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Insect-Resistant GE Rice, Pesticide Use, and Rice Farmers' Health in China

Jikun Huang and Fangbin Qiao

Introduction

The significant and multiple benefits that Genetically Engineered (GE) crops have generated, including increased yield and lower production costs due to reduced insecticide applications, have been well documented in the literature[1-2]. However, the impact of GE crops on farmers' health due to the reduction of pesticide use has not been rigorously analyzed. While previous studies have indicated a reduction in acute (visible) pesticide poisoning in farmers because of GE crops, the impact of this reduction on farmers' invisible health has not been quantitatively analyzed[3].

Our recent study estimated the health impact of pesticide reduction on farmers through the adoption of GE rice. We focused on invisible health effects because they are more common and may ultimately lead to fatal disease[4-5].

Research approach

Two datasets from the same farmers were used in this study. The first dataset was based on GE and non-GE rice trials and was used to compare pesticide use between GE rice plots and non-GE rice plots. Trials were conducted in Fujian province, Southeast China, in August 2010. We conducted the examinations in August, as this is the time when pesticides were intensively used in sampled areas. For all trials we collected household basic information and plot level production input and output data.

The second dataset contains results from 109 farmers' physical examinations. Two rounds of examinations were conducted to control for the impact of time-invariant factors (such as characteristics of farmers and regions); thus, analysis of the difference between these two rounds would be unaffected by the initial health condition of each individual. The time interval between the two rounds of examinations ranged from 1 day to 3 days, which can provide us additional information on the health impacts of pesticide application over different time periods (e.g., within 24 hours, 24- 48 hours and 48-72 hours).

Health examinations included general and blood examinations. In addition to the examinations, a historical record of the visible effects (such as headache, nausea, skin irritation, and digestive discomfort) of pesticide applications was obtained from each farmer. Blood examinations and individual interviews on pesticide application were used to assess the invisible effects of pesticide use. The major indicators of the invisible effects were as follows: (1) Cholinesterase (CHE) and neuron-specific enolase (NSE) to assess the neurological system; (2) Neutrophil granulocyte percentage (N) and red blood cell count (RBC) to assess the hematological system; and (3) Chloride ions (Cl^-) along with sodium ions (Na^+) to assess

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electrolyte balance[6-8]. Following the collection of blood samples, detailed information was obtained from the farmers regarding pesticide usage prior to the blood test. Data from blood examinations and individual interviews on pesticide application were used to assess the invisible effects of pesticide use.

Since many factors may affect the magnitude of the three sets of measured health indicators, the multiple regression models using the individual Fixed Effect (FE) estimation based on the panel health examination data were used. Since the characteristics of the farmers and environment are time-invariant variables during the two rounds of blood tests, the FE model can be written as follows:

$$\Delta Indicator_{it} = \beta_0 + \beta_1 * \Delta Pesticide_{it} + \varepsilon_{it}$$

where $\Delta Indicator_{it}$ is the change in each health indicator from its mean. $\Delta Pesticide_{it}$ is the change in pesticide use from its mean. *Pesticide* is measured by three dummy variables: D1 equals 1 if the farmer applied pesticides within 24 hours of the second blood test; D2 equals 1 if the farmer applied pesticides more than 24 hours but less than 48 hours before the second blood test; D3 equals 1 if the farmer applied pesticides more than 48 hours but less than 72 hours before the second blood test. The value of each of the three dummy variables was 0 if the condition was not met. In an alternative specification, *Pesticide* is measured by the following: 1) the quantity of pesticide applied in the 24 hours before the second blood test; 2) the quantity of pesticide applied more than 24 hours but less than 48 hours before the second blood test; and 3) the quantity of pesticide applied more than 48 hours but less than 72 hours before the second blood test.

