SİDAS MEDYA
Akademik Gıda® / Academic Food Journal
ISSN Print: 1304-7582, Online: 2146-9377
http://www.academicfoodjournal.com

Akademik Gıda 12(1) (2014) 57-62

Review Paper / Derleme Makale

Prevention from Iodine Deficiency Disorders and Iodine Analysis Methods in Food

Nesrin Kurtar Bozbiyik[1], Yasin Özdemir[1, ✉], Barış Tuncel[2]

[1]Atatürk Central Horticultural Research Institute, Food Technology Department, Yalova, Turkey
[2]Çanakkale 18 March University, Food Engineering Department, Çanakkale, Turkey

Received (Geliş Tarihi): 11.10.2013, Accepted (Kabul Tarihi): 28.12.2013
✉ *Corresponding author (Yazışmalardan Sorumlu Yazar): yozdemir@yalovabahce.gov.tr (Y. Özdemir)*
☏ +90 226 814 25 20-1263 ☎ +90 226 814 11 46

ABSTRACT

More than two million people were under the risk of iodine deficiency disease due to inadequate iodine nutrition. Big budgets are spent by governments to eliminate the iodine deficiency in the field of medicine and various iodine enriched foods. In plant origin food the amount of iodine varies according to season, climate and growing conditions. Different parts of the plant origin foods also show differences in iodine content. The form of iodine is important for determining of the iodine content. Plant and animal tissues constitute iodine in organic form but natural water sources constitute iodine in inorganic form. Therefore, quantitative analysis of iodine in food is thought to be identified as matrix to determine the form and accordingly with the selection of a specific method to determine the method of measurement.

Key Words: Iodine, Iodine in food, Odized salt, Iodine loss

İyot Eksikliğinin Neden Olduğu Hastalıkları Önleme ve Gıdalarda İyot Analiz Yöntemleri

ÖZET

İki milyondan fazla kişi iyot yetersiz beslenme nedeniyle iyot eksikliğinin neden olduğu hastalıklara yakalanma riski altındadır. İyot eksikliğini gidermek amacıyla devletler tıp alanında ve çeşitli iyot zenginleştirilmiş gıdaların üretilmesi konusunda büyük bütçeler harcamaktadırlar. Bitkisel kökenli gıdaların iyot miktarı mevsim, iklim ve yetiştirme koşullarına göre değişiklik göstermektedir. Bitkisel gıdaların farklı kısımları farklı iyot içeriklerine sahiptir. Gıdalardaki iyodun formu iyot içeriğinin tespit edilmesi için önemlidir. Bitki ve hayvan dokularında organik formda, doğal su kaynaklarında ise inorganik formda iyot bulunmaktadır. Bu nedenle, gıdalarda kantitatif iyot analizi matris olarak düşünülmektedir. Kantitatif ölçüm yönteminin belirlenmesi için iyot formunun ve buna özel analiz yönteminin tespit edilmesi gereklidir.

Anahtar Kelimeler: İyot, Gıdalarda iyot, İyotlu tuz, İyot kaybı

INTRODUCTION

Iodine is an element that is needed for the production of thyroid hormone. The body does not make iodine, so it is an essential part of your diet. If you do not have enough iodine in your body, you cannot make enough thyroid hormone. Thus, iodine deficiency can lead to enlargement of the thyroid, hypothyroidism and to mental retardation in infants and children whose mothers were iodine deficient during pregnancy [1, 2]. Iodine deficiency is the most common preventable cause of mental retardation and approximately 800 million people are at risk of iodine deficiency in the world [3]. This review is aimed to present iodine deficiency status of the world, new preventing methods against iodine deficiency and new iodine analysis method in food.

IODINE DEFICIENCY

Iodine deficiency is the world's most common cause of preventable mental retardation. In this sense, iodine is the one of the most important trace elements which serves the health from nature to people [4]. Iodine statuses of the countries are illustrated in Figure 1. As can be seen in Figure 1, in spite of the iodine fortification programs, iodine deficiency is still a health problem for some countries such as Russia, Australia, Algeria, Sudan and Mongolia.

