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Effect of Heat Penetration During Cooking on Some Physico-chemical Properties and Microstructure of Sweet Potatoes

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ABSTRACT

The temperature at the central portion of sweet potato roots increased with prolonged blanching and baking times. However, the mode of heat penetration in blanched roots was different and that was directly correlated with the suitability for eating. The internal temperature, obtained during the first 10 and 30 min of blanching and baking processes, enhanced the amylase activity and resulted in major conversion of starch to reducing sugars. A slight increase in the amount of non-reducing sugars occurred upon cooking.

The differences in the ultrastructure between raw and cooked sweet potato roots were studied with a scanning electron microscope. All the starch granules gelatinized with complete deformation of shape after blanching for 20 min, while those of baked roots showed great resistance to deformation. The dispersion of the starch suspension was evident after 30 and 50 min in blanched and baked roots, respectively. Variations in the over-cooked roots were studied.

INTRODUCTION

Sweet potato (*Ipomoea batates* L.) roots are popular in Egypt where they are grown as summer and autumn crops and are consumed locally. They have long been recognized as good sources of carbohydrates and of vitamins C and A, thiamine, riboflavin and niacin (Elkins, 1979). It was also shown that

sweet potato protein is of high chemical score (Purcell, *et al.*, 1972). The behaviour of carbohydrates in baked sweet roots as affected by curing and varieties has been investigated (Scott & Mathews, 1957; Lambou, 1958; Walter *et al.*, 1975, Picha, 1985). Cooking processes account for marked changes in chemical composition and, consequently, change in the nutritional value of cooked roots (Arthur & McLemore, 1957; Hoover & Harmon, 1967; Sarhan *et al.*, 1975, Walter & Catignani, 1981; Purcell & Walter, 1982; Walter *et al.*, 1983).

Sweet potatoes are very starchy when freshly harvested, and are usually cooked before being eaten (Purcell & Walter, 1982).

Information concerning the relationship of internal temperatures of sweet potato roots and the rate of carbohydrate conversion during cooking processes is limited. This work was carried out to study the effect of heat penetration during blanching and baking on some physico-chemical properties and on the ultrastructure of sweet potato roots.

MATERIALS AND METHODS

Freshly harvested sweet potato roots of 'Giza 69' variety were obtained from the experimental farm of the college of Agriculture, Alexandria University, Alexandria. They were washed and air-dried. Their length, diameter and weight ranged between 15 and 17 cm, 4·7 and 5·4 cm and 160 and 172 g, respectively. The roots were divided into two portions; one was blanched in boiling water and the other baked in a gas oven at 175°C for designated time intervals, removed, cooled and the edible portion removed for analysis.

Temperature measurement during cooking

The changes in temperatures at the central portion of sweet potato roots during blanching and baking were continuously recorded at 10-minute intervals during the cooking periods by means of a thermocouple (Type K, Atkins technical, INC, Gainesville, Florida, USA).

Physical tests

The texture of cooked sweet potato roots was measured using an Ottawa Texture Measuring System (OTMS) (Model McL., Canada Machinery Ltd, Simcoe, Ontario) with a 453 kg load cell. The force (kg) required to compress, shear and extrude 75 g of cooked roots was measured.

Analytical procedures

Alcohol-insoluble solids were determined as described by Szyperski *et al.* (1986). Reducing and non-reducing sugars were determined according to the methods of the AOAC (1980). All determinations were carried out in duplicate and the data were expressed on a dry basis.

Scanning electron microscopy (SEM)

Dry raw and cooked sweet potato roots were fractured near the centre of the tuber and mounted on aluminum stubs with Duco cement and coated with 150 Å thick gold in a vacuum chamber before observation with the SEM (Jeol-JSM, 25 SII, Tokyo).

Statistical analysis

The simple linear correlation coefficient between variables was calculated according to Snedecor & Cochran (1967).

