Exposure assessment: Total Diet Studies

Le Donne C., Lombardi-Boccia G., Lucarini M., D'Evoli L., Tesone V., Turrini A.

in

Sanchís V. (ed.), Líebana E. (ed.), Romagosa I. (ed.), López-Francos A. (ed.).
Food safety challenges for mediterranean products

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 111

2015
pages 43-50

Exposure assessment: Total Diet Studies

C. Le Donne, G. Lombardi-Boccia, M. Lucarini, L. D'Evoli, V. Tesone, and A. Turrini[1]

Consiglio per la Ricerca e la Sperimentazione in Agricoltura (CRA) – Centro di Ricerca per gli alimenti e la NUTrizione (CRA-NUT), Via Ardeatina 546, 00178 Rome (Italy)

Abstract. *Total diet studies (TDS)* are designed to assess dietary exposure to both beneficial and harmful substances. Average dietary intake of chemicals is estimated in a two-phase approach, whereby the food consumption data collection to estimate the reference diet represents the first phase and the total diet study the second one. In this stage a representative food shopping list is elaborated and food samples are market basket collected to reproduce the reference diet, then the foods are prepared according to the most popular home treatments of food, and finally chemically analyzed to estimate the content of target substances. TDS provide a useful informative basis to complement food monitoring and surveillance programs either for screening purpose or refined exposure assessment. A need for structuring a harmonized European TDS approach was identified by the European Food Safety Authority and a specific project – TDS-exposure project, was undertaken in the context of the 7th Framework Program. The present work starts from the definition of dietary exposure estimated from a TDS to illustrate the TDS process also highlighting some critical points to tackle in achieving the goal.

Keywords. Total Diet study – Exposure assessment – Population study.

Évaluation de l'exposition : études de l'alimentation totale

Résumé. *Les études de l'alimentation totale (EAT) sont conçues pour évaluer l'exposition alimentaire à la fois à des substances bénéfiques et néfastes. L'apport alimentaire moyen est estimé dans une approche en deux phases : la collecte de données sur la consommation alimentaire pour évaluer le régime de référence représente la première phase et l'étude de l'alimentation totale la deuxième. A ce stade, un panier représentatif de la consommation est collecté pour reproduire le régime de référence, puis les aliments sont préparés selon les modes de préparation domestiques les plus courants, et sont enfin analysés chimiquement pour estimer leur teneur en substances cibles. Les EAT constituent une base d'information utile pour compléter les programmes de surveillance que ce soit dans une procédure de criblage ou pour une évaluation de l'exposition raffinée. Le besoin de structurer une approche européenne harmonisée pour les EAT a été identifié par l'Autorité européenne de sécurité des aliments et le projet TDS- exposure a été lancé dans le cadre du 7e programme-cadre de recherche. Le présent travail s'appuie sur la définition de l'exposition alimentaire estimée à partir d'une EAT pour illustrer le processus des EAT, tout en soulignant certains points critiques à traiter afin d'atteindre les objectifs.*

Mots-clés. *Etude de l'alimentation totale – Exposition alimentaire – Étude de la population.*

I – Introduction

It is worldwide recognized that the availability of reliable and detailed occurrence data for chemicals in food is essential in order to perform dietary risk assessment. For estimating dietary exposure of the population, the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) recommend the use of the total diet studies (TDS) approach (EFSA/FAO/WHO, 2011a). The primary purpose of total diet studies is to measure the average amount of each chemical ingested by different age/sex groups living in a country (Moy, 2013). In TDSs, representative samples of widely consumed foods are collected and analysed for the constituents of interest (Kroes *et al.*, 2002).

[1]On behalf of the WP3 contributors and the TDS-exposure project Consortium (www.tds-exposure.eu).

In general, a TDS is designed to assess dietary exposure to both beneficial and harmful substances (EFSA/FAO/WHO, 2011a). A huge amount of work have been done since the '60s initially to face the exposure to environmental contaminants of food only, but subsequently extended to estimate nutrients (see as an example, Turrini and Lombardi-Boccia, 2002).

