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The effects of temperature and relative humidity on ochratoxin A formation in fresh liquorice root

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In this study, the effects of temperature and relative humidity (RH) on ochratoxin A (OTA) formation during liquorice root storage were investigated. For this purpose, a real storage procedure in which fresh root was dried in the open air was simulated. Four RH-temperature combinations corresponding to average climate conditions (RH-temperature) of each season in an important liquorice growing and processing region were simulated as follows: A, autumn ($T = 15^{\circ}\text{C}$, $\text{RH} = 49\%$); B, winter ($T = 9^{\circ}\text{C}$, $\text{RH} = 51\%$); C, spring ($T = 22^{\circ}\text{C}$, $\text{RH} = 35\%$); and D, summer ($T = 29^{\circ}\text{C}$, $\text{RH} = 27\%$). The crushed fresh roots were incubated for 60 days, and the OTA content of the roots was determined at 20-day intervals by using inverse ion mobility spectrometry. The results showed that the maximum levels of OTA occurred after 40 days and were 4.3 ± 1.1 , 0.9 ± 0.2 , 7.3 ± 0.0 and $24.2 \pm 2.5 \text{ ng g}^{-1}$ in roots stored under simulated conditions A, B, C and D, respectively. After 40 days, the amount of OTA started to decline in all samples but at different rates. The results seem to indicate that temperature plays a more significant role than RH in producing OTA by moulds in liquorice root. It appears that 22°C could be considered as the critical temperature for OTA formation in liquorice root stored under experimental conditions. It could be concluded that liquorice-processing plants should obtain, dry and store fresh moist root when the temperature is below the critical point. Moreover, the roots stored in the open shade condition should not be covered by plastic films even when it is raining as this increases the root temperature.

Keywords: ochratoxin A; liquorice; storage condition; IMS

Introduction

The second most dangerous mycotoxin for agricultural products after aflatoxin B₁ is ochratoxin A (OTA), a derivative of isocoumarin linked to L-phenylalanine (Mateo et al. 2007). OTA is extensively produced by *Aspergillus* and *Penicillium* species, especially *A. ochraceus*, *A. carbonarius* (section *Nigri*) and *P. verrucosum* (Kapetanakou et al. 2009). OTA is classified as a nephrotoxic, hepatotoxic, teratogenic and immunotoxic compound. It is also considered a possible human carcinogen due to the evidence of carcinogenicity in animal tests (group 2B) (IARC 2009). OTA has been reported to be a common contaminant of cereal products (Duarte et al. 2010), beer and wine (Mateo et al. 2007), coffee beans (Batista et al. 2009), cocoa (Mounjouenpou et al. 2008), nuts (Molyneux et al. 2007), spices (Goryacheva et al. 2007) and dried fruits (Romero et al. 2005; Karbancioglu-Guler and Heperkan 2008).

OTA formation, like that of other mycotoxins, occurs in some poorly stored raw material from

agricultural products (Paterson and Lima 2010). Therefore, it is important to prevent OTA formation by making conditions unfavourable for mould generation. Controlling the storage factors has been shown to lower the growth rate and OTA formation by fungi strains and, therefore, the storage conditions play a major role in the formation of OTA. Intrinsic eco-physiological factors, such as pH, moisture and the composition of the substrate, as well as extrinsic factors, or in other words environmental parameters, influence OTA biosynthesis. The competitive endogenous flora in biological products is a contributing factor as well (Khalesi and Khatib 2011).

One of the crops that can easily be contaminated by OTA is liquorice root (Arino et al. 2007; Herrera et al. 2009). Liquorice has a wide range of applications in food products, medicines and the tobacco industry (Pan et al. 2000; Gabriele et al. 2001; Carmines et al. 2005). Although there is a lack of information on OTA contamination of certain minor food commodities such as liquorice, spices and teas (Fink-Gremmels 2005), there exists a Commission Regulation (No. 105/2010),

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setting maximum levels for certain contaminants in foodstuff such as OTA, for which the following maximum levels are proposed: liquorice root 20 µg/kg and liquorice extract 80 µg/kg (European Commission 2010).

