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GENERAL PAPER

Improving data quality in food composition databanks: a EuroFIR contribution

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Abstract Food composition databanks (FCDBs) should provide nutrient composition data comparable over time at national and international levels. However, the linkage between national database compilers and permanent structures to support the upgrading and monitoring of nutrient values in foods are far from satisfactory. This paper focuses on European efforts to improve the quality of nutrient values entered into FCDBs, emphasizing initiatives under the EU Network of Excellence: European Food Information Resource (EuroFIR – NoE). The general concept of quality assurance is described and results obtained in the project's first year are presented. A survey among EuroFIR partners aimed at evaluating the current situation in comparability of nutrient values suggests that an integrated approach has two requirements: the implementation of a quality management system (QMS) and a harmonized data-quality assessment system (DQAS) to select values from different sources. The use of reference materials (RMs) is a key criterion in deciding on comparability and reliability of candidate nutrient values. Consequently, results of a survey on food matrix reference materials are presented. These suggest that developments in RMs for nutrient analysis in foods have a great impact on the quality of data to be included in FCDBs.

Keywords Data quality · Food composition · EuroFIR · Reference materials

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Introduction

In 1940, McCance and Widdowson wrote that "Knowledge of the chemical composition of foods is the first essential in dietary treatment of disease or any quantitative study of nutrition" [1]. This statement remains justifiable after all these years, as many epidemiological and biological studies have demonstrated the involvement of food in the development of certain diseases and the contribution of diet to health status. This evidence of the central role of nutritional sciences has increased the interest of the scientific community in the nutritional value of food consumed by individuals and population groups at national or international levels, and has led to an increasing number of food composition tables, databases and databanks. Initially, these were produced only in printed format to provide nutrient data for country-specific requirements. More recently, printed food composition tables have been replaced by computerized data systems designed for use in the development of standardized calculation procedures to estimate nutrient intakes [2].

The main purpose of modern food composition databanks (FCDBs) is to provide qualitative and quantitative information on the chemical composition of foods. This information should be compatible with data collections or sets between countries. Its function is to support clinical practice, research, public health and the food industry at a national and

international level over time. These data are based either on laboratory analysis or estimated from appropriate nutrient values. Consequently, FCDBs can contain original analytical values, imputed values estimated from analytical values obtained for a similar food, calculated values usually derived from recipes, borrowed values taken from other tables, and presumed values achieved by consensus or established by regulations [3, 4].

The above circumstances require appropriate methodologies for analytical and compilation activities that guarantee confidence in the values entered into FCDBs. Analytical processes encompass the following activities: creating a sampling plan for the collection and preparation of food samples; choosing and validating an analytical method; performing the appropriate method with evidence of quality control procedures; and critically reviewing the values obtained [5].

Three methods of compiling FCDBs are described by Greenfield and Southgate [5]. The first is a direct method in which all values result from analyses carried out in laboratories operating under good laboratory practice (GLP). Second is the indirect method, where values are taken from published literature or manufacturers. Finally, the combined method utilizes values obtained from original values and values taken from literature or other databases.

The above methods have become reliable and consensus exists on key criteria for creating high-quality databases. General publications are available covering quality criteria for laboratories, analytical methodology, and sampling protocols. Quality requirements for attaining data quality have been described both for unspecified nutrients and for specific components such as carotenoids and flavonoids [6, 7]. These include tools for assessing data suitability in terms of representativeness; component and food identification; accuracy and documentation. As a consequence, advances have been made in the field of comparability and reliability of data [8]. However, the linkage between national database compilers and the strength of permanent structures to support the upgrading and monitoring of nutrient values in foods are far from satisfactory.

This paper focuses on quality assurance practices carried out during the first year of the project by the European Food Information Resource Network – (EuroFIR) with the aim of improving comparison of nutrient values in foods contained in national FCDBs. Prior European initiatives are outlined. EuroFIR activities aimed at enhancing the quality of data include: (1) Strategies for implementing a quality management system suited to the type of work and taking in account the existing standards ISO/IEC 17025 and ISO 9001; (2) Design of a data-quality assessing system to select nutrient values; (3) Survey on availability and relevance of food matrix RMs for assuring data quality.

