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Lithium content of some common edible wild-growing mushrooms

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Abstract

Occurrence, content and biological role(s) of lithium in plant-, animal- and human tissues are partly understood, but information about Li levels of fungi (macrofungi) is practically absent. 171 samples of 38 common, edible wild mushroom species, originating from different localities in Hungary, were analysed. 44 samples had undetectable and 127 detectable (i.e. higher than 0.03 ppm) lithium concentrations. The average Li level of all analysed sporocarp samples was 0.189 ppm, which is below the upper limit (0.2 ppm) for plant lithium content in Hungary. The highest, average Li contents were found in *Craterellus cornucopioides* (0.609 ppm), *Amanita strobiliformis* (0.520 ppm) and *Psathyrella candolleana* (0.390 ppm). However, these species are not members of the so-called ''bioaccumulator'' fungi (their concentrations are only two–three fold higher than the average).

The mushrooms samples, collected from habitats of Mt. Vértes (in middle-Hungary), have significantly higher Li contents than mushrooms originating from other localities. Lithium contents of edible mushrooms of the three important types (saprotrophic, mycorrhizal and wood-destroying ones) do not differ significantly (although the wood-destroying group has the lowest average content).

According to our data and calculations, a daily consumption of 100 g fresh mushroom can give only 1–6 μg Li intake per person. This is less than 1% of the human daily Li requirement.

Keywords: Lithium; Sporocarps; Edible mushrooms

1. Introduction

Lithium (Li) is an ultramicroelement, relatively little known or investigated. The total Li content of soils varies from 8 to 4000 ppm but the concentration of extractable Li is about only 0.3–0.5 ppm (Pais, 1980). Lithium in soil is probably bound as organomineral compounds. According to Tölgyesi (1983) the average total Li content in acidic brown soil in Hungary is 28.9 ppm; the soluble fraction is 0.67 ppm. The rate of Li uptake is regulated by the soluble, extractable fraction and by the soil moisture content, respectively (Jurkowska & Rogoz, 1991). Li contents of main plant species of grassland are within the range 0.5–2.0 ppm; the highest level is found in *Ranunculus repens* (Lambert, Sapek, & Sapek, 1983). In Hungary, the measured common forage plan species range from 0.2 to 200 ppm, Li accumulating plants belong to the Asteraceae and Solanaceae families (Tölgyesi, 1983). Increasing N rate generally increases Li concentrations in both roots and shoots (Jurkowska, Rogoz, & Wojciechowitz, 1990). Li level is higher in dicot plants than in monocots. The actual Li level of plants is regulated by the levels of other microelements: applying Cu, Zn, Pb increased the Li content of oat tops, but Cd decreased it (Jurkowska & Rogoz, 1993); sodium application increased the Li concentration of barley and mustard (Jurkowska, Rogoz, & Wojciechowitz, 1995). A treatment with lime reduced Li content of oats and fodder beet (Jurkowska & Rogoz, 1992). Application of Li increased N content of leaves of wheat and the rate of CO_2-fixation, especially at flowering; the average rate of photorespiration was 26–28% higher in Li-treated than in control plants (Bogdan, Kuzmenko, Stasik, & Tkachuk, 1994).

Li-deficiency in certain insulin-sensitive tissues may be associated with blood glucose imbalance in Chinese hamsters (Hu, Wu, & Wu, 1997). Li supplements have

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positive effects on productivity of pigs (Kokorev, Guryanov, & Petunenkov, 1996). Metabolic relationships between Li and other elements were estimated in adult goats (Arnold, Anke, & Krauter, 1991). Li-deficiency tended to increase Fe and Zn but decreased Cu accumulation. Feeding with a Li-deficient diet affected both the reproduction and the lifespan; high Li doses decreased feed intake and increased water consumption (Kosla & Skibniewska, 2001).

Li content of human hair shows an approximately linear response to extradietary Li supplementation (Schrauzer, Shresta, & Flores-Arce, 1992). The mean hair Li concentration is 0.063 μg/g in adults; mean Li intake is calculated to be 730 μg/day. A significant correlation was found between Li and Co concentrations of hair, which suggests a role of Li in the transport and distribution of vitamin B_{12}. Lithium may stimulate the production of new brain cells, thus raising hope that it can treat strokes and Alzheimer's disease. Lithium is used in psychiatric practice, for regulating higher nervous activity. Low dosages of Li generally have a beneficial effect on human behaviour. Increasing human Li intake by supplementation (lithiation of drinking water) was suggested as a possible means of reduction of crime, suicide and drug-dependency (Schrauzer & Shrestha, 1990).

