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Cereal Quality III

Mineral status of British wheat

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SUMMARY

Four hundred samples of wheat grain were collected by the Home Grown Cereals Authority (HGCA) in 1992 from the major cereal growing areas in Britain. Concentrations of P, K, Ca, Mg, Fe, Zn, Cu and Mn were determined in wholemeal flour subsamples. The concentrations of all the elements were found to be normally distributed with 80% of the data lying in a narrow range. The minimum and maximum concentrations were 0.44-4.55 mg P g^{-1}; 2.27-6.70 mg K g^{-1}; 0.41-1.44 mg Mg g^{-1}; 0.17-0.90 mg Ca g^{-1}; 1.49-7.34 μg Cu g^{-1}; 7.48-52.38 μg Zn g^{-1}; 9.93-40.88 μg Mn g^{-1} and 12.07-73.62 μg Fe g^{-1}. Mean concentrations of the elements in the grain decreased in the order K > P > Mg > Ca >> Fe > Zn = Mn > Cu. There was a significant positive correlation between grain K and P ($r = 0.56$) and between grain Mg and P ($r = 0.68$). Similarly, a significant positive correlation existed between grain Zn and Mg ($r = 0.54$). Most elemental concentrations showed positive correlations, with the exception of Mn and Cu where there was a slight negative correlation ($r = -0.09$). Analysis of variance of the concentration data showed highly significant ($P < 0.001$) varietal differences. The bread-making varieties generally contained slightly larger concentrations of all elements, except K. Comparison of the 1992 grain elemental concentrations with an earlier 1982 survey showed small decreases in grain P and Cu over a 10 year period, and slight decreases in Zn and Fe. However, there were no differences in the concentrations of K, Ca, Mg and Mn in grain in the two surveys.

INTRODUCTION

The average yield of winter wheat in Britain has increased from 3 t ha^{-1} in 1953 to about 7.25 t ha^{-1} in 1991 (Anon., 1993). Increased growth may, however, lead to a decrease in elemental concentrations in the grain due to a dilution effect which results from growth rates which exceed the rate of nutrient uptake (Jarrell & Beverly, 1981). In severe cases, this may lead to nutrient deficiency in the crop which limits growth. For example, it has been demonstrated that the copper requirement of a crop increases when nitrogen fertiliser is applied (Mulder, 1950). Complete crop failure has been recorded after heavy nitrogen fertilisation of a copper deficient soil (Fleming & Delaney, 1961). By contrast, the addition of increasing amounts of nitrogen fertiliser in field experiments resulted in both increased yields and increased concentrations of elements in grain, with the exception of Mn (McGrath, 1985). These increases were attributed to an increase in the root mass of the plants which allowed greater uptake of the elements from the soil (McGrath, 1985).

Even if the decline in plant tissue concentrations of these elements does not limit growth, then their value as food for humans and animals may be reduced due to inadequate provision of sufficient minerals for normal dietary requirements. Food is frequently amended with iron to meet nutritional requirements. For example, cereals contribute about 40% of the daily intake of iron in UK diets with 10% of this being derived from fortification, largely by statutory additions to flour (Buss, 1983; McGrath, 1985). Processing of grain to flour can remove up to 50% of the iron, zinc and copper in the bran (Pedersen & Eggum, 1983), thus making fortification necessary. Furthermore, processing grain low in mineral content will exacerbate this problem and possibly lead to human health problems (Hambridge, 1981). McGrath (1985) recognised this potential problem and examined the effect of increasing yields on the concentrations of nutrients in the grain of winter wheats grown in Britain. These concentrations were found to vary considerably. For example, the concentrations of P, K, S, Ca and Mg varied twofold, the elements Fe, Zn, and Cu varied threefold, whilst Mn varied by a factor of five. Small varietal differences in grain composition of these elements were also detected.

Generally there is a lack of data on nutrient composition in grain. In this paper we present results for the elemental composition of winter wheat grain collected for the wheat quality assessments for 1992 done by the Home-Grown Cereals Authority (HGCA). Concentrations of elements in grain from the 1992 winter wheat survey are also compared with those of the 1982 survey carried out by McGrath (1985).

MATERIALS AND METHODS

Four hundred samples of wheat grain were collected by the HGCA in 1992 from the major cereal growing areas in Britain. The samples were milled by the Flour Milling and Baking Research Association (FMBRA) at Chorleywood. Wholemeal flour subsamples were dried at 80 °C for 12 h, before digesting with a mixture of perchloric-nitric acids (13% : 87% v/v) in a Carbolite heating block. Ramp rates, dwell temperatures and dwell duration of digestion were controlled through an Eurotherm 818 Controller/Programmer according to Zhao, McGrath and Crosland (1993). The concentrations of P, K, Ca, Mg, Fe, Zn, Cu, Mn and S in the digests were determined using an ARL34000 inductively-coupled plasma spectrometer. The S and N concentrations in the HGCA samples and their relationship with quality parameters are reported elsewhere in these proceedings by McGrath, Zhao, Crosland & Salmon (1993). The reliability of the analytical procedure was tested on NIST (National Institute of Standards and Technology, Gaitherburg, Maryland, USA. Anon., (1988) standard wheat flour samples. Variability of the measurements of each element was determined by analysis of nine replicate digests of the standard wheat flour sample. The agreement with the certified values was good (Table 1).

