

Emerging Issues on Tropane Alkaloid Contamination of Food in Europe

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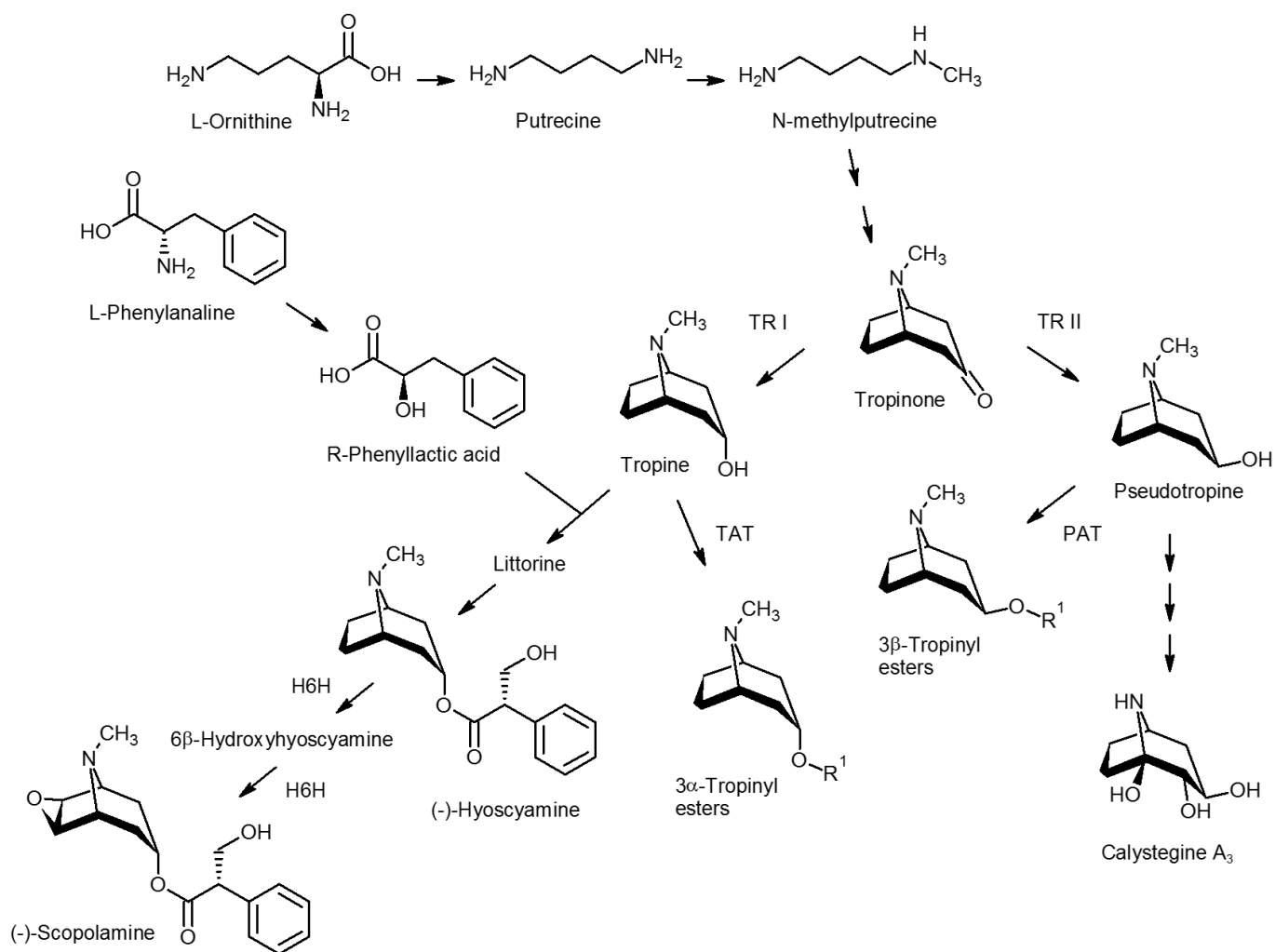


Figure S1. Biosynthetic pathways of tropanes from the amino acid ornithine. TR I = tropinone reductase I, TR II - tropinone reductase II, H6H: hyoscyamine 6β-hydroxylase, TAT = tropine acyltransferase, PAT = pseudotropine acyltransferase.

