Food and Chemical Toxicology 111 (2018) 207–267

Contents lists available at ScienceDirect

Food and Chemical Toxicology

journal homepage: www.elsevier.com/locate/foodchemtox

Refined assessment and perspectives on the cumulative risk resulting from the dietary exposure to pesticide residues in the Danish population

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ARTICLE INFO

Keywords:
Pesticides
Residues
Cumulative risk assessment
Exposure assessment
Consumer risk

ABSTRACT

Relatively few studies are available on realistic cumulative risk assessments for dietary pesticide exposure. Despite available studies showing low risk, public concern remains. A method to estimate realistic residue levels based on information from spraying journals and supervised residue trials was described in a previous publication. The present article proposes a new method to estimate average residue levels in imported foods based on residue monitoring data and knowledge about agronomic practices. The two methods were used in combination to estimate average pesticide residue levels in 47 commodities on the Danish market. The chronic consumer exposure was estimated in six Danish diets. The Hazard Index (HI) method was used to assess consumer risk. Despite the conservative (cautious) risk assessment approach, low HI values where obtained. The HI was 16% for adults and 44% for children, combining the risk of all pesticides in the diet. Conclusion: the present study adds support to the evidence showing that adverse health effects of chronic pesticide residue exposure in the Danish population are very unlikely. The HI for pesticides for a Danish adult was on level with that of alcohol for a person consuming the equivalent of 1 glass of wine every seventh year.

1. Introduction

According to European Union (EU) law (Regulation (EC) No 396/2005 and Regulation (EC) No 1107/2009), once suitable methods are available, the cumulative risks of plant protection products and their residues to consumers have to be taken into account before approving pesticide active substances, authorizing plant protection products or setting of Maximum Residue Levels (MRLs). This is because both on the short and on the long term consumers are exposed to residues of multiple different pesticides (EFSA, 2015; EFSA, 2016). There is public concern that the effects of these residues might add up and jointly pose a risk for the consumer. In practice, however, the dietary risk assessments conducted before approving active substances, authorizing plant protection products or setting MRLs largely focus on the effects of single active substances taken in isolation or on the combined effects of substances present in the same plant protection product. Since an appropriate methodology is not available yet, the cumulative risks that might result from the use of multiple plant protection products are not considered yet. The responsibility for developing such a methodology lies with the European Food Safety Authority (EFSA) which has been spending considerable efforts on this topic since 2006, reviewing existing methodologies (EFSA, 2008; EFSA, 2013a), setting a framework for the use of probabilistic risk assessment approaches (EFSA, 2012; Van der Voet et al., 2016) proposing a mathematical model for the evaluation of combined effects (EFSA, 2013b) and defining groups of pesticides for cumulative risk assessment, the so-called cumulative assessment groups (CAGs) (EFSA, 2014). Besides EFSA and other institutes funded by EU authorities, activities aiming at the implementation of cumulative risk assessments in accordance with the EU legislation on pesticides are also on-going in some Member States (Solecki et al., 2014; Stein et al., 2014).

It is generally admitted that cumulative risk assessments are best performed using a tiered approach in which the assessment is progressively refined based on exposure and/or toxicity considerations, depending on what is more straightforward and more efficient (Meek et al., 2011). While some cumulative risk assessments start by considering residues of all possible types of pesticides, this is usually considered to be over-conservative and it is commonly recognized that refined cumulative risk assessments should focus on groups of pesticides that share similar toxicological properties. While EFSA decided to group compounds that have similar toxicity effects to the same target organ (EFSA, 2013b; EFSA, 2014), there is still debate about whether it

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https://doi.org/10.1016/j.fct.2017.11.020
Received 21 July 2017; Received in revised form 5 October 2017; Accepted 14 November 2017
Available online 16 November 2017

is possible to refine the cumulative risk assessments even further by focusing on even smaller groups. For instance, cumulative risk assessments were performed for groups of pesticides having similar chemical structures, similar modes of action or similar mechanisms of action (Boobis et al., 2008; EFSA, 2009). The reasons for these grouping approaches are varied and besides scientific arguments also include practical considerations (availability of monitoring data) and regulatory aspects (according to current US law cumulative risk assessments needs to be conducted for compounds sharing a common mechanism of action).

In the literature, reports on the cumulative risks resulting from pesticide residues typically focus on a few pesticide groups, e.g. insecticides (Boon et al., 2008; Jensen et al., 2009; Wong et al., 2014) or a specific mode of action, e.g. endocrine (Jensen et al., 2013). There is one report in which the full dietary residue exposure was quantified, accompanied with a cumulative risk assessment, using the hazard index method (Jensen et al., 2015). In quantifying the total mean exposure, previous studies all struggle with some basic methodological problems: 1) they are based on residue data from a limited number of food samples, originating from National Monitoring Programs (NMPs), or taken by researchers 2) the sampling programs usually do not analyze all pesticides possibly present in the foods 3) the quantification limits (LOQ) are usually in the 0.01–0.05 mg/kg range, and residues below this level cannot be quantified. We recently published an alternative method, based on spraying journal data in combination with data from supervised residue trials that can overcome these limitations (Larsson et al., 2017). However, comprehensive accessible spraying journal data is not available from most food producing countries. Therefore, NMP-data is still the main source of data to estimate average residue levels.

