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Cultivar and Maturity Effects on Muskmelon (*Cucumis melo*) Colour, Texture and Cell Wall Polysaccharide Composition

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Abstract: Cell wall polysaccharides (CWP) of two types of melons were isolated and purified. Fractionations were performed using cyclohexane *trans*-1,2-diamine tetraacetate (CDTA), Na_2CO_3, guanidinium thiocyanate (GTC) and KOH. Alditol acetate derivatives of neutral sugars from each CWP fraction were prepared and analysed by gas chromatography. Trifluoro-acetic acid insoluble fractions were analysed colorimetrically and uronic acid was determined. The CDTA and Na_2CO_3 fractions were found to be composed of typical pectic materials containing primarily galacturonic acid with the neutral sugars arabinose, galactose, rhamnose and a smaller amount of xylose. As maturity increased, CDTA fraction yields increased, though total neutral sugar CWP compositions decreased. GTC and KOH fractions were typical of hemicellulose, and contained principally xylose, glucose, galactose, mannose and fucose, with very small amounts of uronic acid, arabinose and rhamnose. The residues contained principally glucose and galactose, with smaller amounts of mannose, xylose, arabinose and fucose. With the exception of xylose and glucose, all neutral sugars decreased significantly during ripening in both the Cantaloupe and Honey Dew melons. Total uronic acid did not change as maturity increased, except for Cantaloupe, where total uronic acid decreased from the ripe to overripe stages. Relationships between firmness, drip loss and other composition measurements, as well as the total CWP sugar composition, were also determined. Only the CDTA fraction yields were negatively correlated with the changes in firmness of both melons and positively correlated with changes in drip loss as maturity increased.

Key words: muskmelons, cell wall polysaccharides, texture, maturity.

INTRODUCTION

The quality of both fresh and frozen muskmelons (*Cucumis melo*) is dictated by colour, flavour and textural parameters. Melon harvest is typically determined by subjective measurements and little information exists on the changes in qualitative properties with maturity. One of the most critical shelf-life limiting quality factors for melons is textural integrity.

Textural modifications observed in intact fruits and vegetables are generally attributed to the metabolism of polysaccharides which are constituents of the cell wall and middle lamella (Ahmed and Labavitch 1980; Huber 1983a; Gross and Sams 1984; Huber and Lee 1986; Brady *et al* 1987; Redgwell *et al* 1990, 1992). Changes in the composition and solubility of cell wall polysaccharides (pectin, hemicellulose and cellulose) with increasing maturity appear to play a major role in melon texture. The most widely reported changes in wall structure of many other fruits are an increase in soluble polyuronides, which are released from the pectic fraction, and a loss of galactose and arabinose residues. Both enzymatic and non-enzymatic mechanisms have been suggested for observed changes in fruit texture.

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Very little information exists on the textural integrity and softening of muskmelons during maturation. McCollum *et al* (1989) found that total polyuronide content, in particular pectin and hemicellulose, decreased while soluble polyuronide content increased with muskmelon ripening and maturation. Gross and Sams (1984) reported a loss of cell wall galactose and arabinose during ripening in 14 of 17 different fruits examined, including muskmelons. Mannose was reported to be constant, fucose and xylose increased, and rhamnose decreased during muskmelon ripening.

This study focuses on the effects of harvest at three different maturity stages on Cantaloupe and Honey Dew muskmelon composition, colour, drip loss, texture and cell wall composition. Relationships between changes in cell wall polysaccharide (CWP) fractions and firmness are also reported, as well as relationships between total sugars with respect to changes in firmness or drip loss.

MATERIALS AND METHODS

Two muskmelon cultivars (*Cucumis melo*), Cantaloupe (Superstar) and Honey Dew (Volga), were harvested from the Hermiston Agriculture Research and Extension Center (Corvallis, Oregon, USA) at three stages of maturity: half-slip, green full-slip and yellow full-slip (Seelig 1973; Evensen 1983; Reed 1991, per comm) and stored at 2°C prior to processing. Underripe, ripe and overripe melons of both cultivars were randomly divided into two replicate groups, processed separately into melon discs 1·2 cm in thickness and 2·2 cm in diameter, and then mixed thoroughly prior to packaging. Subsamples were taken for determination of composition, firmness and colour and discs were stored at −40°C prior to CWP which took place within 6 days.

