The determination of Magnesium, Calcium, Sodium and Potassium in assorted foods with special attention to the loss of electrolytes after various forms of food preparations

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Zusammenfassung

Bestimmung von Mg, Ca, Na und K in ausgewählten Lebensmitteln unter besonderer Berücksichtigung des Verlustes von diesen Elektrolyten nach verschiedenen Formen der Zubereitung.
Ziel der Studie war es, den Einfluß von verschiedenen Formen der Lebensmittelzubereitung auf den Gehalt von Mg, Ca, Na und K in ausgewählten Lebensmitteln zu untersuchen. Nicht unerhebliche Mengen dieser Elektrolyte gingen durch Zubereitungsarten wie z. B. Kochen von Frischwaren, von gefrorenen Waren und Dosenwaren verloren.
Die Komplemente dieser Elektrolyte wurden als Rückstand im Kochwasser gefunden.
Wegen der geringen Anzahl der Untersuchungen wurde keine Untersuchung auf Signifikanz der Ergebnisse vorgenommen.
Die Aussage der Ergebnisse ist dennoch eindeutig:
Bestehende Lebensmitteltabellen müssen auf ihren Aussagegehalt hinsichtlich der Elektrolytmenge einer kritischen Betrachtung unterzogen werden, wenn diese Lebensmitel einem Zubereitungsprozeß unterliegen.

Summary

The objective of this study was to investigate the influence of various ways of food processing on the contents of Mg, Ca, Na and K in assorted food.
Significant amounts of these cationic elements were lost after processing such as boiling fresh, frozen and canned food. These lost amounts were then redetected by determination of the supplement electrolytes in the cooked supernatant.
Although a statistical evaluation was not feasible due to low numbers of observations, the impact of "cooking" on the amounts of these cationic elements is obvious and indicates that established nutrition tables have to be re-considered when dealing with processed food.

Résumé

Determination de Mg, Ca, Na et K dans des aliments de choix en tenant compte du perte s'éffectué après la preparation des aliments.
C'était l'objectif de cette étude d'analyser l'influence des modes divers de préparation des aliments sur le teneur de Mg, Ca, Na et K.
Il en resulte qu'une quantité considerable de ces électrolytes se sont perdues pendant le processus de préparation, par example par la cuisson des produits frais, surgélés et en conserve. Le reste se trouvrait dans le bouillon.
L'analyse statistique n'etait pas éffectuée à cause de la nombre reduite des observations.
Mais évidemment il faut douter les tableaux trouvés dans la littérature établie quand il ne s'agit pas des produits frais mais préparés.

Introduction

Magnesium (Mg), Calcium (Ca), Sodium (Na) and Potassium (K) are important cationic elements in biological systems. These are essential for the structure of organisms, the activity of many enzyme systems and play important roles with regard to neurochemical and muscular excitability [1–3].
These elements are only obtained by extrageneous route, so that, diets and their deficiencies in humans are related to several diseases [4, 5].
Analysis of these cationic elements have been carried out in various food [6–8]. In the established international nutrition tables of electrolyte elements, the values are based on fresh food.
If some studies, for which the controlled intake of electrolyte elements is essential, are performed only by refering to the values of established nutrition tables, this procedure is then bound to lead to misleading results and hence to artefacts — a bad experience we have made in a physiological study of cardiac mechanism.

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We searched for the reasons and decided to re-evaluate the contents of electrolytes in food products after having submitted them to a processing procedure such as cooking.
In case of meat, usually speaking, it is frozen in the refrigerator at least for one week, and then cooked. In case of several standard vegetables, fresh, frozen or canned products can be obtained in commercial grocery stores, also these are used for cooking.

In this study, the differences between the amounts of these cationic elements in the various food, based on "cooking" and the different preparations of food are focused on. This substantial gap could be critical especially not only by falsifying the results of a study but also in diet plans for infants, pregnant women, elderly people and patients.

Experimentals

Materials

If not otherwise mentioned, substances used are analytical grade.

Triple distilled water is used in all experiments. Only quartz and plastic containers are used for all cooking and analytical procedures.