RESULTS AND DISCUSSION

The temperature profile in the central portion of sweet potato roots during blanching and baking is shown in Fig. 1. The internal temperature of roots rose linearly with time from the moment the cooking process had started and

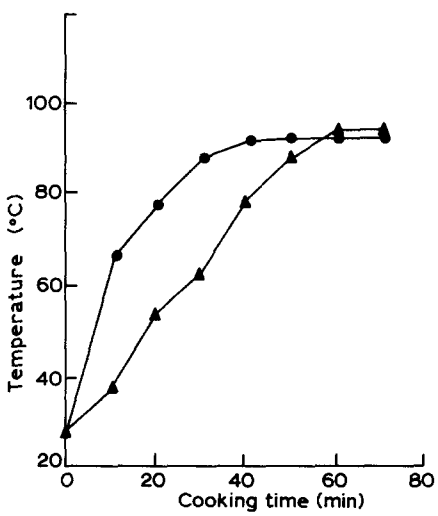


Fig. 1. Temperature profile in the central portion of (●) blanched and (▲) baked sweet potato roots during cooking.

reached nearly the maximum, i.e. 97·2°C and 94°C after 40 and 60 min in blanched and baked roots, respectively. It is obvious that the mode of heat penetration in blanched roots is different from that in baked ones. After 10 min, the internal temperature at the central portion reached 65·2°C and 36·4°C in blanched and baked roots, respectively.

Suitability of sweet potatoes for eating was directly proportional to the length of cooking, which affects the central temperature of roots.

Sweet potato roots blanched for 30 min, reached 86·4°C at the central portion, had moist peel, soft texture and were most satisfactory for eating. After that time, the blanched roots became syrupy in texture with separated damaged peel. Roots baked for 30 min reached only 66·5°C at the central portion and were still predominantly hard-fleshed with raw flesh in the centers. Those baked for 50 min with 87·6°C at the central portion, were suitable for eating. Burned periderms and drier flesh roots, than the others were obtained after 60 min baking time.

The texture of sweet potato roots as indicated by OTMS was improved as cooking time increased (Table 1). A high correlation ($t = -0{\cdot}93$ and $-0{\cdot}89$) was found between the texture of roots (shearing force) and the temperature at the central portion of the blanched and baked roots over the same cooking time, respectively. Prolonging the exposure to the internal temperature of 186·8°F during cooking was accompanied by an exponential reduction in the force needed to compress, shear and extrude the roots. Reeve (1972) ascribed the softness of root cells on cooking to the swelling pressure created by starch on gelatinization. Warren & Woodman (1974) attributed the decrease in strength of potato tissue, which occurs on cooking, to water uptake by the polysaccharides of the cell walls.

Alcohol insoluble solids (AIS) were highest in the raw sweet potato roots and tended to decrease upon cooking. Figure 2 reveals that baking was more effective than blanching in this respect. The major conversion of starch in the alcohol-insoluble solids to other constituents, such as reducing sugars, dextrins and maltose, occurred during the first 10 and 30 min of blanching and baking, respectively; little change occurred with the longer cooking time. As shown above, the internal temperatures of blanched and baked roots after 10 and 30 min cooking (65·2°C and 66·5°C, respectively) enhanced amylase activity (mainly-beta-amylase), which is maximum between 60–70°C as previously reported (Hoover, 1967; Hoover & Harmon, 1967; Deobald *et al.*, 1969).

Figure 3 shows that baking was more effective than blanching in the formation of reducing sugars. These sugars increased from 5·46% in raw to 11·1% and 14·3% in 60 min blanched and baked roots, respectively. Nora (1965) found that baked sweet potato roots contained more reducing sugars than steam blanched roots. The increase in reducing sugar content

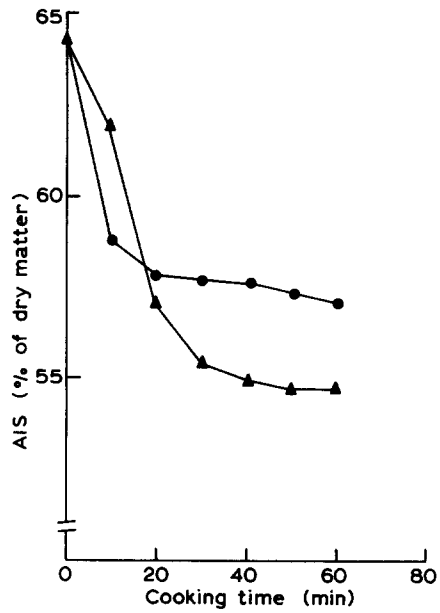


Fig. 2. Effect of cooking upon alcohol insoluble solids (AIS) in (●) blanched and (▲) baked sweet potato roots.

