

Ricinoleic Acid as a Marker for Ergot Impurities in Rye and Rye Products

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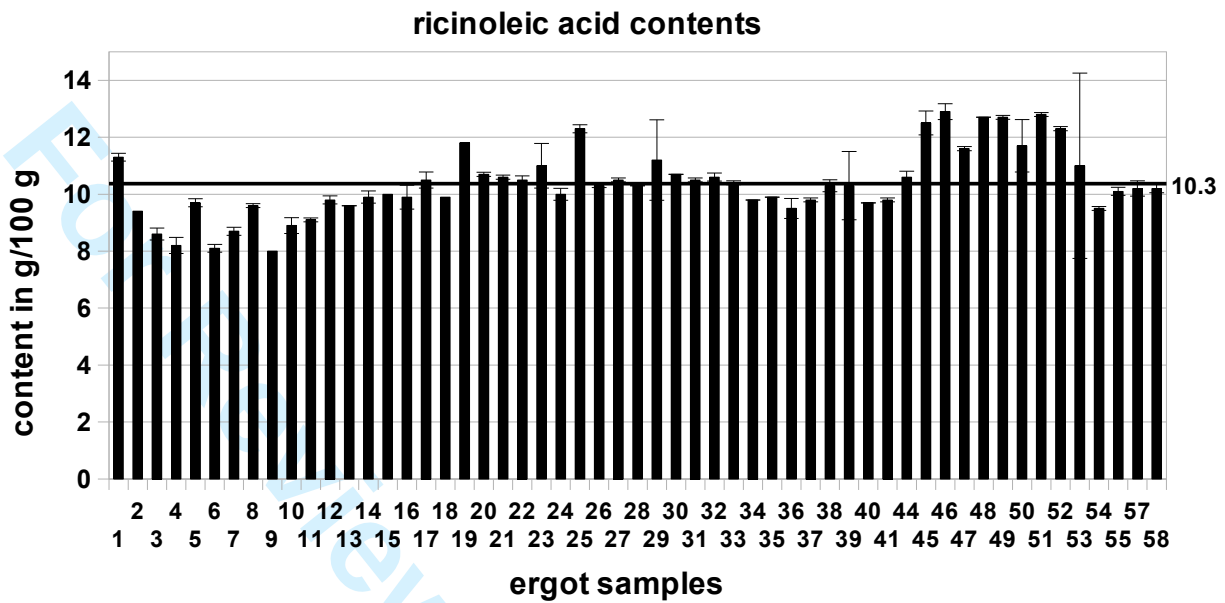


Figure 8: Ricinoleic acid contents in ergot sclerotia samples.

Table 4: Ergot alkaloid contents of sclerotia samples of the harvest years 2005-2009.

