Available online at www.sciencedirect.com

SCIENCE DIRECT®

Food Chemistry 100 (2007) 491–497

Food Chemistry

www.elsevier.com/locate/foodchem

Amounts of polyamines in foods in Japan and intake by Japanese

Naoyoshi Nishibori [a,*], Shinsuke Fujihara [b], Toshiko Akatuki [a]

[a] *Shikoku University Junior College, Ojin Tokushima 771-1192, Japan*

[b] *Laboratory of Plant Nutrition and Diagnosis, National Agricultural Research Center, Kannondai, Tsukuba 305-8666, Japan*

Received 4 July 2005; received in revised form 20 September 2005; accepted 20 September 2005

Abstract

The amounts of polyamines (putrescine, spermidine and spermine) in foods available in Japan were analyzed by HPLC. Though the polyamine concentrations varied in individual foods and food groups, significant differences in polyamine concentrations and distribution patterns were observed between food groups. Beans showed high concentrations of spermidine and spermine, vegetables had higher levels of putrescine and spermidine, fruit and seasonings had high levels of putrescine, fish and shellfish, meat and nuts had high levels spermine. Using the average polyamine concentrations and the amount of each food group consumed, the polyamine intake from foods by the Japanese was estimated to be 200 μmol/day/person, and about half of the polyamine intake was putrescine. This value is significantly lower than those reported for European countries.

Keywords: Polyamine; Food in Japan; Polyamine intake

1. Introduction

Polyamines are small, positively charged molecules distributed ubiquitously in living organisms and are known to play some essential roles in cell proliferation, regeneration and differentiation (Tabor & Tabor, 1984). A number of studies have reported the relation of polyamines to growth (Löser, Eisel, Harms, & Fölsch, 1999), cell cycle regulation (Alm, Berntsson, Kramer, Porter, & Oredsson, 2000; Oredsson, 2003) and gene expression (Kaminska, Kaczmarke, & Grzelakowska-Sztabert, 1992). At the molecular level, polyamines have an effect on structural changes of RNA, stimulation of 30 S ribosomal subunits and Ile-tRNA formation (Igrashi & Kashiwagi, 2000).

Reports of increased polyamine transport as cellular polyamine levels fall and cell cycle dependent polyamine transport have been published (Byers, Kameji, Rannels, & Pegg, 1987; Byers, Wechter, Hu, & Pegg, 1994; Kakinuma, Hoshino, & Igarashi, 1988; Martin, Ilett, & Minchin, 1991). The inter-organ distribution of dietary supplied polyamines shows the incorporation of exogenously supplied polyamines into in vivo polyamine circulation (Bardócz et al., 1995; Bardócz et al., 1998; Lösre, Torff, & Fölsch, 1997; Xu et al., 2002), although it was believed previously that polyamines necessary for growth were synthesized in situ. Additionally, the association of polyamines with food allergy (Dandrifosse et al., 2000) and improvement of arteriosclerosis through reduction of leukocyte function antigen-1 on the leukocyte cell surface (Soda, 2003) are also reported and the importance and nutritional efficiency of dietary polyamines have been recognized (Bardócz, Grant, Brown, Ralph, & Pusztai, 1993; Bardócz, 1995; Bardócz et al., 1995). However, information on polyamine content in different foods (Hernández-Jover, Izquierdo-Pulido, Veciana-Nogués, Mariné-Font, & Vidal-Carou, 1997; Kalač & Krausová, 2005a; Kalač, Křížek, Pelikánová, Langová, & Veškrna, 2005b; Okamoto, Sugi, Kozumi, Yanagida, & Udaka, 1997; Yamamoto, Itano, Kataoka, & Makita, 1982) and the daily intake are limited (Bardócz, 1995; Ralph, Englyst, & Bardócz, 1999).

Here, we have analyzed the amounts of polyamines in foods commonly used in Japanese households and

* Corresponding author. Tel.: +81 88 665 9900; fax: +81 88 665 8037.
E-mail address: n-nishibori@shikoku-u.ac.jp (N. Nishibori).

