New approaches to understanding and controlling cell separation in relation to fruit and vegetable texture

A. Ng, K.W. Waldron, A.C. Smith, A.J. Parr and M.L. Parker

Introduction

The texture of edible plant tissues depends largely on the cell wall. The structural characteristics of plant-based foods will be influenced by contributions from the different interacting levels of structure (Figure 1). When fruit or vegetable tissue is masticated, its texture is strongly affected by the way in which the cell walls break. The firm crunchy texture of uncooked vegetables or unripe fruits is associated with tissue fracture involving rupture across the cell walls. Turgor and water mobility will have an important role here. In contrast, many of the cells of over-cooked vegetables and over-ripe fruits separate easily during eating, giving the tissues a very soft texture. In this situation, there is a total loss of tissue structure. Such cell separation results from the solubilisation of the wall polymers involved in cell adhesion. This is generally thought to be due to dissolution of the (pectic) polysaccharides of middle lamella which are perceived to be involved in cell adhesion.

Fig. 1. The levels of structure underlying the mechanical properties of plant tissues

Crispness in Chinese Water Chestnut

In nearly all vegetables and fruits, cooking and other thermal processes such as canning and sterilization will usually induce tissue softening. These results from dissolution of those middle lamella (pectic) polysaccharides involved in cell adhesion, which leads to an increase cell separation. The solubilisation in these polymers is though to result from a combination of depolymerisation by β-eliminative cleavage and chelation of divalent cations by endogenous organic acids. Ripening-related solubilisation is

---

1Institute of Food Research, Norwich Research Park, Colney Lane, Norwich NR4 7UA, UK
In Chinese water chestnut (CWC) the edible portion of the corm comprises thin-walled cells, full of starch, very similar to those in potato. However, unlike potato, CWC retains its firm and crunchy texture even after extensive heat treatments. This is due to the maintenance of cell adhesion, resulting in cell wall rupture during tissue fracture. Analysis of cell-wall phenolics in CWC indicate that the maintenance of crispness in cooked or canned CWC may be attributed to the presence of diferulic acid cross-links between arabinoxylans involved in cell adhesion. Cell separation of CWC can be achieved by extracting with hot and dilute alkali. Fluorescence microscopy has demonstrated that the single separated CWC cell exhibits an interesting pattern on the cell surface. This pattern corresponds to the edges of the cell faces, where cell adhesion is probably controlled. The phenolic components in these fluorescent zones have been extracted and analysed by using an HPLC-Diode Array method. A number of alkali-stable phenolic components acid dimers have been identified, in which the two 8-8'-dimers (8-8'-diferulic acid and 8,8'-diferulic acid aryltetralyn form) are particularly prominent and may have a special role in adhesion.

**Potential For Control**

Apart from Chinese water chestnut, other work on the dicotyledonous plants such as members of Chenopodiaceae including sugar beet and beetroot have provided further evidence for the involvement of ferulic acid dimers in determining texture. How might these findings be used to enhance the textural quality of fruit and vegetable tissues? In most fruits and vegetables studied, phenolics are present only in very small amounts. In order to enhance the phenolic cross-linking at the required locations in the wall (e.g. edge of cell faces), it is important to increase the availability of phenolics moieties. Perhaps the intracellular availability of ferulic acid may have a direct effect on the levels of phenolics in the cell wall. In addition, ionically-bound peroxidase enzyme, catalysing oxidative cross-linking (e.g. peroxidases), has been located in the middle lamella in apple and bean tissues, often concentrated at the edges of cell faces and in the plasmodesmata. There appears to be little information concerning the location of peroxide-generating enzymes, although it would be logical to assume that these would also be present in locations where peroxidases are located. Therefore, detailed study of the phenylpropanoid metabolism, cell-wall biosynthesis and peroxidation in the cell wall (Figure 2) may provide a means to manipulate texture of other fruits and vegetables.

**Acknowledgments**

The work mentioned above was funded by the UK Biotechnology and Biological Sciences Research Council.

**References**