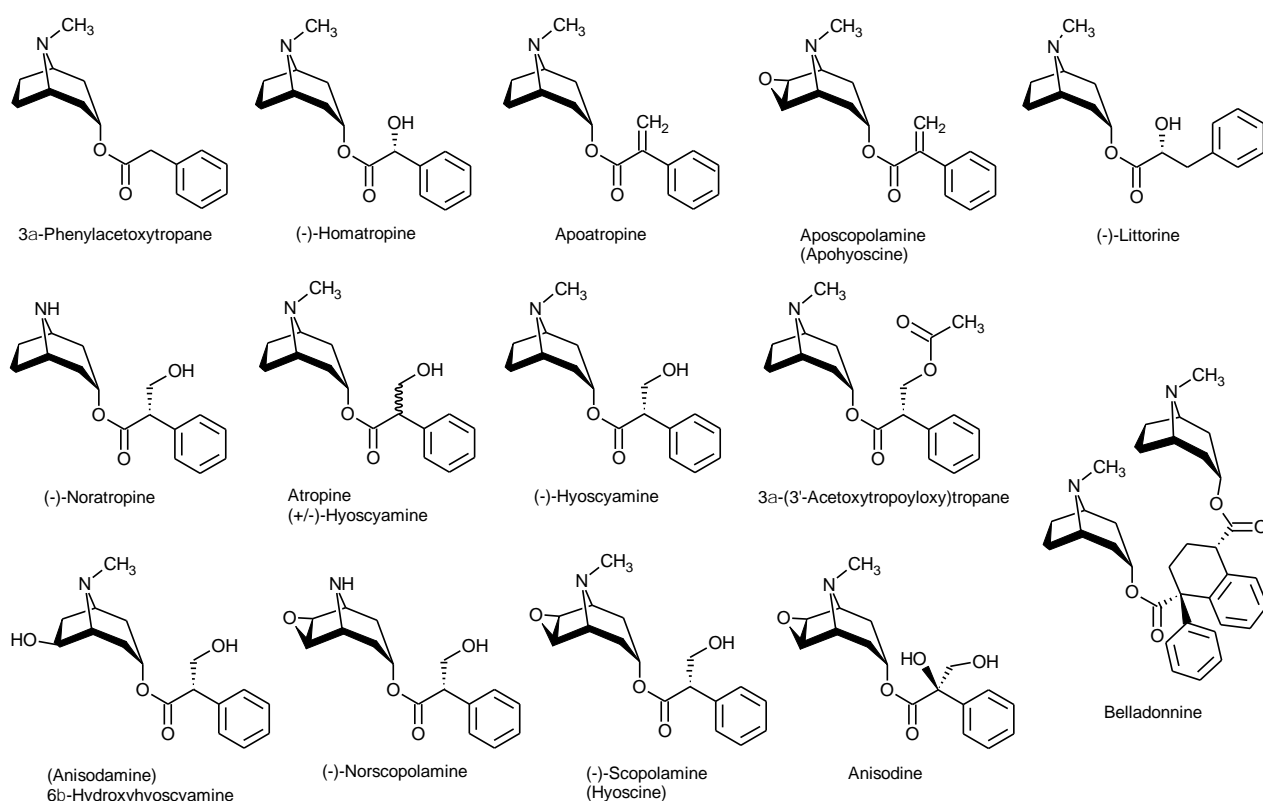


Figure S2. Structures of atropine and scopolamine and related compounds.

