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Leaching of Heavy Metals (Cr, Fe, and Ni) from Stainless Steel Utensils in Food Simulants and Food Materials

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The majority of cooking and storing utensils are made up of different metals alone or in combination. Evidences are available that constituent metals could leach from utensils during cooking and storage of food (Brittin et al., 1986; Inoue et al., 1988; O'Neill et al., 1989; Reilly, 1985; Stoewsand et al., 1979). Intake of heavy metals is an important problem in human health. Although some of the metals are essential however, their excessive ingestion is undesirable (Masironi, 1973; Venugopal et al., 1978). The standards have been laid down by the regulatory agencies for the intake of metals from the diet and other sources as well (Buhler, 1973). However, food standard regulation and tables of food composition are of limited assistance to the toxicologist investigating dietary intake of metals by individual becuase during the cooking and the storage of food in metallic utensils significant quantities of toxic elements may leach out and increase the uptake of metal above the admissible daily intake (ADI) values even in well regulated and hygenic household. In India, food habits i.e. component of diet, type of utensils, methods of preparation and storage of food are conceively different from those of developed countries. Hence there is need to evaluate the leaching behaviour of constituent metals from utensils in a wide variety of food materials. Stainless steel is supposed to be noncorrosive and resistant to variety of foods. It is made up of Fe,Cr and Ni in general and in some cases Mn and Cu are also introduced to get better quality or cheaper utensils. The present study describes the leaching of Fe,Cr, Ni in food simulants and food materials which have been in contact of stainless steel surfaces during the cooking and storing. The information generated will be useful to consumers

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being acquainted that which type of food should be cooked/stored in the stainless steel utensils. These will be also helpful to regulatory agencies for laying down consumer protection standards.

MATERIALS AND METHODS

The stainless steel utensils tumblers, bowls of three different brands in anticipation that each brand will have different composition were purchased from local market. The utensils already in use for more than past five years were collected from houses. All the utensils were analysed on Atomic Absorption Spectrophotometer, Perkin Elmer-5000 for the Fe, Cr and Ni contents, the % of Ni, Cr and Fe in different utensils tested was as follows:

Metal composition (% content of Fe, Cr and Ni of stainless steel utensils used in experiments)

Utensils	Fe	Ni	Cr
Tumbler (Brand A)	71.03	2.30	12.67
Tumbler (Brand B)	67.86	3.42	9.74
Tumbler (Brand C)	68.23	2.31	12.03
Bowl new (Brand A)	66.25	2.90	13.56
Bowl new (Brand B)	68.92	3.85	13.73
Bowl new (Brand C)	69.25	2.81	11.01
Tumbler old (Brand A)	61.88	9.13	17.28
Tumbler old (Brand B)	58.33	9.30	17.88
Bowl old (Brand A)	66.95	9.31	20.80
Bowl old (Brand B)	67.25	9.02	19.95

All the utensils were washed thoroughly with detergent, hot tap water and finally rinsed with double glass distilled water. To study the migration of the metals in food simulants the utensils were boiled for one hour in distilled water (Redistilled water prepared by millipore apparatus), 5% acetic acid (m/v prepared in distilled water), 5% sodium carbonate (m/v prepared in distilled water) in a glass beaker. The quantity of food simulant was thrice to the volume of utensils. Simultaneously corresponding blanks were also prepared by boiling the food simulants in glass beakers in an identical way. The leaching in different food viz. milk, coffee, tea, pickle, fruit juice was studied. Milk, tea, coffee, were prepared in utensils following domestic procedures. The corresponding controls were prepared in glass containers. The mausami fruit juice samples after extraction were kept for three hours in test utensils. The curd or pickle 50 g was kept for two hours in the test utensils. The required quantity of all the food simulant and of food samples were digested in nitric acid and perchloric acid except the pickle which was dried in oven and ashed in muffle furnace. The digested samples were made to desired volume in 1% nitric acid to get the content of Ni, Cr and Fe within detection limit of Atomic Absorption Spectrophotometer. The sensitivity of Atomic Absorption Spectrophotometer for Fe, Cr and Ni in solutions were 0.12, 0.1 and 0.15 ug/ml respectively. The recovery percentage of these metals from the fortified samples under the present set of the experimental conditions ranged between 90-100%. The actual content of the metals migrated in different food/food simulants were obtained by substracting the values of metal contents of experimental with those of the control. pH of the food simulants and food materials were measured on a digital pH meter, model Scientronic SDPH-200.