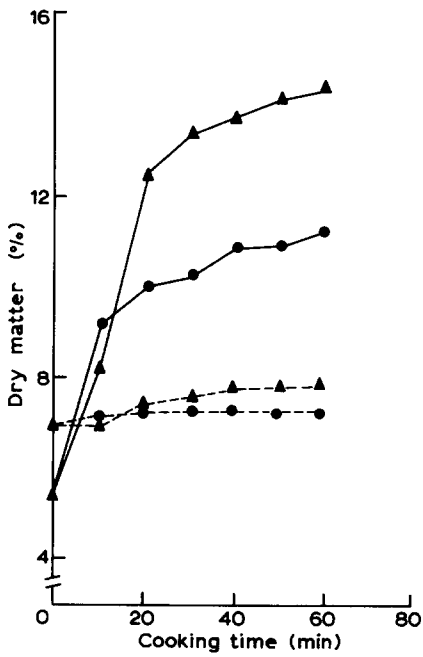


Fig. 3. Effect of cooking time upon reducing (——) and non-reducing (– – –) sugars in (●) blanched and (▲) baked sweet potato roots.

corresponded with the decrease in the starch content of the roots (as measured by AIS). These increases apparently represent the action of beta-amylase on starch. Although the initial effect of heat during the first 20 min of cooking was to promote reducing sugar production, its effect at higher temperatures was to limit the increase in reducing sugars, accompanied by a lower apparent degradation of starch. Denaturation and subsequent lowered activity of the sweet potato amylases, are both responsible for the lowered reducing sugar production after longer cooking time.

A slight increase in the amount of non-reducing sugars occurred upon cooking (Fig. 3). However, baked roots showed relatively higher non-reducing sugars than blanched. The differences may be due to the release of sugars in boiling water during the blanching process (Sarhan *et al.*, 1975).

Nora (1965) reported that maltose was formed in steam-blanched sweet potato, while the amounts of sucrose, glucose and fructose were unchanged. Picha (1985) found that the major sugars in raw sweet potato roots were sucrose, glucose and fructose, but no maltose was detected. He also found that maltose was the most abundant sugar in baked roots.

In raw sweet potato roots, the ultrastructure of the compound nature of starch was well defined (Fig. 4). The starch granules vary in size and shape. The majority are large flattened ellipsoids, while the rest are small and nearly spherical. The granules generally occur singly and are attached to the cell wall. The cell wall shows extensive folding. The primary cell wall consists of a fibrous substructure, probably cellulose fibrils, which are loosely woven together in a pattern and embedded in an amorphous matrix (Sterling, 1963). Marked differences in the appearance of the starch granules were evident upon cooking. In sweet potato roots, blanched for 10 min, the starch granule gelatinization had progressed inward toward the centre with volume

TABLE 1
Effect of Cooking Time on Texture Measurement of Blanched and Baked Sweet Potato Roots

Cooking time (min)	*Texture (Kramer shearing forces, kg)*	
	Blanched roots	*Baked roots*
10	261·4	323
20	94	149·8
30	22·4	82·2
40	20·6	27·4
50	16·8	21·8
60	15·2	18

