Appendix 1

Estimated Risk of Zinc Deficiency by Country

This table presents country-specific information on the per capita amounts of selected nutrients and food components (including absorbable zinc content) of national food supplies. Information is included on the individual and combined indicators of risk of zinc deficiency: prevalence of stunting (height- or length-for-age < –2 SD) of children under 5 years of age, and the percent of the population at risk for inadequate zinc intake, based on data derived from national food supplies. See section 2.2 for details on the derivation of these data, the definition of risk categories, and the limitations in their interpretation.

Region/Country	Population (thousands)	Energy (kcal/d)	Zinc (mg/d)	Phytate (mg/d)	Phytate: zinc molar ratio	% of energy from animal-source foods	Zinc density (mg/ 1000 kcal)	Estimated zinc absorption (%)	Absorbable zinc (mg/d)	Absorbable zinc as % of IZiNCG EAR	Estimated % of population at risk of inadequate intake, IZiNCG	Prevalence of stunting	Risk category
Western Europe													
Austria	8,140	3,607	13.0	1,239	9.4	34.4	3.6	24.1	3.1	152.6	8.4		Low
Belgium-Luxembourg	10,563	3,618	11.3	985	8.6	32.0	3.1	26.3	3.0	144.6	10.9		
Denmark	5,270	3,354	13.3	1,420	10.6	37.5	4.0	23.2	3.1	149.8	9.2		Low
Finland	5,154	3,101	13.5	1,033	7.6	38.5	4.4	25.0	3.4	165.5	5.7		Low
France	58,683	3,551	14.8	1,086	7.3	37.9	4.2	24.2	3.6	176.2	4.2	5.8	Low
Germany	82,133	3,379	12.2	1,410	11.5	31.2	3.6	23.7	2.9	140.3	12.5		
Greece	10,600	3,604	12.7	1,364	10.7	22.6	3.5	23.7	3.0	144.8	10.8		
Iceland	276	3,138	16.2	1,205	7.4	41.3	5.2	23.1	3.7	187.7	3.1		Low
Ireland	3,681	3,527	14.3	1,264	8.8	31.4	4.1	23.5	3.4	168.6	5.2		Low
Israel	5,984	3,463	12.2	1,842	14.9	19.5	3.5	22.2	2.7	141.0	12.2		
Italy	57,369	3,546	12.5	1,107	8.8	26.1	3.5	25.0	3.1	150.0	9.1	2.7	Low
Malta	384	3,383	12.8	1,610	12.4	26.6	3.8	22.7	2.9	145.4	10.6		
Netherlands	15,678	3,254	13.6	1,304	9.5	34.5	4.2	23.6	3.2	157.0	7.3		Low
Norway	4,419	3,297	12.9	1,218	9.3	34.0	3.9	24.3	3.1	154.2	8.0		Low
Portugal	9,869	3,555	13.0	1,464	11.1	26.9	3.7	23.2	3.0	147.4	9.9		Low
Spain	39,628	3,305	12.5	1,117	8.9	27.1	3.8	24.9	3.1	150.4	9.0	3.1	Low
Sweden	8,875	3,089	10.9	918	8.4	33.7	3.5	26.9	2.9	143.3	11.3		
Switzerland	7,299	3,293	12.6	1,009	7.9	34.7	3.8	25.5	3.2	155.8	7.6		Low
Turkey	64,479	3,423	9.9	1,817	18.2	11.4	2.9	23.4	2.3	123.7	22.2	16.0	Medium
United Kingdom	58,649	3,255	12.1	1,049	8.6	31.6	3.7	25.5	3.1	151.9	8.6	1.3	Low
USA/Canada													
Canada	30,563	3,105	11.1	1,185	10.6	28.7	3.6	25.3	2.8	138.5	13.3	4.7	Low
USA	274,028	3,658	12.7	1,355	10.6	27.8	3.5	23.7	3.0	150.1	9.1	2.0	Low
Eastern Europe													
Albania	3,119	2,788	9.9	1,036	10.4	25.5	3.5	26.7	2.6	138.2	13.4	15.4	Medium
Armenia	3,536	1,981	6.4	826	12.8	16.3	3.2	30.9	2.0	100.4	49.4	12.3	Medium
Azerbaijan	7,669	2,222	6.9	1,020	14.7	15.6	3.1	29.0	2.0	101.6	47.5	22.2	High
Belarus	10,315	3,140	15.1	1,771	11.6	29.7	4.8	21.3	3.2	164.9	5.8		
Bosnia and Herzegovina	3,675	2,699	11.3	2,752	24.1	13.2	4.2	20.5	2.3	114.7	30.4		

