report

Field Reports

Nutrient Density as a Dimension of Dietary Quality

Part I: Theoretical considerations of the nutrient-density approach in a multicenter evaluation

Marieke Vossenaar, Noel W. Solomons
Center for Studies of Sensory Impairment, Aging and Metabolism (CeSSIAM), Guatemala City, Guatemala

Eva Monterrosa, Kesso Gabrielle van Zutphen
Sight and Life, Basel, Switzerland

Key messages

> The approach of expressing nutrient density in the description of dietary intake for individuals and populations provides an additional dimension by emphasizing the role of the background diet.

> A nutrient-density expression is a ratio, with the numerator as a value of nutrients (e.g., nutrient units, percentage of recommended intake) and the denominator as a quantifier of the diet (e.g., portion size, weight, volume, dietary energy).

> The 'critical nutrient density' is a reference value for a person or population derived from the recommended daily intake for a specific nutrient in the numerator and daily energy requirements as the denominator, typically expressed per 1000 kcal.

> When a diet is constituted with at least the critical nutrient density, one is assured that the requisite amount of a nutrient of interest will be consumed when energy needs are met.

> The nutrient-density approach is a handy tool for both planning and evaluation of diets.

Background and context

The late Prof. Doris Calloway is quoted as noting, during the process of revising the Recommended Dietary Allowances of the United States, that: *"People eat foods, not nutrients."*[1] Nevertheless, the product of the effort was a refined tabulation of the daily recommended intakes of the essential macro- and micronutrients. When planning or evaluating the adequacy of diets, the focus has remained on these two-dimensional tables of recommendations, whether they be from the Dietary Reference Intakes,[2] United Nations agencies,[3] or European Food Safety Authority[4] processes; these are limited to matching a quantity of a specific nutrient to an average or protective level of daily intake.

If we return to first principles, the fundamental origins of essential nutrients are the foods and beverages in the diet. To meet the intakes that satisfy the needs of individuals, an assortment of nutrient-rich foods or of less-nutritious foods needs to be consumed in enormous quantities. A combination of these two dietary patterns was operative in the hunter-gatherers of Paleolithic prehistory. The clan would subsist on the energy from roots, tubers and herbs during their quest for the animal of the hunt, and then gorge themselves with the abundant nutrients of the muscle and viscera of their prey. With the advent of primitive agriculture, farmers expended large quantities of energy toiling in their potato or cassava fields, or their maize and millet plots, extracting sufficient vitamins and minerals from the bulk of the tubers and grain staples ingested.

In the modern era, agriculture is increasingly mechanized, and more than half of the world's population lives in urban settings. On the one hand, this has limited the amount of food (the number of calories of daily energy) that can routinely be consumed. On the other, however, the diets are still based on carbohydrate-rich root, tuber, and cereal staples with limited availability of animal-source foods.

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Currently, the world is undergoing an epidemic of obesity.[5,6] The large body size, with additional weight to carry and greater muscle mass to support it, should theoretically obligate persons with obesity to consume more energy than those of normal weight. In a more constrained extent, the margin for consuming a lower-quality diet by virtue of a larger total amount is analogous to that of the primitive agriculturalist.

Nutrient density: Definition and concept

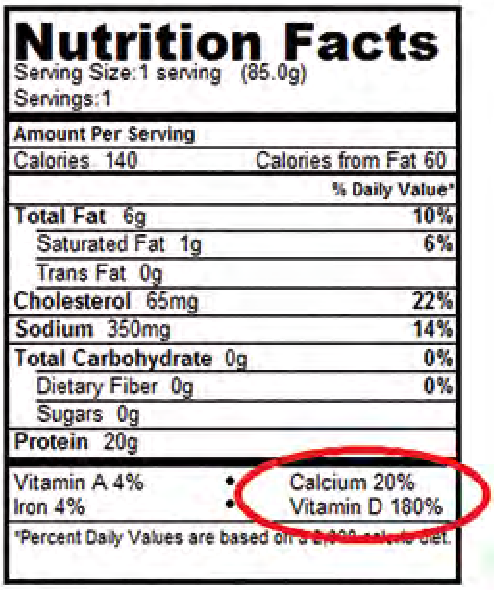
A nutrient-density expression is formed as a ratio, with a numerator and denominator. To understand the concept, it is necessary to specify the nature of the numerators and denominators that make up the expression.

The nature of the numerator: In the numerator is a quantity of a macro- or micronutrient, either in gravimetric or molar units or else as a percentage of adequate intake. This could be 40 mg of vitamin C, 2 mg of copper, or 20% of the Daily Value (DV) for sodium, for example. It can represent either the amount offered in a preparation or menu, or an amount estimated to have been consumed.