Results

Table 1 shows that 8% of farmers who did not plant GE rice suffered from acute poisoning illnesses related to pesticide use, while none of the farmers reported any poisoning symptoms in their GE rice fields. Statistics from our rice trial plots also showed that pesticide use in GE plots and non-GE plots differed significantly. Farmers sprayed pesticides 1.38 times in their GE plots, and 2.72 times in non-GE rice plots. The amount of pesticide use (or cost of pesticide use) per ha in GE plots is about 1/3 of that in non-GE rice plots. Finally, we also found that the yield of GE plots was slightly higher than that of non-GE plots in villages with GE rice trials.

Table 1. Pesticide use, acute poisoning cases, and rice production

	GE rice adopters	Non-GE rice adopters
Number of Households	20	38
Acute poisoning cases (%)	0.00	0.08
Frequency of pesticide use (times)	1.38	2.72
Amount of pesticide use (kg/ha)	3.71	13.06
Cost of pesticide use (Yuan/ha)	187.07	507.78
Rice yield plots (ton/ha)	8.21	8.04

The significant and new finding is that reduction of pesticide use has important effects on farmers' health. Health examination results indicated that pesticide use within 24 hours had a significant impact on the magnitude of various health indicators. For example, the average N value decreased by 7.76% from the first test to the second test in farmers who sprayed pesticides within 24 hours before the second blood test. However, the average change in N between the two blood tests was not significant if pesticide exposure occurred more than 24 hours prior to the second test. A similar pattern was observed in all other health indicators.

The estimated coefficients on pesticide use, when measured either by dummy variables or the actual amount of pesticide sprayed, were negative and statistically significant, which means that CHE values decrease following pesticide exposure (**Table 2**). For example, the average value of CHE decreased by 32.03 within 24 hours of pesticide exposure. The estimation results additionally show that the effect would not be observed more than 24 hours after pesticide exposure. Similarly, if farmers sprayed pesticides within 24 hours before the blood test, the value of NSE, another indicator of nervous system, may increase by 1.94 (or 34.28%).

Significant effects of pesticide use within 24 hours on Cl^- and Na^+ were also found using the econometric analysis. The estimation results show that pesticide use increases Cl^- and Na^+ values in farmers. Similar to the impact on the neurological and hematological system, the effect of pesticide exposure is not significant after 24 hours.

We assessed whether pesticide use leads to changes in the health indicators by re-estimating our models and assigning the abnormal readings of these indicators as dependent variables. Regression results showed that pesticide use affected both the magnitude of these indicators and the normal function of nervous and hematological systems. Similarly, these effects were also detected when pesticides were sprayed within 24 hours.

Conclusions

This study shows that commercialization of GE rice may reduce pesticide use by more than two thirds. This translates into a national pesticide reduction of more than 196 thousand tons, or about 6 billion Yuan, annually. This study provides new evidence on the benefits of GE technology to the health of farmers. About 8% of rice farmers still suffer from acute pesticide-related poisoning. Thus, the estimated 16 million Chinese farmers who suffer acute poisoning illnesses each year can benefit from the use of GE technology and the consequent reduction in pesticide exposure. Hence, the commercialization of GE rice is expected to improve the health of farmers in countries where pesticide application is necessary to mitigate crop loss.

More importantly, this study provides empirical new evidence of the benefits of GE technology to farmers' health. This study shows that GE technologies such as GE rice can significantly improve farmers' health through avoiding

Table 2. Estimated parameters using an individual fixed-effects model for estimating the effect of pesticide use on farmers' health indicators in China

	0-24 hours	24-48 hours	48-72 hours
Cholinesterase (CHE)	-32.03***	5.56	2.85
Neuron-specific enolase (NSE)	1.94*	-0.19	-0.13
Neutrophil granulocyte % (N)	-5.25***	3.00	0.42
Red blood cell count (RBC)	-0.08**	0.07*	0.04
Chloride (Cl^-)	1.57***	0.07	0.61
Sodium (Na^+)	1.28***	-0.11	-0.09

Note: The symbols *, ** and *** denote significance at 10, 5, and 1%, respectively.