RESULTS AND DISCUSSION

Table 1 shows the pH of various food simulants and food materials tested for leaching of Fe, Cr, Ni from

Table 1. pH of food simulants and food materials

Distilled water	7.00
5% Sodium carbonate	11.50
5% Acetic Acid	2.11
Tea	6.65
Coffee	6.50
Milk	6.88
Curd	4.30
Fruit juice	4.20
Lemon pickle	2.55

Table 2. Leaching of Fe, Cr and Ni (ug/ml) from new utensils in food simulant solvents following repeated extractions

Food simulant	Utensils	Fe			Cr			Ni		
		1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
5% Sodium carbonate (ug/ml)	Tumbler	0.21	0.273	0.181	0.120	0.040	0.005	0.31	0.051	0.02
	Bowl	0.88	0.500	0.450	0.013	0.021	0.015	0.07	0.012	0.005
5% Acetic acid (ug/ml)	Tumbler	3.42	0.331	0.306	0.030	0.032	0.008	0.17	0.092	0.007
	Bowl	0.24	0.011	0.100	0.033	0.075	0.055	0.09	0.012	0.004

1st, 2nd and 3rd represents number of extraction.
All values are mean of three samples.

stainless steel utensils. The amount of Fe, Cr and Ni leached out in food simulants is shown in Table 2. Fe, Cr and Ni were found to leach out in alkaline (5% sodium carbonate) and acidic (5% acetic acid) medium while none of these metals leached out in distilled water. The leaching of Fe, Cr and Ni was also observed in acidic and alkaline food simulants following the repeated extraction. The leaching of Fe, Cr and Ni was observed from the old as well as new utensils in acidic and alkaline food simulants (Table 2 and 3).

Table 3. Leaching of Fe, Cr and Ni from household used utensils in food simulant solvents (ug/ml)

Food simulant	Utensils	Fe	Cr	Ni
5% Sodium carbonate	Tumbler	0.04	0.06	0.045
	Bowl	0.08	0.012	0.015
5% Acetic acid	Tumbler	0.02	0.07	0.036
	Bowl	0.02	0.03	0.013

All values are mean of three samples.

The leaching of the Fe was observed in all food materials (Table 4). Ni was found to leached out in

Table 4. Leaching of Fe, Cr and Ni in food materials from utensils

Food Materials	Utensils	Fe	Cr	Ni
Curd (ug/gm)	New tumbler	0.188	0.038	0.100
	New bowl	0.255	0.420	0.164
	Old tumbler	0.630	0.029	0.219
	Old bowl	0.255	0.109	0.168
Fruit juice (ug/ml)	New tumbler	0.280	ND	0.09
	New bowl	1.76	ND	0.15
	Old tumbler	1.70	ND	0.07
	Old bowl	1.50	ND	0.06
Lemon pickle (ug/gm)	New tumbler	1.31	0.247	0.136
	New bowl	0.57	0.196	0.136
	Old tumbler	0.56	0.131	0.540
	Old bowl	1.68	0.273	0.410
Milk (ug/gm)	New tumbler	0.105	ND	ND
	New bowl	0.070	ND	ND
	Old tumbler	0.030	ND	ND
	Old bowl	0.035	ND	ND

Tea (ug/ml)	New tumbler	0.152	ND	ND
	New bowl	0.103	ND	ND
	Old tumbler	0.065	ND	ND
	Old bowl	0.050	ND	ND
Coffee (ug/ml)	New tumbler	0.161	ND	ND
	New bowl	0.085	ND	ND
	Old tumbler	0.052	ND	ND
	Old bowl	0.062	ND	ND

All values are mean of three samples.
ND = Not detected.

curd, pickle, fruit juice. No leaching of the Cr and Ni was observed in milk, tea and coffee. Fe leached out in all the food substances. As evident from the table that Ni and Cr appear to leach out in foods of comparatively high acidic while the Fe leached out even in slight acidic foods (tea, coffee and milk).

There are many factors which probably effect the release of Fe, Cr and Ni in food. These will include stainless steel surface area of contact, physical nature of surface area, pH of food products,its temperature, time and contact, agitation, chemical composition of steel alloy and presence of organic chelating constituents like citric acid, tartaric acid and oxalic acid (Joel Kuligowiski et al., 1992; Offenbacher et al., 1983; Ohkutso et al.,1983; Stoewsand et al., 1979) in food. The presence of organic chelating agent in curd, lemon pickle and fruit juice could be a reason for the observed increased leaching of metals in these food substances. Our observations support the views of others who reported the leaching of constituent metals from the utensils in food (Joel et al., 1992; Offenbacher et al., 1983; Stoewsand et al., 1979). Although, Fe and Cr are considered to be essential trace elements, excess exposure to Cr is known to cause dermatitis, bronchial asthama and ulcer and Ni is a toxic element and has been reported to exert variety of disorders even cancer (Krishnamurti et al., 1991). The uptake of the Fe, Cr and Ni is 15084 ug/day, 602.36 ug/day, 246.1 ug/day, respectively, from the different sources of food, water and air (Buhler, 1973). Thus the stainless steel utensils may put reasonable amount of Fe and Cr trace element in diet. The concentration of the Ni leached out in food products probably do not constitute hazard to consumers as the amount of Ni leached out through utensils is lower to that of recommended values (0.02 mg/day) of EPA (US, 1991; EHC, 1991) considered to be safe for human consumer protection. However, if it is needed that stainless steel utensils should not

contribute toxic metal Ni to diet, the cooking/storing of acidic/alkaline food in stainless steel cookwares may be avoided or discouraged. Attempts should be made to develop stainless steel utensils devoid of it or contain very low percentage of Ni. The result of the present study suggest that small quantities of Fe, Ni and Cr leach out in acidic and alkaline food during the cooking and storage.

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