continued

Region/Country	Population (thousands)	Energy (kcal/d)	Zinc (mg/d)	Phytate (mg/d)	Phytate: zinc molar ratio	% of energy from animal-source foods	Zinc density (mg/1000 kcal)	Estimated fractional absorption	Absorbable zinc (mg/d)	Absorbable zinc as % of IZiNCG EAR	Estimated % of population at risk of inadequate intake, IZiNCG	Prevalence of stunting	Risk category
Eastern Europe (cont'd)													
Bulgaria	8,336	2,787	9.9	1,056	10.6	24.4	3.5	26.6	2.6	128.7	18.6		Medium
Croatia	4,481	2,502	7.9	1,078	13.5	20.6	3.2	27.8	2.2	109.0	37.0	0.8	Medium
Czech Republic	10,282	3,157	10.6	967	9.0	27.1	3.4	26.7	2.8	140.8	12.3	1.9	Low
Estonia	1,429	2,898	13.8	1,827	13.1	30.9	4.8	21.6	3.0	152.7	8.4		
Georgia	5,059	2,289	8.1	1,782	21.8	14.3	3.5	24.6	2.0	101.7	47.3	11.7	Medium
Hungary	10,116	3,388	9.9	838	8.4	32.2	2.9	28.1	2.8	135.6	14.7	2.9	Low
Kazakhstan	16,319	3,009	11.6	1,170	10.0	21.9	3.8	25.1	2.9	148.3	9.6	15.8	Medium
Kyrgyzstan	4,643	2,547	9.5	823	8.6	21.6	3.7	28.5	2.7	137.4	13.8	24.8	Medium
Latvia	2,424	2,930	12.1	1,469	12.0	30.1	4.1	23.5	2.8	145.1	10.7		
Lithuania	3,694	2,983	13.0	1,568	12.0	26.2	4.3	22.8	3.0	150.9	8.9		
Macedonia, The Fmr Yug Rep	1,999	2,707	9.5	1,656	17.2	18.9	3.5	24.1	2.3	113.7	31.5		
Moldova, Republic of	4,378	2,840	10.2	2,262	22.0	16.3	3.6	22.0	2.2	114.4	30.8		
Poland	38,718	3,342	12.5	1,371	10.9	27.4	3.7	23.8	3.0	148.7	9.5		
Romania	22,474	3,216	11.1	1,663	14.8	21.7	3.5	23.3	2.6	129.2	18.3	7.8	Medium
Russian Federation	147,434	2,896	10.8	1,102	10.1	24.6	3.7	25.9	2.8	142.3	11.7	12.7	Medium
Slovakia	5,377	3,012	10.6	1,244	11.6	27.0	3.5	25.2	2.7	132.4	16.4		Medium
Slovenia	1,993	2,988	12.7	1,762	13.7	30.1	4.3	22.3	2.8	140.3	12.5		
Tajikistan	6,015	2,075	5.5	811	14.5	9.2	2.7	31.9	1.8	90.2	66.8	30.0	High
Turkmenistan	4,309	2,618	8.2	874	10.5	18.1	3.1	28.9	2.4	121.2	24.2		Medium
Ukraine	50,861	2,953	10.3	1,247	12.0	21.6	3.5	25.4	2.6	133.4	15.8		Medium
Uzbekistan	23,574	2,528	8.4	941	11.1	17.5	3.3	28.3	2.4	121.0	24.4	31.3	Medium
Yugoslavia, Fed Rep of	10,635	2,909	11.6	1,192	10.2	34.9	4.0	25.0	2.9	143.5	11.3	6.8	Low
Eastern Mediterranean													
Afghanistan	21,354	1,737	12.0	3,143	26.0	9.2	6.9	19.5	2.3	132.4	16.4	51.6	Medium
Algeria	30,081	2,952	17.2	4,240	24.4	10.0	5.8	16.5	2.8	160.2	6.6	18.3	Medium
Cyprus	771	3,207	17.7	2,946	16.5	28.2	5.5	18.1	3.2	162.4	6.2		
Egypt	65,978	3,279	17.4	4,830	27.5	7.0	5.3	15.9	2.8	151.8	8.6	20.6	Medium
Iran, Islamic Rep of	65,758	2,938	16.0	3,984	24.6	9.1	5.4	17.1	2.7	159.9	6.7	15.4	Medium
Iraq	21,800	2,196	11.1	2,919	26.2	4.2	5.0	20.3	2.2	128.8	18.5	27.5	Medium
Jordan	6,304	2,718	14.5	3,349	22.9	12.1	5.3	18.3	2.7	153.1	8.3	7.8	Low
Kuwait	1,811	2,987	17.1	2,828	16.3	23.6	5.7	18.4	3.2	176.4	4.2	3.2	Low

Lebanon	3,191	3,165	16.5	3,754	22.5	13.0	5.2	17.3	2.9	154.2	8.0	12.2	Medium
Libyan Arab Jamahiriya	5,339	3,271	17.2	3,874	22.4	11.7	5.2	17.0	2.9	168.2	5.2	15.1	Medium
Morocco	27,377	2,971	17.3	4,553	26.0	7.0	5.8	16.2	2.8	155.6	7.6	24.2	Medium
Saudi Arabia	20,181	2,787	13.8	2,786	20.0	14.7	4.9	19.5	2.7	149.0	9.4	41.0	Medium
Sudan	28,292	2,312	13.1	3,159	23.9	19.1	5.7	19.1	2.5	144.8	10.8	34.8	Medium
Syrian Arab Republic	15,333	2,958	15.3	3,594	23.3	13.0	5.2	17.8	2.7	161.1	6.5	20.8	Medium
Tunisia	9,335	3,270	18.6	4,525	24.1	9.2	5.7	16.0	3.0	159.5	6.8	8.3	Low
United Arab Emirates	2,353	3,122	16.7	2,394	14.2	25.0	5.3	19.3	3.2	156.4	7.5		
Yemen	16,887	2,039	11.7	3,157	26.7	6.4	5.7	19.6	2.3	138.9	13.1	51.7	Medium
China													
China	1,262,817	2,918	12.4	2,056	16.4	16.5	4.3	21.5	2.7	136.7	14.1	15.6	Medium
Western Pacific													
Australia	18,520	3,145	13.3	928	6.9	32.9	4.2	25.7	3.4	169.1	5.1	0.0	Low
Fiji Islands	796	2,773	10.1	1,369	13.4	20.2	3.6	24.9	2.5	134.6	15.2	2.7	Medium
French Polynesia	227	2,826	12.2	1,344	10.9	28.6	4.3	24.0	2.9	157.3	7.3		
Japan	126,281	2,793	11.0	1,754	15.8	21.2	3.9	23.0	2.5	122.0	23.5	5.6	Medium
Kiribati	81	2,826	9.1	1,519	16.5	12.3	3.2	24.9	2.3	111.7	33.7	28.3	High
Korea, Dem People's Rep	23,348	2,204	9.8	2,834	28.8	5.9	4.4	21.0	2.1	107.6	38.8	59.5	High
Korea, Republic of	46,109	3,031	11.9	2,157	18.0	13.8	3.9	21.5	2.6	127.6	19.4	18.3	Medium
Mongolia	2,579	1,930	12.7	453	3.5	45.3	6.6	30.6	3.9	216.7	1.6	24.6	Medium
New Caledonia	206	2,746	10.7	1,077	9.9	25.8	3.9	26.0	2.8	137.7	13.7		
New Zealand	3,796	3,248	14.1	1,096	7.7	34.7	4.3	24.4	3.4	172.9	4.6	2.9	Low
Solomon Islands	417	2,191	7.9	1,223	15.3	9.9	3.6	27.0	2.1	123.0	22.8	27.3	Medium
Vanuatu	182	2,573	11.2	1,576	14.0	16.5	4.3	23.6	2.6	129.7	18.0	19.1	Medium
Latin America													
Antigua and Barbuda	67	2,334	9.5	766	8.0	34.6	4.1	28.9	2.8	147.1	10.0	6.6	Low
Argentina	36,123	3,157	14.0	890	6.3	31.2	4.4	25.7	3.6	186.2	3.2	12.4	Medium
Bahamas	296	2,481	11.2	1,139	10.1	31.5	4.5	25.5	2.8	146.0	10.4		
Barbados	268	3,071	11.6	1,474	12.6	24.7	3.8	23.7	2.8	138.4	13.3	7.0	Low
Belize	230	2,829	9.5	1,612	16.8	23.4	3.4	24.3	2.3	123.7	22.2	39.5	Medium
Bermuda	64	3,034	14.7	1,450	9.8	27.7	4.8	22.6	3.3	177.2	4.1		
Bolivia	7,957	2,173	8.8	1,556	17.4	16.7	4.1	24.9	2.2	123.2	22.6	26.8	Medium
Brazil	165,851	2,890	10.5	1,931	18.2	19.2	3.6	22.7	2.4	126.2	20.3	10.5	Medium
Chile	14,824	2,783	10.5	1,203	11.4	21.5	3.8	25.5	2.7	140.3	12.5	1.9	Low
Colombia	40,803	2,541	9.0	1,613	17.7	16.7	3.5	24.6	2.2	117.6	27.4	15.0	Medium
Costa Rica	3,841	2,749	8.6	1,534	17.7	17.5	3.1	25.2	2.2	116.1	29.0	3.3	Medium