The regression analysis shows that pesticide use exerts a significant short-term influence on the measured hematological indicators. N values decreased by 5.25, and RBC values decreased by 0.08 in farmers who reported pesticide exposure within 24 hours of the blood test. Similar to the effects on CHE, the impact of pesticide use on N and RBC are mainly evident the first day after pesticide exposure. This remains true, if the quantity of pesticide is used as an explanatory variable.

the incidence of not only pesticide-related illness (or visible effect), but also the invisible short time effects on farmers' neurological system, hematological system, and blood electrolytes. While most of the effects observed in this study are short-term (e.g., invisible effects within 24 hours), farmers spray pesticides many times during the entire crop-growing season. It follows that frequent short-term effects may affect the long-term health of farmers.

Source: Huang, J., Hu, R., Qiao, F., Yin Y., Liu, H., and Huang, Z. (2015). Impact of Insect-resistant GM Rice on Pesticide Use and Farmers' Health in China. Science China Life Sciences. doi: 10.1007/s11427-014-4768-1

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US Patent Office Revises Rules, While Courts Give USDA Nothing to Whine About

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The US Supreme Court has been issuing patentee-unfriendly decisions in recent years. The Supremes' 2013 *Association for Molecular Pathology v. USPTO* decision, for example, concerned the patentability of certain isolated DNA molecules. "[A] naturally occurring DNA segment is a product of nature," Justice Clarence Thomas wrote, "and not patent eligible merely because it has been isolated . . . ."

Under US patent law, certain subjects are not eligible for patent protection. A naturally occurring substance – 'a product of nature' – is one of these exceptions. The reasoning behind this exception is that a patent on a product of nature would prevent the use of something that should reside in the public domain. An inventor can argue that a substance is not a product of nature by showing that it has markedly different characteristics compared with its counterpart in nature. For decades, claiming an *isolated* DNA molecule that encodes a protein usually distinguished that DNA molecule from the gene's nucleotide sequence that resides within a chromosome. After the *Association for Molecular Pathology v. USPTO* decision, however, the mere isolation of a molecule found in nature fails to provide a markedly different characteristic that distinguishes the claimed molecule from its naturally occurring counterpart.

While the Supreme Court blissfully overturns decades of patent practice, the USPTO struggles to craft new patent examination guidelines. During March 2014, the USPTO issued guidelines for determining subject matter eligibility of claims reciting natural products. The unpopular document offered a confusing 12-factor test with a heavy focus on structural differences to establish markedly different characteristics. By the end of the year, the USPTO published revised examination guidelines. At a forum held in January, Raul Tamayo, a USPTO legal advisor, explained that "markedly different characteristics" now include biological functions, biological activities, phenotype, and other properties.

To illustrate application of the revised guidelines, the USPTO released a set of example patent claims to nature-based products. Two examples focus on nucleic acid molecules and a product of genetic engineering.

The nucleic acid example concerns a gene found in Virginia nightshade plants. A damaged nightshade leaf produces a hormone called Protein W, which is encoded by Gene W on chromosome 3. The hypothetical patent application discloses the nucleotide sequence of Gene W (SEQ ID NO: 1). The application also discloses nucleic acid molecules that have nucleotide substitutions, compared with SEQ ID NO: 1.

One claim is directed to "isolated nucleic acid comprising SEQ ID NO: 1." The USPTO does not deem the claim eligible for patent protection. Although the claimed nucleic acid differs from naturally occurring Gene W, because the claimed nucleic acid is isolated from chromosome 3, it has the same nucleotide sequence as the natural gene. "In other words," explains the USPTO, "the claimed nucleic acid is different, but not markedly different, from its natural counterpart in its natural state (Gene W on chromosome 3), and thus is a 'product of nature' exception." The rationale conforms with Supreme Court decrees.