0308-8146/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2005.09.070

Table 1
Polyamine contents of foods available in Japan

Food	Polyamine concentration (n mol/g or ml)						
	Putrescine		Spermidine		Spermine		*n*
	Mean	Range	Mean	Range	Mean	Range	
Cereals							
Bread	44	13–105	73	15–159	24	6–52	5
Flour	32	13–60	34	28–40	7	5–8	5
Macaroni	5	4–6	23	14–34	9	5–14	4
Rice	2	2–3	3	2–4	3	1 – 4	6
Wheat noodles	4	1–9	3	2–3	1	1 – 1	5
Potatoes							
Potato	82	66–119	50	30–112	14	3–23	6
Sweet potato	43	7–76	31	12 – 55	4	1–14	7
Taro	34	18–49	30	23–34	6	2–8	5
Yam	127	111–145	144	23–300	4	1–7	4
Sugar							
Sugar	0	0–0	0	0–0	0	0–0	6
Beans							
Adzuki bean	41	23–58	454	322–556	392	261–521	5
Cow pea	16	13–18	361	288–445	381	266–684	5
Soybean	194	73–275	728	608–865	181	150–206	5
Soybean flour	42	11–89	102	30–279	18	7–46	5
Natto (fermented soybean)	175	81–267	232	150–314	19	10–26	4
Tofu (soybean curd)	0	0–0	1	0–1	0	0–0	4
Deep-fried tofu	9	6–11	59	33–82	34	27–40	4
Nuts							
Almond	19	13–33	41	35–51	67	58–77	5
Cashew	9	3–14	32	22–36	119	91–140	5
Peanut	18	9–32	110	88–132	88	66–127	4
Pistachio	207	82–314	77	59–86	66	48–92	5
Vegetables							
Asparagus	61	37–75	120	15–222	28	1–64	5
Bean sprout	207	174–279	50	37–66	3	2–5	5
Broccoli	21	15–30	156	111–195	43	28–62	5
Burdock root	111	15–286	114	18–245	43	15–68	5
Butterbur	22	11–31	13	8–15	2	2–3	6
Cabbage	31	8–71	61	23–136	12	4–33	8
Carrot	168	91–281	42	31–53	7	6–9	5
Celery	194	97–263	98	78–130	19	8–27	5
Chinese cabbage	10	5–18	72	21–109	4	0–12	12
Cucumber	149	24–293	107	31–224	1	0–2	5
Eggplant	198	128–250	31	18–39	2	1–3	4
Field pea	23	10–55	115	80–180	28	12–42	5
Garlic	26	8–69	77	51–130	29	18–35	4
Ginger	30	7–42	26	12–55	2	0–4	6
Green peas	367	63–581	341	31–651	32	21–43	6
Green pepper	621	354–955	80	53–123	45	20–103	10
Green soybeans	147	68–218	334	240–463	20	11–34	5
Japanese hornwort	178	63–421	110	25–281	33	10–79	6
Japanese radish	13	6–24	40	5–89	2	1–5	7
Kidney French bean	24	8–54	81	28–189	29	11–54	7
Komatsuna	32	4–45	118	11–202	25	12–41	6
Lettuce	235	116–481	303	102–717	16	2–64	7
Lotus root	116	50–209	210	119–354	2	1–4	6
Maize	576	208–969	144	56–269	8	1–25	6
Onion	7	2–11	16	8–21	4	2–11	6
Parsley	99	45–148	33	21–46	9	7–11	5
Pumpkin	75	37–123	42	39–68	91	33–205	5
Spinach	50	20–153	123	97–154	19	15–27	5
Tomato	114	60–235	15	10–25	1	1–2	5
Welsh onion	14	3–26	141	65–189	9	5–14	4
Pickled Japanese radish	50	34–64	78	56–98	4	0–7	5

Table 1 (*continued*)

