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Structure and properties of the polysaccharides from pea hulls — II. Modification of the composition and physico-chemical properties of pea hulls by chemical extraction of the constituent polysaccharides

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Fibres, prepared from pea hulls as the alcohol insoluble residue (AIR), were modified by two sequences of chemical treatments. In one, chelating agent (CDTA), acid (HCl) then increasing concentrations of alkali (0·05, 1 and 4 M KOH), removed firstly the pectins, and then the xylans, whereas in the second (alkali alone: 0·05, 1 and 4 M KOH) only significant quantities of xylans were extracted. The AIR was rich in total polysaccharides and was characterised by low water holding capacity (WHC; 3·2 ml/g), low swelling capacity (SC; 5·2ml/g), and high cation exchange capacity (CEC; 0·52 meq/g)/. The fibre preparations CSPR, HSPR and OHSPR-I, recovered after CDTA, HCl and 0·05 M KOH, gave an augmentation in WHC and SC, respectively to 5·8 and 8·3 ml/g in CSPR and 6·6 and 12·6 ml/g in OHSPR-I, while the CEC decreased (to 0·18 meq/g in OHSPR-I) in proportion to extraction of pectins. After depectination, extraction with 1 and 4 M alkali caused a breakdown in cell wall structure of the preparations, followed by changes in average particle size, and microscopic examination of the pea hull particles. As the structure broke down, a concomitant decrease in the hydration properties was measured in these fibre preparations. In contrast, the residues produced by extracting the AIR with 0·05, 1 and 4 M alkali, respectively, showed a marked increase in hydration capacities and also in CEC. This phenomenon was due to the fact that almost no pectin was extracted by alkali-only treatment. Examination of the residues by light microscopy confirmed that significant breakdown of particles only occurred after depectination and extraction with alkali. These results show that chemical treatments which extract specific classes of polymers can provide fibre preparations with increased hydration properties and with either increased or decreased CEC.

INTRODUCTION

Peas (*Pisum sativum* L.) are widely grown temperate grain legume species, the mature seeds of which are used for both human and animal feeding. De-hulling of the seed takes place during production of split or canned peas for human use, and can also be utilised to improve the energy value of the legume seeds for animals by reducing the concentration of 'crude-fibre' (Pastuszewska *et al.*, 1992). The pea hulls so-formed constitute a crop by-product which is rich in fibre, light in colour, virtually tasteless and which has been incorporated successfully into white breads (Sosulki & Wu, 1988). Pea hulls, therefore, have potential as a readily available fibre source for the food industry (Ralet *et al.*, 1993*a*).

The water holding capacity of the native pea hulls is fairly low compared with other sources of vegetable fibre, and is decreased slightly by grinding (Ralet *et al.*, 1993*a*). Since extrusion-cooking treatment of pea hulls also has little effect on physico-chemical properties of the product (Ralet *et al.*, 1993*a*), and the digestibility or fermentability of a particular plant fibre is strongly dependent on its hydration properties (Auffret *et al.*, 1993), it is perhaps not surprising that autoclaving also

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has little effect on the digestibility of the non-starch polysaccharide component of whole peas (Goodlad & Mathers, 1992). Because the dietary fibre content of peas appears to vary little in response to growing conditions (Weightman *et al.*, 1993), the source of peas is probably also unimportant in influencing the physico-chemical properties of pea fibre. In contrast, enzymatic or chemical treatments which extract certain polysaccharides from plant residues may increase the pore size and swelling capacity of the fibre source by removing cross-linking agents within the cell wall matrix and may, therefore, offer a means by which to modify the physico-chemical properties of fibre.

In order to better understand the physico-chemical properties of pea hulls, and their modifications by chemical, enzymic or physical treatments, we have already carried out a study of their constituent polysaccharides (Weightman *et al.*, 1994) by sequential chemical extractions. Pea hulls are very rich in cellulose (about 600 mg/g dry matter) but almost devoid of lignin. Their other major polysaccharides are poorly methylated pectins and acidic xylans. In the present study, we examine the physico-chemical properties of the pea hull residues from which the constituent polysaccharides had been sequentially extracted by chemical means.

