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Determination of quaternary ammonium compound residues in fruits and vegetables by QuEChERS following LC-MS/MS analysis

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Determination of quaternary ammonium compound residues in fruits and vegetables by QuEChERS following LC-MS/MS analysis

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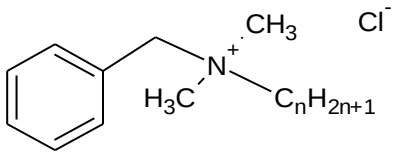
Abstract

A simple and fast method to determine residues of quaternary ammonium compounds (QAC) in fruit and vegetable samples is presented. The analytes were extracted applying the frequently used QuEChERS method. Analysis was performed by liquid chromatography-electrospray tandem mass spectrometry (LC-ESI-MS/MS) in the positive mode using a triple quadrupole instrument. The method was validated for the following representative matrices: cucumber (high water content), raisin (high sugar content), lemon (sour) and wheat (dry) at 0.1 mg kg^{-1} level. The method validation resulted in satisfying recoveries and relative standard deviations (RSDs) for all QAC. In cucumber, raisin, lemon and wheat matrices, recoveries ranged between 88 and 104% and RSDs ranged between 1.1 and 9.8%. All analytes were regularly detected at very low level (<0.005 mg kg^{-1}) in blank sample material and even when only solvent was injected. Therefore, the reporting limit was set to 10 µg kg^{-1}. Our results demonstrate that determining QAC can easily be integrated in routinely conducted QuEChERS extraction followed by LC-MS/MS analysis. In a final step we proved the method's performance analyzing conventional and organic grown samples from the common market.

Introduction

Quaternary ammonium compounds (QAC) are surface active substances containing a quaternary cationic nitrogen atom, substituted by alkyl chains of varying length. The important representatives benzalkonium chlorides (BAC) and didecyldimethylammonium chloride (DDAC) are shown in figure 1. QAC are enriched in cell membranes of living organisms and can impair cell membrane functions [1]. Due to these characteristics, QAC are used as biocides [2], pesticides [3,4], disinfectants [5,6], wood preservatives [7,8] and additives for technical applications [9], furthermore as ingredients in human and veterinary medicinal products and cosmetics [9]. Additionally, plant protection products like plant strengtheners can contain QAC not as active ingredients but as additives. The authorization of such plant strengtheners has meanwhile been withdrawn within Germany.



a) n=8, 10, 12, 14, 16,1

b)

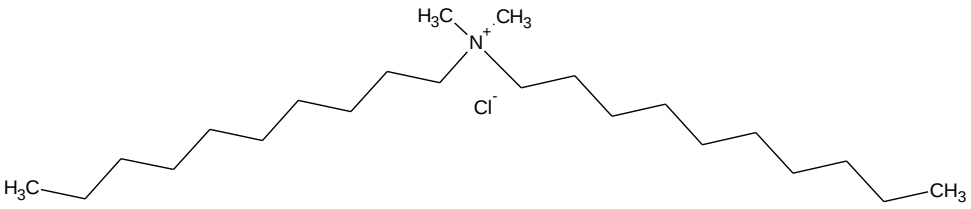


Fig. 1 (a) Benzalkonium chloride (BAC) with chain length of n=10, 12, 14, 16 (b) Didecyldimethylammonium chloride (DDAC)

The use of QAC in plant protection products or biocides were expected not to result in any residues in food and no maximum residue levels (MRLs) have been fixed. Based on the broad application spectrum of QAC food and feed can probably be cross-contaminated due to contact with contaminated surfaces, containers and transport equipment.

Some QAC have been listed in Commission Regulation (EC) 1112/2002 [10] of the European Union to be assessed as active substances for pesticide use. With Commission Decision 2004/129/EC [11] most of the QAC have not been included in Annex I of Commission Regulation 91/414 of the EU which is now repealed by Commission Regulation (EC) 1107/2009. Therefore, QAC are not authorized for the use in plant protection products within the EU. Only DDAC is approved within Commission Regulation (EC) 1107/2009 [12] as an active substance for plant protection products and authorizations are in place in Spain, Belgium and France [9]. As no specific MRLs are established within Commission Regulation (EC) 396/2005 [13] the default MRL of 0.01 mg kg^{-1} according to Art (1) (b) of Regulation (EC) 396/2005 is in force for residues of QAC in food and feed items listed in Annex I of that Regulation, no matter if the residue is caused by application of biocides or plant protection products. Recent analyses carried out by food businesses and regulatory authorities in Germany have detected unexpected residues of BAC and DDAC high above the statutory MRL of 0.01 mg kg^{-1}. It is assumed that disinfectant use is the primary source of these residues - caused by disinfection of water used for food washing and irrigation or by treatment of surfaces with biocide products. In July 2012, the Standing Committee on the Food Chain and Animal Health (SCFCAH) thereupon decided that food and feed of plant and animal origin with a level of DDAC as well as BAC higher than 0.5 mg kg^{-1} should not be placed on the market and be withdrawn from the market and disposed of safely [14,15].