Fresh liquorice with up to 70% moisture content is stored usually in open shade at the liquorice plant in large quantities exceeding a few thousand metric tons. They are dried naturally over a period of time depending on climate conditions, particularly relative humidity (RH) and temperature. Therefore, factors such as RH and storage temperature play a vital role in the root-drying process. This period (before the water content reaches equilibrium relative humidity (ERH) in liquorice root) is of critical importance for mould activities in the root. Although there is almost no study on optimisation of liquorice storage, it is supposed that the most important factors influencing mould growth and consequently OTA formation in stored grained ecosystems are storage temperature, RH, gas composition and incubation time (Haggbloom 1982; Ramos et al. 1998; Cairns-Fuller et al. 2005; Kapetanakou et al. 2009). Prevention is perhaps the best way to lower the risk of OTA contamination in liquorice products (Magan and Aldred 2007). Optimised storage condition could be of utmost importance for major producers of liquorice products particularly in developing countries.

Therefore, the objective of this study was to examine the best RH-temperature combination to store fresh liquorice root obtained by manufacturers based on the climate condition in a major production area to reduce OTA formation in roots regardless of OTA producers. For the first time in a real practice, an ion mobility spectrometer (IMS) at the positive inverse mode was used to measure the OTA in liquorice roots.

Materials and methods

Liquorice root samples

A total of 6 kg of fresh liquorice root (65% water content) was provided by Rishmac Co. obtained from Beiza region, Shiraz, Iran, and was transferred to the Food Microbiology Laboratory at Isfahan University of Technology in less than 8 hours by road transportation in March 2010. They were then prepared to be analysed further (Table 1).

Storage conditions

Fresh liquorice roots were stored under four combinations of temperature and RH on the basis of the actual average temperature and RH of four seasons in Shiraz, one of the main regions of liquorice production in the world. The data were extracted from average seasonal statistics of the last 10 years of Shiraz obtained from Iran's metrological organisation.

Table 1. The analysis results of fresh used liquorice roots.

Analysed parameters	Quantity
Moisture content (%wb)	54.3
Gums and starch (%db)	9.03
Glycyrrhizin (%db)	7.11
Total carbohydrate (%db)	5.98
Sucrose (%db)	2.88
pH of diluted extract in water (1:9 w/w)	5.3

Note: wb = wet basis, db = dry basis.

These four conditions were called A (T = 15°C, RH = 49%), B (T = 9°C, RH = 51%), C (T = 22°C, RH = 35%) and D (T = 29°C, RH = 27%) on the basis of the average weather conditions in autumn, winter, spring and summer, respectively. To simulate these storage conditions, 12 desiccators with a diameter of 15 cm were placed in four incubators at different temperatures (three desiccators as replication in each incubator). To create the specified RH, desiccators were filled with sulphuric acid at different concentrations (Chen and Mujumdar 2008). The fresh roots were incubated under all the above-described conditions for 60 days, and samples were taken from each desiccator at a 20-day interval to determine the OTA formed on the liquorice root.

OTA extraction and purification

OTA extraction was carried out on the basis of the method described by Khalesi et al. (2011). Briefly, shredded liquorice root (3 g) was added to a mixture of 30 mL of sodium bicarbonate 0.13 M and methanol (9:1 v/v) in an Ultrat-Turrax homogeniser (ULTRA-TURRAX T 25 digital, IKA, Germany) for 2 minutes. The extract was then centrifuged at 200 g for 15 minutes by using a laboratory centrifuge (SiGMA 6K15, GmbH, Germany). The supernatant (10 mL) was purified by using immunoaffinity columns (Puri-Fast OTA IAC, libios, France). The column was pre-conditioned in advance by 10 mL of phosphate buffered saline (pH 7.4). The purified extract was then eluted slowly (1 drops⁻¹) through the column. Trapped OTA in the immunoaffinity column (IAC) was recovered by using 10 mL of the solvent mixture containing methanol/acetic acid (98:2 v/v). To concentrate the recovered OTA, the solvent was completely evaporated under a gentle stream of nitrogen at 30°C, and the remaining sample was re-dissolved in 1 mL of methanol.

OTA analysis

Total OTA concentrations in samples were determined by using IMS at the positive mode (Khalesi et al. 2011). The IMS used in this study was constructed in the IMS Laboratory at the Isfahan University of Technology.

