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EXTRACTION, COMPOSITION
AND SOME OF THE
PHYSICAL AND CHEMICAL PROPERTIES
OF
COMPONENTS OF DIETARY FIBRE

by

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A thesis presented in partial fulfilment of the
requirements for the degree of

DOCTOR OF PHILOSOPHY

in the

Department of Food Technology

MASSEY UNIVERSITY

1985

"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

ACKNOWLEDGEMENTS

I wish to acknowledge the following people and organisations that have assisted in the preparation of this thesis. The chief supervisor Professor E.L. Richards and the second supervisor Dr J. Lelievre and the acting supervisor Dr M. Taylor, all from the Department of Food Technology; also Applied Biochemistry Division, Department of Scientific and Industrial Research, Palmerston North for financial and material support that enabled this project to be undertaken.

Thanks are also due to Dr J. Lill, Horticultural Research Station, Ministry of Agriculture and Fisheries, Levin, and Applied Biochemistry Division for supplying samples.

My thanks are also due to the staff of ABD for their encouragement and guidance, particularly to Dr J. Monro for discussions and comments, to Dr J. Lee for running the Inductively-Coupled Argon Plasma Emission Spectrometer for multiple metal analysis; Mr D. Hopcroft and Mr R. Bennett of the electron microscopy unit and Mr P.C. Van Dingenen of the workshop.

Helpful suggestions and contributions were received from members of the Chemistry, Biochemistry, Biophysics Department; Dr M. Hardman for access to a computerised nonlinear curve-fitting procedure, Mr R. MacKenzie for assistance with measurement of zinc, iron, sodium and potassium and Dr R. Greenway for the use of the osmometer.

Thanks to Mr G.C. Arnold of the Mathematics Department for discussions on the interpretation of the statistical procedures used in studying the relationship between fibre composition and metal binding.

I am also indebted to the staff and students of the Faculty of Technology for advice, comments and references, particularly Dr M. Earle, Dr G.I. Robertson, Mr R. Greig, Mr M. Reeves, Mr Sen Wong and Mrs Bewley for her unstinting help in assisting to locate chemicals and equipment and Mr Alger for manufacturing a cutting tool that enabled the UMO5 membranes to be cut to size.

Grateful thanks to Mrs J. Tipoki for running the graphics program, to my wife for typing the drafts, and to Miss D.J. Rosvall for typing the final script of this thesis.

T A B L E O F C O N T E N T S

	Page Nos
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	v
LIST OF FIGURES AND TABLES	vii
ABSTRACT	1
INTRODUCTION	5
PURPOSE OF THIS STUDY	8
PART I	
Isolation and Determination of the Chemical Composition of some of the Fibre Components of Fruits, Vegetables, Pasture Grasses and Wheat Bran	
Introduction	10
Materials and Methods	14
Results	19
Discussion	25
PART II	
Study of the viscosity of Wheat Bran Hemicelluloses	
Introduction	31
Materials and Methods	34
Results	36
Discussion	41

PART III

Morphological Changes in Wheat Bran as a result
of polymer extraction

Introduction	45
Materials and Methods	49
Results	52
Discussion	64

PART IV

Metal Adsorption to Water Soluble and
Insoluble Fibres and from Fruits,
Vegetables, Bran and Grasses

Introduction	67
Materials and Methods	69
Results	74
Discussion	88

PART V

Zinc Adsorption to Wheat Bran, its Fibre
Components and to Phytate

Introduction	99
Materials and Methods	104
Results	109
Discussion	123

GENERAL DISCUSSION	134
--------------------	-----

CONCLUSIONS	141
-------------	-----

REFERENCES	142
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APPENDICES	168
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L I S T O F F I G U R E S A N D T A B L E S

