



THE CHARACTERIZATION OF SUGAR BEET PECTIN USING THE EcoSEC® GPC SYSTEM COUPLED TO MULTI-ANGLE LIGHT SCATTERING, QUASI-ELASTIC LIGHT SCATTERING, AND DIFFERENTIAL VISCOMETRY

Amandaa K. Brewer, P.h.D, Tosoh Bioscience LLC, Hoa K.Chau, Arland Hotchkiss, and Marshall L. Fishman, Dairy and Functional Food Unit, Eastern Region Research Center, Agricultural; Research Service, U.S. Department of Agriculture*

ABSTRACT

The need to increase the use of low valued co-products derived from the processing of sugar beets has prompted the investigation of the structure of the pectin extracted from sugar beet pulp. The characterization of sugar beet pectin is essential as it has the potential to be used in the production of industrial products, e.g., as an emulsifying agent in food systems. This added use of sugar beet pectin should be of help to sugar beet growers and processors by increasing the demand and value of their by-product without increasing the cost of sugar to the consumer. Here we discuss the characterization of sugar beet pectin utilizing the EcoSEC GPC System with an internal dual-flow differential refractive index detector and UV detector coupled to multi-angle light scattering, quasi-elastic light scattering, and differential viscometry. Implementing this multi-detector SEC technique allowed for the determination of the molar mass averages, in a calibrant-independent fashion, as well as several sizing parameters.

INTRODUCTION

An estimated 2 million tons of dry sugar beet pulp is generated annually by U.S. industries as a result of the extraction of sugar from sugar beets¹. Currently sugar beet pulp is

mainly dried and sold as low-value animal feed at little profit because of the costly energy required to dry it for storage and shipment. Sugar beet pulp, especially the high molar mass pectin portion, has the potential to be an enormous untapped source of a valuable polysaccharide for U.S. industry. The need to increase the utilization of low-value co-products derived from the processing of sugar beets has prompted the investigation of the structure of the pectin extracted from sugar beet pulp.

Sugar beet pulp on a dry weight basis is composed of about 67% plant cell wall polysaccharides, 19% of which are pectin, 21% pectin-associated arabinan, and 24% cellulose¹, all of which can potentially add value to the pulp if isolated and characterized. The pectin in sugar beets has different chemical features than that from other sources of pectin, i.e. citrus, as the former tends to have a higher degree of acetylation, a higher natural sugar content, and contains feruloyl groups. Furthermore, unlike citrus pectin which is currently used as a gelling and thickening agent, sugar beet pectin (SBP) has very poor gelling properties, thus the isolation and characterization of it could result in new applications, especially in the production of industrial products. Thus far, SBP has demonstrated the potential to be used as an emulsifying agent in food systems, as it has been found to reduce the interfacial tension between oil and water phases¹. The capability of SBP to reduce surface tension has been attributed to the presence of acetyl groups and hydrophobic proteins in SBP preparations².

PHYSICAL PROPERTIES OF SUGAR BEET PECTIN

	Detection Method			
	RI	UV@250 nm	UV@278 nm	UV@ 310 nm
M_w (g/mol) ^a	1.098 x 10 ⁶ (0.003 x 10 ⁶) ^b	1.097 x 10 ⁶ (0.004 x 10 ⁶)	1.147 x 10 ⁶ (0.004 x 10 ⁶)	1.187 x 10 ⁶ (0.002 x 10 ⁶)
$R_{G,z}$ (nm) ^a	43 (1)	43 (1)	45 (1)	42 (1)
$R_{H,z}$ (nm) ^c	53 (1)	43 (1)	43 (1)	44 (1)
$[\eta]_w$ (dL/g)	3.5 (0.1)	3.4 (0.1)	3.5 (0.1)	3.5 (0.1)