European food information resource network

Since 1982, several initiatives have been carried out to assemble European scientists involved in food composition data [3, 5, 8]. Efforts have been made to harmonize food description, nutrient definitions, analytical methods, and compilation processes. These actions have identified some potential sources of random and systematic errors caused by different approaches, different interpretations of guidelines and lack of documentation. The projects concluded that national food composition tables were not standardized sufficiently to be suitable for comparison of intake data at the nutrient level. Taking into account the foregoing conclusions, it was decided to develop a pan-European system on food information and to design a specific standard for these activities, which led to the creation of EuroFIR.

EuroFIR is sponsored by the Sixth Framework Programme for Research and Technological Development under the Food Quality and Safety Priority. The NoE (Network of Excellence) was formally launched in 2005 and is funded up to 2009. EuroFIR is a partnership of 47 members from universities, research institutes and small to medium-sized enterprises. It brings together partners who carry out laboratory analysis and the national centres (or co-centres) responsible for the compilation and management of national nutrient databases for twenty EU states, as well as candidate members and other states, in a total of 25 countries [2].

EuroFIR is founded firmly on earlier actions funded by programmes of the Commission of the European Communities. The network aims:

1. to improve the compatibility of national tables in order to assist multi-centre studies at the European level;
2. to strengthen scientific and technological excellence in FCDB systems by integrating at the European level the critical mass of resources and expertise needed to create European leadership;
3. to offer new information on missing data for some nutrients and biologically active compounds with putative health effects - covering all food groups, including traditional, ethnic minority, novel and prepared food; and
4. to develop a Quality Framework for food composition data in order to improve harmonization between compliers, laboratories and stakeholders.

During the first year of the project, the adoption of quality-assurance principles and practices by EuroFIR members was evaluated; two questionnaires were developed and distributed among EuroFIR partners and contractor laboratories: one for laboratories analysing food products, and a second for compilers of FCDBs. Almost all partners and contractor laboratories responded to the questionnaires, which

contained questions about the implementation of quality systems, sampling, technical requirements and the needs of users and stakeholders. The responding partners expect that quality assurance practices in compliance with ISO 9001 and ISO/IEC 17025 may improve customer satisfaction. However, some partners argue that such practices may also increase bureaucracy and paperwork, and more than 40% of respondents expressed the need for a better understanding of their costs and benefits. A majority of laboratories have implemented a quality system in compliance with ISO/IEC 17025 or GLP. However, this does not apply to research and development activities for which no standard is available. For such activities, some laboratories follow The Eurachem guide – Quality Assurance for Research and Development and Non-routine analysis [9], whereas others argue that quality requirements for research should address quality management of positive and negative non-conformity and non-confirmation of hypothesis [10]. Therefore, in the coming months, a checklist will be elaborated to assist laboratories in the fields of quality management, sampling, analysis and documentation. When asked about recognition of quality systems, more than 75% of participants expressed themselves in favour of formal accreditation. Compilers are familiar with quality assurance practices in the domain of data management; however there is much work to be done when it comes to the compilation process.

The dissemination of the EuroFIR quality policy through young scientists was achieved by way of lectures incorporated in the Graduate Course on Production and Use of Food Composition Data in Nutrition, organized jointly by EuroFIR & FAO (Food Agriculture Organization of the United Nations). The main topics were the importance of quality management, quality requirements of existing standards, and examples of identifying risks and assuring QA/QC (quality assurance and quality control) in FCDB processes.

Workshops organized each semester acted as a platform for brainstorm sessions during which information about national quality practices was exchanged. Also, these led to agreement on the quality framework to be developed, as well as a new task allocation. Four tasks forces were created: Quality Management Systems; Compilation Processes; Data Quality Assessment Systems; and Computerized Systems.

The purpose of this new organizational structure of EuroFIR's quality practices, led by the project coordinator, is to strengthen the linkage between analysts and compilers while applying quality assurance principles to achieve NoE objectives. One of the first tasks is to develop a harmonized approach which will guarantee that values entered into the EuroFIR databank fit the users' requirements in terms of representativeness and accuracy.

