Title

Overlap of US FDA residue tests and pesticides used on imported vegetables: Empirical findings and policy recommendations

Journal

Food Policy, 34(5)

ISSN

0306-9192

Author

Galt, Ryan E

Publication Date

2009-10-01

DOI

10.1016/j.foodpol.2009.05.005

Peer reviewed

Published in *Food Policy* 34(5):468-476

Overlap of U.S. FDA residue tests and pesticides used on imported vegetables: empirical findings and policy recommendations

Abstract

In the United States, the Environmental Protection Agency (EPA) registers pesticides and sets crop-specific tolerances while the Food and Drug Administration (FDA) enforces EPA regulations by testing plant-based foods for pesticide residues. Pesticide treatment histories are almost always unknown, especially on imported produce, posing an empirical question: to what extent do FDA's residue testing methods used on imported produce correspond to the pesticides used on the crops? In this paper I show that FDA residue testing would have missed residues of the majority of pesticides used on two crops exported to the U.S. from Costa Rica in 2003, suggesting that FDA residue testing on imported produce is inadequate in its coverage. Policy recommendations discussed include better communication of U.S. tolerances to exporters around the world; increased testing for pesticides, especially fungicides, that are currently not part of FDA's regular testing procedures; and the creation of price floors and fair trade relationships in the transnational vegetable market to support farmers' attempts to comply.

Introduction

Pesticide residues are traces of pesticide active ingredients and metabolites that remain on food after being applied on the farm or in post-harvest handling. Pesticide degradation rates depend upon many factors, including characteristics of the compound and environmental conditions (Mahler et al., 1991). At high levels, pesticide residues can cause poisonings when ingested, but these types of poisonings appear relatively rare (Chan, 2001; Chan and Critchley, 1996; Farley and McFarland, 1999; Green et al., 1987). Cumulative

effects of low-level exposures through pesticide residues in food have created concern and scientific and political debate for more than a century (Whorton, 1974). Producing definitive answers on the effects of lifelong, low-level exposure to pesticides is extremely difficult and tests the limits of toxicology and epidemiology (Shrader-Frechette, 1985). As Cohen (1987, p. 48, cited in Culliney et al., 1993, p. 143) writes, "Definitive data could be obtained from experiments involving people … . [However,] the logistics would be formidable and the cost astronomical, and the outcome might not be known for from 10 to 20 years." Despite a lack of definitive evidence of harm or safety of these cumulative exposure risks, many agree that dietary exposures pose some public health risks, especially for young children (National Research Council, 1993; Wargo, 1998).

Scientific findings and recent events have escalated public concern over pesticide residues on food, and food contamination generally. These include (1) findings that low doses of hormone-mimicking chemicals can have negative chronic impacts on the body's endocrine, immune, and neurological systems (Colborn, 1995; Porter et al., 1984; Porter et al., 1999; vom Saal et al., 1997), (2) reports on people's "body burden" of synthetic chemicals that demonstrate the importance of dietary exposure in causing widespread bodily pesticide contamination (Duncan, 2006; Houlihan et al., 2003; Schafer et al., 2004), and (3) food scares, including recent reports about the death of U.S. pets caused by melamine-contaminated pet food ingredients imported from China (Snyder, 2007; The Lancet, 2007) and consumer methamidophos poisonings in Japan blamed on Chinese dumplings (Channel News Asia, 2008).[i]

A recent study of consumer confidence in food systems showed that while 85 and 88 percent of U.S. consumers perceived local and regional produce as somewhat or very safe, respectively, only 12 percent consider the global food system safe (Pirog and Larson, 2007,

p. 11). Rachel Carson's ([1962] 1994) *Silent Spring* spurred concerns over pesticide residues in food and the environment, while Weir and Schapiro's (1981) *Circle of Poison* reoriented public anxiety in industrialized nations toward restricted or banned pesticide residues on imported produce (Galt, 2008). Imported food is of particular concern since pest problems, pesticide regulations, and pesticides used are different in exporting countries. Additionally, concern arises from the lack of data on pesticide use patterns in other countries (Wargo, 1998) and from the growth in the global North's dependence on produce imported from the global South (Freidberg, 2004). From 1977 to 1979, 3.3 of vegetables and 17.6 percent of fruit consumed in the U.S. was imported, compared to 10.1 and 33.6 percent, respectively, in 1999 (Putnam and Allshouse, 2001, p. 21). Public concern likely grows as imported produce accounts for more of what we eat and questions about production practices in other countries go largely unanswered.

In the face of citizen concern, poisoning from high residue levels, and the uncertainty about the long-term effects of pesticide residues, governments regulate pesticide residue levels by setting pesticide tolerances, also known as maximum residue levels (MRLs). MRLs are generally set by using scientific risk assessment based on rodent laboratory tests and models of human exposure (Abelson, 1994; National Research Council, 1983, 1987).

In the U.S., a division of labor exists in setting and enforcing MRLs. The Environmental Protection Agency (EPA) is responsible for registering pesticides for specific uses and setting crop-specific tolerances. The U.S. Food and Drug Administration (FDA) enforces EPA regulations by testing a small portion of plant-based domestic and imported foods for pesticide residues using methods from analytical chemistry (López-García, 2003; Nestle, 2003; Wargo, 1998).[ii] While FDA commonly employs multiresidue methods (MRMs) that can detect residues of nearly 200 pesticides at a time, there are at least 600

pesticide active ingredients registered in the U.S. (Wargo, 1998) and 51 others banned by EPA (Environmental Protection Agency, 2006). Since the pesticide treatment history of imported produce tested by FDA is almost always unknown, an empirical question emerges: to what extent do FDA's residue testing methods used on imported produce correspond to the pesticides used on crops? Following this, a policy-relevant question unfolds: how might the congruence between pesticide use and regulation be improved?

This paper answers these questions using the case of two crops from Costa Rica by relying on primary data collected during fieldwork conducted from 2003 to 2004. The paper then assesses the representativeness of Costa Rican vegetables, showing that they represent a best-case scenario, as they are more thoroughly tested and below the average rate of violation of U.S. tolerances compared to vegetables from other nations. The conclusion explores the incongruence between pesticide use and enforcement. It also suggests policy recommendations for EPA and FDA and a need for scholars to better understand export sectors in other countries.

Methods

Effective enforcement of tolerances is difficult because regulatory bodies know little about specific patterns of pesticide use in their own country and even less about patterns in other countries (General Accounting Office, 1979, 1986a, 1986b, 1994a, 1994b; Wargo, 1998). To determine the extent to which the residue testing methods employed by FDA on imported produce overlap with pesticides used on crops, fieldwork examining vegetable farmers' pesticide use in Northern Cartago and the Ujarrás Valley, Costa Rica, was conducted from April 2003 to early January 2004. I chose Costa Rica because of the importance of vegetable production for export and the national market and because it is a major vegetable exporter. Costa Rica accounted for 2.6 percent of all fresh vegetable

imports into the U.S. from 1996 to 2006, ranking third behind Mexico at 65.1percent and Canada at 22.9 percent (Table 1).

