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Determination of Nitrite Levels in Maize Samples From Different Regions of Turkey

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Introduction

The content of nitrates and nitrites in agricultural products has been assessed as an indicator of the quality of the products and has important health influences [1]. Changes in patterns of agricultural practice, food processing and industrialization have impacted accumulation of nitrates/nitrites in the environment. Intensive farming practice has resulted in an increasing use of nitrogen-based fertilizers, particularly with corn, vegetables, other row crops and forages [2]. The toxicity due to nitrate ingestion is relatively low. On the other hand, 5% to 20% nitrates taken from different sources including water and several foodstuffs are endogenously converted to nitrites, which have higher toxicity and are thought to be responsible of several adverse health effects. Nitrite content of agricultural products has been in concern of public, toxicologists, public health providers and governmental regulators for decades [1, 3, 4].

There are two toxicological outcomes regarding nitrite exposure: Nitrite exposure causes methemoglobinemia. It is a fact that exposure to high levels of nitrate and nitrite ions cause changes in hemoglobin (Hb) molecule, which is the most important oxygen-binding molecule in vertebrates. Hb Consists of four globular subunits where each subunit is composed of Hb protein, which is tightly associated with a non-protein heme group. The heme iron is in reduced form (ferrous iron, Fe^{2+}) in the

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structure of Hb and it can be oxidized to ferric iron (Fe^{3+}) by several oxidizing agents including nitrites and nitrates. Immoderate levels of nitrites and nitrates causes acquired methemoglobinemia, a fatal condition, in which hemoglobin's one or more iron atom is oxidized [5,6]. Methemoglobin is unable to bind or carry oxygen [7]. Therefore, high methemoglobin concentrations can cause severe tissue hypoxia [8]. Infants, pregnant women, nursing mothers, and elderly people are the most susceptible to the contamination [9, 10]. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) and Scientific Committee on Food (SCF) have proposed an acceptable daily intake (ADI) for nitrite of 0-0.07 mg kg^{-1} (body weight, b.w.) per day while EPA has set a reference dose (RfD) of 0.10 mg nitrite nitrogen per kg b.w. per day (equivalent to 0.33 mg nitrite ion kg^{-1} b.w. per day). The no observed effect level (NOEL) of sodium nitrite was established as 10 mg $NaNO_2$ kg^{-1} b.w. (equivalent to 6.7 NO_2^- per kg b.w.) and the NOEL of potassium nitrite was established as 10 mg KNO_2 kg^{-1} b.w. (equivalent to 5.4 NO_2^- per kg b.w.) [11,12].

On the other hand, nitrosamines and other N-nitroso compounds (NOCs) are formed endogenously from nitrites and nitrates in stomach where the presence of hydrochloric acid favors nitrosation reactions [13,14]. Though the acute toxicity of NOCs varies in wide limits and no correlation has been shown between acute toxicity and carcinogenicity, many NOCs and nitrosamines have been shown to be potent carcinogens in chronic exposure [13]. Nitrates or nitrites (ingested, under conditions that result in endogenous nitrosation) are Group 2A carcinogens (probably carcinogenic to humans). International Agency for Research on Cancer (IARC) has classified four NOCs as probable, and another fifteen NOCs as possible carcinogenic in humans [15]. As there is a genotoxic mechanism of action, no safe level has been determined for NOCs. There is thought to be an association between gastric cancer (GC) and the endogenous formation of mutagenic NOCs, from secondary amines and nitrites by the catalyzation of thiocyanate, which is found in human saliva and stomach. NOCs were found to cause induction of GC in several animal studies and there is thought to be a possible relationship between esophageal cancers (EC) and nitrite and nitrosamine intake [16, 17]. Moreover some NOCs induce oxidative stress and lipid peroxidation and are thought to be hepatocarcinogenic [13]. In a review by Jakszyn and Gonzalez (2006), the researchers studied on all the published cohort and case-control studies from 1985-2005, and analyzed the relationship between nitrosamine and nitrite intake and the most important related food intake and cancer risk. The paper covered 11 cohorts and 50 case-control studies. A high proportion of case-control studies found a positive association with meat intake for both tumors (11 of 16 studies on GC and 11 of 18 studies on EC). A relatively large number of case-control studies showed quite consistent results supporting a positive association between processed meat intake and GC and EC risk (10 of 14 studies on GC and 8 of 9 studies on EC). Almost all the case-control studies found a positive and significant association between preserved fish, vegetable and smoked food intake and GC though the evidence regarding EC was more limited [14].