In fact, the TDS approach is particularly helpful in evaluating substances not regularly occurring in foods either because these are not structural constituents of foods and then irregularly occur (natural toxicants, migrated substances, substances generated by the food production process, etc.) or because even usually being structural part of the food the distributions is not easy estimated in short survey period (e.g., trace elements). Average dietary compounds intakes are estimated in a two-phase approach, whereby the food consumption data collection to estimate the reference diet represents the first phase and the TDS the second one (Saba *et al*., 1992). Differently, when a dietary study concerns structural food constituents with a well-known distribution like some nutrients are, a preliminary estimate of intake is often performed applying food composition tables to food intakes (Leclercq *et al*., 2001). Nevertheless, TDS is suitable also in this case either as validation tool (Carnovale *et al*., 2000; WHO, 2007a) or as tool when up-to-date food composition data are not available (Turrini and Lombardi-Boccia, 2002; WHO, 2007a).

The accuracy of population intakes estimated using TDS results depends on the extent to which the foods analysed represent important dietary sources of the chemicals. International organisations like the FAO and the WHO have been supporting the TDS approach since the 1970s and have provided general guidelines (EFSA/FAO/WHO, 2011a). Nevertheless, there has so far been no attempt towards an agreement on a generally harmonized TDS approach. At the beginning of 2010, a Working Group of experts on TDS was established and coordinated by European Food Safety Authority (EFSA). Participants from European Member States, FAO and WHO covered the needs for expertise and knowledge on TDS at European and international level. The Working Group aimed at preparing a review of the state of the art on TDSs worldwide with a particular emphasis on activities in Europe and at developing a guidance document for a harmonised TDS approach (EFSA/FAO/WHO, 2011a, 2011b).

In line with EFSA activities, the EU Total Diet Study Exposure project (TDS-Exposure, http://www.tds-exposure.eu/) was approved for financial support in the EU 7th Framework Programme (FP7) to perform a research aimed at: (i) to identify clearly what kind of information TDS studies can provide for exposure and risk assessment; (ii) to encourage the development of total diet studies across Europe and worldwide; (iii) to propose a harmonized method; (iv) to build and test a European database of TDS studies useful for risk assessors and risk managers; and (v) to develop or adapt existing exposure assessment models to TDS studies and to assess uncertainties.

In the present work the methods of evaluating the dietary exposure through the implementation of a TDS provides the input to identify some critical points to tackle in order to achieve the goal and contributing to the brainstorming about the implementation of an European TDS system.

II – Material and methods

The reports of the joint guidance of EFSA/FAO/WHO 'Towards a harmonized Total Diet Study approach: a guidance document' (EFSA/FAO/WHO, 2011a) have been the starting point to analyze the available literature.

A literature search have been conducted using the keywords used for the specific purposes were "food shopping list"; "total diet study", and "food market basket" (Boolean operator OR). Subsequently the term "reference diet" was added to capture works dealing with the formulation of the food list only.

A database of papers was compiled with the contribution of TDS-exposure partners involved in this specific task of the project. Non-English publications have been examined thanks to the translation by each of them.

Papers from 19 countries have been included in June 2012, comprehending the WHO reports (WHO 1999; 2002; 2004, 2007a,b) specifically dedicated to TDS, have been overall reviewed. The literature search has been widened to include the most recent publications on TDS (Moy and Vannoort, 2013).

III – Results and discussion

1. Exposure assessment

Exposure assessment starts from a simple assumption: dietary exposure is obtained by multiplying food intake and concentration of chemicals in foods (EFSA/FAO/WHO, 2011a; Boorman *et al.,* 2013a). However,

In TDS three possible methods can be used for long-term dietary exposure (Boorman *et al.,* 2013a):

(i) Point estimate of concentration and food consumption per each food analyzed:

Dietary exposure$_k$ = Σ_j *intake$_j$ x concentration$_{kj}$*

where
j=1,…, t and *t* is the number of TDS foods containing the substance k

(ii) Point estimate of concentration by distribution of food consumption

Dietary exposure$_{ik}$ = Σ_j *intake$_{ji}$ x concentration$_{kj}$,*

where
i=1,…, n and *n* is the number of individuals in the total sample
j=1,…, t and *t* is the number of TDS foods containing k

(iii) Combining food consumption distributions and food chemical concentration in a probabilistic approach so multiplying the two functions *f*(intake$_{ijk}$) * *g*(*concentration$_{kj}$*)

All the above considered approaches require that the food sample collection is representative for the diet otherwise unpredictable and non-evaluable inconsistencies could occur.