Another claim is directed to "isolated nucleic acid comprising a sequence that has at least 90% identity to SEQ ID NO: 1 and contains at least one substitution modification relative to SEQ ID NO: 1." This claim is patent eligible, because the claimed nucleic acid has different structural characteristics than naturally-occurring nucleic acid. Furthermore, some of the claimed nucleic acids may have different functional characteristics, because they may encode a different protein than the natural gene.

Yet another claim is directed to a "vector comprising the nucleic acid of claim 1 and a heterologous nucleic acid sequence." The patent application defines a "heterologous nucleic acid sequence" as a nucleotide sequence that does not naturally occur in Virginia nightshade, such as the cauliflower mosaic virus 35S promoter. Because the claim is limited to a vector comprising a non-natural combination of Gene W (SEQ ID NO: 1) with a nucleotide sequence from another organism, the claim is not a product of nature, and it is patent-eligible.

The USPTO's genetically engineered (GE) bacteria example concerns plasmids encoding proteins that enable the degradation of different hydrocarbons. The first claim is directed to a “stable energy-generating plasmid, which provides a hydrocarbon degradative pathway.” According to the USPTO, “there is no indication that the claimed plasmid has any characteristics (structural, functional, or otherwise) that are different from naturally occurring energy-generating plasmids.” Because the claimed plasmid lacks markedly different characteristics compared with a naturally-occurring plasmid, the claimed plasmid is a “product of nature” and is not eligible for patent protection. According to the USPTO, “there is no indication that the claimed plasmid has any characteristics (structural, functional, or otherwise) that are different from naturally occurring energy-generating plasmids.” Because the claimed plasmid lacks markedly different characteristics compared with a naturally-occurring plasmid, the claimed plasmid is a “product of nature” and is not eligible for patent protection.

The second claim in this example is directed to a “bacterium from the genus *Pseudomonas* containing therein at least two stable energy-generating plasmids, each of said plasmids providing a separate hydrocarbon degradative pathway.” This claim is eligible for patent protection. First, the claimed GE bacterium can degrade at least two different hydrocarbons as compared with naturally-occurring *Pseudomonas* bacteria that degrade a single type of hydrocarbon. So, the claimed GE bacterium has a different functional characteristic from its naturally-occurring counterpart. Second, the claimed GE bacterium has a different structural characteristic, because it has more plasmids than a single naturally-occurring *Pseudomonas* bacterium. These different functional and structural characteristics qualify as marked differences between the claimed GE bacterium and its natural counterpart. The claimed GE bacterium is not a “product of nature.”

The USPTO’s examples do not include claims to GE plants. However, the GE bacteria example shows that genetic engineering creates the types of functional and structural changes in a cell that should prevent a patent examiner from classifying a GE cell as a product of nature. Of course, patent eligibility is only one hurdle that a patent applicant must overcome.

Patents on Grapes Escape Legal Scrapes

An inventor can be barred from obtaining a patent if the claimed invention was used in public before the inventor filed a patent application on the invention. This restriction was designed to prevent the removal of an invention from the public domain after the public reasonably believes that the invention is freely available. In *Delano Farms Company et al. v. California Table Grape Commission et al.*, the Court of Appeals for the Federal Circuit decided whether the public use bar destroyed two plant patents for new varieties of grapes.

On August 22, 2001, the US Department of Agriculture held an experimental variety open house at California State University, Fresno, where the agency displayed mature fruit of Scarlet Royal, Autumn King, and other unreleased table grape varieties. The USDA imposed restrictions on visitors: They could not see unreleased varieties growing in test fields, nor could they take plant material of unreleased varieties. As described by the Federal Circuit, this subdued event triggered a cluster of capers with unreleased grapes.

