Nitrate in Leafy Vegetables
Toxicity and Safety Measures

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Vegetables have been a significant part of human diet since time immemorial. Besides adding the elegance and attractiveness to a meal, vegetables are an abundant source of vital minerals, vitamins and several biologically active compounds essential for maintaining human health. Most importantly, vegetables account for 70-85% of total human nitrate intake—ubiquitous within food and physiological systems (Huarte-Mendicoa et al. 1997; Moorcroft et al. 2001); after ingestion, the ingested nitrate gets converted into nitrate by microflora in the oral civility and in the gastrointestinal tract. This results in increased oxidation of hemoglobin to methemoglobin, leading to methaemoglobinemia. Simultaneously, increased production of free oxide radical and free radical nitrate oxide occurs. These radicles predispose person for carcinogenic and other effects. The other effects observed were increased infant mortality, abortions, birth defects, recurrent diarrhea, recurrent stomatitis, early onset of hypertensions, histopathological changes in cardiac muscles, alveoli of lungs and adrenal glands, recurrent respiratory tract infection in children, hypothyroidism and diabetes. Recent ongoing studies indicated that nitrate ingestion adversely affects the immune system of the body as well.

Among vegetables, mainly the green leafy vegetables (such as lettuce, spinach, beets, radishes, celery, etc.) contain the highest levels of nitrates (Prasad and Chetty 2008). Moreover, nitrate contamination in vegetables occurs when crops absorb more than they require for their sustainable growth. Hence, nitrate content is considered an important quality characteristic of vegetables; where, excessive-use of nitrogenous fertilizers largely boosts the accumulation of nitrate in leafy vegetables which is wrongly considered by farmers as reasonable insurance against yield loss (Anjana et al. 2007). Therefore, considering severe human health concerns due to high nitrate containing vegetables’ ingestion and limited availability of the literature on the nitrate in leafy vegetables, its toxicity and safety measures in humans, the decision of publishing a book focusing mainly on the nitrate in leafy vegetables emphasizing nitrate-mediated toxicity in human health and approaches for safety measures is timely and relevant to the present/future diet scenario.

Editors of *Nitrate in Leafy Vegetables: Toxicity and Safety Measures* have done an admirable job of assembling a wealth of information on the subject contributed by eminent researchers and scientists working in the field of nitrate in soils and plants, and its human health consequences and sustainable solutions.
I am sure that his comprehensive volume thereby will enlighten readers of various disciplines and at various levels; and should prove useful for advanced students, researchers, faculty of both plant and animal sciences, and environmentalists and policy makers.

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REFERENCES
Nitrate ($\text{NO}_3^-$) and nitrite ($\text{NO}_2^-$) are ubiquitous within environmental, food, industrial and physiological systems, and while our understanding of their role within such matrices has increased, a substantial degree of uncertainty and speculation remains (Moorcroft et al. 2001). When ingested within permissible limit, these ions play significant roles in various physiological functions of human body including their roles in vascular and immune functions. However, excess nitrate and its metabolites are toxic and lead to various ailments in humans (Gupta et al. 2001, 1999a,b; Sharma and Sharma 2012). Nitrates enter human body through sources such as drinking water, food and air. Out of the total human nitrate intake, fruit and vegetables account for 70%, drinking water 21%, and meat and meat products 6%. However, the common nitrate-rich vegetables are lettuce, beetroot, celery, eggplant, beet, banana, strawberry, tomatoes and peas. The leafy vegetables are important source of nitrates in human body (Dich et al. 1996; Hord et al. 2009). In fact, nitrate content is an important quality characteristic of vegetables. The use of excessive nitrogenous fertilizers has been regarded as one of the major reasons leading to accumulation of nitrate in leafy vegetables which is wrongly considered by farmers as reasonable insurance against yield loss. Therefore, vegetable nitrate content is of interest to governments and regulators owing to the possible implications for health and to check that controls on the content are effective (Anjana et al. 2007).

It is worth mentioning here that although there exists a plethora of publications focused on nitrate in soils, plants and their potential impact on human health, the available research reports and findings from different arenas are largely disorganized and not critically cross-linked and/or integrated. Therefore, this book is an effort to provide a common platform for plant scientists and health professionals working with a common aim of sustainable solutions to nitrate-led human and environmental health consequences.