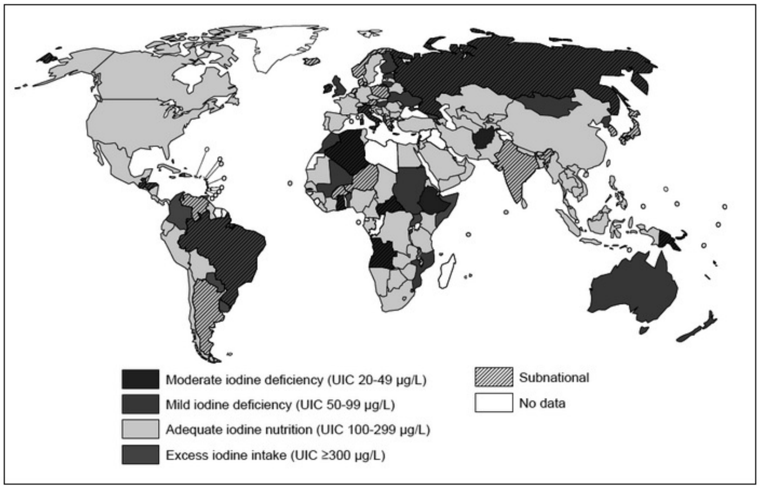

Figure 1. National iodine status in 2013 [5]

The most extensive occurrence of iodine deficiency diseases, especially in the long term of years with snow-covered mountainous regions are the central regions of continents away from the sea. Iodine deficiency is an important public health problem in Himalayas, Andes Mountain and inner parts of Africa. Iodine deficiency have been taken under control in Europe, Austria, Finland, Sweden, Norway and Switzerland but it is still constitutes a serious problem in Romania, Italy, Germany, Spain, Greece and other many countries [6].

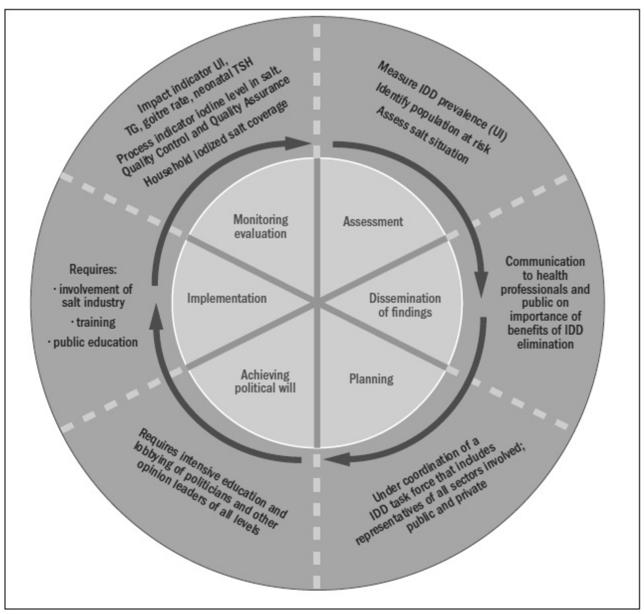

Figure 2. Social process involved in a national iodine deficiency control program [8]. IDD: Iodine deficiency disorders, UI: Urinary iodine, TSH: Thyroid stimulating hormone, TG: Total goitre

The sustainability of iodine deficiency prevention program depends on relationship of the all sides of the population. These include political commitment of the public health authorities, the decision-makers of governments. Also an effective and operational monitoring and evaluation system, a strong collaboration between the partners involved in the control of iodine deficiency and public education are needed [7]. Social process of national iodine deficiency control program should involve assessment, monitoring, evaluation, dissemination and implementation steps which are illustrated in Figure 2 [8].

IODINE in FOODS

Amount of iodine in food such as meat, milk, eggs, cereals and plant origin foods depends on iodine level of region, season and breeding conditions [9,10]. Iodine levels of soil, irrigation water and fertilization of plant during the growing of fruit and vegetables affected the iodine content of plant origin food. Iodine level of feed also affected the iodine content of animal origin food [10].

Biogeochemical transfer of iodine into the spinach, radishes and Chinese cabbage was carried out with iodized fertilization (iodine was obtained from algae) and iodine accumulation and absorption in plant was determined. There was a positive correlation between the iodine content of soil and plant except excess amount of iodine in soil [11].

The amount and absorption of iodine by vegetable varieties and even the same plant show varieties in different parts of the plant. Physiological factors and genetic factors of plants effects the concentration of iodine in plant tissue [12]. Therefore, the iodine content of food is change in the wide range. The amount of iodine found in most natural foods is typically quite small and varies depending on environmental factors such as the soil concentration of iodine and the use of fertilizers. Some of the iodine rich food sources are shown in Table 1. Some of the richest food sources of iodine are often processed foods that contain iodized salt, and breads that contain iodate dough conditioners [13,14]. According to Weng HX et al. [11] and Hong et al [12], vegetable breeding in iodized soil system was an effective technique in preventing iodine deficiency disease and referred to as an environmentally friendly practice.