<Insert Table 1 here>

I conducted standardized, face-to-face surveys of 148 vegetable farmers. The survey contained detailed questions on all pesticides used on specific crops grown for export to the U.S., Canada, the European Union, and the domestic market, including the dose and pre-harvest interval (PHI, or the time between the last spray and the harvest). Exporters were also interviewed to assess their understanding of export regulations and MRLs. All exporters in the area are relatively small businesses that contract with small farmers for most of their produce. Some engage in farming themselves.

Results reported here pertain to the pesticides used on two cucurbits exported to the U.S. The first is squash (*Cucurbita pepo* L.), grown by 15 farmers in the survey. The other is chayote (*Sechium edule* Sw.), grown by 20 farmers in the survey. There are relatively few squash export farmers in Northern Cartago. Starting with a few contacts, I used a "snowball" technique (Patton, 2002) of asking them for the contact information of other export squash farmers. Comparing the farmers contacted through snowballing with farmer lists from the squash exporters allowed me to survey all but a few export squash farmers. In contrast to export squash farmers, there are many more export chayote farmers in the area. For these farmers, I used the same snowball technique described above. In addition, key informants introduced me to many export chayote farmers in their communities and in surrounding towns. Sampling this way meant including farmers with different landholding sizes since I told the key informants that I wanted to include a range of farmers from small-scale to large-scale.

I compiled lists of pesticides used on exported squash and chayote from the survey

data and compared the lists to U.S. pesticide regulation, including EPA registration for crop-specific agricultural use[iii] in the U.S. (Environmental Protection Agency, 2004), EPA-established tolerances for these cucurbits (Environmental Protection Agency, 2004), and FDA's pesticide residue tests in 2003 on these cucurbits from Costa Rica (Food and Drug Administration, 2005).

Results

Figure 1 and Table 2 reveal the regulatory status of the pesticides used on exported squash. Forty-nine of 59 (83.1 percent) of pesticides used are registered for an agricultural use in the U.S.[iv] Twenty-five of the 59 (42.3 percent) have an EPA tolerance on squash or are exempt from needing a tolerance. Seventeen of 59 (28.8 percent) would have been detected by FDA residue testing methods or are exempt.

Figure 1 and Table 2 also allow us to examine the percentage of pesticides in each regulatory category that would be detected. Of the 25 pesticides with a squash tolerance, three would have been detected, and five are exempt (for a total of 32 percent). Of the 22 pesticides registered in the U.S. but without a squash tolerance, eight would have been detected (36.4 percent). Of the 12 pesticides not registered in the U.S., one would have been detected (8.3 percent). The ideal regulatory situation—in which a pesticide is registered, has a tolerance, and is tested for by FDA or has an exemption—occurs with eight of 59 (13.6 percent) of pesticides used.

<Insert Figure 1 here>

<Insert Table 2 here>

The overlap pattern is similar but slightly higher for chayote (Figure 2 and Table 3). Forty-three of 47 (91.5 percent) of pesticides used are registered for an agricultural use in the U.S. Twenty-five of 47 (53.2 percent) have an EPA tolerance on chayote or an exemption.

Seventeen of 42 (40.4 percent) would have been detected by FDA residue testing methods or considered exempt.

The percentage of pesticides in each regulatory category that would be detected is as follows. Of the 25 pesticides with a chayote tolerance, five would have been detected, and four are exempt (for a total of 32 percent). Of the 17 pesticides registered in the U.S. but without a chayote tolerance, eight would have been detected (47.1 percent). Of the five pesticides without U.S. registrations, one would have been detected (20 percent). The ideal regulatory situation as defined above occurs with nine of 47 (19.1 percent) of pesticides used.

<Insert Figure 2 here>

<Insert Table 3 here>

Discussion

These data allow an answer to the first question posed above about the extent of overlap between FDA's residue testing methods and pesticides used on the crops. The overlap is less than half, specifically, 28.8 percent in squash and 40.4 percent in chayote. Relatively little overlap exists in part because FDA does not know the treatment history or even general patterns of pesticide use on imported produce. While FDA has "[a] standing request for information from foreign governments on pesticides used on their food exported to the U.S." (Food and Drug Administration Pesticide Program, 2005, p. 4), most governments do not collect data on the specific pesticides used on different crops. Even if the data were available, governments have a vested interest in not reporting it since it could lead to rejections of their produce—thereby lessening foreign exchange earnings—if FDA changes its testing methods to reflect that information. There is also a paucity of pesticide use information on specific crops in different countries because few researchers engage in

field-based research on this topic (but see Dasgupta, 2007; Ngowi et al., 2007).

In the absence of information and for cost effectiveness, FDA relies mostly on multi-residue methods (MRMs) that will detect many insecticides in the n-methyl carbamate, organochlorine, organophosphorus, and pyrethroid chemical classes. Table 4, which groups the pesticides in Figures 1 and 2 by chemical classes, reveals this pattern. The commonly used MRMs can determine residues of nearly 200 pesticides for which EPA has set tolerances (Food and Drug Administration Pesticide Program, 2005). Other pesticides can only be determined by single residue methods (SRMs), which detect only one residue, or selective MRMs, which detect a handful of pesticides in the same chemical class. Many pesticides, including many commonly used fungicides, can only be determined with SRMs or selective MRMs. FDA's lack of use of tests for dithiocarbamates (e.g., mancozeb, maneb, propineb, and ziram) and the azoles and benzimidazoles (myclobutanil, prochloraz, benomyl, carbendazim, thiabendazole, and thiophanate-methyl) means that despite their common use often in a way that violates their PHIs, FDA would not detect them in the study crops, nor in most produce it examines (Table 4).

<Insert Table 4 here>

Table 4 also reveals important oversight gaps for acutely toxic pesticides. The n-methyl carbamates as a chemical class are very acutely toxic, and some have caused consumer poisonings through ingestion of produce with high residue levels (Hirsch et al., 1988). Despite this, FDA did not employ tests that would have detected these in the study crops. Another important gap concerns the organophosphate insecticide methamidophos in chayote. This lack of testing is especially problematic because methamidophos is acutely toxic — having caused a large number of documented consumer poisonings like some n-methyl carbamates (Galt, 2009) — and has caused previous violations on Costa Rican

chayote (Food and Drug Administration Pesticide Program, 1988; Thrupp et al., 1995). Farmers and exporters in the area describe the continued temptation to use it because it is so effective, so maintaining regulatory oversight of methamidophos and other chemicals that have caused residue problems on these and other crops is a minimum step toward food safety.

Importance of lack of overlap

The disconnect between pesticide use and regulation matters in two important ways. The first is the regulatory implication: U.S. regulations are failing to be performed in a way that makes food imports fully conform. Pesticides that could not be detected by FDA methods fall into three categories: those with tolerances on the crop, those registered for some agricultural use but without a specific tolerance, and those not registered for agricultural use. All three categories can cause "adverse" residues and cause rejections of produce. The first category, those with tolerances, cause adverse residues if they exceed the tolerance. In contrast, the last two categories would cause rejections if detected in any amount above a trace. In other words, having anything above a trace of residues of pesticides without tolerances is actually illegal according to U.S. law, yet many of these pesticides cannot be detected with FDA's methods.

