An evaluation of the phytate, zinc, copper, iron and manganese contents of, and Zn availability from, soya-based textured-vegetable-protein meat-substitutes or meat-extenders

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1. A study has been made of the zinc, copper, iron, manganese, protein (nitrogen × 6·25) and phytic acid contents of nineteen soya-bean-based textured-vegetable-protein (TVP) meat-extenders and meat-substitutes and of three 'ready-prepared' canned meals containing TVP.

2. Phytate analysis was performed using a newly-developed method based on Holt's (1955) procedure. This method enabled the phytate content of milligram quantities of TVP to be estimated, with an SD for six replicates of 3 %.

3. The Fe, Cu and Mn contents (mg/kg) of the meat-extenders or meat-substitutes varied, with values of 59·4–144, 14·1–19·7 and 19·5–29·1 respectively. The protein content of these products was approximately 500 g/kg.

4. The phytate content of the meat-extenders and meat-substitutes ranged from 11·0 to 20·2 g/kg and the Zn content from 35·0 to 49·4 mg Zn/kg. The calculated molar ratio, phytate:Zn varied from 25 to 42.

5. The trace element, phytate and protein contents of the 'ready-prepared' canned meals were 30–50 % lower than the meat-extenders and meat-substitutes.

6. Cooking the 'ready-prepared' meals as specified by the manufacturers was without effect on the trace element or phytate content.

7. When TVP was fed to rats as the only protein source, they had significantly lower growth rates and plasma Zn concentrations than rats given an egg-albumen-based diet of similar Zn content (14·5 mg Zn/kg). Supplementation of the TVP diet with Zn (100 mg Zn/kg) significantly increased growth rate and plasma Zn concentration whereas Zn supplementation of the albumen diet was without effect.

8. The possible implications of consumption of TVP products in relation to Zn status of the human population is discussed.

It is now well established that zinc present in cereal and soya-based diets fed to pigs (Oberleas *et al.* 1966*a*, *b*) or poultry (O'Dell & Savage, 1960) is poorly available relative to Zn in diets containing protein of animal origin. O'Dell & Savage (1960) suggested that phytic acid (*myo*-inositol-1,2,3,4,5,6-*hexa-kis*-dihydrogen phosphate), naturally present in a number of plant seeds, legumes and tubers was the agent responsible. This proposal has been substantiated by numerous studies in pigs (Oberleas *et al.* 1966*a*, *b*), poultry (Likuski & Forbes, 1964) and rats (Oberleas *et al.* 1966*b*; Davies & Nightingale, 1975). Furthermore high dietary intakes of phytate, either from cereals or fed as purified sodium phytate have similarly been shown to reduce Zn retention as determined by Zn balances with human subjects (Reinhold *et al.* 1973).

Recently, many soya-bean-based meat-extenders or meat-substitutes have become generally available in supermarkets and food shops as well as 'health-food' shops catering for the vegetarian market. Furthermore, meat-extenders based on soya bean are being increasingly used in schools and hospital meals (Edmunds, 1975) with apparently little thought as to the consequences this may have on the Zn status of the recipients. In view of these observations it seemed opportune to consider what possible consequences an increased consumption of soya-bean-based meat-substitutes or meat-extenders, from which Zn availability may be poor due to endogenous phytate, may have on the Zn status of the human population.

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Accordingly this present study was undertaken, in which soya-bean-based, textured-vegetable-protein (TVP) meat-substitutes or meat-extenders, currently on sale either in bulk to institutions such as schools and hospitals, or to the retail market, were analysed for their phytate and Zn contents. In addition this paper reports the results of a dietary study in which Zn availability from TVP was assessed in young rats from growth trials and plasma Zn concentrations.

MATERIALS AND METHODS

Materials. TVP meat-extenders or meat-substitutes, and 'ready-prepared' canned meals containing TVP were obtained either as gifts from the manufacturers or purchased from food stores and supermarkets. The manufacturers included: Cadbury's Typhoo Ltd, Birmingham; Meat Extenders Ltd, Guildford, Surrey; Cross & Blackwell Ltd, Croydon. Raw dried soya beans were purchased from a 'health-food' shop.