ergot alkaloid content in mg/100 g	sample number	1	2	3	4	5	6	7	8	9	10	11
	harvest year	2005	2006	2006	2006	2007	2007	2007	2007	2007	2007	2007
	ergometrine	1.01	1.57	1.45	7.00	3.46	1.00	0.81	0.74	0.54	1.00	1.07
	ergometrinine	0.11	0.36	0.48	1.53	0.74	0.10	0.07	0.00	0.05	0.16	0.10
	ergosine	3.50	2.99	2.47	9.87	13.04	4.48	2.09	3.54	1.30	3.91	5.00
	ergosinine	1.98	1.10	1.12	4.17	5.43	2.03	0.89	1.46	0.48	1.79	2.33
	ergotamine	11.28	3.30	3.11	23.92	22.67	5.81	4.38	5.47	1.68	7.54	8.16
	ergotaminine	7.08	2.57	2.68	10.57	10.42	5.17	4.17	4.51	1.50	5.72	6.52
	ergocornine	2.97	2.67	3.16	4.86	9.07	1.95	2.13	2.63	0.86	3.13	2.71
	ergocorninine	1.63	1.25	1.65	1.87	3.60	1.09	1.36	1.09	0.57	1.28	1.21
	α -ergocryptine	2.60	1.85	2.43	2.84	5.12	2.32	2.07	1.55	0.50	3.11	3.12
	α + β -ergocryptinine	2.02	1.49	2.30	2.39	3.06	1.80	2.22	1.70	0.80	2.10	2.25
	ergocristine	3.14	1.80	2.47	14.05	9.10	5.80	2.72	3.06	2.44	7.97	8.78
	ergocristinine	1.59	0.52	0.70	5.25	3.69	1.79	1.08	0.91	0.87	2.11	2.42
	total alkaloid content	38.9	21.5	24.0	88.3	89.4	33.3	24.0	26.7	11.6	39.8	43.7
ergot alkaloid content in mg/100 g	sample number	12	13	14	15	16	17	18	19	20	21	22
	harvest year	2007	2007	2007	2007	2007	2007	2007	2007	2007	2007	2007
	ergometrine	1.25	1.49	1.48	1.28	1.62	1.35	0.97	1.18	8.40	6.44	5.14
	ergometrinine	0.12	0.17	0.21	0.17	0.31	0.16	0.00	0.13	2.56	1.87	1.55
	ergosine	5.19	4.54	4.56	5.27	5.07	3.68	3.90	4.39	7.75	9.56	7.60
	ergosinine	3.82	2.31	2.91	2.14	1.30	1.95	2.31	1.64	2.27	3.32	2.69
	ergotamine	9.81	8.07	11.59	6.50	8.41	9.29	5.79	8.47	35.53	33.64	23.35
	ergotaminine	8.24	7.90	7.33	5.10	3.73	9.68	7.04	6.02	8.97	8.15	6.56
	ergocornine	1.91	2.82	3.11	4.12	3.44	2.40	2.79	3.04	4.64	7.96	5.53
	ergocorninine	1.64	1.48	2.07	1.85	1.12	1.47	1.82	1.39	1.66	2.32	2.06
	α -ergocryptine	2.59	2.80	3.31	3.63	2.64	2.08	2.98	3.10	2.97	6.92	4.37
	α + β -ergocryptinine	3.97	2.64	3.82	2.66	1.37	2.08	3.69	2.34	1.61	2.80	1.89
	ergocristine	5.61	6.25	6.04	8.90	6.97	5.95	6.32	7.45	42.46	44.46	28.76
	ergocristinine	4.15	2.26	3.48	2.34	1.31	2.73	3.06	1.95	14.62	8.64	6.10
	total alkaloid content	48.3	42.7	49.9	44.0	37.3	42.8	40.7	41.1	133.4	136.1	95.6
ergot alkaloid content in mg/100 g	sample number	23	24	25	28	29	30	31	32	33	34	35
	harvest year	2007	2007	2007	2007	2007	2007	2007	2007	2007	2007	2007
	ergometrine	1.00	5.09	7.18	10.35	5.50	5.76	7.10	6.97	4.17	4.78	1.11
	ergometrinine	0.17	1.43	2.25	2.93	1.51	1.52	2.05	1.89	0.76	0.99	0.25
	ergosine	5.63	11.84	10.40	10.51	7.45	4.54	3.86	4.53	3.88	5.19	6.56
	ergosinine	2.00	7.48	4.25	5.78	3.64	2.30	1.85	2.86	1.60	2.94	3.74
	ergotamine	13.29	18.66	27.96	31.30	24.74	23.06	30.22	30.19	30.11	22.02	16.72
	ergotaminine	3.92	11.85	11.94	17.13	13.24	13.27	13.72	15.97	11.69	11.51	8.03
	ergocornine	2.08	8.24	14.05	8.41	7.90	3.59	3.72	7.14	4.62	3.58	3.59
	ergocorninine	0.95	5.55	5.49	3.49	3.61	2.02	1.65	3.45	1.87	2.01	2.29
	α -ergocryptine	2.64	4.72	9.39	10.19	5.17	2.88	4.18	5.57	3.10	3.67	4.07
	α + β -ergocryptinine	2.05	4.12	3.98	4.66	2.99	1.82	2.75	2.99	1.91	2.78	3.51
	ergocristine	7.17	21.95	22.79	19.92	26.68	24.36	27.90	29.91	31.52	26.09	7.75
	ergocristinine	1.85	14.30	7.56	7.57	14.56	14.74	13.53	15.63	11.44	12.45	3.53
	total alkaloid content	42.7	115.2	127.2	132.2	117.0	99.9	112.5	127.1	106.7	98.0	61.2