The second reason that this lack of overlap matters is the potential health effects of the pesticides that were not detected, but likely persist as residues. As noted above, many acutely toxic pesticides in the organophosphate and n-methyl carbamate classes would not have been detected. Failure to oversee these creates poisoning hazards for consumers (Chan, 2001; Hirsch et al., 1988). Low dose exposures also present uncertain risks. As discussed before, no studies have conclusively shown the harm or safety of pesticide residues over a lifetime of low doses to hundred of different pesticide active ingredients. Yet,

because of the lack of overlap, we do not even have good estimates of all of the residues that actually exist on produce consumed in the U.S. At a very minimum, it is reasonable to assert that U.S. citizens expect not to be exposed to pesticides not registered in their country, but this expectation is clearly violated.

Information available to exporters and farmers

Through my surveys and interviews, it became evident that farmers and exporters, while wanting to comply with U.S. regulations, have relatively vague understandings of specific U.S. tolerances and are frustrated by the lack of access to information. In 2003, EPA's tolerance database was available only as a Microsoft DOS program for download. I discussed the program with exporters, and some noted that the program had important deficiencies, such as not listing all pesticide tolerances for the general category of cucurbits when queried for chayote, even though these pesticides would be permitted if detected and determined to be below tolerance. This was a more general problem of pesticides registered on a large group of crops (e.g., cucurbits) not appearing when specific crops were queried. EPA removed this DOS program from the website in 2004. Only recently did EPA post a searchable tolerance database, although the same deficiency remains of not displaying crop-group-registered pesticides when specific crops are queried (Environmental Protection Agency, 2009). Nor has EPA provided any information in a language other than English.

Since these are small businesses with few resources to invest in navigating U.S. regulations, exporters' knowledge about U.S. regulations comes mostly from experience. Residues of the organochlorine BCH and the organophosphate insecticides acephate, dimethoate, and methamidophos detected in shipments from the area have caused violations (Food and Drug Administration Pesticide Program, 1988; Galt, 2006). These rejections led exporters to restrict export farmers' use of these entire insecticide classes, in addition to the

organophosphate's cousins, the n-methyl carbamates. In contrast, fungicides have never caused rejections of produce from the study area despite the common use of fungicides that do not have tolerances on squash or chayote (Galt, 2007). Many of these fungicides would cause violations if detected by FDA. Inadequate fungicide residue enforcement by FDA has not provided the negative feedback (in the form of pesticide tolerance violations that cost exporters $10,000 or more) that is necessary to change fungicide use toward greater compliance with U.S. regulation.

Generalizing from the case

To what extent can these findings be generalized to all produce imported into the U.S.? The lack of negative feedback for fungicide use is far more widespread than the case of Costa Rican produce, since FDA does not employ residue tests for many of these fungicides in its monitoring of other export sectors (see last column of Table 4). For other generalizations, it is important to recognize that the above data refer to export sectors that are dominated by small businesses owned by Costa Rican nationals, not multinational firms that might have better access to information on U.S. regulations. With this in mind, Costa Rica appears to represent a best-case scenario for sectors dominated by small businesses for two reasons.

First, of the countries with the greatest volume of vegetable exports to the U.S., Costa Rica's vegetables are the most heavily tested for possible residue-food combinations. Determining the representativeness of Costa Rican vegetables' residue situation involves comparing at the country level the total possible residue-food combinations to those actually tested for by FDA (Table 5). "Possible residue-food combinations" (Column B) refers to the concept that any existing pesticide active ingredient could be applied to any vegetable. The estimate of possible residue-food combinations is derived from 600 EPA-registered

pesticide active ingredients (Wargo, 1998) plus 51 pesticide active ingredients on EPA's list of banned pesticides (Environmental Protection Agency, 2006). In other words, each vegetable imported into the U.S. could have any of 651 pesticide active ingredients applied to it. "Tested residue-food combination" (Column C) refers to those residue tests actually performed by FDA on specific vegetable types. Tested residue-food combinations were determined by using FDA (2005) data and counting the number of active ingredients for which FDA tested in 2003 for each country-vegetable combination (e.g., the number of residues tested for in Mexican chayote, Costa Rican chayote, etc.). "Ratio of tested to possible" (Column D) compares the tested versus possible residue-food combinations for each country. Table 5 demonstrates that of the countries that exported more than 10 vegetable types to the U.S. in 2003, Costa Rican produce received the most thorough FDA testing in terms of possible residue-food combinations.[v] A more thorough testing program will in theory encourage export farmers to use pesticides according to U.S. regulation, as they will learn from mistakes that cause violative residues (Galt, 2007).

<Insert Table 5 here>

Second, of vegetable exporting countries, Costa Rican fresh vegetables have lower than average rejection rates from detected illegal residues (Table 1). These rates were calculated from FDA's Pesticide Monitoring Database, a publicly accessible database on residue tests and violations on imported produce. I compiled all data on residues found on imported and U.S. fresh vegetables from the fiscal years 1996-2006.[vi] Adverse residue rates for domestically produced vegetables in the U.S. during that period are 1.6 percent, whereas vegetable imports had an overall adverse residue rate of 5.2 percent. Costa Rican vegetables had adverse residue rates below that average (4.4 percent) and considerably lower than its neighbors, Dominican Republic (7.8 percent), Guatemala (18.3 percent), and Honduras (7.5

percent).

Considered together, these checks on the representativeness of Costa Rican vegetables suggest that the gap between pesticide use on export crops and U.S. regulation as shown in Figures 1 and 2 is likely even greater in produce from other Caribbean Basin countries, and likely in other countries outside the region. The question about differences in the level of compliance between multinational-controlled sectors and those controlled by small business cannot be answered by this data and remains an important academic and policy question.

Conclusion and policy recommendations

The U.S. government's official statement concerning pesticide residues in the U.S. food supply comes from FDA's annual publication on the subject. This position has stayed consistent from 1994 to 2002: "the levels of pesticide residues in the U.S. food supply are *well below established safety standards*" (Food and Drug Administration Pesticide Program, 1995: 118A; 2004: 3, emphasis added). Similarly, upon the release of pesticide residue data, officials commonly note that the percentage of produce with detectable residues is low and that illegal residues are rare. The government promotes the idea that the U.S. has the safest food supply in the world to maintain public calm about a situation that many citizens feel is intolerable—that FDA does not know which pesticides are used on which imported crops, so its testing cannot be informed by the most basic necessary information to help protect the public from residues prohibited by U.S. law.

One important problem with FDA's official statement is that it ignores the fact that there are consistently violations of U.S. standards by U.S. produce, and that the foods that violate the standards are consumed by the U.S. population. For example, 1.9 percent of U.S. vegetable samples tested by FDA in 2003 contained illegal residues (Food and Drug

Administration Pesticide Program, 2005). Between 1996 and 2006, the average annual violation rate for U.S. vegetable samples tested by FDA is 1.6 percent, with some years as high as 2.6 percent (Galt, in review).