Food	Polyamine concentration (n mol/g or ml)						
	Putrescine		Spermidine		Spermine		*n*
	Mean	Range	Mean	Range	Mean	Rangez	
Fruits							
Apple	3	2–5	9	3–15	1	0–2	4
Banana	140	127–156	40	29–57	3	0–8	5
Cherry	19	4–49	11	0–25	4	2–10	6
Chinese citron	315	234–394	4	2–7	0	0–0	4
Mandarin orange	256	118–468	10	1–16	0	0–1	5
Orange	244	73–413	4	0–10	0	0–1	7
Strawberry	11	9–14	14	11–20	2	1–3	5
Mushrooms							
Enoki mushroom	50	26–75	224	172–266	0	0–0	6
Mushroom	45	23–67	610	430–959	17	15–22	5
Shiitake mushroom	2	0–7	388	229–495	0	0–0	6
Shimeji mushroom	108	61–151	153	75–255	2	1–3	5
Seaweed							
Tangle	0	0–1	0	0–1	3	0–12	6
Wakame seaweed	5	0–16	3	0–7	0	0–1	6
Fish and shellfish							
Horse mackerel	53	3–146	21	10–37	62	33–97	5
Japanese needlefish	1	1–3	3	1–6	5	0–15	4
Mackerel	9	4–14	19	15–22	21	8–34	5
Octopus	12	8–17	25	23–28	157	130–189	5
Salmon	21	16–30	26	18–34	45	32–69	5
Sardine	9	4–18	17	15–20	28	19–36	5
Sardine (the small fry, dried)	81	63–100	203	157–253	199	155–250	5
Short-necked clam	27	20–33	104	73–137	208	162–246	4
Shrimp	0	0–1	1	1–3	2	1–3	4
Squid	1	1–2	0	0–1	47	25–74	5
Tuna	3	2–3	14	4–22	82	36–129	5
Fish sausage	10	4–14	6	2–7	9	5–13	4
Meat							
Beef	10	4–15	16	8–28	154	132–170	5
Chicken	8	5–11	45	31 -57	226	187–270	4
Pork	3	1–6	8	5–12	129	96–143	5
Ham	6	2–23	10	5–26	50	10–155	7
Eggs							
Eggs (chicken)	3	0–7	1	0–2	1	0–2	4
Dairy products							
Cheese (processed)	0	0–0	30	17–46	7	2–13	4
Milk (cow)	0	0–1	0	0–0	0	0–0	5
Yoghurt	0	0–1	1	0–3	0	0–1	5
Oil							
Rape seed oil	0	0–0	0	0–0	0	0–0	5
Sesame oil	0	0–0	0	0–0	0	0–0	5
Confectionery							
Candy	0	0–1	0	0–0	0	0–0	4
Chocolate	4	0–10	17	15–17	7	4–11	5
Cookie	3	1–5	7	1–14	3	0–7	6
Potato chips	69	0–142	65	8–110	12	1–25	4
Rice cracker	18	4–49	3	0–7	3	1–4	5
Beverages							
Beer	46	37–51	0	0–0	0	0–2	5
Sake (Japanese rice-wine)	2	0–3	0	0–0	0	0–0	7
Cocoa	3	0–7	3	0–7	1	0–2	5
Coffee	0	0–0	0	0–1	0	0–0	5
Tea	0	0–0	0	0–0	0	0–0	7

(*continued on next page*)

Table 1 (*continued*)

Food	Polyamine concentration (n mol/g or ml)						
	Putrescine		Spermidine		Spermine		*n*
	Mean	Range	Mean	Range	Mean	Range	
Seasonings							
Salt	0	0–0	1	0–2	0	0–0	5
Soy sauce	696	338–1547	82	43–115	10	1–19	6
Ketchup	140	65–371	29	6–96	2	0–9	7
Mayonnaise	11	4–26	18	11–27	2	1–5	6
Miso (soybean paste)	296	224–389	12	3–41	5	0–31	6

calculated the intake of the major polyamines (putrescine, spermidine and spermine) by Japanese from food.

2. Materials and methods

2.1. Sample preparation and HPLC analysis

Over 100 food items were analysed for polyamine (putrescine, spermidine and spermine) concentrations. Samples were purchased at local markets and homogenized in 5% trichloroacetic acid (TCA) on the same day without drying. In the case of liquids, TCA was added to a concentration of 5%. The homogenized samples were stored at −20 °C until analysis. After being thawed at room temperature, the samples were centrifuged at 2000*g* for 15 min, and the supernatants containing free polyamines were analyzed using HPLC with a cation exchange resin (Hitachi 2619 F) as described by Hamana et al. (1994).