Determination of pH, titratable acidity and soluble solids

Melon homogenate pH was measured using a Metrohm 605 pH meter and an automatic titrator. Sample homogenates (10 g) were mixed with 40 ml distilled water, from which 10 ml of solution was titrated with 0·1 M NaOH until an end-point pH of 8·1 was achieved (TTA 80 titration assembly, Brinkmann-Metrohm, Herisau Inc, Switzerland). Total acid was calculated as percent (w/w anhydrous) citric acid. Soluble solids (°Brix) were determined from filtered melon homogenate using a Bausch and Lomb refractometer (20°C).

Determination of moisture content and drip loss

Duplicate 10-g melon disc homogenates were vacuum dried at 60°C for 24 h and moisture was calculated as weight loss times 100 over sample weight. Drip loss determination was carried out on frozen discs 5 days after harvest. Duplicate 150 g samples were placed on a #8 metal screen and exudate was collected in a 50 ml glass cylinder after 2 h at room temperature. Drip loss was calculated as the percentage difference between initial and final melon weight.

Determination of firmness and colour

Firmness (g force) was determined using a penetrometer (Sears Craftsman model 335.25926), fitted with a 5 mm diameter tip. Two readings were recorded from each of 20 replicate discs and the average calculated. Melon disc homogenate colour was determined using a Colorquest Hunterlab (specular included mode) reflectance meter. L (lightness), a (redness to greenness), and b (yellowness to blueness) values were recorded and hue angle ($\theta°$) was calculated as follows: θ (°) = arctangent a/b.

Isolation of cell wall polysaccharides

Cell wall polysaccharides were isolated following a modification of the method of Redgwell *et al* (1988). Duplicate 1000 g samples of frozen discs were cryomilled with 1 l of liquid nitrogen (−196°C) to a fine powder and blended with 1350 ml 15 g litre^{-1} aqueous sodium laurylsulphate (SLS) containing 5 mM sodium metabisulphite ($Na_2S_2O_5$) and a few drops of octanol for 2 min at 2°C. The suspension was centrifuged for 10 min at 23 000 × g (2°C), the supernatant decanted and the residue washed twice with 400 ml cold (2°C) distilled water. Washes and supernatants were combined and filtered using 1 μm pore glass fiber filter paper (type A/E Gelman Sciences) to recover the residue.

Residues were stirred with 400 ml phenol/acetic acid/water (PAW; 2 : 1 : 1, w/v/v) for 1 h in an ice bath to remove non-covalently bound proteins and glycoproteins, then washed four times with 400 ml of cold distilled water followed by centrifugation. Supernatant washings of PAW treatments were combined and filtered to recover residues. Iodine tests for the presence of starch in the CWP preparations were negative. Residues were dialysed against cold distilled water (2°C) with a change of water each 6 h for 10 repetitions, dialysed materials were centrifuged and residues freeze-dried for 75 h (−70°C, 2 Pa vacuum, Labconco freeze-drier). Freeze-dried residues were placed in a desiccator containing P_2O_5 prior to weighing, CWP yields were recorded and the material was stored at −40°C prior to fractionation.

Fractionation of cell wall polysaccharide

Fractionation of CWP was based on the modified method of Selvendran and O'Neill (1987) which

employed 200 ml each of 0·05 M cyclohexane-trans-1,2-diamine tetra acetate (CDTA), 0·05 M Na_2CO_3, 6 M guanidinium thiocyanate (GTC), 4 M KOH, and cold (2°C) distilled water for washing. To isolate CDTA soluble pectins, 2 g CWP were stirred with 0·05 M CDTA at pH 6·5 for 6 h (20°C) then centrifuged at 23 000 × *g* for 10 min. The 0·05 M CDTA treatment was repeated with stirring for another 2 h and both residues and supernatants were combined. The residue was washed twice with cold distilled water, centrifuged and both washings combined with the supernatant. Supertnatants of all isolated fractions were filtered through glass fibre filter paper and dialysed using spectra por (6000–8000 MW cutoff) membranes against distilled water at 2°C, with a change each 6 h (10 repetitions). Dialysed materials were concentrated using polyethylene glycol (MW = 10 000), redialysed, then freeze-dried.

Following the CDTA treatment, the residue was stirred into 0·05 M Na_2CO_3 containing 20 mM $NaBH_4$ at 2°C for 20 h, then stirred for an additional 2 h at 20°C to isolate the CDTA insoluble pectins. The suspension was centrifuged and the supernatant collected. This treatment was repeated for 2 h at room temperature, the residue and supernatant were collected and the residue was washed twice with cold distilled water. Washings were combined with the supernatant and treated as above.

