RELATION BETWEEN THE BEHAVIOUR OF PECTIC SUBSTANCES AND CHANGES IN FIRMNESS OF HORTICULTURAL PRODUCTS DURING HEATING

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(with 4 figs.)

INTRODUCTION

The changes in firmness of plant tissues during heating are partly caused by alterations in the structure of the cell walls. Because this structure is only partly known, it is rather difficult to give an explanation of these processes which take place during heating. In many cases (6, 18, 38, 39, 40, 49, 51, 60) an explanation of the observed phenomena has been based upon analyses of the pectic substances, which are considered to be the cementing materials between the cells (20, p. 60).

Most pectin preparations contain a rather large amount of hemi-celluloses from the cell wall (3, 5, 25, 27, 28, 29, 32, 33, 35, 45, 48, 50, 55, 56) which are difficult to separate from pectin by ordinary physico-chemical methods (50). For this reason, it has often been assumed that these substances are bound to pectin by covalent bonds (35, 36). Later it became clear that these substances form no part of the pectin molecule (50, 33) or only a small part of it; in the latter case these non-uronide substances may be bound in the polygalacturonic chains (32, 48) as well as in side-chains (25).

In addition to the fact that the insoluble protopectin is mixed with hemi-celullose, we have to take into account that very soon after cell division, cellulose and protopectin are deposited during formation of the primary wall (19, 20).

The presence of cellulose is masked by protopectin (2, 20, 43, 61) and often cannot be detected by chemical micro-assays. In electron microscopy the cellulose structure of the primary wall becomes visible only after removal of the protopectin by the use of pectolytic enzymes (61). For this reason, we must take into account the fact that the cellulose micella are separated by hydrophilic colloidal material, which consists largely of protopectin (2, 34).
The presence of cellulose in the primary wall is shown by the occurrence of a weak birefringence (19), but this relation may be disrupted due to the fact that in the inner parts of the primary wall cellulose micella are not orientated in one direction (43, 61).

Small quantities of lignin which have been revealed by means of new, more sensitive methods might influence the behaviour of other cell wall compounds during boiling (4, 30).

In addition to the influence of the constituents of the cell walls, the behaviour of pectic substances can also be determined by components from the cell contents. Thus, it has been shown that the cookability of peas is governed by the quantity of phytic acid in the product (39, 40). The protopectin would be decomposed by the calcium-binding action of the phytic acid; certainly such an influence can be attributed also to the anionic buffer system in the cells (9, 14).

The latter explanation is based on the validity of HENGLIN's theory (22, 23) on the structure of protopectin. It is assumed in this theory that pectin molecules are bound together and to the cellulose by calcium bridges between the carboxyl groups. However, pectins with a relatively high degree of esterification, which are often found in plant tissues, are not made insoluble by Ca-salts. Thus the formation of insoluble protopectin must also depend on other factors (10), such as covalent or secondary bonds to other cell wall substances or mechanical twisting with these (47, 56). The latter factor may be evident from the observation that after Ca-extraction from the cell wall, the removal of pectin by washing (13) takes a long time.

HINTON (26) considers the jellification of pectins as an artefact of the processes in the plant and is of the opinion that gel formation is controlled by the same factors involved in the formation of the gelstructure of protopectin (37), though the importance of various factors may be different. In this connection it can be said that Ca-salts really play a role in the jellification by pectins of a relatively high degree of esterification (11, 15). KERTESZ (35) postulated that pectins with a similar high degree of esterification would be insoluble in the presence of Ca-salts if these pectins have a very high molecular weight.

**Experimental**

Investigations were made on the relation between firmness of tissues and behaviour of the pectic substances when cooking of the tissues at different pH-values. For the explanation of the observed phenomena the relation between firmness, pectic substances and pH