2.2. Estimation of daily polyamine intake from food

The Nation-wide Nutrition Survey in Japan (J-NNS) conducted by the Ministry of Health, Labor and Welfare of Japan in 2004 provides a wealth of detailed information on food composition. Over 1000 foods are listed and categorized into 17 groups, and the daily consumption of each food group is given as g/person/day in the J-NNS. The samples analyzed were categorized according to the classification used in the J-NNS, and the average polyamine concentration of each food group was calculated. From the daily consumption given in the J-NNS and the average polyamine concentration of each food group, the intake of polyamines/person/day in Japan was estimated.

3. Results and discussion

The polyamine concentrations of the foods analyzed are listed in Table 1. The amounts of polyamines varied greatly in individual samples among the same food item, as reported previously for meat, meat products, milk and cheeses (Hernández-Jover et al., 1997; Novella-Rodríguez, Veciana-Nogués, & Vidal-Carou, 2000). Although wide variations in polyamine concentrations were observed in individual food items, specific distribution patterns of polyamines were observed in some foods. Soy sauce, green peppers, and maize contained extremely high concentrations of putrescine. Soybeans, and mushrooms showed high spermidine concentrations. Adzuki beans and cowpeas had high spermine content.

These foods were categorized into the 17 groups as by the J-NNS, and the mean polyamine concentration of each food group is shown in Fig. 1. Although the polyamine concentrations and distribution patterns varied with in the same food group, statistical analysis (*t*-test) showed significant differences in amounts of polyamines and distribution patterns between food groups. Beans, mushrooms, seasonings and vegetables showed higher polyamine contents than other food groups ($p \leqslant 0.01$), and polyamine contents in sugar, oils and eggs were poor. Beans had high spermidine and spermine levels, vegetables were high in putrescine and spermidine, fruit and seasonings were high in putrescine, mushrooms had much spermidine, and fishes and shellfishes, meat and nuts had much spermine ($p < 1 \times 10^{-4}$, respectively, Fig. 1). These results corresponded to those in previous reports (Bardócz, 1995; Bardócz et al., 1995; Eliassen, Reistad, Risøen, & Rønning, 2002; Hernández-Jover et al., 1997; Kalač & Krausová, 2005a; Kalač et al., 2005b; Novella-Rodríguez et al., 2000; Okamoto et al., 1997; Ralph et al., 1999; Yamamoto et al., 1982).

The daily intake of polyamines by Japanese adults (mean value of ages 15–69) was calculated as described above and is shown in Table 2. Not all foods listed in the

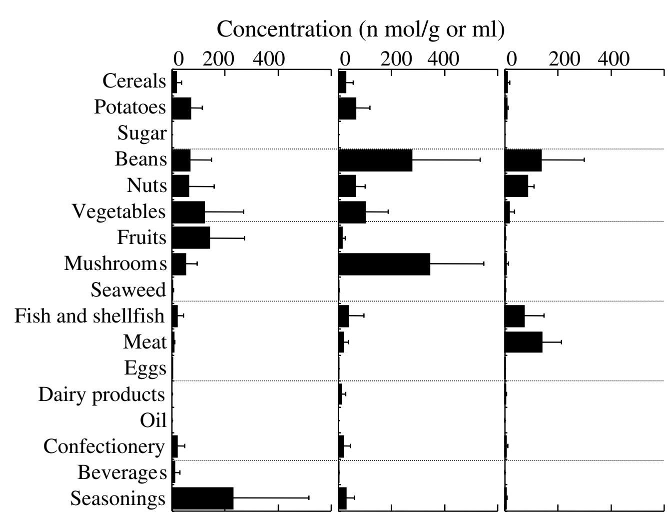

Fig. 1. Average amounts of polyamines in each food group calculated from Table 1. a, putrescine; b, spermidine; c, spermine. Error bars represents SE.

