THE IMPORTANCE OF SODIUM IN THE FOOD CHAIN OF PLANTS, ANIMALS AND MAN

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SUMMARY

The geological origin of the soils influences the sodium concentration of the plant species significantly, despite fertilisation with sodium from manure, phosphate and nitrogen fertilisers. In Germany, the Holocene flood plains deliver, on average, the highest sodium amounts to the vegetation, whereas Syenite, Gneiss, Prophyry and Granite weathering soils produce a vegetation that is by a quarter poorer in sodium. In Hungary and Romania, the vegetation of the "szikes" is richest in sodium whereas the weathering soils of the Triassic time are by one third poorer in sodium. Rye, wheat and red clover of the fields and meadows in Germany and Hungary contain similar sodium concentrations. Trifolium repens, Lolium perene and especially Plantago lanceolata accumulate high sodium concentrations; Medicago falcato, Alchemilla vvulgaris and Avena sotivea store significantly lower sodium amounts. The winter grazings of game contain between 500 to 1600 mg Na/kg dry matter, so that the animals nedd sodium supplementation. Leaf-rich plants accumulate more sodium than stem-rich vegetables. Sodium is concentrated in leaves. Flowers, fruits, and most kinds of seeds and grain are poor in sodium. With increasing age of annual plant species, their sodium concentration decreases from April to the end of June by about one quarter to two thirds of the sodium concentration found in spring.

ÖSSZEFOGLALÁS

Anke, M. – Regius-Mőcsényi, Á.Ms. – Lösch, E.Ms. – Müller, R. – Gundel, J.: A NÁTRIUM JELENTŐSÉGE A NÖVÉNY, ÁLLAT, EMBER TÁPLÁLÉKLÁNCBAN

A termőhely geológiai származása szignifikánsan befolyásolja a növények nátriumkoncentrációját, annak ellenére, hogy a trágyával, a foszfor és nitrogén műtrágyával kerül nátrium a talajba. Németországban a kolocén öntéstalajon termelt növényállomány tartalmazza a legtöbb nátriumot, míg a synite, gneiss, porfir és gránit mállástalajokon jóval Na-szegényebb a növényzet. Magyarországon és Romániában, a szikes talajok vegetációja nátriumban gazdag, míg a triasz mállástalajokon egyharmaddal nátriumban szegényebb a növényállomány. Az árpa, a búza és a vöröshere, valamint a rozs, Na-tartalma Németországban és Magyarországon közel azonos. A fehérhere (*Trifolium repens*), angol perje (*Lolium perenne*) és különösen a lándzsás útifű (*Plantago lanceolata*) tárol sok nátriumot. A vadállomány téli legelőjének nátriumtartalma 500–1600 mg/kg a szárazanyagban, úgyhogy Na-kiegészítésre mindenképpen szükség van. A levélben gazdag növények több nátriumot akkumulálnak, mint a szálas, levélben szegényebb füvek, vagyis a nátrium a levélben koncentrálódik. Virágok, a gyümölcs és a legtöbb mag- és abrakféleség nátriumszegény. A különböző növényfajták nátriumtartalma a vegetáció előrehaladtával áprilistól júniusig csökken, a csökkenés mértéke a tavaszi kiindulási mennyiséghez képest 25–35%-ot érhet el.

INTRODUCTION

The French and English languages retain the importance since antiquity of salt — i.e. sodium chloride (NaCl) — in the word "salair" or "salary", resp., which is derived from the extra money (salarium) given to the officers of the Roman army to buy salt. Annual salt production worldwide is in excess of 150 million tons. The salt (NaCl) intake of humans increased with civilization. Early man was mainly carnivorous, and their diets therefore contained adequate amounts of sodium. However, as societies became agriculturally orientated and the consumption of vegetables and grain increased, the addition of salt to the diet became important for that reason. Control over the supply of salt has frequently been of political importance in the world's history.

Formerly, the salt tax in Germany amounted to 60 Euro per tonne. From the salt tax, salt intakes by men and women of more than 15 and 12 g/day, respectively, have been deduced, which was certainly not the case.

The aim of the experimental examination of sodium transfer to the food chain of man (and animals) has been to obtain information about the real intake of sodium depending on gender, habitat, time season, age and body weight, and in relation to several diseases. The rules of sodium transfer from the geological origin of the soils of plant habitats to the plants and from there to animals and man are very important and in same cases have been forgotten. The sodium intake of man is not only a medical but also a practical problem in human nutrition.