MATERIALS AND METHODS

Material

Pea hulls (11% moisture content) were obtained from Sofalia (Ennezat, France). An alcohol insoluble residue (AIR) was first prepared by extracting the pea hulls in boiling 70% (v/v) ethanol for 20 min. The hulls were filtered on sintered glass, and washed repeatedly with 70% (w/v) ethanol at room temperature until extracts were free of sugars. AIR was dried by solvent exchange, oven-dried at 40°C then milled on an IKA Universal mill. The AIR was then used as the starting material for subsequent chemical extraction.

Chemical extractions

Residues were produced during the course of a study to examine the structure and properties of the constituent polysaccharides of pea hulls, and these data are presented elsewhere (Weightman *et al.*, 1994). Extraction conditions are shown in Table 1. Two extraction schemes were employed; the first employed five successive treatments (150 ml of each of CDTA 50 mM, HCl 50 mM, KOH 0·05, 1 and 4 M) and began with five (each 5 g) of the AIR. The second extraction procedure employed three extraction steps (150 ml of each of KOH 0·05, 1 and 4 M), and began with three samples (each 5 g) of the AIR. In both extraction schemes, the alkaline solvents contained sodium borohydride, 12·6 mM to prevent degradation of the polysaccharides. At each extraction step, one residue was recovered on sintered glass, washed repeatedly with water, dried by solvent exchange and its yield recorded. All samples were analysed in duplicate for chemical composition and physico-chemical properties.

Table 1. Extraction conditions used in preparation of fibre residues from AIR of commercial pea hulls

Residue	Extractant	Duration (h)	Temperature (°C)
First extraction series			
CSPR	CDTA (50 mM)	16, 3, 3	20
HSPR	HCl (50 mM)	3 × 0·5 h	85
OHSPR-I	KOH (50 mM)	16, 3, 3	4
1OHR-I	KOH (1 M)	16, 3, 3	4
4OHR-I	KOH (4 M)	16, 3, 3	4
Second extraction series			
OHSPR-II	KOH (50 mM)	16, 3, 3	4
1OHR-II	KOH (1 M)	16, 3, 3	4
4OHR-II	KOH (4 M)	16, 3, 3	4

Analytical

All results are presented on a dry weight basis, which was determined by drying at 120°C for 2 h. Lignin was measured in the AIR using the method of Klason (1931). Neutral sugars were measured as alditol acetates after hydrolysis of samples. All samples were pre-treated with 72% sulphuric acid (1 h, 20°C) then hydrolysed in 2 N sulphuric acid (3 h, 100°C) (Englyst & Cummings, 1984). Uronic acids were measured in the hydrolysates using the automated *m*HDP assay (Thibault, 1979). Galacturonic and glucuronic acids were differentiated by HPLC on a Dionex Carbopac PA1 column (Dionex Corporation, USA). The column was washed with 150 mM NaOH at 1 ml/min, and sugars eluted from the column using a linear acetate gradient (0–300 mM sodium acetate in 150 mM NaOH) over 15 min, then isocratic elution with 300 m sodium acetate/150 mM NaOH. The column was re-equilibrated in 150 mM NaOH for 10 min prior to re-injection. Methanol and acetic acid contents were estimated by HPLC according to the method of Voragen *et al.* (1986).

Physico-chemical properties

Particle size of the fibre residues was determined by sieving on 500, 400, 315, 250, 200, 125 and 50 μm sieves, and weighing the fibre present in each size class. Weights of fibre in each class were converted to proportions (%) of the total weight of fibre. Average particle size was then estimated by plotting cumulative percentage (CP) of fibre in each particle size class against particle size, and interpolating to determine the particle size at CP = 50%.

