Estimating the probability of exceeding the maximum residue limit for Japanese tea using a crop residue model

Yuki Shiga,1 Haruko Yamaguchi2 and Akihiro Tokai1,*

1 Graduate School of Engineering, Osaka University, 2–1 Yamadaoka, Suita, Osaka 565–0871, Japan
2 National Institute of Health and Science, 1–18–1 Kamiyoga, Setagaya, Tokyo 158–0098, Japan

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Introduction

1. Background and purpose

Green tea*1 is an important item in the agricultural product export policy of Japan. To export agricultural products, it is necessary to comply with the export countries’ regulations, e.g., their import controls for radioactive material and the maximum residue limits (MRLs) of pesticides. For tea in particular, the MRLs of pesticides in export countries are often much lower than those in Japan or have not yet been set by the destination country. Therefore, to promote the export of Japanese tea, establishing new prevention systems to avoid exceeding the MRLs of pesticides in export countries has become necessary.

The MRLs of each pesticide are set for each agricultural product or food. Each pesticide has a pesticide use standard*2 to prevent the pesticide usage from exceeding the MRL.3) Farmers avoid exceeding the MRL by following these standards. However, the pesticide use standards may not be sufficient to prevent farmers from exceeding overseas MRLs because these standards are established based on domestic MRLs. Measures to meet the MRLs of export countries include using pesticides whose overseas MRL value is equal to or greater than the domestic MRL value or modifying the pesticide use standard, e.g., the application amount and pre-harvest interval (PHI). From the viewpoints of using a pesticide suitable for cultivating export tea and generating scientific data necessary to reconsider the pesticide use standard, the objectives of this study are to develop a method for estimating the probability of pesticide residue levels in Japanese tea exceeding the MRLs of export countries and to apply this method to three pesticides.

2. Significance of this study

2.1. Development of a model to estimate the pesticide residue levels in green tea

Recent studies by Fantke et al. have focused on estimating the pesticide residue levels in crops. In one of their studies,2) they developed a generic crop residue model for pesticides by combining several crop-specific plant uptake models based on a review of multiple existing studies. They also validated this model for wheat, rice, tomatoes, apples, lettuce, and potatoes.3) The level of fitting of this model was found to be within a 4.5 factor of deviation between modeled and experimental data for all 12 substance–crop combinations.

* To whom correspondence should be addressed.
E-mail: tokai@see.eng.osaka-u.ac.jp
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*1 Most tea traditionally produced in Japan is green tea; therefore, we targeted green tea, and “Japanese tea” is therefore equivalent to green tea. The term “tea” includes black tea and green tea in this study.

*2 The pesticide use standard includes applicable crops, applicable diseases or insects, application amount, use time, and the pre-harvest interval (PHI).
However, a crop residue model for tea has not yet been developed.\(^2\) The unique characteristics of tea include harvesting the leaves from trees, unlike the foliage plants cultivated directly on soil such as lettuce and spinach. Several foliage plant models have already been developed.\(^2\) In tea, the harvested leaves are a subset of the total leaves, and the plucked leaves are processed to become the tea product. Therefore, we developed a crop residue model specifically for green tea.

2.2. Probabilistic estimation of pesticide residue level in crops

Estimations of the pesticide residue level in crops are highly influenced by the half-lives on the plant, which describe the pesticide dissipation rate from the plant. However, half-life values on plants vary according to substance–crop combinations and can also be greatly influenced by environmental conditions, such as temperature.\(^4,5\) The relevant values are currently estimated using the available data; however, a highly valid prediction method has not yet been established for the estimation of the pesticide residue level.\(^5\) For deterministic estimations of the crop residue level, the estimation accuracy changes according to the half-life value on the plant, which is used as a parameter in the model. Therefore, it is necessary to treat the half-lives on plants probabilistically based on their variability and data sufficiency. This study introduces a probabilistic estimation method that takes into account the data uncertainty of this parameter in the crop residue model. This method allows for the estimation of the residue level with the available data and offers more reliable values for decision-making regarding pesticide use in Japanese tea for export.