The nitrite content of agricultural products has been in concern of scientists and public for decades and the toxicological outcomes of nitrate/nitrite exposure have been studied widely in both human and animal studies. The present study was aimed to assess nitrite levels in maize samples collected from different regions of Turkey and to evaluate the possible toxicological outcomes.

Materials and Methods

Sample Collection

A total of 51 maize samples were randomly collected from Black Sea (n=15), Mediterranean (n=16), Marmara (n=12), and Central Anatolia (n=8) regions in a minimum weight of 20 g in the period of 2004-2005. The maize samples were crumbled by a teflon blender and maize flours were put in nylon bags with shackles to prevent contamination with air and therefore the effect of humidity on nitrate/nitrite content of the samples was deterred. All samples were stored at –20 °C until the analysis.

Chemicals

All chemicals used in this study were analytical grade (Sigma Co., St. Louis, MO, USA and Merck Co., Darmstadt, Germany). Ultra-high pure distilled water was used in the analytical work.

Standards

Stock nitrite solution was prepared by dissolving 50 mg sodium nitrite per dl of ammonium hydrochloride buffer (prepared from HCl and ammonia; pH=9.7). A working solution containing 50 g mL^{-1} sodium nitrite was prepared daily by proper volume of stock solution. Standard solutions containing 0.025, 0.05, 1, 1.5, 2, 5, and 10 g mL^{-1} sodium nitrite were obtained with dilution.

Extraction Procedure

For each sample, 10 g of ground maize was used for the nitrite analysis. 40 ml hot water was added on the sample and blended for 5 min in a blender. The mixture was heated to 75ºC for the prevention of ascorbic acid interference. The solution was transferred to a volumetric glass and 50 ml hot water and 12 ml sodium hydroxide (2% w/v in water) was added and blended again for another 10 mins. 10 ml of zinc hydroxide (7.2% w/v in water) was added and the mixture was shaked for 5 min. The next step was to add 5 ml sodium hydroxide and the mixture was blended for 5 min. Distilled water (83 ml) was added and mixed for 5 min. The last volume was 200 ml. The mixture was filtered using filter paper (Whatman No. 1) until the filtrate was completely clear.

Determination of Nitrite

The Griess method was employed with slight modifications. The principle of the method was based on the reaction between nitrites and sulfanilic acid (1% w/v in 30% acetic acid) and Marshall's reagent to produce a colored complex [18]. The absorbance can be measured at 550 nm.

In order to detect the nitrite level in the samples, the clear 1 ml filtrate was used. Ammonium hydrochloride buffer (0.9 ml) and 0.5 ml of 60% acetic acid were added on the filtrate tubes. 0.5 ml of sulfanilic acid and 0.5 ml of Marshall's reagent (N- (1-naphtyl) ethylene diamine hydrochloride; 0.1% w/v in 60% acetic acid) was added, and then diluted to 5 ml by water and the mixture was vortexed for 30 sec. The mixture was incubated in the dark for 25 min. The same procedure was applied to sodium nitrite standard solutions and the absorbance was determined at 550 nm by using a spectrophotometer (Shimadzu 160 UV, Japan).

The concentration-absorbance intensity relationships were assessed by linear regression. The detection limit of the method was 0.025 g mL^{-1}. Recovery studies were performed on blank samples of maize spiked with level of 0.5 and 1 g mL^{-1} nitrite. Within-day precision and between-day precision were also determined. The average recovery value was determined to be 95.33 ± 0.8%; within-day precision was 3.8% coefficient of variance and between-day precision was 95.59%. The nitrite content of the sample was presented as mg of nitrite per kg of the sample.

Statistical Analysis

All of the results were expressed as mean ± standard error of mean (SEM). The differences among the groups were evaluated with Kruskal-Wallis analysis of variance. p values <0.05 were considered as statistically significant.