The cation exchange capacity (CEC) was determined as described by Bertin *et al.* (1988) by titration of 100 mg of sample in acid form with 0·02 N KOH; conversion to the acid form was achieved by stirring 300 mg of the product overnight at 4°C in 30 ml of 0·05 N HCl. Residues were then prepared for CEC measurements by extensive washing with distilled water until neutral and drying by solvent exchange. CEC was calculated on the material obtained after conversion to the acid form.

Swelling was measured by the bed volume technique (Kuniak & Marchessault, 1972). Fibre (100 mg) was weighted into a glass cylinder and left to swell overnight at room temperature in distilled water. Results were expressed as millilitres of swollen sample per gram of initial dry sample. Water holding capacity (WHC) and its kinetics were determined using the Baumann apparatus (1967) with a 100 mg sample of fibre. Results were expressed as millilitres of water held per gram of dry fibre. Water binding capacity (WBC) was measured by centrifugation using the method of MacConnell *et al.* (1974). Approximately 300 mg of fibre was soaked overnight in distilled water at 4°C, and centrifuged for 20 min at 14,000 ***g***. The supernatants were carefully removed and the residues left for 1 h on a G2 sintered glass. The samples were weighed, dried for 2 h at 120°C and re-weighed. Results were expressed as grams of water held per gram of dry fibre.

Microscopy

The powdery fibre residues were prepared for microscopic analysis by including in gelose (3%) at 40–45°C. Once solidified, the gelose was cut into small cubes which were placed into deionised water (30–45 min), and after imbibing were blotted dry on filter paper. The gelose blocks were fixed in glutaraldehyde (3% in 0·1 M sodium cacodylate buffer, pH 7·2) for 2 h. The samples were subsequently rinsed successively in six baths (each 5 min) of 0·1 M sodium cacodylate, pH 7·2, then six baths (each 5 min) of deionised water. Dehydration was carried out by washing in increasing concentrations of ethanol (five steps, each 30 min, from 25 to 95% ethanol) then three times (each 12 h) in absolute alcohol. The samples were next impregnated (four steps, each of 30 min duration) with increasing concentrations of propylene oxide, and finally (20 h) with the inclusion medium, Epon. Inclusion was carried out in gelatine capsules by polymerisation in an oven, 3 h at 40°C followed by 4 days at 60°C. Sections were then cut, dry, to a thickness of 3 μm using a glass blade on a JEOL JUM 7 microtome. Sections were viewed with the aid of an Olympus Vanox light microscope, and either mounted directly in water and observed using differential interference contrast, or were coloured for 1 h in an aqueous solution of ruthenium red stain specific for carboxylic groups of pectin.

RESULTS

Recoveries and chemical composition of the residues

Sequential chemical extraction was carried out on the AIR of pea hulls. After each extraction step, a fibre residue was recovered for analysis. In this way, although only single samples of residues were obtained for each chemical treatment, replicate samples were obtained for extracted polysaccharides. Analyses of yields and chemical composition of the extracts showed that the procedure was repeatable. Care was taken to extract under strictly controlled conditions which would not cause degradation of the polysaccharides. The most important source of error would be expected in estimation of yield, as some residue may have been lost on the sintered glass filters.

Yields and compositions of the AIR and its residues are shown in Table 2. Methanol and acetic acid contents were not measured in any of the residues extracted with

Table 2. Composition (mg/g) and yields (% of AIR) of residues after chemical extraction of commercial pea hulls

Residue	Yield	Rha	Fuc	Ara	Xyl	Man	Gal	Glc	AUA	GalA/GlcA	Methanol (DM)	Acetic acid
AIR		16	nd	39	122	6	28	581	150	97/3	4 (12)	17
First extraction series												
CSPR	90	14	3	36	128	3	11	630	122	98/2	2 (8)	10
HSPR	78	12	nd	10	132	nd	7	721	73	93/7	1 (10)	10
OHSPR-I	73	9	nd	9	137	nd	5	759	49	89/11		
1OHR-I	65	7	nd	5	72	7	5	820	46	88/12		
4OHR-I	61	10	nd	9	27	nd	nd	906	44	100/0		
Second extraction series												
OHSPR-II	94	17	nd	40	126	12	22	608	173	96/4		
1OHR-II	91	16	nd	34	95	nd	12	611	143	94/4		
4OHR-II	84	13	nd	35	66	nd	10	679	157	98/2		