Analytical methods

Sample preparation. Samples of freeze-dried TVP were ground to a fine powder and thoroughly mixed.

Trace element analysis. Duplicate 0·5 g samples of ground TVP were wet-ashed in 18 M-sulphuric acid, 12 M-perchloric acid, 16 M-nitric acid (0·5 : 1·0 : 5·0, by vol.). After dilution, the Zn, copper, iron and manganese contents of the samples were estimated by atomic absorption spectrophotometry (Techtron AA5; Varian-Techtron Pty, Melbourne, Australia).

Protein analysis. The nitrogen content of the freeze-dried powder was analysed by a Kjeldahl procedure. The factor $N \times 6{\cdot}25$ was used to estimate the protein content (g/kg).

Phytate analysis. Triplicate 0·5 g samples of the freeze-dried, finely-ground TVP products were extracted with 20 ml, 0·5 M-HNO_3 for 3–4 h with continuous shaking. After filtering, phytate analysis was performed on 0·2–0·5 ml of the filtrate by a modification of Holt's (1955) method. Sodium phytate (British Drug Houses, Poole, Dorset) was used for preparation of a standard phytic acid solution. Its purity was assessed both by the Fe-precipitation assay described by Oberleas (1971) and by difference from the acid-soluble inorganic phosphorus content and total P content (obtained after wet-ashing). P determinations were made by the method of Sumner (1944). It contained (g/kg): sodium phytate 803·9, water 195, inorganic P 1·05.

The modified Holt (1955) procedure adopted routinely for phytate analysis was as follows: 0·2–1·0 ml of the filtrate or standard Na phytate solution (0·2 mM) was diluted with distilled water to a final volume of 1·4 ml to which was added 1·0 ml of a solution of ferric ammonium sulphate containing 50 μg Fe. After mixing, the test-tubes were stoppered and placed in a boiling water-bath for 20 min. When cooled to room temperature, 5 ml amyl alcohol was added to each test-tube followed by 0·1 ml of a solution of ammonium thiocyanate (100 g/l). The contents of the test-tubes were immediately mixed by inversion and shaking. After centrifuging for a short time at low speed, the intensity of the colour in the amyl layer was determined at 465 nm using a spectrophotometer (SP 600; Pye-Unicam Ltd, Cambridge) against an amyl alcohol 'blank', exactly 15 min after addition of the HN_4CNS. Since the principle of the method is based on the observation that ferric ions complexed with phytate at pH 1–2 cannot react with thiocyanate ion to give the characteristic pink complex, the extinction at 465 nm in the amyl layer is inversely related to the phytate anion concentration. Under these conditions an inverse linear relationship was found over a range of phytate concentrations from 40 to 200 nmol.

Dietary study

Animals. Twenty-four male rats (Hooded-Lister rats of Rowett Research Institute strain) weighing between 130 and 140 g were allocated at random to four groups of six rats and maintained on the experimental diets for 28 d. The animals were group housed (three rats/cage) in cages constructed of polypropylene and stainless-steel and were offered their respective diets and deionized water *ad lib.* Weight gains were recorded twice weekly. At the end of the experiment the rats were lightly anaesthetized with sodium pentobarbitone (Sagatal; May & Baker Ltd, Dagenham) (administered intraperitoneally, 45 mg/kg body-wt) and blood samples withdrawn by cardiac puncture.

Plasma Zn concentration was determined by atomic absorption spectrophotometry (Varian AA5) after protein precipitation with trichloroacetic acid (50 g/l).

Diets. Two diets containing a mixture of TVPs (TVP mix) as the only protein source were prepared and two diets using egg albumen. The albumen diets were similar in composition to the basal diet of Williams & Mills (1970) except the calcium content was 12 g/kg, the Cu content was 5 mg/kg and the diet was supplemented with $Na_2SiO_3.5H_2O$, NH_4VO_3, $NiCl_2.6H_2O$, Na_2SeO_3, $Cr_2(SO_4)_3K_2SO_4.24H_2O$ and $SnCl_4.5H_2O$ to give final dietary contents (mg/kg) of: silicon 100, vanadium 0·2, nickel 1·0, selenium 0·1, chromium 5·0, tin 2·0. The Zn contents of the two diets were adjusted by the addition of $ZnSO_4.7H_2O$ to give 14·5 and 100 mg Zn/kg, respectively.

