Chapter 28
The French Total Diet Studies

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Introduction

French national authorities carry the responsibility for checking that chemical substances are not present in food in quantities that may adversely affect public health. While food control and monitoring programs are essential for the surveillance of production practices and imports, the government has also to assess the public health and consumer risks associated with the presence in food of additives, pesticide residues, environmental contaminants, and other substances of possible concern.

The French Agency for Food, Environmental and Occupational Health and Safety (ANSES) is a public, independent risk assessment agency contributing, through surveillance, monitoring, alerts, research, and investigations, to the protection and improvement of human health and safety in the fields of environment, occupational health, food safety, animal health and welfare, and plant health. While biological and chemical safety issues are major challenges, ANSES's jurisdiction also covers the risks relative to human nutrition and foods of animal origin. To evaluate health and nutritional risks via collective expert assessments, the ANSES conducts and coordinates national studies, like the total diet study (TDS) to assess the occurrence of chemicals of interest in foods as consumed in order to perform accurate dietary exposure estimates to those substances for different population groups. A TDS is a key tool for French population exposure monitoring and is based on a standardized methodology recommended by the World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO) and the European Food Safety Authority (EFSA) [1], and is the method used in many

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countries to evaluate food safety risks. The use of the TDS also facilitates international comparisons of consumer exposures. Conducted in 2000–2001 by the French National Institute for Agronomical Research in collaboration with ANSES (previously AFSSA), the first French TDS assessed population exposures to 30 substances, including mycotoxins, trace elements and minerals. Five years later, ANSES began implementing a new study over the 2006–2010 period, extended to more than 400 substances requiring updated or in-depth knowledge, such as plant protection product residues, environmental contaminants, emerging hazards, natural toxins, additives, trace elements and minerals. A TDS for infants was launched in 2010 to provide dietary exposure of children less than 3 years of age to more than 200 substances (see below).

The advantage of a TDS analyzing foods "as consumed" is that it provides a more realistic "background" concentrations of chemicals in foods and the actual diet and "background" dietary exposure data than other more conservative methods that are generally used to prioritize substances for monitoring, like theoretical exposure indicators. TDS results help direct health protection measures and guide French authorities in charge of food safety risk management. This exposure evaluation is useful when drafting and making decisions on the regulation of chemical products and the safety of food products consumed by the nation's population. It is necessary that member states of the World Trade Organization base their consumer protection regulations on sound scientific assessment of the risks using this type of methodology. And last but not least, TDSs represent the most comprehensive and accurate tool for risk assessors to follow and evaluate trends in "background" levels in food and exposure in order to better protect and inform consumers.

A TDS Based on the Individual Food Item Approach

Among the key points of TDS methodology and design, the choice in food grouping remains of high interest. Two main trends are described in the international literature: the food group composite approach and the individual food approach [2]. The French TDSs are based on the individual food item approach rather than on the food group sampling approach [3–5]. Taking into account cost constraints, the second French TDS focused on 212 different individual core foods representing about 20,000 products and covering approximately 90 % of the total diets of adult and children. Choices were made not to sample foods that were consumed in very small amounts and that were not significant contributors to the exposure of contaminants of interest.

Moreover, each sample is a composite sample. In the French TDSs, each sample is a composite sample of subsamples of equal weight of the same food (5 in the first TDS, 15 in the second one and 12 in the infant TDS). This increase in the number of subsamples was done to ensure a better representativeness of the market shares of the products and the purchasing habits of the population, and to allow consideration of the interindividual variability of composition or contamination between

subsamples without losing too much information. The ideal number of subsamples was assessed considering a maximum confidence interval of 15–25 % for the mean composition or contamination results, taking into account a standard deviation of 30–50 % for each subsample, based on usual "background" data, including data from the first French TDS.

A Combination of Different Data Sources to Design the Sampling Plan

The French TDS sampling plans use three main data sources to select the core foods and to design the sample composition. The first source is the updated national individual food consumption survey conducted by the ANSES every 5 years. The most current is the second "Enquête Individuelle Nationale de Consommation Alimentaire" (INCA2 survey), which is the main information source on consumption [6–8]. The latest 11-month survey was conducted by ANSES in 2006–2007 with two independent random samples of 3–17 year-old children ($n = 1{,}444$) and 18–79 year-old adults ($n = 1{,}918$), representative of the French population through stratification. Population consumption data (kind of foods, quantities, as well as consumption frequencies) were collected by a 7-day food record diary (consecutive days), including other questionnaires on anthropometrical and socioeconomic factors. The food record included questions on consumption details and food preparation. For instance, subjects were asked if they consume raw meat, such as steak tartar and carpaccio, and for cooked meat, they were asked for the cooking degree (rare, medium, etc.) and the use of added fat. This kind of information is essential to prepare the samples "as consumed" by the population and to be representative of consumption habits. Other types of information were collected, including which brands and purchasing locations. For the infant TDS, consumption data used were completed by an online survey targeting about 400 parents who were asked for details on the preparation of foods for their children (cooking methods, times, utensil material and uses, etc.).