AUA, anhydrouronic acids; GalA, galacturonic acid; GlcA, glucuronic acid; DM, degree of methylation; nd, not detected. For definitions of the residues, see Table 1.

alkali, given the saponifying effect of high pH solutions on pectins. The AIR was very rich in glucose-containing polymers (580 mg/g), and was also rich in xylose (122 mg/g). The degree of methylation of the pectins, calculated from the galacturonic acid and methanol content, was low (~12). Their degree of acetylation was not calculated as pea hulls also contain acetylated xylans (Ralet *et al.*, 1993*b*). Lignin concentration was low (6 mg/g of AIR), as was starch concentration. Depectination (sequential extraction with CDTA, HCl and 0·05 M KOH) reduced uronic acid contents from 150 mg/g in the AIR to approximately 50 mg/g in OHSPR-I. In contrast, treatments only with alkali in the second extraction series had little effect on overall uronic acid concentrations in the residues OHSPR-II, 1OHR-II and 4OHR-II. Loss of arabinose was also much more marked for the first extraction series. The xylose concentration decreased from 122 mg/g in the AIR to 27 mg/g in the residue 4 OHR-I, and to 66 mg/g in 4OHR-II. For this sugar also, though it was extracted mostly by the concentrated alkalis, the first extraction series resulted in more complete extraction. The residues 4OHR-I and 4OHR-II thus had markedly different compositions: 4OHR-I was composed of more than 90% glucose, presumably cellulose, whereas the composition of 4OHR-II was close to that of the AIR (decrease of xylose and galactose, loss of acetyl and methyl substituents); glucose represented 'only' ~70% of that last residue.

Particle size distribution of the pea hull fibres

Particle size distributions as determined by dry sieving are presented in Fig. 1. In the AIR, after milling, 86% of the particles were between 125 and 500 μm, with 11% above 500 μm and only 3% below 125 μm in size. The residues were then collected after mild drying (solvent exchange) and did not need to be reground. In the CDTA and HCl treatments, particle size distribution appeared to sway towards a greater distribution of particles in the range 0–200 μm (28·3% and 34·3% vs 17·5%, for CSPR, HSPR and AIR, respectively). However, in OHSPR-I and 1OHR-I, the distribution resembled more that seen in the original AIR. The major effect of the chemical treatments was observed after final sequential extraction with 4 M KOH, when average particle size was greatly reduced and consequently approximately 77% of particles were measured in the range 0–200 μm in 4OHR-I. The second extraction procedure had little effect on the average particle size, although particle sizes were more evenly distributed across the range measured, and no longer followed the 'normal' type distribution of particle sizes presented by the AIR. When expressed in terms of average particle size (Table 3) all chemical extraction treatments in the first series appeared to reduce particle size with respect to AIR. However, the trend was not consistent, with