Tab. 1: Content of magnesium and calcium in fresh food compared to standard literature

	Magnesium [mg/100 mg]				**Calcium** [mg/100 mg]			
	Reference			this study	Reference			this study
	[6]	[7]	[8]		[6]	[7]	[8]	
tomatoes	15	11	20	15.0	13	13	14	19.1
carrots	18	21		13.1	42	37		38.3
French beans	28	26	25	27.7	47	56	57	44.0
small peas	33	30	33	27.0	22	26	24	32.5
red cabbage	17	18	18	12.5	45	35	35	59.5
apples	6	5	6.4	6.0	7	7	7.1	5.5
potatoes	24	27	25	22.1	9	14	9.5	10.8
peaches	9	10	9.2	14.0	6	9	7.8	6.8
bananas	39	31	36	27.3	8	8	8.7	7.8
oranges	13	10	14	16.2	41	41	42	38.8
garden lettuce	10	10	11	7.9	30	35	37	26.0
strawberries	13	12	15	15.1	23	21	26	19.7
mushrooms	13	13	13	11.5	7	9	8	10.0
rye rolls	35	47	35	27.5	29	22	29	27.6
muffins	30	24	30	20.5	27	24	27	54.8
toast (white)	24	24	24	25.7	58	58	58	96.8
milk (1.5 % fat)	12	13	12	14.9	120	133	118	120.8
eggs	12	13	12	15.2	56	54	56	57.4
full milk powder	90	112	110	92.1	920	909	920	770.9
milk chocolate	75			87.6	220			183.4
full cream yoghurt			12	10.3	120	150	120	109.3
butter	3	1	3	1.4	13	16	13	15.1
margarine	1	13	1	1.8	10	5	10	4.8
ice cream	14			19.8	140		140	110.6
Parmesan cheese	50	44.5	53.6			1140	1290	1348.6
Edam cheese (40 % fat)	30	-	31	32.1	770	765	793	868.7
Camembert cheese	19	18	15	14.8	430	382	510	334.6
cottage cheese (20 % fat)	10		11	11	95		85	103.5
sun flower oil				5.5		-		7.1
beef, mean fat	20	24	24.6	19.8	12	3	8.9	6.5
pork, mean fat	18	22	31.0	20.0	9	12	8.0	7.3
broiled chicken	11		12.0	16.6	11		12.0	7.7
spaghetti		-	67	19.1		22	27.0	27.0
rice, refined	20			22.6	11			10.7
rice, not refined				46.4				5.5
wheaten flour, type 405	25		-	24.4	16		15	19.7
corned beef	17		-	19.6	33		33	25.7
smoked ham	20	20	20	17.4	10	10	10	25.2
boiled ham	24		24	19.0	15		15	8.2
mortadella	-	-	-	-		12	42	24.6
German beer		-	7	8.9		4	4	3.6
German white wine		7-16	10	8.9		7	9	12.0

The study is performed on 41 items of food. The preparations of food are devided into 5 categories.

Fresh:
The food substances are obtained, the samples of the food are made immediately.

Fresh-cooked:
The food substances are cooked by the following procedures:
1. Vegetable types of food
   100 g of food substances are boiled in 500 ml of distilled water for 20 minutes.
2. Animal types of food
   100 g of food substances are boiled in 500 ml of distilled water for 30 minutes.

Frozen-cooked:
The food substances are frozen for two weeks, then they are defrosted, left in room temperature for 3 – 4 hours. The cooking procedures are the same as of the "fresh-cooked".

Canned:
When the can of food is opened, the sample is prepared immediately.

Canned-cooked:
After the can of food is opened, the food is cooked by the same procedures as of the "fresh-cooked".