Table 4: Ergot alkaloid contents of sclerotia samples of the harvest years 2005-2009 (continuation).

ergot alkaloid content in mg/100 g	sample number	36	37	38	39	40	41	42	43	44	45	46
	harvest year	2007	2007	2007	2007	2007	2007	2007	2007	2008	2008	2008
	ergometrine	1.09	1.52	1.32	1.27	1.07	1.60	3.31	2.51	8.78	7.68	9.17
	ergometrinine	0.19	0.19	0.21	0.14	0.00	0.25	0.56	0.88	1.82	0.94	1.22
	ergosine	5.35	5.56	5.16	4.18	4.34	4.60	3.82	4.51	10.39	38.20	16.10
	ergosinine	2.77	3.17	3.70	2.75	2.67	1.88	1.93	2.36	3.48	12.26	6.48
	ergotamine	11.78	12.15	9.69	9.45	12.01	10.31	10.74	21.31	24.52	29.13	32.00
	ergotaminine	5.11	6.61	6.76	6.29	7.62	3.26	2.98	5.48	6.19	11.05	11.08
	ergocornine	2.72	3.04	2.80	3.31	2.26	5.23	4.90	4.32	11.52	43.12	18.04
	ergocorninine	1.69	2.05	2.26	2.38	1.61	1.99	2.01	2.65	4.47	14.39	6.57
	α -ergocryptine	2.90	3.12	3.31	3.29	2.06	4.60	3.82	5.14	6.11	26.33	9.54
	α + β -ergocryptinine	3.07	4.40	3.86	3.81	2.79	2.73	1.36	3.92	3.32	6.13	2.34
	ergocristine	7.75	6.33	6.06	6.19	6.45	12.33	6.68	9.79	31.92	36.63	51.01
	ergocristinine	3.23	3.16	3.67	3.67	3.83	2.85	1.55	3.51	9.25	10.37	14.69
	total alkaloid content	47.7	51.3	48.8	46.7	46.7	51.6	43.7	66.4	121.8	236.2	178.2
ergot alkaloid content in mg/100 g	sample number	47	48	49	50	51	52	53	54	55	56	57
	harvest year	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008	2008
	ergometrine	1.49	1.79	12.55	13.82	11.86	13.94	12.75	2.29	1.15	11.74	5.74
	ergometrinine	0.33	0.39	1.77	2.09	1.74	2.04	1.93	0.46	0.19	3.08	1.14
	ergosine	5.15	5.58	25.75	21.40	23.80	21.16	21.34	6.73	2.41	15.05	9.93
	ergosinine	2.42	2.51	9.41	7.11	9.67	7.91	6.93	4.14	1.35	5.52	5.93
	ergotamine	11.21	8.42	51.91	36.46	38.86	41.22	31.10	10.62	5.30	36.48	16.88
	ergotaminine	4.02	3.11	14.26	10.15	13.13	12.89	9.47	5.15	2.71	9.49	8.37
	ergocornine	3.69	6.06	16.87	16.50	12.41	10.84	17.02	5.41	3.57	16.64	4.86
	ergocorninine	1.88	2.78	5.14	4.94	4.18	3.39	5.61	2.71	1.66	3.34	2.48
	α -ergocryptine	2.92	5.14	11.56	7.01	7.92	5.06	11.34	5.58	3.36	9.71	4.43
	α + β -ergocryptinine	1.43	1.93	2.50	1.45	1.93	1.42	2.15	3.75	3.04	1.75	2.69
	ergocristine	6.53	9.18	31.21	33.77	30.50	37.13	39.56	9.12	3.75	22.63	20.77
	ergocristinine	2.40	2.87	7.69	7.70	8.94	10.26	9.88	2.43	1.01	1.52	5.54
	total alkaloid content	43.5	49.8	190.6	162.4	164.9	167.3	169.1	58.4	29.5	137.0	88.7
ergot alkaloid content in mg/100 g	sample number	58	59	60	61	62	63	64	65			
	harvest year	2008	2009	2009	2009	2009	2009	2009	2009			
	ergometrine	1.41	3.38	2.13	1.14	1.59	1.81	1.60	1.37			
	ergometrinine	0.23	0.84	0.51	0.33	0.41	0.40	0.36	0.40			
	ergosine	2.84	4.98	4.26	1.81	4.09	4.83	4.87	4.09			
	ergosinine	1.68	2.71	3.01	1.19	1.91	2.14	2.00	1.64			
	ergotamine	4.95	6.85	4.31	4.03	10.15	9.42	8.53	7.76			
	ergotaminine	2.41	3.08	2.80	2.17	3.56	3.46	2.75	2.84			
	ergocornine	2.00	2.36	3.12	1.57	2.80	2.61	3.11	3.64			
	ergocorninine	0.94	1.03	1.83	0.85	1.32	1.25	1.43	1.69			
	α -ergocryptine	2.55	1.83	2.57	1.70	3.04	2.99	3.15	3.59			
	α + β -ergocryptinine	2.73	0.58	1.11	0.67	2.11	2.31	2.04	2.30			
	ergocristine	7.08	6.47	4.19	3.09	7.92	9.05	9.05	8.52			
	ergocristinine	1.84	1.93	2.05	1.25	1.81	2.07	1.94	1.87			
	total alkaloid content	30.6	36.0	31.9	19.8	40.7	42.3	40.8	39.7			