The nature of the denominator: In the denominator is a measure for a quantity of food or beverage, also as offered or consumed or, in a special application, as an amount theoretically required. The elements of the denominator can be expressed in multiple manners, including serving portion (unitary), net weight (grams), liquid volume (mL), or a quantity of dietary energy (kcal or kJ).

BOX 1: The nature of the ratio as density

The most common and familiar application of a nutrient-density expression in daily life is found on the Nutrition Facts panel on the nutritional label of commercial food products.



Nutrition Facts
Serving Size: 1 serving (85.0g)
Servings: 1

Amount Per Serving	
Calories 140	Calories from Fat 60
	% Daily Value*
Total Fat 6g	10%
Saturated Fat 1g	6%
Trans Fat 0g	
Cholesterol 65mg	22%
Sodium 350mg	14%
Total Carbohydrate 0g	0%
Dietary Fiber 0g	0%
Sugars 0g	
Protein 20g	
Vitamin A 4% • Calcium 20%	
Iron 4% • Vitamin D 180%	

*Percent Daily Values are based on a 2,000 calorie diet.

Let us exemplify the concept with a hypothetical product offering a specified percentage of the Daily Value (DV) for calcium:

20% of the calcium DV per serving

This can also be interpreted as one getting 100% of the DV by consuming five servings in a day.

The current DV of the Food and Drug Administration is 1300 mg for calcium. This would mean that, in quantitative terms, the numerator would become 260 mg of the mineral. The density expression by serving is transformed to:

260 mg of calcium per serving

The density expression can be transformed to a weight or volume basis, as the label also describes what the manufacturer defines as a serving portion. In the case of the product of interest, a serving weighs 160 grams. This would represent 1.625 mg per gram. Since a denominator of 100 g might be most conventional and convenient, the weight-based nutrient-density expression becomes:

162.5 mg per 100 grams of product

The nutrition label also reports the calories (kcal) in a serving, such that one can base the density denominator on energy. The 100 g serving of this product provides 200 kcal. The conventional energy-based nutrient-density expression has a denominator of per 1000 kcal. The numerator would then be multiplied fivefold. Thus, the energy-related density for this product becomes:

812.5 mg per 1000 kcal

This calculation approach can be generalized for any food or beverage in a food composition database, relating the 100 g portion's content extrapolated to 1000 kcal of energy.

The concept and definition of critical nutrient density: One can expand the nutrient-density concept to a prescriptive or reference fashion by assigning the denominator energy to the individual daily energy requirement, or more commonly to the reference energy needs for a specific class of individuals, such as preschool children or adult men. The resulting expression is called the 'critical nutrient density.' The numerator is the reference daily requirement for a specific nutrient for an individual of the class. This can be the protective value, such as the Recommended Dietary Allowance (RDA) of the Dietary Reference Intakes (DRI) or the Recommended Nutrient Intake (RNI) of the UN agencies series. Alternatively, it could be the population-normative Estimated Average Requirement (EAR) value.

Nutrient density was illustrated for calcium in the previous section. The DV value of 1300 mg corresponds to the recommended dietary allowance for an adolescent boy. That would be the numerator value for the critical nutrient density for this population class. It is conventional to assume a daily energy intake of 2000 kcal, as is done for the Nutrition Facts labeling procedure in critical nutrient-density creation. A first approximation around the 1300 mg value for calcium would be 650 mg/1000 kcal. However, adolescent boys as a group have a higher daily energy expenditure, estimated at 2800 kcal/day. Expressed in conventional denominator terms, this would yield 464/1000 kcal for the more refined critical nutrient density for calcium in male adolescents at the RDA recommendation level. This age-group has an EAR for calcium of 1100 mg/day, such that the critical nutrient density based on the population distribution assumptions would be 393 mg/1000 kcal.

A brief history of nutrient-density concerns

When the ratio procedure described above is used, it represents a nutrient-density application. The approach dates back at least three decades – a period during which the estimates of both human energy requirements and specific micronutrient recommendations have been refined by ongoing research and advanced conceptual innovations.

Nutrient-density-based dietary guidelines: There have been two important international initiatives using the nutrient-density approach and the critical nutrient-density criterion. The first was undertaken in 1986 by an ad hoc committee of Latin American nutritionists convened in Caracas, Venezuela, which in the following year published a report entitled *Guías de Alimentación: Bases para su Desarrollo in América Latina* [Food Guidelines: The bases for their development in Latin America].[7] It reasoned, quite correctly, that planning and evaluation using the recommended allowances of the era was a cumbersome procedure. Based on the cultural practices of families of the region consuming the majority of their meals in congregate fashion, the dietary fare consumed in the home became the fulcrum for positive change.