Data analyses

The distributions of the concentration data were checked for normality using Genstat (Anon., 1987). The data was also analysed for varietal differences using analysis of variance.

Table 1. *Means and coefficients of variation of elemental concentrations found in nine replicate digests of the Certified Wheat Flour Standard NBS 1567a (dry matter basis). Certified elemental concentrations are also included for comparison*

	mg g^{-1}				$\mu g\ g^{-1}$			
	P	K	Ca	Mg	Cu	Zn	Mn	Fe
Certified*	1.34 ±0.06	1.33 ±0.03	0.19 ±0.004	0.40 ±0.02	2.10 ±0.2	11.60 ±0.40	9.40 ±0.9	14.10 ±0.5
Mean	1.36	1.36	0.19	0.39	1.95	11.08	8.96	14.31
CV (%)	1.68	2.39	2.65	1.84	8.21	3.62	1.77	9.38

* ± 95% confidence limits

RESULTS AND DISCUSSION

The mean, median and concentration ranges of P, K, Ca, Mg, Cu, Zn, Mn and Fe are represented in Fig. 1. In each case schematic plots (Tukey, 1977) are used to representthe distribution of the elements in the grain. The box represents the 25-75% range, and the solid and dotted lines within it are the median and mean values respectively. The end of the bars represent the 10-90% range.

The concentrations of all the elements were found to be normally distributed. Eighty percent of the data were found to lie in a narrow range for P, K, Zn, Mn and Fe, and in even a smaller range for Ca, Mg and Cu (Fig. 1*a* and *b*). The minimum and maximum concentrations differed by factors of ten for P (0.44-4.55 mg g^{-1}); three for K (2.27-6.70 mg g^{-1}) and Mg (0.41-1.44 mg g^{-1}); five for Ca (0.17-0.90 mg g^{-1}) and Cu (1.49-7.34 $\mu g\ g^{-1}$); seven for Zn (7.48-52.38 $\mu g\ g^{-1}$); four for Mn (9.93-40.88 $\mu g\ g^{-1}$) and six for Fe (12.07-73.62 $\mu g\ g^{-1}$). The largest elemental concentrations in the whole wheat grain were those of K and P and the smallest was Cu. The mean elemental concentrations decreased in the order K > P > Mg > Ca >> Fe > Zn = Mn > Cu (Fig. 1*a* and *b*). Other workers have found a similar order of elemental concentrations in whole wheat grain (Lockhart & Nesheim, 1978; McGrath, 1985).

There was a significant positive correlation between grain K and P (r = 0.56), indicating a degree of constancy in the deposition of K and P in the grain (Table 2). A significant positive correlation was also found between grain Mg and P (r = 0.68). Similarly, a significant positive correlation existed between grain Zn and Mg (r = 0.54). Most elemental concentrations showed positive correlations, with the exception of Mn and Cu where there was a slight negative correlation (r = -0.09).

The analysis of variance of the concentration data showed highly significant ($P < 0.001$) varietal differences (Table 3). The bread-making varieties generally contained slightly larger concentrations of all elements, except K. The differences between all the varieties, although statistically significant because they are based on a large number of degrees of freedom, are not thought to be large enough to be agriculturally important (McGrath, 1985).

These differences may arise as result of natural variation in cereals due to genetic and environmental factors. For example, small kernels caused by environmental stress or genetic factors may contain larger concentrations of elements than larger kernels. This may explain the slight difference in elemental concentrations between the bread-making and other varieties. Varietal differences in mineral content may be best investigated in future by analysis of different varieties grown in the same locations. In this way, any genetic differences could be seen separately from the effects of soil and climate.

The mean grain P and Cu concentrations in the 1992 survey were smaller then those from the earlier 1982 survey carried out by McGrath (1985). Similarly, there were slight decreases in the mean concentrations of grain Zn and Fe in 1992 compared to 1982. However, there was no difference in the mean concentrations of K, Ca, Mg and Mn in grain between the 1992 and 1982 surveys. It is possible that these reductions in the grain P, Cu, Zn and Fe concentrations in the 1992 survey may be due to increased yield resulting in growth dilution. For example, grain yields increased from about 6 t ha^{-1} in 1983 (Spencer, 1983) to 7.25 t ha^{-1} in 1991 (Anon., 1993). McGrath *et al.* (1993) found no change in the concentrations of N in wheat grain during this period, possibly due to increased N fertiliser use.