Amongst other things, the length and branching of the alkyl chains contribute to the QAC's toxicity. The German Federal Institute for Consumer Protection (BfR) has derived the acute reference dose (ARfD) and acceptable daily intake (ADI) for DDAC and BAC of 0.1 mg per kg body weight per day [16,17] . Quaternary ammonium compounds are only considered acutely toxic in few cases. Toxic effects on aquatic organisms have been reported [9], whereas in reproductive toxicity studies on DDAC, neither adverse effects on the reproductive parameters, nor any indication of teratogenic properties were observed [18]. However, QAC increase the permeability of membranes by damaging the protective water lipid mem-

branes of the outer skin and can thus have an effect on the absorption level of other toxic substances.

Several approaches for the analysis of quaternary ammonium compounds are described in literature. There are different types of methods for QAC determination in varying matrices, e.g. enzyme-linked immunosorbent assay [19], photometry [20], liquid chromatography [8] as well as ion chromatography [21] and matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF) [22]. A growing number of methods has been reported using liquid chromatography coupled to mass spectrometry with quadrupole [23-26] and TOF [27,28] detection.

Only small investigations have been reported for the determination of QAC applying the frequently used QuEChERS (short for Quick Easy Cheap Effective Rugged and Safe) [28,29] method. QuEChERS permits a simple and fast extraction procedure and provides high recoveries for a broad spectrum of pesticides. Aim of this work was to include the determination of QAC into a multiresidue scheme applying QuEChERS extraction. Analysis was performed applying liquid chromatography coupled with triple quadrupole mass spectrometry detection (LC-MS/MS).

Experimental

Chemicals and standards

Acetonitrile and methanol of gradient grade were purchased from Merck (Darmstadt, Germany). Water for liquid chromatography was deionized in the laboratory using a Direct-Q 3 UV Ultrapure Water Purification System (Billerica, MA, USA). Dry ice for sample comminution was delivered in blocks by a local provider, stored at - 80°C until use and was tested not to contain any of the analysed QAC at relevant levels. Ammonium formate was purchased from Sigma-Aldrich (Steinheim, Germany). Magnesium sulfate anhydrous grit, trisodium citrate tribasic dihydrate and disodium hydrogencitrate sesquihydrate all used for phase separation after QuEChERS extraction were from Sigma-Aldrich (Steinheim, Germany). Sodium chloride was purchased from Merck (Darmstadt, Germany).

The analytical pesticide standards DDAC and the internal standard substance chlorpyrifos D10 (purity > 98%) were obtained from Dr. Ehrenstorfer (Augsburg, Germany), BAC 10, 12 and 16 (purity > 99.9%) were purchased from Sigma-Aldrich (Steinheim, Germany) and BAC 14 (purity > 98 %) was purchased from Fluka (Buchs, Germany). All standards were stored at - 18°C. Stock solutions of 1 mg mL^{-1}, considering

standard purity, were prepared in acetonitrile. For the internal standard chlorpyrifos D10 a working solutions of 20 µg mL^{-1} was prepared in acetonitrile. All solutions were stored in the dark at 4°C.

Samples and commodities

Different fruit and vegetable samples of different origins were collected in the routine laboratory for pesticide analysis in fruits and vegetables located at the Chemisches und Veterinäruntersuchungsamt (CVUA) Stuttgart. Representative parts of the fresh blank samples were pre-chopped and deep-frozen at -18°C overnight after arriving in the routine pesticide laboratory. The pre-chopped samples were subsequently milled with dry ice and stored at -18°C until extraction.