Li contents of different (edible or not edible, cultivated or not cultivated) mushrooms are practically not investigated, but it was estimated that the LiCl has a selective inhibitory effect on *Trichoderma* fungi species (Wildman, 1991).

Our earlier data were concerned with sporocarps of some wild-growing *Agaricus* and *Pleurotus* species (Vetter, 1990a), and particularly with cultivated *Agaricus bisporus* and *Pleurotus ostreatus* (Vetter, 1994) and *Lentinula edodes* (Vetter, 1995); the publication of Quinche (1982) has data on *Lepista nebularis* only. The aims of the present work – as a "pioneer" investigation are:

- to investigate and to compare the lithium contents of the most important and most widespread edible, wild-growing mushroom species, based on independent samples originating from different habitats of Hungary;
- to investigate any possible connection between the taxonomical position and the Li content of the mushroom;
- and, finally, to identify the possibility of any Li-accumulating mushroom species.

2. Materials and methods

The mushroom samples were harvested from different habitats of Hungary, principally in mountains. The sporocarps (fruit bodies) of the species were carefully cleaned, cut, dried (at 40 °C) and milled. The digestion was carried out, on the powder of sporocarps, by a mixture (200 mg mushroom + 2 cm^3 HNO_3 + 2 cm^3 H_2O_2) in closed Teflon bombs at 1.56×10^5 Pa pressure for 20 min, in three independent replications. Lithium content of the filtered and diluted solution was determined by an inductively coupled plasma spectroscopy (ICP) method, according to an earlier published description (Vetter, 1990b). The symbol < d.l. (= <detection limit) is given in the tables if the Li concentration is lower than 0.03 ppm of dry matter. In other cases, the lithium content of the sample is characterized by the arithmetical means (in ppm of dry matter) and by standard deviation (±SD). In summarizing different samples of the same species or of genera, the arithmetical means and the standard deviation are calculated and given.

3. Results and discussion

Lithium contents of 171 samples of 38 edible mushrooms species were determined. All data are given in Table 1 (ppm of D.M.). Li contents of 44 samples are below the detection limit; 127 samples however, have higher and measurable Li contents. The distribution of the Li contents of samples (Fig. 1) is normal, but the occurrence of some higher concentrations shows the presence of some species with higher Li contents. The average Li content (all measurable samples and species) is 0.189 ± 0.243 ppm. The remarkable standard deviation originates from the broad distribution of the samples (species). The estimation of the samples of the same category (species) shows a double characteristic. Most species have samples with remarkable variability (*Amanita strobiliformis*: 0.18–1.4 ppm; *Craterellus cornucopioides*: 0.11–1.9 ppm; *Lepista nuda*: detection limit – 0.428 ppm). Other, smaller group of species can be characterized by the relative constancy of their Li content (*Macrolepiota rhacodes*: detection limit – 0.09 ppm; *Pleurotus pulmonarius* 0.063–0.077 ppm; *Xerocomus chrysentheron*: 0.080–0.166 ppm). The highest Li contents were found in the species *C. cornucopioides* (1.476 ppm in the habitat of Mt. Vértes), in *A. strobiliformis* (1.476 ppm in Botanical Garden of Soroksár), and *Psathyrella candolleana* (1.15 ppm in habitat of Mt. Vértes and 0.472 ppm in Mt. Budai). Li contents of all samples of *Boletus edulis*, *Hydnum repandum* and *Suillus grevillei* were below the detection limit, Li is undetectable in 8 samples of *Macrolepiota rhacodes*, and only one sample had a detectable level. Two samples of *Lycoperdon excipuliformis* were undetectable; one sample, however, had a detectable Li content.

