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Original Article

Sodium and potassium in composite food samples from the Canadian Total Diet Study

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ABSTRACT

Sodium (Na) and potassium (K) are essential nutrients. Like people in many Western societies, Canadians consume too much Na and not enough K, both of which contribute to hypertension. We analysed the Na and K content of 154 food composites, broadly representative of the foods most commonly consumed in Canada, from the Canadian Total Diet Study collection of 2007. Foods were prepared as if for home consumption before compositing. No salt was added during food preparation. Samples prepared by aqueous extraction were analysed by atomic emission (Na) or atomic absorption spectrometry (K). Processed foods and soups contained large amounts of Na per reference amount (serving) of the food, with 17 samples containing over 1/3 of the Adequate Intake (AI) for adults, or >500 mg Na/serving. Fluid milk, unprocessed meats and several fruits and vegetables contained large amounts of K per reference amount, with 11 samples containing over 10% of the AI for adults, or >470 mg K/serving. Na:K molar ratios were typically either high or low, with few values near unity. Thus, with few exceptions, foods high in Na were lower in K, and vice versa. Through judicious food selection it may be possible for consumers to decrease Na intake while increasing K, with associated health benefits. Such choices would be consistent with common nutrition advice to decrease consumption of processed foods, while increasing intakes of fresh fruits and vegetables.

1. Introduction

Sodium (Na) and potassium (K) are essential mineral nutrients (Institute of Medicine, 2005). In North America, the Adequate Intake (AI) for Na has been set at 1500 mg/d for adults. This value is higher than the purported physiological requirement, but takes into account the requirements for other nutrients in an achievable diet and allows for higher Na losses in unacclimatized people exposed to warm temperatures or moderately active people (Institute of Medicine, 2005). The Tolerable Upper Level of Intake (UL) for Na was set at 2300 mg/d based on blood pressure elevation as documented in dose-response trials. The AI for K was set at 4700 mg/d in adults based on lowering blood pressure, reducing bone turnover and kidney stone formation. Due to generally low intakes of K in the North American population and its ready excretion given normal kidney function, no UL was established for K (Institute of Medicine, 2005).

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Many people in Western societies consume too much Na and not enough K, both of which contribute to the high prevalence of hypertension in these populations (He and MacGregor, 2001, 2009). Chronic, progressive hypertension is strongly associated with adverse functional and structural vascular and cardiovascular changes leading to multi-organ damage, morbidity and death (Heart and Stroke Foundation of Canada, 1999). High salt intake has been associated directly with increased risk of stroke and total cardiovascular disease in a meta-analysis of 19 independent cohort samples from 13 studies (Strazzullo et al., 2009). The estimated total direct health care cost savings in Canada of Na intake reduction to a level near the AI would be $1.38 billion; growing to $2.99 billion if indirect costs were also included (Heart and Stroke Foundation of Canada, 1999). Increasing K intake is associated with lowering of blood pressure and the effects of increasing K intake are additive to the effects of lowering Na intake (He and MacGregor, 2001). Thus ongoing monitoring of both Na and K in foods is important in order to gauge progress towards optimizing dietary management of blood pressure in the population.

Total Diet Studies (TDS), known in some regions as Market Basket Surveys, are promoted by the World Health Organization as an efficient means of monitoring for contaminants in the food supply. Although there are acknowledged limitations arising from food selection and compositing of food samples prior to analysis,

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the TDS has been used for many years in the United States to track changes in food composition, including mineral nutrient levels, over time (Pennington, 2000). TDS have the advantage that foods being analysed have been prepared as if for household consumption, rather than being analysed raw or as purchased (Leblanc et al., 2005). The representative nature of the Canadian TDS collection (Health Canada, 2009), which is designed to represent the majority of the foods commonly purchased in Canada, suggested to us that these samples should also be useful for monitoring Na and K in the Canadian food supply. TDS have been conducted in Canada since 1969, although the pattern of sampling and compositing of the food samples purchased has undergone some changes over the decades (Conacher et al., 1989). TDS samples from 1974–1975, collected from Halifax, Montreal, Winnipeg and Vancouver, had been composited into 10 food groups and assayed for Na and K, showing 2–5-fold higher than recommended intakes for Na (depending on age/sex group (Shah et al., 1982)). Based on those analyses, K intakes were sufficient to meet the recommendations of that time (Shah et al., 1982), although the calculated intakes in that report fell below the current AI value for K.

Current activity in the Canadian TDS involves collecting samples in one city per year such that five regions across Canada (British Columbia, Prairie provinces, Ontario, Quebec, and Atlantic provinces) are represented in a five-year cycle. The present study, based on samples collected in Vancouver, Canada in 2007 is the first report of Na and K in Canadian TDS samples in several decades.