Methods
Oxidation procedures were performed in food substances weighing 2 – 5 g (actual dry substances 100 – 500 mg) by hy-

Tab. 2: Content of sodium and potassium in fresh food compared to standard literature

	Sodium [mg/100 mg]				**Potassium** [mg/100 mg]			
	Reference			this study	Reference			this study
	[6]	[7]	[8]		[6]	[7]	[8]	
tomatoes	6.0	3	6.3	6.6	285	268	297	305.4
carrots	71	50		24.2	290	311		376.6
French beans	4	1.7	2.4	2.1	255	256	248	256.9
small peas	2	2	2	4.3	320	370	304	265.6
red cabbage	18	4	4	12.8	285	266	266	286.5
apples	3	1	3.0	.5	145	116	144	138.4
potatoes	6	3	3.2	2.2	500	410	443	494.2
peaches	2	0.5	1.3	2.2	235	160	205	226.7
bananas	1	1	1	2.6	370	420	393	324.4
oranges	2	0.3	1.4	1.3	190	170	177	168.3
garden lettuce	10	12	10	5.3	230	140	224	188.9
strawberries	2	1	2.5	2.2	155	145	147	299.4
mushrooms	9	5	8	10.4	420	520	422	416.7
rye rolls	550	220	552	602.5	170	100	169	257.2
muffins	170	100	169	257.2	110	115	110	144.4
toast (white)	385	385	385	647.6	130	132	132	178
milk (1.5 % fat)	48	75	47	38.8	155	139	155	218.8
eggs	140	135	144	122.4	140	138	147	177.2
full milk powder	370	410	371	364.8	1150	1330	1160	1016.7
milk chocolate	91			84.3	425			413.9
full cream yoghurt	48	62	48	40.7	155	190	157	196.3
butter	5	10	5.1	8.1	16	23	16	22.7
margarine	76	104	76	31.1	7	7	7	10.8
ice cream	61		110	101.0	175		99	194.4
Parmesan cheese		755	704	1358.6		153	131	129.1
Edam cheese (40 % fat)	900	737	900	994.1	135	76	105	104.7
Camembert cheese	1100	1150	900	707.3	120	109	96	147.7
cottage cheese (20% fat)	34		35	58.5	82		87	139.6
sun flower oil		-		7.9		-		7.0
beef, mean fat	77	51	89	44.8	345	340	329	442.2
pork, mean fat	66	74	84	52.6	290	348	321	386.8
broiled chicken	70		82.5	75.7	305		359	365.8
spaghetti		5	17	22.1		-	164	163.5
rice, refined	6			11.4	100			133.1
rice, not refined				4.1				230.7
wheaten flour, type 405	2.0		2.0	2.6	100		108	175.9
corned beef	830		833	1194.7	130		131	192.8
smoked ham	2500	2530	2530	2336.7	250	248	248	274.4
boiled ham	970		965	1212.3	270		270	338.9
mortadella		668	668	718.0		207	207	317.3
salami		1260	1260	1480.2		302	302	306.7
German beer			5.0	6.6			38	52.5
German white wine			2.0	5.3			82	126.9

Tab.: 3 Content of magnesium in assorted food after processing

	Magnesium [mg/100 g]							
	fresh	fresh cooked	fresh cooked supernat. in 500 ml water	frozen cooked	frozen cooked supernat. in 500 ml water	canned	canned cooked	canned cooked supernat. in 500 ml water
tomatoes	15.0	5.4	6.7			10.8	4.7	6.2
carrots	13.1	8.7	3.1	8.8	3.9	2.6	1.6	0.9
French beans	27.7	24.0	2.9	25.2	1.7	10.0	5.4	5.0
small peas	27.0	23.1	3.4	24.5	1.6	20.4	11.5	9.0
haricot beans						25.6	11.4	13.5
red cabbage	12.5	5.9	6.0			6.6	2.4	3.8
apples	6	3.6	2.0					
peeled potatoes						8.4	5.1	3.1
mushrooms	11.5	7.5	4.1			5.6	3.9	1.3
beef, mean fat	19.8	9.5	10.4	15.2	3.9			
pork, mean fat	20.0	10.6	9.1	17.5	2.4			
broiled chicken	16.6	11.5	4.0	14.8	0.6			
spaghetti	19.1	15.0	4.1					
rice, refined	22.6	12.0	10.6					
rice, not refined	46.4	34.5	10.9					
corned beef, German	19.6					13.9		
boiled ham	19.0	6.6	11.1					
powdered coffee	174.5	17.7	149.3					
powdered tea	152.6	17.7	127.1					
* sea pike	27.7			22.7	2.4			
* herring	20.5			4.3	13.4			
* fillet of plaice	26.8			16.7	8.9			