The other important problem, and the one highlighted here, is that the official statements assume that the residues that FDA finds on produce are the only ones that exist on that produce. This paper reveals how little is known about residues on imported produce. If the majority of pesticides used on imported produce cannot be detected by methods FDA currently employs then we cannot accurately estimate the level of food safety based on levels of ingestion, since real levels of residues and ingestion are very much unknown. Thus, this paper challenges the basic assumption that residues detected on tested produce are all there are to detect. Absence of evidence cannot be taken as evidence of their absence in the context of residue testing, i.e., one cannot find what one does not look for. If methods employed cannot detect a pesticide, we cannot conclude that residues of that pesticide are not on the produce. Since tests used by FDA would not detect the majority of pesticides used in what is nearly a best-case scenario for imported vegetables, it is likely that most imported vegetables contain many pesticide residues that go undetected by FDA.

To close the gap between regulation and pesticide use on imported produce, I see two necessary minimum steps for the U.S. government to take. First, communication of U.S. regulations to exporters needs to be greatly improved, a responsibility that likely would fall to U.S. EPA. Despite exporters' and farmers' attempts and desire to comply with U.S. residue regulations (Galt, 2007), the disconnect exists in large part because exporters and export farmers have little access to information on EPA tolerances for the crops they grow and export. EPA should start by making these tolerances available in an easily accessed manner on the Internet. The information currently available is organized by specific

pesticide active ingredients (Environmental Protection Agency, 2009). This may work well for regulators, but growers and exporters primarily want to know which pesticides they can use on specific crops. Thus, this information should be in a database with an interface that allows for searching by specific crops that will create a table for that crop, including all the tolerances that pertain to the larger group (such as cucurbits) to which the specific crop belongs. Dividing pesticides by their modes of action (insecticides, fungicides, herbicides) would be another useful option in the creation of these tables. These suggestions should be relatively simple programming tasks, yet ones that would greatly improve regulatory information available to exporters and export farmers. Additionally, English is not the first language of most exporters around the world, so having tolerance databases available in multiple languages, especially the most common ones of Spanish, French, and Chinese, would be very helpful. To continue to make tolerance information difficult to access is a very poor practice, since it causes anxiety among exporters and export farmers who want to comply with U.S. regulations. It also contributes the U.S. population being exposed to pesticide residues that do not conform to U.S. law.

Second, FDA's residue testing, especially for fungicides and the acutely toxic n-methyl carbamates and organophosphates, should be increased. Increasing testing for fungicide residues would help shift fungicide use on imported crops toward better compliance. Importantly, it would change the perception in Costa Rican export sectors that fungicides are not dangerous because they have never caused residue violations (Galt 2007), thereby leading farmers to have more caution with these pesticides both in terms of residues and in terms of exposure to themselves, their workers, and rural residents, including children. Increased testing should also be based upon data from previous years. The disconnect between methamidophos as a past illegal residue on Costa Rican chayote and

FDA's lack of testing for methamidophos in Costa Rican chayote suggests that this minimum step is not occurring.

The sequencing of these two steps — better communication and increased residue testing — is extremely important. EPA should improve communication of tolerances before FDA increases its monitoring efforts so exporters and export farmers have time to adjust before stricter regulation takes place. The required registration of every exporter with U.S. regulatory agencies as part of the U.S. Bioterrorism Act (U.S. Congress 2002; Nestle, 2003) creates an opportunity to communicate these changes to exporters before they occur, as all exporter addresses and contact information should now be on file with U.S. Customs.

A longer-term policy recommendation for those working on food systems issues is the creation of fair trade vegetables, and, more generally, the creation of price floors for fresh produce. While not the focus of this paper, elsewhere I have shown that farmers who receive a fixed price for their produce are better able and more likely to use pesticides that leave fewer residues (Galt, 2006). In contrast, those who have to contend with vegetable prices that fluctuate rapidly must aim to minimize costs, and often do so by using older and more hazardous insecticides which leave higher levels of residues (Galt, 2009). Fair trade vegetables and vegetable price floors can also address the problem that increasingly tight regulations in the North have squeezed small farmers out of the more lucrative export market because of the great burden of complying with demands such as setting up child-care facilities for workers (Barrett et al., 1999; Freidberg, 2004). Thus, fair trade and price floors in vegetable markets could powerfully link farmers' interest in economic viability to consumers' interests in fewer residues in their produce and general societal interest of maintaining livelihoods for small farmers around the world.

In addition to these policy and market changes to increase food safety of imported

produce vis-à-vis pesticide residues, more research should be done on the environmental, health, and social implications of production practices on imported produce and their relationship to regulation. While U.S. consumption of imports is increasing, knowledge about them is generally not. Information about pesticide use and other agricultural and handling practices used on these imported foods is essential to effectively regulate conventional produce that is outside of alternative agricultural governance regimes like organic and fair trade certification. More research can also test hypotheses about differences between export sectors and their abilities to adapt to regulation, such as the idea that compliance with U.S. residue tolerances is better (or worse) when larger-scale exporters are involved.

Figure captions

Figure 1: Regulatory and monitoring diagram for pesticide use on export squash, 2003. Each box represents a pesticide identified by common chemical name. The regulatory and monitoring status are shown with overlays of different colors. At the lowest level of the figure are white and red overlays. White signifies registration for an agricultural use in the U.S. and red shows a lack of U.S. agricultural registration. The yellow overlay above the red and white layers shows a U.S. tolerance or exemption on the crop in question. The blue overlay above means that FDA tested for the pesticide or it is exempt from EPA tolerances. In the legend, "average minimum PHI" is the average of the lowest number of days that farmers wait between pesticide application and harvest.

Figure 2: Regulatory and monitoring diagram for pesticide use on export chayote, 2003. See explanation for color-coding in Figure 1.

References

Abelson, P.H. 1994. Risk assessment of low-level exposures. Science 265 (5176), 1507.

Public health security and bioterrorism preparedness and response act of 2002. 107-188. 107th Congress, June 12, 2002.

Barrett, H.R., Ilbery, B.W., Browne, A.W., and Binns, T. 1999. Globalization and the changing networks of food supply. Transactions of the Institute of British Geographers 24, 159-174.

Carson, R. 1994. Silent spring. New York: Houghton Mifflin Company. Original edition, 1962.

Chan, T.Y.K. 2001. Vegetable-borne methamidophos poisoning (letter). Clinical Toxicology 39 (4), 337-338.

Chan, T.Y.K., and Critchley, J.A. 1996. Childhood poisoning in Hong Kong. Hong Kong Medical Journal 2 (2), 191-195.

Channel News Asia. 2008. Officials say Chinese-made dumplings not contaminated in China, [cited 28 February 2008]. Available from http://www.channelnewsasia.com/stories/eastasia/view/331663/1/.html.

Colborn, T. 1995. Environmental estrogens: Health implications for humans and wildlife. Environmental Health Perspectives 103, Supplement 7, 135-136.

Culliney, T.W., Pimentel, D., and Pimentel, M. 1993. Pesticides and natural toxicants in foods. In The pesticide question: Environment, economics, and ethics, pp. 126-150, Pimentel, D. and Lehman, H. (Eds.). New York: Chapman and Hall.

Dasgupta, S. 2007. A pinch or a pint? Evidence of pesticide overuse in Bangladesh. Journal of Agricultural Economics 58 (1), 91-114.

Duncan, D.E. 2006. The pollution within. National Geographic 210 (4), 116-134.