Table 5: Ergot alkaloid contents of rye products.

ergot alkaloid content in µg/kg		rye flour type 1150 1	SD	rye flour type 1150 2	SD	rye flour type 1150 3	SD	rye flour type 1150 4	SD	rye flour type 997	SD	wholemeal flour 1	SD
	ergometrine	31.93	± 0.69	11.61	± 1.23	3.43	± 0.03	13.60	± 2.79	14.81	± 1.56	28.37	± 1.69
	ergometrinine	14.09	± 1.46	4.59	± 0.26	< LOD		n.d.		n.d.		10.03	± 0.37
	ergosine	50.51	± 2.38	7.74	± 0.07	n.d.		8.60	± 0.59	14.83	± 2.95	32.58	± 3.20
	ergosinine	18.22	± 0.00	n.d.		n.d.		n.d.		5.54	± 0.27	10.83	± 0.11
	ergotamine	89.51	± 3.14	17.20	± 0.29	10.98	± 1.09	20.38	± 0.20	33.83	± 0.54	58.28	± 1.10
	ergotaminine	24.88	± 3.59	7.15	± 1.17	n.d.		9.75	± 1.02	9.09	± 0.74	22.01	± 0.65
	ergocornine	34.21	± 2.16	12.48	± 0.11	n.d.		n.d.		10.21	± 0.73	32.58	± 3.54
	ergocorninine	15.79	± 2.62	6.11	± 0.20	n.d.		< LOD		3.44	± 0.41	14.06	± 0.03
	α-ergocryptine	28.09	± 0.47	11.50	± 0.05	n.d.		n.d.		6.74	± 0.25	22.68	± 0.65
	α+β- ergocryptinine	13.89	± 0.13	21.22	± 0.05	8.27	± 0.38	n.d.		8.55	± 0.69	14.34	± 0.01
	ergocristine	43.64	± 0.21	17.20	± 1.33	n.d.		24.44	± 1.50	36.60	± 6.69	48.08	± 2.85
	ergocristinine	18.23	± 2.17	6.52	± 0.08	n.d.		9.56	± 0.24	7.41	± 1.42	12.07	± 0.96
total alkaloid content	383.0		123.3		22.7		86.3		151.1		305.9		
ergot alkaloid content in µg/k g		wholemeal flour 2	SD	wholemeal flour 3	SD	wholemeal flour 4	SD	wholemeal flour 5	SD	wholemeal flour 6	SD	wholemeal flour 7	SD
	ergometrine	7.03	± 1.50	10.07	± 0.43	63.68	± 0.76	4.78	± 0.80	12.66	± 1.24	4.53	± 0.04
	ergometrinine	n.d.		n.d.		7.56	± 0.10	n.d.		n.d.		n.d.	
	ergosine	4.30	± 0.66	11.91	± 1.51	84.68	± 2.44	n.d.		9.60	± 0.42	n.d.	
	ergosinine	n.d.		5.58	± 0.32	27.33	± 0.60	n.d.		3.42	± 0.40	n.d.	