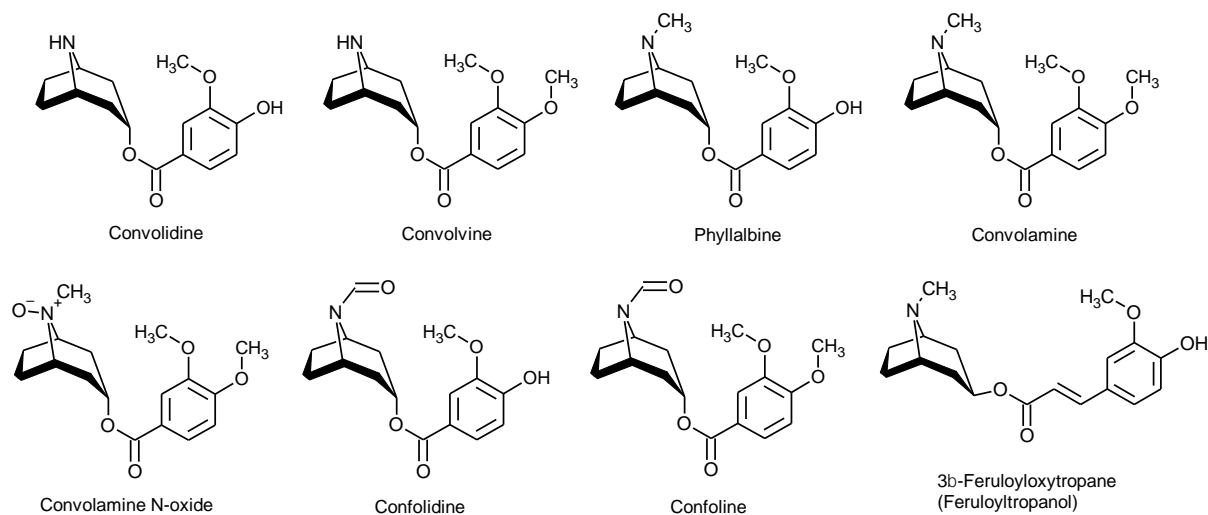


Figure S3. Structures of Convolvulaceae-type tropane esters

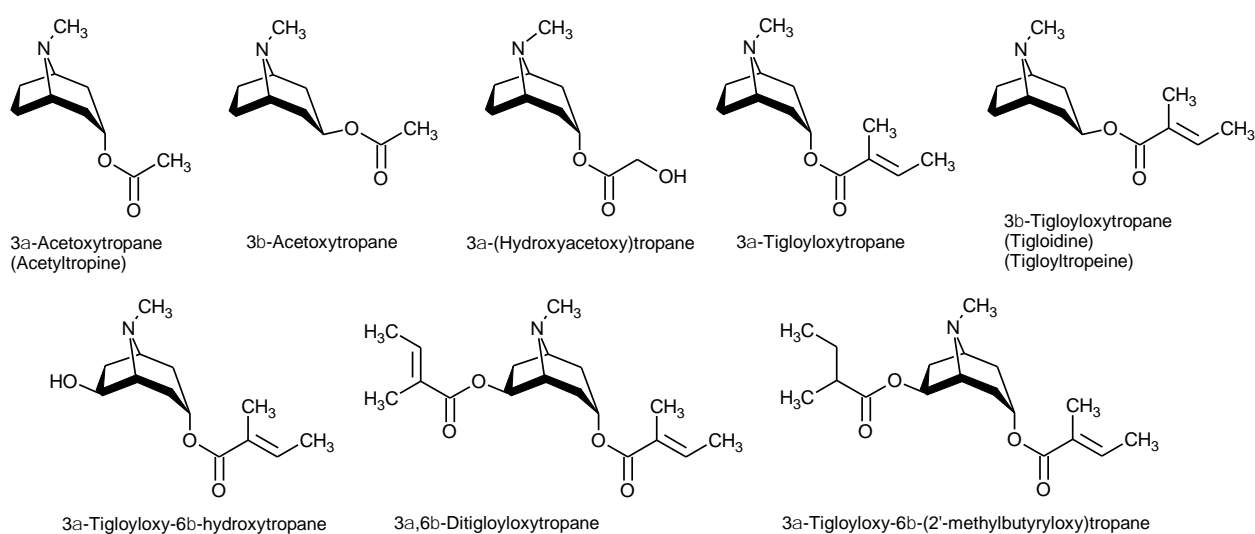


Figure S4. Structures of low molecular weight (LMW) tropane esters

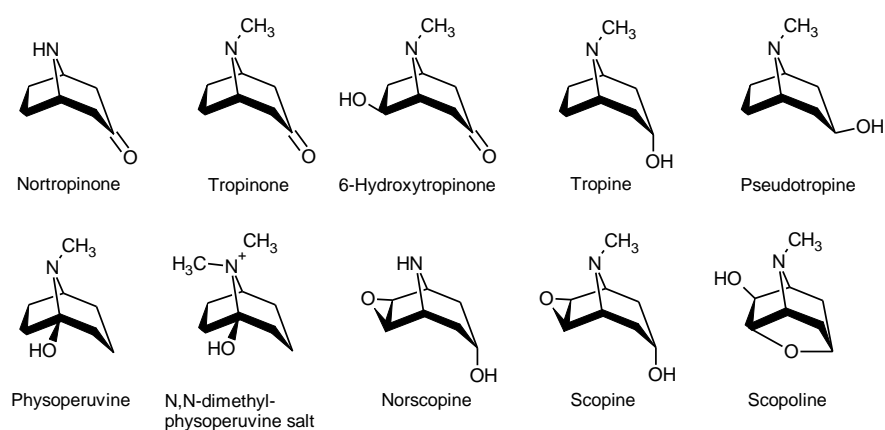


Figure S5. Structures of low molecular weight (LMW) tropanes.

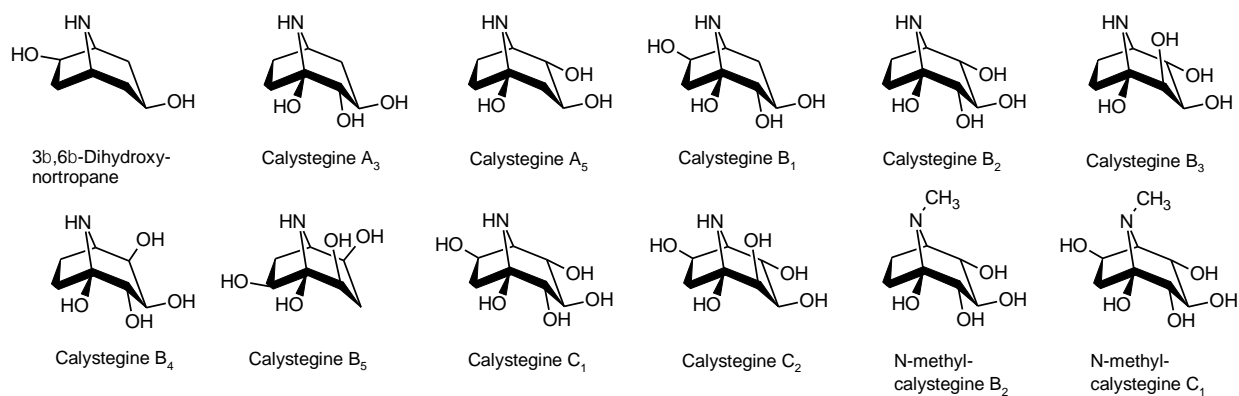


Figure S6. Structures of calystegines.

Table S1. Occurrence of calystegines in potato, eggplant and bell pepper plants from the Solanaceae family available at retail stores in Europe [31].

Food category	Number of samples collected and analysed	% samples > LOD ¹⁾	Mean conc. ²⁾ (mg/kg f.w. ³⁾)	Maximum conc. (mg/kg f.w.)	Calystegine, mean concentration (mg/kg f.w.)					
					A ₃	A ₅	B ₁	B ₂	B ₃	B ₄
<i>Potatoes</i>	308	100.0%	161.6	507.3						
Potatoes, fresh	297	100.0%	164.0	507.3	108.3	0.4	n.d.	52.1	0.1	3.7
Potatoes, processed	11	100.0%	95.6	207.7	67.1	n.d.	n.d.	24.7	0.3	3.5
<i>Eggplant & bell pepper</i>	96	92.7%	19.8	181.5						
Eggplant	90	96.7%	21.1	181.5	2.7	n.d.	3.9	14.5	n.d.	n.d.
Bell pepper	6	33.3%	0.2	0.5	n.d.	n.d.	0.2	n.d.	n.d.	n.d.
Total Solanaceae food plants	404	98.3%	127.9	507.3						

¹⁾ >LOD = higher than Limit of Detection²⁾ conc. = concentration³⁾ f.w. = fresh weight

Table S2. Occurrence of tropane alkaloids in single component flours, cereal-based food products and other products available at retail stores in Europe [31].