The TVP mix consisted of equal proportions by weight of freeze-dried, ground TVP beef, TVP bacon and unflavoured meat-extender. On analysis it contained 540 g protein (N × 6·25)/kg and 12·7 g phytate/kg. The TVP mix was included in the diets at a concentration of 330 g/kg to give final protein and phytate contents of 180 and 4·23 g/kg, respectively. Both TVP diets were supplemented with L-lysine and L-methionine (5 g/kg).

The trace element content of the TVP mix was (mg/kg): Zn 44·2, Mn 33·6, Fe 86, Cu 16·9. Due allowance was made for the contributions these trace elements made to the complete diets so that the final trace element composition of the TVP and albumen diets were identical. The Zn content of the basal TVP diet was 14·5 mg/kg and the second TVP diet was the basal diet supplemented with $ZnSO_4.7H_2O$ to give a final Zn content of 100 mg Zn/kg.

The other ingredients of both diets, i.e. arachis oil, mineral salts and vitamins, were added at the same levels as in the albumen diets. The higher content of TVP mix relative to albumen was allowed for by a reduction in the amount of added sucrose.

RESULTS

The original method of phytate analysis described by Holt (1955) on which the present method was based, required relatively large samples (5–10 g) and large volumes of reagents. In preliminary experiments in which the assay volumes were scaled down to enable test-tubes rather than flasks to be used, it was found that the relationship between the extinction at 465 nm of the final aqueous solution and phytate concentration exhibited poor linearity with a relatively shallow slope. Under the conditions used in this present study in which the relative proportions and concentrations of reagents were altered and the coloured Fe^{3+}-thiocyanate complex was extracted into amyl alcohol, colour intensity was inversely related to phytate content with linearity maintained over a working range of 40–200 nmol. In addition, the use of amyl alcohol considerably improved the precision of the assay due to an increase in slope of the assay curve.

A comparison of standard curves using the original 'aqueous' procedure and the modified procedure is shown in Fig. 1. Over the linear portion of the curve for the 'aqueous' assay, the slope was −0·0013 extinction units/nmol phytate while using the modified assay the slope was −0·0029 extinction units/nmol phytate.

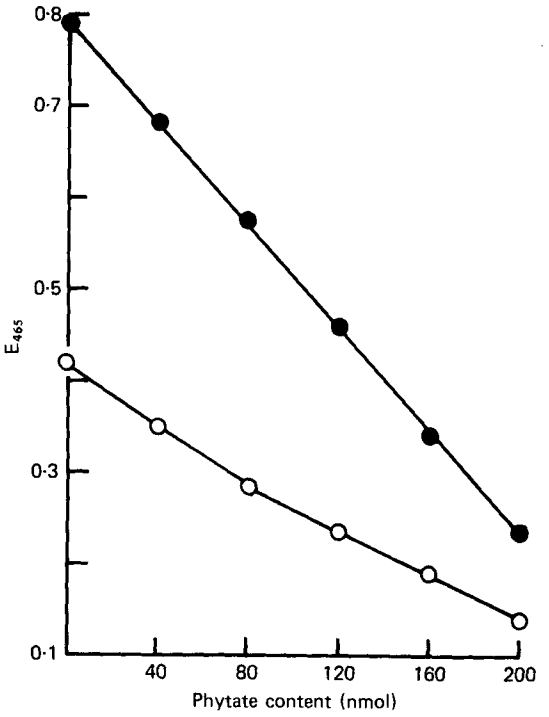

Fig. 1. A comparison of the standard curves relating phytate content (nmol) and extinction at 465 nm (E_{465}) using the original aqueous Holt (1955) procedure (○—○) and the modified assay (●—●), as described on p. 580.

Six replicate analyses of a standard phytate solution (100 nmol sodium phytate) using the modified assay procedure gave an SD of ± 2·5 % and the corresponding value for six replicate analyses of a TVP sample was ± 3·2 %.