When data were insufficient to build a representative sample of a consumed food, another source of information was used in the TDS sampling plan, namely the SECODIP-TNS purchase panel. This is a panel of 17,150 French households, which are followed every year and provide supply habit data and market share information for more than 400 different product groups (unpublished data). This panel also provides details on the purchased food products, such as origin or species for fruits or vegetables, conditioning and packaging for commercially prepared products, flavoring if any, etc. All this information can be merged and included in the sampling plan in order to be as representative as possible of the consumption of the population, maintain the variability of dietary habits, and be as close as possible to the real French food supply diet.

A third information source can be used for homemade foods. Part of the French TDS samples includes commercial foods, bought ready-to-eat foods or

ready-to-cook foods. For some products, the final preparation methodology only involved following the packaging instructions. But some samples are partly composed of homemade foods, such as cakes, pies, or mixed dishes. For these types of foods, it is necessary to provide recipes taking into account home-cooking habits. Some recipes used for the nutritional evaluation conducted by the ANSES can be used, i.e. validated recipes from cookbooks, some being recipes from the INCA2 survey. To be concordant with other national activities involving risk assessment and nutritional evaluations, all the recipes have to be taken from the national food survey. More than 600 recipes had been updated or created by the Agency taking into account European recommendations, and have to be concordant with the composition of foods provided by the national food nutrient database [9] on one hand, and to be used for contaminant risk assessment on the other hand. As TDS is included in the general hazard and risk assessment area, the concordance of the methodologies and tools used in this field have to be improved and the use of this new database should be one of the key tools of future French TDSs in conjunction with the use of the updated third national individual food consumption survey (INCA3 survey) and also the updated purchase panel of French households providing food supply habits data and market shares.

National and Regional Considerations

The sampling of the second French TDS (2006–2010) was performed in eight large regions for two reasons. The first reason was the need to tie in with the national consumption survey, which is used to build the sampling plan and which provides the consumption data used for the exposure evaluation. In this survey, the subject samples, adults as well as children, were made representative of the French population through stratification, notably by including regions of residence, which were comprised of eight large regions, including areas [6–8].

The second reason was the need to take into account the specificity of each region in France. France is known for the diversity of its foods and diets and there are important regional variations in dietary habits. Dietary habits are region-dependent and highlight the intermediate geographical position of France in Europe, between Northern and Mediterranean diets [6]. Northern French inhabitants eat more butter, margarine, potatoes, and pastries than southern inhabitants, who eat more fruit and vegetables. Some food consumption patterns are typical of the identified region and have to be taken into account in the French TDS food sampling. Consequently the sampling plan was tailored for each region. If some foods are consumed in enough regions, they were included in the sampling lists as core foods.

Seasonal variation in consumption also appeared in the national consumption survey, as well as in the data from household supply. These trends were also taken into account in the sampling strategy with two sampling periods were conducted for each region. Each period lasted 3 months at the most and the starting dates of the

two periods were spaced at least 6 months apart. This option allowed taking into account seasonal purchases, such as certain fruit or vegetables, as well as meat cuts, and covered potential variability in the contamination and composition levels between seasons, for instance in mycotoxin or pesticide residue contamination. For each region, samples were therefore collected in summer and winter, or in autumn and springtime.

Another specificity, ethnic foods, may also be integrated in future TDSs as already occurs in Canada. Ethnic foods are not yet included in the sampling plan for two reasons. The first is that in the national food survey, ethnic foods are not well covered by the individual sampling because of a low yearly consumption, despite a large population of foreign origins. Most ethnic foods are still considered to be occasional foods and are not available everywhere, except in the capital and in big cities. The second reason is that the consumption survey did not include categories, such as 'halal' or 'kosher', if those interviewed did not raise it themselves. It was only recorded if the interviewed person chose its foods mainly or partly according to production methods or followed a particular regime for "personal or religious reasons". However, these were without any details on the precise religious or ethnic preferences.

Using the French TDS Results and Methodology to Perform Risk Assessment

The results of the French TDS are used in food safety risk assessment. At a local level, they are used by the interregional groups of epidemiologists to perform risk assessments when they confront by a problem, such as local pollution. The TDS results can also be used to evaluate the total exposure to a contaminant and provide background exposures through food to augment environmental and occupational exposure assessments.

At the national level, ANSES uses the TDS results to conduct population-based risk assessments and to help risk managers implement or update European or international/Codex food standards and improve their monitoring and sampling of chemicals in the food supply. In a first round, from the risk assessment performed by scientific experts committees of ANSES, main conclusions and formulated recommendations addressed particularly risk management challenges or research requirements. Out of the overall analyzed substances and on the basis of available knowledge, it was concluded that risk could not be excluded for certain specific consumer groups in the general population to 13 substances or substance groups (lead, cadmium, inorganic arsenic, aluminum, methylmercury, sodium, dioxins and PCBs, bisphenol A, deoxynivalenol and its derivatives, acrylamide, sulfites, and dimethoate) [10, 11]. In a second round, and following request mandates received from risk managers on specific safety situations, updated TDS data are often used by the ANSES scientific panels to take into account general "background" exposure