Results

Fifty-one samples of maize collected from different regions were analyzed for nitrite levels by spectrophotometric method. The mean concentration of nitrite in all of the samples was determined to be 39.09 ± 4.34 mg kg^{-1}. 20% of the samples were found to contain nitrite under the detection limit of method. The mean levels of nitrite of maize samples in Black Sea (n=15), Mediterranean (n=16), Marmara (n=12) and Central Anatolia (n=8) were 46.67 ± 10.63, 36.89 ± 6.38, 36.27 ± 7.82 and 33.8 ± 9.48 mg kg^{-1}, respectively (Figure 1). The differences between the groups were not found to be statistically significant possible due to high standard deviation. The minimum and maximum levels along with median levels of nitrite in the samples were also shown in Table 1.

Discussion

Being acquainted with the origin and quality of agricultural products, as well as the quality of locally produced food, is getting more important for the consumers and health care providers. There are many factors in-

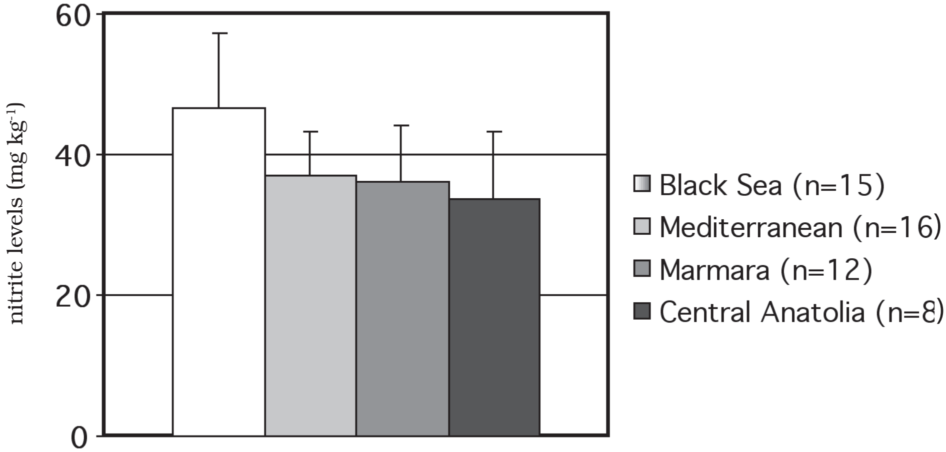

Figure 1
Nitrite levels in the maize samples from different regions of Turkey

TABLE I

Nitrite levels of maize samples from different regions of Turkey

Region	Number of Sample		Nitrite Level (mgkg^{-1})			
	Non-detectable	Detectable	Minimum	Maximum	Mean ± SEM	Median
Black Sea	3	12	3.85	119.90	46.67 ± 10.63	36.63
Mediterranean	3	13	7.57	75.83	36.89 ± 6.38	36.69
Marmara	3	9	9.80	81.97	36.27 ± 7.82	30.99
Central Anatolia	1	7	7.33	88.03	33.80 ± 9.48	34.84
Overall	10	41	3.85	119.90	39.09 ± 4.34	34.71

fluencing the nitrate and nitrite content of agricultural products. These factors may be listed as the kind of the product; time of harvesting (nitrite content may differ through seasons and years); ammonium containing fertilizer use; irradiation; temperature and humidity; type of growing (in open air or under protective conditions); length of the growth period;

pedologic properties of soil (nitrogen content of soil) and contamination after harvesting [1,19-23].

In human diet, vegetables are considered to be one of the major sources of dietary exposure to nitrates and nitrites [22]. Thompson et al. (2007) performed a study on 200 foodstuff and 1021 water samples from 561 different supplies. They found that green vegetables had the highest nitrite content as expected. Watercress had the highest nitrate content (mean 1640 mg kg^{-1}), whereas celery samples had the second place (mean 1610 mg kg^{-1}). They also worked on other vegetables including potatoes, carrots and pumpkins. Potatoes had 48-240 mg kg^{-1}, with a mean nitrate content 129 mg kg^{-1} and carrots had <5-290 mg kg^{-1}, with a mean nitrate content as 58.3 mg kg^{-1} [24]. Mozolewski and Smoczynski (2004) reported a study on nitrate and nitrite levels in different potato tubers. They found that nitrite levels of Ibis potato tubers were the highest among groups (4.3 mg NO_2 kg^{-1}). Culinary processing also reduced the nitrite levels. It was indicated that potato peeling and thermal processing raised the hygienic quality of potato meals [25].

