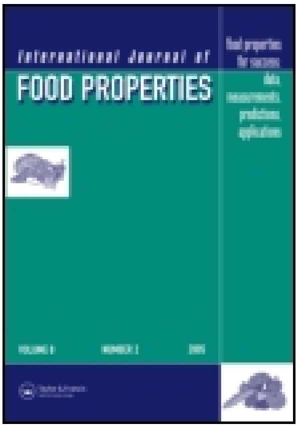

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DENSITY STANDARDS MEETING ORGANIZED BY PURDUE UNIVERSITY: A REPORT

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SUMMARY

A food density measurement meeting was convened at Purdue University March 15–16th, 2011. The agenda of the meeting was to address the problems involved with measuring the volume of food products and predicting density. Currently, there are no standards available for accurately measuring and predicting the density and porosity of foods. Given this problem, the objective of this meeting was to establish a consensus as to which methods would be most viable to pursue for measuring and predicting the density and porosity of foods and to determine the right track for future research. Several experts from various research institutions and industry were invited for the discussion.

COMMENTARY

Martin Okos, Professor of Agricultural & Biological Engineering, Purdue University and Carol J. Boushey, Professor of Food & Nutrition, Purdue University and their research group are currently working on using mobile technologies to estimate nutrient and calorie intake (Technology Assisted Dietary Assessment, TADA). Nutrient databases are populated on a food weight basis; therefore it is necessary to determine the weight of the food before dietary analysis can be made. In this particular regard, the volume assessed using image analysis is converted to gram weight using the conversion factor, density.

Mohammad Shafiur Rahman, Professor of Food Science and Nutrition, Sultan Qaboos University, Oman gave a detailed background on the available and conventional methods to determine density of foods. In general density is defined as mass per unit volume. In the literature different types of density are defined considering different forms of volume. These include true, substance, material, particle, apparent, bulk-particle and bulk density. Apparent density, material density, and apparent porosity are most commonly used density measures. The conventional measurement techniques of these three density measures were discussed based on its definition by emphasizing their advantages and limitations. The simplest method of measuring apparent density is to measure the volume of a regular geometric object based on its geometric dimensions. Other complicated methods

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are based on buoyant force, liquid and gas pycnometer, and solids displacement. The material density could be estimated simply by assuming it as true density. True density can be estimated from its components' densities considering conservation of mass and volume. Other methods are liquid and gas pycnometer including mercury porosimetry, and gas adsorption methods. Any specific method is not suitable for all situations, thus an attempt needs to be made to explore the valid conditions of these measurement methods so that appropriate selection and measures could be taken.

Shivangi Kelkar, a graduate student at Purdue University, explained that for porous foods such as grain food products, accurate measurement of density is challenging. Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are non-destructive diagnostic tools useful for studying such food microstructure. Preliminary experiments on the MRI were encouraging. CT was successfully used to calculate the porosity and the apparent density of baked foods. Density values were comparable and similar to those obtained from the displacement technique. CT and MRI have great potential for complex food systems as a full 3D image can be obtained. The image analysis of the microstructure including the size, shape, networking, connectivity and distribution of various phases is possible with good resolution. However, better tools need to be established to effectively use the 3D image data for density. This will assist enhancing the density prediction process for all kinds of complex food systems. The research work in this direction is currently under progress.

The method that was proposed by Scott Stella, a graduate student at Purdue University, to fill in missing data in existing databases and to provide ground truth volume information for the image analysis portion of this project was the use of a three dimensional laser scanner. A potential benefit of such a device is the lack of subjective results. Current methods for density measurement require significant amounts of sample handling and cannot account for complex food mixtures such as a sandwich or a salad both of which may have many layers. With this imaging technique the databases can be populated with the required volume, and therefore density, information for use with the mobile phone application. He further discussed the different predictive techniques which can be employed for predicting food density. In the Food and Nutrient Database for Dietary Studies (FNDDS) there is sufficient information to calculate true density from the nutrient information using the Choi-Okos equations, a set of empirical equations relating food composition to physical properties including density. These equations, however, do not account for air voids or packing voids and therefore cannot be used for apparent or bulk density calculation. FNDDS does include a large section on portion size and portion weight which can be used to calculate these densities, however, the most complete portions of this data fall within the true density regime and lists ambiguous portion sizes for the foods that would fall into the other two categories such as "1 cup diced" and "one piece." A multi-step algorithm is needed to predict food density that uses regression equations, FNDDS food categories, and feed forward artificial neural networks which are situationally coupled with mechanistic transport equations. As more information about ingredients and process become known mechanistic equations, ie. heat and mass transfer and reaction kinetics, can be applied to reduce the dimensionality of the input space of the neural network-thus allowing a larger number of hidden layer neurons. Ultimately density can be predicted solely on mechanisms, but until those mechanisms are fully understood and computation becomes more efficient, quality density data will be required to train these machine learning techniques