^a with MALS; ^b Standard deviation; ^c with QELS

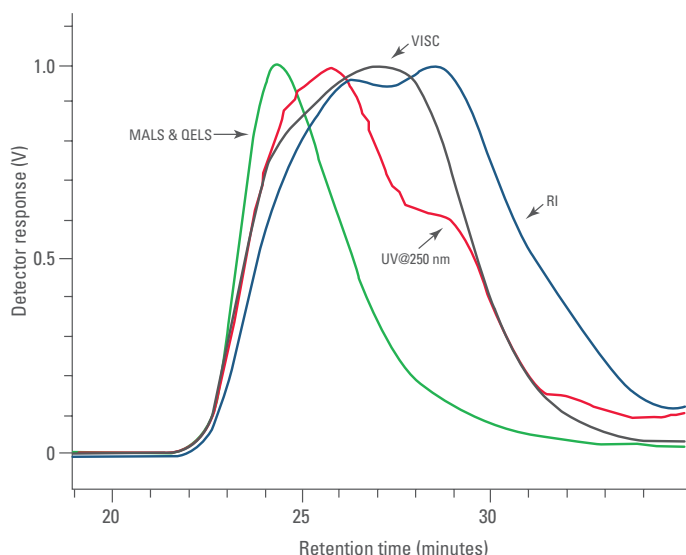
In order to better understand the ability of SBP to act as an emulsifier, we have investigated the structure of SBP using size exclusion chromatography coupled to a multiplicity of physical detection methods, namely multi-angle light scattering (MALS), quasi-elastic light scattering (QELS), multi-wavelength UV, differential refractometry (RI), and differential viscometry (VISC), and corroborated these results with results from atomic force microscopy¹.

EXPERIMENTAL CONDITIONS

Sugar beet pectin was prepared using microwave-assisted flash-extraction as described in reference 1. Size exclusion chromatography analysis of the sugar beet pectin was performed on a system consisting of an EcoSEC GPC System (Tosoh Bioscience) with an internal dual-flow differential refractive index detector and UV detector connected in series to a HELEOS II MALS photometer (Wyatt Technology Corp.), a QELS photometer (Wyatt), and a ViscoStar differential viscometer (Wyatt). The UV absorbance was monitored at wavelengths of 310, 278, and 250 nm. The solvent and mobile phases were water with 0.05 M NaNO₃ and 0.01% NaN₃, at a flow rate of 0.7 mL/min. 200 µL injections of 1 mg/mL solutions were injected onto a column bank consisting of three TSKgel GMPW_{XL} columns (30 cm x 7.8 mm) with a particle size of 13 µm obtained from Tosoh Bioscience. These mixed-bed columns have a separation range, based on polyethylene oxides, of 1000 to 8 x 10⁶ g/mol. Detectors, pump oven, and column oven were maintained at 35°C. Data acquisition and processing were performed using Wyatt’s ASTRA 5.3.4.16 software.

The HELEOS II detector was normalized in-house using a pullulan standard, with a molar mass of 47,300 g/mol, while calculation of interdetector delays and interdetector band broadening correction were performed using BSA. Calibration of the MALS unit was performed using toluene. The ∂n/∂c of sugar beet pectin was determined previously to be 0.130 mL/g.

SEC ELUTION PROFILE OF SUGAR BEET PECTIN AS MONITORED BY MALS & QELS (GREEN), RI (BLUE), UV @ 250 NM (RED), AND VISC (BLACK) AT 0.7 ML/MIN.