continued

Region/Country	Population (thou-sands)	Energy (kcal/d)	Zinc (mg/d)	Phytate (mg/d)	Phytate: zinc molar ratio	% of energy from animal-source foods	Zinc den-sity (mg/1000 kcal)	Estimated fractional absorption	Absorb-able zinc (mg/d)	Absorbable zinc as % of IZiNCG EAR	Estimated % of population at risk of inadequate intake, IZiNCG	Prevalence of stunting	Risk category
Latin America (cont'd)													
Cuba	11,116	2,395	7.1	1,132	15.7	14.0	3.0	28.1	2.0	100.5	49.3		
Dominica	71	2,964	11.8	1,204	10.1	23.0	4.0	24.8	2.9	156.7	7.4	6.1	Low
Dominican Republic	8,232	2,295	6.7	1,107	16.5	14.7	2.9	28.7	1.9	103.4	44.7	10.7	Medium
Ecuador	12,175	2,644	8.0	1,323	16.4	16.1	3.0	26.5	2.1	115.5	29.6	34.0	High
El Salvador	6,032	2,498	8.9	3,132	34.7	11.4	3.6	20.9	1.9	105.5	41.7	23.3	High
Grenada	93	2,709	9.9	1,292	12.9	23.3	3.7	25.4	2.5	134.5	15.2		Medium
Guatemala	10,801	2,274	8.0	2,950	36.3	8.6	3.5	21.8	1.8	101.1	48.3	46.4	High
Guyana	850	2,531	8.3	1,445	17.2	14.1	3.3	25.7	2.1	113.3	31.9	20.7	High
Haiti	7,952	1,901	6.8	1,870	27.3	6.1	3.6	25.3	1.7	96.6	55.6	31.9	High
Honduras	6,147	2,369	7.9	2,466	30.7	13.9	3.4	22.8	1.8	103.7	44.3	38.9	High
Jamaica	2,538	2,622	8.7	1,131	12.8	15.0	3.3	26.9	2.3	123.2	22.6	6.9	Medium
Mexico	95,831	3,146	12.2	3,413	27.7	16.9	3.9	19.0	2.3	126.4	20.2	17.7	Medium
Netherlands Antilles	213	2,507	10.8	1,106	10.2	32.1	4.3	25.8	2.8	148.8	9.5		
Nicaragua	4,807	2,185	7.5	2,696	35.4	8.1	3.4	22.6	1.7	100.2	49.7	24.9	High
Panama	2,767	2,385	8.1	1,407	17.1	22.3	3.4	26.0	2.1	112.4	33.0	18.2	Medium
Paraguay	5,222	2,519	11.0	1,926	17.3	23.7	4.4	22.5	2.5	138.4	13.4	13.9	Medium
Peru	24,797	2,391	7.6	1,547	20.2	13.9	3.2	25.8	2.0	105.6	41.6	25.8	High
Saint Kitts and Nevis	39	2,598	10.0	1,015	10.1	25.4	3.8	26.8	2.7	142.8	11.5		
Saint Lucia	150	2,797	11.1	1,020	9.1	27.0	4.0	26.2	2.9	155.0	7.8	10.8	Medium
Saint Vincent/ Grenadines	112	2,499	9.4	1,423	15.1	18.6	3.7	25.1	2.4	125.7	20.7	23.5	Medium
Suriname	414	2,623	8.1	1,316	16.1	13.6	3.1	26.4	2.1	114.9	30.2		
Trinidad and Tobago	1,283	2,642	7.5	1,250	16.5	15.8	2.8	27.2	2.0	109.2	36.9	4.8	Medium
Uruguay	3,289	2,803	14.7	1,150	7.7	34.6	5.2	23.9	3.5	177.9	4.0	9.5	Low
Venezuela	23,242	2,366	7.6	1,488	19.4	15.5	3.2	26.0	2.0	106.0	41.0	14.3	Medium
South Asia													
Bangladesh	124,774	2,061	7.4	2,064	27.7	3.1	3.6	24.2	1.8	99.7	50.4	54.8	High
India	982,223	2,419	10.9	2,906	26.3	7.5	4.5	20.4	2.2	119.3	25.9	42.6	High
Maldives	271	2,533	11.0	2,166	19.5	22.4	4.3	21.9	2.4	137.6	13.7	26.9	Medium
Nepal	22,847	2,317	11.1	3,146	28.2	6.8	4.8	19.9	2.2	124.9	21.3	53.1	Medium