Environmental Protection Agency. 2004. Title 40: Protection of environment (Revised July 1, 2004). Environmental Protection Agency,, [cited 14 September 2004]. Available from http://www.access.gpo.gov/nara/cfr/waisidx_04/40cfr180_04.html.

———. 2007. UN PIC & U.S. PIC-nominated pesticides list, [cited 31 January 2007]. Available from http://www.epa.gov/oppfead1/international/piclist.htm.

———. 2009. Electronic Code of Federal Regulations (simple search, Title 40). Environmental Protection Agency, [cited 1 April 2009]. Available from http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?sid=7d2b59b366cae3eab37df677187b67bf&c=ecfr&page=simple.

Farley, T.A., and McFarland, L. 1999. Aldicarb as a cause of food poisoning—Louisiana, 1998. Morbidity and Mortality Weekly Report 48, 269-271.

Federighi, V. (Ed.) 2001. Regulating pesticides: the California story. Sacramento: California Environmental Protection Agency and California Department of Pesticide Registration.

Food and Drug Administration. 1998a. Pesticide Program pesticide monitoring database 1996, edited by Food and Drug Administration.

———. 1998b. Pesticide Program pesticide monitoring database 1997, edited by Food and Drug Administration.

———. 1999. Pesticide Program pesticide monitoring database 1998, edited by Food and Drug Administration.

———. 2000. Pesticide Program pesticide monitoring database 1999, edited by Food and

Drug Administration.
———. 2002a. Pesticide Program pesticide monitoring database 2000, edited by Food and Drug Administration.
———. 2005. U.S. Food and Drug Administration pesticide monitoring database: User's manual, [cited January 27 2005]. Available from http://www.cfsan.fda.gov/~dms/pes02usr.html.
———. 2003. Pesticide Program pesticide monitoring database 2001, edited by Food and Drug Administration.
———. 2004. Pesticide Program pesticide monitoring database 2002, edited by Food and Drug Administration.
———. 2005. Pesticide Program pesticide monitoring database 2003, [cited 27 January 2005]. Available from http://www.cfsan.fda.gov/~download/pes03db.html.
Food and Drug Administration Pesticide Program. 1988. Residues in foods - 1987. Journal of the Association of Official Analytical Chemists 71 (6), 156A-174A.
———. 1995. Residue monitoring 1994. Journal of the Association of Official Analytical Chemists 78 (5), 121A-142A.
———. 2004. Residue monitoring 2002. Washington, D.C.: Food and Drug Administration.
———. 2005. Residue monitoring 2003, [cited October 28 2005]. Available from http://www.cfsan.fda.gov/~acrobat/pes03rep.pdf
———. 2008. Pesticide program residue monitoring 2004-2006, [cited August 15 2008]. Available from http://www.cfsan.fda.gov/cgi-bin/printall.cgi.
Freidberg, S.E. 2004. French beans and food scares: culture and commerce in an anxious age. New York: Oxford University Press.
Galt, R.E. 2006. Political ecology and the pesticide paradox: markets, pesticide use, and human-environment relations in Costa Rican agriculture. Doctoral Dissertation, Department of Geography, University of Wisconsin–Madison, Madison.
———. 2007. Regulatory risk and farmers' caution with pesticides in Costa Rica. Transactions of the Institute of British Geographers 32 (3), 377-394.
———. 2008. Beyond the circle of poison: significant shifts in the global pesticide complex, 1976-2008. Global Environmental Change 18 (4), 786-799.
———. 2009. "It just goes to kill Ticos": national market regulation and the political ecology of farmers' pesticide use in Costa Rica. Journal of Political Ecology 16, 1-33.
———. in review. Food safety of imports: a geographical political ecology of illegal pesticides on fresh vegetable imports, United States, 1996-2006 Annals of the Association of American Geographers.
General Accounting Office. 1979. Better regulation of pesticide exports and pesticide residues in imported food is essential. Washington, D.C.: General Accounting Office.
———. 1986a. Better sampling and enforcement needed on imported food. Washington, D.C.: General Accounting Office.
———. 1986b. Need to enhance FDA's ability to protect the public from illegal residues. Washington, D.C.: General Accounting Office.
———. 1994a. Food safety: changes needed to minimize unsafe chemicals in food. Washington, D.C.: General Accounting Office.
———. 1994b. U.S.-Chilean trade: Pesticide standards and concerns regarding Chilean sanitary rules. Washington, D.C.: General Accounting Office.
Green, M.A., Heumann, M.A., Wehr, H.M., Foster, L.R., Williams, L.P., Jr., Polder, J.A., Morgan, C.L., Wagner, S.L., Wanke, L.A., and Witt, J.M. 1987. An outbreak of

watermelon-borne pesticide toxicity. American Journal of Public Health 77 (11), 1431-1434.
Hirsch, G.H., Mori, B.T., Morgan, G.B., Bennett, P.R., and Williams, B.C. 1988. Report of illnesses caused by aldicarb-contaminated cucumbers. Food Additives and Contaminants 5 (2), 155-160.
Houlihan, J., Wiles, R., Thayer, K., and Gray, S. 2003. Body burden: The pollution in people. Washington, D.C.: Environmental Working Group.
López-García, R. 2003. United States import/export regulations and certification. In Food Safety Handbook, pp. 741-758, Schmidt, R.H. and Rodrick, G.E. (Eds.). Hoboken, New Jersey: John Wiley & Sons.
Mahler, R.L., Holman, H.W., and Carpenter, G.P. 1991. Pesticides and their movement in soil and water. Moscow, Idaho: University of Idaho, College of Agriculture.
National Research Council. 1983. Risk assessment in the federal government: Managing the process. Washington, D.C.: National Academy Press.
———. 1987. Regulating pesticides in food: The Delaney paradox. Washington, D.C.: National Academy Press.
———. 1993. Pesticides in the diets of infants and children. Washington, D.C.: National Academy Press.
Nestle, M. 2003. Safe food: bacteria, biotechnology, and bioterrorism. Berkeley: University of California Press.
Ngowi, A.V.F., Mbise, T.J., Ijani, A.S.M., London, L., and Ajayi, O.C. 2007. Smallholder vegetable farmers in Northern Tanzania: pesticides use practices, perceptions, cost and health effects. Crop Protection 26 (11), 1617-1624.
Patton, M.Q. 2002. Qualitative research and evaluation methods. 3 ed. Thousand Oaks, California: Sage Publications.
Pirog, R., and Larson, A. 2007. Consumer perceptions of the safety, health, and environmental impact of various scales and geographic origin of food supply chains. Ames, Iowa: Leopold Center.
Porter, W.P., Hinsdill, R.D., Fairbrother, A., Olson, L.J., Jaeger, J., Yuill, T., Bisgaard, S., Hunter, W.G., and Nolan, K. 1984. Toxicant-disease-environment interactions associated with suppression of immune system, growth, and reproduction. Science 224 (4652), 1014-1017.
Porter, W.P., Jaeger, J.W., and Carlson, I.H. 1999. Endocrine, immune, and behavioral effects of aldicarb (carbamate), atrazine (triazine) and nitrate (fertilizer) mixtures at groundwater concentrations. Toxicology and Industrial Health 15 (1-2), 133-150.
Putnam, J., and Allshouse, J. 2001. Imports' share of U.S. diet rises in late 1990s. FoodReview 24 (3), 15-22.
Schafer, K.S., Reeves, M., Spitzer, S., and Kegley, S.E. 2004. Chemical trespass: Pesticides in our bodies and corporate accountability. San Francisco: Pesticide Action Network North America.
Shrader-Frechette, K.S. 1985. Risk analysis and scientific method: Methodological and ethical problems with evaluating societal hazards. Boston: D. Reidel Publishing Company.
Snyder, A. 2007. Protein pretense. Scientific American 297 (2), 18-19.
The Lancet. 2007. Food safety reform in the USA. The Lancet 369 (9573), 1575.
Thrupp, L.A., Bergeron, G., and Waters, W.F. 1995. Bittersweet harvests for global supermarkets: challenges in Latin America's agricultural export boom. Washington, D.C.: World Resources Institute.