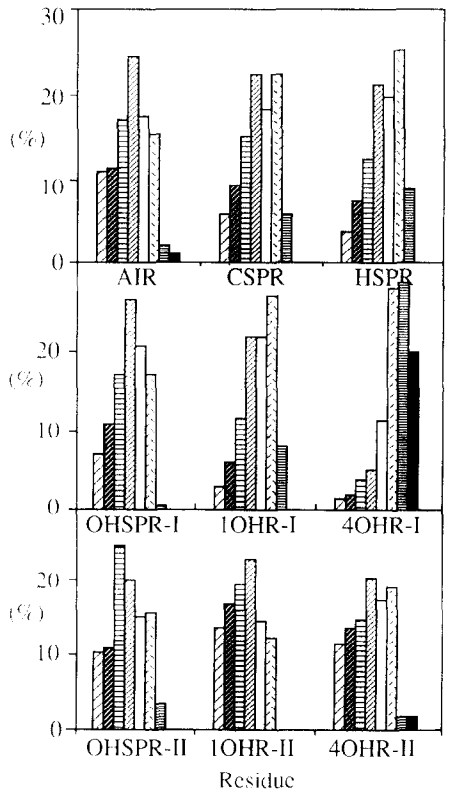

Fig. 1. Particle size distribution of the alcohol insoluble residue (AIR) of pea hulls and its residues, after sequential extraction with CDTA (CSPR), HCl (HSPR), 0·05 M KOH (OHSPR-I), 1 M KOH (1OHR-I) and 4 KOH (4OHR-I) or after sequential extraction with alkali alone (OHSPR-II, 1OHR-II and 4OHR-II, respectively). Particle size ranges (μm): > 500 ▨, 400–500 ▩, 315–400 ▤, 250–315 ▨, 200–250 □, 125–200 ▨, 50–125 ▤, 0–50 ■.

OHSPR-I having a slightly greater average particle size than HSPR. In the second series, chemical extraction with alkali alone had little effect on average particle size.

Physico-chemical properties

Hydration properties of the pea fibre residues were markedly influenced by chemical extraction treatment (Table 3). Hydration capacity was low in the initial AIR (5·2 ml/g), but rose markedly as the pectins were extracted and this was particularly true for WHC, which approximately doubled in OHSPR-I compared with that measured in the AIR. In the first extraction series WHC decreased with further chemical extraction, a value being measured in 4OHR-I which was close to that measured in the initial AIR. Extraction with alkali alone also greatly increased WHC until in 4OHR-II it was more than doubled and similar to the value measured in HSPR. Initial rates of uptake were highest in the alkali-treated residues, and appeared slowest in HSPR and OHSPR-I for comparable WHC values (not shown). WBC was variable and no consistent trends

Table 3. Physico-chemical properties of pea hulls and residues after chemical treatments

Residue	Average particle size (μm)	WHC (ml/g)	WBC (g/g)	SC (ml/g)	CEC (meq/g)
AIR	375	3·2 ± 0·01	7·4 ± 2·19[a]	5·2 ± 0·07	0·52 ± 0·031
First extraction series					
CSPR	315	5·8 ± 0·23	9·5 ± 2·12[a]	8·3 ± 0·84	0·41 ± 0·031
HSPR	285	6·9 ± 0·04	7·8 ± 1·53	13·5 ± 1·40	0·23 ± 0·000
OHSPR-I	340	6·6 ± 0·01	9·2 ± 0·69	12·6 ± 0·45	0·18 ± 0·007
1OHR-I	280	5·9 ± 0·01	7·1 ± 0·70	8·9 ± 0·06	0·14 ± 0·000
4OHR-I	220	3·5 ± 0·27	5·6 ± 0·64	4·9 ± 0·06	0·14 ± 0·000
Second extraction series					
OHSPR-II	360	5·2 ± 0·21	6·1 ± 0·66	8·2 ± 0·35	0·59 ± 0·029
1OHR-II	390	6·2 ± 0·01	7·2 ± 0·36	9·4 ± 0·19	0·67 ± 0·007
4OHR-II	350	7·0 ± 0·14	5·8 ± 0·72	9·9 ± 0·18	0·68 ± 0·007

Values expressed on dry matter basis with relevant standard deviation ($n = 2$ unless otherwise stated).
WHC, water holding capacity; WBC, water binding capacity; SC, swelling capacity; CEC, cation exchange capacity.
[a] SD, $n = 3$.

were seen in response to chemical extractant (Table 3). In fact, pea hulls tend not to form distinct pellets easily using the centrifugation method employed. SC followed a similar trend to that seen for WHC, with over a two-fold increase in SC measured in HSPR and OHSPR-I compared with the initial value measured in the AIR. This increase was followed by a diminution in SC after subsequent extraction with strong alkali. In the alkali-only (second) series, extraction with strong alkali increased swelling by almost a factor of two.