Materials and Methods

Materials and Methods

1. Estimation of the pesticide residue level in green tea products

1.1. Crop residue model and processing factor

We developed a pesticide residue model for tea, referred to as the Tea crop model, based on dynamicCROP, which is the dynamic plant uptake model developed by Fantke et al.\(^2,3\) A graphical representation and the mass balance equations of the Tea crop model are shown in Fig. 1 and Table 1 (Eqs. (1)–(6)), respectively. Each value of the rate coefficients, \(k\) [1/sec], was calculated using dynamicCROP, where the crop-specific parameters used data specific to tea (Table 2) and the other parameters used the default values.

The pesticide residue mass on the leaf surface, \(m_{\text{leaf surface}}\) [kg], and in the leaf, \(m_{\text{leaf}}\) [kg], were calculated as the fate and transport of pesticides after each spraying by an unsteady numerical analysis of the ordinary differential equations, i.e., the mass balance equations (Eqs. (1)–(6)). The raw leaf residue level, \(C_{\text{leaf}}\) [mg/kg], was calculated by dividing the sum of \(m_{\text{leaf surface}}\) and \(m_{\text{leaf}}\) by the mass of the leaf, \(M_{\text{leaf}}\) [kg]. Initial values of the unsteady analysis were set using distributions of the amounts of pesticide sprayed for each component, i.e., air, soil, and leaf surface. The distribution rates were calculated using Eqs. (7) and (8).

\[fr_{\text{m_{dep,leaf}}} = fr_{\text{m_{applied}}} - (fr_{\text{m_{drift,air}}} + fr_{\text{m_{dep,soil}}})\]  
\[fr_{\text{m_{dep,soil}}} = e^{-ccs \cdot LAI}\]

\[fr_{\text{m_{drift,air}}}: \text{Distribution rate of the air volatilization and wind drift}\ [\text{kg}_{\text{air}}/\text{kg}_{\text{applied}}]\]
\[fr_{\text{m_{dep,soil}}}: \text{Distribution rate of the soil deposition}\ [\text{kg}_{\text{soil}}/\text{kg}_{\text{applied}}]\]
\[ccs: \text{Substance capture coefficient}\ [\text{kg}/(\text{m}^2)/\text{kg}_{\text{air}}]\]

\[LAI: \text{Leaf area index}\ [\text{m}^2/\text{m}^2_{\text{soil}}]\]

\[
d(m_{\text{soil}})/dt = k_{\text{soil}} \cdot m_{\text{soil}} + k_{\text{soil}} \cdot m_{\text{leaf}} - (k_{\text{soil}} + k_{\text{soil}} + k_{\text{soil}} + k_{\text{soil}} + k_{\text{soil}} + k_{\text{soil}}) \cdot m_{\text{soil}}\quad (1)
\]
\[
d(m_{\text{air}})/dt = k_{\text{air}} \cdot m_{\text{air}} + k_{\text{air}} \cdot m_{\text{root}} - (k_{\text{air}} + k_{\text{air}} + k_{\text{air}} + k_{\text{air}} + k_{\text{air}} + k_{\text{air}}) \cdot m_{\text{air}}\quad (2)
\]
\[
d(m_{\text{leaf surface}})/dt = k_{\text{leaf surface}} \cdot m_{\text{leaf surface}} + k_{\text{leaf surface}} \cdot m_{\text{stem}} - (k_{\text{leaf surface}} + k_{\text{leaf surface}} + k_{\text{leaf surface}} + k_{\text{leaf surface}} + k_{\text{leaf surface}} + k_{\text{leaf surface}}) \cdot m_{\text{leaf surface}}\quad (3)
\]
\[
d(m_{\text{leaf}})/dt = k_{\text{leaf}} \cdot m_{\text{leaf}} + k_{\text{leaf}} \cdot m_{\text{stem}} + k_{\text{leaf}} \cdot m_{\text{root}} - (k_{\text{leaf}} + k_{\text{leaf}} + k_{\text{leaf}} + k_{\text{leaf}} + k_{\text{leaf}} + k_{\text{leaf}}) \cdot m_{\text{leaf}}\quad (4)
\]
\[
d(m_{\text{stem}})/dt = k_{\text{stem}} \cdot m_{\text{stem}} - (k_{\text{stem}} + k_{\text{stem}} + k_{\text{stem}} + k_{\text{stem}} + k_{\text{stem}} + k_{\text{stem}}) \cdot m_{\text{stem}}\quad (5)
\]
\[
d(m_{\text{root}})/dt = (k_{\text{root}} + k_{\text{root}} + k_{\text{root}} + k_{\text{root}} + k_{\text{root}} + k_{\text{root}}) \cdot m_{\text{root}} - (k_{\text{root}} + k_{\text{root}} + k_{\text{root}} + k_{\text{root}} + k_{\text{root}} + k_{\text{root}}) \cdot m_{\text{root}}\quad (6)
\]