*= commercially frozen food was used

Tab.: 4 Content of calcium in assorted food after processing

	Calcium [mg/100 g]							
	fresh	fresh cooked	fresh cooked supernat. in 500 ml water	frozen cooked	frozen cooked supernat. in 500 ml water	canned	canned cooked	canned cooked supernat. in 500 ml water
tomatoes	19.1	11.2	4.7			12.6	6.8	2.5
carrots	38.3	31.7	6.2	28.8	6.8			
French beans	44.0	41.0	4.8	26.2	5.2	61.0	44.3	15.6
small peas	32.5	27.6	5.9	25.7	4.9	31.2	26.2	5.5
haricot beans						43.6	40.0	3.6
red cabbage	59.7	35.5	21.0			44.0	22.0	21.3
apples	5.5	3.1	2.2					
peeled potatoes						14.7	6.8	6.6
mushrooms	10.0	8.9	1.6			19.9	12.9	7.2
beef, mean fat	6.5	6.0	0.5	4.1	2.8			
pork, mean fat	7.3	6.7	0.5	6.5	1.0			
broiled chicken	7.7	3.9	3.4	5.5	2.4			
spaghetti	27.0	22.7	4.3					
rice, refined	10.7	4.2	6.5					
rice, not refined	5.5	3.4	2.1					
corned beef, German	2256					14.2		
boiled ham	8.2	6.0	2.4					
powdered coffee	91.3	14.2	78.0					
powdered tea	301.8	69.4	169.5					
* sea pike	33.9			18.6	7.1			
* herring	42.1			24.8	17.0			
* fillet of plaice	26.8			24.1	1.8			

*= commercially frozen food was used

Tab. 5: Content of sodium in assorted food after processing

	Sodium [mg/100 g]							
	fresh	fresh cooked	fresh cooked supernat. in 500 ml water	frozen cooked	frozen cooked supernat. in 500 ml water	canned	canned cooked	canned cooked supernat. in 500 ml water
tomatoes	6.6	6.3	0.2			29.1	7.7	16.6
carrots	71	50	4.9	9.0	10.3	302.6	66.1	201.2
French beans	2.1	1.6	0.4	1.1	0.9	248.5	69.0	147.6
small peas	4.3	2.0	2.1	1.9	3.0	311.9	50.1	239.6
haricot beans						225.7	66.1	161.5
red cabbage	12.8	5.6	5.5					
apples	5.1	2.3	2.3					
peeled potatoes						335.7	138.5	176.8
mushrooms	10.4	4.3	4.4			2002.4	93.0	1851.3
beef, mean fat	44.8	29.4	14.5	14.3	30.4			
pork, mean fat	52.6	17.1	33.2	26.4	24.5			
broiled chicken	75.7	24.6	50.9	65.5	7.4			
spaghetti	22.1	7.7	14.4					
rice, refined	11.4	5.6	5.8					
rice, not refined	4.7	2.1	2.6					
corned beef, German	1194.7					458.1		
boiled ham	1212.3	153.3	1046.7					
powdered coffee	13.2	3.6	9.5					
powdered tea	13.2	2.2	10.8					
* sea pike	104.9			61.7	38.5			
* herring	2622.0			493.7	1918.9			
* fillet of plaice	81.9			18.1	60.7			