California grape growing cousins Jim Ludy and Larry Ludy attended the open house. Jim wanted plant material for the Scarlet Royal and Autumn King varieties. During early 2002, Rodney Klassen, who was employed by the USDA at the facility where the grape varieties were being developed, met with Jim Ludy. Although Klassen was not authorized to distribute unreleased plant material, he provided Jim Ludy with plant material for various unreleased varieties, including Scarlet Royal and Autumn King. Klassen instructed Ludy to keep the plant material to himself. Ludy understood that he should not sell grapes grown from the plant material until the varieties were commercially released.

Soon, Ludy grafted vines of the Scarlet Royal and Autumn King varieties. He also provided plant material to cousin Larry, who understood that he should keep his possession of the material confidential. During 2003, Larry Ludy cultivated 108 vines of Scarlet Royal and 650 vines of Autumn King. He arranged for table grape marketer Richard Sandrini to sell Larry’s 2004 harvest of Autumn King. To avoid detection, Sandrini labeled the grapes as “Thompson Seedless.” Larry also gave Sandrini plant material to graft Autumn King in his own fields.

On September 28, 2004, the USDA filed applications that resulted in plant patents for Scarlet Royal and Autumn King table grape varieties. The agency granted an exclusive license of the patents to the California

Table Grape Commission. Three California grape growers purchased grapevines covered by the patents, signed license agreements with the California Table Grape Commission, and paid the licensing fee. Then, they filed a lawsuit alleging that the public use bar invalidated the patents. At this time, US patent law stated that a patent applicant cannot be granted a patent for an invention that was in public use in the United States for more than one year prior to the filing date of the patent application.

A California district court found that the Ludys' actions did not constitute a public use of the two plant varieties and rejected the plaintiffs' challenge to the patents. The plaintiffs appealed the decision to the Federal Circuit.

On appeal, the California grape growers offered three arguments to support their position that the public use bar invalidated the patents. First, they argued that the cultivation of the unreleased varieties by Jim Ludy and Larry Ludy constituted public use. The Federal Circuit disagreed, finding that Jim Ludy sought to maintain control of the plants he obtained from Klassen. Although Jim Ludy shared the plants with his cousin, Larry Ludy treated his possession of the unreleased varieties as confidential and non-public. In order to be invalidating, Judge William Bryson explained, third party use must be publicly accessible. Secret third-party uses of an invention do not invalidate a later-filed patent.

In their second approach, the appellants argued that the disclosure of the existence of the unreleased plants to Sandrini demonstrates the lack of confidentiality with which the Ludy cousins treated the unreleased varieties. But the Federal Circuit agreed with the district court judge who found that the Ludys and Sandrini were motivated to maintain secrecy about the Ludys' possession of Scarlet Royal and Autumn King vines. The fact that they could be the first to commercialize the grapes after approval of the varieties created a significant competitive advantage.

Finally, the appellants contended that the Ludys failed to cultivate the unreleased grape varieties in secret. "The appellants are correct that the district court found that both Ludys grafted the plants and grew them in locations that were visible from public roads," Judge Bryson wrote. "However, the appellants ignore the district court's finding that grape varieties cannot be reliably identified simply by viewing the growing vines alone." The appellants did not offer evidence that a person other than the Ludy cousins and Sandrini had ever recognized the unreleased varieties.

The Federal Circuit affirmed the district court decision.

The America Invents Act (AIA) changed some aspects of US patent law. Judges decided the *Delano* case using pre-AIA law, because the USDA filed the grape patent applications before March 2013. Patent applications filed on or after March 16, 2013, follow AIA rules, which eliminate the one-year grace period of the public use bar. Under the AIA, public use of an invention before the effective filing date of a patent application bars issuance of a patent on the invention. The *Delano* plaintiffs might have won if judges had applied the new law, according to University of Missouri law professor Dennis Crouch. "In this case," Crouch said, "that change would likely have made a difference because the third-parties were less private in the year leading up to the application filing, including commercial sales of the grapes."