The anion most likely to interfere with the assay is phosphate since, as demonstrated by Holt (1955), this like phytate will compete with thiocyanate for Fe^{3+} and reduce the intensity of colour produced. However experiments showed that there were no effects on the phytate assay until the inorganic phosphate content in the final assay exceeded 80 μg P.

The validity of this method for phytate analysis of TVP was assessed by comparing the results obtained by this procedure when applied to three TVP samples and analysis by the commonly used Fe-precipitation assay described by Oberleas (1971). The results are shown in Table 1.

The values found by either method differed by no more than 5 % and hence because of its relative speed and simplicity this modified Holt (1955) procedure was applied routinely for analysis of the remaining TVP samples.

The results of the analyses for Cu, Mn, Fe, protein and phytate, together with the calculated molar ratios, phytate : Zn for nineteen meat-extenders or meat-substitutes, and three ready-prepared TVP-based meals and of raw soya-beans are shown in Table 2.

Protein contents. Most of the meat-substitutes and meat-extenders contained approximately 500 g protein/kg, whereas the mean protein content of the 'ready-prepared' meals was 313 mg/kg. Since the contribution to the protein content by the other listed ingredients would have been slight, it would indicate that soya-bean-based components accounted for 50–60 % on a dry matter basis of the final product.

Table 1. *A comparison of phytate contents of three textured-vegetable-protein samples when analysed* (1) *by the iron-precipitation assay of Oberleas* (1971) *or* (2) *by a modification of the procedure of Holt* (1955)

(Each value is the average of three replicate analyses)

	Phytate content (g phytate/kg)		Relative value (method 2 : method 1) (%)
Method ...	1	2	
Sample no.			
1	11·5	12·1	105
2	15·6	14·9	96
3	18·7	18·3	98

Fe, Cu and Mn contents. The Cu and Mn contents (mg/kg) varied between 14·1 and 19·7 and 19·5 and 29·1, respectively.

The Fe contents of the meat-extenders or meat-substitutes were more variable than the other trace elements, ranging from 59·4 to 144 mg Fe/kg. The contents of Fe, Cu and Mn in the 'ready-prepared' meals were 30–50 % lower than in the meat-extenders and meat-substitutes.

Zinc. The Zn contents of the meat-substitutes and meat-extenders ranged from 35·0 to 49·4 mg/kg. The Zn contents of the 'ready-prepared' meals, varying from 14·4 to 29·5 mg Zn/kg were, again 30–50 % lower than in the other products, probably due to dilution of the soya-bean-based component with other ingredients of low Zn content.

Phytate. The phytate content (g/kg) of the meat-extenders and meat-substitutes ranged from 11·0 to 20·2, whereas those of the 'ready-prepared' meals were, as found for protein and trace element concentrations, 30–50 % lower than the meat-extenders and meat-substitutes. The phytate content of raw soya beans, 12 g/kg, agrees well with values published by Oberleas *et al.* (1966*b*).

When the phytate and Zn contents of these products were expressed as the molar ratio, phytate : Zn the TVP meat-extenders and meat-substitutes had values in the range 25·3–44·6 compared with 25–31 for the 'ready-prepared' meals; for the sample of raw soya beans the value was 29·6. These results indicate that processing of the soya beans into meat-substitutes or further processing into 'ready-prepared' meals had little effect on the relative proportions of Zn and phytic acid.

Effects of cooking on phytate, protein and trace element composition of TVP

Since it has been shown that autoclaving of soya-bean isolates for 4 h at 115° destroys most of the phytate and increases Zn availability (Rackis, 1974) it seemed important to determine whether cooking of these soya bean products similarly reduced their phytate contents, Accordingly an experiment was carried out in which two 'ready-prepared' meals were cooked exactly as recommended by the manufacturers. Cooking had no effect on the Zn, Cu, Fe, Mn or phytate contents. Thus in the two samples tested the phytate : Zn ratios were initially 27 and 29 and after cooking 26 and 27 respectively.