Pakistan	148,166	2,423	13.0	2,974	22.7	17.1	5.3	19.4	2.5	144.0	11.1	36.6	Medium
Sri Lanka	18,455	2,278	8.6	2,221	25.4	6.1	3.8	23.0	2.0	103.4	44.7	20.4	High
Southeast Asia													
Brunei Darussalam	315	2,750	12.3	2,094	16.8	20.5	4.5	21.5	2.6	139.6	12.8		
Cambodia	10,716	1,945	7.1	1,722	24.0	8.0	3.7	25.5	1.8	104.2	43.6	53.3	High
Indonesia	206,338	2,866	10.0	2,859	28.4	4.4	3.5	20.9	2.1	111.2	34.4	42.2	High
Laos	5,163	2,168	7.9	2,031	25.6	6.6	3.6	24.0	1.9	110.1	35.7	47.3	High
Malaysia	21,410	2,895	10.3	1,534	14.7	20.2	3.6	24.1	2.5	136.7	14.1	26.6	Medium
Myanmar	44,497	2,764	9.3	2,612	27.9	3.9	3.4	21.7	2.0	111.0	34.6	41.6	High
Papua New Guinea	4,600	2,192	9.0	1,036	11.4	11.2	4.1	27.3	2.4	135.9	14.6	43.2	Medium
Philippines	72,944	2,300	7.8	1,344	17.1	14.0	3.4	26.5	2.1	113.3	31.9	32.7	High
Thailand	60,300	2,407	8.1	1,610	19.7	12.7	3.4	25.2	2.0	105.6	41.6	16.0	Medium
Viet Nam	77,562	2,461	9.2	2,008	21.6	9.5	3.7	23.2	2.1	117.3	27.8	38.7	High
Sub-Saharan Africa													
Angola	12,092	1,830	6.5	1,616	24.6	8.3	3.6	26.4	1.7	102.6	46.0	53.3	High
Benin	5,781	2,489	10.8	2,826	26.0	4.0	4.3	20.6	2.2	132.1	16.5	25.0	Medium
Botswana	1,570	2,270	10.2	2,244	21.8	18.7	4.5	22.1	2.3	131.1	17.1	28.9	Medium
Burkina Faso	11,305	2,333	13.4	4,149	30.7	4.6	5.7	17.7	2.4	138.6	13.3	36.8	Medium
Burundi	6,457	1,690	7.6	2,668	34.6	2.7	4.5	22.6	1.7	102.3	46.5	47.4	High
Cameroon	14,305	2,192	9.0	2,339	25.6	5.8	4.1	22.5	2.0	117.3	27.7	26.0	High
Cape Verde	408	3,186	10.8	2,548	23.3	14.6	3.4	21.1	2.3	132.0	16.6	16.2	Medium
Central African Republic	3,485	1,901	8.8	1,920	21.5	9.8	4.7	23.7	2.1	123.0	22.7	28.4	Medium
Chad	7,270	1,978	11.2	3,462	30.6	7.3	5.7	19.4	2.2	125.1	21.1	40.1	Medium
Comoros	658	1,815	6.0	1,348	22.4	5.9	3.3	28.1	1.7	100.1	49.9	33.8	High
Congo, Dem Republic of	49,139	1,770	5.7	1,421	24.7	2.9	3.2	28.0	1.6	95.5	57.5	45.2	High
Congo, Republic of	2,785	2,084	6.2	1,163	18.7	7.4	3.0	28.8	1.8	104.7	42.9	27.5	High
Côte d'Ivoire	14,292	2,523	8.8	1,914	21.5	4.0	3.5	23.7	2.1	125.5	20.8	24.4	Medium
Djibouti	623	2,046	6.2	955	15.4	11.7	3.0	30.1	1.9	108.8	37.3	25.7	High
Eritrea	3,577	1,654	8.2	2,223	26.8	5.8	5.0	23.2	1.9	112.9	32.4	38.4	High
Ethiopia	59,649	1,770	9.9	2,747	27.3	5.9	5.6	21.1	2.1	124.3	21.7	64.2	Medium
Gabon	1,167	2,511	9.0	1,345	14.7	14.5	3.6	25.6	2.3	128.7	18.6	22.0	Medium
Gambia	1,229	2,279	8.1	2,200	26.9	5.3	3.6	23.4	1.9	109.7	36.1	30.1	High
Ghana	19,162	2,493	9.0	1,828	20.1	4.3	3.6	23.9	2.1	125.2	21.0	25.9	Medium
Guinea	7,337	2,228	7.3	1,592	21.7	3.1	3.3	25.9	1.9	111.5	33.9	26.1	High
Guinea-Bissau	1,161	2,400	8.9	2,163	24.2	7.0	3.7	23.0	2.0	116.1	29.0		
Kenya	29,008	1,932	8.1	2,195	26.7	12.6	4.2	23.4	1.9	112.5	32.9	33.0	High

continued

Region/Country	Population (thousands)	Energy (kcal/d)	Zinc (mg/d)	Phytate (mg/d)	Phytate: zinc molar ratio	% of energy from animal-source foods	Zinc density (mg/1000 kcal)	Estimated fractional absorption	Absorbable zinc (mg/d)	Absorbable zinc as % of IZiNCG EAR	Estimated % of population at risk of inadequate intake, IZiNCG	Prevalence of stunting	Risk category
Sub-Saharan Africa (cont'd)													
Lesotho	2,062	2,282	10.2	3,500	33.8	5.0	4.5	19.7	2.0	114.0	31.2	44.0	High
Liberia	2,666	2,112	5.4	1,162	21.2	3.3	2.6	29.6	1.6	94.5	59.2	32.8	High
Madagascar	15,057	2,018	7.4	1,554	20.8	10.4	3.7	25.9	1.9	112.5	32.9	48.3	High
Malawi	10,346	2,030	8.9	3,370	37.3	2.7	4.4	20.6	1.8	111.4	34.2	48.3	High
Mali	10,694	2,314	12.6	3,284	25.7	9.1	5.5	19.1	2.4	144.0	11.1	48.6	Medium
Mauritania	2,529	2,654	10.0	1,793	17.7	17.1	3.8	23.4	2.3	137.0	14.0	44.0	Medium
Mauritius	1,141	2,935	9.1	1,535	16.6	14.0	3.1	24.8	2.3	115.6	29.5	9.7	Medium
Mozambique	18,880	1,797	6.2	1,861	29.6	2.8	3.5	25.8	1.6	93.7	60.5	35.9	High
Namibia	1,660	2,572	11.7	2,886	24.5	9.2	4.5	20.1	2.3	136.6	14.2	28.5	Medium
Niger	10,078	2,000	13.6	3,651	26.5	5.8	6.8	18.2	2.5	149.1	9.4	39.5	Medium
Nigeria	106,409	2,780	12.0	3,035	25.1	3.2	4.3	19.7	2.4	139.8	12.8	37.6	Medium
Rwanda	6,604	2,073	7.5	2,329	30.7	2.9	3.6	23.5	1.8	106.9	39.8	41.8	High
Sao Tome and Principe	141	2,246	7.0	1,489	21.0	4.4	3.1	26.5	1.9	109.3	36.7	25.9	High
Senegal	9,003	2,267	9.1	2,184	23.9	9.1	4.0	22.8	2.1	119.9	25.3	30.6	High
Seychelles	76	2,375	8.3	1,303	15.6	19.4	3.5	26.3	2.2	128.4	18.8	5.1	Medium
Sierra Leone	4,568	2,021	6.2	1,703	27.1	3.4	3.1	26.3	1.6	96.1	56.5	34.7	High
Somalia	9,237	1,586	7.9	1,092	13.6	40.3	5.0	27.7	2.2	131.2	17.1		Medium
South Africa	39,357	2,862	11.2	2,710	23.9	13.5	3.9	20.6	2.3	127.0	19.7	22.8	Medium
Swaziland	952	2,517	10.3	2,503	24.0	12.8	4.1	21.4	2.2	125.9	20.5	30.3	Medium
Tanzania, United Rep of	32,102	1,915	7.9	2,392	30.1	6.7	4.1	23.0	1.8	108.7	37.5	43.4	High
Togo	4,397	2,307	9.8	2,657	26.9	3.5	4.2	21.4	2.1	122.8	22.9	34.0	Medium
Uganda	20,554	2,279	9.4	2,661	28.2	6.6	4.1	21.6	2.0	121.7	23.8	38.3	Medium
Zambia	8,781	1,918	8.3	2,874	34.3	5.1	4.3	21.8	1.8	108.3	38.0	42.4	High
Zimbabwe	11,377	2,033	8.3	2,953	35.2	7.1	4.1	21.6	1.8	104.3	43.4	21.4	High