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Carotenoid-enriched Transgenic Corn in Poultry Nutrition

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Vitamin A deficiency (VAD) is one of the most important micronutrient deficiencies globally. It is prevalent throughout the world, but it is particularly severe in Africa and South-East Asia. The main underlying cause of VAD is a chronic insufficient vitamin A intake in the diet, which can lead to disorders such as xerophthalmia, anaemia and weakened resistance to infection. It has been estimated that VAD affects up to one third of the world's pre-school-age children and up to 15% of pregnant women[1].

Vitamin fortification programs are unsustainable due to poor governance, inefficient food distribution networks, and the prevalence of subsistence agriculture in rural populations[2]. Biofortification of staple crops with organic nutrients is a cost-effective and sustainable approach as exemplified by Golden Rice[3] with high-levels of β-carotene, and Multivitamin Corn[4] accumulating high levels of β-carotene, zeaxanthin, lutein, lycopene, ascorbic acid, and folate.

Vitamin A and carotenoid metabolism in chickens is closely related to the equivalent processes in humans. Consequently chickens are also susceptible to vitamin A deficiency with similar symptoms[5].

Importance of carotenoids in poultry production

Skin color plays a major role in consumer preference for poultry meat. It is the first quality attribute that the consumer can evaluate, so possible shortcomings related to color might have a negative impact in terms of consumer buying preferences. A golden skin color is desirable because it is associated with better health, albeit consumer preferences vary by region.

The commercial poultry diet based on corn/soybean does not supply enough carotenoids to produce the golden skin preferred by many consumers and does not confer additional health benefits such as enhanced protective immunity. The antioxidant activity of carotenoids can result in their depletion from the circulation during immune stress periods and lead to reduced pigmentation[6].

Like other animals, chickens cannot synthesize carotenoids *de novo* and must obtain them from their feed. Natural pigments such as marigold flower rich in lutein and zeaxanthin, paprika rich in capsanthin, and canthaxanthin, or synthetic pigments such as β-apo-8'-carotenal have to be added to poultry feed to meet consumer demands and health benefits, but this increases the production costs[7].

Transgenic high-carotenoid corn delivers nutritionally important carotenoids to poultry

The presence of carotenoids in poultry breast and thigh meat is important from a production point of view due to their activity as antioxidants. Oxidation affects skin color as well as the shelf life of poultry meat.

We evaluated commercial broilers fed diets supplemented with different types of corn including: control white corn; high carotenoid corn which accumulates high levels of β-carotene, lycopene, lutein and zeaxanthin[8]; a standard commercial corn-based diet with the colour additives normally used in commercial poultry production; and a standard corn-based diet without additives. Birds reared on the high-carotenoid diet accumulated higher carotenoid levels in breast meat.

The skin and meat color was evaluated with the CIELAB trichromatic system based on three-dimensional color space produced by plotting in rectangular coordinates, L*, a*, and b*. L* is the value for lightness, a* for redness, and b* for yellowness. The birds fed the high-carotenoid diet exhibited much more intense color than birds fed on the control diet (**Fig. 1**). Importantly the yellow skin color did not lose its intensity in shelf life studies, demonstrating the strong antioxidant activity achieved by consuming the carotenoid-rich diet[9].

Bioavailability of carotenoids and conversion to retinol

The bioavailability of nutrients in staple crops is a better indicator of nutritional quality than the nutrient content alone. The health-promoting effects of vitamins depend on overall intake and bioavailability, which is influenced by food processing, absorption efficiency, and the utilization or retention of the vitamin in the body[10].

