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Some crucial elements of the uncertainty of the consumption data used for the estimation of pesticide residue exposure

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1. Summary

Before issuing permits to use pesticides, it has to be ensured, that pesticide residues remaining in the treated products are not harmful to the human body and to the environment. The calculated value of consumer pesticide residue exposure is influenced by several uncertainty factors. In our article, the parameters influencing the estimation of the amount of food consumed, the use of the picture book showing standardised food portions, the determination of the composition of the reported foods when assessing food consumption, and issues related to the body weight measurement of the person interviewed are addressed. The analysis was based on the daily consumer exposure calculated using the standard food portions selected on the basis of the approximation obtained during the interviews, as well as accurately known food ingredients and their quantities, and bifenthrin residues. Results show, that in the hands of experts with the necessary dietary knowledge and experience, exposure data obtained with the help of the NutriComp software and database, used in the dietary survey (EU-MENU) currently under way in Hungary, do not differ significantly from daily exposure values calculated by taking into consideration the known composition and quantities of the foods consumed. Daily deviations are expected to offset each other when calculating average consumption figures. It can therefore be assumed, that the data obtained during the survey provide reliable information for the calculation of the average daily exposure of Hungarian consumers.

2. Introduction

It is inevitable to use pesticides in order to produce crops of sufficient quality and quantity to feed the ever increasing population of our planet. By the year 2050, it is estimated that 9.1 billion people will have to be provided for. The majority of pesticides are toxic compounds. To eliminate or minimize their undesirable side effects, their use is limited to specific application conditions, determined by extensive preliminary investigations. An important part of the assessment of experimental results prior to issuing permits is the determination of the chronic and acute consumer pesticide residue exposure, carried out at the international and national levels, with the exception of the USA, using a deterministic method. Calculation of the estimated daily intake (EDI, the amount of pesticide residue consumed daily, in mg/kg body weight) is very simple:

$$EDI=\Sigma(STMR_i \times F_i) \quad (1)$$

where $STMR_i$ is the median value of the pesticide residues in the i^{th} food (supervised trials median residues)

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[mg/kg], and F_i is the average daily consumption [kg], including „non -consumers". In the case of processed products, the median value of the pesticide residue measured in the processed product is indicated (STMR-P). Intakes calculated from available international (IEDI) or national (NEDI) data are compared to the acceptable daily intake (ADI; mg/kg body weight/day) value of the pesticide.

Calculation of the short-term intake, the pesticide residue ingested with food consumed within 24 hours, is carried out similarly in the simplest case:

$$IESTI = \frac{LP \times (HRorHR\text{-}P)}{tt} \quad (2)$$

where LP (large portion) is the 97.5 percentile of the quantity of a given food consumed daily by consumers, HR (highest residue) is the highest pesticide residue concentration measured in the experiments, and tt [kg] is the body weight. A detailed description of the formulas to be used in the different cases can be found in the FAO manual, **[1]**, and in the description of the Primo model used in the European Union **[2]**. Acute intake is calculated for the pesticide residue - food combination resulting in the highest intake, assuming that if a person consumes a large quantity of a particular food, then only small amounts of other foods can be consumed, because of physical limitations.

The actual value of both members of the simple formula and, consequently, the calculated consumer exposure is influenced by a number of uncertainty factors, such as, in the case of the STMR and HR, the number of experiments with a given pesticide (on the edible fraction and the whole crop), the ratio of the pesticide residues, usually measured by specialised laboratories, sampling, pesticide residue determination, or the conditions of industrial processing procedures or kitchen operations.

The quantity and composition of the food consumed are estimated by various methods. The accuracy and the variability of the result obtained are also influenced by several factors, and there are a number of scientific publications on the topic. A review of the literature on the theoretical basis of risk assessment and the sources of its uncertainty, as well as the results of our own studies, using specific consumption and pesticide residue concentration data have been published in three articles **[3], [4], [5].**

The amount of contaminants, including pesticide residues, ingested with foods can be estimated if, in addition to the contamination of the foods, food consumption (the types, ingredients and quantities of the foods consumed) can be characterized as well. In the present article, the effect of factors influencing the variability (uncertainty) of data obtained during food consumption surveys based on 2×24 hour recall are analyzed.