The chronic health risk due to the exposure to single pesticide residues may be estimated based on average residue levels and typical diet compositions (Boobis et al., 2008). The cumulative chronic health risk of the exposure to a group of pesticides can be assessed using the Hazard Index (HI) method, which is based on the dose addition model (Boobis et al., 2008; Kortenkamp et al., 2012; Reffstrup et al., 2010; Wilkinson et al., 2000).

The purpose of this study was to improve the model for calculating average residue levels from monitoring data, by incorporating knowledge about agronomic practices in the main exporting countries. The hypothesis was that incorporating knowledge about how many different pesticides are typically used in a crop in a season, would allow for more correct estimation of average residue levels. This would offer improved ways to deal with the majority of measurements, which are those showing no residues above the reporting limit (hereafter referred to as the limit of quantification, LOQ). The purpose was also to take into account the monitoring data from EU, as published by EFSA, to make a risk assessment in the Danish population also including pesticides that are not monitored in the Danish NMP.

The main final purpose of the study was to make a dietary risk assessment for typical diets in the Danish population. By combining the two newly developed methods for exposure assessment, realistic but nevertheless conservative average exposure levels were derived:

Method 1 based on spraying journal data and data from supervised residue trials for foods produced in Denmark (Larsson et al., 2017).

Method 2 based on NMP-data refined with data on number of applied active ingredients in major producing countries, for foods imported to Denmark.

The purpose was also to follow up on the results published by Jensen et al. (2015), that suggested low risk from combined pesticide residue exposure in the Danish population in the period 2004–2011, although there was some level of uncertainty in the results depending on the method used to account for below LOQ (left censored) measurements (Jensen et al., 2015). We wanted to investigate whether their findings were repeatable for the period 2013–2014, and whether our refined methods could estimate average residue levels in a more accurate way.

Table 1
Consumer groups from which consumption data was derived (Petersen et al., 2013). Detailed consumption data can be found in Table 2.

	Adult	Male	Female	Child	Male HFV[a]	Female HFV[a]
Age	15–75	15–75	15–75	4–6	15–75	15–75
Bodyweight (kg)	75.1	83.5	68.2	21.8	84.4	69
Number	1599	721	878	106	118	258

[a] HFV = High Fruit & Vegetables, consuming higher than average amount of fruits and vegetables, e.g. vegetarians.

Finally, the purpose was to place the risk level of chronic pesticide exposure in relation to other dietary exposures. For that purpose we chose to compare with common mycotoxin intakes from grains and maize, and with average caffeine and alcohol intakes in the Danish population.

2. Method

2.1. Dietary data, crop selection and crop areas

Six different diets were used to represent the consumption pattern in the Danish population: Adult, Man, Woman, Child and Male with High fruit & Vegetable consumption (HFV) and Female with HFV consumption (Table 1). The diets were based on consumption data reported by the National Food Institute, Technical University of Denmark (Petersen et al., 2013). The data originated from the Danish National Dietary Survey 2003–2008 (Pedersen et al., 2010). This cross-sectional survey included 2700 participants aged 4–75 years old drawn from the Danish Central Person Register. The participants were characterized as closely representative of the Danish population, and the data has been used in a previous pesticide residue exposure study (Jensen et al., 2015). The consumption of sugar was estimated from the results of the national food survey 2011–2013, published by Danish Technical University (Pedersen et al., 2015). The consumption of beer was estimated from statistics published by Danish Statistics (www.dst.dk) and the Brewers Union (www.bryggerforeningen.dk).

All crops that contributed at least 0.1% of the adult or child diets were included in the analysis. This ensured coverage of more than 99% of the diet by weight (Table 2). No products of animal origin were included, since no pesticide residues have been detected in the 477 animal product samples taken in Denmark in 2013 and 2014 (Fødevarestyrelsen, 2014; Fødevarestyrelsen, 2015). Coffee was not included either since pesticide residues are largely eliminated in the roasting process (Mekonen et al., 2015).

The total crop areas cultivated in 2013 and 2014 for Danish produced crops where obtained from Danish Statistics web database (www.dst.dk, see Table 2).

2.2. Method 1: estimation of residues from spraying journal and EU residue trial data, foods produced in Denmark

Method 1 has been completely described and validated in a previous publication (Larsson et al., 2017).

Method 1 was applied unchanged in the present report, with the exception of it being adjusted for the fraction of consumption expected to be of domestic production origin, as described below:

The average residue resulting from each pesticide treatment was calculated according to equation (1):

$$Estimated\ Residue\left(\frac{mg}{kg}\right) = STMR\left(\frac{mg}{kg}\right) \times Dosage\ Factor \times Area\ Factor \times DF \quad (1)$$

STMR = Supervised trial median residue level, as measured during