Appendix 2

Resources for Food Composition Data for Zinc and Phytate, and Phytate Content of Selected Foods

INFOODS (International Network of Food Data Systems) Secretariat
c/o FAO
ESNA
Viale delle Terme di Caracalla
00100 Rome
Italy
Telephone: +39 06 570 53728
FAX: +39 06 570 54593
http://www.fao.org/infoods/index_en.stm

International Minilist/WorldFood Dietary Assessment System, 2.0.
(University of California, Berkeley; Berkeley, CA)
The software program including food composition databases can be downloaded at no cost from the INFOODS website: http://www.fao.org/infoods/software_worldfood_en.stm

US Department of Agriculture (USDA). Nutrient database for standard reference. Release 14. Washington, DC: United States Department of Agriculture, 2001.
Nutrient Data Laboratory
Agricultural Research Service
Beltsville Human Nutrition Research Center
10300 Baltimore Avenue
Building 005, Room 107, BARC-West
Beltsville, MD 20705-2350
Telephone: 301-504-0630
FAX: 301-504-0632
http://www.nal.usda.gov:80/fnic/foodcomp/

Phytate content of foods (adapted from the International Minilist [WorldFood Dietary Assessment Program, 2.0; University of California, Berkeley, USA])

Food group	Description	Phytate content (mg/100 g)
Cereals and grains	Whole-grain cereals (barley, maize, millet, sorghum)	800
	Refined cereals (extracted flours, rolled oats)	197
	Bran, maize	263
	Bran, wheat	3,011
	Bread, whole-wheat	845
	Bread, white, wheat	30
	Bread, unleavened	200
	Rice, brown	262
	Rice, white	126
	Tortilla, maize	480
Seeds, nuts, and legumes	Beans, peas, lentils	358
	Seeds (lotus, pumpkin, sesame)	3,465
	Nuts (almonds, peanuts, walnuts)	1,760
	Soybean and products (tempeh, tofu)	374
Starchy roots and tubers	Cassava, potatoes, yams	54

continued

Phytate content of foods (adapted from the International Minilist [WorldFood Dietary Assessment Program, 2.0; University of California, Berkeley, USA]) *(continued)*

Food group	Description	Phytate content (mg/100 g)
Vegetables	Broccoli, cabbage, carrots, eggplant, lettuce, mushrooms, onions, squash, sweet corn, tomatoes, turnip	0
	Green beans, green peas	60
	Green leaves	42
	Pepper (capsicum), chiles	35
	Seaweed, kelp	97
Fruits	Berries, citrus, melons, stonefruit	0
	Apple	63
	Coconut	324
	Mango	20
Meats	Beef, pork, other game, poultry, organ meat	0
Fish and seafood	Fish, shellfish	0
Insects	Grubs, locusts	0
Dairy and eggs	Milk, cheese, yogurt	0
	Eggs	0

Appendix 3

Techniques for Measuring Zinc Absorption

The specific features of zinc metabolism—a high endogenous intestinal excretion, a rapid turnover of zinc in plasma, and a constant urinary excretion over a wide range of dietary intakes—limit the possible range of methods that can be used to measure zinc absorption. The conventional chemical balance technique, where the *apparent absorption* is calculated as the difference between dietary zinc intake and fecal zinc content, can at best give information about the overall balance of body zinc. However, long periods (> 30 days) of constant zinc intake are needed to achieve steady state conditions and gain reliable information [1]. To measure *true absorption* of zinc, endogenous sources of excreted zinc must be separated from unabsorbed dietary zinc, and for this determination, isotope techniques are necessary. Suitable radio- and stable-zinc isotopes are available and have been used extensively to study zinc absorption from single meals and, to a limited extent, from total diets. These techniques require advanced analytic equipment and skills and are mainly suited for research laboratories and studies of small groups of subjects. Further research in this area is required to better quantify the effects of physiologic and dietary conditions that affect the efficiency of zinc absorption, particularly from total diets. These techniques will also be useful in assessing the potential efficacy of different zinc compounds for use in food fortification as well as zinc supplements.

Whole-body counting

The use of the gamma-emitting radioisotope ^{65}Zn with a physical half-life of 243.6 days and determination of absorption from measurements of the whole-body retention of the isotope is regarded as the reference method for zinc absorption. Test meals or total diets are extrinsically labeled before intake and retention is measured in a whole-body counter at a time when unabsorbed isotope has been excreted from the body (minimum seven days) [2]. Endogenous excretion of absorbed isotope from the time of intake to the first retention measurement is corrected for by measuring the excretion of an intravenous dose in the same subject, or using the average rate of excretion determined in a group with similar characteristics. The whole-body counting technique has high precision and is simple for the participating subjects, but the required equipment is available in only a limited number of centers.