An IMS cell (installed in an oven), a needle for producing the corona, two high-voltage power supplies, a pulse generator, an analog-to-digital converter and a computer to record spectra comprised the main components of the instrument. A detailed description of the instrument and its corona discharge ionisation source can be found in a previous publication of group members (Tabrizchi et al. 2000; Shamlouei and Tabrizchi 2008). To enhance the differentiation of the OTA peak, the inverse mode of IMS was applied (Tabrizchi and Jazan 2010; Khalesi et al. 2011). Experimental conditions for obtaining ion mobility spectra of OTA were optimised by using OTA standard purchased from Sigma-Aldrich (St. Louis, MO). The calibration curves were prepared by using the obtained spectra under the optimised condition and at the inverse mode in different concentrations ranging from 0.01 ng to 1.00 ng standard OTA dissolved in methanol. To analyse the OTA in real samples, aliquots of 10 μ L of the purified solvent were injected into the IMS injection port at optimised condition (Khalesi et al. 2011). The solvent was evaporated quickly, and then the dissociated fragments of OTA could compete with positive ions created in the corona region to be protonated. The protonated fragments could then pass through the drift region, reach the detector and as a result produce a number of signals. All measurements were carried out in triplicate, for initial fresh roots, and after 20, 40 and 60 days of storage.

Recovery test

The OTA method used in this study was initially validated by the analysis of standard solutions and spiked samples at three concentrations of OTA (20, 50 and 100 ng mL^{-1} of extracted samples of liquorice root; $n = 3$) (Karbancioglu-Guler and Heperkan 2008). The recovery was determined by comparing the peak area of OTA obtained from the root extract of spiked samples with the peak area of OTA obtained by the standard calibration curve.

Data analysis

All statistical analyses were performed by using the Microsoft Excel software (version 10). The analysis of variance analysis was used to evaluate the significance of the differences observed between groups. Whenever p was ≤ 0.05 , differences were considered to be statistically significant.

Results and discussions

Method verification

After clean-up of liquorice extract containing OTA by using immunoaffinity column (IAC), the purified

Table 2. Recovery results in triplicate.

Spiked OTA (ng mL^{-1})	Recovery (%)	RSD (%)
20	111	2
50	109	2
100	111	3

Note: OTA, ochratoxin A; RSD, relative standard deviation.

Figure 1. The spectra of blank, real and spiked samples (20, 50 and 100 ppb). OTA, ochratoxin A; RIP, reactant ion peak.

extract was injected into the IMS injection port. No interfering peaks were observed in the region of interest where the OTA emerged (i.e. 6.18 milliseconds) far from the reactant ion peak. This highlights the efficiency of the clean-up procedure. Linearity was assessed in the 0.01–1.00 ng OTA range ($R^2 = 0.988$). Table 2 shows the recovery results. The relative standard deviation of the recovery values was less than 3%.

Figure 1 compares the standard blank, the real sample containing OTA and the spiked samples. The ion mobility spectra of OTA in the range of 0.01–1.00 ng show only one fragment peak at 6.18 milliseconds in all samples.

The detection limit was obtained to be about 10 pg based on a signal-to-noise ratio of 3:1. The level of sensitivity for this rapid method is comparable to that of other reports using high-performance liquid chromatography to determine OTA (Alarcon et al. 2006; Herrera et al. 2009).

The effects of temperature and RH on OTA formation in liquorice root

Table 3 shows the amount of OTA formed in liquorice root stored at different RH-temperature combinations

Table 3. The concentration of OTA (ng g^{-1}) in liquorice root at different storage conditions.

Season	Initial sample	20 days	40 days	60 days
Spring	0.6 ± 0.1^a	4.7 ± 0.4^c	7.3 ± 0.0^d	6.5 ± 1.1^d
Summer	0.6 ± 0.1^a	11.6 ± 1.4^e	24.2 ± 2.5^f	21.0 ± 2.0^f
Autumn	0.6 ± 0.1^a	1.4 ± 0.3^b	4.3 ± 1.1^c	2.8 ± 0.4^c
Winter	0.6 ± 0.1^a	0.7 ± 0.1^a	0.9 ± 0.2^a	0.7 ± 0.1^a

Notes: Means followed by different lowercase letters are significantly different ($n = 3$; $p \leq 0.05$).
OTA, ochratoxin A.

corresponding to Shiraz climate at the beginning of the storage and 20, 40 and 60 days after incubation.

All the samples contained OTA, from initial low concentration ($0.9 \pm 0.2 \text{ ng g}^{-1}$) up to relatively high concentrations ($24.2 \pm 2.5 \text{ ng g}^{-1}$). Because of the required temperature for the growth of OTA-producing moulds (from $<10^\circ\text{C}$ to $>47^\circ\text{C}$ (Karbancioglu-Guler and Heperkan 2008), it can be realised that the temperature of the corresponding region is favourable to OTA producers.