CEC were close to the calculated values taking into account galacturonic acid contents and degree of methylation. In the first series, CEC diminished with chemical extraction such that CEC of 4OHR-I was approximately 27% of the AIR value. In the second series, CEC was augmented after extraction with alkali alone, particularly in 1OHR-II and 4OHR-II.

Microscopy

Examination of the pea hulls by light microscopy enabled a visual comparison of the changes in pea hull structure during chemical extraction to be made. Figure 2a–d shows the micrographs from selected treatments which showed the biggest changes in WHC and average particle size, produced by differential interference contrast microscopy. Preparations stained for pectin with ruthenium red are shown in Fig. 2e–f for both residues after extraction by 4 M KOH. In Fig. 2a, the AIR can be seen to comprise tightly packed cells, which form three distinct layers. The inside layer is a lacunate parenchyma which is in contact with the cotyledons in the mature seed. A second layer contains supporting pillar cells, much fewer in number than the parenchyma cells. The third layer is composed of thin palisade cells approximately 70 μm long, extending towards the outside of the seed and covered at the outer surface (and thus the whole seed) by a thin cuticle. The major cell type in terms of its contribution towards total cell wall material is the palisade cells, which are particularly compact and show thick secondary cell walls. In Fig. 2b, HSPR is presented, showing breakdown of the cuticle, a slight separation of the palisade cells towards the external surface, and much dislocation of the parenchyma cells. In 4OHR-I (Fig. 2c) the cuticle has completely disappeared, the parenchyma cells have been dispersed and only smaller particles containing strongly degraded palisade cells remain. There is now complete separation between adjacent palisade cells, although those that remain in particles appear to be joined at the base, with only thin cell wall skeletons remaining. For comparison with 4OHR-I residue which had reduced particle size, the 4OHR-II fibre is shown (Fig. 2d) which retained the average particle size of the AIR. Here the essential structure is shown intact, although some cuticle has been degraded, and there is some separation or loosening between cells. Selective staining of pectin in the preparations showed that the 4OHR-II (Fig. 2f) residue contained large amounts of non-esterified pectin which shows as grey regions in the cell wall; firstly in the cuticle, secondly in a region approximately halfway along the length of the palisade cells, and also in the parenchyma. By contrast, the cell walls of 4OHR-I (Fig. 2e) are very clear because little or no pectin remains, and so no staining took place.

DISCUSSION

The AIR of pea hulls was rich in total polysaccharides (95% of AIR) a large proportion of which was cellulose, and was characterised by low WHC, low SC and relatively high CEC, reflecting the biological role of the pea