There was general consensus in the 1980s that the requirements for the cofactors in the Krebs cycle chemistry for ATP generation in the mitochondrion were related to the amount of energy presented to the body. The relationships for thiamine, riboflavin and niacin were 0.4, 0.6 and 7.0 mg, respectively, per 1000 kcal. This was the model standpoint. For critical nutrient-density calculation for adults of both sexes, they assumed a daily energy requirement of 2000 kcal, with lesser amounts at younger ages. So, this process was extended, with the assumption that a critical nutrient density could be assigned for all nutrients that cover the needs of the most sensitive individual in the family unit, and the value was expressed per 1000 kcal. The Guidelines document contains a table in which the protective (for positive essential nutrients including protein and fiber) or the non-offensive (for negative nutrients such as sodium) nutrients are outlined.[8] According to the rationale of the conveners, any family that followed all of the nutrient-density guidance in the document would assure appropriate nutrient intakes for most members. There are exceptions within the family unit: exempted from Guidelines were infants, pregnant and lactating women and the elderly of the family, as each of these groups has special circumstances or nutrient needs that do require adaptation of the diet.

The Cavendas Report[7] was widely discussed and circulated, but it never became a working guideline for any part of the Latin American region. To this date, Latin American countries have relied on the international recommendations of the UN agencies, on the US-Canada Dietary Reference Intakes, or on their own, national formulations. We feel that the conceptual approach for nutrient-density-based dietary recommendations was a visionary one with possibilities for the needs in the 21st century.

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Nutrient density and complementary feeding

Two decades ago, in 1998, Brown, Dewey and Allen addressed a very vexing feeding problem for young children using the nutrient-density and critical nutrient-density approaches in the WHO/UNICEF monograph *Complementary Feeding of Young Children in Developing Countries: A Review of Current Scientific Knowledge*.[9] It had a dual relationship with nutrient density. The nutrient density for the diet of an exclusively breastfed infant is effectively the cumulative nutrient concentrations in human milk. However, breast milk's capacity to support growth is exceeded in the seventh month of life, when additional energy, protein and micronutrients are needed to address an expanding requirement.

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The fare prepared with the texture and presentation suitable for an edentulous infant, in the forms of gruels, porridges and compotes, is termed 'complementary food.' The term implies its role, to complement the nutritional delivery of human milk, which remains the most important source of food through the second semester of life. After accounting for the energy contribution of a day's intake of maternal milk, complementary food closes the calorie gap. This can be as little as 100 kcal. The simultaneous process, however, is that the vitamin and mineral delivery from breast milk also becomes insufficient for growth and nutritional reserves. With a limited denominator allowance of energy in the complementary feeding, the nutrient density of the fare emerges as a focus of concern. What Brown and colleagues[9] achieved in their monograph was a way of determining the critical nutrient density for specific nutrients in complementary feeding and what food combinations could supply the amounts needed in small volumes. Models to maximize nutrient density in complementary foods were developed for many vitamins and minerals. A general conclusion was that vitamin A, calcium, iron and zinc were 'problem nutrients,' which defied satisfaction from food combinations and required fortification to meet requirements of the mixed-fed nutrients.

"There has been a resurgence of interest in the use of the nutrient-density concept"

Contemporary applications of nutrient density

In recent years, there has been a resurgence of interest in the use of the nutrient-density concept. This is amply manifested in the concepts and applications of 'nutrient profiling' put forward by Adam Drewnowski.[10,11] Two of the present authors drew out some aspects of nutrient density in terms of the Guatemalan situation to renew its application.[12–14] Forums on nutrient density have appeared at major international nutrition meetings, such as the CeSSIAM-sponsored satellite symposium at the International Congress on Nutrition in Buenos Aires, Perspectives on Nutrient Density: Too Little and Too Much. More recently at the Nutrition 2018 meeting of the American Society of Nutrition in Boston, an evening symposium entitled "Academia and Industry Working together toward a Common Goal: Increasing Nutrient Density of the Diet" was presented with a panel from leading industries.

Correspondence: ***Dr M Vossenaar,***
Center for Studies of Sensory Impairment,
Aging and Metabolism (CeSSIAM), 17 Avenida no. 16–81, Zona 11,
Guatemala City 01011, Guatemala
Email: *mvossenaar@hotmail.com*

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