Secondly, the food category should be thoroughly aligned. This aspect defined also as food mapping (Boorman *et al.,* 2013b) can be incorporated in the procedure at both food description and food aggregation level (Charrondiere, 2013). In this line each food sample needs to be: (i) described in detail and in a standardized way, possibly using the LanguaL standard (www.langual.org) in order to facilitate the identification of the specific item; and (ii) categorized adopting a classification criteria shared at international level, like the FoodEX system implemented by EFSA (2011a).

This issues must be considered when treating the information in the collection of food sample to verify when the food shopping list for each food category in the food list is completed. The information will be maintained along the whole TDS process, i.e., when the purchased food products will be prepared and then pooled to form the composite samples for the chemical analyses so determining the occurrence of substances (EFSA/FAO/WHO, 2011a).

This will be extremely useful at a subsequent stage in the same study (interpretation of the results) or in comparative analyses of different studies. Food intake profiles differ across population groups and region/countries so resulting in different level of foods consumption but also in the brand and/or

varieties of food products included in each category depending on the specific trend of food demand. This is certainly reflected in the national food lists and shopping strategies (Moy and Vannoort, 2013).

2. Food samples collection

Food samples collections is a multi-stage process including two organizational steps and one implementation steps. The results of these activities led to the market basket of products that will be prepared for consumption and pooled for chemical analyses (EFSA/FAO/WHO, 2011a).

TDS provide a useful informative basis to complement food monitoring and surveillance programs either for screening purpose or refined exposure assessment. This has effects on the length of the food list because a most refined exposure assessment is aimed to identify foods representing the sources of the target substances other than the overall dietary content (EFSA/FAO/WHO, 2011a).

The effectiveness of the food products collection in obtaining a representative sample of the TDS food list is a crucial aspect. A conceptual representation helps in identifying critical points in the process that can limit the correct interpretation of the results. Critical points concerns the available information trying to answer the questions: which, where, when, and how much food purchase? According to the first question (*which*), critical issues are the availability of food intake data and the possibility to disaggregate food items, home treatment and recipes information, the possibility to have data for the relevant food categories for prioritized chemicals and population groups of concerns, market share/varieties. The second question (*where*) requires information on the relevant parameters characterizing the territory, the retail system. The knowledge of food procurement habits helps partly to identify where people buy foods and *when*. This allows for the evaluation of seasonality from the demand point of view, so complementing the seasonality assessed at offer level (production + import). Combination of different situation can occur and tracking the process enhances the reliability of the results. Finally, recording the information in ad hoc designed databases will allow for comparison (EFSA/FAO/WHO, 2011a). Source of information and information derived at each stage in planning a food products collection in a TDS according to the selected papers are synthesized in the diagram in Fig. 1.

Food consumption data provide the informative basis to extract food categories and the respective amount daily eaten on average by the population (reference diet). The more detailed are the easier is the selection in accordance to the kind of substances whose exposure is object of study. The more substances are taken into account the more detailed is required the list to be (EFSA, 2011a).

The detail facilitates the process of aggregation in case of small quantities and/or very low consumers rate (<5%) for food not relevant for the target substances (EFSA/FAO/WHO, 2011a). This also reduce the possibility that a food category needs to be split in different subcategories to match the inherent classification, so requiring either a step of data processing on the food intake database when individual data are available, or an indirect estimation.

Relevant breakdown of food intake must be considered for estimating figures at population group level taking into account the specificity of each of one. The question whether a food category is representative or not will be repeated for the formulation of each specific food list (EFSA/FAO/WHO, 2011a).

The determination of food products to be included to represent each category can be obtained applying information taken from the dietary survey of from other sources (Table 1), like production/trade statistics on varieties of raw foods and market share data for processed foods (EFSA/FAO/WHO, 2011a).

Geographical distribution and Information on the food distribution system are used to map the territory and the type of shops where to buy the food products. Diverse seasons should also be considered for those items with different availability along the year (EFSA/FAO/WHO, 2011b).

Information on home food treatments for preparation of foods will be applied because the pooled sample for chemical analyses will contain foods as consumed (EFSA/FAO/WHO, 2011a; Moy and Vannoort, 2013).