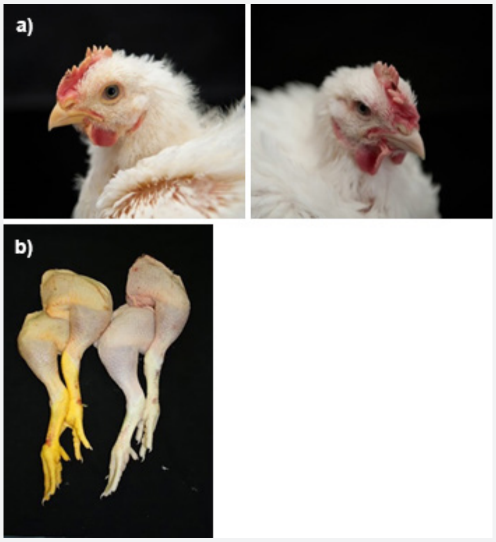

Figure 1. Chickens fed the high-carotenoid corn (left) and the control (right) diets. (a) Beak, crest, eyelids and facial feathers. (b) Dissected thighs.

The serum carotenoids represent the mobile pool of pigments, whereas the liver is the primary storage organ for carotenoids. Carotenoid and retinol levels tend to be maintained at constant levels in serum until storage pools are depleted; thus, liver carotenoid and retinol pools provide a more reliable indicator of nutritional status.

The livers of birds fed the high carotenoid diet contained much higher levels of carotenoids than the other diet groups, including the commercial diet supplemented with natural pigments. Birds reared on the high-carotenoid diet accumulated the highest levels of liver retinol (814 µg/g DW) compared to the control group (471 µg/g DW) and the commercial diets with and without color additives (573 and 531 µg/g DW, respectively). Most likely this reflects the greater supply of β-carotene and β-cryptoxanthin in the carotenoid-enriched diet.

Protection of poultry against *Eimeria tenella*

Birds succumb to coccidiosis, caused by protozoan parasites of the genus *Eimeria*, when they ingest sporulated oocysts that are found in abundance on poultry farms. It is an economically important poultry disease which is currently controlled using drugs and vaccines. Plants and commercial products rich in carotenoids have been tested for their ability to prevent coccidiosis[11].

As control strategies depend on vaccination and the incorporation of anticoccidial drugs in the diets, development of drug resistant coccidian strains is becoming an increasing problem.

In our experiments, the high-carotenoid diet appears to delay the *E. tenella* reproductive cycle. Enhanced resistance against oocysts was observed in chickens fed the high carotenoid diet and the excretion of massive numbers of oocysts observed in all the other diets was reduced or delayed. Poultry reared on the high carotenoid diet exhibited a reduction in the severity of coccidiosis symptoms concomitant with a delay in the parasite life cycle, reducing the oocyst load in the feces.

The bursa of Fabricius is a lymphoid gland located on the posterodorsal wall of the cloaca that regresses with sexual maturity but plays an important role in disease resistance in poultry. This organ was heavier in the birds fed the high-carotenoid diet, providing a basis for their much improved immunomodulatory response to vaccination. The ability of the high-carotenoid diet to interact beneficially with vaccination schemes suggests that carotenoid-enhanced corn could be used as a complementary strategy to boost resistance to coccidiosis and increase the efficacy of co-presented vaccines against coccidiosis and other diseases.

Litter conditions influence poultry performance. Poor litters cause birds to develop foot pad dermatitis or pododermatitis characterized by inflammation and ulcers on the foot pad and toes. Feed composition helps to prevent pododermatitis lesions by maintaining general animal welfare, thus avoiding the economic losses of the disease. The high-carotenoid diet may have promoted faster follicular repopulation, thus reducing initial inflammation and enhancing the overall immune response. The incidences of footpad dermatitis and digital ulcers were significantly lower in animals fed the carotenoid-rich diet, suggesting that this diet protects against lesions in the presence but also in the absence of coccidiosis.

Economic analysis

The poultry industry worldwide raises approximately 40 billion chickens annually. Avian coccidiosis results in annual economic losses of approximately $2.4 billion, including production losses, disease prevention and treatment costs[12].