Table 2. *Correlation coefficients between the elements*

	P	K	Ca	Mg	Cu	Zn	Mn	Fe
P	1.00	0.56	0.42	0.68	0.19	0.39	0.20	0.36
K	---	1.00	0.12	0.36	0.16	0.21	0.09	0.15
Ca	---	---	1.00	0.37	0.25	0.37	0.27	0.27
Mg	---	---	---	1.00	0.22	0.54	0.12	0.39
Cu	---	---	---	---	1.00	0.35	-0.09	0.21
Zn	---	---	---	---	----	1.00	0.28	0.47
Mn	---	---	---	---	---	---	1.00	0.15
Fe	---	---	---	---	---	---	---	1.00

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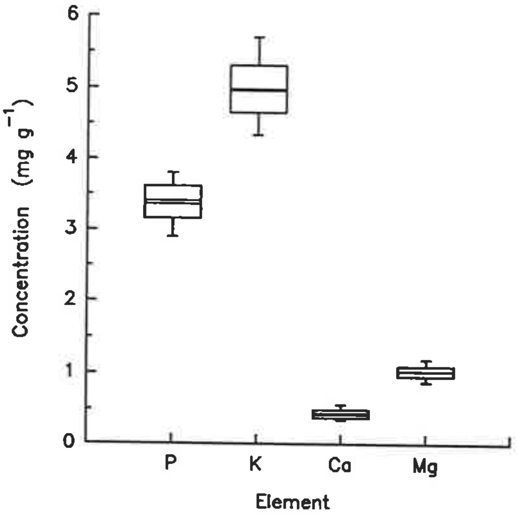
a)



b)

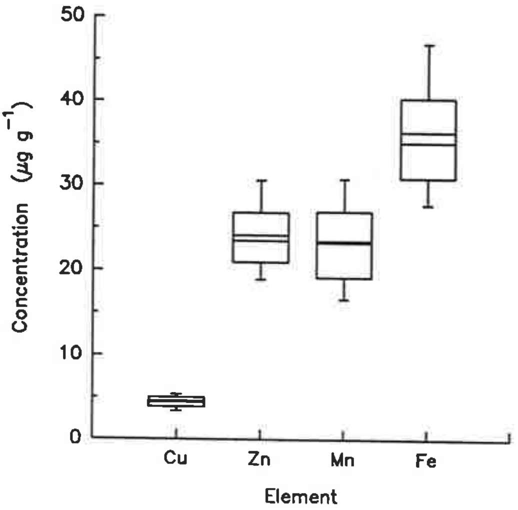


Fig 1. Concentrations of *a)* major and *b)* trace elements in the dry matter of wholemeal flour. Boxes indicate the range between the 25th and 75th percentiles; the horizontal solid and dotted lines mark the median and means respectively. The ends of the bars indicate the 10th and 90th percentiles.

Table 3. *Mean concentrations of elements in HGCA winter wheat grain dry matter, for varieties with three or more samples*

		mg g^{-1}				μg g^{-1}			
Variety	n[a]	P	K	Ca	Mg	Cu	Zn	Mn	Fe
Bread-making varieties									
Mercia	57	3.67	4.90	0.53	1.12	4.40	26	26	39
Hereward	33	3.29	4.85	0.44	1.01	4.03	24	23	39
Soissons	5	3.32	4.26	0.47	1.11	4.47	22	29	35
Tonic	4	3.90	5.10	0.51	1.27	4.13	31	32	37
Estica	3	3.52	4.92	0.41	1.20	3.36	20	23	30
Urban	3	3.78	4.96	0.43	1.19	4.04	29	29	47
Avalon	3	3.03	4.57	0.46	0.83	4.60	24	28	34
Mean		*3.53*	*4.86*	*0.49*	*1.09*	*4.24*	*25*	*26*	*38*
Other varieties									
Riband	108	3.23	4.81	0.44	0.96	4.22	21	21	32
Beaver	52	3.30	5.36	0.44	1.05	3.98	23	24	35
Haven	40	3.29	5.41	0.40	1.03	4.04	23	22	34
Apollo	25	3.43	4.92	0.41	1.06	4.04	24	22	41
Slejpner	17	3.48	5.19	0.41	0.99	4.73	24	22	41
Galahad	7	3.35	5.32	0.47	1.00	3.76	22	26	36
Hornet	3	3.35	4.99	0.44	1.03	2.93	20	24	32
Mean		*3.30*	*5.07*	*0.43*	*1.00*	*4.13*	*21*	*22*	*35*
F ratio[b]		2.57	3.51	3.86	5.37	2.39	4.57	2.97	2.87
Signif.[c]		***	***	***	***	***	***	***	***

[a]n = number of samples
[b]F ratio = variance ratio
[c] *** = $P < 0.001$

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