Table 2 lists the average contents of samples of 15 species and of 2 genera (*Agaricus* and *Xerocomus*) (on the basis of a minimum 3 or more samples; other species

Table 1
Lithium contents of sporocarps of some edible mushroom species (arithmetical mean (ppm) and the standard deviation (±SD))

Mushroom species	Site of gathering	Li content (ppm of D.M. ± SD)
Agaricus arvensis Schff.:Fr	Mt. Börzsöny	0.074 ± 0.005
	Mt. Bakony	0.130 ± 0.089
	Mt. Zemplényi	0.300 ± 0.080
A. campestris L.:Fr	Mt. Börzsöny	0.221 ± 0.177
A. esettei Bon	Miskolc/1, Mt. Zemplén	0.240 ± 0.002
	Tatabánya/2, Mt. Vértes	0.146 ± 0.084
	Miskolc/2, Mt. Zemplén	0.206 ± 0.130
	Rákospalota (Budapest)	<d.l.
	Mt. Mátra	0.200 ± 0.010
A. haemorrhoidarius Schulz.: Kalchbr.	SBK (Budapest)	0.087 ± 0.025
	Hárskút, Mt. Bakony	0.092 ± 0.050
A. strobiliformis (Paul.:Vitt.) Bert.	SBK (Budapest)	0.564 ± 0.028
	SBK (Budapest)	0.184 ± 0.022
	SBK (Budapest)	0.232 ± 0.066
	SBK (Budapest)	0.167 ± 0.077
	SBK (Budapest)	1.476 ± 0.032
Armillaria mellea (Vahh.:Fr.) Karst.	Kamara wood (Budapest)	0.151 ± 0.026
	Mt. Mátra	<d.l.
	Tatabánya, Mt Vértes	0.500 ± 0.070
	Miskolc/1, Mt. Zemplén	0.099 ± 0.049
	Miskolc/1, Mt. Zemplén	0.049 ± 0.007
	Miskolc/2, Mt. Zemplén	0.189 ± 0.089
	Mt. Budai	0.146 ± 0.087
	Tatabánya/4, Mt. Vértes	0.103 ± 0.078
	Tatabánya/1, Mt. Vértes	0.262 ± 0.045
	Miskolc/3, Mt. Zemplén	0.061 ± 0.002
	Tatabánya/4, Mt. Vértes	<d.l.
	Herend, Mt. Bakony	0.046 ± 0.002
	Hárskút, Mt. Bakony	0.106 ± 0.004
	Farkasgyepü, Mt. Bakony	<d.l.
	Mt. Bakony	<d.l.
	Normafa, Mt. Budai	<d.l.
	Miskolc, Mt. Zemplén	0.176 ± 0.089
	Normafa, Mt. Budai	0.472 ± 0.006
	Mt. Karancs	0.037 ± 0.003
Boletus edulis (Bull.) Fr.	Budakeszi, Mt. Budai	<d.l.
	Normafa, Mt. Budai	<d.l.
Camarophyllus pratensis (Pers.:Fr.) Kummer	Mt. Mátra	0.116 ± 0.028
Clitocybe odora (Bull.:Fr.) Kummer	Tatabánya/2, Mt. Vértes	0.084 ± 0.002
	Miskolc/1, Mt. Zemplén	0.175 ± 0.109
	Miskolc/1, Mt. Zemplén	0.132 ± 0.075
	Tatabánya/2, Mt Vértes	0.308 ± 0.101
	Mt. Pilis	0.176 ± 0.012
	Herend, Mt. Bakony	0.038 ± 0.037
C. cornucopioides (L.) Pers.	Tatabánya/2, Mt. Vértes	1.800 ± 0.232
	Mt. Bakony/1	0.668 ± 0.081
	Mt. Mátra	0.330 ± 0.035
	Herend, Mt. Bakony	0.133 ± 0.057
	Farkasgyepü, Mt. Bakony	0.114 ± 0.084
Fistulina hepatica (Schaeff.) Fr.	Tatabánya, Mt. Vértes	<d.l.
	Mt. Bükk	0.096 ± 0.009
	Tatabánya, Mt. Vértes	0.307 ± 0.074
	Domonyvölgy	<d.l.
Flammulina velutipes (Curt.:Fr.) Sing.	Érd/1, (near to Budapest)	0.421 ± 0.040
	Érd/2 (near to Budapest)	0.245 ± 0.035
Gomphidius glutinosus (Schff.) Fr.	Miskolc/3, Mt. Zemplén	0.203 ± 0.056