Food category	Number of samples collected and analysed	All tropane alkaloids ¹⁾			Atropine + scopolamine		
		% samples > LOD ²⁾	Mean conc. ³⁾ (µg/kg)	Maximum conc. (µg/kg)	% samples > LOD ²⁾	Mean conc. (µg/kg)	Maximum conc. (µg/kg)
<i>Single component flours</i>	268	21.3%	3.11	361.2	20.1%	2.87	334.8
Buckwheat	113	9.7%	2.69	258.1	9.7%	2.58	246.8
Millet & sorghum	102	23.5%	5.15	361.2	22.5%	4.67	334.8
Corn & others	53	20.8%	0.07	2.2	18.9%	0.03	0.8
<i>Cereals-based products</i>	838	14.0%	0.30	111.8	12.5%	0.25	108.5
Bread and pasta	195	9.2%	0.06	4.2	7.7%	0.04	4.2
Bread	114	15.8%	0.10	4.2	13.2%	0.07	4.2
Pasta	81	0.0%	0.00	0.0	0.0%	0.00	0.0
Breakfast cereals	219	6.8%	0.63	111.8	5.9%	0.59	108.5
Biscuits and pastry	164	14.6%	0.14	12.0	13.4%	0.06	2.3
Biscuits	150	14.7%	0.14	12.0	13.3%	0.05	2.3
Pastry	14	14.3%	0.15	1.9	14.3%	0.15	1.9
Cereal-based foods for children	260	20.0%	9.49	859.5	14.2%	0.09	4.2
Breakfast cereals	135	13.3%	0.16	4.5	12.6%	0.13	4.2
Cookies	107	13.1%	0.85	86.2	11.2%	0.03	0.8
Pasta and cereal-based meals	18	55.6%	130.7	859.5	22.2%	0.20	1.5
<i>Other products available at retail stores</i>	199	52.3%	73.35	4357.6	39.7%	8.15	428.5
Dry (herbal) teas	121	70.2%	71.38	4357.6	63.6%	13.40	428.5
Legumes, stir-fry mixes, oil seeds	78	24.4%	76.42	2215.9	2.6%	0.00	0.2
Legumes, stir-fry mixes	65	26.2%	91.70	2215.9	0.0%	0.00	0.0
Oil seeds	13	15.4%	0.02	0.2	15.4%	0.02	0.2
Total	1305	22.5%	12.90	4357.6	18.5%	1.96	428.5

¹⁾ Analysis of 24 tropane alkaloids, including atropine and scopolamine.²⁾ Products containing at least one tropane alkaloid above the Limit of Detection (LOD). LOD differs between components, matrices and laboratories.³⁾ conc. = concentration.

Table S3. RASFF notifications for tropane alkaloids atropine and scopolamine in food (December 31, 2022) [109]