MATERIALS AND METHODS

After dry ashing of the cleaned samples at 450 °C, the sodium content was determined by flame photometry at 589 nm (Flapho 4, Carl Zeiss Jena). The precision of the analytical method was checked using the ARC/CL total diet reference material (HDP).

An analysis of the influence of the geological origin of the soil on the sodium content in the vegetation was carried out with four ubiquitously spread plant species: field red clover in buds, meadow red clover in blossom, rye in blossom, and wheat in shooting. The samples were collected all over Germany with the help of phenological maps (*Anonymus,* 1953) and geological ordnance survey maps (sale 1:25 000). Generally, the plants were gathered when rye was in blossom. The geological origin of the sites was checked with pickukp stones. The influence of the age of plants on the sodium content of the vegetation was investigated in lucerne, wheat, couch grass and field red clover on six different marked sites of the upper Muschelkalk in Thuringia between the end of April and June 11th. The various wild and cultivated plant species were collected in Thuringia from soils of the Trias formation (Bunter, Muschelkalk, Keuper).

The distribution of sodium in plants was measured in field red clover and its flowers, leaves, leaf stalks and stems. *Table 1.* informs about the kind and number of the samples analysed.

Table 1.

Kinds of samples, table numbers, and number of samples

Kind of samples(1)	Table(2)	Number of samples(3)
Influence of geological origin, Germany(4)	3	5345
Influence of geological origin, Hungary(5)	4	423
Indicator plants, Germany and Hungary(6)	5	5768
Influence of plant age on the sodium contents of several species(7)	6	4x6x10
Sodium content of several parts of red clover(8)	7	4x6
Sodium content of several plants(9)	8	29043
Sodium content of legumes herbs and grasses(10)	9	24
Sodium content of wild grazings of game(11)	10, 11	192

1. táblázat: A minták származása, táblázatok sorszáma és a vizsgált minták száma
minták származása(1), táblázat(2), mintaszám(3), geológiai származás hatása, Németország(4), geológiai származás hatása, Magyarország(5), jelzőnövények, Németország és Magyarország(6), a fejlődési állapot hatása a növények Na-tartalmára(7), a vöröshere különböző részeinek Na-tartalma(8), különböző növények Na-tartalma(9), hüvelyesek, gyógynövények és fűfélék Na-tartalma(10), Na-tartalom a vadon élő állatok legelőjében(11)

RESULTS

Influence of the geological origin of the habitat

Magmatic rocks contain, on average, 28 g Na/kg, whereas sedimentary rocks accumulate lower sodium concentrations. These rocks lose their soluble sodium during weathering. In a process that continues today, sodium has been transported to the sea by running water. In fact, NaCl accounts for 78% of the salts dissolved in sea water. The sodium concentration of soils is determined by the geological origin of the rocks. All minerals of the feldspar group (sodium feldspar, potassium feldspar, calcium felspar, potassium mica and hornblende) are rich in sodium. The same applies to the clay minerals montmorillanite and illite (*Kabata-Pendias and Pendias,* 2001). With the exception of saline soils (solonek, solontschac), the amount of exchangeable sodium in soils is very low. The soils in the humid and semihumid areas of the world cannot deliver sufficient sodium to the vegetation to satisfy the sodium requirements of animals (and man).

It is assumed that the sodium content of plants varies considerably reflecting different factors such as ecosystems and genotypes. Fertilisation of the soils with manure is one of them, which is superimposed on, and in some cases conceals, the influence of the geological origin of the soil. The correlation coefficient of the sodium content in the indicator plants (*Table 2.*) is low varying between r 0.85 (lucerne:field red clover) and 0.03. The correlation coefficients for zinc (0.87 to 0.61), nickel (0.83), iodine (0.83) and molybdenum (0.63) are higher and more significant (*Anke,* 2004a).

Table 2.