Data-quality assessment systems

A data-quality assessment system can be defined as a system implemented in FCDBs to ensure that the determination of data quality and the accompanying procedures are carried out effectively. Such a system is applied, particularly by compilers, to assess the quality of two types of data. The first, "original raw data", is defined as published and unpublished research papers, and reports containing analytical data taken directly from their source (scientific literature, laboratories, manufacturers, other food composition databases, recipes and calculation). The second type is aggregated data: the complete pool of rigorously scrutinized data in which all nutrient values have been converted into formalised modes of expression (e.g. /100 g edible portion of food) [3] obtained by compiling "original raw data" for a specific food and nutrient, thus ensuring that values are representative of the foods in terms of use (e.g. to estimate nutrient intake).

Data-quality systems were first introduced in food composition in a USA databank by Exler [11], who wanted to analyze the level of data quality in literature on iron content in foods. Since then, other researchers have introduced this concept in national food composition tables.

In Europe, France was one of the first countries to apply a data-quality assessment system in this manner. The FCDB managed by the French Food Safety Agency (AFSSA) was created in 1985. As for most national nutrient tables, its main purpose is to provide representative data for the assessment of nutrient intakes in the population, which in turn forms an essential basis for the definition of national food and nutrition policies.

Whereas scientific publications generally include precise descriptions of the data production protocol (as part of the scientific work itself), most other data sources aim at giving short and simple information to a non-scientific public. In many cases, only food names, nutrient names, and values are available. Consequently, the first quality-rating scales developed for the US and French databases were limited to food composition data from scientific publications, as these provide a considerable amount of easily available descriptive information on which quality assessment can be based.

The USDA quality evaluation system [6] distinguishes six criteria for the evaluation of original raw data from scientific publications: sampling protocol, number of samples analyzed, sample handling, analytical method, execution of the analytical method by the laboratory and quality control in the laboratory. AFSSA has added a seventh criterion: food description. For each of these criteria, FCDB compilers have defined the types of objective information relevant to the assessment of reliability and representativeness of food composition data given in a publication. In most national FCDBs, compilers have general knowledge in food chemistry but are not analytical experts. Therefore, it is necessary

to agree on common assessment criteria in order to attain reproducibility of assessment between compilers. For each value entered into the databank, information on the above quality criteria is stored in coded form, allowing traceability of the data production protocol and easy retrieval.

The French assessment system also provides guidelines for compilers to assess this information on a rating scale. Points can be attributed to each value (couple food/component) for each of the criteria, and are finally summed to determine a score (Quality Index) that reflects overall data quality.

In this quality-rating system, the use of RMs [12] is crucial for a laboratory when it comes to demonstrating its ability to obtain accurate and traceable results. In addition, it provides information required to evaluate the criterion "execution of the analytical method by the laboratory". First, the compiler has to determine whether the analysis was performed by a laboratory with accreditation for the testing nutrient in that matrix. If so, the datum gets the maximum score for this criterion, without any further questioning. In the cases that a laboratory is not accredited, or when the scope of the accreditation does not cover the analysis of the nutrient under study, further questions have to be answered. The use of RMs, with or without certified values (with a gradation in the points given), as well as the use of in-house standards and the participation in proficiency testing (PT), are elements indicating the reliability of the analytical work. The absence of RMs when they are not yet available, or the non use of such materials by the laboratory, results in the same score on AFSSA's quality rating scale.

Apart from AFSSA's data-quality assessment system, other systems are applied implicitly or explicitly by national compilers who are members of the EuroFIR partnership. It is now under debate to use the available systems as a starting point to build up a EuroFIR data-quality assessment system. The aim is to develop an integrated approach to quality indices. All categories (food description; sampling; number of samples; analytical method; laboratory performance and quality control) should be revised, precise guidelines for their assessment should be defined, and a test of this new system for relevant nutrient and food groups should be conducted. To guarantee a realistic approach, the EuroFIR system will take into consideration existing data-quality assessment systems. The use of RMs will certainly represent a key issue in the traceability chain to assign quality indices to food composition data.

Applicability of RMs in food composition databanks

Figure 1 represents quality systems implemented by EuroFIR partners, and illustrates the application of RMs within these systems to the analysis, compilation and interchange of nutrient data in food composition databank processes.

RMs [13] are used by sources of analytical data operating under ISO/IEC 17025 or GLP practices for assuring the accuracy and precision of assigned values and for demonstrating source competence. For national compilers, RMs play an important role in quality assessment systems where they are used as criteria for evaluating the analytical quality of values. When it comes to the interchange of data between compilers, RMs serve as criteria for data comparability.