* = commercially frozen food was used

Tab. 6: Content of postassium in assorted food after processing

	Potassium [mg/100 g]							
	fresh	fresh cooked	fresh cooked supernat. in 500 ml water	frozen cooked	frozen cooked supernat. in 500 ml water	canned	canned cooked	canned cooked supernat. in 500 ml water
tomatoes	305.4	190.1	113.8			360.0	73.9	259.1
carrots	376.7	227.8	123.8	130.0	178.9	56.6	11.3	40.1
French beans	256.9	232.5	17.3	196.7	44.8	150.6	42.2	99.6
small peas	256.6	172.5	81.0	184.6	60.4	180.0	31.7	139.4
haricot beans						277.8	68.9	199.2
red cabbage	286.5	89.1	181.2			179.0	35.5	128.1
apples	138.4	55.5	81.3					
peeled potatoes						180.0	68.3	102.9
mushrooms	416.7	221.1	189.6			106.7	28.0	67.6
beef, mean fat	442.2	276.4	160.3	106.1	294.6			
pork, mean fat	386.8	248.3	122.8	167.8	193.1			
broiled chicken	365.8	95.1	241.7	253.7	77.6			
spaghetti	163.5	37.6	125.9					
rice, refined	133.1	4.5	128.6					
rice, not refined	230.7	59.6	171.1					
corned beef, German	192.8					255.6		
boiled ham	338.9	43.7	279.2					
powdered coffee	2441.2	544.4	1599.8					
powdered tea	2038.9	138.9	1838.9					
* sea pike	406.7			208.9	191.7			
* herring	141.7			33.1	96.2			
* fillet of plaice	169.4			31.3	138.1			

* = commercially frozen food was used

drogenperoxide (30 %) and concentrated sulfuric acid. All organic contents of food materials (i.e. carbohydrate, protein, fats and so on) were completely oxidized by repeated addition of hydrogenperoxide. The final clear solution indicated the complete oxidation. Magnesium (Mg), Calcium (Ca), Sodium (Na) and Potassium (K) were determined by Atomic Absorption Spectrophotometry (Perkin Elmer 2380 Apparatus).

In case of Magnesium (Mg), the standard curve is shown in fig. 1. Triplicated standard samples ranging in concentrations from 0.00 to 10.00 mg/1g apple shows the linearity (the correlation

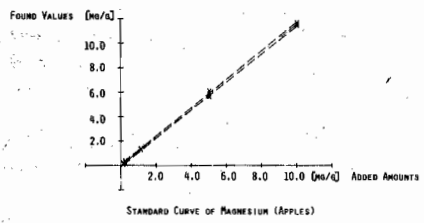

Fig. 1: Standard curve of Magnesium (Apples)

coefficient $r^2 = 0.9962$). The residual error was 0.00813. The maximum deviation was 0.17766. The sensitivity of Magnesium in this method was calculated to 1.17714.

The coefficients of variation of each cationic elements were calculated by total standard samples of other cationic elements (Mg: 5.7 %, Ca: 9.9 %, Na: 12 %, K: 3.9 %).

Result

We have investigated the amounts of Magnesium (Mg), Calcium (Ca), Sodium (Na) and Potassium (K) in the selected fresh foods which are usually prepared in representative German families. The level of these cationic elements are compared to those of other studies [6 – 8].

The result shown in tab. 1, 2 are in good accordance with other studies, suggesting that our analytical methods are valid. Deviations of the values of these cationic elements could be explained by different source of food materials and different laboratories.

However, as shown in tab. 3, 4, 5, 6, if the fresh food is cooked by the procedures which are already mentioned in "Methods and Materials", a remarkable change in the amounts of these cationic elements is observed. Also the defrosted food after a two-week freezing process and canned food show similar results to the fresh food after cooking. When these are cooked in boiling water, remarkable amounts of these cationic elements are lost. The lost amounts of these cationic elements are redetected by checking the cooked supernatants.

Discussion

The effect of "cooking" on the amounts of these cationic elements in the various types of food preparations cannot be denied although statistical evaluation was not carried out due to the low number of observations.

The extensive loss of these cationic elements during the cooking procedures appears very critical, and this — in turn, implies added importance to the actual intake of cationic elements by human subjects. Although our cooking procedures cannot represent all kinds of cooking methods, it would suggest the basic idea of the impact of cooking.

Therefore the actual intake of these cationic elements by human subjects are strongly related to the cooking procedures of food and hence affect the results of a study which is geared towards obtaining exact data on the systemic influence of electrolyte deficiency. More attention should be given to the actual content of these cationic elements when a very strict cationic element control becomes important.

It is suggested that established nutrition tables have to be reconsidered when dealing with processed foods.

We believe that these results, though not conclusive for each cationic element, are promising enough to initiate further study of cationic elements in various types of food preparations.

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