SOURCES OF VARIATION IN NUTRIENT COMPOSITION DATA

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As consumers and professionals, we know that the American marketplace offers thousands upon thousands of food products. Products in the retail market may be commodity items--fresh produce, fresh meats, coffee beans--or they may be brand-name, complex processed recipe formulations. Also, within each product category there are many items and brands from which to choose. For example, the category salty snack foods includes cheese twists, pretzels, potato chips, and crackers of all kinds. The flavors, shapes, and textures of these are limited only by the imagination of product development teams. Each product may have from 1 to 30 different ingredients. The various ingredients may have been extracted, dehydrated, enriched, etc.; treated with a list of chemicals inherent in these processes; then fried or baked; packaged and shipped from coast to coast.

This cornucopia of products may be exciting to the consumer, but it represents a giant-size headache for those of us who sample the food system in an attempt to prepare representative samples of food products for subsequent nutrient analyses. As analysts and contractors, we cannot afford the time and money to determine the nutrient content of every product (nor would we want to). As nutritionists or dieticians, we want to do as little coding as possible. If the nutrient content of potato chips varies little from brand to brand, then we don't need to code each brand of potato chip. How can we, as professionals who are concerned about the nutrient composition of foods, determine which products are the same and which are different?

I would like to share some of my observations and experiences concerning the evaluation of variations in nutrient composition data and the implications of this variation for food sampling.

For the purposes of this discussion, variation can be defined as deviation from a central position or value. If the amount of deviation is small, one can have higher confidence in the central value than if the deviation is relatively large. The ultimate goal in the area of nutrient composition of foods is to have statistically meaningful data for all nutrients in all foods. However, in the real world of limited budgets and deadlines, we must develop a specific strategy, determined by priorities, for sampling the foods which people eat. The Nutrient Composition Laboratory has developed just such a strategy. The strategy includes a systematic approach to determining which foods and which nutrients should be analyzed (G. R. Beecher and J. T. Vanderslice).

Using the strategy we have developed for selecting food products and nutrients, we have sampled beef and pork, fruit juices, yogurt, salty snack foods, and cereals. Planning a nutrient composition project for a selected product type is an iterative process. One must define the potential sources of variation for that product in order to evaluate the extent of variability. Then, one can incorporate those data into the next phase of the project to estimate mean values for nutrients.

Table 1 shows potential sources of variation in all aspects of the sampling process. Some of these sources can be controlled to limit their effects on total variation; others are peculiar to the product and food supply and must be left to vary as they will. However, important but uncontrolled sources of variation should be quantifiable.

TABLE 1: POTENTIAL SOURCES OF VARIATION RELATIVE TO NUTRIENT COMPOSITION DATA

- PRODUCT CHARACTERISTICS
- PLANT LOCATION
- QUALITY ASSURANCE PROGRAMS
- SEASONAL EFFECTS
- DISTRIBUTION TECHNIQUES
- SAMPLE SELECTION
- SAMPLE PREPARATION
- ANALYTICAL METHOD

Product characteristics which define the generic product are of central importance (Table 2).

TABLE 2: PRODUCT CHARACTERISTICS

- PRODUCT TYPE
- BRAND NAME
- FOOD SOURCE
- PART OF PLANT OR ANIMAL
- PHYSICAL STATE, SHAPE, OR FORM
- PRESERVATION METHOD
- TREATMENTS APPLIED TO PRODUCT
- USER GROUP
- PACKAGING

"Product Type" refers to the food group to which the product belongs. Products belonging to the same group may have common consumption, functional, or manufacturing characteristics. A product type may include specific products or brands which are different from each other in other characteristics. These differences or multiple values can affect the extent of variation in some nutrients. Certain types of products which can be differentiated primarily by brand can differ due to variations in formulation and ingredients. For others the source of the primary ingredient may vary. For example, in a study of ready-to-eat (RTE) cereals the main ingredients of various flaked cereals may be corn, wheat, or oats.

"Food Source" denotes the individual plant, animal, or chemical from which the food product or its major ingredient is derived. Food source also includes the natural variability attributable to species, variety, and cultivar. If we were dealing with meat products, we might need to define the various products in terms of the species used in the preparation of these products. Within a product class, such as bacon, there is great variation in the ratio of physical components, fat and lean. When we sampled bacon, we compensated for the large amount of variability by compositing several pounds of each brand, instead of selecting one package. Our purchasing agents were strongly advised to select those several packages at random from the meat case instead of selecting the leanest packages.

"Part of Plant or Animal" refers to the anatomical part of the plant or animal source used to prepare the product. For yogurt, the part of animal would be milk; for salty snacks, the part may be endosperm. For certain meat products, the definition of cuts used would be important. As I mentioned earlier, factors for a given product class become more important when they have multiple values.

"Physical State, Shape, or Form" of the product includes particle size, product shape, and viscosity. Do pretzel sticks have more salt on the outside than the large, hard Dutch pretzels?