\(m_i\): mass in compartment \(i\) [mg], \(k\): rate coefficient [1/sec]

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**Fig 1.** Graphical representation of the crop residue model for tea leaves.

**Table 1.** Mass balance equations of Tea crop model
Table 2. Specific parameters of tea in crop residue model

| Parameter name                  | Value | Unit    | Reference |
|--------------------------------|-------|---------|-----------|
| Leaf area index; LAI           | 10.6  | [m²/m²] | Sakai (1987) |
| Fruit area index; FAI          | 0.00  | [m²/m²] | Original setting |
| Time period from plant growth to harvest of plant (life time) | 30.0  | [day]   | Original setting |
| Time period from plant growth to application | 10.0  | [day]   | Original setting |
| (Bio-)mass (fresh weight) of leaf; m_{leaf} | 1.52  | [kg/m²] | Own calculation |
| (Bio-)mass (fresh weight) of stem; m_{stem} | 11.2  | [kg/m²] | Own calculation |
| (Bio-)mass (fresh weight) of root; m_{root} | 6.35  | [kg/m²] | Own calculation |

Notes: a) Calculated value from plucked leaves mass and the ratio of plucked leaves in all tea leaves. b) Calculated value from the mass of leaf (own assumption based on Sakai (1987)).

Descriptions of $k$ and each calculated value of $k$ and its distribution rate can be found in Supplemental Table S1.

In addition, green tea processing, e.g., steaming, rolling, and drying, increases the pesticide residue level because of the condensation of the tea leaves. The green tea residue level, $C_{\text{green tea}}$ [mg/kg], was calculated by multiplying $C_{\text{leaf}}$ by $P_f$, the processing factor (= 3.1).\(^8\)

### 1.2. Pesticide dissipation processes in the plant

Pesticide dissipation processes in the plant, such as chemical and microbial degradation and the dilution effect because of plant growth (growth dilution), directly influence the pesticide residue level in a plant. In dynamiCROP, the degradation half-life on a plant is estimated from the degradation half-life in soil. The degradation half-life on a plant based on the degradation half-life in soil is not the degradation half-life on a specific-crop but rather a general degradation half-life on plants. Therefore, using a general plant half-life as the half-life on tea leaves is not appropriate. In addition, growth dilution is represented by the plant growth curve, a logistic growth function, and applying the growth curve of other plants to tea plants is not appropriate.

In contrast, Fantke et al.\(^5\) performed a regression analysis of the dissipation half-lives from plants using 4442 dissipation half-life data for 183 crops and 333 pesticides and developed a regression model to predict the half-lives according to temperature, substance, and crop type. These dissipation half-life data were quoted or estimated values based on pesticide residue data from literature published in 2012 (collected in Fantke and Juraske\(^4\)). Of these, more than 99% of the literature was peer reviewed.