Type	Date of case	Reference	Notifying country	Product Category	Food	Country of origin	Concentration (µg/kg)	
							Atropine	Scopolamine
Alert notification ¹⁾	27/7/2022	2022.4374	Germany	Prepared dishes and snacks	Tortilla chips	Undecided	NR*	
Alert notification	27/7/2022	2022.4371	Germany	Prepared dishes and snacks	Tortilla chips	Belgium	NR	
Alert notification	1/7/2022	2022.3840	Germany	Prepared dishes and snacks	Corn chips	Belgium	NR	
Alert notification	6/5/2022	2022.2692	Germany	Herbs and spices	Savory	Austria	Sum 106±21.2	
Alert notification	7/4/2022	2022.2074	Germany	Food additives and flavorings	Soybean meal	Austria	56	-
Alert notification	9/11/2021	2021.6084	Belgium	Cereals and bakery products	Corn flour	Belgium	25.12	6.50
Information notification for follow-up	9/11/2021	2021.6059	Belgium	Cocoa and cocoa preparations, coffee and tea	Infusion	Netherlands	184	21
Alert notification	8/11/2021	2021.6052	Germany	Cereals and bakery products	Organic flaxseed meal	Hungary	100-238	-
Notification	12/08/2021	2021.4323	Germany	Other food product/ mixed	Buckwheat flour, extruded	Austria/Germany	240+97	87+35
Alert	20/07/2021	2021.3836	Germany	Herbs and spices	Parsley stalks, broken	Hungary	NR	NR
Alert	07/04/2021	2021.1741	Germany	Cereals and bakery products	Millet	the Netherlands	40.1	29.1
Alert	17/03/2021	2021.1390	Slovakia	Fruits and vegetables	Frozen spinach puree	Slovakia	850-3,446	1,033-3,860
Alert	18/01/2021	2021.0236	Germany	Cereals and bakery products	Popcorn maize	Spain	23, 35	1.2, 1.9
Information	11/12/2020	2020.5696	Germany	Cereals and bakery products	Wild ground brown millet	Germany	36	22.4
Alert	27/11/2020	2020.5394	Belgium	Cereals and bakery products	Maize for popcorn	Belgium	-	14.6
Information	04/11/2020	2020.4733	Germany	Herbs and spices	Peppermint	Turkey	26.8	39.9
Information	04/09/2020	2020.3576	Germany	Cereals and bakery products	Wild brown millet	Germany	24.2	13.3
Information	25/05/2020	2020.2159	Germany	Cocoa and cocoa preparations, coffee and tea	Blackberry leaves	Bulgaria	543.1	31.4
Alert	24/01/2020	2020.0366	Germany	Cereals and bakery products	Soy flakes	Czech Republic	19	6.4
Alert	26/08/2019	2019.3045	France	Cereals and bakery products	Buckwheat	France	47	30
Alert	06/08/2019	2019.2867	Netherlands	Cereals and bakery products	Breakfast porridge 8 cereals with honey	Spain	2.2	2.7

Type	Date of case	Reference	Notifying country	Product Category	Food	Country of origin	Concentration (µg/kg)	
							Atropine	Scopolamine
Information	01/04/2019	2019.1214	Croatia	Cereals and bakery products	Corn grits	Serbia	4.5	4.3
Information	29/01/2019	2019.0315	Croatia	Cocoa and cocoa preparations, coffee and tea	Peppermint	Serbia	200.5	488.7
Alert	20/12/2018	2018.3720	France	Cereals and bakery products	Organic buckwheat flour	France	53	20
Alert	26/09/2018	2018.2695	Germany	Cereals and bakery products	Organic muesli	Austria	60.7	38.8
Alert	16/07/2018	2018.2009	Czech Republic	Herbs and spices	Herbal infusion	Poland	213	44.7
Alert	24/05/2018	2018.1447	Germany	Cereals and bakery products	Popcorn	France	6.60	1.77
Information	21/03/2018	2018.0774	Hungary	Nuts, nut products and seeds	Whole cumin seeds	Hungary	16,177.6	4,658.3
Alert	07/06/2017	2017.0803	United Kingdom	Dietetic foods, food supplements, fortified foods	Dried herbs (<i>Ruscus aculeatus</i>)	Bulgaria	NR	NR
Alert	24/02/2017	2017.0239	Czech Republic	Cocoa and cocoa preparations, coffee and tea	Herbal tea with Echinacea	Poland	72	23
Alert	06/02/2017	2017.0153	Germany	Cocoa and cocoa preparations, coffee and tea	Organic burdock root (<i>Arctium lappa</i>) tea	Albania/Croatia	520	NR
Alert	28/12/2016	2016.1818	Czech Republic	Cocoa and cocoa preparations, coffee and tea	Herbal tea	Poland	206.4	31.7
Alert	20/09/2016	2016.1298	Austria	Cereals and bakery products	Millet flour	Hungary	23.5	9.5
Alert	22/07/2016	2016.0975	Austria	Cereals and bakery products	Corn	Germany	10.5; 12.2; 12.3	2.0; 3.8; 3.1
Alert	13/04/2016	2016.0144	Czech Republic	Dietetic foods, food supplements, fortified foods	Baby porridge without milk	Spain	7.9	NR
Alert	01/02/2016	2016.0106	Czech Republic	Cereals and bakery products	Gluten-free baking mix based on sorghum	Czech Republic	180; 130	36; 27
Alert	26/11/2015	2015.1487	Czech Republic	Cereals and bakery products	Sorghum flour	Czech Republic/Slovakia	1,200; 1,500	360; 460
Alert	18/09/2015	2015.1190	Germany	Cereals and bakery products	Microwave popcorn	Spain	29	6
Alert	04/06/2015	2015.0684	Germany	Cereals and bakery products	Organic polenta cornmeal	Germany	198.5	45
Alert	31/03/2015	2015.0399	Germany	Cereals and bakery products	Millet balls	Hungary	384	388