Table 1. Some iodine rich foods (µg /100g) [15]

Fruits		Vegetables		Dried Foods		Other Foods	
Avocado	1.4	Leek	1	Apple slice	0.1	Honey	5
Orange	0.5	Lettuce	1	Banana slice	1	Egg	44
Pear	1	Onion	1	Corn slice	5	Rice	5
Plum	1	Pumpkin	1	Carrot slice	8.7	Sea salt	2000
Mulberry	1	Spinach	1			Tuna fish	30
Watermelon	1	Lemon	1			Yogurt (2.5% fat)	19
						Boiled chicken	15
						Beef and lamb meat	3

IODINE BIOAVAILAILITY

Inorganic iodide is readily and completely absorbed from the gastrointestinal tract [16]. It is believed that iodate and protein-bound iodine are reduced to iodide for absorption. However, neither the reducing agent nor the site of reduction is clear. While iodine absorption from the gastrointestinal tract has been reported to be virtually 100%, the absorption of iodine by the thyroid gland was estimated to be around 10 to 15% under normal intakes [17]. Reported bioavailability of iodine in various food stuffs vary from 2 to 89% [9, 13, 18]. Given the presence of various reducing and oxidising agents in foods there is a wide range of possible interactions between iodide and iodate with respect to their bioavailability. The various studies that used iodate as an iodine source for salt iodisation suggest that iodate bioavailability is extremely high. However, these studies have not included interactions within the food matrix, or *in vivo* changes during digestion and absorption [19].

IODINE FORTIFICATION METHODS of FOODS

The average daily amount of iodine should be taken 150-200µg. UNICEF, ICCIDD (The International Council for the Control of Iodine Deficiency Disorders) and WHO prepared a table of recommended daily iodine intake for prevention from the iodine deficiency disorders are shown in Table 2 [20]. Basic approach to overcome iodine deficiency is to increase people's daily iodine intake. So addition of iodine into commonly consumed foods is a proper way to ensure rich iodine consumption. As an example to the world food enriched with iodine are water, bread, milk, sugar and fish sauce [21].

Table 2. Recommended daily intake of iodine

Type of People	Recommended Daily Intake (µg)
Pre-school child (0-59 month)	90
School child (6-12 years)	120
Puberty child (12 years old and more) and adult	150
Pregnant and lactating women	250

Mostly used methods for food enrichment with iodine to prevent iodine deficiency are iodized salt, iodized water, iodized oil capsules and iodized oil injection [8, 22]. In a study that carried out in Malaysia, investigators put iodine in poppy plant seed oil capsule and injections. They tested the effectiveness of these iodized oil capsules and injections especially on school-age children and pregnant women. Thyroid hormone levels, urinary iodine excretion and mental activities compared in both experimental groups. The results of the study showed that, the values of thyroid parameters were significantly decreased [23].

Iodization of salt is the world's most commonly used method for the enrichment of food with iodine [24]. Iodization programs were initiated by ICCIDD in some countries where iodine deficiency was a major and common problem, like Philippines, Indonesia, New Zealand, Papua New Guinea, Srilanka, Vietnam. Successful results were began to achieve but targeted results have not been met [25]. Also preventing the loss of iodine is important for elimination of iodine deficiency disorders [7]. Chanthilath [26] added iodine to salt after fermentation of some fish sauce with iodized salt. Keep the fermented fish sauce under daylight and darkness and determined the change in iodine content and loss of iodine by titrimetrisch, spectrophotometric and inductively coupled plasma mass spectrometry methods. After fermentation, the level of residual iodine was 7.61 ppm (16% loss) infermented fish, 5.57 ppm (55% loss) in fish sauce prepared with exposure to sunlight, and 9.52 ppm (13% loss) in fish sauce prepared in the shade.

There are some studies which were aimed to increase the iodine content of soil in vegetable production area by artificial ways and observed that iodine was presented mostly in Chinese cabbage, spinach, radish tomato and potato. They reported that the results of this study show a new artificial way to deal with iodine deficiency in theoretical and practical meaning [27-29].

IODINE ANALYSIS METHODS in FOODS

Methods of identification and quantitative determination for iodine species are decided by the types of compound and the matrices in which they occur. Iodine analysis could be performed by different methods such as catalytic method (Sandell and Kolthoff), titrimetric spectrophotometric and chromatographic Inductively Coupled-Mass Spectrometry (ICP-MS), Gas Chromatography (GC), Gas Chromatography-Mass Spectrophotometer (GC-MS), Ion-Specific Electrode (ISE), High Performance Liquid Chromatography (HPLC), etc. methods -by using one or the combination of these methods- due to the organic and inorganic forms of the element [30].