"Degree of Preparation" denotes the degree of cooking and preprocessing, factors which may affect the stability of nutrients within a product. The method of cooking for prepared food products is also included. The effect of various cooking methods on nutrient retention in foods can influence the extent of variability in nutrients inherent in the product. In addition, various cooking methods can contribute significant amounts of ingredients which are nutrients. For example, cheese curls or twists may be fried or baked. One would expect the two products to differ in their fat content. This may or may not be true; analysis of the two products would provide the answer. Across the Product Type Salty Snack Foods various methods of preparation and cooking will contribute to the nutrient variability of the product class.

"Treatments Applied . . ." include enrichment, as well as the application of specific processes such as fermentation and the addition of secondary ingredients. Secondary ingredients include sugar, fat, salt. Certainly variation in the amount and source of these ingredients affects the nutrient composition of the product.

"Preservation Method" refers to the primary method used to prevent or retard spoilage. What are the effects of the preservation method upon the nutrient composition of foods? In a study of fruit juices, we found significant differences in the vitamin C content of chilled reconstituted juices and frozen concentrates.

The definition of specific product characteristics is only part of the evaluation process. We must also define other aspects of the manufacturing and distribution process. The location of manufacturing plants for classes and brands of products can be an important source of variation. Certain brands of cookies are manufactured in one plant for the whole country while other brands of cookies are produced at several plants. Other products, such as dairy products, sausages, and bacon are produced in many regional plants all over the U.S. Many of these products are not distributed nationwide.

We found that some brands of bacon are produced at various plants within a meat processing company. In many cases the brine specifications and pump rates for that brand are the same from plant to plant. However, at least one brand was marketed nationwide and produced by different meat processors. All processors producing that brand were not using the same brine specifications and pump rate. However, we could identify only the specific brand-plant combination that we picked up; fortunately we had access to the approved brine specifications for that product. Since bacon is so complex, we limited our objective to the estimation of a range of concentration for selected nutrients. The selected nutrients will be determined in products manufactured according to different brine specifications and pump rates. So, you see, the aspect of manufacturing plant location can be quite complex.

Quality assurance programs within each plant affect the amount of variability in the nutrient composition of a product. Fortunately, economic considerations force portion control and product standardization and, in turn, reduce product variability within each plant. A measure of lot-to-lot variability would be an indicator of quality control.

At this point, it is important to emphasize that we must consider the amount of variation, nutrient by nutrient, or at least define an indicator nutrient for that product type. As you know, some nutrients are affected more by a lack of standardization than others. Also, if the nutrient is inherent or bound to the raw ingredient, there may be less cause for concern than if the nutrient is added by spraying or mixing a solution or tablet into the recipe. We have observed large differences between labeled iron content and the analyzed iron content of several brands of RTE cereals. Let me emphasize that analytical values for most brands that we sampled were within $\pm$20% of the label value. However, for certain brands the iron values were between 160% and 260% of the label value. Mean values were derived from analysis of one package from each of three lots. Coefficients of variation for the mean values varied from brand to brand. In our experience, we have found that lot-to-lot variation or within-plant variation is of little concern except for special studies of quality assurance.

Moving from quality assurance, we may discuss the effects of season on nutrient variation. In the Nutrient Composition Laboratory we have not dealt with seasonal variation to any great extent. Many foods are harvested at one time and then stored until they are used in the manufacture of products. Other foods are harvested and are partially or fully processed soon after harvest. Still others have long shelf stability and are not affected by season. For certain projects, seasonal effects are worthy of consideration.

Having defined the characteristics of the product class to be sampled, and other relevant factors, one must determine the sampling plan to insure selection of representative samples. The use of statistically based sampling techniques insures the selection of samples which are representative of the population of products to be evaluated. Careful planning to determine the types and numbers of samples to be selected can prevent the collection of a biased sample and subsequent erroneous estimates of the extent of variation within the population of products.

After representative samples have been selected they must be prepared for nutrient analysis. Preparation may include dissection, cooking, weighing and other specific processing techniques. These procedures are usually followed by homogenization according to predetermined and carefully tested protocol under controlled conditions (time, temperature, and humidity). Subsamples of the ground food product are stored in appropriate containers according to conditions prescribed by the specific nutrient methods.

The final source of variation is nutrient analysis including all steps of the analytical procedure. The use of standard reference materials and control samples to facilitate accuracy, precision, and specificity of the technique must be considered (W. Wolf; J. M. Harnly et al.). Careful handling of the samples at every step with attention to timing, reagents, instrumentation, and environmental conditions will minimize the spurious and random variation which can occur.

These procedures for sample preparation and nutrient analysis should be evaluated and standardized to control unwanted variability which can mask the central issue, "What are the sources and extent of variation in nutrient composition data which are attributable to the food product, from the point of manufacture through distribution to the point of consumption?"

The evaluation of the sources and the extent of variation in nutrient composition data can permit the confident estimation of mean values of nutrients in foods. In addition, knowledge of the sources and amount of variation permits the maximum use of financial and human resources.

This general discussion of the sources and extent of variation in nutrient composition data will be discussed in greater detail in future papers to be published in the Journal of Food Science. References which have been included should supplement the present discussion and clarify certain general points.

Literature Cited

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