Type	Date of case	Reference	Notifying country	Product Category	Food	Country of origin	Concentration (µg/kg)	
							Atropine	Scopolamine
Alert	30/03/2015	2015.0388	Austria	Cereals and bakery products	Gluten free organic millet	Austria	30	24
Alert	30/03/2015	2015.0387	Austria	Cereals and bakery products	Millet honey poppies	Germany	26	11
Alert	20/03/2015	2015.0339	Austria	Cereals and bakery products	Millet dumplings	Hungary	304	358
Alert	20/03/2015	2015.0338	Austria	Cereals and bakery products	Organic millet dumplings	Hungary	481	533
Alert	20/02/2015	2015.0210	Germany	Cereals and bakery products	Organic polenta cornmeal	Germany	156.2; 207.5	27.2; 31.3
Alert	20/02/2015	2015.0203	Austria	Cereals and bakery products	Brown millet	Germany	62	33
Alert	18/12/2014	2014.1724	Germany	Dietetic foods, food supplements, fortified foods	Millet/cereal porridge with rice	Hungary	36.6	NR
Alert	11/12/2014	2014.1694	Germany	Dietetic foods, food supplements, fortified foods	Organic baby food apple pear millet	Germany	3.7; 6.7; 31.9	NR
Alert	04/12/2014	2014.1652	Germany	Cereals and bakery products	Brown millet flour	Austria/ Hungary/ the Netherlands	46	25
Alert	21/11/2014	2014.1596	Germany	Dietetic foods, food supplements, fortified foods	Baby food porridge	Germany/ Austria	12.1	NR
Alert	13/06/2013	2013.0829	Slovenia	Cereals and bakery products	Buckwheat flour	Austria/ Slovakia	18	5.5
Alert	22/05/2013	2013.0706	Slovenia	Cereals and bakery products	Buckwheat flour	Czech Republic	14	11
Information	08/06/2012	2012.0794	Slovenia	Cereals and bakery products	Buckwheat flour	Slovenia	20	6.1
Information	30/04/2009	2009.0558	Slovenia	Cereals and bakery products	Buckwheat flour	Hungary	110	47
Information	03/07/2006	2006.BMT	Slovenia	Cereals and bakery products	Buckwheat flour	Ukraine	37	48
Alert	03/07/2006	2006.0424	Slovenia	Cereals and bakery products	Buckwheat flour	Czech Republic	35	65
Alert	28/10/1994	1994.18	United Kingdom	Cocoa, coffee and tea	Burdock root tea	United Kingdom	NR	NR

* NR = not reported.

¹⁾ updated version of the RASSF portal from mid-2021 makes no difference between alert or notification and Alert notification.