John C. Russ, Professor Emeritus, Materials Science and Engineering Department, North Carolina State University, Raleigh, gave a detailed background about using image processing for determined volume and density of foods. Measurements of the microstructure of food are often performed using images from microscopes (light, electron, stylus, etc.) and to some extent using CT or MRI scans. The greatest efficiency for obtaining metric parameters such as volume fractions, surface areas, lengths and curvature utilizes stereological rules based on simple measurements on random 2D sections. Topological parameters such as the number of objects and the connectivity of networks require a minimum of two parallel section planes. Full 3D volumetric imaging, either using the confocal light microscope, destructive sectioning, or tomographic reconstruction, is much more costly and does not typically produce higher quality data because of limitations in resolution. These structural properties do not directly provide density information. Some measurements of density based on absorption or emission rules for photons or electrons can be made, and of course if the component densities are known, they can be used with measured volume fractions to calculate overall density. Examples were shown of the principal measurement methods, both for discrete objects and internal structures, along with some of the image processing steps necessary to make them possible, with the intent to elicit specific questions.

Considerations for estimating food density with magnetic resonance imaging were discussed by Gregory Tamer, PhD from Purdue MRI Facility. Current research at the Purdue MRI Facility involving high-resolution MR scanning of bread slices and FiberOne bars did not yielded sufficient data to estimate density. Possible solutions for attaining usable images for density estimation and the viability of estimating food density using MRI include scan time for one food item and financial cost of that scan, identifying voids/air pockets vs. solids (e.g., chocolate chips), and confidence level of food density estimation given noisy measurements acquired with MRI were considered.

Rose Tobelmann MS, RD, LD from General Mills, Inc gave the food industry perspective. Food industry is required to provide nutrition information for all foods intended for human consumption and offered for sale to the consumer. This information must be declared in relation to a serving whereby a serving is the amount customarily consumed. FDA has determined the Reference Amounts Customarily Consumed (RACC) for foods which are used when determining serving sizes. Product densities are determined when a food is sold in a multi-serving package or when the RACC is stated for the prepared version of the food. There are specific procedures followed to determine product densities. These procedures vary depending on the type of product. Examples of density methods for various product types were presented.

Carrie Martin, MS, RD, a nutritionist with the Food Surveys Research Group at the USDA, Beltsville Human Nutrition Research Center provided a background on the USDA Food and Nutrient Database for Dietary Studies (FNDDS), 4.1. FNDDS is an extensive database of foods as consumed in the U.S used to code foods and portion sizes and to calculate nutrients for the large-scale Federal food consumption survey, What We Eat in America (WWEIA), the dietary intake component of the National Health and Nutrition Examination Survey (NHANES). FNDDS contains information for more than 7,000 foods, including values for energy and 64 other nutrients, as well as weights for common portions of foods. Many of these values are derived from the USDA National Nutrient Database for Standard Reference, release 22. FNDDS is regularly updated to reflect the current state of the U.S. food market and to support processing of WWEIA. New versions of FNDDS are released every two years to accompany the release of the NHANES dietary intake data. The most recent version of FNDDS (version 4.1) was used to process intakes from WWEIA, NHANES 2007–2008. Extensive documentation accompanies the database. The database may be used in conjunction with research utilizing dietary data from WWEIA, NHANES 2007–2008, or it may be used in other dietary studies. The database is available for downloading from the FSRG Web site (http://www.ars.usda.gov/ba/bhnrc/fsrg).

Robin Thomas, MS, RD from the USDA-ARS Beltsville Human Nutrition Research Center, Beltsville, MD gave information about the weights and measures included in the USDA National Nutrient Database for Standard Reference (SR). It includes common household measures with corresponding gram weights for most food items. The weights and measures in SR are derived from multiple sources, including the USDA National Food and Nutrient Analysis Program (NFNAP), food industry files, published sources, and U.S. Agricultural Marketing Service standards. As part of NFNAP, Virginia Tech and other collaborators weigh specified measures of foods that are composited for nutrient analysis. They also weigh refuse in foods such as fruits, vegetables and meats in order to calculate the percent refuse. In recent years they have been photographing these foods, as well, often next to a ruler when appropriate. SR23 has 13,200 weights and measures. Of the 7636 food items in SR, close to 95% (7111) have at least one household measure. Raw tomatoes and glazed doughnuts have the most at 13 different measures. Over 2500 food items have cup measures and about 70% of those are fruits, vegetables, breakfast cereals, soups, and legumes. MS Access can be used to sort the cup weights from highest (corn syrup, 341 g) to lowest (freeze-dried chives, 3 g) to help estimate density. The SR weights and measures (volumes), % refuse, and other documentation may help with the development of methods to predict food density.

CONCLUSION

The conclusion of the meeting was that clear definitions for material, true, particle, apparent, bulk-particle, bulk densities are needed. The scientific community is unaware of the complexity of density resulting in incorrect usage. A universal measurement method food density measurement in needed. The research on using x-rays for directly measuring density looks promising and has great potential. Density prediction using stepwise regression using the data from FNDDS, SR database, FDA RACCs and nutrition labels was suggested and is currently under progress.