Vegetables constitute a major dietary source of nitrate, contributing to the daily dietary intake for a percentage ranging from 30 to 94%. Although nitrate itself is relatively non-toxic, or even beneficial, the possible harmful effects of nitrate derived compounds on human health arouse public concern and have led to the development of government regulations and monitoring programs aimed at protecting the public health. In this perspective, the Chapter 1 by Di Gioia et al. focuses on the factors concerning nitrate accumulation in vegetables and their contribution to nitrate intake in the human diet, taking into account the recent EU
Regulation No. 1258/2011 and the Scientific Opinion of the Panel on Contaminants in the Food chain (CONTAM) of the European Food Safety Authority (EFSA). Öztürk et al. in Chapter 2 present some interesting outcomes from recent experiments performed in Turkey where a large number of producers apply both inorganic as well as organic fertilizers (in a rage of 40–75 kg/da) which is tenfold of the average recommended for the area. In this important perspective, in addition to suggesting important strategies for reducing nitrate accumulation in soil, water and crop, the authors advocate the use of correct nutrient application at optimum rate and appropriate plant phonological growth stage when the crop plants requirement for nutrients is high. The accumulation of NO₃ in the edible parts of varied vegetables depends on various factors, especially the amounts, timing and sources of N fertilizers and cultivars. Therefore, decreasing these types of contaminants is necessary for the promotion of human health. The problem of nitrates is endemic internationally as well as nationally, but so far no compiled data at national level are available. The data available are either of small areas or of scattered zones/areas. Keeping in view the aforesaid facts, Chapter 3 (Gupta et al.) overviews: (a) national and international perspectives of nitrate toxicity in humans, (b) major exogenous and endogenous sources of nitrates, (c) total daily intake of nitrate and its kinetics and metabolism, (d) major acute and chronic toxic effects of nitrate ingestion in humans and animals, mechanisms of methemoglobin formation, and (e) major results of nitrate toxicity-based experiments performed in animal and human systems; and critically discusses in detail the major strategies for treatment and prevention of nitrate toxicity. In Chapter 4, Malakouti et al. present an overview of sources of nitrate to soil, crop and human health, nitrate metabolism in plants, nitrate contents in edible parts of major vegetables, nitrate risk assessment, and hazardous effect of nitrate on human health and critically discuss major strategies for minimizing the risk of NO₃ contamination. Furthermore, the authors assure that the country’s nutritional ranking may improve and the yield and quality of crops, especially taste and shelf-life of vegetables may be upgraded significantly, and hence the problem of malnutrition will be solved by practicing balanced and appropriate/correct fertilization. Organic farming has emerged as an outcome of consumer’s reaction against harmful toxins and the desire for healthier life and safe environment. Not only does organic farming supply healthy foods to human beings, but also conserves the environment in which agricultural practices occur. Vegetables occupy an important role in human diet, and are consumed in large quantities. However, vegetables, especially leafy vegetables, could contain some undesired compounds that are hazardous for human health like nitrate, being toxic to humans in higher concentrations. Through case studies performed on spinach and cabbage - two of the most important leafy vegetables in terms of their cultivation area and consumption rate in the world, Chapter 5 (Sonmez and Citak) discusses important factors in maintaining the nitrate level in these vegetable crops and the effectiveness of the farmyard manure, chicken manure, guano type and blood meal in accumulation of nitrate in vegetables. Soil is the only finite resource to feed the increasing population, and soil fertility is vital to sustain the food
productivity of soil. Additionally, fertilizers are required for sustained food production but their widespread use has roused concern about resulting environmental pollution. In this context, hundreds and thousands of tons of chemical and organic fertilizers are produced globally each year for application in agricultural lands; however, it is estimated that only about half of the applied fertilizers goes into the crops. Therefore, the potential economic losses and negative environmental impacts are obvious. Nevertheless, chief among these problems are the excessive concentration of N compounds in the atmosphere (green house gasses), contributions of phosphate and nitrogen compounds to the eutrophication of surface waters, and risk to human health from manure associated pathogens. Keeping in view these aspects, Chapter 6 (Ahmad et al.) presents a critical discussion on some of these important issues taking into consideration especially the use of chemical-based fertilizers versus organic fertilizer for crop nutrition and the assessment of its potential impact on environmental and threats to human health in detail. A number of concerted efforts have been made to reduce the excessive nitrogen fertilizer use-mediated negative environmental impacts from agronomic to genetic engineering. However, the potential, strategies, namely, the use selection of nitrogen-efficient crops and/or adoption of strategies for enhancing nitrogen-use efficiency may largely work in isolation or combination in reducing ingestion of crop products with high nitrate-mediated anomalies in human. To this end, Chapter 7 (Umar et al.) overviews the significance of plant nutrients for enhancing crop production, highlights nitrogen use in leafy vegetables production and critically discusses important approaches useful for enhancing nitrogen-use efficiency in crops in general and leafy vegetable crops in particular. Balancing the amount of N needed for optimum plant growth while reducing nitrate accumulation in plants and other N losses from soil remains a major challenge for everyone attempting to understand and improve agricultural nutrient use efficiency. Considering these aspects, Chapter 8 (Singh et al.) discusses current crop, soil, and N fertilization management strategies and identifies future research needs aimed at reducing nitrate accumulation in plants. In this chapter, the authors advocate the combination of soil management practices and inherent physical, chemical, and biological characteristics of the soil as well as the physiological and environmental factors as the main reasons for increasing nitrate accumulation in varied environmental compartments, food and human health. Nitrogen losses from soil to water and air have become a global concern. Attempts are being made to put forth some of the best management practices to be used for controlling nitrogen loss from the fields or glasshouses.

In conclusion, Nitrate in Leafy Vegetables: Toxicity and Safety Measures represents the first comprehensive compilation of the latest science of the dietary nitrate sources, potential human health effects and sustainable remedial strategies. This text provides practical, data-driven resources based upon the totality of the evidence to help the reader understand the basics, treatments, and preventive strategies that are involved in the understanding all about nitrate in plants and humans. The overarching goal of the scholarly chapters is to provide fully referenced