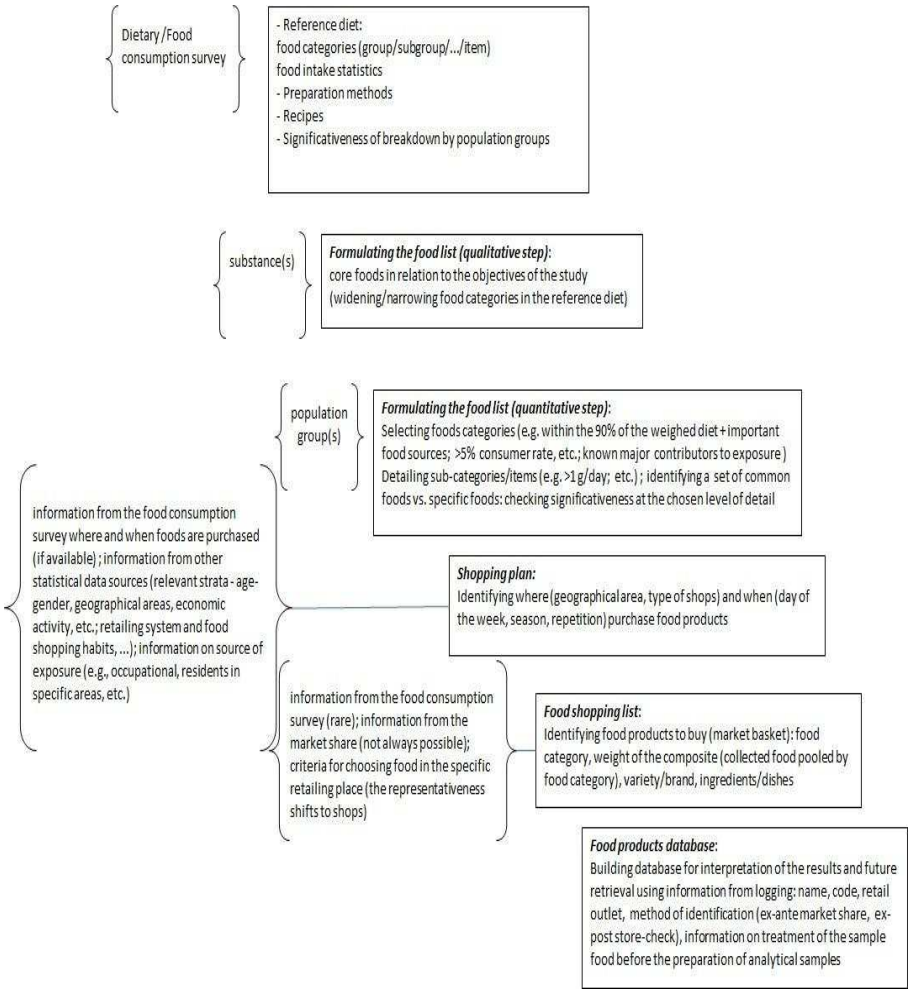

Fig. 1. Information used in the food products collection in a total diet study (TDS).

Table 1. Sources of food consumption data (Source: EFSA/FAO/WHO, 2011a)

Food consumption data	Method
Food Balance Sheets (FBS)	Food disappearence data
Household Budget Survey (HBS)	Food expenditure with/without quantities record
Dietary Surveys	Food record: Recall; Food Frequency Questionnaire
Trade statistics	Current statistics
Combinations	

The more comprehensive the information are at each stage the higher representativeness will be reached and the more reliable will be the estimate of exposure. In this way, the subsequent problems related to analytical parameters like the level of detection (LOD) and the level of quantification (LOQ) (Aerts *et al.,* 2013) will regard the particular substances and the analytical method only.

Overall, variability and uncertainty are inherent parts of the statistical treatment from the sampling design, to the collection plan, and, finally, the evaluation. When these aspects are under control both effects can be measured (WHO/FNU/FOS, 1995). Otherwise, unpredictable errors could occur without possibility to quantify its amount.

This can make really difficult to manage when several chemicals are analysed, i.e., the usual situation in a TDS.

The following Table 2 reports the list of chemicals studied through TDS in Australia and Italy.