	Page Nos	
Figure 1:	Flow diagram of the five stages of the investigations in this thesis.	9
Figure 2:	Sequence of extraction of fibre components.	20
Figure 3:	Separation of sugars through a column packed with 3% ECNSS-M at 190°C using a Hewlett Packard 5840A Gas Chromatograph.	21
Table I:	Yield in grams of dried polymers from the starting material.	22
Table II:	Composition of isolated fibres from fruits, vegetables, grasses and wheat bran.	23
Table III:	Regions of New Zealand where the foods and grasses used for 'fibre' extraction were grown.	24
Figure 4:	Sequence of synthesis of N-methyl-morpholine-N-oxide.	34
Figure 5:	Kinematic viscosity of wheat bran hemicellulose extracted in alkali before and after delignification.	37
Figure 6:	Kinematic viscosity of wheat bran hemicellulose after solubilisation and recovery from N-methyl-morpholine-N-oxide.	38
Table IV:	Limiting viscosity numbers of the hemicelluloses extracted in alkali before and after delignification and after recovery from N-methyl-morpholine-N-oxide.	39
Table V:	Relative viscosity of nondelignified hemicellulose in alkali as a function of time.	40
Figure 7:	Caryopsis of wheat (<u>Triticum aestivum</u>) and parts of its pericarp in longitudinal section.	48
Figure 8:	DMSO cell wall preparation procedure.	50
Figure 9 A to D:	Wheat bran, bran ex ethanol, bran ex oxalate and bran ex alkali observed at 380 magnification by light microscopy.	55

Figure 10 A to D:	Wheat bran, bran ex ethanol, bran ex oxalate and bran ex alkali observed by light microscopy.	57
Figure 11 A and B:	Wheat bran after DMSO and chloramine-T, observed by light microscopy.	59
Figure 12 A to D:	Wheat bran after DMSO and chloramine-T, observed by electron microscopy.	60
Table VI:	Yields of hemicellulose obtained by alkali and DMSO extraction from wheat bran.	62
Table VII:	Composition of nondelignified hemicellulose extracted from wheat bran with alkali and DMSO.	63
Figure 13:	Amicon MPS-1 micropartition unit.	73
Figure 14:	Percent zinc bound to wheat bran hemicellulose over a pH range 2.12 to 8.3.	76
Figure 15:	Percent zinc bound to wheat bran hemicellulose with different mixing times.	77
Table VIII:	Influence of osmolality on zinc binding to wheat bran hemicellulose.	78
Table IX:	Reliability study from ten analysis of the metals in the standard solution and after binding to wheat bran.	79
Table X:	Percent metal retention to the Amicon MPS-1 microportion system.	80
Table XI:	Metal content ($\mu\text{g}/\text{mg}$ dry weight) of water soluble (SF) and water insoluble (IF) fibres from fruit, vegetable, bran and grasses.	81
Table XII:	Mean metal content ($\mu\text{g}/\text{mg}$ dry weight) of fruit, vegetable, wheat bran and grass fibres.	82
Table XIII:	Changes in metal content ($\mu\text{g}/\text{mg}$ dry weight) of water soluble (SF) and insoluble fibres (IF) from fruits, vegetables, bran and grasses after mixing with a 'standard' metal solution.	83
Table XIV:	Bound metal content ($\mu\text{g}/\text{mg}$ dry weight) of fruit, vegetable, wheat bran and grass fibres after mixing with 'standard' metal solution.	84

Table XV:	Mean bound metal content ($\mu\text{g}/\text{mg}$ dry weight) of water soluble (SF) and insoluble fibre (IF) after mixing with 'standard' metal solution.	84A
Table XVI:	Mean, standard deviation ($\mu\text{g}/\text{mg}$) and T values of bound metals from matched paired fibres, before and after mixing with 'standard' metal solution.	85
Table XVII:	Percent nondialysable metal content of the water soluble and insoluble fibres.	86
Table XVIII:	Total ion-binding capacity ($\mu\text{M}/\text{g}$) of fibres extracted from fruits, vegetables, bran and grasses.	87
Figure 16:	Extraction sequence for the preparation of lignin.	106
Table XIX:	Composition of the cold water soluble fibre and the purified water soluble fibre from wheat bran.	111
Table XX	Yields of the water soluble fibres and lignocellulose from wheat bran.	112
Table XXI:	Lignin content of wheat bran, lignocellulose and hemicellulose.	113
Figure 17 A to K:	Zinc binding to wheat bran, its fibre components and phytate.	114
Figure 18 A to K:	Scatchard plots of zinc binding to wheat bran, its fibre components and phytate.	118
Table XXII:	Zinc binding capacities, ligand 50%, ($\mu\text{M}/\text{g}$) and Hill coefficients for wheat bran, its fibre components and phytate.	122

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 ($\mu\text{M/g}$ 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.