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Availability of essential trace elements in Indian cereals, vegetables and spices using INAA and the contribution of spices to daily dietary intake

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Abstract

Indian diet is primarily vegetarian and consists of various cereals and vegetables along with spices, often used in the preparation of curries. The nutritive potential of each ingredient, in terms of trace element contents, has been evaluated using instrumental neutron activation analysis (INAA). Four minor (Na, K, P and Cl) and 16 trace elements (Br, Co, Cr, Cs, Cu, Fe, Hg, Mn, Mo, Rb, Sb, Sc, Se, Sr, Th and Zn) have been determined in six cereals, nine vegetables and 20 spices and condiments, including two betel leaves. None of the carbohydrate-rich cereals or potato was rich in any of the essential elements but leafy vegetables showed higher contents of Fe and other nutrients. Fe/Zn is well correlated with Fe contents in cereals and spices. Out of various spices, cinnamon was most enriched in Fe, Co, Cr, Na, K, P and Zn, whereas turmeric and curry leaves were found to be particularly rich in Se. Cumin and mustard seeds were rich in Cu. Some environmental contaminants, such as Hg, Cr, Br and Th, were also present in significant amounts. An attempt has been made to evaluate the contribution of essential elements (Cr, Cu, Fe, Mn, P, Se and Zn) in spices to the daily dietary intake (DDI) through an Indian vegetarian diet. For a typical mixture of six commonly used spices, contributions of Cr, Fe, Mn and Zn, were found to be 7.5% of DDI in each case.

Keywords: Cereals; Vegetables; Spices; Essential nutrients; Instrumental neutron activation analysis; Daily dietary intake; Toxic contaminants

1. Introduction

It is now well recognized that several trace elements are essential constituents of enzymes and play a vital role in human metabolism. All the nutrient elements are primarily supplied through diet. However, this may change, depending on age, sex, health status, geographical and climatic conditions (O' Dell & Sunde, 1997; Prasad, 1993). For all the elements essential for metabolism, there exists a range of intake over which their supply is adequate for the body. However, beyond this range, deficiency and toxic effects are observed (Merian, 1991). Therefore, it is essential to determine elemental contents of food items and to estimate their daily dietary intake (Jansen, Kandall, & Jansen, 1990). WHO and the Indian Council of Medical Research (ICMR) have recommended selective studies of individual foodstuffs as an important step in the estimation of dietary intake of trace elements (ICMR, 1987; WHO, 1985). The American Chemical Society has published a monograph on antioxidant properties of spices often used in the preparation of vegetable curries (Risch & Ho, 1997).

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The Indian vegetarian diet primarily consists, typically of bread baked at home, boiled rice and curries prepared from pulses (lentils) and vegetables, including spices added during cooking. Though bread is often made from wheat flour, other cereals, such as maize, barley, millet and sorghum, are also used, depending on the region or socio-economic status. Indian curry is spiced with salt, red chilies and other spices, such as turmeric & coriander powder, depending on individual taste and other considerations. Besides, condiments such as cloves, black pepper, cardamom and bay leaves are also used to spread over cooked/fried rice and curry preparations. Several workers have discussed the constituents of these spices in terms of their volatile oils and other vitamin contents (Gopalan et al., 1999; Pruthi, 1999). Pruthi (1999) has extensively reviewed various characteristics and determination of chemical and toxic constituents of Indian spices. Gopalan et al. (1999) have compiled selected elemental data for various food items, including cereals, vegetables and spices used in different parts of India. Crosby (1977) reviewed determination of metals in food items from all parts of world. Ila and Jagam (1980) reported 24 elements in six Indian spices. Abou-Arab and Abou-Donia (2000) have determined heavy metal contaminants in Egyptian spices.