In this study, the dissipation half-lives from tea leaves, $HL_{\text{tea}}$ [day], were estimated using the regression model developed by Fantke et al.\(^5\) (Eq. (9)). The value of $HL_{\text{tea}}$ comprises every dissipation process in tea, e.g., metabolic degradation, photolysis, volatilization, growth dilution, washout, and mass balance with other compartments. Therefore, when $HL_{\text{tea}}$ is directly used as the half-life on the leaf surface and leaf components in the Tea crop model, there is a risk of the crop residue level being underestimated. Therefore, we assumed that 95% of the pesticide dissipation is influenced by plant degradation and plant growth (Jacobsen et al.\(^9\)) and calculated the dissipation rate coefficient (based on the half-life in soil) by multiplying the value of $k$ estimated from $HL_{\text{tea}}$ with 0.95 (Eq. (10)).

\[
\log H_{\text{subst,i}} = \alpha + \beta_{\text{subst,i}} + \beta_{\text{tea}} + \beta_T \times (T - 20) \quad (9)
\]

\[
k_{\text{deg}} + k_{\text{growth}} = k_{\text{dia}} \times 0.95 = \frac{\ln(2)}{HL_{\text{tea}}} \times 0.95 \quad (10)
\]

In this study, the dissipation half-lives from tea leaves were estimated using the regression model developed by Fantke et al.\(^5\) (Eq. (9)). The value of $HL_{\text{tea}}$ comprises every dissipation process in tea, e.g., metabolic degradation, photolysis, volatilization, growth dilution, washout, and mass balance with other compartments. Therefore, when $HL_{\text{tea}}$ is directly used as the half-life on the leaf surface and leaf components in the Tea crop model, there is a risk of the crop residue level being underestimated. Therefore, we assumed that 95% of the pesticide dissipation is influenced by plant degradation and plant growth (Jacobsen et al.\(^9\)) and calculated the dissipation rate coefficient (based on the half-life in soil) by multiplying the value of $k$ estimated from $HL_{\text{tea}}$ with 0.95 (Eq. (10)).

After specifying the deterministic estimation model for $C_{\text{green tea}}$, we set the probabilistic distributions for $HL_{\text{tea}}$ the most sensitive parameter in the crop residue model, and estimated the frequency distribution of $C_{\text{green tea}}$ using a Monte Carlo simulation. Then, the probability of exceeding the MRL was estimated by calculating the fraction exceeding the MRL value from the $C_{\text{green tea}}$ distribution. To set the probabilistic distributions for $HL_{\text{tea}}$, we set the normal distributions of the estimation errors to the estimated parameters (Eq. (9): $\alpha, \beta_{\text{subst,i}}, \beta_{\text{tea}}$, and $\beta_T$). This setting reflects the variability and uncertainty of the dissipation half-lives from plants and includes all possible variations of the measured pesticide residue values, i.e., variations based on measurement errors, environmental factors, and plant factors.

### 3. Evaluation of the pesticide residue risk in first plucked tea leaves

#### 3.1. Evaluation overview

In Japan, tea leaves are harvested 1–5 times in a year, e.g., the first plucked tea, the second plucked tea, and so on.\(^10\) In general, the pesticide use amounts tend to increase in the latter tea seasons because pest species and pest density increase as the season elapses.\(^10\) Therefore, the advancing tea season increases the risk
of pesticide residue in tea leaves, and the first plucked tea is suitable for exportation.

As a practical application example of our method, we evaluated the pesticide residue risk in the first plucked tea leaves to consider pesticides and their standards of use according to the MRLs of export countries. The selected cultivation area was in Shizuoka, a prefecture in Japan. The target export countries were EU nations and Taiwan, which are important export countries for Japanese tea.

In this study, acslX (developed by the AEgis Technologies Group) was used as the simulation software. The number of trials in the Monte Carlo simulation was kept as 1000 for all simulations.