3. The practice of 2×24 hour recall consumption survey

In the 24-hour recall method, the quantity and quality of the food and drinks consumed during the previous day by the person surveyed, as well as the time of consumption are asked and recorded, preferably by using a suitable computer program, such as the NutriComp **[6], [7]**, used in the EU MENU survey currently under way in Hungary, or the EPIC-SOFT **[8], [9]** used in several European countries. The survey can be conducted through a personal interview or via telephone. Recalling of the food consumed depends on the respondent's memory. Accurate estimation of the portions consumed can be facilitated by a skilled interviewer and by the application of a picture book **[10]**.

The picture book generally shows the photographs of different portions (4-6), in increasing order, of typical foods, consumed most often, taken under standardized conditions (***Figure 1***). Taking into consideration that the size of the picture book and the number of food items that can be presented are limited, a single series of photographs can be used for the estimation of the portions of several foods of similar appearance.

Since different foods can have different bulk densities, depending on the raw material or the method of preparation, the weights of foods with similar apparent quantities may be different. The amount of food consumed is compared to the photograph in the picture book by the persons participating in the survey. Therefore, for the most accurate portion estimation, it is necessary to know and to take into account the exact weights of the foods represented in the pictures by proportionally increasing portions.

4. Determining the weight equivalent of foods

The method developed for the determination of weight equivalents is presented through the example of "identical" versions of five foods in the EPC-SOFT (ES) picture book, prepared from Hungarian raw materials, according to a Hungarian recipe. Taking a „seemingly identical portion" is burdened by an individual perception[1] error.

In the experiment, five foods were prepared from raw materials available for the domestic catering industry. The amounts of freshly prepared foods, seemingly identical to the preselected portions (w_k [g]) shown in the ES picture book, were taken by 21 participants onto pre-weighed plates, and the weight of the portion taken was measured to the nearest 0.1 g (w_h, [g]). The conversion factor was calculated from the aver-

[1] Perception is the ability of the person performing portion estimation to estimate accurately and take the portion in the photograph.

age weight obtained by repeated portion estimation and weighing ($_h$), and the food weight assigned to the portion in the ES photograph (w_k):

$$\rho=\overline{W}_h/W_k \quad (3)$$

The actual weight of the portions estimated on the basis of the picture book:

$$w_f=w_k\times\rho \quad (4)$$

Table 1 contains the original weight of the ES portions for each food, the weight of the portions taken onto plates and estimated to be of identical amount, and the conversion factor calculated using equation (3).

The relative standard deviation of the repeated measurements was virtually close to the 30% considered the acceptance criterion when validating the picture book **[3]**. For the foods in our experiment, the weight of cooked potatoes and spaghetti differed from the weight given in the picture book with a probability of 95%. In the case of spinach stew and roast meat slices, the difference was not significant.

5. Estimation of the composition of dishes reported during the food consumption survey

In order to estimate the amount of contaminants entering the human body with food, one has to know the characteristics of food consumption, i.e., what kind of foods have been consumed in what quantities, what raw materials the dishes have been made from, and what the concentrations of the contaminants in question in the foods consumed have been. In the majority of cases, pesticide residues are detected in raw agricultural commodities (RAC), for example, in raw, uncleaned fruits, and so it is essential that ready-made foods and compound foods are broken down into raw material components in consumer surveys.

There are countless recipes on the internet from cookbooks or individual recipe collections. There are many recipe variations for the preparation of the same dish. The method of preparation of products with the same name, or the ratio of the ingredients may differ significantly **[5]**. For experienced food makers, deviation from the given recipe may exceed 30%. This is so, because they usually do not measure the weight of the individual components, but mix them "by feel" until reaching the required consistency.