To isolate guanidinium thiocyanate (GTC) soluble hemicellulose, the residue was stirred into 6 M GTC at room temperature for 18 h under nitrogen gas, centrifuged and the supernatant was collected. The residue was resuspended in 6 M GTC at room temperature for an additional 2 h under nitrogen, centrifuged and washed twice with 200 ml cold distilled water. Washings were combined with the supernatant and treated as above.

The GTC-insoluble hemicellulose fraction was isolated by twice stirring the residue into 4 M KOH containing 20 mM $NaBH_4$ for 2 h and centrifuging. The supernatant was collected and was washed twice with cold distilled water. Washings were combined with the supernatant and treated as above.

The residue (α-cellulose) was dialysed then freeze-dried. All fractions were placed in a desiccator containing P_2O_5 prior to final weighing and stored in a Teflon screw capped vial at −40°C prior to analysis.

Analysis of neutral sugars

Analysis of the CWP fractions for neutral sugars was based upon the method of Albersheim *et al* (1967). Duplicate 20 mg samples CWP fraction were hydrolysed in 2 ml 2 M TFA, heated at 121°C for 1 h in a heating block, cooled, then filtered through glass fibre filter paper. TFA insoluble materials were analysed using the phenol-sulphuric acid method (see below). The filtrate was dried using filtered air (40°C) and 1 mg myo-inositol was added as an internal standard to 0·5 ml 1 M ammonia containing 10 mg $NaBH_4$ (added to reduce sugars and produce alditols) and allowed to sit for 1 h at room temperature. Excess $NaBH_4$ was removed by the dropwise addition of glacial acetic acid until effervescence ceased. The mixture was washed and dried with 5 × 1 ml methanol, using filtered air at 40°C. One millilitre acetic anhydride was added and the samples were heated at 121°C for 3 h to produce the alditol acetates. Standards were prepared in the same manner.

One duplicates (standard and sample) of the alditol acetates were injected onto a Varian aerograph series 1200 gas chromatograph, with a stainless-steel column (2 m × 2·2 mm id) packed with SP 2330 on 100/120 Supelcoport. The initial temperature of 150°C was maintained for 2 min, then raised to 220°C at the rate of 20°C min^{-1} and maintained for an additional 25 min. Nitrogen (20 ml min^{-1}) was used in the carrier gas and a flame-ionisation detector (FID) with hydrogen gas was used for detection.

Trifluoro-acetic acid insoluble fraction analysis

TFA insoluble materials were determined by the phenol–sulphuric acid method for total sugar determination, following the method of Dubois *et al* (1956). Preliminary analyses indicated that 4 ml concentrate (720 g kg^{-1}) H_2SO_4 was required to dissolve and hydrolyse the polysaccharide from the CDTA, Na_2CO_3, GTC and KOH fractions, and 50 ml 720 g kg^{-1} H_2SO_4 was required to dissolve and hydrolyse the residue fractions. Glass-fibre filter paper containing TFA insoluble material was placed in a beaker with H_2SO_4, shaken and allowed to sit at room temperature for 3 h. A duplicate 1 ml solution was diluted with 11·6 ml distilled water, and heated in a boiling water bath for 2 h (Selvendran *et al* 1979).

Five standard glucose solutions (2 ml) were prepared containing 10, 20, 30, 40 and 50 μg glucose respectively. Fifty 800 g kg^{-1} microlitres phenol followed by 5 ml concentrated H_2SO_4 were added to samples and standards, tubes were allowed to stand for 10 min at room temperature, then shaken in a water bath at 25°C for 20 min and absorbance read at 486 nm (Shimadzu spectrophotometer, model UV160U).

Analysis of uronic acid

Uronic acid analysis followed the method of Blumenkrantz and Asboe-Hansen (1973). Duplicate 10 mg CWP fractions were mixed with 0·5 ml 720 g kg^{-1} H_2SO_4 for 3 h at 20°C, diluted with 6 ml distilled water and filtered through glass fibre filter paper. A cold test tube was filled with 1 ml filtrate and mixed with 6 ml

0·0125 M sodium tetraborate ($Na_2B_4O_7$) in concentrated H_2SO_4. Galacturonic acid standards (five 1 ml solutions containing 5·0, 10·0, 15·0 and 20·0 μg, respectively) were prepared, the tubes were heated (100°C) for 5 min and cooled prior to addition of 0·1 ml 1·5 g litre^{-1} *m*-hydroxybiphenyl in 0·125 M NaOH. The solution was shaken and absorbance at 520 nm was read after 5 min. The amount of uronic acid in each CWP fraction was calculated using standard curve for galacturonic acid.