Table 1 (*continued*)

Mushroom species	Site of gathering	Li content (ppm of D.M. ± SD)
	Mt. Mátra	<d.l.
Hericium coralloides (Scop.:Fr.) S.F. Gray	Tatabánya/2, Mt. Vértes	0.086 ± 0.004
	Normafa, Mt. Budai	0.064 ± 0.048
	Normafa/2, Mt. Budai	0.153 ± 0.002
	Normafa/3, Mt. Budai	0.115 ± 0.007
Hirneola (Auricularia) auricula-judae (Bull.:Fr.) Wettst.	Miskolc/3, Mt. Zemplén	0.096 ± 0.026
	Farkasgyepü, Mt. Bakony	0.105 ± 0.008
	Normafa, Mt. Budai	0.226 ± 0.005
Hydnum repandum L.:Fr.	Mt. Mátra	<d.l
	Mt. Pilis	<d.l.
Hygrophorus eburneus (Bull.:Fr.) Fr.	Normafa, Mt. Budai	0.328 ± 0.059
	Mt. Bakony	0.180 ± 0.061
	Mt. Karancs	<d.l.
Hypholoma capnoides (Fr.:Fr.) Kummer	Mt. Pilis	0.136 ± 0.006
	Mt. Pilis/2	<d.l.
	Miskolc/3, Mt. Zemplén	<d.l.
	Pilisszentkereszt, Mt. Pilis	0.048 ± 0.004
	Mt. Bükk	<d.l.
Kuehneromyces mutabilis (Schff.:Fr.)	Farkasgyepü, Mt. Bakony	0.125 ± 0.030
Lactarius deliciosus Fr.	Miskolc/3, Mt. Zemplén	<d.l.
	Herend, Mt. Bakony	0.064 ± 0.007
	Farkasgyepü, Mt. Bakony	<d.l.
	Miskolc/3, Mt. Zemplén	0.082 ± 0.050
Laetiporus sulphureus (Bull.:Fr.) Murrill	Mt. Pilis	<d.l.
Lepista nuda (Bull.:Fr.) Cke.	Tatabánya/2, Mt. Vértes	<d.l.
	Mt. Börzsöny	<d.l.
	Mt. Bakony/1	0.036 ± 0.002
	Mt. Bakony/3	0.020 ± 0.001
	Herend, Mt. Bakony	0.065 ± 0.002
	Farkasgyepü, Mt. Bakony	<d.l.
	Farkasgyepü, Mt. Bakony	0.055 ± 0.001
	Örség (West Hungary)	0.083 ± 0.006
	Hüvösvölgy (Mt. Budai)	0.142 ± 0.076
	Mt. Karancs	0.052 ± 0.060
Lepista nebularis Fr.	Mt. Bükk	0.428 ± 0.018
	Mt. Börzsöny	0.074 ± 0.055
	Mt. Bakony/1	0.072 ± 0.031
	Mt. Bakony/2	0.028 ± 0.003
	Mt. Mátra	0.130 ± 0.060
	Farkasgyepü, Mt. Bakony	0.050 ± 0.002
	Miskolc/2, Mt. Zemplén	0.148 ± 0.003
	Mt. Karancs	<d.l.
Lepista flaccida (Sow.:Fr.) Pat.	Miskolc/1, Mt. Zemplén	0.123 ± 0.009
	Miskolc/2, Mt. Zemplén	0.213 ± 0.010
	Miskolc/2, Mt. Zemplén	0.148 ± 0.032
	Mt. Pilis	0.090 ± 0.002
Lycoperdon (Calvatia)excipuliformis (Scop.:Pers.) Perdeck	Mt. Bakony/2	0.171 ± 0.010
	Normafa Mt. Budai	<d.l.
	Mt. Karancs	<d.l.
Lycoperdon perlatum Pers.: Pers.	Miskolc/1, Mt. Zemplén	<d.l.
	Miskolc/1, Mt. Zemplén	<d.l.
	Miskolc/1, Mt. Zemplén	0.160 ± 0.011
	Miskolc/3, Mt. Zemplén	<d.l.
	Mt. Pilis	<d.l.
	Miskolc/3, Mt. Zemplén	0.110 ± 0.008
	Tatabánya/1, Mt. Vértes	0.141 ± 0.097
	Mt. Mátra	0.093 ± 0.003