Dried fruits (e.g. raisins) were mixed with cold water at a ratio of 1:1.7, homogenized with the addition of dry ice and the homogenates were deep-frozen at -18°C until use.

Dry samples (e.g. wheat) were grinded thoroughly without adding water and were stored at room temperature until extraction.

Apparatus

Frozen samples were chopped with dry ice using a Prime Cut UM5 universal machine from Stephan Machinery GmbH (Hameln, Germany). Dry samples were ground at room temperature using a Grindomix GM 200 knife mill by Retsch (Haan, Germany).The automatic shaking machine Geno Grinder 2010 (SPEX Sample Prep, Metuchen, USA) was used for QuEChERS automated extraction. The centrifuge Rotana 460 by Hettich (Tuttlingen, Germany), appropriate to the centrifuge tubes employed in the procedure and capable of achieving 4000×g, was used. Electronic pipettes applicable for volumes of 10–100 µL and 100–1000 µL, respectively, and manual pipettes applicable for volumes of 1–10 mL were from Eppendorf (Hamburg, Germany). Analytical balances capable of weighing to 0.1 mg or to 0.01 g were from Mettler-Toledo (Greifensee, Switzerland). The Fortuna Optifix 10 mL Universal Dispenser was used to add solvent to the samples. The automatic dispenser system Opus (20-50 mL; Ex 20°C; Hirschmann Laborgeräte, Eberstadt, Germany) was used for dilution of the working solutions.

50-mL PP (114×28 mm) single-use tubes with screw caps for the sample extraction were from Sarstedt (Nümbrecht, Germany). 1.5-mL LC autosampler vials and 20-mL screw-cap vials were from Ziemer GmbH (Mannheim, Germany). Stackable plastic cups for the storage of pre-weighed partitioning salt mixture were from Juro-Labs (Henfenfeld, Germany). Salt mixtures for phase separation were pre-weighed using a rotary sample divider from Fritsch (Idar-Oberstein, Germany).

An Agilent 1100 HPLC system (Agilent, Waldbronn, Germany), consisting of a quaternary pump, a standard autosampler and a column oven, combined with the mass spectrometer API 4000 (ABSCIEX, Darmstadt, Germany), run in ESI positive mode, was used for analysis of the QuEChERS extracts. The samples were injected on a Phenomenex Synergi Hydro RP 2.1 x 150 mm column with 4 µm particle size (Phenomenex, Aschaffenburg, Germany).

QuEChERS extraction

For the QuEChERS method 10 ± 0.1 g (5 g in case of dry matrices and 13.5 g in case of frozen homogenates from dried fruits) of the prepared frozen samples were weighed into 50-mL PP tubes. 10 mL of acetonitrile followed by 100 µL of the internal standard working solution of chlorpyrifos D10 were added to the samples. The tube was closed and shaken by a mechanical shaker for one minute as a first extraction step. The second extraction step subsequently followed including the addition of a pre-weighed partitioning salt mixture (4 g magnesium sulfate anhydrous grit, 1 g sodium chloride, 0.5 g disodium hydrogen citrate sesquihydrate, 1 g trisodium citrate dihydrate) and shaking for 1 min by hand or mechanical shaker. The tube was centrifuged for 5 min at 3500 x g and the upper acetonitrile phase was transferred to vials and directly applied to LC-MS/MS measurement without any further cleanup.

LC-MS/MS analysis

Mobile phase A consisted of 5 mM ammonium formate in purified water, mobile phase B was 5 mM ammonium formate in methanol. A gradient program was used starting with a flow rate of 0.1 mL min^{-1} and 100% of mobile phase A (0%B) at injection time, gradually changing to 30% A (70% B) over 3 min and to 15% A (85% B) until 6 min after injection. Then, the flow was set to 0.3 mL min^{-1} and mobile phase composition was shifted to 10% A (90% B) over 3 min. This mobile phase composition was kept for 11.5 min and was then shifted back to starting conditions within 0.5

min. The conditions were maintained for 11 min for column equilibration. The injection volume was 3 µL, automatically diluted with 10µl of mobile phase A during injection procedure. The column temperature was set to 40°C. ESI interface in positive mode was applied, the MS/MS detection was performed in the multiple reaction monitoring (MRM) mode. The ion spray voltage was 5500 V, the nebulizer gas and the turbo gas were synthetic air, both at 60 psi, and the curtain gas was nitrogen at 30 psi, the source temperature was 500°C.