Statistical analysis

A two-way analysis of variance (ANOVA) was used to compare cultivars and maturity stages for composition, firmness, drip loss, colour, CWP yields, CWP fraction yields and the neutral sugar compositions of CWP fractions.

RESULTS AND DISCUSSION

pH and titratable acidity

Honey Dew melons had a lower pH than did Cantaloupe and for both cultivars there was slight progressive increase in pH from underripe to ripe and overripe stages of maturity (Table 1). It was also observed that titratable acidity (TA) was higher in Honey Dew melons than in Cantaloupe and decreased for both as maturity increased from underripe, to ripe and overripe stages. A similar increase in pH was also reported by Lester and Dunlap (1985) during the development and ripening of 'Perlita' muskmelon fruits and a similar decrease in TA was reported in muskmelon by Reddy (1986).

Soluble solids

Soluble solids (SS) levels in Honey Dew melons were higher than in Cantaloupe, and in both cultivars there was an increase in SS coincident with increased maturity (Table 1). The SS range was from 8·45% to 10·10% for the three stages of maturity for Cantaloupe and from 9·45% to 12·70% for Honey Dew melon. Significant changes in SS ($P < 0·01$) were observed in both melons as maturity increased.

Firmness, drip loss and moisture content

Honey Dew had significantly higher firmness and lower drip loss compared with Cantaloupe melons (Table 1). In both types of melons, an inverse relationship between firmness and drip loss was observed and, with increasing maturity, firmness decreased and drip loss increased. Similar observations have been reported by previous investigators (Reddy 1986; Miccolis and Saltveit 1991) for muskmelons. The moisture content of Cantaloupe melons increased slightly whereas that for Honey Dew decreased as maturity increased (Table 1). However, differences in moisture content between the two cultivars for the different stages of maturity were quite small and these values were similar to those reported by previous investigators (Pratt 1971; Eitenmiller *et al*).

Colour

Increases were observed in Hunter *a* (red to green) values from the underripe to ripe stages in both Cantaloupe and Honey Dew melons, whereas *b* values (yellow to blue) decreased (Table 1). The positive and negative *a* values indicate the redness or greenness, respectively, of an object. Therefore it is reasonable to observe a positive *a* value for Cantaloupe, which is orange in colour, and a negative *a* value for Honey Dew melon, which is greenish in colour (Table 1). Cantaloupe redness increased, while Honey Dew greenness decreased from a given stage of maturity to the next.

The *b* values, which provide an indication of yellowness, were positive for both cultivars. The *b* value of Cantaloupe increased slightly from the underripe to the ripe then decreased from ripe to overripe stages.

TABLE 1
Composition, firmness and colour of melon discs at different maturities

Cultivar	*Maturity stages*	*pH*	*TA*[a] (%)	*SS* (°*Brix*)	*Firmness* (*g*)	*Drip loss* (%)[b]	*Moisture* (%)[b]	*Colour*			
								L	*a*	*b*	*Hue angle* (°)
Cantaloupe	Underripe	6·19	0·08	8·5	290	10·6	90·4	47·3	9·2	19·7	25·1
	Ripe	6·49	0·05	9·2	189	12·9	91·4	44·4	12·3	22·7	28·5
	Overripe	6·87	0·04	10·1	140	14·0	92·0	43·9	12·4	20·9	30·7
Honey Dew	Underripe	5·65	0·16	9·5	1290	10·2	90·4	58·3	−7·9	21·4	−20·2
	Ripe	6·16	0·08	11·0	1201	11·2	89·2	54·9	−7·4	20·8	−19·7
	Overripe	6·43	0·07	12·7	877	13·8	88·8	61·9	−7·1	20·2	−19·3

[a] TA is % w/w anhydrous citric acid.
[b] % is w/w.

Whereas the *b* value of Honey Dew decreased as maturity increased.

Lightness (*L* value) decreased slightly (ie melon became darker in colour) in the Cantaloupe as maturity increased. In the Honey Dew there was a decrease in *L* value from the underripe to ripe stages, followed by an increase from the ripe to overripe stages. Hue angle increased with maturity in both melons (Table 1), indicating a change from light to darker orange in Cantaloupe and a decline in greenness in Honey Dew.