► Figure 1

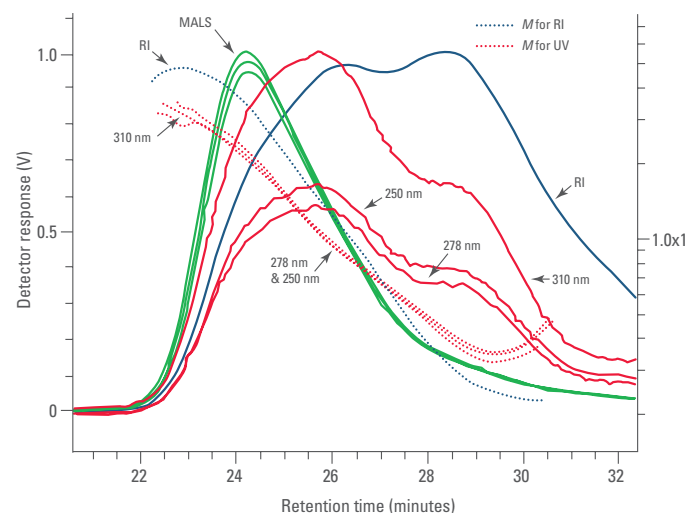
RESULTS AND DISCUSSION

As described above, the EcoSEC GPC System equipped with TSKgel SEC columns was coupled to a train of MALS, QELS, UV, RI, and VISC detectors to determine the molar mass and size of sugar beet pectin. The results of the experiments are given in Table 1. Figure 1 shows the chromatograms of the sugar beet pectin, as monitored by the individual detectors. The SEC elution profile of the SBP, as measured by both of the concentration-sensitive detectors, RI and UV, displays a distinct bimodal distribution. The weight-average molar mass values MW, given in Table 1, are calculated via:

$$M_w = \frac{\sum_i c_i M_i}{\sum_i c_i}$$

where, at each elution slice *i*, *c_i* is the concentration of the analyte provided by the concentration-sensitive detector and *M_i* is the molar mass of the analyte provided by the MALS detector after correction for interdetector delay. As indicated in Table 1, the weight-average molar mass for the SBP was determined to be approximately 1.1 x 10⁶ g/mol and shown to vary less than 7% amongst the four concentration-sensitive detectors (UV @ 310, 278, and 250 nm and RI). Evidence of molar mass polydispersity of SBP is seen in Figure 2, where *M* is plotted across the SEC elution for each concentration sensitive detector. From the detector response for the four concentration-sensitive detectors it appears as if the chromatogram is bimodal. Additionally, if one observes the molar mass of the SBP as a function of SEC elution volume, it can be seen that the molar mass of the SBP decreases by an order-of-magnitude with increasing elution volume, an indication the SBP is poly-disperse with respect to molar mass. It should also be noted that if one compares the molar mass distributions of the four concentration-sensitive detectors, the molar mass of the SBP is higher at lower elution volumes and lower at

SEC ELUTION PROFILE OF SUGAR BEET PECTIN USING FOUR CONCENTRATION-SENSITIVE DETECTORS (UV @ 310, 278, AND 250 NM AND RI) AND MOLAR MASS DISTRIBUTIONS ACROSS THE ELUTION PROFILES AS DETERMINED BY MALS.



► Figure 2

larger elution volumes via the RI detector than via the UV detector.

The difference in molar masses between the various detection methods is an indication that the particles with higher molar masses have fewer UV absorbing molecules associated with them than their lower molar mass counterparts. The addition of the two light scattering detections, MALS and QELS, and viscometry detection to the EcoSEC GPC System not only allows for the determination of the molar mass of SBP in a calibrant-independent fashion but also for the determination of polymeric size and intrinsic viscosity. The radius of gyration R_G and the hydrodynamic radius R_H for the SBP were determined via MALS and QELS, respectively, and are given in Table 1. The difference in the value of R_G for SBP as determined by the four concentration-sensitive detectors is minimal, ± 3 nm. Conversely, the difference in the value of R_H for SBP as determined by the RI detector compared to the three UV wavelengths varies by 10 nm, a direct reflection of the dependence of concentration, as determined by the concentration-sensitive detector, on the calculation of R_H .

CONCLUSIONS

The EcoSEC GPC System with refractive index and UV detection was coupled to MALS, QELS, and VISC detection to characterize the physicochemical properties of sugar beet pectin. The sugar beet pectin was determined to be polydisperse with respect to molar mass and to have a weight-average molar mass value around 1.1-million g/mol. Two polymeric size parameters were also determined, R_G and R_H , as well as the intrinsic viscosity. The coupling of the EcoSEC GPC System to external detectors was successful for the analysis of complex macromolecules based on molar mass, size, and intrinsic viscosity.

REFERENCES

1. M.L. Fishman, H.K. Chau, P.H. Cook, and A.T. Hotchkiss Jr. *J. Agric. Food Chem.* 56, 1471-1478 (2008).
2. J. Leroux, V. Langendorff, G. Schick, V. Vaishnav, J. Mazoyer *Food Hydrocolloids* 17, 455-462 (2003).

*Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.