vom Saal, F.S., Timms, B.G., Montano, M.M., Palanza, P., Thayer, K.A., Nagel, S.C., Dhar, M.D., Ganjam, V.K., Parmigiani, S., and Welshons, W.V. 1997. Prostate enlargement in mice due to fetal exposure to low doses of estradiol or diethylstilbestrol and opposite effects at high doses. Proceedings of the National Academy of Sciences 94, 2056-2061.

Wargo, J. 1998. Our children's toxic legacy: How science and law fail to protect us from pesticides. Second ed. New Haven: Yale University Press.

Weir, D., and Schapiro, M. 1981. Circle of poison: Pesticides and people in a hungry world. San Francisco: Institute for Food and Development Policy.

Whorton, J.C. 1974. Before *Silent Spring*: pesticides and public health in pre-DDT America. Princeton: Princeton University Press.

Endnotes

[i] Contamination by pathogens is also a major consumer concern and a major economic problem, as highlighted by the recent case of FDA's warnings of salmonella in tomatoes, then jalapeño peppers, and the widespread peanut and pistachio recalls due to salmonella contamination in 2009.

[ii] California's Department of Pesticide Regulation (DPR) has a residue testing program that complements that of FDA, and tests about 8,000 samples annually of 150 different commodities (Federighi, 2001: 61). If out-of-state produce is found to have illegal residues, DPR sends the case on the FDA (Federighi, 2001).

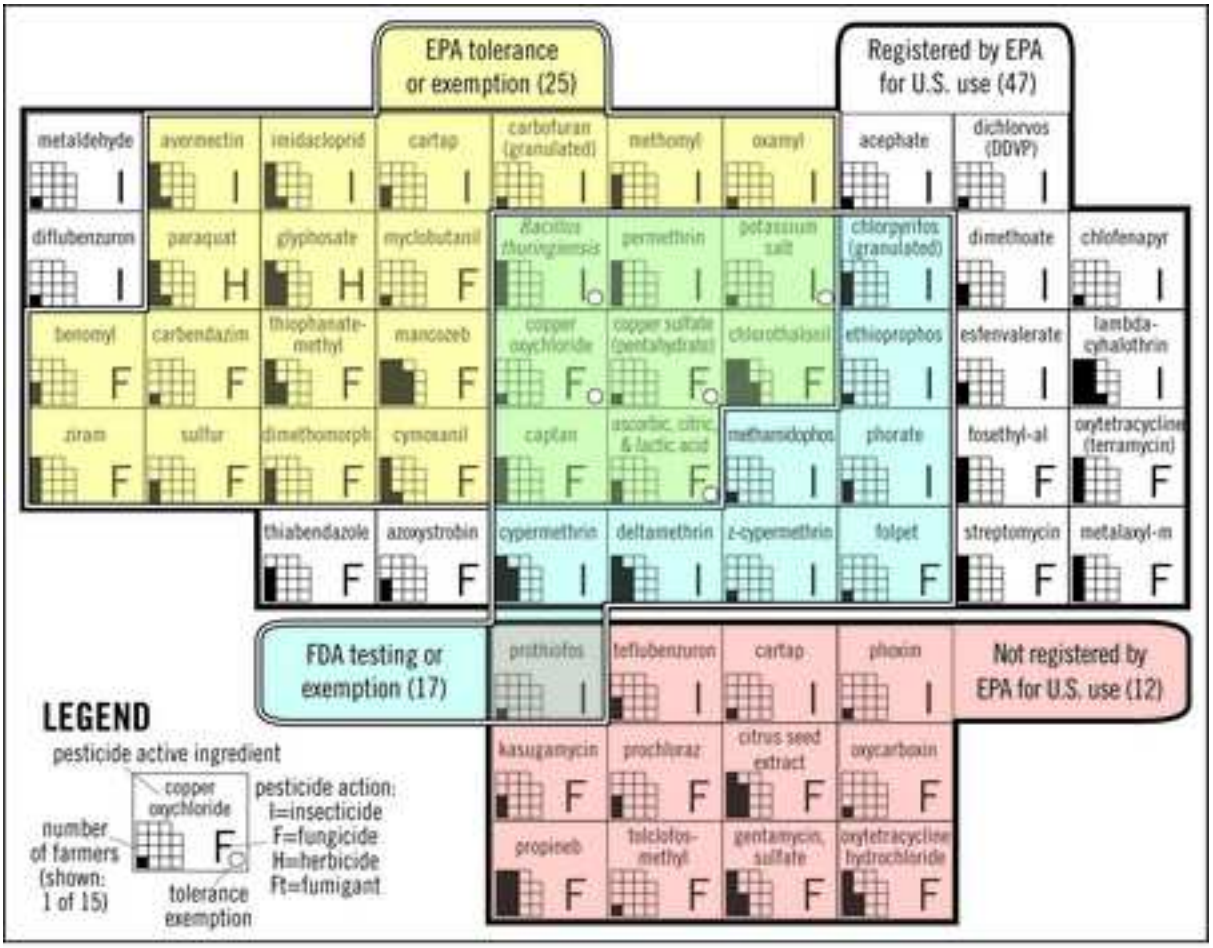
[iii] EPA registers pesticides for use on specific crops or families of crops. For example, methamidophos in the U.S. can be used on potato but not squash. Thus, in the U.S. there is no general registration, but rather always crop-specific registrations for use.

[iv] Details on the pesticide active ingredients featured in Figures 1 and 2 are found in Table 4.

[v] Only vegetables from the minor exporting countries of Russia and Iran are more thoroughly tested.

[vi] FDA divides its data into numerous databases by crop, market, chemical, and other characteristics. These databases include data on country, produce type, pesticide active ingredient tested for, residues detected, and violative (or "adverse") agrochemicals found for

imported vegetables and spices. To fully understand the databases I consulted the user's manual (FDA 2002b) and contacted FDA personnel with questions unanswered by the manual. I used the imported vegetable databases for all available years (databases "IMVE1996" to "IMVE2006," from FDA 1998a, 1998b, 1999, 2000, 2002a, 2003, 2004; 2008), and included only fresh vegetables and botanically-defined fruits-used-as-vegetables, like cucumbers and tomatoes, by removing all processed vegetables and spices.