The Cantaloupe colour observations were reasonable since β-carotene (orange in colour) is subject to increase during the development and ripening of melons (Pratt 1971; Lester and Dunlap 1985). The decrease in green colour in the Honey Dew melons was most likely due to a decline in the chlorophyll content as the fruit developed and ripened (Pratt 1971). The *a* values demonstrated consistent increases for both Cantaloupe and Honey Dew as maturity increased. Therefore *a* and hue angle values appeared to provide a good indication of maturity.

Cell wall polysaccharide yields

As shown in Table 2, CWP yields for Honey Dew were higher than for Cantaloupe. Dry CWP yields for Cantaloupe were 5·0, 4·9 and 4·8 mg g^{-1} of fresh weight for the three respective stages of maturity (underripe, ripe, and overripe), whereas those for the Honey Dew were slightly higher (5·6, 5·2 and 5·1 mg g^{-1}).

There was no significant changes in CWP yields as maturity increased for either cultivar. Since cellulose has the function of providing rigidity and resistance to tearing, whereas the pectins and hemicelluloses contribute to plasticity and the ability to stretch (Van Buren 1979), higher CWP yields for the Honey Dew melon were most likely contributor to its greater firmness, especially since a large percentage of the CWP consists of α-cellulose (Table 2).

Cell wall polysaccharide fraction yields

There were significant differences observed between Cantaloupe and Honey Dew melons in terms of CWP fractions yields (Table 2). In Cantaloupe the CDTA fraction (pectin) yield increased by 10% from underripe to ripe stages and by 14% from the ripe to overripe stages, whereas comparative increases for the Honey Dew melon were 21% and 33%. The increase in CDTA fraction yields suggests that modification and solubilisation of pectins occurred as the maturity of both melons increased.

CWP were not fractionated with distilled water because most water-soluble pectins had already been removed during the process of isolating and purifying CWP. It was found that the use of 0·05 M CDTA solubilised the water-soluble as well as chelator-soluble pectins, resulting in an increase in the CDTA fraction as maturity increased.

The decrease in Na_2CO_3 (CDTA insoluble pectin) fraction yields most likely occurred because more pectins were extracted by CDTA as maturity increased. The GTC (hemicellulose) fraction decreased as maturity increased in the Cantaloupe, whereas in Honey Dew it

TABLE 2
Yields of CWP and CWP fractions of Cantaloupe and Honey Dew at different maturities

	Underripe (mean)	*SD*	*Ripe (mean)*	*SD*	*Overripe (mean)*	*SD*
Cantaloupe						
CWP mg g^{-1} FW melon discs[a]	4·95	0·05	4·92	0·06	4·84	0·06
CWP fraction mg g^{-1} CWP[b]						
CDTA	195·00	2·58	215·00	4·13	246·00	5·10
Na_2CO_3	145·00	4·25	113·00	2·26	89·20	3·03
GTC	112·00	2·77	79·50	2·49	68·30	4·38
KOH	128·00	2·41	131·00	2·88	138·00	4·80
Residue	461·00	12·10	499·00	13·40	504·00	16·80
Honey Dew						
CWP mg kg^{-1} melon discs[a]	5·59	0·06	5·20	0·06	5·09	0·10
CWP fraction mg g^{-1} CWP[b]						
CDTA	186·00	6·07	225·00	7·69	300·00	3·79
Na_2CO_3	132·00	2·90	82·50	2·74	83·60	2·56
GTC	76·8	2·74	136·00	3·61	73·80	3·79
KOH	168·00	6·50	78·50	2·50	89·30	2·93
Residue	466·00	15·90	516·00	17·30	515·00	13·20

[a] The average of two isolations.
[b] The average of two fractionations (duplicate) from combination of the two.

increased by 77% from underripe to ripe, followed by a decrease to 4% lower than its underripe level at the overripe stage.

In general, as maturity progressed differences were observed between Cantaloupe and Honey Dew melons in terms of the fractions solubilised by GTC and KOH. The increase in hemicelluloses solubilised by GTC and decrease in the KOH fraction in Honey Dew from underripe to ripe suggests that modification and solubilisation of hemicelluloses occurred during ripening, whereas in Cantaloupe degradation to smaller molecular weight polymers may have occurred after the solubilisation of the hemicelluloses, as maturity increased (Huber 1983b; Redgwell *et al* 1991). For the same reason, from ripe to overripe in Honey Dew, hemicelluloses may have been degraded, resulting in the decrease of GTC soluble hemicelluloses.