Within the quality framework under debate in EuroFIR, RMs are proposed as quality indicators which ensure that values are representative of the foods and meet the needs of different user groups. However, a realistic grading of RMs has to take in consideration the availability of food matrix RMs. One of the quality-assurance tasks of EuroFIR was to identify the availability and relevance of RMs for assisting the compilation process. The results are presented in Table 1.

Protein values in foods with high protein content, such as meat, eggs, fish, are very important in deriving missing values for minerals and water soluble vitamins. This approach using the Chan method [14], which was introduced in the British Table in 1995, derives the missing value from nitrogen content, under the condition that nitrogen content in both foods is determined by the same analytical method. The missing value is then extrapolated from the ratio

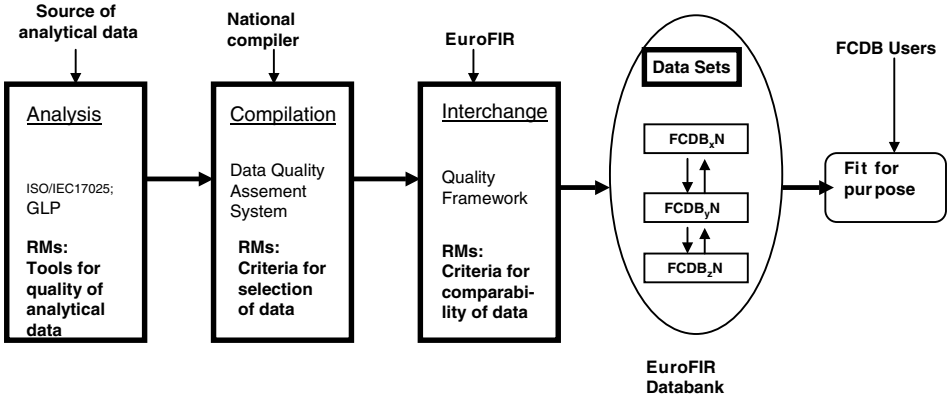

Fig. 1 Schematic overview of quality assurance in EuroFIR and applications of RMs

nutrient–protein value in reference food. Matrix RMs with certified values for protein and ash matching the foods usually analysed and taken as reference could be helpful tools in the process of estimating nutrient values.

Fat is defined in several ways; no common definition among compilers exists. According to Deharveng et al., total fat is a sum of triglycerides, phospholipids, sterols and related compounds [15]. Values for total fat are available in all tables, because it is an essential nutrient with crucial roles in the formation of hormones, as a carrier of fat soluble vitamins, and as a source of energy. However, these values are not comparable, and significant differences in fat content of foods were detected due to artificial differences (fat fraction designation, extraction methods, and CRMs used). As a consequence, such values can not be aggregated.

European national tables distinguish the following specifications of carbohydrate: (a) total carbohydrate as a derived value, obtained by subtracting water, protein, fat and ash expressed in g/100 g of food to give total carbohydrate by difference, and (b) available carbohydrate (glycemic), defined as a sum of free sugars (glucose, fructose, sucrose, lactose, maltose), starch, dextrin and glycogen. Furthermore, information about individual carbohydrate species and their values expressed as monosaccharide equivalents are given: some tables report total sugars, defined as all carbohydrates with the exception of tetramers, polyhydroxyaldehydes and polyhydroxyketones; in others total sugars include mono and disaccharides. Additional information is available for added sugar, defined as sucrose or other sugars in the form of an ingredient. This pragmatic approach takes into consideration the former inconsistencies caused by approaches to estimating carbohydrate values (analysis versus calculation). Differences up to 8% are reported in per capita energy supply calculations and depend on nutrient definition applied [16].