Another study performed by Chung et al.(2003) on the nitrate and nitrite content of vegetables grown in Korea showed that winter and summer nitrite content of vegetables show differences. Among the vegetables analyzed *Allium tuberosum* had the highest content (5.3 mg kg^{-1}) in winter while Chinese cabbage had the highest nitrite content in winter (14.3 mg kg^{-1}) [22].

In a large survey performed by Susin et al. (2006) in Slovenia during 1996-2002, the researchers determined the nitrate content of silage maize as 12.2 mg kg^{-1}, The concentrations of nitrite in cereals (8.9 mgkg^{-1}) were found to be lower than our samples[1].

Although there are some studies on the levels of nitrite in different foods consumed and produced in Turkey such as baby foods, vegetables, cured meat and cheese, there were not any studies on the determination of nitrite content in cereal and cereal products including maize [26-30]. Besides, monitoring studies on nitrite and nitrate contents in cereal products as well as other foods were not carried out routinely by Ministry of Agriculture in our country. Turkdogan et al. (2003) determined that herb-enriched cheese contained 4.14 mg g^{-1} nitrite, while bread baked by wood fire contained 0.82 mg g^{-1} nitrite and bread baked by animal manure contained 3.02 mg g^{-1} nitrite in Van, Turkey. They suggested that nitrite and nitrate rich diet could significantly affect the development of endemic upper gastrointestinal cancers in this city. It is a fact that diet can be the major determinant of risk in several diseases including cancer[28]. Dogan et al. (2008) measured nitrite levels ranged in 0.0- 0.261 mg kg^{-1} in different fruits grown in Van district and reported that nitrite and nitrate concentrations of fruits delivered to street market from the other regions were higher than that of the fruits grown in this region[31].

Maize is one of the most important crops in Turkey especially for some regions. In the last five years, maize production has ranged from 2.1 to 3 million tons and these amounts correspond to almost 10% of total cereal productions in Turkey [32]. The largest maize-producing areas in Turkey are in Black Sea and Mediterranean Regions. It has been reported that ~45% and 30% of maize growing areas of our country are in Black Sea and Mediterranean Regions, respectively [33]. However, the production in Mediterranean Region is stated to be more than the other regions. Therefore, 60% of the samples analyzed were collected from these regions. Maize is primarily used for human consumption in Turkey especially in Black Sea region and it is a considerable component especially in children's diet. Moreover, it is also one of the major livestock feeds.

The mean nitrite level in all of the maize samples was found to be 39.09 ± 4.34 mg kg^{-1} in this study. Although the differences between the groups were not significant statistically, the highest concentration of nitrite was determined in the maize samples collected from Black Sea Region. The high nitrite content of the maize samples from different regions of Turkey may be attributed to several reasons. High ammonium containing fertilizer use throughout Turkey may be the first and most important reason of this high nitrite levels. Though chemical fertilizers are used extensively in modern agriculture, in order to improve yield and productivity of agricultural products, nutrient leaching from agricultural soil into groundwater resources poses a major environmental and public health concern [34]. High humidity in the storage of maize samples after harvesting may be another reason. Besides, the type of soil, type of water used in the watering of maize fields and type of growing may be other factors affecting the total nitrite content of the plant [35, 36]. Contamination of samples with several nitrogen containing compounds may be another important cause of these high levels [8]. Furthermore, contamination of soil with airborne nitrogenous compounds emitted from industry and automobiles might have an effect of the total nitrite content of the soil and therefore this may be effective in the total nitrite content of the plant [10].

Although Marmara region is the most industrialized region in Turkey, the maize samples from that region have lower levels of nitrite than Black Sea and Mediterranean regions. This may emphasize that other than the effects of industry and industrial contamination, type of soil and type of the fertilizers used have importance in the total nitrite content of the maize samples.