Under these conditions, clearly little or no phytic acid is destroyed and thus the phytate contents of the uncooked TVP shown in Table 2 would approximate to that normally eaten.

Dietary studies

The growth rates of rats offered the basal and Zn-supplemented TVP diets and the two albumen diets are shown in Table 3. Supplementation of the TVP diet with Zn brought about a 136 % increase in average daily weight gain, indicating that the low growth rate of the rats receiving the basal TVP diet was due to a Zn deficiency. No stimulation in growth

Table 2. *The zinc, copper, iron, manganese, protein (nitrogen × 6·25) and phytate contents (kg* DM*) and molar ratio phytate : Zn of textured-vegetable-protein (TVP) meat substitutes and meat extenders, ready prepared TVP-based canned meals and raw soya beans*

(Mean values with standard errors for duplicate determinations except phytate where values are for triplicate determinations)

	No. of samples	Zn (mg)		Cu (mg)		Fe (mg)		Mn (mg)		Protein (g)		Phytate (g)		Phytate : Zn	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Meat extenders	10	44·1	1·29	18·2	0·58	98·2	5·19	23·8	1·21	521	12·2	17·2	0·59	38·7	0·96
Meat substitutes															
Beef analogues	3	44·3	2·74	17·8	1·01	98·3	6·67	24·9	0·52	487	6·7	15·5	1·50	34·3	2·91
Pork analogues	6	42·1	0·75	16·9	1·22	102·6	21·3	24·4	2·28	486	3·3	15·5	2·35	56·7	5·90
'Ready prepared' meals															
Mince in beef-flavoured gravy	1	29·5	—	11·6	—	54·8	—	18·3	—	310	—	8·8	—	29	—
Chunks in beef-flavoured gravy	1	15·2	—	10·5	—	82·0	—	15·7	—	380	—	4·3	—	27	—
Chunks and kidney pudding	1	14·4	—	4·8	—	5·70	—	6·0	—	250	—	3·8	—	26	—
Raw soya beans	—	40·2	—	13·7	—	93·8	—	21·4	—	380	—	12·1	—	29	—

Table 3. *The effects of two dietary Zn concentrations (14·5 and 100 mg Zn/kg) in diets containing either egg albumen or soya-based textured-vegetable-protein (TVP) as protein sources on growth rates and plasma Zn concentration*

(The TVP-protein source consisted of a mix of equal proportions by weight of freeze-dried ground TVP 'beef', TVP 'bacon' and unflavoured meat-extender. It was included in the TVP diets at a concentration of 330 g/kg together with 5 g/kg each of L-methionine and L-lysine to give a final protein content (nitrogen × 6·25) of 190 g/kg. The protein, iron, copper, manganese, mineral contents of all diets were the same)

Diet no.	Protein source	Zn content (mg/kg)	Phytate content (g/kg)	Phytate : Zn	Average daily wt gain (g)		Plasma Zn concentration (mg/l)	
					Mean	SE	Mean	SE
1	TVP	14·5	4·23	28·7	2·73	0·20	0·54	0·03
2	TVP	100·0	4·23	4·2	6·45	0·09*	1·03	0·04*
3	Albumen	14·5	0	0	5·47	0·06	0·94	0·04
4	Albumen	100·0	0	0	5·45	0·07 NS	1·05	0·05 NS

NS, Not significant ($P > 0·05$).

* The statistical significance of the difference between mean values was $P < 0·001$.

The two groups receiving TVP diets and the two groups receiving albumen-diets were considered separately for statistical analysis by Student's t test.

rate was found in rats given the albumen diet containing 100 mg Zn/kg compared with that of the rats receiving the albumen diet containing 14·5 mg/kg. The results suggested that, whereas 14·5 mg Zn/kg satisfied the growth requirement for Zn in the rats receiving the albumen-based diets, the requirement was higher when rats consumed the phytate-containing TVP-based diets.

