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Contents of polyamines in selected foods

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Abstract

Dietary polyamines, putrescine, spermidine and spermine, participate in many biochemical processes, mainly in cell proliferation and differentiation. Polyamines were determined as *N*-benzamides by micellar electrokinetic capillary chromatography in 153 samples of 21 foods, mostly culinary processed. Very low putrescine contents were observed in processed meats, pork liver and kidney, while the highest mean contents exceeded 55 mg kg^{-1} in stewed green pea, grapefruit and fresh green pepper. Higher spermine than spermidine contents were typical for foods of animal origin, while the opposite was observed in plant products. Mean spermidine contents, exceeding 20 mg kg^{-1}, were found in dry soybean, stewed green pea, yellow pea puree and roasted chicken breast. Roasted chicken breast, stewed pork kidney, roasted pork liver and roasted pork neck had mean spermine contents above the same level. Polyamine content varies widely within individual food items, what makes application of the results by dietitians rather difficult.

Keywords: Polyamines; Putrescine; Spermidine; Spermine; Food

1. Introduction

Polyamines, putrescine (PUT; 1,4-diaminobutane), spermidine (SPD; *N*-(3-aminopropyl)-1,4-diaminobutane) and spermine (SPM; N,N'-bis-(3-aminopropyl)-1,4-diaminobutane), started to be set apart from the group of biogenic amines during the past decade, mainly due to their specific biological roles. They participate in cell membrane stabilisation and cell proliferation and differentiation, namely in rapidly dividing cells such are enterocytes and tumour cells. Earlier, it was believed that polyamines necessary for growth of animal cells were exclusively synthesised in situ. However, the participation of polyamines, both from diet and produced by intestinal microorganisms in cell growth, was proved (Sarhan, Knödgen, & Seiler, 1989).

The intracellular polyamine concentrations have been effectively regulated by polyamine uptake by intestinal cells (Milovic, 2001). Diamine oxidase (EC 1.4.3.6), present in the intestinal mucosa, protects animal cells against excessive amounts of putrescine from the intestinal lumen (Nilsson, Kockum, & Rosengren, 1996). Putrescine uptake from the intestine is elevated in tumour-bearing animals (Desury, Moulinoux, & Delcros, 2002). Polyamines are taken up preferentially by tumours (Seiler, Atanassov, & Raul, 1998) and tissues with high demands, such as in healing wounds. Dietary polyamines have a potential role in growth and development of the child's digestive system and they also seem to be necessary for the adult digestive tract (Deloyer, Peulen, & Dandrifosse, 2001).

However, only limited information has been available on polyamine contents in different foods. Up to now, five original papers have dealt specifically with this topic (Bardócz, Grant, Brown, Ralph, & Pusztai, 1993; Bardócz et al., 1995; Eliassen, Reistad, Risøen, & Rønning, 2002; Hernández-Jover, Izquierdo-Pulido, Veciana-Nogués, Mariné-Font, & Vidal-Carou, 1997; Okamoto, Sugi, Koizumi, Yanadiga, & Udaka, 1997). Nevertheless, the published data were often based on 2–3 samples and selection of the analysed foods took into consideration dietary habits in Scotland, Norway, Spain or Japan. A review on dietary polyamine contents was currently published (Kalač & Krausová, 2004).

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The objective of the present work is to determine polyamine contents in several common foods of both animal and plant origin, mainly in those processed for consumption, and to supplement data which have been fragmentary until now.

2. Materials and methods

2.1. Sampling

Culinary processed foods were sampled from the student canteen of the University of South Bohemia during lunchtime and polyamines were extracted immediately. Fresh pork, beef, liver and kidney, and frozen poultry meat or green pea were used for culinary processing. Other foods were purchased in local supermarkets.

In total, 153 samples of 21 food items were analysed.

2.2. Analytical methods

Acid extracts for determination of polyamines were prepared from 15–30 g of a sample which was homogenised using a kitchen hand blender with addition of the necessary volume of 0.6 M perchloric acid. The mixture was diluted with acid to the 100–170 ml, according to sample weight, and centrifuged at 3000 rpm and rotor diameter 240 mm for 10 min. The superficial lipidic layer was removed and the supernatant was filtered through a filter paper under reduced pressure. The filtrate was mixed with the acid up to final volume 100–170 ml. The extracts were stored in a refrigerator until analysis, maximally for 2 weeks.

