EXTRACTION, COMPOSITION

AND SOME OF THE

PHYSICAL AND CHEMICAL PROPERTIES

OF

COMPONENTS OF DIETARY FIBRE

by

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"The value of what one knows is doubled if one confesses to not knowing what one does not know. What one knows is then raised beyond the suspicion to which it is exposed when one claims to know what one does not know."

Schopenhauer

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A B S T R A C T

The extraction and some of the chemical and physical properties of components from plant cell walls are described in this thesis. The chemical composition of the extracted polymers and the morphological and physical changes occurring in wheat bran at various stages of an extraction sequence and the metal binding capacities of the extracts were determined.

A sequential extraction procedure using water, amylase, oxalate and alkali (before and after delignification) was used to isolate components of plant cell walls. This enabled water soluble and water insoluble fibres from bean, cabbage, lettuce, tomato, peach, pumpkin, kumera, onion, pear, wheat bran, lucerne, clover and ryegrass to be obtained. The water soluble fibres were shown to be composed predominantly of arabinose, galactose and uronic acid, whereas the water insoluble fibres contained mainly arabinose and xylose.

The viscosities of the alkali soluble fibres extracted from wheat bran, before and after chlorite delignification, and after solubilisation in N-methyl-morpholine-N-oxide were determined. The arabinoxylan extracted before delignification, yield of 7.9 g/100 g, had a limiting viscosity number of 220.6 ml/g, whereas the arabinoxylan extracted after chlorite delignification, yield of 3.8 g/100 g, had a limiting viscosity number of 74.2 ml/g. When the solvent N-methyl-morpholine-N-oxide had been used to dissolve the nondelignified arabinoxylan, a considerable decrease in viscosity, to 6.3 ml/g, was observed. It was concluded that direct extraction (no delignification) of wheat bran, enables a less degraded arabinoxylan to be extracted in adequate yields. The use of

N-methyl-morpholine-N-oxide as a solvent for arabinoxylan resulted in extensive degradation.

The structural changes in wheat bran at each stage of the extraction sequence and when dimethylsulphoxide (DMSO) was substituted for alkali were observed using light and scanning electron microscopy. It was shown that the commercially ground sample of wheat bran contained a high proportion of starch, which was removed after the amylase treatment. Alkali removed cell wall material predominantly from the aleurone layer. DMSO was not an efficient extractor of arabinoxylans from cell walls, a yield of only 0.4% being obtained and the aleurone cell walls remaining intact. The arabinoxylan, extracted with DMSO, had a higher ferulic acid and acetyl content than the arabinoxylan extracted with alkali.

The interactions of fibres with metal ions (copper, iron, zinc, calcium, potassium, magnesium, manganese and sodium) using concentrations that would be expected in the human small bowel after a 'typical' meal were investigated. It was found that the water soluble fibres bound more copper, iron and zinc than the water insoluble fibres. The copper, iron and zinc binding occurred with a displacement of calcium, magnesium and manganese. The water insoluble fibres (hemicelluloses) contained a higher calcium content than the soluble fibres (pectins). After acid treatment, sodium was bound preferentially rather than calcium to hemicellulose. Possibly divalent calcium ions play a role in stabilising the hemicellulose components of plant cell walls.

The binding capacities and mechanisms of zinc binding to wheat bran, its components and to phytate were determined. Zinc binding capacities (μM/g dry weight of plant material) in order of magnitude were; phytate (6582 ± 192), DMSO soluble hemicellulose (5089 ± 921), water soluble fibre (4038 ± 216), cell walls (1012.6 ± 193), lignocellulose (510 ± 41.9), cold water soluble fibre (440.0 ± 15.3), alkali soluble hemicellulose (227.9 ± 61.4), bran (167.7 ± 12.7), bran ex oxalate (148.3 ± 50.0), bran ex ethanol (142.3 ± 4.4) and cellulose (57.4 ± 5.3).

The water soluble fibre, fractionated using ammonium sulphate, composed predominantly of arabinose (24.0%), galactose (20.3%), xylose (18.6%), mannose (16.2%), glucose (10.9%) and rhamnose (6.0%), bound zinc more strongly than phytate or the DMSO hemicellulose. The Scatchard plots of zinc binding to phytate and to the fibres, except for the water soluble fibres, were concave and markedly nonlinear, suggesting that the binding mechanism is by negative cooperativity or site heterogeneity. The Scatchard plots of zinc binding to the water soluble fibres showed well pronounced maximum, indicating the binding mechanism is by positive cooperativity.

Part I of this thesis describes the studies undertaken to isolate and determine the chemical composition of different types of fibres from bean, cabbage, sweet potato, lettuce, onion, peach, pear, pumpkin, tomato, wheat bran, white clover, lucerne and ryegrass. This study has been published in the Journal of the Science of Food and Agriculture 1983, 34: 1236-1240 (see Appendix F).

Part II of this thesis describes studies undertaken to investigate the viscosity of hemicelluloses obtained using the extraction procedure and after solubilisation in N-methyl-morpholine-N-oxide. The work has been published in Carbohydrate Research 1985, 143: 271-274 (see Appendix G).

Part III describes studies undertaken to observe the morphological structure of wheat bran, changes occurring during the extraction sequence and influence of DMSO when substituted for alkali.

Part IV describes studies on binding of metals to water soluble and insoluble fibres from fruits, vegetables, bran and grasses.

Part V describes a more detailed study of zinc binding to wheat bran, its fibre components, and to phytate.

The thesis concludes with a general discussion of the findings and a summary of the conclusions.