Table 2
Daily intake of polyamines from each food group by Japanese

Food	Intake (g/d)	Putrescine (n mol)	Spermidine (n mol)	Spermine (n mol)
Cereals	480	8302	13,004	4202
Potatoes	62	4387	3920	427
Sugar	7	0	1	0
Beans	52	3259	14,359	7134
Nuts	2	131	134	176
Vegetables	257	31,144	25,908	4491
Fruits	106	14,929	1392	155
Mushrooms	14	733	4900	69
Seaweed	13	38	21	19
Fish and shellfish	80	1524	2949	5800
Meat	95	646	1897	13,351
Eggs	40	124	38	22
Dairy products	183	33	1917	460
Oil	13	0	1	0
Confectionery	30	557	551	150
Beverages	491	4919	299	116
Seasonings	87	4919	2466	347
Total	2012	11,3028	82,434	39,302

J-NNS table were analyzed, but the foods listed in Table 1 include all the food groups represented in the Japanese diet. Total polyamine intake was about 200 μmol/day/person. About the half the polyamine intake was putrescine (45%), with spermidine and spermine accounting for 37% and 18%, respectively. The total amount of polyamine intake seemed significantly lower in Japan than those reported for Britain, Italy, Spain, Finland, Sweden, and Netherlands (310–390 μ mol/day/person, $p < 0.01$) (Bardócz et al., 1995; Ralph et al., 1999), although the ratios of each polyamine (putrescine, spermidine and spermine) to the total polyamine intake for the Japanese resembled those obtained for these European countries (Bardócz, 1995; Ralph et al., 1999). For the Japanese, the major source of putrescine was vegetables, seasonings, fruits and cereals (Fig. 2), while in European countries, it was

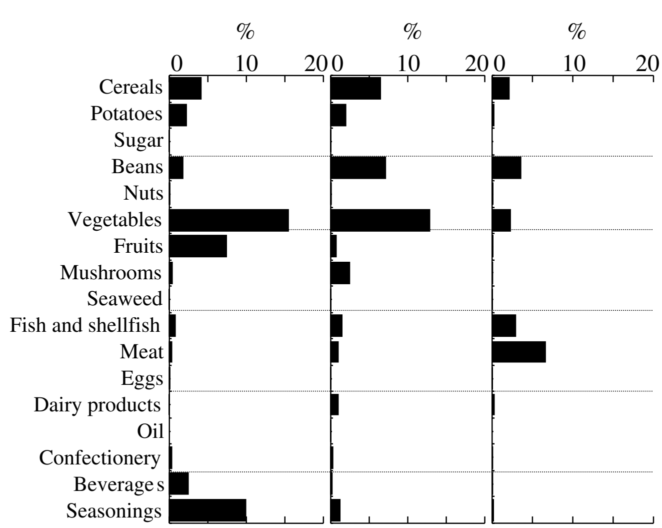

Fig. 2. The source of polyamines in the diet for Japanese adults expressed as the ratio of each polyamine (a, putrescine; b, spermidine; c, spermine) to the total polyamine intake.

fruit, cheese, potatoes and vegetables (Bardócz, 1995). Although cheese contains much putrescine and is one of the important sources of putrescine for Europeans (Ralph et al., 1999; Novella-Rodríguez et al., 2000), the polyamine contents of cheeses in Japan, (most popular in Japan is processed cheese and grouped in daily products here), were low, as was reported in Okamoto et al. (1997). For the Japanese, the most important source of spermidine was vegetables, beans and cereals, and that of spermine was meat (Fig. 2). In Britain also, vegetables are the most important source of spermidine and that of spermine was meat and fish (Bardócz, 1995). Though the classification of food used here was not identical to those used in European countries, the consumption of common food groups in both regions, for example potatoes, vegetables, fruits, meat, fish, etc. were almost identical ($P > 0.05$), except for dairy products ($P = 0.04$) and cereals ($P < 0.01$), which seems to be the result of higher rice consumption in Japan. Additionally, polyamine contents of these common food groups were almost identical between the two regions except for dairy products (Table 3). The lower polyamine intake from food in Japan than the European countries seems to be the result of the differences in food polyamine concentrations and consumption, especially those having high amounts of polyamines, such as cheeses in Europe.

These results show the possible regional variation of polyamine intake based on different food intake and regional dietary habitats. It is important to get these regional variations of polyamine intake in order to map an eventual correlation between the intake of polyamine and specific diseases. Though cooking does not significantly alter the composition and concentration of polyamines in potato and meat (Eliassen et al., 2002), our preliminary results showed the decrease of polyamine contents in some boiled vegetables. Estimation of polyamine contents in cooked food will be required to obtain further information of polyamine intake from food.