Table 1 (*continued*)

Mushroom species	Site of gathering	Li content (ppm of D.M. ± SD)
	Herend, Mt. Bakony	0.110 ± 0.028
	Mt. Bakony	0.089 ± 0.006
Macrolepiota procera (Scop.:Fr.) Sing.	Miskolc/1, Mt. Zemplén	<d.l.
	Wood Kamara, Mt. Budai	0.136 ± 0.069
	Miskolc/2, Mt. Zemplén	0.217 ± 0.007
	Wood Halmi (Budapest)	<d.l.
	Wood Kamara Mt. Budai	0.126 ± 0.006
	Mt. Bakony/2	0.250 ± 0.082
	Mt. Pilis	<d.l.
	Normafa, Mt. Budai	<d.l.
	Tatabánya/4, Mt. Vértes	0.069 ± 0.051
	Tatabánya/4, Mt. Vértes	0.154 ± 0.010
	SBK (Budapest)	0.097 ± 0.027
M. rhacodes (Vitt.) Sing.	Miskolc/2, Mt. Zemplén	<d.l.
	Mt. Pilis	<d.l.
	Mt. Pilis	<d.l.
	Mt. Pilis	<d.l.
	Dobogókö Mt. Pilis	<d.l.
	Miskolc/3, Mt. Zemplén	<d.l.
	Farkasgyepü, Mt. Bakony	<d.l.
	Farkasgyepü, Mt. Bakony	<d.l.
	Miskolc/2, Mt. Zemplén	0.094 ± 0.025
Pleurotus ostreatus (Jacq.:Fr.) Kummer	Szarvaskút, Mt. Bakony	<d.l.
	Gemenc	0.044 ± 0.007
	Csévharaszt	0.109 ± 0.002
	Csévharaszt	0.085 ± 0.002
	Mt. Karancs	0.208 ± 0.079
Pleurotus pulmonarius (Fr.) Quél.	Normafa, Mt. Budai	0.063 ± 0.003
	Miskolc/2, Mt. Zemplén	0.077 ± 0.002
Polyporus squamosus (Huds.) Fr.	SBK (Budapest)	0.074 ± 0.005
	Tatabánya/4, Mt. Vértes	0.172 ± 0.041
	Tatabánya/4, Mt. Vértes	0.326 ± 0.051
P. candolleana (Fr.) Mre.	Miskolc/1, Mt. Zemplén	0.314 ± 0.057
	Wood Kamara (Budapest)	0.194 ± 0.047
	Wood Kamara (Budapest)	0.325 ± 0.100
	SBK (Budapest)	0.092 ± 0.026
	Tatabánya/2, Mt. Vértes	0.290 ± 0.042
	Tatabánya/1, Mt. Vértes	1.150 ± 0.120
Suillus grevillei (Klotzsch) Sing.	Mt. Pilis	<d.l.
	Mt. Pilis	<d.l.
Tricholoma terreum (Schff.:Fr.) Kummer	SBK (Budapest)	0.257 ± 0.063
	Herend, Mt. Bakony	0.060 ± 0.007
	SBK (Budapest)	0.115 ± 0.057
	Mt. Karancs	0.052 ± 0.008
	Domonyvölgy	0.110 ± 0.027
Xerocomus armeniacus (Quél.) Quél.	Wood Halmi (Budapest)	0.119 ± 0.051
X. chrysentheron (Bull.) Quél.	Miskolc/2, Mt. Zemplén	0.103 ± 0.019
	Wood Halmi (Budapest)	<d.l.
	Mt. Börzsöny	0.166 ± 0.031
	Miskolc/1, Mt. Zemplén	0.184 ± 0.007
	Mt. Pilis	0.111 ± 0.027
	Farkasgyepü, Mt. Bakony	0.084 ± 0.033
	Mt. Pilis	0.122 ± 0.082
X. porosporus Imler	Miskolc/1, Mt. Zemplén	<d.1.
	Mt. Börzsöny	0.350 ± 0.055
	Mt. Bakony/2	0.311 ± 0.051
	Herend, Mt. Bakony	0.056 ± 0.003
X. subtomentosus (L.) Quél.	Mt. Börzsöny	0.044 ± 0.002