2. Materials and methods

2.1. Samples and preparation

Samples analysed for this study were collected in Health Canada's TDS program (Health Canada, 2009). The TDS collection in 2007 involved the purchase of a total of 930 food units, representing the most popular brands based on supermarket shelf space, purchased at 4 different retail outlets (supermarkets or fast food restaurants, as appropriate) in Vancouver, Canada. Purchased foods were delivered to the Food Laboratory at the Kemptville, Ontario campus of the University of Guelph where they were processed and prepared as if for normal home consumption (washing, trimming, cooking, etc., as appropriate). Foods were combined in specified ratios to yield a total of 154 food composite samples, which were homogenized and stored frozen (at $-20\,^{\circ}C$) in 250 ml wide-mouth Nalgene bottles until analysis. Where needed, tap water from the Kemptville Food Laboratory was used for cooking, and was included as a separate composite in the analyses (labelled "tap water, kitchen"; note that "tap water, sample area" was collected from the city of the TDS collection, in this instance Vancouver). No salt was added during or after food preparation.

2.2. Sodium and potassium analyses

Triplicate subsamples of each food composite were prepared by an aqueous extraction method (Health Protection Branch Laboratories, 1983). Briefly, this process takes advantage of the high water solubility of Na and K found in food matrices, and as such is not well suited to analyses of other elements. Accurately weighed portions of approximately 1 g were mechanically homogenized and dispersed in 25 ml deionized water to achieve dissolution of Na and K (Kinematica/Polytron rotor/stator laboratory homogenizer, Brinkmann Instruments, Rexdale, Canada). The homogenization apparatus was thoroughly cleaned, by rinsing with deionized water followed by acetone drying, between samples. After filtration using Whatman 541 filter paper, the particle-free filtrate was diluted appropriately (minimum two-fold) in dilute nitric acid containing $CsCl_2$ (1000 μg/ml) as matrix modifier.

Sodium was determined by flame emission spectrometry (wavelength 589.0 nm, slit 0.2 nm) and potassium by flame atomic absorption spectrometry using an element-specific potassium lamp (wavelength 769.9 nm, slit 1.0 nm) on a PerkinElmer AAnalyst 400 (PerkinElmer, CT). Standard curves were prepared using solutions prepared from 1000 mg/kg stocks in 4% HNO_3 (SCP Science, Montreal, QC, Canada). Quality control measures with each run included use of standards as check samples and recovery of Na and K from standard reference materials (SRMs) which had been prepared by the same aqueous extraction method as the test samples: SRM1577b Bovine Liver (certified content: Na 0.242 ± 0.006 wt%, K 0.994 ± 0.002 wt%) or SRM1549 Non-fat Milk Powder (certified content: Na 0.497 ± 0.010 wt%, K 1.69 ± 0.03 wt%) (National Institute of Standards and Technology (NIST), Gaithersburg, MD). RM8414 Bovine Muscle (content: Na 0.210 ± 0.008 wt%, K 1.517 ± 0.037 wt%) and SRM1571 Orchard Leaves (certified content: Na 82 ± 6 μg/g, K 1.47 ± 0.03 wt%) from the same supplier were also used in validation of the method in our laboratory.

2.3. Calculations and presentation of data

Detection limits (DL) were empirically determined based on three times the SD of 16 replicate blank readings for a typical $50\times$ preparation (i.e. 1 g of sample in a 50 ml minimum volume as analysed). The DL determined in this way for Na was 2.4 mg/kg sample wet weight; for K the DL was 1.5 mg/kg sample wet weight. Composite food samples in total diet studies in Canada and elsewhere are commonly grouped according to similarity of source or use of the foods (though the exact groupings may differ from country to country). For calculation of group averages, samples containing less than the DL were assigned a value of one-half the DL. Results of Na and K analyses are presented for each TDS food composite group and for each individual food composite as mean $\pm$ SD based on wet weight of sample, to represent the food as consumed.

Analysed concentration values can have important limitations when comparing different foods, as people habitually eat different amounts of different foods in a "serving". The reference amount of a food, as defined in Part B, Division 1 of Canada's Food and Drug Regulations (Canada, Department of Justice, 2009) can be used as a proxy for serving size. Similar definitions of typical servings exist in the United States (US Government Printing Office, 2009) and in other jurisdictions. Canadian food regulations also define Reference Standard amounts of Na and K for use in food labelling: the reference standard for Na in Canada is 2400 mg and for K is 3500 mg. These definitions are used by food manufacturers in preparing the Nutrition Facts Table on the package label, and by the Canadian Food Inspection Agency in their programs for monitoring of food labelling accuracy (Canadian Food Inspection Agency, 2009). Na and K concentrations per reference amount of food were calculated and reported in this work, and compared to the Reference Standard amounts. Because the ratio of Na to K has been shown to be important in blood pressure (Stamler et al., 1989), the Na:K molar ratio was also calculated for each of the food composites in this study.

3. Results

The aqueous extraction, atomic spectroscopy method used in this study shows a high degree of accuracy for Na and K in a variety of sample matrices. Typical within-run recoveries from standard reference materials for Na were: SRM1577 Bovine Liver 100.2% of the certified value; RM8414 Bovine Muscle 100.2%. Typical within-run recoveries for K were: SRM1577 Bovine Liver 114.0%; RM8414 Bovine Muscle 103.5%; SRM1571 Orchard Leaves 98.5% of the certified value. Inter-day reliability results derived during the