Two precursor-productions were monitored for each compound in the multiple reaction monitoring mode (MRM). The first transition was used for quantification, while the second transition served as a quality control.

Method validation

The method was validated at 0.1 mg kg^{-1} level for the following representative matrices: cucumber (high water content), raisin (high sugar content), lemon (sour) and wheat (dry). Blank samples of cucumber, raisin, lemon and wheat were spiked with a mixture of BAC 10, 12, 14, 16 and DDAC (n=5) following QuEChERS extraction and LC-MS/MS analysis. All blank samples were proved not to contain QAC in relevant amounts right before validation. We applied matrix matched calibration standards at concentrations representing 60 and 120% of the validation level for each matrix and analyte. Quantification was carried out via calculating the ratio between analyte peak area and ISTD peak area for both, calibration standards and recovery samples. We then calculated the concentration of the recovery samples from the known concentration of the calibration standard.

Results and discussion

Each compound could be detected in LC-MS/MS with high sensitivity. The analytes eluted as well-defined and narrow shaped peaks, BAC 10, 12, 14 and 16 at retention times of 11.09, 11.91, 13.03, and 14.42 min respectively, DDAC eluted at 13.17 min. Tab. 1 gives an overview of the compounds' MRM transitions, MS conditions and retention times. A typical LC-MS/MS chromatogram is shown in Fig. 2.

Tab. 1 Properties of the studied compounds including MS operating conditions

	Empirical formula	Retention time (min)	First Transition	DP	CE	CXP	Second Transition	DP	CE	CXP
BAC 10	C19H34ClN	11.09	276→ 184	55	27	10	276→ 91	55	37	36
BAC 12	C21H38ClN	11.91	304→ 212	91	29	10	304→ 91	91	37	16
BAC 14	C23H42ClN	13.03	332→ 240	83	31	10	332→ 91	83	59	8
BAC 16	C25H46ClN	14.42	360→ 268	78	33	12	360→ 91	78	67	10
DDAC	C22H48ClN	13.17	326→ 186	61	39	12	326→ 41	61	93	6
Chlorpyrifos D10 (ISTD)	C9HCl3D10NO3PS	12.50	360→ 199	66	23	12	-	-	-	-