Organic iodine compounds in biological samples have been identified by classical natural products chemical techniques following their isolation, and by modem spectroscopic methods. Routine analysis of such compounds can be done by GC and HPLC. Analysis of inorganic iodine species in waters is carried out by catalytic, electrochemical and spectrometric methods and by GC; possibly HPLC and ICP-MS might be the method of choice in the future [31]. Spectrophotometry was used for the determination of iodine based on an iodide-catalyzed reduction of cerium by arsenic in a variety of food items [32].

Gas chromatography was used for the determination of iodine using derivatization with pentan-3-one following alkaline dry ashing method. ISE method was compared against a more complex HPLC reference technique. All these methods require using more than one instrument and various stages of analyses have to be performed. All these cases cause development of a method called as ICP-MS that is practical and performing multiple analyses rapidly [33].

Some of the above mentioned analytical techniques, particularly those based on radioiodine measurements, require higly specialized and therefore inaccessible equipment or involve multi-step procedures which are prone to iodine losses or contamination. In contrast, ICP-MS, which is becoming an increasingly popular technique in food research and control, allows the direct determination of iodine in solution, and is a highly sensitive, selective and largely interference-free detector for the monoisotopic iodine[34].

Larsen and Ludwigsen [35] reported that ICP-MS is a more reliable method for solid biological materials that food-related certified reference materials used according to the literature that including both loss in sample dissolution methods (wet or dry ashing methods) and interferences in analyses which performed by ICP-MS. The Iodine extraction methods prior the ICP-MS analysis showed the sensitive differences in two dietetic child foods [36]. The concentration of iodine in most foods is low, therefore, accurate determination requires a sensitive analytical method and freedom from contamination [37, 38]. Haldimann et al. [14] developed a more sensitively measuring ICP-MS method in biological samples and determined the isodine isotopes by using the selective isotopes of iodine. They determined trace levels of iodine more sensitively by this technique. They also described the development and evaluation of an analytical method which is based on sample dissolution by wet ashing using a mixture of nitric and perchloric acids in closed steel bombs in combination with ICP mass spectrometer detection of iodine.

Iodine levels of soil and water for plants and affecting iodine levels to the food chain. Thus iodine analyses both in soil and irrigation water and foodstuffs were evaluated and results were illustrated with regional iodine deficiency in a pilot study which carried out in two states of Afghanistan by Watts and Mitchell [39].

Xiaolin Hou et al. [40] determined iodine content as organic iodine, I^- and IO_3^- by a new procedure of molecular activation analysis. Analytical results indicate that the contents of total iodine and various types of iodine (organic iodine, I^- and IO_3^-) were different in various specimens for seven marine algae.

Iodine content of feijoa sellowiana fruits (*feijoa accasellowiana*) was determined with titration ($Na_2S_2O_3$ 0,1 N) and spectrophotometric methods by Ferrara and Montesano [41]. The results were ever reproducible: 3 mg I/100g of fresh fruits.

CONCLUSIONS

Deficient iodine in diet increase risk of retarded brain development in children (cretinism), mental slowness, high cholesterol, lethargy, fatigue, depression, weight gain, and goiter: a swelling of the thyroid gland in the neck. Iodine is a component of almost every living plant and animal. No standard measurements of iodine in food exist because iodine concentrations vary across the world. In general, foods from the sea contain the most iodine, followed by animal foods, and then plant foods. Result of cited studies showed that determination of iodine is very difficult because this substance is very volatile, and then it is necessary to confirm the results using different methods and verifying internal accord of data. Results als indicate that developing the proper extracted method of iodine from food samples with the minimum loss and accurate analyzing methods of the iodine content extremely important and there is a need to develop an official analyzing method of iodine in various food.

REFERENCES

[1] Gökhan, N., Çavuşoğlu, H., 1989. Tıbbi Fizyoloji. Nobel Tıp Kitabevi, İstanbul.

[2] Zimmermann, M.B., 2009. Iodine deficiency. *Endocrine Reviews* 30(4): 376-408.

[3] Saka, N., 2000. Iodine defciency in Turkey. Congress of Child Health at 2000's years, 18-20 Nisan, 2000, İstanbul, Book of Proceedings, 38-40p.