	ergotamine	2.84	± 0.53	33.07	± 0.90	161.16	± 2.47	n.d.		23.60	± 0.05	10.01	± 0.76
	ergotaminine	n.d.		11.65	± 0.99	48.11	± 0.77	n.d.		< LOD		n.d.	
	ergocornine	n.d.		13.00	± 2.22	117.41	± 2.88	n.d.		9.52	± 0.02	n.d.	
	ergocorninine	2.73	± 0.36	6.81	± 0.23	36.42	± 2.36	n.d.		4.65	± 0.63	n.d.	
	α-ergocryptine	n.d.		9.43	± 0.20	62.47	± 0.22	n.d.		5.44	± 0.01	n.d.	
	α+β- ergocryptinine	8.08	± 0.33	14.80	± 0.23	43.28	± 1.41	7.72	± 0.39	14.56	± 1.30	n.d.	
	ergocristine	n.d.		26.20	± 1.56	306.86	± 18.1	n.d.		18.84	± 1.60	5.23	± 0.15
	ergocristinine	n.d.		6.72	± 4.28	60.31	± 4.34	n.d.		4.87	± 0.58	n.d.	
total alkaloid content	25.0		149.2		1019.3		12.5		107.2		19.8	133.43	
ergot alkaloid content in µg/kg		whole rye grain, ground 1	SD	whole rye grain, ground 2	SD	whole rye grain, ground 3	SD	whole rye grain, ground 4	SD	whole rye grain, ground 5	SD	bread mix (24 % rye) 1	SD
	ergometrine	3.29	± 0.06	23.51	± 1.51	2.97	± 0.50	4.55	± 0.15	10.03	± 0.71	< LOD	
	ergometrinine	n.d.		n.d.		n.d.		3.58	± 0.31	n.d.		122.08	± 3.04
	ergosine	n.d.		7.70	± 0.58	n.d.		< LOQ		n.d.		20.19	± 0.37
	ergosinine	n.d.		n.d.		n.d.		< LOD		n.d.		7.14	± 0.61
	ergotamine	n.d.		24.81	± 1.44	n.d.		15.43	± 0.31	21.80	± 2.52	49.25	± 0.90
	ergotaminine	n.d.		6.50	± 0.06	n.d.		< LOD		< LOD		8.16	± 0.22
	ergocornine	n.d.		n.d.		n.d.		n.d.		15.44	± 3.24	14.82	± 0.86
	ergocorninine	n.d.		< LOD		n.d.		n.d.		8.72	± 2.90	< LOD	
	α-ergocryptine	n.d.		n.d.		n.d.		n.d.		< LOD		8.96	± 0.05
	α+β- ergocryptinine	n.d.		4.34	± 0.67	n.d.		< LOD		14.73	± 5.40	< LOQ	
	ergocristine	n.d.		78.94	± 11.0	< LOQ		< LOQ		84.30	± 22.1	22.22	± 0.82
	ergocristinine	n.d.		14.36	± 1.62	n.d.		n.d.		12.30	± 4.20	< LOD	
total alkaloid content	3.3		160.2		3.0		23.6		167.3		252.8		