EPA tolerance or exemption (25)
Registered by EPA for U.S. use (47)
metaldehyde I
avermectin I
imidacloprid I
cartap I
carbofuran (granulated) I
methomyl I
oxamyl I
acephate I
dichlorvos (DDVP) I
diflubenzuron I
paraquat H
glyphosate H
myclobutanil F
Bacillus thuringiensis I
permethrin I
potassium salt I
chlorpyrifos (granulated) I
dimethoate I
chlofenapyr I
benomyl F
carbendazim F
thiophanate-methyl F
mancozeb F
copper oxychloride F
copper sulfate (pentahydrate) F
chlorothalonil F
ethiophrophos I
esfenvalerate I
lambda-cyhalothrin I
ziram F
sulfur F
dimethomorph F
cymoxanil F
captan F
ascorbic, citric & lactic acid F
methamidophos I
phorate I
fosethyl-al F
oxytetracycline (terramycin) F
thiabendazole F
azoxystrobin F
cypermethrin I
deltamethrin I
z-cypermethrin I
folpet F
streptomycin F
metalaxyl-m F
FDA testing or exemption (17)
prothiofos I
teflubenzuron I
cartap I
phoxim I
Not registered by EPA for U.S. use (12)
kasugamycin F
prochloraz F
citrus seed extract F
oxycarboxin F
propineb F
tolclofos-methyl F
gentamycin, sulfate F
oxytetracycline hydrochloride F
LEGEND
pesticide active ingredient
copper oxychloride
F
number of farmers (shown: 1 of 15)
tolerance exemption
pesticide action:
I=insecticide
F=fungicide
H=herbicide
Ft=fumigant

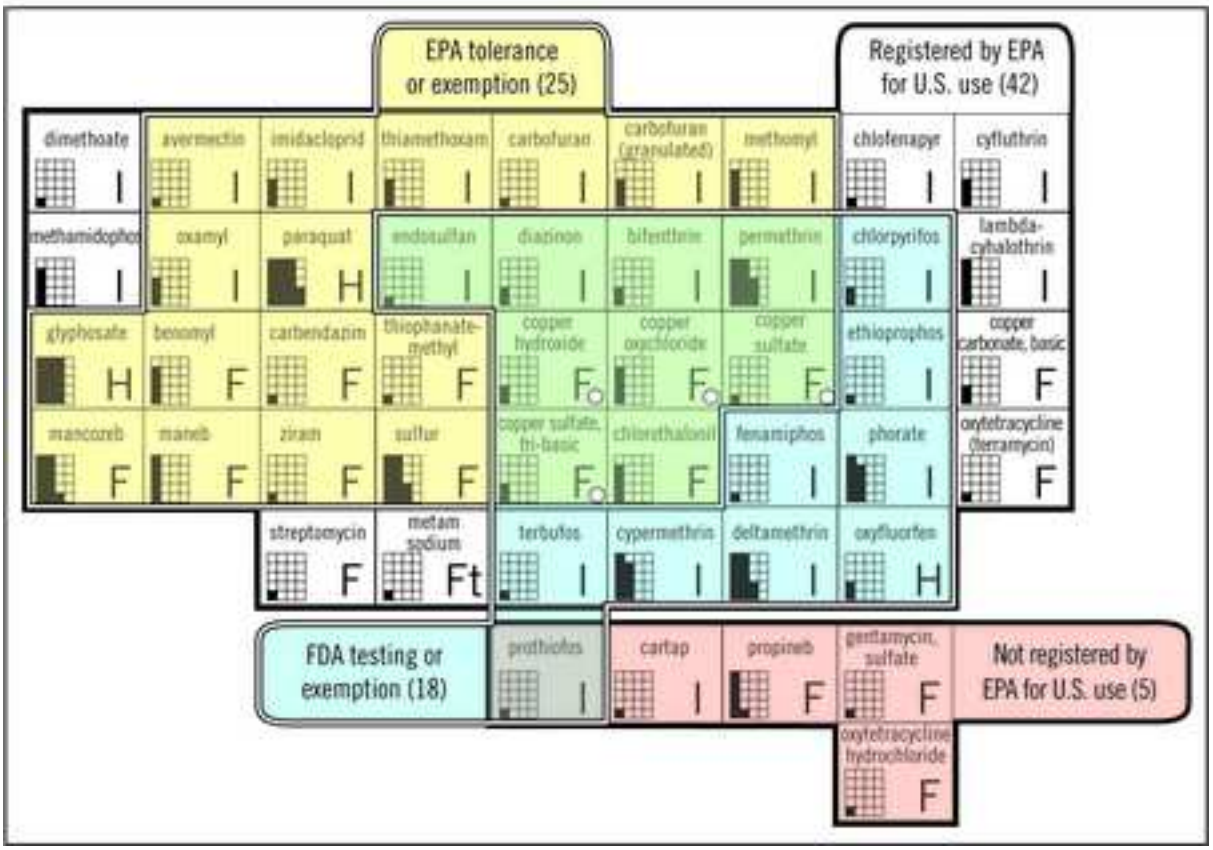

EPA tolerance or exemption (25)
Registered by EPA for U.S. use (42)
dimethoate I
avermectin I
imidacloprid I
thiamethoxam I
carbofuran I
carbofuran (granulated) I
methomyl I
chlofenapyr I
cyfluthrin I
methamidophos I
oxamyl I
paraquat H
endosulfan I
diazinon I
bifenthrin I
permethrin I
chlorpyrifos I
lambda-cyhalothrin I
glyphosate H
benomyl F
carbendazim F
thiophanate-methyl F
copper hydroxide F
copper oxychloride F
copper sulfate F
ethiophrophos I
copper carbonate, basic F
mancozeb F
maneb F
ziram F
sulfur F
copper sulfate, tri-basic F
chlorothalonil F
fenamiphos I
phorate I
oxytetracycline (terramycin) F
streptomycin F
metam sodium Ft
terbufos I
cypermethrin I
deltamethrin I
oxyfluorfen H
FDA testing or exemption (18)
prothiofos I
cartap I
propineb F
gentamycin, sulfate F
Not registered by EPA for U.S. use (5)
oxytetracycline hydrochloride F

Table 1: Vegetable imports into the U.S. and percentage of shipments with adverse residues, top 15 exporting countries

Country	MT (1996-2006)	% adverse residues (1996-2006)
All importing countries	36,221,444	5.2%
U.S.	—	1.6%
Mexico	23,574,040	4.6%
Canada	8,311,604	1.9%
Costa Rica	953,932	4.4%
Peru	800,239	1.9%
Netherlands	499,701	1.1%
Dominican Republic	296,931	7.8%
China	277,847	13.2%
Honduras	264,148	7.5%
Guatemala	207,699	18.3%
Chile	151,054	1.9%
Panama	100,519	5.7%
Israel	92,751	2.2%
Argentina	91,165	2.8%
Spain	90,443	17.5%
Jamaica	83,069	13.6%

Source: FAS 2007; analysis of FDA 1998a-2008

Table 2: Regulatory matrix for pesticide use on export squash, 2003

EPA registered	EPA tolerance	FDA monitoring	n	%
yes	yes/exempt	yes/exempt	8	13.6%
yes	yes/exempt	no	17	28.8%
yes	no	yes	8	13.6%
yes	no	no	14	23.7%
no	no	yes	1	1.7%
no	no	no	11	18.6%
		TOTALS	59	100.0%

Registered for use in U.S. by EPA:	47	79.7%
Not registered for use in U.S. by EPA:	12	20.3%

EPA tolerance/exemption for squash:	25	42.4%
No EPA tolerance/exemption for squash:	34	57.6%

Would be detected by FDA or exempt:	17	28.8%
Would not be detected by FDA:	42	71.2%

Note: The color scheme has the same meaning as in Figures 1 and 2.