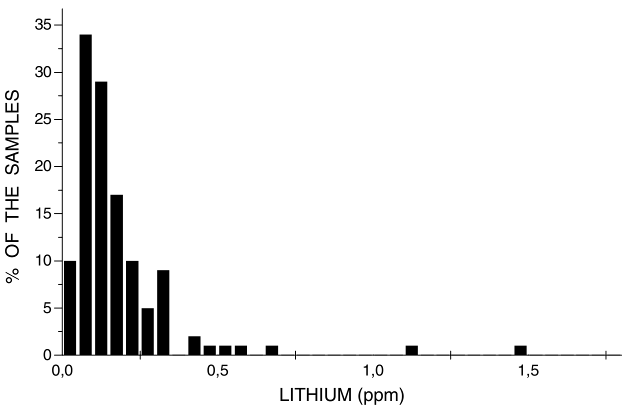

Fig. 1. Distribution of the Li content of samples.

Table 2
The average Li content of some mushroom taxa (in all taxa the number of samples >2)

Mushroom taxa	Number of samples	Li content (ppm of D.M.) (arithmetical mean ± SD)
Agaricus spp.	11	0.169 ± 0.075
A. strobiliformis	5	0.524 ± 0.550
Armillaria mellea	14	0.167 ± 0.155
C. cornucopioides	5	0.609 ± 0.702
Clitocybe odora	6	0.152 ± 0.103
Hericium coralloides	4	0.104 ± 0.038
Hirneola auricula-judae	3	0.105 ± 0.072
Lepista flaccida	4	0.143 ± 0.050
Lepista nebularis	7	0.132 ± 0.136
Lepista nuda	7	0.064 ± 0.039
Lycoperdon perlatum	6	0.117 ± 0.027
Macrolepiota procera	7	0.149 ± 0.064
Pleurotus ostreatus	4	0.111 ± 0.069
Polyporus squamosus	3	0.191 ± 0.127
P. candolleana	6	0.394 ± 0.381
Tricholoma terreum	5	0.118 ± 0.082
Xerocomus spp.	11	0.150 ± 0.098

are missing from this Table). The mean concentrations of three taxa *C. cornucopioides* (0.609), *A. strobiliformis* (0.524) and *P. candolleana* (0.394) are above 0.38 ppm. The lowest concentration is for *Lepista nuda* (0.064 ppm); all other taxa have average Li contents between 0.104 and 0.201 ppm.

Which factors regulate (or can regulate) the actual Li concentrations of the investigated, common, edible mushroom species? Do the habitats have a role in this regulation? We estimated the average Li content of all mushroom samples derived from the Mountain Vértes (number of these data: 15), and their mean was 0.38 ppm. The average of all other data is 0.167 ppm and, according to the statistical *t* probe, the mushrooms from Mt. Vértes have a significantly higher Li content ($p < 0.1$). The second realistic cause (possibility) is the role of nutrition. We tried to evaluate the taxa according to their nutrition types (saprotrophic, wood-destroying, mycorrhizal). The taxa (Table 2) *Agaricus*, *Clitocybe*, and three *Lepista*, *Lycoperdon*, *Macrolepiota*, *Psathyrella* are saprotrophic. The genera *Amanita*, *Tricholoma*, *Craterellus* and *Xerocomus* are mycorrhizal fungi, and the taxa *Pleurotus*, *Polyporus*, *Hericium* and *Hirneola* are wood-destroying ones. The average Li contents of the three groups are: 0.21 (±0.17) (saprotrophic group); 0.26 (±0.22) (mycorrhizal group) and 0.14 (±0.04) (wood-destroying group), but these differences are not statistically significant.

Are there any accumulating mushroom taxa? According to our data, there are three taxa with remarkably high average Li contents (*A. strobiliformis*, *C. cornucopioides* and *P. candolleana*), but the distributions of the data are relatively wide; therefore the accumulating character of these taxa is not documented (proved).

Can the mushrooms be an important Li source for human nutrition? 100 g of fresh mushrooms contain (based on our analytical data in Table 2) 1–6 μg lithium and the consumption of 100 g fresh mushroom/day/person indicates an unimportant part of the human daily Li requirement.

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