Table 2. Examples of groups of substances studied in a TDS

Country: Australia (Moy & Vannoort, 2013)	
Agricultural chemical residue screen	Chlorinated organic pesticides, organophosphorus pesticides, synthetic pyrethroid, fungicides, selected carbamates and fungicides, piperonyl butoxide
Contaminants	Antimony, total arsenic, cadmium, copper, lead, mercury, selenium, tin, zinc, aflatoxins, polychlorinated biphenyls
Natural toxicants	Aflatoxins and ochratoxin A a
Inhibitory substances	Penicillin G, streptomycin, oxytetracycline a
Additives	Sulphites, nitrates, nitrites, benzoates, sorbates
Essential trace elements	Iodine, chromium, molybdenum, selenium and copper
Country: Italy (D'Amato *et al.,* 2013)	
Non-essential trace elements	Al, inorganic As, Cd, Pb, methyl-Hg, inorganic Hg, U
Radionuclides	^{40}K, ^{134}Cs, ^{137}Cs, ^{90}Sr

Procedures and check list to monitor the work and to analyse information at fixed critical points helps to follow the advancement of the study and to plan corrective actions if needed. Once the information basis is arranged mathematical/probabilistic models can be applied to estimate exposure and statistical analysis can be performed to evaluate the reliability of the results (Lavrakas, 2008).

IV – Conclusions

TDS are helpful tool to complement and complete information for risk assessment in the phase of the exposure assessment.

A conceptual structure of the whole process allows for identifying critical points and the systematic cross-country harmonization of the procedures and wherever possible establish standard operational process.

The food sample collection is a delicate stage of a TDS to ensure the diet being adequately represented in its variety and articulation.

This and all the other stages and steps of the whole TDS are considered in the TDS-exposure project for the design of an European system.

Acknowledgements

The research leading to these results received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under Grant Agreement 289108 (Total Diet Study Exposure). This publication reflects only the author's/ authors' view(s), and the Community is not liable for any use made of the information contained therein.

Project coordinator: Dr. Jean-Luc Volatier, Agency for Food, Environmental and Occupational Health Safety, France.

Thanks are due to the great collaborative participation by partners in the task related to the conceptualization of the protocol for food products collection in a TDS.

WP3 Contributors		**Country**
Bundesinstitut fuer Risikobewertung	Heinemeyer Gerhard; Oliver Lindtner	DE
Universidad de Granada	Martínez-Victoria Emilio; Alba Martínez Burgos	ES
University College Dublin, National University of Ireland, Dublin	Kelleher Cecily; Breige McNulty; Anne Nugent; Aine Hearty	IE
Hrvatska Agencija za Hranu	Sokolic-Mihalak Darja; Martina Jurković	HR
Partikas Un Veterinarais Dienests	Ozolins Gatis; Dace Santare	LV
Institute of Food Safety, Animal Health and Environment Bior	Inese Siksna	LV
Agencia Española de Seguridad Alimentaria y Nutrición	M. Teresa Lopez; Pedro Mario Fernández	ES
Instituto Nacional de Saúde Doutor Ricardo Jorge	Oliveira Luisa; Maria da Graça Dias; Elsa Vasco	PT
Instytut Zywnosci I Zywienia	Sekula Wlodzimierz; Katarzyna Stos; Macjei Oltarzewski	PL
Istituto Superiore di Sanità	Francesco Cubadda; Federica Aureli; Marilena D'Amato	IT
Turkiye Bilimsel Ve Teknolojik Arastirma Kurumu	Özer Hayrettin; Canan Doğan; Imge Oktay	TR
Universitat Rovira i Virgili	Domingo José Luis; Martí Nadal; Gemma Perelló	ES
Livsmedels Verket	Darnerud Per Ola	SE

References

Aerts M., Bakker M.I., Ferrari P., Fuerst P., Tressou J. and Verger P.J.-P., 2013. Reporting and Modeling of Results Below the Limit of Detection. Diet Study. In: Moy G. and Vannoort R.M. (eds), *Total Diet Studies*. Springer, p.169-178.

Boorman J.L., Baines J., Hambridge T.L. and Abbey J.L., 2013a. Dietary Exposure Assessment in a Total Diet Study. In: Moy G. and Vannoort R.M. (eds), *Total Diet Studies*. Springer, pp. 179-190.

Boorman J.L., Baines J., Hambridge T.L. and Abbey J.L., 2013b. Food mapping in a total diet study. In: Moy G. and Vannoort R.M. (eds), *Total Diet Studies*. Springer, pp. 435-190.

Carnovale E., Cappelloni M., Lombardi-Boccia G., Turrini A., 2000. Total Diet Studies in Italy. In: *Journal of Food Composition and Analysis*, 13(4), pp. 551-556**.**

Charrondiere U.R., 2013. Preparing a Food List for a Total Diet Study. In: Moy G. and Vannoort R.M. (eds), *Total Diet Studies*. Springer, pp. 53-62.