Table 3: Regulatory matrix for pesticide use on export chayote, 2003

EPA registered	EPA tolerance	FDA monitoring	n	%
yes	yes/exempt	yes/exempt	9	19.1%
yes	yes/exempt	no	16	34.0%
yes	no	yes	8	17.0%
yes	no	no	9	19.1%
no	no	yes	1	2.1%
no	no	no	4	8.5%
		TOTALS	47	100.0%

Registered for use in U.S. by EPA:	42	89.4%
Not registered for use in U.S. by EPA:	5	10.6%

EPA tolerance/exemption for chayote:	25	53.2%
No EPA tolerance/exemption for chayote:	22	46.8%

Would be detected by FDA or exempt:	18	38.3%
Would not be detected by FDA:	29	61.7%

Note: The color scheme has the same meaning as in Figures 1 and 2.

Table 4: Pesticides used in Costa Rican squash and chayote by mode of action, chemical classes, and detection possibility

Pesticide active ingredient	Chemical class	Would have been detected by 2003 FDA residue tests on Costa Rican squash[a]	Would have been detected by 2003 FDA residue tests on Costa Rican chayote[a]	Would have been detected by any 2003 FDA residue test on imported produce
INSECTICIDES				
metaldehyde	aldehyde	no		yes
diflubenzuron	benzoylurea	no		no
teflubenzuron	benzoylurea	no		no
avermectin	botanical	no	no	no
imidacloprid	chloro-nicotinyl	no	no	no
Bacillus thuringiensis	microbial	NA		NA
spinosad	microbial	no		no
thiamethoxam	neonicotinoid		no	yes
cartap	nereistoxin	no	no	no
carbofuran	n-methyl carbamate		no	yes
carbofuran (granulated)	n-methyl carbamate	no	no	yes
methomyl	n-methyl carbamate	no	no	yes
oxamyl	n-methyl carbamate	no	no	yes
endosulfan	organochlorine		yes	yes
acephate	organophosphate	no		yes
chlorpyrifos	organophosphate		yes	yes
chlorpyrifos (granulated)	organophosphate	yes		yes
diazinon	organophosphate		yes	yes
dichlorvos (DDVP)	organophosphate	no		yes
dimethoate	organophosphate	no	no	yes
ethioprophos (ethoprop)	organophosphate	yes	yes	yes
fenamiphos	organophosphate		yes	yes
methamidophos	organophosphate	yes	no	yes
phorate	organophosphate	yes	yes	yes
phoxim	organophosphate	no		yes
prothiofos	organophosphate	yes	yes	yes
terbufos	organophosphate		yes	yes
chlofenapyr	pyrazole	no	no	yes
bifenthrin	pyrethroid		yes	yes
cyfluthrin	pyrethroid		no	yes
cypermethrin	pyrethroid	yes	yes	yes
deltamethrin	pyrethroid	yes	yes	yes
esfenvalerate	pyrethroid	no		yes
lambda-cyhalothrin	pyrethroid	no	no	yes
permethrin	pyrethroid	yes	yes	yes
z-cypermethrin	pyrethroid	yes		yes
potassium salt, oleic acid	soap	exempt		exempt
HERBICIDES				
paraquat	bipyridylium	no	no	no
oxyfluorfen	diphenyl ether		yes	yes
glyphosate	phosphonoglycin	no	no	no
FUNGICIDES				
kasugamycin	antibiotic	no		no
myclobutanil	azole	no		yes
prochloraz	azole	no		yes
benomyl	benzimidazole	no	no	no
carbendazim	benzimidazole	no	no	no
thiabendazole	benzimidazole	no		yes
thiophanate-methyl	benzimidazole	no	no	no
citrus seed extract	botanical	no		no
oxycarboxin	carboxamide	no		no
mancozeb	dithiocarbamate	no	no	no
maneb	dithiocarbamate		no	no
propineb	dithiocarbamate	no	no	no
ziram	dithiocarbamate	no	no	no
copper carbonate, basic	inorganic		no	no
copper hydroxide	inorganic		exempt	exempt
copper oxychloride	inorganic	exempt	exempt	exempt
copper sulfate	inorganic		exempt	exempt
copper sulfate (pentahydrate)	inorganic	exempt		exempt
copper sulfate, tri-basic	inorganic		exempt	exempt
sulfur	inorganic	no	no	no
dimethomorph	morpholine	no		no
tolclofos-methyl	organophosphate	no		no
azoxystrobin	strobin	no		yes
chlorothalonil	substituted benzene[c]	yes	yes	yes
captan	thiophthalimide	yes		yes
folpet	thiophthalimide	yes		yes
ascorbic, citric, & lactic acid	unclassified	exempt		exempt
cymoxanil	unclassified	no		yes
fosethyl-al	unclassified	no		no
gentamycin, sulfate	unclassified	no	no	no
oxytetracycline (terramycin)	unclassified	no	no	no
oxytetracycline hydrochloride	unclassified	no	no	no
streptomycin	unclassified	no	no	no
metalaxyl-m (mefenoxam)	xylylalanine	no		yes
FUMIGANTS				
metam sodium	dithiocarbamate		no	no

[a] FDA 2005

[b] FDA Pesticide Program 2005

[c] also refered to as a chloronitrile or an organochlorine.

Table 5: Level of FDA testing of imported vegetables by possible residue-food combination, 2003

Country	A Number of vegetable types tested by FDA in 2003	B Possible residue-food combinations, assuming 651 active ingredients (A*651)	C Tested residue-food combinations	D Ratio of tested to possible (C/B)
Costa Rica	**14**	**9,114**	**2,097**	**23.0%**
Guatemala	13	8,463	1,881	22.2%
Poland	15	9,765	2,127	21.8%
Belgium	14	9,114	1,981	21.7%
Dominican Republic	21	13,671	2,876	21.0%
Chile	11	7,161	1,471	20.5%
Spain	12	7,812	1,602	20.5%
Netherlands	22	14,322	2,925	20.4%
Mexico	60	39,060	7,720	19.8%
Egypt	11	7,161	1,415	19.8%
Peru	17	11,067	2,159	19.5%
France	13	8,463	1,622	19.2%
Canada	46	29,946	5,714	19.1%
India	25	16,275	2,969	18.2%
Turkey	13	8,463	1,539	18.2%
Ecuador	13	8,463	1,501	17.7%
China	55	35,805	6,038	16.9%
Italy	12	7,812	1,242	15.9%
Thailand	16	10,416	1,505	14.4%
52 remaining countries	160	104,160	19,002	18.2%
Total	563	366,513	69,386	18.9%

Source: Column A and C from analysis of data from Food and Drug Administration 2005.