Correlation coefficients of the sodium contents of the indicator plants grown on soils of the same geological origin

Plants species(1)	n	P	y	r
Lucerne: Field red clover(2)	24	<0.001	–0.046+1.81x	0.85
Wheat: Field red clover(3)	16	>0.05	—	0.49
Rye: Field red clover(4)	19	>0.05	—	0.03
Rye: Wheat(5)	11	>0.05	—	0.28

2. táblázat: Azonos geológiai származású talajon termesztett indikátornövények Na-tartalmának korrelációs együtthatói
növényfaj(1), lucerna: vöröshere(2), búza: vörös here(3), rozs: vörös here(4), rozs: búza(5)

Irrespective of this existing influence, the geological origin varies the sodium content of the vegetation. The Holocene flood plains produce a significantly higher sodium concentration in the vegetation than Bunter, Muschelkalk and Keuper weathering of the Trias time or loess, Pleistocene sands, boulder clay and Syenite, Gneiss, Porpyry and Gneiss weathering soils, which deliver lowest sodium amount to the food chain (*Table 3*).

Table 3.

The influence of the geological origin of the site on the relative sodium content of the vegetation in Germany (n=5345)

Geological origin of the habitat(1)	n	Relative sodium content, %(2)
Holocene flood plains(3)	368	100
Bog, peat habitats(4)	368	87
Bunter weathering soils(5)	320	86
Muschelkalk weathering soils(6)	215	86
Rotliegende weathering soils(7)	219	82
Loess(8)	771	82
Plestocene sands(9)	801	80
Keuper weathering soils(10)	196	80
Slate weathering soils (Silurian, Culm, Devonian(11)	436	79
Boulder clay(12)	943	79
Phyllite weathering soils(13)	261	79
Syenite weathering soils(14)	161	76
Gneiss weathering soils(15)	279	74
Porphyry weathering soils(16)	123	74
Granite weathering soils(17)	325	71

3. táblázat: A talajok geológiai származásának hatása a növények relatív Na-tartalmára Németországban
geológiai származás(1), relatív érték, %(2), holocén öntéstalaj(3), láp, tőzeg(4), bunter mállástalaj(5), meszes mállástalaj(6), vörös mállástalaj(7), lösz(8), plestocén homoktalaj(9), keuper mállástalaj(10), pala mállástalaj(11), meszes agyagtalaj(12), Fillit málástalaj(13), Syenit mállástalaj(14), Gneiss mállástalaj(15), Porphyry mállástalaj(16), gránit mállástalaj(17)

It is interesting that the Holocene flood plains deliver lowest potassium amounts to the vegetation (*Anke et al.*, 2006), whereas their sodium concentration is highest in the plants of the German soil formations. The geological origin of the soil varies the sodium content of the vegetation by only about 30%, compared to 50–80% in case of the trace and ultratrace elements aluminium, lithium, cacmium, copper, molybdenum (*Anke et al.*, 2006) and iodine (in this case together with the distance to the seaside). The geological origin varies the potassium content of the vegetation, similar to the sodium content, by only one third (*Anke et al.*, 2004ab).

In Hungary, the sodium-richest vegetation grows on the "Szikes" saline soils, while those poorest in sodium were found on the calcium-rich Pleistocene sands. The difference is significant (*Table 4*). Like in Germany, the Holocene flood plains deliver more sodium to the vegetation than the weathering soils of the Trias (Muschelkalk, Keuper), the loess, peat and bog regions. The differences are very small and mostly insignificant.

Table 4.

The influence of the geological origin of the site on the relative sodium content of the vegetation in Hungary (n=423)

Geological origin of the habitat(1)	Relative sodium content, %(2)
Szikes	100
Acid sands(3)	87
Holocene flood plains(4)	81
Andesite weathering soils(5)	79
Loess(6)	76
Weathering soils of the Trias(7)	70
Calcium-rich sands(8)	70
Peat, bog(9)	69

4. táblázat: A talajok geológiai származásának hatása a növények relatív Na-tartalmára Magyarországon
geológiai származás(1), relatív érték, %(2), savanyú homok(3), holocén öntéstalaj(4), andezit mállástalaj(5), lösz(6), triasz mállástalaj(7), meszes homoktalaj(8), láp, tőzeg talaj(9)

On average, the vegetation in Hungary and in the surrounding countries with the same geological and climatic conditions store a sodium concentration that is lower by 10 to 20% than the same plant species in Germany (*Table 5*).

Table 5.