Several workers have analyzed individual food items of their respective countries or regions and calculated the contributions of trace elements to the total dietary intakes (Bro, Sandstrom, & Heydorn, 1990; Cunningham & Stroube, 1987; Dermelj et al., 1996; Laiyan, Ying, Wei, & Xi, 1991; Liu, Chung, Chuang, Wang, & Aras, 1991; Mannan, Waheed, Ahmed, & Qureshi, 1992; Sarmani, Wood, Hamzah, & Majid, 1993; Wieteska, Zioiek, & Drzewienkka, 1996). Cunningham and Stroube (1987) analyzed many food composites as part of a study conducted by the Food and Agricultural Organization of the UN. Laiyan et al. (1991), Mannan et al. (1992) and Sarmani et al. (1993) have estimated intake of essential and toxic trace elements in Chinese, Pakistani and Malaysian foodstuffs, respectively. Wieteska et al. (1996) have determined eight elements (Al, Ca, Cd, Cu, Fe, Mg, Pb and Zn) in Polish vegetables. Miyamoto, Kajikawa, Zaidi, Nakanishi, and Sakamoto (2000) determined 26 trace elements in food spices and pulses of different origins by NAA and PAA. Dermelj et al. (1996) and Favaro et al. (2001) have employed NAA for the determination of some essential and toxic elements in food articles in Slovenian and Brazilian nursery diets. In an extensive study, Srikumar, Kallgard, Ockerman, and Akesson (1992) investigated the change in trace element status by switching from a mixed to a lacto-vegetarian diet in Sweden. As part of a IAEA Coordinated Research Programme (CRP), intakes of essential and toxic elements have been estimated in day-to-day foodstuffs (Cortes-Toro et al., 1994).

In view of such studies from other parts of world, we have also analyzed raw as well as cooked, Indian vegetarian diets, including dietary components, by instrumental neutron activation analysis (INAA) and compared daily dietary intake (DDI) with the Recommended Dietary Allowances (RDAs) (Samudralwar & Garg, 1994; Singh & Garg, 1997). In continuation we report here the analyses of six cereals, nine vegetables and 20 spices and condiments, along with two betel leaves, for 20 elements, by employing INAA. The contribution of spices to the daily dietary intake has been estimated on the basis of a typical Indian vegetarian diet formulation (Gopalan et al., 1999). Four biological standard reference materials (SRMs) of plant origin including our data on participation in the intercomparison study of spinach, IAEA-331, are also presented for quality assurance and data validation.

2. Materials and methods

2.1. Sample preparation

All the food articles including cereals, vegetables, spices and condiments, in raw form, were procured from the local market. The quality of the cereal grain was so chosen as that consumed by the middle-income group. In each case, 3–5 samples were collected at intervals of a few days or from different stores, so as to have representative samples as far as possible. The seed type items, such as rice, wheat, fenugreek and black pepper, were wipe cleaned with tissue paper, dried under an IR lamp at ~80 °C and crushed to powder in a food processor/mixer and then in an agate mortar. Leafy and other vegetables were thoroughly washed with distilled water so as to remove all the dirt and surface contamination. All the samples were dried in an oven at <80 °C for overnight and crushed to powder in an agate mortar to a uniform particle size (50 mesh). All the replicate samples of different food products were mixed well for homogeneity and stored in BOROSIL glass bottles. These were then irradiated in a ^{60}Co Gamma Chamber-900 at a dose of 30 kGy to avoid biodegradation according to IAEA recommendations (IAEA, 1984). SRMs of rice flour (SRM 1568), citrus leaves (SRM 1572), both from NIST, USA, and Bowen's kale (Bowen, 1985) were dried before use. Spinach (CRM 331), from Analytical Quality Control Services (AQCS) at the Seibersdorf Laboratory of the International Atomic Energy Agency (IAEA), Vienna, was analysed as part of a inter-comparison study (IAEA, 1997). A synthetic multielemental comparator standard was prepared by spiking 2–5 μg each of AR/GR or high purity grade salts (mostly nitrates and in some cases oxides) in aqueous/nitric acid solution on a Whatman No. 42 filter paper strip.