Fecal monitoring

Measurement of appearance of zinc isotopes (stable or radioactive) in fecal samples is at present the only alternative method that has been validated against the whole-body counting technique [3]. When ^{65}Zn is used, fecal samples can be measured directly in large-volume gamma-counters without further pretreatment. Intake of radio-opaque markers followed by x-ray of the fecal samples or of a non-absorbed marker (e.g., ^{51}Cr) can be used to relate excretion to period of intake and thereby limit the number of fecal samples, which also means less influence of endogenous zinc excretion. This approach could be a relatively cheap and simple field technique.

Three stable isotopes of zinc are of low enough natural abundance to be used in a similar way as tracers. These are ^{67}Zn, ^{68}Zn, and ^{70}Zn, with natural abundance rates of 4.1%, 18.8%, and 0.6%, respectively. Isotopic ratios can be determined using mass spectrometric techniques. Single or dual stable-isotope techniques with fecal monitoring have been applied to study zinc absorption. Endogenous excretion of zinc is corrected for by extrapolating a linear fit of rate of excretion after the unabsorbed, orally administered isotope has been excreted or by simultaneous intravenous injection of a second isotope. This correction is necessary as relatively long fecal collection periods (10–12 days) are required. Sample pretreatment prior to analysis is laborious and contributes to variation in results and therefore larger study groups are needed compared to the whole-body

Food and Nutrition Bulletin, vol. 25, no. 1 (supplement 2) © 2004, The United Nations University.

counting technique [3]. Due to the need for advanced analytic equipment, application of this method is limited to research laboratories.

Urinary monitoring

Total urinary excretion is relatively constant and not related to intake within the range of typical dietary consumption. Thus, this method cannot be used to evaluate dietary zinc absorption. However, urinary ^{65}Zn excretion during 48 hours after intake of a labeled meal does appear to be correlated to zinc absorption determined by the whole-body counting technique.* Urinary radioisotope content can be measured in a similar way as fecal samples in large-volume gamma counters and could also be a relatively inexpensive field technique. A dual-isotope technique with simultaneous oral and intravenous administration of different stable isotopes of zinc and determination of isotope ratios in urine during the following 48 hours has been used to study zinc absorption from single meals [4]. The technique is based on the non-proven assumption that absorbed zinc is cleared from plasma in the same way as intravenously injected zinc. Relatively large oral doses are necessary when a low absorption is expected, as could be the case for diets in many lower-income countries, to achieve a detectable level of enrichment. It has not been conclusively demonstrated that an intravenous infusion of zinc does not affect systemic zinc metabolism. Nonetheless, as only a spot urine sample is required, this method is simple for the participating subjects, and the number of samples to be analyzed is limited. Thus, if the validity of this approach can be documented, it could be a feasible method for field studies. Its application is, however, limited to single-meal studies and it would consequently be most valuable in populations with a monotonous food intake.

* M. Hansen, personal communication.

In vitro methods and models

For mechanistic studies of zinc absorption and evaluation of the effect of individual food components on zinc uptake, cell models (e.g., Caco-2 cells) may be useful. This method is less suited for studies of complex diets and it is unable to give quantitative information about absorption. Qualitative information about zinc availability may also be obtained from animal studies. A rat pup model has been demonstrated to be able to rank zinc absorption from infant formula in the same order as results from human studies using the whole-body counting technique [5], while adult rats were less suitable for this purpose.

An *in vitro* model simulating intestinal absorption conditions originally developed for iron [6] has also been applied to zinc [7]. After pepsin digestion at low pH, > 50% of zinc in cereal-based meals is released and dialyzable (MW cut off 6000–8000) while further trypsin digestion at pH 8 reduces the dialyzable fraction. A comparison with *in vivo* measurements of absorption showed a good correlation at pH 8 but not at the lower pH [7]. It is possible that with further development and validation this method could be used to give qualitative information about zinc availability for the screening of different possible zinc intervention strategies. Its ability to compare different foods or diets and to give information that can be used to judge the adequacy of a total diet is probably limited.

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Appendix 4
List of Contributors

Contributing authors

Zulfiqar Bhutta, MD, PhD, currently holds the Husein Lalji Dewraj Professorship of Paediatrics at the Aga Khan University and is also the director of neonatal services at the affiliated University Medical Center. Dr. Bhutta graduated from the Khyber Medical College (University of Peshawar) and received training in pediatrics at several leading hospitals of Pakistan and the United Kingdom, with subspecialty training in neonatal pediatrics and a PhD in nutrition from the Karolinska Institute, Stockholm. He is a fellow of the Royal College of Physicians of Edinburgh as well as the Royal College of Paediatrics and Child Health (UK). Dr. Bhutta is the president-elect of the Commonwealth Association of Paediatric Gastroenterology and Nutrition and a member of the Global Advisory Group on Health Research for the World Health Organization and the International Zinc Nutrition Consultative Group. He is also a member of the Child Health and Nutrition Board of the Global Forum for Health Research. Dr. Bhutta is the Chair of the Health Sciences projects committee of the Biotechnology Commission of Pakistan and an Advisor to the Pakistan Medical Research Council. He also serves on several international editorial boards of medical journals including the *British Medical Journal*, *Maternal and Child Nutrition*, *Transactions of Royal Society of Tropical Medical & Hygiene*, and *Current Pediatrics.* Dr. Bhutta has wide-ranging research interests including community-based perinatal care, interactions between nutrition and infection, micronutrient malnutrition and public health nutrition interventions. He has written two books, 25 book chapters, and more than 150 indexed publications and was recently awarded the Tamgha-i-Imtiaz by the President of Pakistan for contributions towards education and research.