3.2. Target pesticides
The first plucked tea is harvested early in May; therefore, pest controls are conducted between early and late April as required. 10) The control target insects during this period are Toxoptera aurantii and Apolygus spinolae. 10) Three chemicals were examined in this study: acetamiprid, dinotefuran, and thiamethoxam. 3 These chemicals together can control the two insects mentioned earlier, and the data for the Tea crop model simulation, as well as measured values for model validation, is also available. Table 3 shows data for the physicochemical properties of these three chemicals.

### Results and Discussion

1. **Model validation**
The model was validated by comparing the estimated values with the measured values (see Fig. 2 and Supplemental Table S2). The number of target pesticides was 33, including three pesticides to evaluate the probability of exceeding the MRL. For the measured values, we used the tea crop residue test data from the Pesticide Abstract of each pesticide sampled by the Food and Agricultural Materials Inspection Center (FAMIC). 13) However, the crop residue test data does not include information concerning the temperature during the test. Therefore, the temperature-variation range and estimation-error range of the dissipation half-lives from plants were set accordingly while estimating the distribution of the pesticide residue level. The temperature was varied in a uniform distribution from 15°C to 25°C in accordance with the cultivation periods (from April to October) in Japan. 10)

The measured values of the pesticide residue level vary because of differences in the sample preparation areas and the analysis agencies, even for the same amount of pesticide being sprayed on the crop; e.g., the ratios of maximum and minimum measured values were up to 223 for pyriproxyfen 45 days after spraying. The width of the 90% estimation interval, which is the ratio of the 95th and 5th percentiles, ranged from a high of 4.6×10^6 (chlorfenapyr 21 days after spraying) to a low of 1.4 (flubendiamide 21 days after spraying).

Fig. 3 shows the comparison of estimated values and measured values of the three pesticides to be used for estimating the probability of exceeding the MRL. With regard to the three pesticides, all measured values of dinotefuran were within the 90% estimation intervals on all days. However, some measured values of acetamiprid and thiamethoxam were beyond the 90% estimation intervals.

*Acetamiprid, dinotefuran and thiamethoxam are classified as neonicotinoid insecticides. In 2013, the EU placed a two-year moratorium on the use of neonicotinoid insecticides in an effort to reduce bee losses while the data needed for more accurate characterization of risks from these chemicals are developed. 11*)

### Table 3. Physicochemical property data of target substance

| Name         | MW [g/mol] | VP [Pa] | WS [g/L] | log P ow | Parameters and predicted values for dissipation half-lives in plants | Predicted dissipation half-life (20°C) [day] |
|--------------|------------|--------|----------|----------|----------------------------------------------------------|------------------------------------------|
|              |            |        |          |          | \( \beta_{subst,i} \) |                       | SE | GM | 95% CI |
| Acetamiprid  | 222.7      | 1.0×10^-6 | 4.25     | 0.80     | 0.16 | 0.06 | 5.69 | 5.26–6.15 |
| Thiamethoxam | 291.7      | 6.6×10^-9 | 4.10     | -0.13    | 0.00 | 0.12 | 3.97 | 2.76–5.72 |
| Dinotefuran  | 202.2      | 1.7×10^-6 | 40.0     | -0.55    | 0.41 | 0.19 | 10.1 | 3.82–26.5 |

MW: molecular weight, VP: vapour pressure, WS: water solubility, P ow: n-octanol/water partition coefficient, SE: standard error, GM: geometric mean, CI: confidence interval, \(^a\) Pesticide Handbook ver.2011, \(^b\) Fantke et al. (2014)
the 95th percentile estimated value was up to 2.64 times for both acetamiprid (28 days after spraying) and thiamethoxam (21 days after spraying). We consider these errors to be at acceptable levels based on the variability of the measured values of pesticide residue levels under the same conditions.