[4] Barutçugil, M.B., 2005. Bakırköy Bölgesi Bir İlköğretim Okulu Öğrencilerinde İdrar İyot Atılımı ve Guatr Prevalansı. Uzmanlık Tezi, Sağlık Bakanlığı Bakırköy Dr. Sadi Konuk Eğitim ve Araştırma Hastanesi, İstanbul.

[5] The International Council for the Control of Iodine Deficiency Disorders, National iodine status in 2013, ICCIDD Global Network (www.iccidd.org)

[6] Ursel, A., 2001. Natural Care Vitamins and Minerals Handbook. New York: Plenum Pres London, England.

[7] Andersson, M, de Benoist, B., Darnton-Hill, I., Delange F., 2007. Iodine Deficiency in Europe: A continuing public health problem, World Health Organization Press, Paris, France.

[8] Hetzel, B.S., Pandav, C.S., 1994. The Conquest of Iodine Deficiency Disorders.Oxford University Press, Oxford, England.

[9] De Lange F., 1989. Iodine nutrition and congenital hypothyroidism. In Research in congenital hypothyroidism, Edted by DA. Fisher, D. Gilnoer, , Plenum Press Publication, New York, 185p.

[10] Kurtoğlu, S., 1997. İyot eksikliği sorununun değerlendirilmesi ve çözüm yolları. *Türk Pediatri Arşivi* 32: 4-7.

[11] Hong, C.L., Weng, H.X., Qin, Y.C., Yan, A.L., Xie, L.L., 2008. Transfer of iodine from soil to vegetables by applying exogenous iodine. *Agronomy for Sustainable Development* 28: 575-583.

[12] Weng, H.X., Weng, J.K., Yong, W.B., Sun, X.W., Zhong, H., 2003. Capacity and degree of iodine absorbed and enriched by vegetable from soil. *Journal of Environmental Sciences* 15: 107–111.

[13] Katamine, S., Marmiya, Y., Sekimoto, K., 1987. Difference in bioavailability of iodine among iodine-rich foods and food colours. *Nutr. Rep. Int.* 35: 289-292

[14] Haldimann, M., Alt, A., Blanc, A., Blondeau, K., 2005. Iodine content of food groups. *Journal of Food Composition and Analysis* 18: 461-471.

[15] National Institute for Health and Welfare. Fineli&Finnish Food Composition Database. National Institute for Health and Welfare, Nutrition Unit Based on the Fineli Food Composition Database Release (December 5, 2011) Date of access; March 12, 2013. http://www.fineli.fi/index.php?lang=en

[16] Keating, F.R., Albert, A.. 1949. The metabolism of iodine in man as disclosed with the use of radioiodine. *Recent Progress in Hormone Research* 4: 429-481.

[17] Lamberg, B.A., 1993. Iodine deficiency disorders and endemic goitre. *European Journal of Clinical Nutrition* 47: 1-8.

[18] Jahreis, G., Hausmann, W., Kiessling, G., Franke, K., Leiterer, M., 2001. Bioavailability of iodine from normal diets rich in dairy products results of balance studies in women. *Exp. Clin. Endocrinol. Diabetes* 109:163-167.

[19] Winger, R.J., Koenig, J., House, D.A., 2008. Technological issues associated with iodine fortification of foods. *Trends in Food Science & Technology* 19(2): 94–101.

[20] WHO, UNICEF, and ICCIDD., 2008. Recommended iodine levels in salt and guidelines for monitoring their adequacy and effectiveness. World Health Organization (WHO/NU T/96.13), Geneva, Switzerland.

[21] Aslan, D., Köksal, H., 2003. Gıda zenginleştirilmesi ve bazı yaklaşımlar. *Sürekli Tıp Eğitimi Dergisi* 12(11): 418-420.

[22] Charoensiriwatana, W., Srijantr, P., Teeyapant, P., Wongvilairattana J., 2010. Consuming iodine enriched eggs to solve the iodine deficiency endemic for remote areas in Thailand. *Nutrition Journal* 9: 68-73.

[23] Isa, Z.M., Alias, I.Z., Kadir, K.A., Ali, O., 2000. Effect of iodized oil supplementation on thyroid hormone levels and mental performance among Orang Asli schoolchildren and pregnant mothers in an endemic goitre area in Peninsular Malaysia. *Asia Pac. J. Clin. Nutr.* 9: 274–281.