Control strategies depend mainly on vaccination and the incorporation of anticoccidial drugs in the diet. The development of drug resistant coccidian strains is an increasing challenge for the poultry industry. It has been estimated that the research and development costs of an effective anticoccidial drug is about $500 million. Thus, a diet based on the high-carotenoid corn would be a safe and more economical option to combat avian coccidiosis.

Appearance often determines product preference or rejection by the consumer. In the case of poultry meat, a bright coloration is preferred, especially in North America and the Asia-Pacific markets. In the broiler industry, genetic selection has made the growth period shorter; thus, a high concentration of pigments is necessary to be added to the feed to achieve the desirable skin pigmentation. The pigmentation of poultry feed increases costs from $5 to $15/tonne[13].

Summary

Poultry raised on a high-carotenoid corn diet were healthy and accumulated bioavailable carotenoids. Our results confirm that incorporation of this new strain of corn into commercial poultry diets could maintain poultry health and confer nutritional value to poultry products. In addition we noted a very substantial reduction in the severity of coccidiosis, prevention of pododermatitis lesions, and a general enhancement of the overall immune response.

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12th Annual Biosafety and Biosecurity Training Course

http://www.bbtcfortcollins.com/
July 9 – July 16, 2015

The 12th Annual Biosafety and Biosecurity Training Course will be held this summer at the Hilton Fort Collins in Fort Collins, Colorado. Room rates are $114 for single or double, and $134for suites. The cutoff date for hotel reservations is June 26, 2015. The hotel phone number is 970-482-2626, and the room group/block name is "Biosafety and Biosecurity Training."

Animal Session: July 9 and 10 will be animal oriented. Topics to be covered include large animal ABSL–2 and –3 facilities design, containment and management; Laboratory animal ABSL–2 and –3 facilities design, containment and management; Veterinary hospital, clinic, and farm and ranch Biosecurity [infection control]; Non-Human Primate Biosafety; and Select Agent inspection preparations.

General Session: July 11, 13 and the morning of the 14 will be general Biosafety and Biosecurity. Topics to be covered include rDNA/Synthetic NA (recombinant DNA) Guidelines; Risk assessment; Entity specific inspection and audit preparations and responses; Entity Specific Audit Program; Select Agent regulations and recent changes (Tier 1), administration, and inspection preparations; Design and management of insectaries; HEPA filters and biosafety cabinet certification; BSL-2 and BSL-3 building design and operations; Synthetic Biology; and Dual Use Research of Concern Guidelines/Oversight.

Optional for all attendees: Sunday, July 12, will be open for your enjoyment of the Fort Collins and Rocky Mountain National Park areas.

Plant Session: July 14 afternoon, 15, and 16 morning will be plant oriented: Greenhouse design and management; Regulations and permit procedures; Containment of recombinant plants; Infectious disease research with plants; Biopharmaceuticals; Plant disease diagnostic lab network; Diseases of crops; and Select Agent inspection preparations. We will finish with lunch at noon the 16th.

A detailed schedule/program and faculty biographies are posted on our web site. Please continue to check the web site for updates: http://www.bbtcfortcollins.com/

The cost for the course is:

Animal and General sessions, July 9 - 14, $1900

General and Plant sessions, July 11 - 16, $1900

Complete training course, July 9 - 16, $2100

Registration includes, dinners July 10 (Animal and General Sessions, and Complete Course registrants), and/or July 14 (Plant Sessions and Complete Course registrants), lunches, and breaks, and all course material. A class photo and certificate will be given to all who complete the course. We anticipate full enrollment, so make your course and hotel reservations early. Please dress casual for the course. July 11 is **Hawaiian shirt day**, so bring your favorite Hawaiian shirt to wear.

Registration information, detailed schedule, hotel information, and area maps are at our web site:
http://www.bbtcfortcollins.com/
http://www.bbtcfortcollins.com/course-information/

The Course is directed by Dr. Robert P. Ellis, CBSP. For more information, please contact Robert Ellis robert.ellis@colostate.edu or 970-491-8268