In the extraction plant, liquorice roots are usually stored for long periods depending on the production size of the plant, sometimes up to 24 months (roots are normally processed based on a first-in, first-out scheme). This is a necessity for producers to ensure the availability of products for their customers and at the same time is widely believed by producers to have a positive effect on the quality of the stored roots. It is assumed that the fresh moist roots are dried for a maximum 60 days of storage in the open air depending on the weather conditions.

The results in Table 3 demonstrate that there is a significant difference between four simulated conditions on OTA formation in roots. This could be of particular importance for producers of liquorice products as it influences the root collection and/or storage strategy, which is still a matter of debate amongst some of the experienced producers (Magnoli et al. 2007; Noonim et al. 2008). The importance of these data can be even more obvious when it is emphasised that the best way of keeping the level of OTA below regulated limits is to prevent its formation rather than decontamination. Considering these results, only the roots kept under summer-stimulated condition contained 24.2 ng g^{-1} OTA, which is higher than the maximum regulated level. Our results showed a significant influence of temperature not only on the visual growth of moulds but also on OTA formation. These results are similar to a previous finding that reported a gradual increase in growth and OTA formation by some moulds grown on dried figs in mild temperatures of 15°C – 30°C (Karbancioglu-Guler and Heperkan 2008).

On the other hand, these data indicate that RH has less influence than temperature on OTA formation in

roots. Unlike other similar research, in this project OTA formation in root was investigated by using real environmental conditions whereas OTA formation in laboratory conditions is usually studied on microbiological media. This gave an advantage of better understanding what happens in the root under the storage conditions until roots reach ERH in terms of OTA formation in different seasons. Although the winter conditions had the highest RH (i.e. 51%), it is the single case where there was no significant difference between OTA content over time. If winter conditions are compared with those of autumn, the RH in both cases is very similar (51% and 49%, respectively) but a 6°C increase in temperature led to a considerable difference in the level of OTA formed on the root at any time during incubation. Similarly, if spring and summer conditions are compared, it is evident that temperatures above 22°C cause a significant increase in the OTA content of the root. The RH in summer time is lower than that in spring (lowest among all tested conditions). Therefore, the observed difference could be attributed to the difference in temperature, although to accurately assess any possible effects of interaction between temperature and RH on OTA formation in the root, more experiments and observations are needed. However, as the RH in summer is lower than that in spring and the OTA content in root stored in the summer condition is notably higher than that in root stored in spring, even if such an interaction has any possible effects in these ranges of RH and temperature, it is neglected because of the effects of temperature on the OTA formation. One of the important implications of these findings for liquorice producers is to choose the best season to collect/purchase the fresh roots for their factory, which seems to be the best when the temperature of the stored root does not exceed 22°C , the critical temperature for OTA formation in liquorice root. Fresh roots normally contain a high amount of water (up to 70%) and are highly susceptible to OTA-producing mould activities until reaching the ERH below the critical level for OTA formation. This critical temperature is very important in the storage of liquorice roots due to the fact that these are normally kept in open shade places because of the size of storage.

Figure 2. The trend of OTA formation in different seasons. OTA, ochratoxin A.

Moreover, there is a debate on whether roots stored in winter should be kept away from humidity by covering those by using plastic sheets or not. These results show that covering the roots in winter could even have a negative effect on the OTA content of liquorice roots as it may increase the internal temperature of the bulk roots.

The trends of OTA formation

To assess the effects of those four treatments, it was decided to look at the trends of OTA formation in liquorice root (Figure 2).