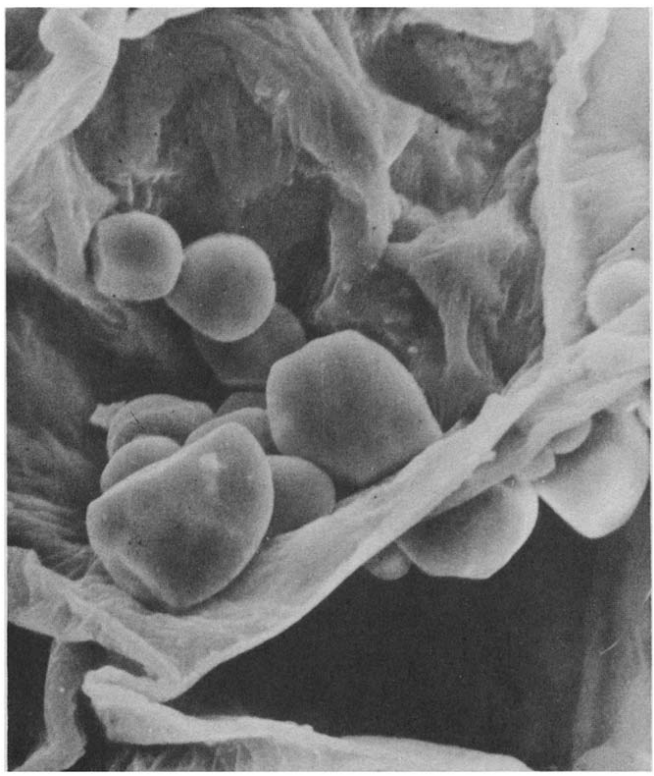
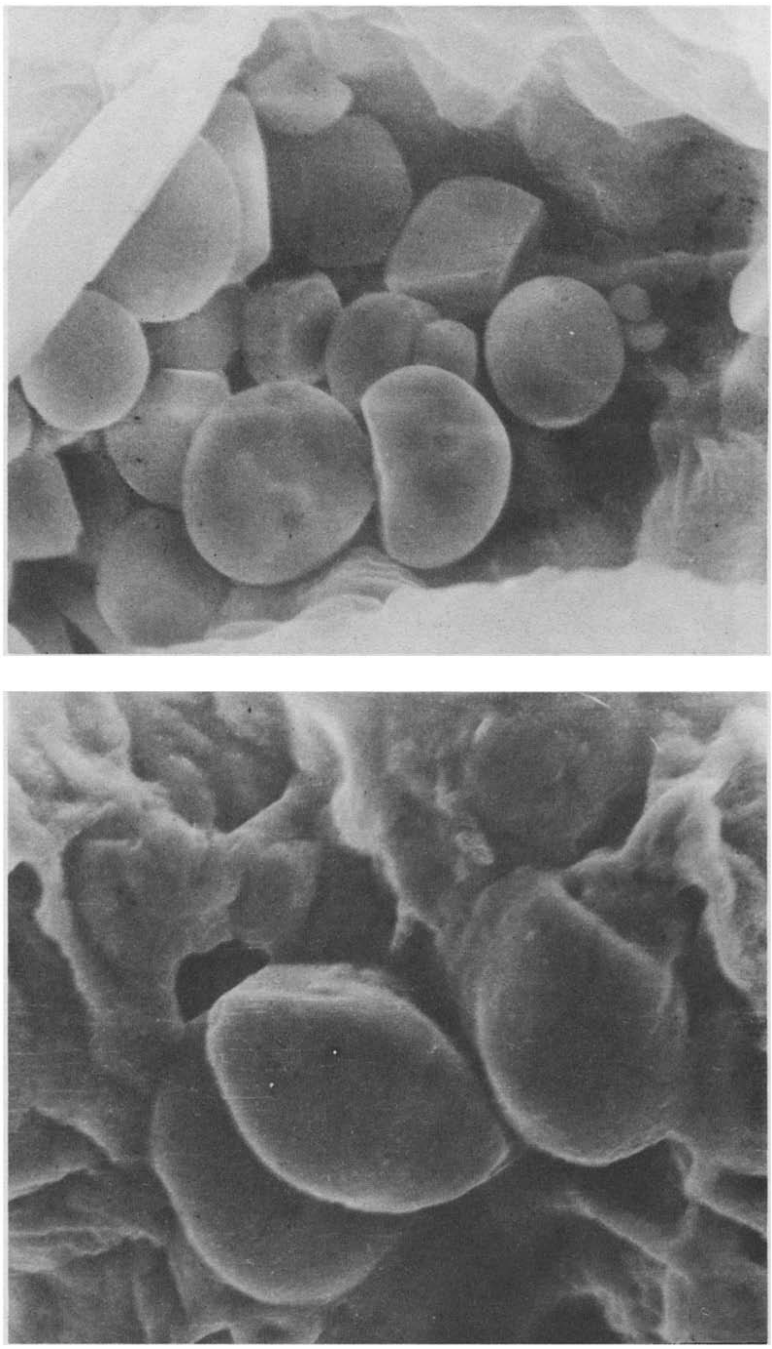


Fig. 4. SEM micrograph of raw sweet potato (× 1500).

expansion. Moreover, cracks on the surface of swollen granules are evident Fig. 5(a). In comparison, no change occurred in the shape of starch granules of sweet potato roots baked for the same time Fig. 5(b).