Support for this conclusion was gained from the results of analysis of plasma Zn concentration. Thus the poor growth rates of the rats receiving the TVP diet of low Zn content, was associated with plasma Zn concentrations that were significantly lower than those of rats receiving the albumen-based diet of the same Zn content. Rats receiving the TVP diet supplemented with additional Zn to give a Zn content of 100 mg/kg had plasma Zn concentrations that were the same as those of rats receiving the albumen diets. Since there was no difference in the plasma Zn concentrations of rats receiving either of the two albumen diets these results again suggest that when albumen is used as the protein source, a dietary concentration of 14·5 mg Zn/kg satisfied the requirement of the rat for this trace element.

DISCUSSION

The method for phytate analysis described in this paper which was modified from that described by Holt (1955) enabled the rapid screening of the phytate contents of soya-bean-based products with a precision of SD $\pm$ 3·2 %. While perhaps less precise then the Fe-precipitation assay first described by McCance & Widdowson (1935) and subsequently modified by Young (1936), Earley & De Turk (1944) and Oberleas (1971) this method is considerably more simple and rapid since it obviates time-consuming precipitation, filtration and wet-ashing procedures. Its applicability to TVP samples was demonstrated in Table 1 in which the analysis of three TVP samples by both procedures showed good agreement. The rapid method has also been satisfactorily applied to peas (*Pisum sativum*), beans (*Vicia faba*), wheat bran, maize, complete pig diets containing soya-bean meal and maize, and to human diet formulations containing either rice, millet (*Setaria italica*), sorghum (*Andropogon sorghum*) or groundnuts (*Arachis hypogaea*) (N. T. Davies, unpublished results). The only difficulties that have been encountered have been with samples of high fat content which have given rise to turbidity in the amyl alcohol layer. This was not a complication in this current series of analyses.

Composition of TVP samples

Protein. The protein content of the meat-substitutes or meat-extenders of approximately 500 g/kg is similar to that quoted by Wolf & Cowan (1971) (510 g/kg) and McCance & Widdowson (1960) (496 g/kg) for defatted soya-bean flours and grits.

Soya-bean-protein concentrates and isolates, produced by further processing of grits and flours, either by alcohol and acid treatments, or alkali treatments and iso-electric precipitation have protein contents of 700–900 g/kg (Wolf & Cowan, 1971). It seems likely therefore that the TVP products analysed in this present study were prepared from defatted soya-bean-grits and not from these more highly-purified isolates. The protein concentration in raw soya beans of 380 mg/kg reported here agreed well with the 400 g/kg found by Kawamura (1967).

Trace element composition. To the authors' knowledge no reports have hitherto been published on the trace element composition of soya-bean-based meat-substitutes or meat-extenders. However, a comparison between the trace element content of raw soya beans with the TVP products indicated that whereas their contents tended to be 30–50 % higher in TVP the relative proportions of Zn : Cu : Fe : Mn were broadly similar, suggesting either that little if any of these components was lost during processing, or that the manufacturers had

supplemented the final products to give a similar profile of trace element contents to that of the starting material.

Since these products are marketed as alternatives to meat as protein sources, it is of interest to compare their trace element composition with that of meat products. The results are shown in Table 4 for beef and pork and their respective TVP analogues. The range of concentrations of trace elements in meat are taken from a number of sources as reviewed by Jaulmes & Hamelle (1971) and Schroeder (1971).

In all products tested, the Mn and Cu contents of the soya-bean-meat analogue greatly exceeded that of authentic meat. The Zn contents however were markedly lower.

Phytate contents. The range of phytate contents of the TVP meat-extenders and meat-substitutes of 11·0–20·0 g/kg was similar to the range 11·5–21·7 g/kg found by Ranhotra *et al.* (1974) and De Boland *et al.* (1975) for a number of soya-bean flours, concentrates and isolates. Similarly the phytate content of whole soya beans found in this present investigation agreed well with previously published values (Oberleas *et al.* 1966*b*). Since the phytate content of the TVPs tended to be higher than that of the raw beans it was clear that little or no phytate had been lost during the defatting and processing procedures.