Table S4. RASFF notifications for Atropa, Belladonna, Datura, Hyoscyamus, Mandragora and Solanum in food and feed (December 31, 2022) [109]

Type	Date of case	Reference	Notifying country	Product Category	Food	Country of origin	Contaminant plant	Concentration
Alert ¹⁾	23/01/2013	2013.0079	The Netherlands	Herbs and spices	Marshmallow tea	Germany/Bulgaria	<i>A. belladonna</i> root	NR*
Alert	29/06/1989	1989.15	France	Herbs and spices	Burdock root	NM	Belladonna	NR
Alert	23/01/1984	1984.03	France	Cocoa, coffee and tea	Bardane herbal tea	NM	Belladonna	NR
Alert	04/02/1983	1983.03	United Kingdom	Cocoa, coffee and tea	Tea	NM	Belladonna	NR
Alert	17/12/2020	2020.5838	Hungary	Cereals and bakery products	Grain oatmeal	Poland	<i>D. stramonium</i> seeds	NR
Alert	20/09/2019	2019.3340	France	Fruits and vegetables	Canned peeled tomatoes	Spain	<i>D. stramonium</i> fruits	NR
Alert	12/09/2020	2019.3256	Austria	Compound feeds	Seedmix for birds	The Netherlands	<i>D. stramonium</i> seeds	0.1235%
Alert	15/03/2019	2019.0993	France	Fruits and vegetables	Frozen beans	France	<i>D. stramonium</i> seeds	NR
Information	01/02/2019	2019.0379	Belgium	Feed material	Sunflower seeds	The Netherlands	<i>D. stramonium</i> seeds	0.12%
Alert	17/05/2013	2013.0696	Finland	Fruits and vegetables	Frozen vegetable-bean-seed mix	Belgium/Spain	<i>D. stramonium</i> seeds	NR
Information	07/03/2012	2012.0354	Denmark	Bird feed	Sunflower seeds	France	<i>D. stramonium</i> seeds	0.1862%
Information	02/10/2007	2007.CGO	Spain	Fruits and vegetables	Vegetable bacon stir-fry	Spain	<i>D. stramonium</i> seeds	NR
Alert	05/09/2007	2007.0613	Austria	Fruits and vegetables	Canned green beans	Hungary	<i>D. stramonium</i> fruit	NR
Alert	27/11/2006	2006.0835	Austria	Fruits and vegetables	Canned green beans	Hungary	<i>D. stramonium</i> fruit	NR
Alert	27/11/2006	2006.0833	Austria	Cereals and bakery products	Organic millet	Austria/Hungary	<i>D. stramonium</i> seeds	130 seeds/kg
Information	20/11/2006	2006.CRE	Austria	Cereals and bakery products	Brown millet	Austria	<i>D. stramonium</i> seeds	NR
Information	08/11/2006	2006.COH	Austria	Cereals and bakery products	Organic millet	Austria	<i>D. stramonium</i> seeds	NR
Alert	24/10/2006	2006.0737	Austria	Cereals and bakery products	Organic millet	Austria	<i>D. stramonium</i> seeds	NR
Information	10/10/2006	2006.CFX	Austria	Cereals and bakery products	Peeled bio gold millet	Austria	<i>D. stramonium</i> seeds	NR
Information	28/08/2006	2006.BYZ	Germany	Pet food	Red millet seeds	Hungary	<i>D. stramonium</i> seeds	0.276%
Alert	06/05/2008	2008.0520	Czech Republic	Nuts, nut products and seeds	Poppy seeds	Czech Republic	<i>H. niger</i> seeds	0.13%
Alert	13/04/2007	2007.0267	Slovakia	Nuts, nut products and seeds	Poppy seeds	Czech Republic	<i>H. niger</i> seeds	0.24%
Alert	10/04/2007	2007.0256	Slovakia	Nuts, nut products and seeds	Poppy seeds	Czech Republic	<i>H. niger</i> seeds	0.42%

Type	Date of case	Reference	Notifying country	Product Category	Food	Country of origin	Contaminant plant	Concentration
Alert notification	10/10/2022	2022.5877	Italy	Fruits and vegetables	Fresh spinach	Italy	<i>Mandragora</i>	NR
Alert notification	24/12/2021	2021.7140	Belgium	Fruits and vegetables	Frozen peas	Belgium	<i>S. nigrum</i>	NR

* NR = not reported.

¹⁾ updated version of the RASSF portal from mid-2021 makes no difference between alert or notification and alert notification.