D'Amato M., Turrini A., Aureli F., Moracci G., Raggi A., Chiaravalle E., Mangiacotti M., Cenci T., Orletti R., Candela L., di Sandro A. and Cubadda F., 2013. Dietary exposure to trace elements and

radionuclides: The methodology of the Italian Total Diet Study 2012-2014. In: *Annali dell'Istituto Superiore di Sanità*, 49(3), pp. 272-280.

EFSA, European Food Safety Authority, 2011a. Evaluation of the FoodEx, the food classification system applied to the development of the Comprehensive European Food Consumption Database. In: *EFSA Journal*, 9 (3): 1970. http://www.efsa.europa.eu/de/efsajournal/doc/1970.pdf

EFSA European Food Safety Authority, 2011b. Use of the EFSA Comprehensive European Food Consumption Database in Exposure Assessment. In: *EFSA Journal,* 9 (3): 2097. http://www.efsa.europa.eu/en/efsajournal/doc/2097.pdf

EFSA/FAO/WHO - European Food Safety Authority [EFSA], Food and Agriculture Organization of the United Nations [FAO], World Health Organization [WHO], 2011a. Towards a harmonised Total Diet Study approach: a guidance document. In: *EFSA Journal,* 9(11):2450.

EFSA/FAO/WHO - European Food Safety Authority [EFSA], Food and Agriculture Organization of the United Nations [FAO], World Health Organization [WHO], 2011b. State of the art on Total Diet Studies based on the replies to the EFSA/FAO/WHO questionnaire on national total diet study approaches. In: *Supporting Publications 2011: 206*. Available at: www.efsa.europa.eu.

Kroes R., Muller D., Lambe J., Lowik M.R.H., van Klaveren J., Kleiner J., Massey R., Mayer S., Urieta I., Vergerj P. and Visconti A., 2002. Assessment of intake from the diet. In: *Food Chemical and Toxicology,* 40, p.327-385.

Lavrakas P.J., 2008. Nonsampling Error. In: *Encyclopedia of Survey Research Methods.* **DOI:** http://dx.doi.org/10.4135/9781412963947.

Leclercq C., Valsta L. and Turrini A., 2001. Food composition issues – implications for the development of food-based dietary guidelines**.** In: *Public Health Nutrition*, 4(2B), pp. 677-682**.**

Moy G., 2013. Total Diet Studies – What They Are and Why. In: Moy G. and Vannoort R.M. (eds), *Total Diet Studies*. Springer, pp. 3-10.

Saba A., Turrini A. and Cialfa E., 1992. Estimates of intakes: methodology and results of some studies carried out in Italy. In: *Food Additives and Contaminants*, 5, pp. 527-534.

Turrini A., Lombardi-Boccia G., 2002. The formulation of the market basket of the Italian total diet 1994-96. In: *Nutrition Research*, 22(10), pp. 1151-1162

WHO, World Health Organization, 1999. Gems/Food Total Diet Studies. Report of a Joint Usfda/Who International Workshop on Total Diet Studies in Cooperation with the Pan American Health Organization. FOOD SAFETY PROGRAMME 140. Kansas City, Missouri, USA.

WHO, World Health Organization, 2002. Gems/Food Total Diet Studies. Report of the 2nd International Workshop on Total Diet Studies Brisbane, Australia 4 – 15 February 2002. FOOD SAFETY PROGRAMME 141. Brisbane, Australia: World Health Organization.

WHO, World Health Organization, 2004. Gems/Food Total Diet Studies: Report on the 3rd International Workshop on Total Diet Studies 14-21 May 2004, Paris, France. 142. Paris: **World Health Organization.**

WHO, World Health Organization, 2007a. GEMS/Food GEMS/Food total diet studies: report of the 4th International Workshop on Total Diet Studies, Beijing, China, 23-27 October 2007.

WHO, World Health Organization, 2007b. Report of the Regional Workshop on Total Diet Studies Held in Jakarta-Indonesia, 5-7 December 2007. 145. Jakarta-Indonesia: World Health Organization.

WHO/FNU/FOS, 1995. Application of Risk Analysis to food standards issue. Report of the Joint FAO/WHO Expert Consultation, Geneva, Switzerland 13 - 17 March 1995. Available at : http://www.fao.org/docrep/008/ae922e/ae922e00.htm#Contents