Table 3
Summary of polyamine contents in foods

Food group	Polyamine concentration (n mol/g or ml)					
	Japanese			European[a]		
	Putrescine	Spermidine	Spermine	Putrescine	Spermidine	Spermine
Cereals	17 ± 19	27 ± 29	9 ± 9	12 ± 4	70 ± 53	30 ± 19
Potatoes	71 ± 42	64 ± 54	7 ± 5	245	105	26
Sugar	0 ± 0	0 ± 0	0 ± 0	0	1	0
Beans	68 ± 81	276 ± 258	137 ± 161	25 ± 30	231 ± 137	139 ± 27
Nuts	63 ± 96	65 ± 36	85 ± 25	184	262	271
Vegetables	121 ± 150	101 ± 87	17 ± 19	100 ± 215	80 ± 132	35 ± 76
Fruits	141 ± 132	13 ± 12	1 ± 1	255 ± 433	36 ± 96	21 ± 40
Mushrooms	51 ± 44	344 ± 203	5 ± 8	2	258	5
Seaweed	3 ± 4	2 ± 2	1 ± 2			
Fish and shellfish	19 ± 25	37 ± 59	72 ± 75	86 ± 109	30 ± 14	43 ± 26
Meat	7 ± 3	20 ± 17	140 ± 72	55 ± 47	33 ± 18	180 ± 72
Eggs	3	1	1	3	0	2
Dairy products	0 ± 0	10 ± 17	3 ± 4	869 ± 2245	233 ± 445	43 ± 63
Oil	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Confectionery	19 ± 29	18 ± 27	5 ± 5	8 ± 4	12 ± 15	3 ± 3
Beverages	10 ± 20	1 ± 1	0 ± 0	32 ± 40	3 ± 4	3 ± 2
Seasonings	229 ± 288	28 ± 32	4 ± 4			

[a] Calculated from the data of some common foods in Ralph et al. (1999).

It is known that only a limited portion of dietary polyamines are absorbed through the intestinal tract as they are metabolized during the passage through the intestine (Bardócz et al., 1995) and other amines, such as histamine and cadaverine, can alter polyamine absorption through competing for diamine oxidase with putrescine. The effect of dietary polyamines should be further elucidated to evaluate the effect of dietary polyamines on health or disease.

Acknowledgement

This work was supported by Shikoku University Grant-in-Aid for Scientific Research.

References

Alm, K., Berntsson, P. S. H., Kramer, D. L., Porter, C. W., & Oredsson, S. M. (2000). Treatment of cells with the polyamine analog N^1,N^{11}-diethylnorspermine retards S phase progression within one cell cycle. *European Journal of Biochemistry, 267*, 4157–4164.

Bardócz, S. (1995). Polyamines in food and their consequences for food quality and human health. *Trends in Food Science and Technology, 6*, 341–346.

Bardócz, S., Duguid, T. J., Brown, D. S., Grant, G., Pusztai, A., & White, A. (1995). The importance of dietary polyamines in cell regeneration and growth. *British Journal of Nutrition*, 819–828.

Bardócz, S., Grant, G., Brown, D. S., Ralph, A., & Pusztai, A. (1993). Polyamines in food – implications for growth and health. *Journal of Nutritional Biochemistry, 4*, 66–71.

Bardócz, S., Hughes, E. L., Grant, G., Brown, D. S., Duguid, T. J., & Pusztai, A. (1998). Uptake, inter-organ distribution and metabolism of dietary putrescine in the rat. *Journal of Nutritional Biochemistry, 9*, 332–338.

Byers, T. L., Kameji, R., Rannels, D. E., & Pegg, A. E. (1987). Multiple pathways for uptake of paraquat, methylglyoxal bis(guanylhydrazone), and polyamines. *American Journal of Physiology, 252*, C663–C669.

Byers, T. L., Wechter, R. S., Hu, R. H., & Pegg, A. E. (1994). Effects of teh S-adenosyl,ethionine decarboxylase inhibitor, 5′-([(*Z*)-4amino-2-butenyl]methylamino)-5′deoxyadenosine, on cell growth and polyamine metabolism and transport in Chinese hamster ovary cell cultures. *Biochemical Journal, 303*, 89–96.

Dandrifosse, G., Peulen, O., Khefif, N. E., Deloyer, P., Dandrifosse, A. C., & Grandfils, C. (2000). Are milk polyamines preventive agents against food allergy? *Proceedings of the Nutrition Society*.