Sodium contents of the indicator plants in Germany and Hungary (mg/kg DM)

Plant(1)	Germany(2)		Hungary(3)		P	%*
	n	x ±s	n	x ±s		
Rye(4)	461	391±250	72	380±180	>0.05	97
Field red clover(5)	3060	428±266	55	350±240	<0.05	82
Meadow red clover(6)	1241	521±378	20	290±90	<0.05	56
Wheat(7)	559	514±281	184	530±300	>0.05	103
Lucerne(8)	24	1100±400	92	840±460	<0.05	76

* Germany=100%, Hungary=x%

5. táblázat: Az indikátornövények Na-tartalma Németországban és Magyarországon (mg/kg sz.a.)
növény(1), Németország(2), Magyarország(3), rozs(4), vöröshere(5), réti vöröshere(6), búza(7), lucerna(8)

The differences were only significant in case of legumes without fertilization with sodium-rich manure and are without practical importance for the nutrition of wild or domestic animals and man (*Anke*, 2004b).

Influence of plant age

The sodium content of the annual plants decreases with increasing age from April to the end of June, independently of plant development (*Table 6*). As a rule, the highest decrease appears in gramineous species, for example in rye, wheat and the grasses of meadows and pastures, whereas the sodium content of legumes (Lucerne, red clover) diminishes continuously over a longer time in June. The sodium intake of young plants is very high. Later on, the plants' assimilates dilute their sodium concentration. Young plants supply animals and man with relatively sodium-rich food.

Table 6.

Influence of plant age on the sodium contents of several species (mg/kg DM) (4x6x10)

Species(1)	30.04.	12.05.	26.06.	11.06.	Lx%*
Lucerne(2)	347	347	365	283	76
Field red clover(3)	447	518	419	318	71
Meadow red clover(4)	510	464	418	325	64
Fescue grass(5)	951	742	664	596	63
Rye, green(6)	1044	624	788	531	51
Wheat(7)	1062	829	730	368	35

* 30.04 =100%, 11.06 =x%

6. táblázat: A fejlődési állapot hatása a növények Na-tartalmára (mg/kg sz.a.)
növény(1), lucerna(2), szántóföldi vöröshere(3), réti vöröshere(4), réti csenkesz(5), rozs, zöld(6), búza(7)

Differences between plant parts

Astonishingly, the flowers of field red clover contain the lowest sodium concentrations of the species (*Table 7*). Stems store almost the same low sodium amount. Leaf stalks accumulate more sodium than blossoms and stems. The highest levels of sodium were found in the leaves of the red clover. The leaf-stem ratio of the plant species is, beside their genetic possibilities for sodium uptake, important for the sodium concentration of the whole plant.

Table 7

Sodium contents of several part of field red clover (mg/kg DM and in percent of leaves content) (n=4x6)

	Blossoms(1)	Stems(2)	Leaf stalks(3)	Leaves(4)
$\bar{x} \pm s$	428±108	447±117	759±201	1322±412
%	32	34	57	100

7. táblázat: Különböző növényrészek Na-tartalma szántóföldi vörösherében (mg/kg sz.a.), illetve a levelek Na-tartalmának százalékában)
virágzat(1), szár(2), levélnyél(3), levélzet(4)

Grain, seeds and fruits are, like blossoms, mostly poor in sodium (*Table 8*). Pulses store a little bit more sodium than grains. Tubers, onions, carrots and kohlrabi can accumulate very low concentrations of sodium (for example potatoes) and very high amount of them (carrots, red radish). Herbs and leaf-rich vegetables scan deliver 500 to 8000 mg Na/kg dry matter to the food chain.

Table 8.

Sodium contents of several plants (mg/kg DM)

Grains(1)		Seeds(2)		Tubers, beets(3)		Leaves(4)	
Maize(5)	20	Broad beans(6)	40	Potatoes(7)	153	Chive(8)	510
Rye(9)	27	Rape(10)	54	Onions(11)	546	Parsley(12)	1605
Triticale(13)	28	Lentils(14)	78	Kohlrabi(15)	2767	Cabbage(16)	2101
Wheat(17)	42	Peas(18)	100	Carrots(19)	3895	Lettuce(20)	4184
Barley(21)	43	Soybean(22)	200	Red radish(23)	4600	Spinach(24)	8210

8. táblázat: Különböző növények Na-tartalma (mg/kg sz.a.)
gabonafélék(1), magvak(2), gumók(3), levélzet(4), kukorica(5), bab(6), burgonya(7), snidling(8), rozs(9), repce(10), hagyma(11), petrezselyem(12), tritikále(13) lencse(14), karalábé(15), káposzta(16), búza(17), borsó(18), sárgarépa(19), saláta(20), árpa(21), szójabab(22), retek(23) spenót(24)

As a rule, leaf-rich vegetables are rich in sodium, whereas seeds and fruits are poor in this macro element.