Kenneth H. Brown, MD, is Professor of Nutrition and Director of the Program in International Nutrition at the University of California, Davis, where he has been a member of the faculty since 1989. Dr. Brown completed medical school at the University of Pennsylvania and specialty training in Pediatrics at the Boston Children's Hospital Medical Center. His research focuses on the nutritional problems of infants and young children in lower income countries, with special emphasis on the diagnosis and control of micronutrient deficiencies, infant and child feeding (breast feeding and complementary feeding), and interactions between nutrition and infection. Dr. Brown has participated in expert committees of the World Health Organization, the Pan American Health Organization, UNICEF, and the US National Academy of Science; and he has served as assistant editor or member of the editorial board of several journals, including the *American Journal of Clinical Nutrition*, the *European Journal of Clinical Nutrition*, and *the Journal of Health, Population, and Nutrition*. He is a former president of the Society of International Nutrition Research and Councilor of the American Society of Clinical Nutrition. He has helped to organize multiple international conferences and symposia on zinc and health and has served as the chairman of the IZiNCG Steering Committee since its inception. Dr. Brown is a recipient of the International Award for Modern Nutrition, the Kellogg International Nutrition Research Prize of the Society for International Nutrition Research, and the E.V. McCollum Award of the American Society for Clinical Nutrition.

Rosalind S. Gibson, PhD, is a Professor of Human Nutrition at the University of Otago, New Zealand, where she has held a personal chair since 1996. From 1979 to 1995, Dr. Gibson held academic appointments in the Division of Applied Human Nutrition at the University of Guelph, Ontario, Canada. She received a BSc degree (nutrition) from Queen Elizabeth College, University of London, a MS degree (public health nutrition) from the University of California, and a PhD degree (nutrition) from the University of London. She has served as a consultant for the World Health Organization and the International Atomic Energy Authority, and been a member of several national committees in Canada and New Zealand, including the New Zealand National Food Advisory Committee. Her research has focused on the etiology and functional health consequences of zinc deficiency and, to a lesser extent, iron deficiency, in high-risk population groups. Much of her recent research has involved the development of food-based strategies to enhance the content and bioavailability of micronutrients, especially zinc, in the diets of infants and children in Malawi, and most recently Thailand. She is the author of a standard reference text and laboratory manual on nutritional assessment, published by Oxford University Press in New York, and the author or co-author with her graduate students of more than 130 refereed scientific papers. In 2002, Dr. Gibson was elected to Fellowship of the Royal Society of New Zealand.

Christine Hotz, PhD, currently works as an investigator and professor at the Instituto Nacional de Salud Pública (Mexico). She received her bachelor and master of science degrees (nutrition) from the University of Manitoba (Canada). She conducted her master's research in the nutrition research laboratories of Health Canada, and worked briefly in the nutrition programs and promotions unit of Health Canada before starting a doctoral program at the University of Otago (New Zealand). During her doctoral research, she worked with communities in rural Malawi, designing and evaluating methods to improve complementary feeding practices, with an emphasis on improved zinc nutrition. Dr. Hotz served as executive officer of IZiNCG during its first 2 years after inception and continues to offer technical assistance to the group. Her research activities include the study of zinc and iron absorption from cereal-based diets using isotopic techniques, methods to improve iron and zinc absorption, methods to evaluate zinc status, and interactions between intake and status of zinc, iron, and copper. Dr. Hotz is a member of the American Society of Nutritional Sciences (U.S.) and the Society for International Nutrition Research (U.S.).

Janet C. King, PhD, RD, is a scientist at Children's Hospital Oakland Research Institute and Professor emerita of Internal Medicine and Nutrition at the University of California, Davis. A member of the Institute of Medicine, she is recognized internationally for her research in zinc metabolism and in maternal nutrition. Dr. King has published more than 200 papers and abstracts and has trained more than 50 graduate students and post-doctoral fellows. She pioneered the use of stable isotopes of iron, copper, and zinc to study mineral metabolism in humans. This technique opened up a new approach for studying dietary mineral requirements of pregnant and lactating women, infants, and children, and the technique is used widely around the world. Dr. King also conducts research on energy requirements during pregnancy. She showed that maternal fat stores at conception dictate changes in energy metabolism during gestation. This finding led to the development of different weight gain standards for underweight, normal weight, and overweight women by an Institute of Medicine (IOM) Committee chaired by Dr. King. She is currently studying the role of maternal diet on body weight and metabolic adjustments during pregnancy. Dr. King also has a strong interest in the translation of research findings into nutrition policies and practice. Therefore, she is working to establish a Center for the Prevention of Obesity in Children at the Oakland Children's Hospital and Research Center. She also was recently appointed to the 2005 Dietary Guidelines Advisory Committee, one of the major sources of nutrition policy in the United States. Dr. King holds a PhD in nutrition from the University of California, Berkeley, where she also has a faculty appointment.

Bo Lönnerdal, PhD, is a Professor of Nutrition and Internal Medicine and a member of the Program in International Nutrition at the University of California (UC), Davis. He received his PhD in biochemistry at the University of Uppsala, Sweden, and has been at UC, Davis since 1978. His research background includes studies of lactation, the composition of breastmilk and the transfer of nutrients from the lactating mother to the breast-fed infant, the biochemistry of breast milk components and the function of breast milk proteins. He has also studied the absorption of trace elements, such as zinc, iron, copper and manganese, in experimental animals and humans and how various dietary factors affect their absorption. Current research interests include mechanisms of trace element absorption and transport, which are studied in cells, experimental animals and humans, and micronutrient interactions, both antagonisms and synergisms. He is a member of the American Society for Nutritional Sciences (ASNS), American Society for Clinical Nutrition (ASCN), Society for International Nutrition Research (SINR), the European Society for Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN), and the International Society for Research on Human Milk and Lactation (ISRHML). He has been awarded the Borden Award, the International Prize in Modern Nutrition, the Macy-Gyorgy Award and an Honorary Doctorate in Medicine at the University of Uppsala, Sweden.

Daniel Lopez de Romaña Forga, MS, is a researcher at the Instituto de Investigación Nutricional in Lima and a professor at the public nutrition master's degree program at the National Agrarian University La Molina in Lima. He has a MS in nutrition from the University of California, Davis and is a doctoral student in the Program in International Nutrition at the same institution. He is a member of the American Society of Nutritional Sciences and the American Society of Clinical Nutrition. His research interests are the causes, treatment and prevention of micronutrient deficiencies in developing countries, with emphasis in iron and zinc.

Janet M. Peerson, MS, has been a senior statistician and statistical programmer for the Program in International Nutrition at the University of California (UC), Davis since 1989. She received her bachelor's and master's degrees in agricultural economics from UC Davis, and has completed doctoral-level coursework in statistics. Ms. Peerson has contributed to more than 40 published articles in the field of nutrition and has acted as a consultant to the UC Davis nutrition department and its associated programs. She is a member of the American Statistical Association.