Blanching the raw roots for an additional 10 min Fig. 6(a), resulted in continued swelling and gelatinization of the starch granules with complete deformation of their shape accompanied by considerable cellular collapse and disorganization at cell–cell interfaces. Although baked roots had undergone a considerable degree of swelling at this time, the walls of starch granules remained relatively intact without marked perturbation of the cell–cell union Fig. 6(b). The amylolytic activity was evident by the pitting of the starch granules as suggested by Watson & Dikeman (1977).

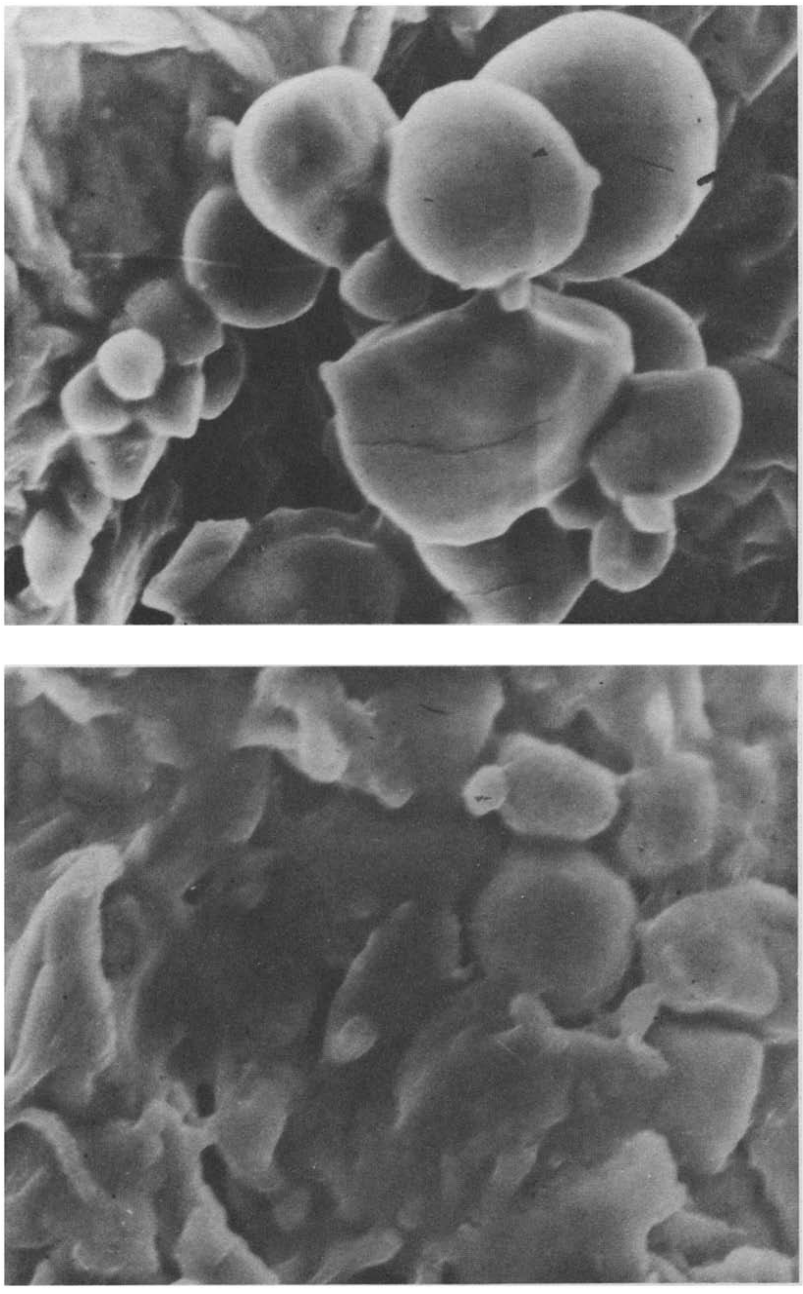
It is evident in Fig. 7(a), that all the starch granules have gelatinized after 30 min, with the dispersion of the starch suspension in the case of blanched roots. In baked roots the rupture of starch granule walls began to show with the dispersion of the starch suspension Fig. 7(b). However, some starch granules still retained their integrity and shape. Figure 8(a) shows a marked difference in the nature of gelatinized starch of roots blanched for 40 min,