The KOH-soluble hemicelluloses did not change in Cantaloupe as maturity increased, whereas in Honey Dew a decrease of KOH soluble hemicelluloses occurred from underripe to ripe, and then increased from ripe to overripe stages. During the ripening of kiwifruits, Redgwell *et al* (1991) reported that both GTC- and KOH- soluble hemicellulose fractions increased. Huber and Lee (1986) reported a trend of consistent decrease in high molecular weight and increase in low molecular weight polymers for 4 M NaOH soluble hemicelluloses during the development of tomato fruits from immature green to ripe. Extraction with GTC was not performed and hemicellulose yield was not reported by Huber and Lee (1986).

There was a slight increase in the weight of the residue fractions from underripe to the ripe stages, 8% and 11%, respectively, for Cantaloupe and the Honey Dew, but there were no further changes from the ripe to overripe stages. Though the residue (α-cellulose) fraction in the Honey Dew was only slightly higher than that in Cantaloupe, this could have contributed to the greater firmness of Honey Dew melons (Table 1).

The firmness of both Cantaloupe and Honey Dew was inversely related to CDTA fraction yields (Tables 1 and 2). The increase in CDTA fraction yield may have been due to the degradation and solubilisation of pectins which typically occurs as maturity increases (Bartley and Knee 1982; Regwell *et al* 1991).

Carbohydrates in cell wall polysaccharide fractions

Neutral sugars in TFA soluble fractions

Results summarised in Table 3 indicate that arabinose, galactose and rhamnose were the major components of the CDTA and Na_2CO_3 fractions, and were subject to decrease as maturity increased. These fractions also had the greatest amount of uronic acid. Thus, CDTA and Na_2CO_3 fractions were typical of pectic polysaccharide contents reported for other plant materials (Bartley and Knee 1982; Redgwell *et al* 1990; Selvendran and Ryden 1990).

Typical of most hemicellulose components, xylose, glucose, galactose and mannose were the principal sugars found in the GTC and KOH fractions in both Cantaloupe and Honey Dew. The GTC and residue fractions contained only a small amount of rhamnose, which was not detected in the KOH fraction. Although arabinose, xylose and galactose were found in all CWP fractions, arabinose was found primarily in the CDTA and Na_2CO_3 (pectin) fractions, whereas the greater part of the xylose galactose were found in the hemicellulose and residue fractions.

Glucose content in the GTC and residue fractions increased from the underripe to ripe stages of maturity, then decreased from the ripe to overripe stages in both Cantaloupe and Honey Dew. Compared with GTC and KOH fractions, the residue fraction had the highest glucose content. In Cantaloupe, total glucose in the TFA soluble fraction was the highest, followed by xylose, galactose and arabinose, in that order. In Honey Dew, total galactose was highest, followed by glucose and then xylose and arabinose. The amounts of TFA insoluble materials did not change as maturity increased for either melon cultivar, though the total sugars in the TFA- insoluble fraction of Honey Dew were slightly higher than for Cantaloupe.

Use of TFA may result in incomplete hydrolysis of cell wall materials (eg cellulose) and therefore may result in an underestimation of sugars. Although TFA may solubilised polymers the process may be incomplete, unless hydrolysis to monomers is achieved, and therefore interpretation should be limited. The authors recognise that use of a mhdp test would complement the data but, for the purpose of this study, results of the TFA hydrolysis were still able to provide an index to the effectiveness of the cell wall fractionation procedure. Results indicate changes in neutral sugars with maturity and reflect solubilisation of different fractions

Total TFA soluble sugars

As the maturity of both Cantaloupe and Honey Dew increased, the proportion of almost all sugars, including galactose, mannose, arabinose and rhamnose, decreased significantly ($P < 0{\cdot}01$) (Table 3). The exceptions were that xylose and glucose increased from the underripe to ripe stage, then decreased from the ripe to overripe stages. Since these sugars are components of both pectin and hemicellulose fractions, these observations suggest that both fractions may have been modified as maturity progressed.

Gross and Sams (1984) reported only a decrease in galactose and arabinose in muskmelon and squash cell walls during maturation and ripening, while mannose, fucose and rhamnose either remained constant or increased as melon maturity was increased. The difference in their observation may have been due to the fact

TABLE 3
Sugar composition of cantaloupe CWP fractions (mg g^{-1} CWP) at different maturities