The effect of phytic acid on trace element availability

Phytic acid has been shown to form stable complexes in vitro with Cu^{2+}, Zn^{2+}, Co^{2+}, Mn^{2+}, Fe^{3+} and Ca^{2+} reviewed by Oberleas, (1973). In the presence of Ca^{2+} and Zn^{2+}, an insoluble Zn–Ca–phytate complex is formed at pH 6 and > 90 % of the Zn is removed from solution (Oberleas *et al.* 1966*a*). The formation of such a complex in vivo in the upper gastro-intestinal tract of single-stomached animals is thought to be the mechanism by which phytate reduces dietary Zn availability.

Since the effectiveness with which phytate can reduce Zn availability in diets depends upon the absolute levels of both Zn and phytate, Oberleas (1975) has suggested that the dietary contents of phytate and Zn expressed as a molar ratio, phytate : Zn could be a satisfactory means of predicting whether a phytate-containing diet may give rise to poor availability.

This proposal by Oberleas (1975) has been critically examined in a detailed study in which it was shown that phytate : Zn values exceeding 15–20 resulted in low hair and plasma Zn concentrations and low growth rates (Davies & Olpin, 1979).

The phytate : Zn values of all products tested in the present study were within a range of 25–44. Calculation of phytate : Zn for diets used in previous studies in rats (Davies, 1977) and pigs (Oberleas *et al.* 1966*a*) in which severe Zn deficiency states were either induced or maintained give values of 28 and 33 respectively. These values were in the middle of the range obtained for the TVP products analysed in the present study, thus it seemed likely that Zn availability from these products would be low.

The results of the dietary study in this present investigation showed that rats given the TVP diet containing no Zn supplement exhibited low growth rates compared with rats given a phytate-free albumen-based diet of the same Zn concentration and this poor growth was associated with low plasma Zn concentrations. Supplementation of the TVP diet with Zn to lower phytate : Zn from 28·7 to 4·01 resulted in a 136 % increase in average daily weight gain and in an increase in plasma Zn concentration to values that were the same as those of rats given the two albumin diets. Since no increase in growth or plasma Zn concentration was observed in rats receiving the albumen-based diet containing 100 mg Zn/kg compared with those offered the diet containing 14·5 mg Zn/kg it is clear that in the absence of factors affecting Zn availability, 14·5 mg Zn/kg was sufficient to meet the Zn requirements for growing rats.

While it is unwise to extrapolate too freely the conclusions drawn from studies with

Table 4. *The zinc, copper, iron and manganese contents of beef and pork meat* and textured-vegetable-protein (TVP) beef and pork analogues†*

	Beef		Pork	
	Meat	TVP analogue	Meat	TVP analogue
Zn	140–200	41–43	56–76	40–43
Cu	6·4–10·0	16–18	0·8–1·8	15–19
Fe	108	85–105	50	73–144
Mn	0·8	24–26	0·12–0·18	22–29

* Values taken from Jaulmes & Hamelle (1971) and Schroeder (1971).
† Values taken from Table 2.

experimental animals to human subjects, in the authors' opinion the results of this present study give cause for concern. Dietary phytate has been shown to reduce Zn availability in humans (Reinhold *et al.* 1973). Furthermore evidence has been presented indicating a hitherto unrecognized high incidence of marginal Zn deficiency in the child population of the USA (Hambidge *et al.* 1972; Hambidge *et al.* 1976). Although similar studies have not been reported from other developed Western countries, recent estimates have shown that the average daily intake of Zn by middle-income group citizens of the UK of 11·2 mg/d only just meets the WHO (1973) recommended requirements of 11 mg/d for adult males and females consuming a mixed meat, cereal and vegetable diet (Davies, 1977). It falls short, however, of the recommended requirements for adolescent males and females (14 mg/d) and pregnant and lactating women (15 and 27 mg/d, respectively). Furthermore, nearly half (4·70 mg) of the Zn intake is apparently contributed by meat products from which Zn would be readily available. The results of this present study show that the TVP meat-substitutes and meat-extenders tested, have considerably lower Zn content than that of the authentic meat products, in addition to which their high phytate contents markedly reduces Zn availability. The possibility exists, therefore, that if consumption of these products increases without consideration being given to dietary Zn supply in an available form, there may be an increased incidence of marginal Zn deficiency states in some sections of the population.

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