[24] Hatemi, H., 1999. Endemik guatr (Ötiroid Diffüz ve Nodüler Guatr). İ.Ü. Cerrahpaşa Tıp Fakültesi Sürekli Tıp Eğitimi Etkinlikleri, Tiroid Hastalıkları Sempozyumu, 15 Ekim, 1999, İstanbul, Book of Proceedings, 7-11p.

[25] Zimmermann, M.B., 2012. International Council For Control of Iodine Deficiency Disorders - IDD Newsletter, Volume 40 Number 3, Zürich, Switzerland.

[26] Chanthilath, B., Chavasit, V., Chareonkiatkul, S., Judprasong, K., 2009. Iodine stability and sensory quality of fermented fish and fish sauce produced

with the use of iodated salt. *Food Nutr. Bull.* 30(2): 183-188.
[27] Weng, H.X., Yan, A.L., Hong, C.L., Qin, Y.C., Pan, L., Xie, L.L., 2009. Biogeochemical transfer and dynamics of iodine in a soil–plant system. *Environmental Geochemistry and Health* 31: 401–411.
[28] Weng, H.X., Weng, J.K., Yan, A.L., Hong, C.L., Yong, W.B., Qin, Y.C., 2008. Increment of iodine content in vegetable plants by applying iodized fertilizer and the residual characteristics of iodine in soil. *Biological Trace Element Research* 123: 218–228.
[29] Caffagni, A., Arru, L., Meriggi, P., Milc, J., Perata, P., Pecchioni, N., 2011. Iodine Fortification Plant Screening Process and Accumulation in Tomato Fruits and Potato Tubers. *Communications in Soil Science and Plant Analysis* 42:706-718.
[30] Edmonds, J.S., Morita, M., 1998. The determination of iodine species in environmental and biological samples. *Pure and Applied Chemistry* 70(8): 1567-1584.
[31] Gamallo-Lorenzo, D., Barciela-Alonso, M.C., Moreda-Pineiro, A., Bermejo-Barrera, A., Bermejo-Barrera, P., 2005. Microwave-assisted alkaline digestion combined with microwave-assisted distillation for the determination of iodide and total iodine in edible seaweed by catalytic spectrophotometry. *Analitica Chimica Acta* 542: 287-295.
[32] Fischer, P.W., L'Abbe´, M. R., Giroux, A., 1986. Colorimetric determination of total iodine in foods by iodide-catalyzed reduction of Ce+4. *J. Assoc. Anal. Chem.* 69(4): 687-9.
[33] Mitsuhashi, T., Kaneda, Y., 1990. Gas chromatographic determination of total iodine in foods. *J. Assoc. Anal. Chem.* 73: 790-792.
[34] Chen, Z.L., Megharaj, M., Naidu, R., 2007. Speciation of iodate and iodide in seawater by non-suppressed ion chromatography with inductively coupled plasma mass spectrometry. *Talanta* 72(5):1842-1846.
[35] Larsen, E.H., Ludwigsen, M.B., 1997. Certified reference materials using wet ashing and detection by inductively coupled plasma mass spectrometry. *Journal of Analytical Atomic Spectrometry* 12: 435-439.
[36] Fecher, P.A., Goldmann, I., Nagengast, A., 1998. Determination of iodine in food samples by inductively coupled plasma mass spectrometry after alkaline extraction. *Journal of Analytical Atomic Spectrometry* 13: 977–982.
[37] Cataldi, T.R.I., Rubino, A., Ciriello, R., 2005. Sensitive quantification of iodide by ion-exchange chromatography with electrochemical detection at a modified platinum electrode. *Anal. Bioanal. Chem.* 382: 134-141.
[38] Błażewicz, A., 2012. A review of spectrophotometric and chromatographic methods and sample preparation procedures for determination of iodine in miscellaneous matrices. In Macro to Nano Spectroscopy, Edited by J. Uddin, InTech Publishing, Rijeka, Croatia, 448p.
[39] Watts, M.J., Mitchell, C.J., 2009. A pilot study on iodine in soils of Greater Kabul and Nangarhar provinces of Afghanistan. *Environ. Geochem. Health* 31: 503–509.
[40] Xiaolin, H., Chifang, C., Qinfang, Q., Xiaojun, Y., Xiao, F., 1997. Determination of chemical species of iodine in some seaweeds (I). *The Science of the Total Environment* 204: 215-221.
[41] Migliuolo, G., Ruggeri, P., 1994. Determinazione quantitativa del contenuto di iodio organico nel frutto Feijoa sellowiana. *Riv. Merceol.* 33(1): 29-32.