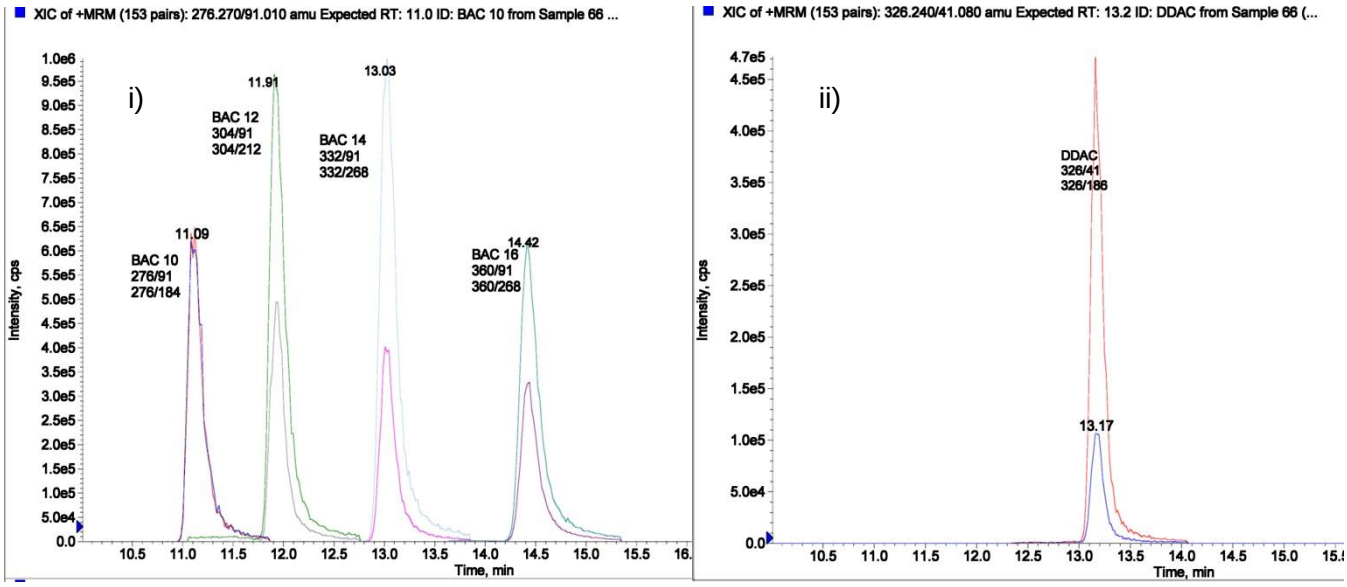


Fig. 2 LC-MS/MS chromatogram of i) BAC 10, 12, 14, 16 and ii) DDAC

Limits of Quantification (LOQ), defined as the lowest concentration showing a signal to noise ratio >10, were well below 10 µg kg^{-1} for all analytes. However, we detected small peaks of all QAC in blank samples as well as in organic solvents. Small amounts of QAC seem to be always present, which can be ascribed to the fact that QAC are commonly used in a broad spectrum of cleaning agents and disinfectants and can also be present in indoor air [21] or house dust [1]. The positive findings of QAC in blank samples and also in solvents remained problematic. Although the LOQs were well below 10 µg kg^{-1}, our Reporting Limit was set to 10 µg kg^{-1}.

The method validation resulted in satisfying recoveries and relative standard deviations (RSDs) for all QAC. In cucumber, raisin, lemon and wheat

matrices, recoveries ranged between 88 and 104% and RSDs ranged between 1.1 and 9.8%. The average recoveries and RSDs for all applied matrices are shown in Tab. 2 and Tab. 3.

Tab. 2 Mean recoveries in % at 0.1 mg kg^{-1} (n=5)

	BAC 10	*BAC 12*	*BAC 14*	*BAC 16*	*DDAC*
Cucumber	98	101	100	95	96
Raisin	101	104	98	97	98
Lemon	99	97	97	100	97
Wheat	98	92	88	88	96

Tab. 3 RSDs in % at 0.1 mg kg^{-1} (n=5)

	BAC 10	*BAC 12*	*BAC 14*	*BAC 16*	*DDAC*
Cucumber	4.2	3.6	4.3	2.2	3.7
Raisin	4.4	1.6	2.0	1.9	2.9
Lemon	3.6	1.1	2.8	1.4	2.3
Wheat	5.6	1.6	3.2	5.0	9.8

Additional recovery data was obtained within the framework of an on-going validation. BAC 12 showed recoveries of 103-124% in mango (2x) and orange (1x) samples and DDAC showed recoveries of 87-120% in banana (3x), parsley (2x), bean (2x), (rocket (1x), mushroom (1x), grape (1x) and blueberry (1x) samples. More data can also be obtained at the EURL Datapool [30].

Since May 2012 a total of 1058 fruit and vegetable samples have been analysed for QAC residues.

19 out of 556 fruit samples (3.4%) were found to contain residues of QAC, thereof 13 samples with amounts exceeding the default MRL of 0.01 mg kg^{-1}. The maximum amount detected was 0.3 mg kg^{-1} DDAC in a mandarin sample. 13 out of 502 vegetable samples (2.6%) were found to contain residues of QAC, thereof 13 samples with amounts exceeding the default MRL of 0.01 mg kg^{-1} and a maximum amount of 0.92 mg kg^{-1} detected in a parsley sample. Residue above the MRL were found for DDAC mostly (18 samples), but in 9 samples residues above the MRL were found for BAC. An overview of QAC residues in the tested samples is given in Tab. 4.

Tab. 4 Residues of QAC in naturally grown fruit and vegetable samples

Commodity	No. of samples	With residues	With residues (%)	Without residues
Berry fruits	255	2	0,8	253
Stone fruits	116	4	3,4	112
Exotic fruits	96	8	8,3	88
Citrus fruits	40	5	12,5	35
Pome fruits	49	-	-	49
Leguminous plants	62	6	9,7	56
Leafy vegetables	131	4	3,1	127
Fruiting vegetables	165	1	0,6	164
Sprout vegetables	66	-	-	66
Root vegetables	28	-	-	28
Cabbage	9	-	-	9
Cucurbit	41	2	4,9	39
Total	**1058**	**32**	**Ø 3,0**	**1026**

Conventional as well as organic fruits and vegetables were affected by positive findings and exceeding MRLs. Residues of QAC were found in different food commodities coming from different countries of origin. Therefore a broader use of products containing QAC seems to be in place. A source of residues of QAC might be the use of biocides in food processing such as washing and packaging. Another source especially of residues of DDAC seems to be the use of plant strengthener products containing DDAC. Therefore, the product “Vi-Care” was recently deleted from the official list of plant strengtheners by the German food safety authority Federal Office of Consumer Protection and Food Safety (BVL). The product is not allowed to be placed on the market in Germany anymore.