2. The probability of exceeding the MRL

Regarding the target pesticides, we calculated the probability of exceeding the MRL, according to the export countries, 7 days, 14 days, 21 days, and 28 days after pesticide spraying. The maximum pesticide application amounts were decided, as the value of application amount, on the basis of the pesticide use standards. The value of the temperature used was the normal value of the average April temperature (13.3°C) in the Kikugawa-Makinohara area, one of the tea cultivation areas in Shizuoka Prefecture. The average temperature data was obtained from the AMeDAS*4 database. Tables 4 and 5 show the pesticide use standards of the target pesticides and the calculation results of the probability of exceeding the MRL, respectively. Supplemental Fig. S1 shows a comparison between the MRL values and the estimated histograms of the pesticide residue level in green tea.

For comparison, we also calculated the probability of exceeding the MRL for minimum pesticide application amounts determined on the basis of pesticide use standards. The pesticide use

Table 4. Standards on the use of target pesticides; for toxoptera aurantii and apolygus spinolae

| Pesticide product | Active ingredient (substance) | Ingredient content | Dilution rate | Application method | PHI | Spraying volume | Maximum used amount of one-time spraying |
|-------------------|-------------------------------|-------------------|---------------|-------------------|-----|-----------------|------------------------------------------|
| MOSPILAN SL       | acetamiprid                   | 18%               | 2000          | spraying          | 14 days | 200∼400[L/10a] | 360[g/ha] |
| ALBARIN (sg)      | dinotefuran                   | 20%               | 2000          | spraying          | 7 days  | 200∼400[L/10a] | 400[g/ha] |
| AKUTARA (sg)      | thiametoxam                   | 10%               | 3000          | spraying          | 7 days  | 200∼400[L/10a] | 133[g/ha] |

sg: water soluble granule, PHI: Pre-Harvest Interval: Interval between last pesticide use and crop harvesting

Table 5. The probability of exceeding MRL in Japan and export countries: EU and Taiwan. Results of minimum pesticide use case in brackets.

| Pesticide | PHI [day] | Japan [%] | MRL [mg/kg] | EU [%] | MRL [mg/kg] | MRL [mg/kg] |
|-----------|-----------|-----------|-------------|--------|-------------|-------------|
| Acetamiprid | 7         | 11.8 (0.00) | 30          | 100 (100) | 0.05       | 100 (100)   | 2 |
|           | 14        | 0.00 (0.00) | 100 (100)   | 99.6 (95.4) | 99.5 (96.8) | 9.1 (61.5)  |
|           | 21        | 0.00 (0.00) | 100 (100)   | 80.0 (35.4) | 64.3 (26.6) | 37.6 (10.2) |
|           | 28        | 0.00 (0.00) | 99.6 (99.2) | 23.3 (3.10) | 23.3 (3.10) | 23.3 (3.10) |
| Dinotefuran | 7         | 92.3 (15.9) | 25          | 100 (100)   | 0.01       | 99.5 (96.8) | 10 |
|           | 14        | 43.4 (5.00) | 100 (100)   | 90.1 (61.5) | 90.1 (61.5) | 90.1 (61.5) |
|           | 21        | 14.6 (0.00) | 99.8 (99.8) | 64.3 (26.6) | 64.3 (26.6) | 64.3 (26.6) |
|           | 28        | 4.90 (0.00) | 99.5 (99.5) | 37.6 (10.2) | 37.6 (10.2) | 37.6 (10.2) |
| Thiamethoxam | 7         | 0.00 (0.00) | 20          | 0.00 (0.00) | 20         | 99.4 (96.1) | 1 |
|           | 14        | 0.00 (0.00) | 0.00 (0.00) | 61.3 (29.0) | 61.3 (29.0) | 61.3 (29.0) |
|           | 21        | 0.00 (0.00) | 0.00 (0.00) | 14.4 (3.30) | 14.4 (3.30) | 14.4 (3.30) |
|           | 28        | 0.00 (0.00) | 0.00 (0.00) | 2.50 (0.30) | 2.50 (0.30) | 2.50 (0.30) |

PHI; Pre-Harvest Interval: Interval between last pesticide use and crop harvesting, MRL; Maximum Residue Limit

*4 Automated Meteorological Data Acquisition System (http://www.jma.go.jp/jp/amedas/)
The excess probability of thiamethoxam was 0.00% at 7 days PHI. For reference, found to be 0.00% under proper pesticide use (at 14 days PHI). The excess probability of acetamiprid for the Japanese MRL was the uniform limit based on MHLW’s regulations.