The trends demonstrate more vividly the difference between the effects of summer conditions and the other three conditions on OTA production on liquorice root. In addition, it shows a small reduction in the OTA content of roots stored for 60 days in all cases. One explanation for this observation is that on the one hand after 40 days the humidity in the root reaches ERH in the desiccator, which in all cases was below the required level for growth and OTA production by mould. Therefore, any increase in the OTA content is either stopped or measurably decreased. It can be safely assumed that after 40 days, no sample has sufficient water content to be further contaminated by OTA. On the other hand, there is an evidence to suggest that moulds, even some OTA producers, could themselves degrade the OTA formed in food samples (Astoreca et al. 2007; Khalesi et al. 2013). This is an exciting topic concerning OTA elimination from food products that needs more extensive study. Although OTA is reported to be a stable metabolite (Turner et al. 2009), a similar observation was reported in some cases in which OTA concentration in culture media decreased considerably over the incubation time (Varga et al. 2000). These report that some strains of *A. fumigatus*, *A. japonicus* and *A. niger* are capable of degrading OTA (Abrunhosa et al. 2002). Researchers

suggested that the strains remove and assimilate the phenylalanine moiety from the OTA molecule like other nitrogen sources in the culture media when they become exhausted (Astoreca et al. 2007). Re-metabolism of OTA could explain a small reduction in OTA observed in this study between 40 and 60 days. However, further experiments are needed to positively verify this hypothesis.

Conclusions and prospective

We draw the conclusion that although OTA formation in liquorice root can be affected by different storage factors, controlling the temperature almost always prevents the production of this mycotoxin. Inverse IMS was successfully applied in real practice for the first time to measure the amount of OTA in liquorice roots. The authors strongly recommend the use of this method to determine mycotoxins in storage products, especially those that are stored in open environments.

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References

- Abrunhosa L, Serra R, Venaoncio A. 2002. Biodegradation of ochratoxin A by fungi isolated from grapes. *J Agr Food Chem.* 50:7493–7496.
- Alarcon SH, Palleschi G, Compagnone D, Pascale M, Visconti A, Barna-Vetro I. 2006. Monoclonal antibody based electrochemical immunosensor for the determination of ochratoxin A in wheat. *Talanta.* 69:1031–1037.
- Arino AM, Herrera M, Estopanan GT, Juan T. 2007. High levels of ochratoxin A in licorice and derived products. *Int J Food Microbiol.* 114:366–369.
- Astoreca A, Magnoli C, Barberis C, Chiacchiera SM, Combina M, Dalcero A. 2007. Ochratoxin A production in relation to ecophysiological factors by *Aspergillus* section *Nigri* strains isolated from different substrates in Argentina. *Sci Total Environ.* 388:16–23.
- Batista LR, Chalfoun SM, Silva CF, Cirillo M, Varga EA, Schwan RF. 2009. Ochratoxin A in coffee beans (*Coffea arabica* L.) processed by dry and wet methods. *Food Control.* 20:784–790.
- Cairns-Fuller V, Aldred D, Magan N. 2005. Water, temperature and gas composition interactions affect growth and ochratoxin A production by isolates of *Penicillium verrucosum* on wheat grain. *J Appl Microbiol.* 99: 1215–1221.
- Carmines EL, Lemus R, Gaworsky CL. 2005. Toxicologic evaluation of licorice extract as a cigarette ingredient. *Food Chem Toxicol.* 43:1303–1322.