In consumer surveys at the individual level, some consumers do not have the knowledge that would allow for such detailed listing of the raw materials of the foods consumed. More accurate characterization of the foods consumed, or the amounts consumed can be facilitated by control question by the interviewers. This is why it is important for the person carrying out the survey to have dietetic knowledge and sufficient practice, which will greatly increase the reliability of the results. Interviewers should also be well informed about the foods present on the market, they should know the approximate preparation methods of the dishes, and should possess basic knowledge about kitchen technology.

To illustrate the uncertainty of the consumption survey, based on information obtained from a 2x24-hour recall survey, the ingredients of standard dishes in the NutriComp database were compared to the ingredients of the same dishes prepared according to the recipes used in our own homes. The person in the survey was asked in advance to measure and record the amounts of the foods consumed, but not to use his notes during the interview, only answer the questions of the interviewer relying on his memory.

During the preparation of the dishes, the weight of each ingredient was measured to the nearest 0.1 g, the total weight of the raw materials used was recorded, as well as the weight of the dish prepared, ready to be consumed. The weight of freshly-consumed or quick-frozen fruits was taken into account in the first case as the approximate size (small, medium) estimated by the consumer. It should be noted that the exact weights were not available when determining NutriComp ingredients. Actual and estimated weights, based on average data, of the dishes consumed are summarized in ***Table 2***. Measured component weights for a single portion and ingredients from the NutriComp database are shown in ***Table 3***.

The recipe database of NutriComp contains the domestic dietary habits also characterized by the work of Venesz and Túrós **[11]**, as well as the material contents of the most important dishes of international "cuisines", or their versions "domesticated" by dietitians. Additional auxiliary questions (for example: "what fat content milk do you usually consume") help the interviewer to estimate the composition of the specific food consumed as accurately as possible. In the absence of additional data, the standard recipes of the database are used **[11]**.

There are many recipes to choose from when preparing a certain dish. In different recipes for a certain dish, the types and ratio of the raw materials may differ, which can be characterized by the coefficient of variation (CV_{cu}). Standard deviations (SDd_{cu}) of the components (i) of dishes prepared by us, due to recipe variability, were calculated on the basis of 5 recipes randomly selected from the internet, taking into account a ±30% expected deviation **[3]**, assuming an equal probability of use of the available recipes:

$$SD_{cu}=\frac{1{,}3\times maxP_i-0{,}7\times minP_i}{2\times\sqrt{3}} \quad (5)$$

From the standard deviation (SD_{cu}) and the median ($\tilde{m}_{Pi}$) of the ratio of the raw materials (P_i) the coefficient of variation related to recipe variability (Cv_{cu}) can be calculated:

$$CV_{cu} = \frac{SD_{cui}}{\bar{m}_{Pi}} \quad (6)$$

The median of the ratios represents the robust estimate of the average value, while the relative standard deviation represents the relative uncertainty due to the different ratios of the raw materials. The material contents of our own and NutriComp recipes (indicating the raw materials relevant from the bifenthrin point of view) and calculated CV_{Cu} values are listed in ***Table 3***. The coefficients of variation (CV_{cu}) of recipe variants for the chosen dishes, based on randomly selected recipes, were in the range of 0.22 to 1.44.

The ratios of the individual components to the total amount of raw material used shows a significant variability. Compared to the "own recipe", ingredients of the NutriComp standard recipe, where identical ingredients are taken into account, fall within the ±95% range.

6. Bifenthrin exposure of the consumer participating in the 2×24-hour survey

Taking into consideration the composition of the foods consumed and the analytical results of different pesticide residues available in the different components, the pesticide bifenthrin was selected for exposure calculation. Bifenthrin is a non-systemic pyrethroid insecticidal and fungicidal, fat-soluble compound with very low water-solubility. It is stable under standard hydrolysis conditions, but decomposes above 168°C. A relatively low ADI value (0-0.01 mg/kg body weight) and an ARfD (Acut Reference Dose) value of 0.01 mg/kg body weight was established by the FAO/WHO JMPR (Joint Meeting on Pesticide Residues), and the conclusion was reached that, for dietary intake calculations, only bifenthrin with an unchanged structure should be taken into account (FAO 2011; JMPR 2010) **[12]**.