Juan A. Rivera, PhD, is the founding Director of the Center for Research in Nutrition and Health at the National Institute of Public Health and Professor of Nutrition in the School of Public Health in Mexico. Dr. Rivera earned both his master's degree and doctorate degree in international nutrition from Cornell University, with a minor in epidemiology. Dr. Rivera's research interests include the epidemiology of nutritional stunting, the short- and long-term effects of supplementary feeding during early childhood in malnourished children, the effects of zinc and other micronutrient deficiencies on growth and health, the study of malnutrition in Mexico, and the design and evaluation of programs to improve nutrition status of children. A leader in nutrition research in Mexico and Latin America, he is a former director of Nutrition and Health at the Nutrition Institute of Central America and Panama (INCAP). More recently, he coordinated a national nutrition survey in Mexico, is a principal investigator of the Global Forum Coalition for the Latin America Region, and serves on several national and international committees. He has been a member of the PAHO Advisory Committee on Nutrition since 1995 and has recently been appointed to the board of the International Union of Nutritional Sciences, as member of the Global Alliance for Improved Nutrition (GAIN) Board, and to the National Academy of Medicine in Mexico. Dr. Rivera is also an adjunct professor at Cornell University and the Rollins School of Public Health at Emory University. He has published more than 100 scientific articles, book chapters, and books and is currently a member of the Latin American Nutrition Society, the American Society for Nutritional Sciences, and the Society for International Nutrition Research.

Marie T. Ruel, PhD, is a research fellow at the International Food Policy Research Institute (IFPRI) in Washington, DC. At IFPRI, Dr. Ruel is currently developing a new multi-country research program on "Diet Quality, Diet Changes and Health of the Poor" to analyze the impacts of food policies on diet quality and nutrition, with concerns ranging from micronutrient deficiencies to problems of over-nutrition. Between 1996 and 2002, she led a research program to analyze the food security and nutrition implications of rapid urbanization in developing countries. In the area of micronutrient deficiencies, Dr. Ruel's research focus has been on developing and evaluating effective food-based strategies, with a special emphasis on the monitoring and evaluation of such interventions. Since 2002, she has been involved in the preparation of a WHO Technical Document to Develop Guidelines on Food Fortification. She has also recently been appointed to the newly formed WHO International Micronutrient Advisory Group of Experts (IMAGE). Dr. Ruel earned a PhD in international nutrition from Cornell University. Before joining IFPRI in 1996, she was head of the Nutrition and Health Division of the Institute of Nutrition of Central America and Panama/Pan American Health Organization (INCAP/PAHO) in Guatemala, where she worked for 6 years. While at INCAP/PAHO, she conducted epidemiological research in maternal and child health and nutrition, in breastfeeding and complementary feeding, and in child growth and micronutrient deficiencies with a special emphasis on zinc and vitamin A deficiencies and the impact of supplementation on child morbidity and growth.

Brittmarie Sandström, PhD, was professor in the research department of human nutrition at the Royal Veterinary and Agricultural University in Copenhagen, Denmark until the time of her death (October 22, 2002). Dr. Sandström received a BSc in home economics from the University of Umeå and a BSc in nutrition from the Institute for Nutrition Research, University of Oslo, Norway. Dr. Sandström trained as a dietician at the Department of Clinical Nutrition, University of Gothenburg, Sweden, where she later received her PhD in nutrition. During her distinguished career, Dr. Sandström developed and validated several methodologies related to mineral absorption including a radioisotope method using whole-body counting and a rat-pup model for measuring zinc absorption, and a radioisotope method for measuring manganese absorption. She was a pioneer in the study of zinc absorption from infant milks and formulas, the effects of phytate on zinc absorption, and the mutual, competitive inhibition of iron and zinc on their absorption. She also contributed to the study of dietary factors affecting iron absorption. Her later research endeavors expanded to include preventive nutrition and contemporary public health issues, encompassing studies of fat quality on risk indicators of cardiovascular disease, the effect of copper in the prevention of cardiovascular disease, and the interactions of diet and osteoporosis. Dr. Sandström's expertise in mineral and trace element requirements had many practical applications, contributing to the establishment of zinc requirements for infants, and later to the recommended dietary intakes for zinc published by the WHO, the latter representing a landmark in our understanding of human dietary zinc requirements. Dr. Sandström participated in executive committees and councils of the WHO, the European Union, the International Life Science Institute (ILSI, Europe) and the Danish Nutrition Council. She had a close affiliation with the Swedish National Food Administration and was part of the Swedish Expert Group for Food and Physical Exercise and Health 1987 and was a key member of a Committee under the Nordic Council of Ministers, with the mandate to establish *Nordic Nutrition Recommendations* (*NNR*), which she chaired from 1992 to 1996. Her research inspired others and will remain of considerable significance in the field of human nutrition for many years to come.

Emorn Wasantwisut (Udomkesmalee), PhD, is the Director of the Institute of Nutrition, Mahidol University. Dr. Wasantwisut holds a BSc in biochemistry from Chulalongkorn University, Thailand (1977), a MSc in nutrition from Brigham Young University, Utah, USA (1980), and a PhD in nutritional biochemistry and metabolism from Massachusetts Institute of Technology, Massachusetts, USA (1985). Her postdoctoral training was at the vitamin and mineral nutrition laboratory, Beltsville Human Nutrition Research Center, US Department of Agriculture, Beltsville, Maryland, USA (1987). Currently she also is the chairwoman of the Thai RDA Sub-Committee on Trace Elements and a consultant to the Ministry of Public Health/Thailand vitamin A program. She is the chairwoman of the Asian Task Force for Capacity Strengthening in Nutrition (under the United Nations Standing Committee on Nutrition–Working Group on Capacity Development) and is on the Global Steering Committee of the Ellison Medical Foundation–International Nutrition Foundation Fellowship Program and the Steering Committee of the International Zinc Consultative Group (IZiNCG). Dr. Wasantwisut is a member of the ILSI/South East Asia Micronutrient Task Force, a vitamin A correspondent for the *Sight and Life Newsletter*, and curator for the *International Journal of Vitamin and Nutrition Research*. Her research interests include vitamin A assessment, nutrient bioavailability and metabolism as well as nutrient interactions, particularly of vitamin A and zinc, and iron and zinc, and nutrients and immune function.

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