2.1. The excess probability for Japanese MRLs

The excess probability of acetamiprid for the Japanese MRL was found to be 0.00% under proper pesticide use (at 14 days PHI). The excess probability of dinotefuran was 92.3% at 7 days PHI and that of thiamethoxam was 0.00% at 7 days PHI. For reference, the excess probability of dinotefuran was 15.9% at 7 days PHI in the case of minimum application amounts. Acetamiprid and thiamethoxam were found to conform to the current pesticide use standards. In contrast, the excess probability of dinotefuran was relatively high. From the comparisons of each pesticide's MRL value (Table 5) and the maximum measured value under the proper pesticide use of each pesticide (Supplemental Table S2), the margin of the MRL value and the measured value of dinotefuran are the lowest; dinotefuran has a deviation of 1.3 between the MRL and measured value, acetamiprid 5.5, and thiamethoxam 2.1. In addition, the pesticide use amounts of each measured value are lower than the maximum pesticide use amounts approved by the pesticide use standards, i.e., the evaluation condition on this study. Therefore, the severity of the Japanese MRL value of dinotefuran caused the high excess probability.

The average temperature in April is lowest during the Japanese tea cultivation period. Therefore, it increases the pesticide residue risk despite proper pesticide use because the dissipation half-lives from tea leaves become longer. In reality, more pests are found after the weather becomes warm and the pesticide residue risk decreases with increasing temperature.

2.2. The excess probability for EU MRLs

Except for thiamethoxam, which has the same MRL as in Japan, the results indicated extremely high excess probability, of the order of at least 99.5% (dinotefuran 28 days after spraying), for the MRLs in the EU. This result suggests that the use of these two pesticides, dinotefuran and acetamiprid, would be inappropriate in the first plucked tea exported to EU nations and that the EU MRLs of dinotefuran and acetamiprid are extremely low for current pesticide usage in Japan.

2.3. The excess probability for Taiwan MRLs

Regarding the three target pesticides, the excess probabilities were found to be high under proper pesticide use, of the order of at least 99.4% (thiamethoxam 7 days after spraying), for the MRL in Taiwan. However, with regard to thiamethoxam, a three-week extension of the PHI decreased the excess probability from 99.4% to 2.50%. In addition, the excess probability of acetamiprid with a two-week extension of the PHI decreased the excess probability to 3.10% in the case of minimum spraying.

Conclusions

This study developed a model to estimate the pesticide residue level in green tea products and a framework to analyze the pesticide residue risk for Japanese tea exports. In addition, the pesticide residue risk in the first plucked tea was evaluated for exports to EU nations and Taiwan. The result of estimating the probability of exceeding the MRL for the three target pesticides indicated that, of the pesticides used on the first plucked tea in Japan, two out of three are inappropriate for export to EU nations, and for Taiwan, it is necessary to change the pesticide use standard by restraining the application amount and extending the PHI. This practical application reveals the versatility and limitations of this model. Further effort is required to analyze the level at which the probability is allowed to exceed the MRL.

From the viewpoint of Japanese tea exports, it is necessary to establish a new pest control system to meet overseas MRLs, because the proper use of pesticides according to pesticide use standards that follow domestic pesticide regulations does not necessarily meet overseas MRLs. In addition, Positive Lists are often adopted for the MRL because of no history of use in overseas countries. Therefore, we need to examine the suggestions of Import Tolerances with regard to severe MRLs.

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