Bifenthrin exposure was calculated from the median values of the pesticide residues obtained from the supervised trials selected by JMPR experts, taking into account the relevant processing factors. When calculating the combined uncertainty of the results obtained, uncertainties due to the variability of the processing conditions, the sampling, the analytical tests and the recipes were taken into account. Calculations were carried out, using identical parameters, with actual consumption data of the dishes prepared according to our own recipes, and with quantities estimated on the basis of the standard recipe of NutriComp. The calculation method was the same as the procedure described in the publication of Szenczi-Cseh and Ambrus **[5]**. Results are shown in ***Table 4***.

Daily intakes calculated on the basis of actual and estimated consumption data differ from each other by less than 30%, which is not significant, taking into account the relative 28 to 30% uncertainty of the calculated exposure.

The degrees of uncertainty of the factors influencing the calculated dietary exposure vary, they depend on the ingredients of the food consumed, the concentration of pesticide residues and the preparation method of the food, therefore, typical values cannot be given. The factors determining the total known relative uncertainty of the calculated daily dietary pesticide residue exposure are:

- primarily the variability of food recipes (CV_{cu}=22.3-144%),
- the error of the estimated weight of the food consumed (CV_{di}=29-98%),
- the number of pesticide experiments used for STMR determination (CV_{STMR}=8-90%),
- the error of sampling (CV_S; fresh fruits: 20-30%, processed solid products: ~10%; sub-sampling of large products: 7-21%),
- variability due to the processing of raw crops (CV_{Pf}=~30-50%, in an optimal case),
- uncertainty of analytical tests derived from monitoring programs (<25%),
- uncertainty of analytical results of pesticide experiments (≤15%).

The calculated daily intake levels of bifenthrin residues for a person with a body weight of 60 kg are 0.00257 mg/kg body weight and 0.00281 mg/kg body weight for the 1st and 2nd day, respectively. Assuming that the measurement was carried out using an ordinary bathroom scale (≤±0.5 kg accuracy), the standard deviation of body weight measurement is:

SD=0.5/1.96=0.2551 kg

and the coefficient of variation is:

CV_w=0.2551/60=0.004252

The combined coefficient of variation of the estimated daily pesticide residue exposure for the first day (CV_{EDI}) can be calculated using the following equation:

$$CV_{EDI} = (0{,}300417^2 + 0{,}004252^2)^{1/2} = 0{,}3004473 \quad (7)$$

The combined coefficient of variation of the estimated daily pesticide residue exposure for the second day is 0.28226. In case the measurement is carried out using a professional scales (±0.1 kg accuracy), common in consumption surveys, the CV_{EDI} value for the first day is 0.300418, and the CV_{EDI} value for the second day is 0.282195. The relative difference of the deviations is 0.010% and 0.011%, respectively. It shows that, by using a professional scales, the estimated uncertainty of the daily dietary exposure would practically remain unchanged, therefore, their use is not necessary.

7. Conclusions, recommendations

There was no significant difference between consumer exposures calculated from actual consumption data of two days and from standard NutriComp recipes selected on the basis of approximate data given by the person participating in the survey. The deviation was positive for the first day and negative for the second day. Of course, general conclusions cannot be drawn from the exposure estimations carried out on the basis of foods consumed over two days. However, because of the different signs of the differences between the results, it can be assumed that in the case of the average consumption data used for the EDI calculation, differences due to the variability of the recipes offset each other, therefore the results obtained by interviewers skilled in the methodology of consumer surveys and having appropriate background information, using the standard NutriComp database, can serve as a reliable basis for the estimation of expected consumer exposure.

Results support the fact that bulk density differences have to be taken into account even in the case of portion estimation of foods that are identical to the foods in the photographs of the picture book. Determination of the actual weight of portions estimated with the help of the international picture book used in national food consumption surveys can be carried out more accurately when knowing the mass equivalents.

The significant variability of the weight of foods with seemingly identical volumes indicates that relatively reliable results during mass equivalent estimation can only be expected if at least 20, but preferably more than 30 people are involved. Gaining more detailed knowledge of this specific area requires further research.

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