The definition of fibre depends on the choice of analytical method. European tables such as the British, French, Portuguese or Danish follow the term proposed by Trowell [17]: the sum of plant polysaccharides and lignin not digested by the enzymes of the gastrointestinal tract. Two analytical methods are available: Englyst and AOAC. Recent CRMs produced in Europe and the USA take into account both methods. The Englyst method measures only the polysaccharide component of dietary fibre, referred to as non-starch polysaccharides. The official AOAC method includes (among others) lignin and one type of resistant starch. Most of the FAPAS (Food Analysis Performance Assessment Scheme) [18] participants, including EuroFIR laboratories, use AOAC methods; nowadays very few use Englyst. There is usually a significant difference in the fibre levels measured by these two methods. The procedure under discussion in EuroFIR is in favour of including in tables results obtained by both analytical methods. This approach is in line with regulations on the labelling of European products.

Fatty acids (FA) are grouped in tables in three major categories: saturated fatty acids (SAF) monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA). The n-6 and n-3 fatty acids are essential dietary nutrients required for growth and development. At present, there is huge interest in European countries in information on FA content in food. Therefore, the most recent versions of most European tables include values on *cis* and *trans* isomers. However, due to the lack of certified or indicative values, sources do not report QA/ QC procedures with CRMs [19].

In the minerals category, values for Ca, Cu, Fe, Mg, Mn, P, K, Na, Zn, Se, are reported for most food groups in national FCDBs. Sources reported the use of RMs in method validation, recovery, day to day analytical accuracy and precision. However, RMs with certified values for halogens are scarce. The role of fluoride in preventing dental caries, as well as in bone and teeth formation, is well recognized. Representative data in tables provides a foundation for the assessment of public health, and is the basis of recommended daily intake. Studies to determine the representative value of fluoride in drinking water used a CRM of fluoride in freeze-dried urine for validation of analytical methods [20].

Speciation has become a relevant topic of nutrition science. It gives information on bioavailability, and essentiality of the chemical form of an element. Hyphenated techniques based on coupling chromatographic separation with inductively coupled plasma mass spectrometric (ICP-MS) detection are now established as the most realistic and potent analytical tools available for real-life speciation analysis. As a consequence, tables exist that incorporate values determined by hyphenated techniques, such as those for trace elements in infant formula and breast milk, and heme and no heme iron in meat. Both works put emphasis on the need for CRMs certified for element species.

Vitamins A, D, E, thiamin (B1), riboflavin (B2), folates or folic acid (B9) and vitamin C are included in most tables, as are values for vitamers (e.g. carotenoids and tocopherols). Dduring the last decade, Finglas et al. [21, 22] have, under EU projects, carried out studies on the feasibility and production of reference materials for vitamins analysis in foods. The EuroFIR coordinator and Dutch EuroFIR partner have organized intercomparison exercises to assess the performance of laboratories for determination water and fat soluble vitamins. These intercomparisons of analytical methods were vital for the comparability of vitamin values in European tables, and were the foundation of CEN Standards.

The determination of vitamin C in foods, particularly in fruits and vegetables, is critical. Variation of values obtained in vitamin C determination can be due to biodiversity of crops, or can be caused by the oxidation of ascorbic acid to dehydroascorbic acid and the conversion to diketogulonic acid by further oxidation due to errors during storage and analysis of foods. To obtain nationally representative values

Table 1 Cross reference table EuroFIR prioritizations and available CRMs for nutrient in food matrices

Component	Meat	Fish	Fruits	Vegetables	Dairy products	Cereals	Others
Proximates							
Water							X
Protein	X	X		X	X	X	X
Fat	X	X		X	X	X	X
Saturated fat							X
Carbohydrate, available	X	X		X			X
Starch				X		X	
Fibre, total		X	X	X		X	
Sugars, total				X		X	
Ash	X	X		X	X		X
Alcohol							X
Cholesterol	X						X
Fatty acids							
Saturated fatty acids, SFA	X	X		X	X		
Monounsaturated fatty acids, MUFA	X	X		X	X		
Polyunsaturated fatty acids, PUFA	X	X			X		
Trans- fatty acids, total	X						
n-3 fatty acids					X		
n-6 fatty acids					X		
Linoleic acid		X		X			X
Linolenic acid				X			X
Carbohydrates							
Fructose				X			X
Galactose							
Glucose				X			X
Lactose					X		X
Maltose							
Sucrose	X			X			X
Oligosaccharides						X	
Minerals							
Calcium	X	X		X	X	X	X
Chloride	X	X		X	X		X
Chromium				X	X		
Copper	X	X		X	X	X	X
Fluorine					X		
Fluoride							
Iodine	X				X		X
Iron	X	X		X	X	X	X

