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Assessment, mapping, and management of health risk from nitrate accumulation in onion for Iranian population

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ABSTRACT

Excess accumulation of nitrate in vegetable crops is normally related to the excessive use of nitrogen fertilizers applied in agricultural fields. This study was performed to evaluate the level of nitrate concentration in onion production in Isfahan province of Iran and the potential health risks associated with high level of nitrate in this crop, as an example of a *case-study*. The risk was estimated by using the United States Environmental Protection Agency (USEPA) method and presented as risk maps. Additionally, the impact of an improved fertilizer management practice in selected vulnerable fields for reducing nitrate concentration in onion production was evaluated. For this assessment, four different onion fields in which onion bulb nitrate concentration was higher than the safety level (70 mg kg^{-1} FW), provided by Welch (2003) in a survey study, were chosen. The risk maps showed that despite higher risk possibility in adults, in comparison with children, all values were lower than the acceptable level. Further, the split application of nitrogen fertilizers in all fields significantly reduced plant nitrate concentration with no reduction in yield and even observed increase in the overall economic yield production. Therefore, considering crop yields and nitrate accumulation impacts, improved nitrogen management could provide an opportunity to promote onion crop production while reducing negative health effects in high-risk regions in Isfahan province of Iran.

1. Introduction

Nitrate (NO_3^-) concentration at excess levels in human food consumptives is a hazardous compound for human health (Ishiwata et al., 2002). Exposure to higher levels of nitrates has been associated with increased incidence of cancer and brain tumors, leukemia and nose and throat tumors in adults (Sanchez-Echaniz et al., 2001; Ward et al., 2000; Pogoda and Preston-Martin, 2001; Volkmer et al., 2005), childhood diabetes (Virtanen et al., 1994), recurrent diarrhea (Gupta et al., 2001), and recurrent respiratory tract infections in children (Gupta et al., 2000).

Vegetables, as an important component of the human diet, are considered as a major source of nitrate that constitute nearly 72–94% of the average daily human dietary intake (Dich et al., 1996). Excess accumulation of nitrate in crop foods is resulted from excessive use of nitrogen fertilizers applied in agricultural lands for enhancing crop yield. Excess nitrate also builds up in soil (Nosengo, 2003) which causes imbalance of nutrients affecting the quality of soil and water resources adversely (NAAS, 2005).

In recent years, increased incidence of carcinogenic and non-carcinogenic diseases resulting from consumption of food crops containing high levels of nitrate raises public concern in Iran. Therefore, a precise and comprehensive assessment on status of nitrate accumulation in vegetables is needed. There are several reports on the status of nitrate accumulation in processed foods and vegetables in different parts of the world (Bondonno et al., 2015; Merino, 2009; Qiu et al., 2014; Burns et al., 2011; Reinik et al., 2005; Susin et al., 2006; Chung et al., 2003; Renseigne et al., 2007), in Iran (Malakouti and Tabatabai, 2006; Shahlaei et al., 2007; Khoshgoftarmanesh et al., 2009; Santamaria et al., 1999; Yeganeh and Bazargan, 2016; Saeedifar et al., 2014; Nori et al., 2012; Rezaei et al., 2014; EFSA, 2008). There is, however, limited information about nitrate concentration in raw vegetables and its associated risks for human health. All governmental institutions, particularly the health and environment sectors, at different levels of success, are attempting to take various measures to carefully monitor and control the contamination of vegetables by nitrate levels. Risk assessment, a valuable tool, is intended to provide complete information to risk managers, specially policymakers and regulators agencies by estimating the potential impacts of nitrate on human population to further being able to make the best possible

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decisions.

Mapping of nitrate risk possibility, related to ingestion of various vegetables, can provide a brief summary of the potential health risk for residence in the study region, helps the decision makers to explore high-risk regions rather easily, and to control nitrate pollution by implementing appropriate policies. A risk map is actually a data visualization tool that indicates the places and the populations in a community or geographical regions that might be adversely affected by a potential hazard (Word Health Organization, 2008). The risk maps can also be used by the government agencies to investigate efficient ways of implementing various management policies over time and appropriate for different regions. Decision making process for large scale implementation, based on risk maps, is a more convenience and time efficient method.

Onion is considered as dominant vegetable which constitute a large portion of vegetable consumption on human diet worldwide particularly in Iran (raw and cooked in most of Iranian foods and stews). Also, it is believed that onions as bulb vegetable accumulate high amount of nitrate in their edible parts (Alexander et al., 2016; Fouda, 2016; Baddour, 2014; Alemzadeh Ansari, 2007). Isfahan province as one of the largest producers of onion in Iran represents a relatively clear view about the quality of these crops in country.

Thus, the aim of this study was to map the variation of nitrate concentration in onion and to assess human health risk related to nitrate via consumption of this crop through an entire region of the province of Isfahan, central Iran, as an example of a *case-study*. For this assessment, the risk map was developed, using the methods provided by the USEPA (United States Environmental Protection Agency). Additionally, we evaluated the impact of using an improved fertilizer management practice in the vulnerable fields for reducing nitrate concentration levels in onion production.