Conclusion

We presented a simple and fast method to determine residues of quaternary ammonium compounds (QAC) in fruit and vegetable samples. The samples were extracted due to the QuEChERS method and QAC were

analyzed by LC-MS/MS. All compounds showed satisfying recoveries and RSDs while method validation. A remaining problem was that QAC could be detected in blank samples and even after the injection of solvents. As a consequence, we set our reporting limit to 10 µg kg^{-1}. We could show that QAC can simply be included into a multiresidue scheme applying QuEChERS extraction followed by LC-MS/MS detection.

Residues of the QAC compounds DDAC and BAC have actually been found in a broad variety of fruits and vegetables exceeding the default MRL of 0.01 mg kg^{-1} in many cases. Conventional and organic produce was affected likewise. The residues might be caused by using QAC containing disinfection products in food processing like washing and packaging but also by applying plant strengtheners containing QAC. To avoid exceeding MRLs QAC containing products should neither be used in cultivation nor in food processing.

References

1. A. Friedle, J. Thumulla, K. Snepvangers, *Quaternary ammonium compounds (QUAT) in house dust*, Indoor Air (**2008**) 4:17-22
2. S.E. Walsh, J.Y. Maillard, A.D. Russell, C.E. Catrenich, D.L. Charbonneau, R.G. Bartolo, *Activity and mechanisms of action of selected biocidal agents on Gram-positive and -negative bacteria*, Journal of Applied Microbiology (**2003**) 94(2): 240-247
3. R.W. Killick, A.R. Killick, P.R. Wrigley, P.W. Jones, *Adjuvants for pyrethroid insecticide formulations* (1999), (Victorian Chemical International Pty Ltd., Australia), 1997-9978895942542, Application: US
4. S. Zhu, W. Abraham, J. Hemminghaus, *Alkoxylated alkylamine quaternary surfactants for glyphosate formulations* (2006), (Akzo Nobel N.V., Neth.), 2005-US340762006034426, Application: WO
5. P.L. McGeechan, W. Woods, *Disinfectant and sanitizer formulations comprising biguanide and/or monoguanide in combination with quaternary ammonium salt* (2012), (Arch Chemicals, Inc., USA), 2012-35153820120157540, Application: US
6. H. Knapp, P. Fecher, W. K., *Desinfektionsmittelrückstände in Lebensmitteln*, Lebensmittelchemie (**2011**) 65(1-16): 8 ff.
7. J.N.R. Ruddick, A.R.H. Sam, *Didecyldimethylammonium chloride - a quaternary ammonium wood preservative: its leachability from, and distribution in, four softwoods*, Mater. Org. (**1982**) 17(4): 299-313
8. C.R. Daniels, *Determination of didecyldimethylammonium chloride on wood surfaces by HPLC with evaporative light scattering detection*, Journal of Chromatographic Science (**1992**) 30(12): 497-499