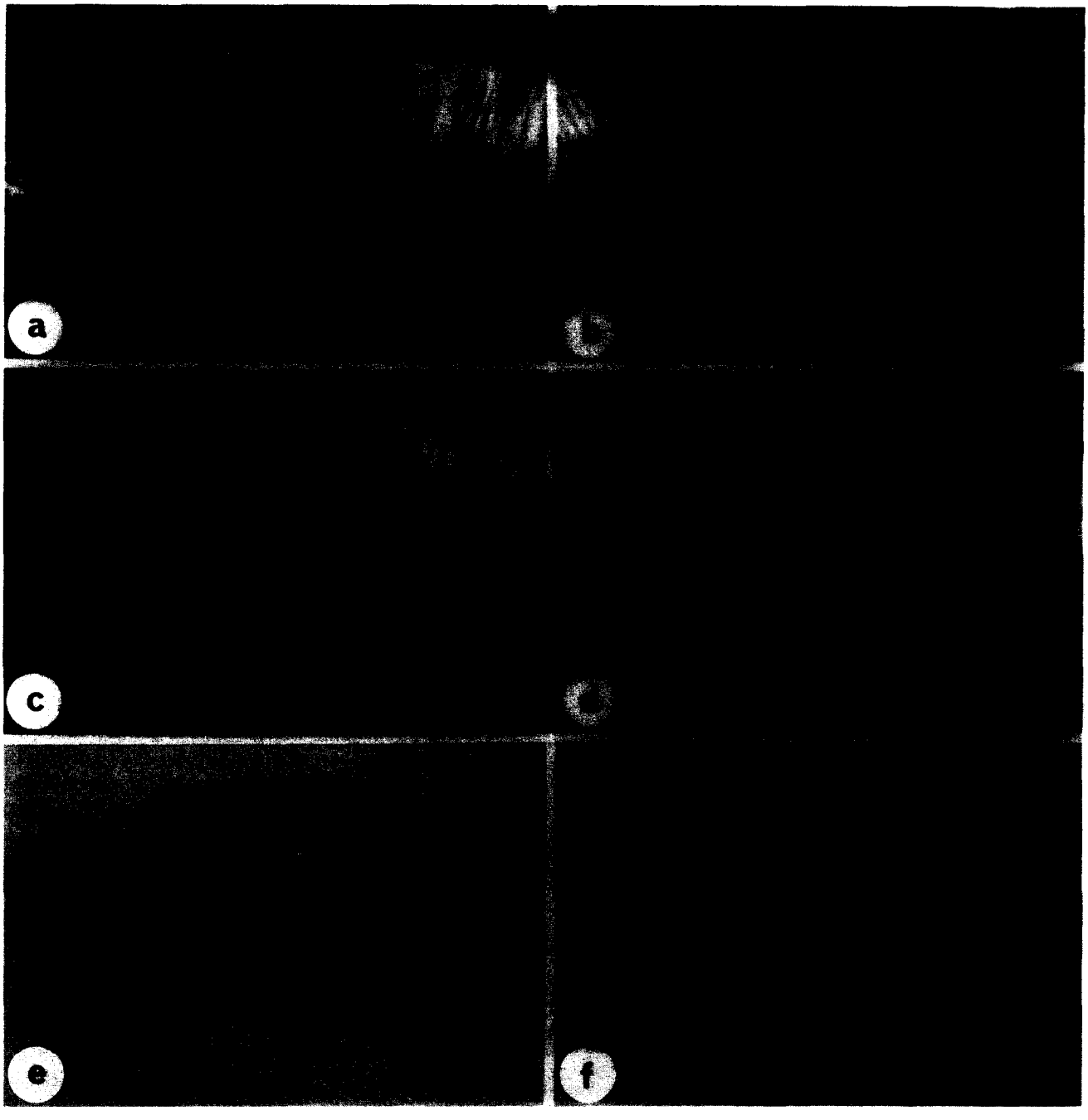

Fig. 2. Light micrographs of (a) the alcohol insoluble residue of pea hulls, and selected residues: (b) HSPR; (c,e) 4OHR-I; (d,f) 4OHR-II, after sequential extraction with chemical agents. See Table 1 for description of treatments. Figures (a–d) produced by differential interference contrast microscopy and (e–f) by treating with a pectin specific stain, ruthenium red. Key: c, cutin; p_l, palisade; s, supporting pillar cells; p_r, parenchyma.

testa as a protective organ during seed dormancy. This contrasts with a fibre source such as sugar beet pulp, which is mainly primary walls from storage cells and has a WBC and SC of 34 g/g and 23 ml/g, respectively (Guillon *et al.*, 1992). The fact that the physico-chemical properties of pea hulls are amenable to chemical modification is probably due to the fact that they are essentially unlignified. Thus the resistance to rehydration and swelling of the native pea hull is likely to be conferred by the presence of tightly packed polysaccharides (notably cellulose) rather than a hydrophobic component.