Polyamines were determined as *N*-benzamides after derivatisation with benzoyl chloride. A method of micellar electrokinetic capillary chromatography was used, described in detail by Křížek and Pelikánová (1998), using a Spectraphoresis 2000 apparatus (Thermo Separation Products, Fremont, CA). The detection limits were 2.1, 1.0 and 1.4 mg kg^{-1} for PUT, SPD and SPM, respectively. All chemicals were of analytical grade.

Repeatability of the analytical procedure was tested by seven parallel analyses of a boiled beef rump sample. Relative standard deviations were 11.7% and 8.8% at mean contents 5.4 and 18.0 mg kg^{-1} for SPD and SPM, respectively. PUT content was below the detection limit.

2.3. Statistical methods

Polyamine contents in the individual food items are characterised by arithmetical mean value, standard deviation and range. Statistical significance of the differences among polyamine contents in different foods was tested by Duncan's test at significance level $P < 0.01$ using the programme STATISTICA, separately for foods of animal and plant origin.

Values below the detection limits were used for the calculations as halves of the limits: 1.05, 0.5 and 0.7 mg kg^{-1} for PUT, SPD and SPM, respectively.

3. Results and discussion

Data on polyamine contents in 95 differently culinary processed samples of beef, pork, chicken meat and pork offal are given in Table 1. PUT was detected in only one fifth of samples. The determined contents were low, usually below 10 mg kg^{-1}. Only in two samples did contents exceed 50 mg kg^{-1}. PUT is produced from ornithine or from arginine via agmatine by the activity of numerous bacteria (Shalaby, 1996; Silla Santos, 1996) and its higher levels thus indicate inappropriate treatment of foods of animal origin. SPD and SPM were detectable in nearly 90% and 95% samples, respectively. Mean SPM contents were higher than those of SPD, with roasted pork liver being the only exception. Roasted chicken breast, roasted pork liver and stewed pork kidney were items with the highest levels of both SPD and SPM. This is in agreement with opinion that increased SPD and SPM contents are typical for young and metabolically active tissues.

The determined contents of all polyamines in the processed pork, beef and chicken meat are very similar to data reported by Bardócz et al. (1993), Hernández-Jover et al. (1997) and Eliassen et al. (2002) for both raw and processed meats. Thus, it seems that common culinary processing procedures do not markedly decrease SPD and SPM contents of raw meat. However, experimental data have yet been lacking. To our knowledge, information on polyamine contents of processed turkey meat, pork liver and kidney have not yet been published.

Data for foods of plant origin are given in Table 2. Detectable contents of PUT, SPD and SPM were observed in 81%, 93% and 24% of samples, respectively. This is quite different from foods of animal origin. SPM contents were very low. Similar data were reported in numerous papers reviewed by Kalač and Krausová (2004). Dry soybean was an exception; comparable and even higher SPM contents were reported by Bardócz et al. (1993) and Okamoto et al. (1997).

The observed PUT and SPD contents in cooked potatoes are well comparable with results of Bardócz et al. (1993), Ziegler, Hahn, and Wallnöfer (1994) and Eliassen et al. (2002). Dry soybean has significantly the highest SPD content (91–305 mg kg^{-1}) among all the tested foods; however, dry matter content is several times higher than in other processed and fresh foods. Within the group of processed pulses, PUT content was very high in stewed green pea and SPD contents in both stewed green pea and yellow pea puree. Nevertheless,

Table 1
Polyamine contents (mg kg^{-1}) in culinary processed meats and offal

Food item	Number of samples	Putrescine		Spermidine				Spermine			
		n >ND	Range	n >ND	x	S^x	Range	n >ND	x	S^x	Range
Beef rump, cooked	16	3	ND-54.8	12	6.7^{a}	13.5	ND-51.2	15	16.3^{ab}	11.3	ND-40.6
Beef rump, roasted	21	6	ND-9.6	16	3.7^{a}	2.4	ND-10.0	20	17.1^{ab}	11.4	ND-44.0
Pork chop, roasted	11	3	ND-51.6	10	7.9^{ab}	8.9	ND-26.0	10	13.6^{a}	13.5	ND-35.9
Smoked pork chop, cooked	11	1	ND-2.8	11	3.3^{a}	1.2	1.7–5.4	11	15.9^{ab}	8.2	2.0–33.6
Pork neck, roasted	9	1	ND-3.4	9	6.1^{a}	6.1	1.0–19.0	9	26.3^{ab}	14.9	2.8–44.8
Chicken breast, roasted	10	4	ND-5.5	10	25.5^{bc}	16.2	2.4–49.8	10	54.1^{c}	20.0	22.0–81.6
Turkey meat, stewed	6	1	ND-11.8	6	5.4^{a}	5.0	1.1–14.2	5	16.3^{ab}	15.6	ND-40.4
Pork liver, roasted	5	1	ND-7.1	5	45.6^{c}	25.2	17.7–77.2	5	32.7^{ab}	10.0	23.2–44.6
Pork kidney, stewed	6	0	ND	6	17.8^{ab}	5.4	11.8–26.7	5	44.7^{bc}	28.5	ND-80.8

ND, content below the detection limit; n >ND, number of samples with polyamine content above the detection limit.
Means with different superscript letters in a column indicate significant differences at $P < 0.01$.