Table 1 continued

Component	Meat	Fish	Fruits	Vegetables	Dairy products	Cereals	Others
Potassium	X	X		X	X	X	X
Magnesium	X	X		X	X	X	X
Manganese	X	X		X	X	X	X
Molybdenum	X			X	X		X
Sodium	X	X		X	X	X	X
Phosphorus	X			X	X	X	X
Sulphur	X	X			X	X	X
Selenium		X			X	X	X
Zinc	X	X		X	X	X	X
Vitamins							
Vitamin A/Retinol							X
Vitamin D							X
Vitamin D3/Vitamin 25-OH					X		
Vitamin E					X		X
Vitamin K							X
Vitamin K1							
Vitamin C/Ascorbic acid				X	X		X
Vitamin B1/Thiamin	X				X	X	X
Vitamin B2/Riboflavin	X			X	X		
Vitamin B3/Niacin/PP	X			X	X		X
Vitamin B5/Pantothenic acid	X						X
Vitamin B6	X				X	X	X
Vitamin B7/Biotin	X						X
Vitamin B9/Folic acid/Folates							
Vitamin B12	X				X		X
Choline							
Carotenoids							
Lutein							X
Zeaxanthin							X
Lycopene							X
β-cryptoxanthin							X
α-carotene							X
β-carotene				X			X
Flavonoids							
Apigenin							X
Phytosterol							
Beta-sitosterol					X		
Stigmasterol					X		

for vitamin C, Rimestad et al. have studied its content in Norwegian potatoes, as these can supply up 18% of dietary vitamin C intake [23]. Any natural and artificial differences observed were recorded in this study using dedicated sampling protocols and careful QC/QA procedures. The Norwegian researchers used vitamin C in house control materials with concentrations matching vitamin C values in the samples.

There are several published definitions for bioactive compounds. In EuroFIR, they are considered to be food plant and edible mushrooms constituents with anticipated health promoting effects. They include various classes of phytochemicals: flavonoids, glucosinolates, phenolic acids and carotenoids. At the EuroFIR Web site, a comprehensive databank is available based on scientific publications, most of which were carried out by EuroFIR laboratories. These publications have been of special interest to the USDA, since analytical data on flavonoids from American sources is scarce. Based on European publications, a comprehensive American database was published [7]. The lack of RMs with certified values for flavonoids is reported in both datasets. Chemical substances and in-house materials are used by sources to ensure comparability of glucosinates and phenolic acids analyses. CRMs are available for carotenoid analysis; however they do not cover the complete range.

RMs without certified values are used by EuroFIR laboratories for different purposes, such as to verify the appropriate execution of analytical procedures or to evaluate the analytical values in terms of day to day accuracy and precision. An ongoing complementary strategy is to develop food matrix reference materials using consensus values obtained for specific major or minor components through reference methods. This is done in collaboration with nationally selected laboratories (research institutes and universities) interested in producing values to be incorporated in FCDBs. At EuroFIR, due to the interest in the characterization of phytochemicals present in traditional and ethnic foods, these tailor made RMs will support quality control programmes including the proficiency testing programmes launched by FAPAS as part of the EuroFIR analytical protocol.

Conclusions

In the last decades, progress has been made in the comparison of nutrient values at the international level. European projects in the area of FCDBs have contributed to the improvement of data interchange.

EuroFIR is committed to strengthening the linkage between compilers and laboratories. In the first year of the project, progress has been made in terms of the reliability of analytical and compilation processes. The network promotes the effective use of quality resources to answer important questions on the harmonization of FCDBs. The quality framework in progress is based on ISO 9001 and ISO/IEC 17025 requirements. It will establish a coherent approach between quality elements, food science, and databank systems.

The model proposed for a data-quality assessment system needs to be tested and refined. The model considers RMs as a cornerstone for the evaluation of analytical methodologies and the compilation of nutrient values in a standardized way. Among the EuroFIR partners, consensus exists to consider RMs as key tools for distinguishing differences in nutrient values. Discrepancies caused by variability due to food biodiversity and artificial differences as a consequence of analytical procedures can be identified with the appropriate RMs. This work intended to illustrate the relevance of RMs for improving data quality in FCDBs.

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