2. Material and methods

2.1. Study area

Iran is probably one of onion production origins in the world (Hanelt, 1990). Most of the dry farming of onion in Iran is located in Gilan, Golestan, and Mazandaran provinces of Iran that have Mediterranean environmental conditions, but all other provinces in Iran use irrigated cultivation practices. Overall, Azarbayejan Sharghi, Isfahan, Khorasan, and Khouzestan provinces account for 24.8%, 16.7%, 9.3%, and 8.3% of onion production, respectively (Alemzadeh Ansari, 2007). Our study area located in Isfahan province (east of 49° 36′ to 55° 31′ longitude and north of 30° 43′ to 34° 27′ latitude), situated in the center of Iran with a total area of 107,1700 km^2 (6.5% of land area in Iran). Isfahan is the second most populous metropolitan area in Iran after the capital city of Tehran (Fig. 1) with a population of over 5.1 million people. The cultivation area (ha) and production (ton) of onion in Isfahan are 4893 and 305,115 in 2015–2016, respectively (Organization of Agriculture Jahad Isfahan, 2014). Onion is one of the major vegetable crop, cultivating widely in Isfahan province, and exported to other parts of county as well as to other neighborhood counties.

The most famous cultivars of onion in Iran are "Ghermaz Azarshahr, Ghom, Kashan, Dorcheh, Tarom Esfahan, and Sefid Kashan" (Alemzadeh Ansari, 2007). Cultivars of "Aftab boland (Sweet Spanish), Falat, Ghahdarijan and Sorkh Khanevadeh" are also grown in Isfahan more than other cultivars.

2.2. Plant sampling

At the time of harvest (October to December 2015), Onion bulbs (390 samples) were sampled from fields in counties with predominant production. The number of fields in each county was determined considering the field area. Thus, the number of sampling fields in counties with small fields was higher than those in counties with larger fields

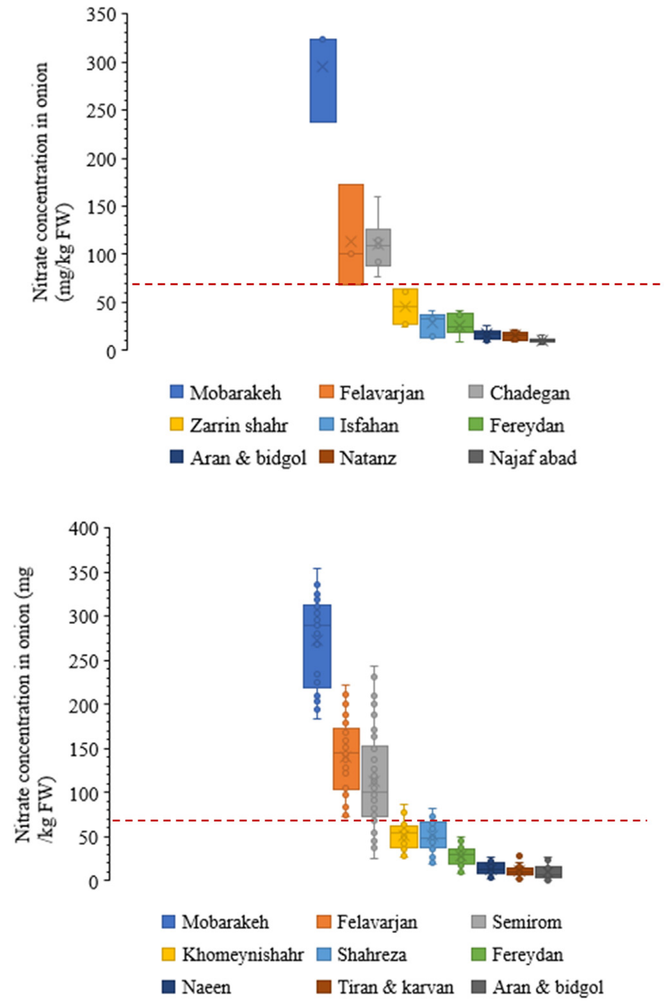

Fig. 1. Maximum, minimum and mean (× sign) concentration of nitrate (mg kg^{-1} FW) in onion bulb collected from fields (up) and markets (down) of Isfahan province. Dash line represents the critical level of nitrate in onion given by Welch (2003). Limit of detection (LOD) = 0.05 and limit of quantification (LOQ) = 0.15.

(Table 1). The longitude and latitude of each sampling point was recorded by Global Positioning System (GPS). In addition to the samples collected from local fields, onion bulbs were also collected from the markets in each country at the same time that the field samples were taken.

2.3. Nitrate analysis

2.3.1. Selection of method

As a first step, before analyzing the plant samples, three different rapid spectrophotometric methods (i.e., sulfusalicylic acid) (Cataldo et al., 1975), phosphomolybdenum (Zatar et al., 1999), and diazo (Singh, 1988) season, not washed, and peeled or cooked. The spectrophotometric absorbance of cucumber, potato, and spinach extracts were determined in three replicates. These plant samples were considered as reference materials because their nitrate concentration had previously been analyzed by an accredited lab (Isfahan University of Technology Lab.), using a standard method based on ion chromatography. Results showed that sulfusalicylic acid method was more accurate and reproducible in high-nitrate extracts (spinach) in comparison with other spectrophotometric methods. Due to low detection limit, the reproducibility of phosphomolybdenum method for spinach samples with high nitrate concentration was lower than the other methods