	CWP fraction	Neutral sugars in TFA soluble fraction[a]							Total TFA soluble[b]	TFA insoluble[c]	Uronic acid[d]	Total sugars
Cantaloupe												
Underripe	CDTA	1·56	nd	4·13	0·44	nd	2·53	nd	8·66	16·10	196·00	220·00
	Na_2CO_3	1·29	nd	4·49	0·62	nd	3·83	nd	11·60	12·10	128·00	151·00
	GTC	0·25	0·92	1·51	10·90	1·82	3·72	5·36	24·50	3·35	25·80	53·60
	KOH	nd	2·95	0·42	20·10	4·64	6·22	17·70	52·00	2·20	13·80	68·00
	Residue	1·02	tr	2·88	2·24	2·59	6·40	16·20	31·30	316·00	88·80	437·00
	Total	4·13	3·87	13·40	34·0	9·06	22·70	39·30	128·00	350·00	452·00	930·00
Ripe	CDTA	1·05	nd	3·67	0·60	nd	2·49	nd	7·81	14·60	222·00	245·00
	Na_2CO_3	0·70	nd	3·12	0·58	nd	1·56	nd	6·98	7·95	107·00	122·00
	GTC	0·29	0·89	2·07	17·50	1·66	3·55	9·23	35·50	3·61	19·70	58·80
	KOH	nd	2·25	0·34	20·20	3·57	5·54	17·70	49·60	2·47	11·10	63·10
	Residue	1·04	0·71	2·79	2·93	2·86	6·55	18·10	35·00	320·00	82·80	438·00
	Total	3·09	3·84	12·00	41·80	8·09	19·70	45·10	135·00	349·00	443·00	926·00
Overripe	CDTA	0·98	nd	3·46	0·45	nd	1·48	nd	6·36	17·10	252·00	276·00
	Na_2CO_3	0·35	nd	1·27	0·50	0·17	1·45	0·14	4·97	2·70	47·00	54·70
	GTC	0·34	0·50	0·90	5·02	1·82	2·45	5·50	16·50	1·54	15·90	33·90
	KOH	nd	1·59	0·42	13·80	2·04	3·87	8·31	30·60	2·19	12·00	44·80
	Residue	0·81	1·39	2·26	2·48	2·05	6·70	12·50	28·20	313·00	75·00	416·00
	Total	2·48	3·48	8·31	22·20	6·07	15·90	26·40	86·60	336·00	402·00	825·00
Honey Dew												
Underripe	CDTA	2·13	nd[e]	5·93	0·29	nd	9·51	nd	18·30	23·00	164·00	205·00
	Na_2CO_3	0·70	nd	3·47	0·58	nd	6·14	nd	12·10	6·44	111·00	129·00
	GTC	tr[f]	1·18	1·53	7·59	3·57	8·07	13·50	35·50	2·09	20·10	57·70
	KOH	nd	1·47	1·43	10·90	3·29	6·12	9·09	32·30	4·39	22·50	59·20
	Residue	0·52	tr	4·49	1·93	2·73	15·70	18·90	44·30	362·00	101·00	507·00
	Total	3·35	2·64	16·90	21·30	9·58	45·60	41·50	142·00	398·00	418·00	958·00
Ripe	CDTA	1·45	nd	5·14	0·95	nd	7·86	nd	15·40	28·50	191·00	235·00
	Na_2CO_3	0·31	nd	1·33	0·20	nd	2·49	nd	4·32	5·01	60·70	59·10
	GTC	0·20	0·70	1·74	12·70	4·13	6·75	19·80	47·30	4·44	25·80	93·20
	KOH	nd	0·47	0·46	7·59	1·31	2·39	3·41	15·70	1·92	7·40	25·10
	Residue	tr	1·10	4·20	1·82	1·94	16·70	22·20	48·00	365·00	118·00	531·00
	Total	1·95	2·26	12·90	23·30	7·38	36·20	45·50	1310·00	405·00	403·00	944·00
Overripe	CDTA	1·05	nd	4·01	0·45	nd	4·89	nd	10·40	27·30	210·00	248·00
	Na_2CO_3	0·34	nd	1·21	0·41	nd	2·90	nd	5·86	2·39	43·50	39·10
	GTC	0·05	0·54	0·87	8·45	1·08	3·86	9·44	24·30	1·99	18·80	57·70
	KOH	nd	0·40	0·16	4·04	0·92	1·11	3·06	9·69	1·46	7·47	18·60
	Residue	tr	1·19	3·24	3·93	3·79	11·60	21·90	45·70	364·00	117·00	527·00
	Total	1·44	2·13	9·49	17·30	5·78	24·40	34·40	96·00	397·00	397·00	890·00

[a] Rham, rhamnose; Fuc, fucose; Ara, arabinose; Xyl, xylose; Man, mannose; Gal, galactose; Glu, Glucose. Mean TFA soluble values from four injections.
[b] As determined as alditol acetates.
[c] As determined by phenol–sulphuric acid assay.
[d] As determined by mhdp method.
[e] nd, not detected, $\leqslant 0{\cdot}02$ mg g^{-1} CWP.
[f] tr, trace.

that different CWP isolation and fractionation methods were used.