Table 2
Polyamine contents (mg kg^{-1}) in cooked potatoes, processed pulses, fresh fruits and vegetables

Food item	Number of samples	Putrescine				Spermidine				Spermine	
		n >ND	x	S_x	Range	n >ND	x	S_x	Range	n >ND	Range
Potato, cooked	5	5	7.6^{a}	4.8	2.2–16.3	5	6.5^{a}	1.7	5.3–9.8	0	ND
Yellow pea puree	6	4	3.5^{a}	2.0	ND-6.6	6	26.4^{a}	10.4	10.2–36.1	2	ND-1.8
Frozen green pea, stewed	5	5	56.7^{bc}	29.6	14.7–95.4	5	43.1^{a}	30.1	20.6–90.8	2	ND-2.6
Lentil, stewed	5	3	5.7^{a}	–	ND-20.2	5	8.7^{a}	6.9	3.7–20.8	0	ND
Sterilised red kidney beans in salt brine	5	2	–	–	ND-4.0	5	3.7^{a}	1.0	2.5–5.0	2	ND-2.5
Baked white kidney beans in tomato sauce	4	3	3.4^{a}	1.6	ND-4.8	4	3.9^{a}	0.9	2.6–4.9	1	ND-2.7
Dry soybean	4	4	30.9^{ab}	15.5	16.3–57.0	4	180^{b}	82.7	90.8–305	4	7.2–19.1
Apple	4	4	20.3^{a}	10.6	5.8–34.9	3	1.6^{a}	0.4	ND-2.1	0	ND
Grapefruit	5	5	62.1^{c}	32.8	22.9–89.2	5	7.3^{a}	5.2	2.3–15.0	0	ND
Green pepper, fresh	5	5	70.0^{c}	31.0	13.2–96.9	5	9.9^{a}	6.9	1.0–18.4	2	ND-2.1
Carrot, fresh	4	4	12.1^{a}	3.9	7.0–18.0	3	5.2^{a}	2.7	ND-8.9	1	ND-1.7
Yellow onion, fresh	6	3	12.6^{a}	13.9	ND-36.3	4	2.2^{a}	1.8	ND-5.2	0	ND

Mean spermine content and SD of dry soybean were 11.3 and 4.6 mg kg^{-1}, respectively.
Means with different superscript letters in a column indicate significant differences at $P < 0.01$.

these elevated levels were not significantly different from most of other food items even at $P < 0.05$. Increased PUT levels in green pea can be caused by bacterial activity during the interval between harvest and freezing and/or during thawing within culinary processing. However, high PUT content in the harvested pea cannot be excluded, because high, similar PUT and SPD mean contents, as given in Table 2, were also observed in culinary unprocessed frozen green pea (Kalač, Švecová, & Pelikánová, 2002). Green pea is a young, quickly developing plant organ and high SPD level could thus be anticipated. However, SPD content was several times higher in yellow pea puree than in processed lentil and kidney beans. Further research is thus needed.

Mean PUT contents in fresh apple, carrot and onion are higher than those reported by Bardócz et al. (1993), Ziegler et al. (1994) and Okamoto et al. (1997) mainly due to sporadic high values. High mean PUT content (62.1 $mg\,kg^{-1}$) in grapefruit is comparable with values commonly exceeding 100 $mg\,kg^{-1}$ in orange (Bardócz et al., 1993; Eliassen et al., 2002; Okamoto et al., 1997) and mandarin (Eliassen et al., 2002). PUT content in mandarin flavedo increased with decreasing field temperatures prior to harvest (Gonzalez-Aguilar, Zacarias, Perez-Amador, Carbonell, & Lafuente, 2000) and after mechanical damage (Valero, Martinez, Riquelme, & Serrano, 1998). The highest mean PUT content, 70 $mg\,kg^{-1}$, was determined in fresh green pepper. No literature data are available for this vegetable.

Wide variations of both SPD and SPM contents were observed in virtually all tested foods. This rather complicates utilisation of the data by dietitians.

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