With a simple calculation, if a 70 kg person consumes 100 g of bread (3 slices) prepared from maize-flour everyday, he may approximately get 3.9 mg of nitrite and it is below the ADI given by JECFA, however the overall nitrite intake of the organism in one day must also be considered. Water, vegetables and other cured-meat products may have nitrite high levels. Chronic intakes of nitrite in excess of ADI may lead to increased risk of mild to moderate methemoglobinemia, especially for susceptible populations such as young children and elderly. Furthermore, high nitrite intake favors the formation of NOCs in gastrointestinal tract. Therefore, it can be suggested that nitrite contamination should be monitored routinely in different agricultural products. Ultimately, surveillance should be continuous, widespread, and must be conducted by authorities to prevent the threat to human health.

Summary

Maize is a largely produced cereal grain throughout the world. Turkey is a wide-consumer and producer of maize. Maize flour is used for making bread and several meals. Nitrite content of agricultural products has been in concern of public, toxicologists, public health providers and governmental regulators for decades. Nitrites have been implicated with a variety of long-term adverse effects on the human health. Being acquainted with the origin and quality of agricultural products, as well as the quality of locally produced food, is getting more important for the consumers and health care providers. The present study was aimed to evaluate the nitrite content of maize from different regions of Turkey. We have collected totally 51 samples from Black Sea (n=15), Mediterranean (n=16), Marmara (n=12) and Central Anatolia (n=8) regions. The mean nitrite levels of maize in these regions were found to be 46.67 ± 10.63, 36.89± 6.38, 36.27 ± 7.82 and 33.8 ± 9.48 mg kg^{-1}, respectively. The highest mean concentration of nitrite was determined in the samples from Black Sea Region, but the differences were not significant statistically. It must be considered the overall intake of the organism in one day from the other sources along with cereals. Water, vegetables and other cured-meat products may have nitrite high levels. It can be concluded that the nitrite high levels in different cereals, vegetables and fruits should be monitored routinely to prevent food-borne hazards and for the safety of susceptible populations such as infants, young children and elderly.

Key Words: Maize, nitrite, food toxicity, Turkey

Özet

Türkiye'nin Farklı Bölgelerinden Alınan Mısır Örneklerinin Nitrit İçeriğinin Belirlenmesi

Mısır tüm dünyada yaygın olarak üretilen bir tahıldır. Türkiye önemli bir mısır üreticisi ve tüketicisi durumundadır. Mısır unu, ekmek ve birçok gıda ürününün yapımında kullanılır. Tarım ürünlerinin nitrit içeriği toplumun, toksikologların, sağlık personelinin, yönetsel otoritelerin ilgisini yıllardır çekmektedir. Nitritlerin insan sağlığı üzerinde uzun dönem ters etkileri bulunmaktadır. Lokal olarak üretilen gıdaların kalitesi gibi tarımsal ürünlerin kaynağı ve kalitesinin bilinmesi, tüketici ve sağlık personeli için son derece önemlidir. Bu çalışmada Türkiye'nin farklı bölgelerinden alınan mısır örneklerinin nitrit içeriğinin değerlendirilmesi amaçlanmıştır. Toplam 51 mısır örneği Karadeniz (n=15), Akdeniz (n=16), Marmara (n=12) ve İç Anadolu (n=8) bölgelerinden toplanmıştır. Ortalama nitrit değerleri sırasıyla 46.67±10.63, 36.89±6.38, 36.27±7.82 ve 33.8±9.48 mg kg^{-1} olarak bulunmuştur. En yüksek ortalama nitrit değeri

Karadeniz Bölgesindeki örneklerde tayin edilmiştir, ancak farklar istatistiksel olarak anlamlı bulunmamıştır. Organizmanın tahıllar ile birlikte diğer kaynaklardan bir gün içindeki toplam nitrit alımını dikkate almak gerekir. Su, sebzeler ve işleme tabi tutulmuş etlerin de nitrit içerikleri yüksektir. Sonuç olarak tarımsal ürünlerin nitrit içerikleri gıdalardan gelebilecek tehlikelerin önlenmesi ve bebek, çocuk ve yaşlılar gibi hassas popülasyonların güvenliğinin sağlanması için rutin olarak izlenmelidir.

Anahtar kelimeler: Mısır, nitrit, gıda toksisitesi, Türkiye

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