TFA insoluble fractions

TFA insoluble fractions were analysed to facilitate recovery calculations of CWP fractions. It was then possible to calculate total sugars (Table 3) by adding together TFA soluble. TFA insoluble and uronic acid. The amount of sugars found in the TFA-insoluble fraction was much larger than that found in the TFA soluble fraction which was 10–14% of the CWP (weight). Total sugars in the TFA insoluble fractions for Cantaloupe and Honey Dew did not change as maturity increased.

Generally, total sugars from TFA insoluble fractions were higher in Honey Dew than in Cantaloupe at the

same level of maturity. This suggests that TFA insoluble materials may also contribute to the higher degree of firmness in the Honey Dew (Table 1). However, there were no significant correlations between TFA insoluble fractions and firmness as maturity progressed.

Uronic acids in CWP fractions

The CDTA fraction, followed by the Na_2CO_3 and residue fractions, had the highest uronic acid content in the underripe and ripe stages of Cantaloupe and in the underripe of Honey Dew. However, the CDTA followed by the residue and Na_2CO_3 fractions were highest in uronic acid content in the overripe stage of Cantaloupe and in ripe and overripe stages of Honey Dew (Table 3).

McCollum *et al* (1989) determined that the total polyuronides in ethanol-insoluble powder (EIP) from the cultivar Galia muskmelon in preripe, ripe and overripe stages were only approximately one-half of the total uronic acid measured in this study. Values for both studies were obtained using the Blumenkrantz and Asboe-Hansen (1973) method. The difference in these results may be due to the different methods of isolating cell wall materials. Total uronic acids were determined by McCollum *et al* (1989) from extractions based upon an Na-acetate buffer containing 20 mM disodium ethylenediamine tetraacetate (Na_2-EDTA) at pH 5·0 and incubated for 24 h at 23°C. In our study, total CWP uronic acids were determined from all five CWP fractions measured.

Uronic acids in the CDTA fractions increased, but decreased in Na_2CO_3 fractions, whereas total CWP uronic acids did not change as maturity progressed in Honey Dew melons and did not change in total uronic acid of Cantaloupe from underripe to ripe, but decrease from ripe to overripe. However, changes in total uronic acid in the Honey Dew were less obvious. This observation is slightly different from that of Ahmed and Labavitch (1980) for ripening pear fruits where it was observed that the uronic acid content of fruits declined sharply as the fruit softened.

In the GTC and KOH fractions compared with the other fractions, the amount of uronic acids was lower for both melons as maturity increased. The uronic acid in the KOH fractions of Cantaloupe increased from the underripe to ripe, then decreased in the overripe stage, whereas in Honey Dew uronic acid in the KOH fractions increased as maturity increased.

Relationship between firmness and total sugars

Firmness was inversely related to drip loss in both Cantaloupe and Honey Dew melons as maturity increased. With increased maturity, firmness decreased and drip loss increased as rhamnose, fucose, arabinose, mannose and galactose also decreased. This suggests that both pectin and hemicellulose were solubilised from the muskmelon CWP as softening occurred. Prior to solubilisation, polysaccharide degradation into smaller molecules may have occurred. It is likely that these molecules were discarded during the isolation and purification of CWP, causing a decreasing in total sugars as maturity increased.

CONCLUSIONS

There were significant differences between Cantaloupe and Honey Dew melons in terms of composition, firmness and colour, however, these parameters showed the same types of changes as maturity increased. In general, Honey Dew melons were significantly firmer and showed lower drip loss than Cantaloupe melons. Cantaloupe melons showed an increased red colour while Honey Dew were less green with maturity.

Decreased neutral sugar composition in the CWP of both melons was evidenced as maturity increased. Decreases in rhamnose, arabinose, mannose and galactose suggest that both pectins and hemicellulose were modified and solubilised as maturity increased. The fact that CWP yields and TFA insoluble sugars were higher in Honey Dew may be correlated to its greater firmness compared with Cantaloupe melons. In both Cantaloupe and Honey Dew melons, firmness was inversely related to CDTA fraction yields and firmness was positively correlated with total sugars (rhamnose, arabinose, mannose and galactose) in the TFA- soluble fraction.

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