9. Umweltbundesamt GmbH, Austria, *Grundlagen zur Risikoabschätzung für quaternäre Ammoniumverbindungen* (2005), Vienna
10. *COMMISSION REGULATION (EC) No 1112/2002 laying down the detailed rules for the implementation of the fourth stage of the programme of work referred to in Article 8(2) of Council Directive 91/414/EEC of 20 June 2002* (2002) European Commission, Brussels
11. *COMMISSION DECISION concerning the non-inclusion of certain active substances in Annex I to Council Directive 91/414/EEC and the withdrawal of authorisations for plant protection products containing these substances of 30 January 2004* (2004) European Commission, Brussels
12. *REGULATION (EC) No 1107/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC of 21 October 2009* (2009) Official Journal of the European Union, Strasbourg
13. *REGULATION (EC) NO 396/2005 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on maximum residue levels of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EEC of 23 February 2005* (2005) Official Journal of the European Union, Strasbourg
14. *Guidelines as regards measures to be taken as regards the presence of DDAC in or on food and feed agreed by the Standing Committee on the Food Chain and Animal Health (SCFCAH)* (2012) European Commission - DG SANCO, Brussels
15. *Guidelines as regards measures to be taken as regards the presence of Benzalkonium Chloride (BAC) in or on food and feed agreed by the Standing Committee on the Food Chain and Animal Health (SCFCAH)* (2012) European Commission - DG SANCO, Brussels
16. Bundesinstitut für Riskiobewertung (BfR), *Health assessment of didecyldimethylammonium chloride (DDAC) residues in food* (2012), BfR opinion No 027/2012, Berlin
17. Bundesinstitut für Riskiobewertung (BfR), *Health assessment of benzalkonium chloride residues in food* (2012), BfR opinion No 032/2012, Berlin
18. European Food Safety Authority, *Summary of the EFSA Scientific Report - Peer review of the pesticide risk assessment of the active substance incorrectly named didecyldimethylammonium chloride* (2008), Parma
19. T. Chen, C. Dwyre-Gygax, R.S. Smith, C. Breuil, *Enzyme-linked immunosorbent assay for didecyldimethylammonium chloride, a fungicide used by the forest products industry*, J. Agric. Food Chem. (**1995**) 43(5): 1400-1406
20. I. Momohara, A. Kato, T. Nishimura, *Spectrophotometric assay of a wood preservative, didecyldimethylammonium chloride (DDAC), in aqueous solution*, Journal of Wood Science (**2010**) 56(4): 314-318
21. G. Vincent, M.C. Kopferschmitt-Kubler, P. Mirabel, G. Pauli, M. Millet, *Sampling and analysis of quaternary ammonium compounds (QACs) traces in indoor atmosphere*, Environmental Monitoring and Assessment (**2007**) 133(1-3): 25-30

22. A.P. Morrow, O.O. Kassim, F.O. Ayorinde, *Detection of cationic surfactants in oral rinses and a disinfectant formulation using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry*, Rapid Communications in Mass Spectrometry (**2001**) 15(10): 767-770

23. P. Bassarab, D. Williams, J.R. Dean, E. Ludkin, J.J. Perry, *Determination of quaternary ammonium compounds in seawater samples by solid-phase extraction and liquid chromatography-mass spectrometry*, Journal of Chromatography, A (**2011**) 1218(5): 673-677

24. E. Martinez-Carballo, C. Gonzalez-Barreiro, A. Sitka, N. Kreuzinger, S. Scharf, O. Gans, *Determination of selected quaternary ammonium compounds by liquid chromatography with mass spectrometry. Part II. Application to sediment and sludge samples in Austria*, Environmental Pollution (Amsterdam, Netherlands) (**2007**) 146(2): 543-547

25. O. Nunez, E. Moyano, M.T. Galceran, *Determination of quaternary ammonium biocides by liquid chromatography-mass spectrometry*, Journal of Chromatography A (**2004**) 1058(1-2): 89-95

26. T. Suortti, H. Sirvio, *Determination of fungistatic quaternary ammonium compounds in beverages and water samples by high-performance liquid chromatography*, Journal of Chromatography (**1990**) 507(421-425)

27. X. Li, B.J. Brownawell, *Analysis of Quaternary Ammonium Compounds in Estuarine Sediments by LC-ToF-MS: Very High Positive Mass Defects of Alkylamine Ions as Powerful Diagnostic Tools for Identification and Structural Elucidation*, Analytical Chemistry (Washington, DC, United States) (**2009**) 81(19): 7926-7935

28. M. Villar-Pulido, B. Gilbert-Lopez, J.F. Garcia-Reyes, N.R. Martos, A. Molina-Diaz, *Multiclass detection and quantitation of antibiotics and veterinary drugs in shrimps by fast liquid chromatography time-of-flight mass spectrometry*, Talanta 85(3): 1419-1427

29. M. Anastassiades, S.J. Lehotay, D. Stajnbaher, F.J. Schenck, *Fast and easy multiresidue method employing acetonitrile extraction/partitioning and "dispersive solid-phase extraction" for the determination of pesticide residues in produce*, Journal of AOAC International (**2003**) 86(2): 412-431

30. Datapool of the EU Reference Laboratories for Residues of Pesticides www.eurl-pesticides-datapool.eu Cited 10 January 2013

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