- Chen XD, Mujumdar AS. 2008. Drying technologies in food processing. 2nd ed. Chichester: Blackwell Pub.
- Duarte SC, Pena A, Lino CM. 2010. A review on ochratoxin A occurrence and effects of processing of cereal and cereal derived food products. *Food Microbiol.* 27:187–198.
- European Commission. 2010. Regulation No. 105/2010 of 5 February 2010 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in food-stuff as regards ochratoxin A. *Off J Eur Union L.* 35/7–35/8.
- Fink-Gremmels J. 2005. Conclusions from the workshops on ochratoxin A in food: recent developments and significance. *Food Addit Contam A.* 22(1):1–5.
- Gabriele D, Curcio S, Cindio B. 2001. Optimal design of single-screw extruder for liquorice candy production: a rheology based approach. *J Food Eng.* 48:33–44.
- Goryacheva IY, de Saeger S, Nesterenko IS, Eremin SA, van Peteghem C. 2007. Rapid all-in-one three-step immunoassay for non-instrumental detection of ochratoxin A in high-coloured herbs and spices. *Talanta.* 72:1230–1234.
- Hagblom P. 1982. Production of ochratoxin A in barley by *Aspergillus ochraceus* and *Penicillium viridicatum*: effect of fungal growth, time, temperature, and inoculum size. *Appl Environ Microbiol.* 43(5):1205–1207.
- Herrera M, Herrera A, Arino A. 2009. Estimation of dietary intake of ochratoxin A from liquorice confectionery. *Food Chem Toxicol.* 47:2002–2006.
- International Agency for Research on Cancer (IARC). 2009. Agents reviewed by the IARC monographs volumes 1–100a (by CAS numbers). 10.
- Kapetanidou AE, Panagou EZ, Gialitaki M, Drosinos EH, Skandamis PN. 2009. Evaluating the combined effect of water activity, pH and temperature on ochratoxin A production by *Aspergillus ochraceus* and *Aspergillus carbonarius* on culture medium and Corinth raisins. *Food Control.* 20:725–732.
- Karbancioglu-Guler F, Heperkan D. 2008. Natural occurrence of ochratoxin A in dried figs. *Anal Chim Acta.* 617:32–36.
- Khalesi M, Khatib N. 2011. The effects of different ecophysiological factors on ochratoxin A production. *Environ Toxicol Pharmacol.* 32:113–121.
- Khalesi M, Sheikh-Zeinoddin M, Tabrizchi M. 2011. Determination of ochratoxin A in licorice root using inverse ion mobility spectrometry. *Talanta.* 83:988–993.
- Khalesi M, Venken T, Deckers S, Winterburn J, Shokribousjein Z, Gebruers K, Verachttert H, Delcour J, Martin P, Derdelinckx G. 2013. A novel method for hydrophobin extraction using CO₂ foam fractionation system. *Ind Crop Prod.* 43:372–377.
- Magan N, Aldred D. 2007. Post-harvest control strategies: minimizing mycotoxins in the food chain. *Int J Food Microbiol.* 119:131–139.
- Magnoli C, Astoreca A, Ponsone ML, Fernandez-Juri MG, Barberis C, Dalcero AM. 2007. Ochratoxin A and *Aspergillus* section *Nigri* in peanut seeds at different months of storage in Cordoba, Argentina. *Int J Food Microbiol.* 119:213–218.
- Mateo R, Medina A, Mateo EM, Mateo F, Jimenez M. 2007. An overview of ochratoxin A in beer and wine. *Int J Food Microbiol.* 119:79–83.
- Molyneux RJ, Mahoney N, Kim JH, Campbell BC. 2007. Mycotoxins in edible tree nuts. *Int J Food Microbiol.* 119:72–78.
- Mounjouenpou P, Gueule D, Fontana-Tachon A, Guyot B, Tondje PR, Guiraud JP. 2008. Filamentous fungi producing ochratoxin A during cocoa processing in Cameroon. *Int J Food Microbiol.* 121:234–241.
- Noonim P, Mahakarnchanakul W, Nielsen KF, Frisvad JC, Samson RA. 2008. Isolation, identification and toxigenic potential of ochratoxin A-producing *Aspergillus* species from coffee beans grown in two regions of Thailand. *Int J Food Microbiol.* 128:197–202.
- Pan X, Liu H, Jia G, Shu YY. 2000. Microwave-assisted extraction of glycyrrhizic acid from licorice root. *Biochem Eng J.* 5:173–177.
- Paterson RRM, Lima N. 2010. How will climate change affect mycotoxins in food? *Food Res Int.* 43:1902–1914.
- Ramos AJ, Labernia N, Marin S, Sanchis V, Magan N. 1998. Effect of water activity and temperature on growth and ochratoxin production by three strains of *Aspergillus ochraceus* on a barley extract medium and on barley grains. *Int J Food Microbiol.* 44:133–140.
- Romero SM, Comerio RM, Larumbe G, Ritieni A, Vaamonde G, Pinto VF. 2005. Toxigenic fungi isolated from dried vine fruits in Argentina. *Int J Food Microbiol.* 104:43–49.
- Shamlouei HR, Tabrizchi M. 2008. Transmission of different ions through a drift tube. *Int J Mass Spectrom.* 273:78–83.
- Tabrizchi M, Jazan E. 2010. Inverse ion mobility spectrometry. *Anal Chem.* 82:746–750.
- Tabrizchi M, Khayamian T, Taj N. 2000. Design and optimization of a corona discharge ionization source for ion mobility spectrometry. *Rev Sci Instrum.* 71(6): 2321–2328.
- Turner NW, Subrahmanyam S, Piletsky SA. 2009. Analytical methods for determination of mycotoxins: a review. *Anal Chim Acta.* 632:168–180.
- Varga J, Rigo K, Teren J. 2000. Degradation of ochratoxin A by *Aspergillus* species. *Int J Food Microbiol.* 59:1–7.