Differences between plant species

The sodium contents of the plant species vary extremely under the influence of the geological origin of the habitat, fertilization with sodium-rich manure, and plant age. The sodium contents of the pasture and meadow floras, which have similar conditions with regard to the influencing factors, fluctuates species-specifically between 300 mg/kg dry matter in legumes, herbs and grass, and 2600 mg Na/kg dry matter in ribwort plantain, which is extremely rich in this essential element for animals (*Table 9*).

Grazing cows and horses prefer ribwort plantains and select this plant species. The perennial rye grass also stores higher sodium amounts than other species of grass, which contain only 300 to 500 mg Na/kg dry matter.

Whith 300 to 600 mg Na/kg dry matter, all species of legumes contain only small amounts of sodium (*Anke et al.*, 2000). The winter grazing of wild ruminating animals is quite different to the feed of farm animals. Wavy hair grass, bilberry bushes, heather twigs of several trees and bark are the most important grazings of roe deer, red deer, fallow deer and mouflons in Germany and Europe. Varying with the geological origin of the habitat, the consumed parts of perennial plants in the wood deliver wild ruminants with 650 to 1650 mg Na/kg dry matter through wavy hair spruce and oak vary not so much (500 to 1000 mg Na/kg dry matter) (*Table 10.*), but and green rye of the field grazing provide sodium-rich food wild ruminants, delivering 2000 to 3000 mg Na/kg dry matter.

Table 9.

Sodium contents of legumes, herbs and grasses of meadows and pastures (g/kg DM)

Legumes(1)		Herbs(2)		Grass(3)	
Black medic (*Medicago lupulina*)(4)	0.6	Ribwort plantain (*Plantago lanceolata*)(5)	2.6	Perennial rye grass (*Lolium perenne*)(6)	1.2
White clover (*Trifolium repens*)(7)	0.6	Cow parsley (*Anthriscus silvestris*)(8)	0.7	Orchard grass (*Dactylis glomerata*)(9)	0.5
Red clover (*Trifolium pratense*)(10)	0.4	Common dandelion (*Taraxacum officinale*)(11)	0.4	Smooth meadow grass (*Poa pratensis*)(12)	0.4
Meadow pea (*Lathyrus pratensis*)(13)	0.4	Common yarrow (*Achilea millefolium*)(14)	0.4	Tall fescue (*Festuca pratensis*)(15)	0.4
Vicia cracca(16)	0.4	Caraway (*Carum carvi*)(17)	0.4	Red fescue (*Festuca rubra*)(18)	0.3
Bush vetch (*Vicia sepium*)(19)	0.3	Lady's mantle (*Alchemilla vulgaris*)(20)	0.3	Timothy grass (*Phleum pratense*)(21)	0.3
Sickle medic (*Medicago falcata*)(22)	0.3	Jack-go-to bed at noon (*Tragopogon pratensis*)(23)	0.3	Oat grass (*Avena sativa*)(24)	0.3

9. táblázat: Hüvelyesek, gyógynövények és fűfélék nátriumtartalma (g/kg sz.a.)
hüvelyesek(1), gyógynövények(2), fűfélék(3), komlós lucerna(4), lándzsás útifű(5), angol perje(6), fehér here(7), erdei turbolya(8), csomós ebir(9), vöröshere(10), pitypang(11), réti perje(12), réti lednek(13), cickafark(14), réti csenkesz(15), kaszanyüg bükköny(16), kömény(17), vörös csenkesz(18), sövény bükköny(19), palástfű(20), réti komocsin(21), sarlós lucerna(22), réti bakszakáll(23), zab(24)

Table 10.

Sodium contents of several winter grazings of game on several geographical fields (mg/kg DM)

Place(1)	Wavy hair grass(2)	Bilberry bush(3)	Pine twigs(4)	Pine bark(5)	P	Relative number(6)
Ziegenrück, Thuringia	1645	1142	684	619	<0.001	100
Tharandt Forest, Saxony	1071	754	1031	501	<0.001	82
Siptenfelde, Harz Mts.	738	1064	852	675	<0.001	81
Eibenstock, Ore Mts.	920	733	785	657	<0.05	76
Glauchau, Saxony	678	674	809	666	>0.05	69
Nedlitz, Flaeming hills	860	682	624	567	<0.05	67
Hohenbucko, Lower Lusatia	669	599	556	475	<0.05	56
All places(7)	879	797	746	599	—	—

