the USTN plots and plants were self pollinated. The grain from these plants was analyzed for quality.
- The HM cultivars averaged 12.9% protein and 0.28% methionine on a total dry basis. These results are typical of results in the past.
- This is approximately 43% more protein and methionine than is generally found in normal corn hybrids in this study and others.
- Initial projections from data on one site suggest that the HM hybrids produced approximately 1/3rd more protein and methionine per acre more than did the conventional hybrids but approximately 13% less starch.

Breeding corn that has more carotenoids. These are powerful anti-oxidants and precursors for vitamin A.

They turn the yolks of eggs orange and the skin of poultry orange. Eggs get carotenoids into people!

Individual Tester Scores

<table>
<thead>
<tr>
<th>Variety</th>
<th>Sample ID</th>
<th>On Bill</th>
<th>Alan</th>
<th>Stefan</th>
<th>Gail</th>
<th>Walter</th>
<th>Lindsay</th>
<th>Ave.</th>
<th>Std. Dev.</th>
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<td>2.9</td>
<td>1.1</td>
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</tbody>
</table>

Quality: However high it yields, someone has to eat it; they will only eat so much of it, and it may or may not taste as good as it should. Taste can raise or lower the level of enjoyment of life. We share that with our animals.

Feeding Trials Broilers:

Floury-2 grain replaced normal corn plus synthetic methionine in feed

- Broiler feeding trial:
- Organic Valley/MFAI; (Levendoski, et al):
- Cornish Cross Cockerells; small experiment with 3 pens.
- Birds fed out from when they were chicks.
- Three treatments: normal control, high methionine corn, potato extract.
- Gain, feed consumption, and feed:gain ratio were the same for control and methionine corn (2.8) but higher for potato extract (3.3).
- Birds with high methionine corn were more enthusiastic about the corn and had more energy. Control group was calmer.
Feeding Trials Layers:
Floury-2 grain replaced normal corn plus synthetic methionine in feed

- Layer feeding trial:
- University of Minnesota/Organic Valley/MFAI; (Jacob, et al):
- 13 Bovan Brown pullets in 6 replicated pens.
- Birds fed out from when they were chicks.
- Gain, feed consumption were the same for control and methionine corn. Egg production was 2-5% less/pen for the high methionine corn.
- Birds with high methionine corn were more enthusiastic about the corn and luxury consumption had to be controlled.
- By the end of the trial half of the pens with control feed had been progressively disqualified because hens were eating their own eggs.

Cost Relationships for Feed

<table>
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<th>Normal Corn</th>
<th>Floury 2 high meth corn</th>
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<tr>
<td></td>
<td>total food</td>
<td>soy meal corn</td>
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<tr>
<td>Pounds of feed per pen 33 weeks</td>
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<td>9</td>
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<tr>
<td>% soy meal</td>
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<td>13</td>
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<tr>
<td>Costs of feed</td>
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<tr>
<td>same cost for corn</td>
<td>$7.90</td>
<td>$3.62</td>
</tr>
<tr>
<td>at 21% higher cost for high corn</td>
<td>$7.90</td>
<td>$3.62</td>
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<tr>
<td>Assumptions:</td>
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<td>corn 4000 bu</td>
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</table>

Organic Seed Alliance
http://www.seedalliance.org/

NOVIC
http://eorganic.info/novic/

Carrot Improvement
http://eorganic.info/carrotimprovement

Philipp Simon: psimon@wisc.edu
Jim Myers: myersja@hort.oregonstate.edu
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Find all upcoming webinars and archived eOrganic webinars including many more recordings from the 2012 Organic Seed Growers Conference at http://www.extension.org/pages/25242

Find the slides as pdf handouts and the recording at http://www.extension.org/pages/62564

Additional questions? Ask them at http://www.extension.org/ask

We need your feedback! Please fill out our follow-up email survey!