Eliassen, K. A., Reistad, R., Risøen, U., & Rønning, H. F. (2002). Dietary polyamines. *Food Chemistry, 78*, 273–280.

Hamana, K., Hamana, H., Niitsu, M., Samajima, K., Sakane, T., & Yokota, A. (1994). Occurrence of tertiary and quaternary branched polyamines in thermophilic archaebacteria. *Microbios, 79*, 109–119.

Hernández-Jover, T., Izquierdo-Pulido, M., Veciana-Nogués, M. T., Mariné-Font, A., & Vidal-Carou, M. C. (1997). Biogenic amine and polyamine contents in meat and meat products. *Journal of Agricultural and Food Chemistry, 45*, 2098–2102.

Igrashi, K., & Kashiwagi, K. (2000). Polyamines: mysterious modulators of cellular functions. *Biochemical and Biophysical Research Communications, 271*, 559–564.

Kakinuma, Y., Hoshino, K., & Igarashi, K. (1988). Characterization of the inducible polyamine transporter in bovine lymphocytes. *European Journal of Biochemistry, 176*, 409–414.

Kalač, P., & Krausová, P. (2005a). A review of polyamines: formation, implications for growth and health and occurrence in foods. *Food Chemistry, 90*, 219–230.

Kalač, P., Křížek, M., Pelikánová, T., Langová, M., & Veškrna, O. (2005b). Contents of polyamines in selected foods. *Food Chemistry, 90*, 561–564.

Kaminska, B., Kaczmarke, L., & Grzelakowska-Sztabert, B. (1992). Inhibitors of polyamine biosynthesis affect the expression of genes encoding cytoskeletal proteins. *Federation of European Biochemical Societies, 304*, 198–200.

Löser, C., Eisel, A., Harms, D., & Fölsch, U. R. (1999). Dietary polyamines are essential luminal growth factors for small intestinal and colonic mucosal growth and development. *Gut, 44*, 12–16.

Lösre, C., Torff, L., & Fölsch, U. R. (1997). Uptake of extracellular, dietary putrescine is an important regulatory mechanism of intracellular polyamine metabolism during camostate induced pancreatic growth in rats. *Digestive Diseases and Science, 42*, 503–513.

Martin, R. L., Ilett, K. F., & Minchin, R. F. (1991). Cell cycle-dependent uptake of putrescine and its importance in regulating cell cycle phase transition in cultured adult mouse hepatocytes. *Hepatology, 14*, 1243–1250.

Novella-Rodríguez, S., Veciana-Nogués, M. T., & Vidal-Carou, M. C. (2000). Biogenic amines and polyamines in milks and cheeses by ion-pair high performance liquid chromatography. *Journal of Agricultural and Food Chemistry, 48*, 5117–5123.

Okamoto, A., Sugi, E., Kozumi, Y., Yanagida, F., & Udaka, S. (1997). Polyamine content of ordinary foodstuffs and various fermented foods. *Bioscience Biotechnology and Biochemistry, 61*, 1582–1584.

Oredsson, S. M. (2003). Polyamine dependence of normal cell cycle progression. *Biochemical Society Transactions, 31*, 366–370.

Ralph, A., Englyst, K., & Bardócz, S. (1999). Polyamine content of the human diet. In S. Bardocz & A. White (Eds.), *Polyamines in health and nutrition* (pp. 123–137). Massachusetts: Kluwer Academic Publishers.

Soda, K. (2003). Polyamine. *Food Science Journal, 11*, 40–49 (in Japanese).

Tabor, C. W., & Tabor, H. (1984). Polyamines. *Annual Review of Biochemistry, 53*, 749–790.

Xu, Y. J., Hara, T., Samejima, K., Sasaki, H., Kobayashi, M., Takahashi, A., et al. (2002). Simultaneous determination of endogenous and orally administered ^{15}N-labeled polyamines in rat organs. *Analytical Biochemistry, 301*, 255–260.

Yamamoto, S., Itano, H., Kataoka, H., & Makita, M. (1982). Gas–liquid chromatographic method for analysis of di- and polyamines in food. *Journal of Agricultural and Food Chemistry, 30*, 435–439.