in risk evaluation and before proposing recommendations to risk managers to better protect consumers. For instance, the results concerning the arsenic exposure have been used in 2009 in an ANSES scientific opinion on the recommended maximum inorganic arsenic content of *Laminaria* and consumption of these seaweeds in light of their high iodine content [12]. It was necessary to assess the population's "background" exposure to inorganic arsenic to allow assessment of the risk associated with supplementary exposure from the consumption of seaweeds. At the national level, contamination data on inorganic arsenic were insufficient to perform the calculations. Data on inorganic arsenic from monitoring plans mainly concern seafood and the rest of the diet was not well covered. Therefore inorganic arsenic exposure through food was evaluated by considering the total arsenic exposure from the first French TDS results and applying contribution factors from a WHO evaluation. It was considered that in meats and dairy products, 75 % of the arsenic was inorganic, 65 % in poultry and cereals, 10 % in fruit, and 5 % in vegetables and seafood/fish [13]. This work highlighted the fact that, even if seaweed is not a major contributor to exposure of inorganic arsenic for French consumers, its contribution is in the same range as some food groups. Given seaweed is not a food group but a single food item, even its low contribution should be considered with caution. By providing an overview of the exposure through the whole diet, French TDS results were a good comparative support tool. As another example, the results of cadmium exposure were used in a 2011 opinion on the revision of maximum content for cadmium in foodstuffs intended for human consumption [14]. The results were used to assess the safety impact on the exposure of the French population of proposed maximum levels (MLs), following the 2009 lowering of the health-based guidance value by EFSA. According to the model results, the experts concluded that the MLs under discussion at European level as well as MLs established according to the ALARA (as low as reasonably achievable) principle would neither have a significant impact on mean levels of foods, nor on consumer exposure.

The TDS methodology is also used in more specific studies. For instance, the sampling methodology was applied to the Calipso study, which was a fish and seafood consumption study using biomarkers of exposure to trace elements, pollutants and omega-3 fatty acids [15–17]. Due to the lack of representative data in the national consumption survey, the individual food consumption survey focused on high percentile of seafood consumers and was the first conducted around four coastal regions in France involving about 1,000 consumers in order to base the TDS sampling on representative data [18]. After that, fish and other seafood samples were collected in order to assess the exposure through seafood consumption to some specific contaminants for which seafood are known to be high contributors, such as methylmercury, dioxins, polychlorinated biphenyls and cadmium [13, 15, 19]. Based on the first French TDS methodology, composite samples of up to 5 subsamples of 200 g of the same species were prepared. Several criteria were taken into account to build the sampling plan, such as quantities consumed by the studied population and consumption frequencies to select the specific food, but also

preservation and processing methods, if any (fresh, semi-fresh, frozen, canned, etc.), supply source (beach fishing, purchase on the fish dock, at the market, from a fishmonger, in another type of shop, or consumption outside the home), and geographical origin of product (preferably local, regional, etc.). This kind of study also stresses the importance of adapting the food sampling to the studied contaminants that are not ubiquitous. For instance, TDS was not really adapted to assess the exposure of the general population to methylmercury. Actually, it has been shown that food and especially fish provided more than 90 % of exposure to methylmercury. Indeed, the main contributors are predatory fish, which are not generally consumed in France in terms of quantity or consumer frequency. In the French TDS, it was then decided not to include them in the sampling plan. Therefore studies, such as the Calipso study, which focus on particular contaminants in specifically identified food types, can be a complementary method to the TDS in risk assessment and reinforces the importance of a standardized and transportable methodology.

As explained previously, another TDS is currently on-going at the national level for the 2010–2014 period. It consists of an infant TDS (children aged 0–3 years), focusing on infant foods, including infant formulae and ready-to-eat infant foods. The sampling plan aims to be representative of the purchasing habits of the parents and the market shares of the different products. Foods will be prepared as consumed by the infant population. While the infant TDS methodology differs slightly from the general population TDS, it had to be adapted to this specific population for these specific foods. For example, for several products, the sampling plan does not include composite samples of all the different available brands according to the market shares for a same core food, but separates individual food brands to take into account brand loyalty that is common for infant foods. Twelve samples of the same product and the same brand were bought (one per month during 1 year to take account of the seasonal variations) and mixed together in a composite sample.

A specific 2005 consumption survey on infants of 0–3 years old has been used, excluding breast-feeding children, to assess the exposure of this particular population. To take into account the product market shares of this particular and dynamic sector, data from a national purchase panel have also been used. This new study will also be an example of adaptation of the sampling strategy in that not only in situ additives, persistent organic pollutants, pesticides residues, acrylamide, traces elements and minerals will be analyzed, but also other chemical known as endocrine disruptors substances that migrate from food contact and cookware, such as inks, bisphenol A, phthalates and phenols. For that purpose, the sampling plan integrates information to take into account different home-cooking methods using different cookware known to be a source of contamination, and separates not only brands but also packaging types (cans, plastic boxes, jars, etc.).

In conclusion, the work completed in France over the 12 years since the implementation of the first French TDS shows how progress has been made to achieve a comprehensive overview of the occurrence of chemical in foods and the diet and “background” exposures to these chemicals based on TDS methodologies in order to better assess and manage food safety risks of public health importance.

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