10. táblázat: Különböző téli vadlegelők füvének Na-tartalma földrajzi területek szerint (mg/kg sz.a.)
hely(1), erdei sédbúza(2), áfonyalomb(3), erdei fenyőhajtás(4), erdei fenyőkéreg(5), relatív érték(6), összes mintaszám(7)

Like annual plants, oak nuts and beech nuts are extremely poor in sodium (*Table 11.*) (160 to 240 mg Na/kg dry matter). The bark of aspen, birch, black alder, Serbian and German spruce deliver 200 to 500 mg Na/kg dry matter to the game. Heather and bilberry bushes contain 500 to 800 mg Na/kg dry matter, and the twigs of pine, raspberry, willow tree, rowan tree and oak deliver between 600 and 1300 mg Na/kg dry matter to the wild ruminants (*Anke et al*., 2003).

Generally, the sodium intake of animals and man from plants is relatively low and does not cover the normative sodium requirement. Both groups of living things need sodium supplementation with sodium-rich animal food and/or supplementation by sodium chloride.

Table 11.

Sodium contents of several winter grazings of game (mg/kg DM)

Species(1)	$\bar{x}$	Species(1)	$\bar{x}$
Oak nuts (*Quercus petraea*)(2)	160	Raspberry shoots (*Rubus idaeus*)(3)	640
Aspen bark (*Populus tremula*)(4)	188	Pine twigs (*Pinus silvestris*)(5)	746
Rowan tree bark (*Sorbus aucuparia*)(6)	224	Billberry bush (*Vaccinium mirtillus*)(7)	797
Beech nuts (*Fagus silvatica*)(8)	240	Spruce twigs (*Picea abies*)(9)	818
Birch bark (*Betula bendula*)(10)	264	Wavy hair grass flexuosa (*Deschampsia flexuosa*)(11)	879
Black alder bark (*Alnus glutionosa*)(12)	288	Willow tree twigs (*Salix caprea*)(13)	928
Calamagrostis villosa(14)	384	Rowan tree twigs (*Sorbus aucuparia*)(15)	968
Serbian spruce bark (*Picea omorica*)(16)	528	Beech twigs (*Fagus silvatica*)(17)	1076
Spruce bark (*Picea abies*)(18)	541	Oak twigs (*Quercus petraea*)(19)	1285
Heather (*Callunna vulgaris*)(20)	564	Rye, green (*Secale cereale*)(21)	2092
Pine twigs (*Pinus silvestris*)(22)	599	Rape, green (*Brassica nabus*)(23)	2811

11. táblázat: Különböző téli vadlegelők füvének Na-tartalma (mg/kg sz.a.)
fajták(1), tölgy makk(2), málnahajtás(3), rezgőnyár kéreg(4), fenyőhajtás(5), berkenye kéreg(6), áfonyabokor(7), bükk makk(8), lucfenyő hajtás(9), nyirkéreg(10), erdei séd búza(11), éger kéreg(12) fűzfa hajtás(13), nádtippan(14), berkenye hajtás(15), szerb fenyőkéreg(16), bükkhajtás(17), fenyőkéreg(18), tölgyhajtás(19), hangafű(20), rozs, zöld(21), fenyőhajtás(22), repce, zöld(23)

Only sodium-accumulating plant species deliver high sodium amounts to the food chain. Consequently, wild and domestic ruminants with sodium deficiency prefer these plant species as feed (*Bugdol*, 1961). Apart from these salt-collecting species, there are halophytes, which are adapted to sodium-rich soils near seaside regions and slat-rich springs (*Atropia distans, Atropia maritime*, and several species of *Chenopodium*). Spinach, sugar beet, chard and beetroot are members of this plant family (*Anke*, 2004b). Highest concentrations of sodium were also found in champignons or field mushrooms and mixed mushrooms, which contain 43,000 and 46,000 mg Na/kg dry matter, respectively (*Schäfer et al*., 2001).

CONCLUSIONS

The sodium contents of the plant species are varied by the geological origin of their habitat, their age, their species and their leaf-stem proportion. Seeds, fruits and flowers are extremely poor in sodium, whereas leaves accumulate most sodium. Only halophytes (several species of *Chenopodium*) and mushrooms deliver high amounts of sodium to the food chain of animals and man.

Animals and man with plant nutrition need sodium supplementation or animal food with higher sodium concentrations.

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Érkezett: 2006. augusztus

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