The fibre preparations CSPR, HSPR and OHSPR-I, recovered after removal of the pectins from the AIR, gave an augmentation in SC, indicating that the pectins were important cross-linking reagents within the pea hull cell walls, which resulted in expansion in these tissues when they were removed. Predictably, the loss of

pectins by these treatments caused a loss of CEC measured in the residues, as also noted for apple fibres (Renard & Thibault, 1991). After depectination, extraction with 1 and 4 M alkali caused a breakdown in cell wall structure of the preparations 1OHR-I and 4OHR-I, followed by a concomitant decrease in their hydration properties and CEC and a change in particle size distribution, so that average particle size in 4OHR-I was only 60% of that in the AIR. This reduction in particle size had little consistent effect on WBC in the present study, but the range in average particle sizes was fairly small (220–390 μm) compared with differences which can be achieved by grinding through different sieve sizes. For example, pea hulls with average particle sizes of 500 and 80 μm had WBC values of 7·0 and 4·6 g/g, respectively (Ralet *et al.*, 1993*a*). WBC was greatly increased in CSPR, HSPR and OHSPR-I. These residues took a relatively long time to reach equilibrium compared with the residues from the alkali-only series. The high swelling capacity in depectinated fibres may explain the longer hydration period of CSPR, HSPR and OHSPR-I, because during measurement of WHC, swelling may have begun on initial uptake of water causing an increased volume within the wall matrix, and this then drove continued uptake of water into the fibre.

By contrast with the first series, the residues OHSPR-II, 1OHR-II and 4OHR-II produced by extracting the AIR with alkali alone, showed marked increases in hydration capacities and in CEC as well. De-esterification of the pectins in alkaline conditions and increased galacturonic acid concentration in these residues resulted in an increase in CEC. Though the hydration capacities of OHSPR-II all increased relative to the initial values, they stayed lower than the values reached for OHSPR-I. It was only for 4OHR-II that all values were superior to those of 4OHR-I. Removal of the xylans which appear to act as 'filler' substances in the pea hull cell walls, may have resulted in a greater pore size in the residues and so greater WHC and SC. Some of the increased WHC and SC may also have been due to the electrostatic repulsion between charged groups, predominantly pectins in the hydrated fibres, especially as the residues from the second extraction series had slightly higher galacturonic acid concentrations after alkaline extraction. However, balancing this phenomenon, would be the fact that the remaining pectins still cross-linked the wall matrix, and so resisted expansionary forces.

Light micrographs of pea hulls and their residues were interpreted by reference to the description given by Gassner (1973). The pea hulls contained three distinct layers of tissue; lacunate parenchyma, pillar cells and palisade cells, with cutin covering the outer face. Much of the total cell wall material appeared to be present in the thickened palisade cells, although parenchyma cells were more numerous. Microscopic examination of the residues confirmed the breakdown in particle size after complete chemical extraction, and the maintenance of basic stucture after alkali-only extraction of the pea hulls. Pectin-specific stain showed much pectin to be present in the cuticle, in selected regions of the palisade cell walls and in the parenchyma. The maintenance of particle size in the second series of extractions may be due to the fact that the cuticle was resistant to alkaline degradation when depectination treatment had not been carried out. Removal of the cuticle would allow more access to the intercellular space between palisade cells, and so, cell separation.

These results confirm that chemical treatments which extract specific classes of polymers provide fibre preparations with modified physical structure. In particular, WHC was increased through removal of pectins, possibly by increasing pores between adjacent palisade cells and increasing swelling. Further removal of xylans and pectins results in cell separation, with a subsequent loss of intercellular spaces which could previously have held water, and so a reduction in WHC. Removal of the xylans and small amounts of pectins using alkali-only extraction, probably also increased pore size by removing the xylans which are the most abundant single group of polysaccharides in the pea hull cell wall after cellulose. Because much of the pectin remained in the cell wall with this second treatment, values for swelling were less than those measured in HSPR and OHSPR-I.

It can be seen that extraction of specific classes of polysaccharides can influence physico-chemical properties in a predictable way in pea hull fibres, and can result in hydration capacities for the modified pea hulls much closer to the values measured in other commercial products such as wheat bran (Van Soest & Robertson, 1976). Chemical agents such as acid and strong alkali may, however, be unsuitable for large scale processing because of environmental problems caused by their disposal. Thus, use of commercial enzymes may offer potential for modification of pea fibres without the environmental costs, and their effectiveness is currently being evaluated in this laboratory.

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