Table 5: Ergot alkaloid contents of rye products (continuation).

ergot alkaloid content in µg/kg		bread mix (25 % rye) 2		bread mix (25 % rye) 3		rye bread (32 % rye) 1		rye bread (43 % rye) 2		rye bread (32 % rye) 3		wholemeal bread 1	
			SD		SD		SD		SD		SD		SD
	ergometrine	8.31	± 1.23	6.99	± 0.84	20.96	± 0.50	17.71	± 2.57	23.89	± 0.51	21.93	± 0.73
	ergometrinine	n.d.		22.94	± 0.58	< LOQ		< LOQ		< LOQ		< LOQ	
	ergosine	7.36	± 0.32	7.78	± 1.46	16.42	± 0.91	18.26	± 2.07	19.29	± 3.58	12.77	± 0.10
	ergosinine	n.d.		n.d.		4.01	± 0.04	8.23	± 1.91	6.13	± 1.14	4.77	± 0.60
	ergotamine	9.03	± 0.40	7.91	± 0.03	7.31	± 0.61	11.06	± 0.35	11.06	± 0.35	2.61	± 0.04
	ergotaminine	n.d.		n.d.		< LOQ		7.99	± 0.43	< LOQ		< LOQ	
	ergocornine	n.d.		n.d.		< LOD		< LOQ		< LOQ		n.d.	
	ergocorninine	n.d.		n.d.		< LOQ		4.06	± 0.85	2.37	± 0.50	n.d.	
	α-ergocryptine	n.d.		n.d.		< LOQ		< LOQ		4.09	± 0.74	n.d.	
	α+β- ergocryptinine	n.d.		n.d.		< LOQ		4.34	± 0.02	4.29	± 0.14	n.d.	
	ergocristine	n.d.		n.d.		< LOQ		9.39	± 0.19	9.08	± 1.47	n.d.	
	ergocristinine	n.d.		n.d.		3.84	± 0.02	3.72	± 0.21	4.31	± 0.21	n.d.	
total alkaloid content	24.7		45.6		52.5		84.8		84.5		42.1		

ergot alkaloid content in µg/kg		wholemeal bread 2		wholemeal bread 3		wholemeal bread 4		wholemeal bread 5		wholemeal bread 6	
			SD		SD		SD		SD		SD
	ergometrine	20.38	± 1.13	18.95	± 0.84	6.97	± 0.94	11.28	± 0.50	49.98	± 4.25
	ergometrinine	< LOQ		< LOQ	± 0.58	< LOQ		3.14	± 0.07	24.74	± 7.89
	ergosine	12.61	± 0.93	8.69	± 0.49	< LOQ		< LOQ		8.30	± 0.23
	ergosinine	3.84	± 0.29	1.46	± 0.09	n.d.		n.d.		1.38	± 0.01
	ergotamine	n.d.	± 1.06	2.25	± 1.06	n.d.		4.74	± 0.09	n.d.	
	ergotaminine	n.d.		< LOD		n.d.		< LOQ		n.d.	
	ergocornine	n.d.		< LOQ		n.d.		n.d.		n.d.	
	ergocorninine	n.d.		6.09	± 0.19	n.d.		n.d.		n.d.	
	α-ergocryptine	n.d.		< LOQ		n.d.		n.d.		n.d.	
	α+β- ergocryptinine	n.d.		n.d.		n.d.		n.d.		n.d.	
	ergocristine	< LOQ		< LOQ		n.d.		n.d.		n.d.	
	ergocristinine	n.d.		< LOD		n.d.		n.d.		< LOQ	
total alkaloid content	36.8		37.4		7.0		19.2		84.4		