(b)

(a)

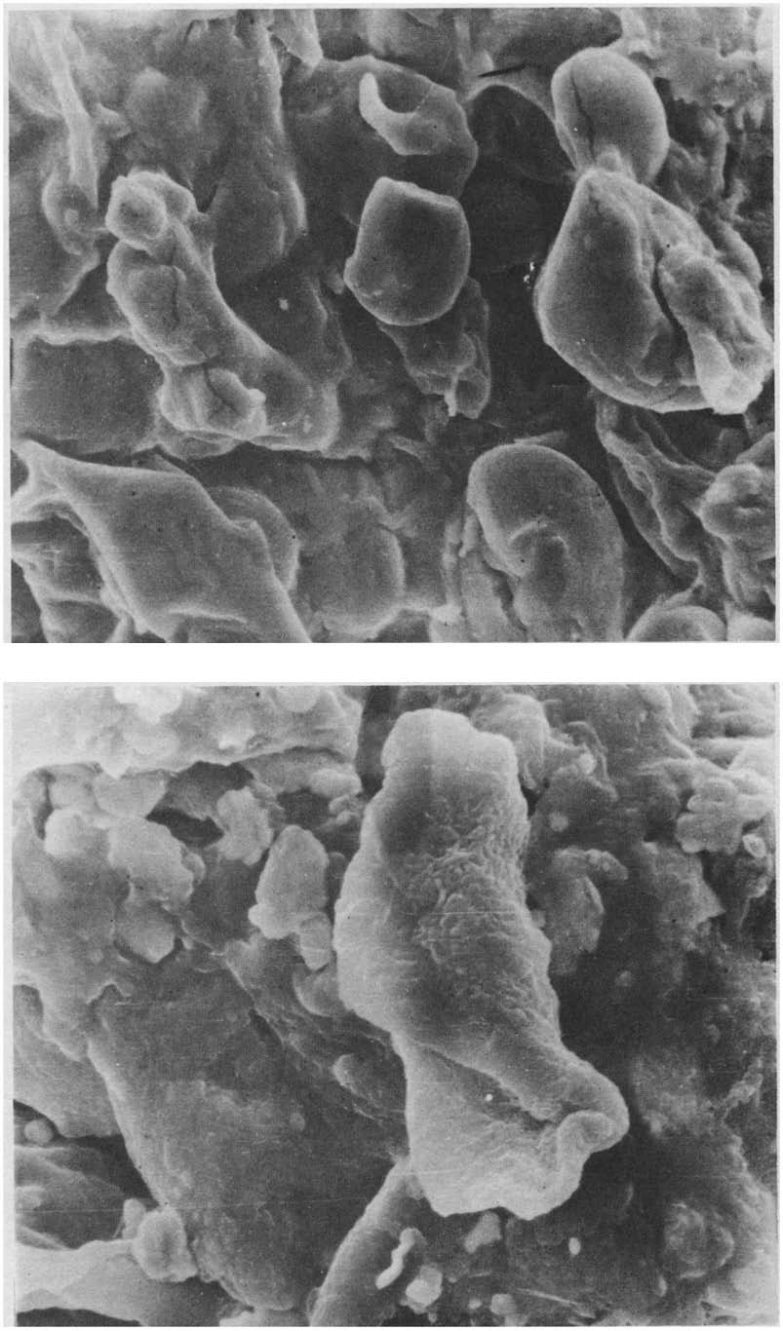
Fig. 5. SEM micrographs of (a) blanched (×1500) and (b) baked (×2000) sweet potato; both cooked for 10 min.



(b)

(a)

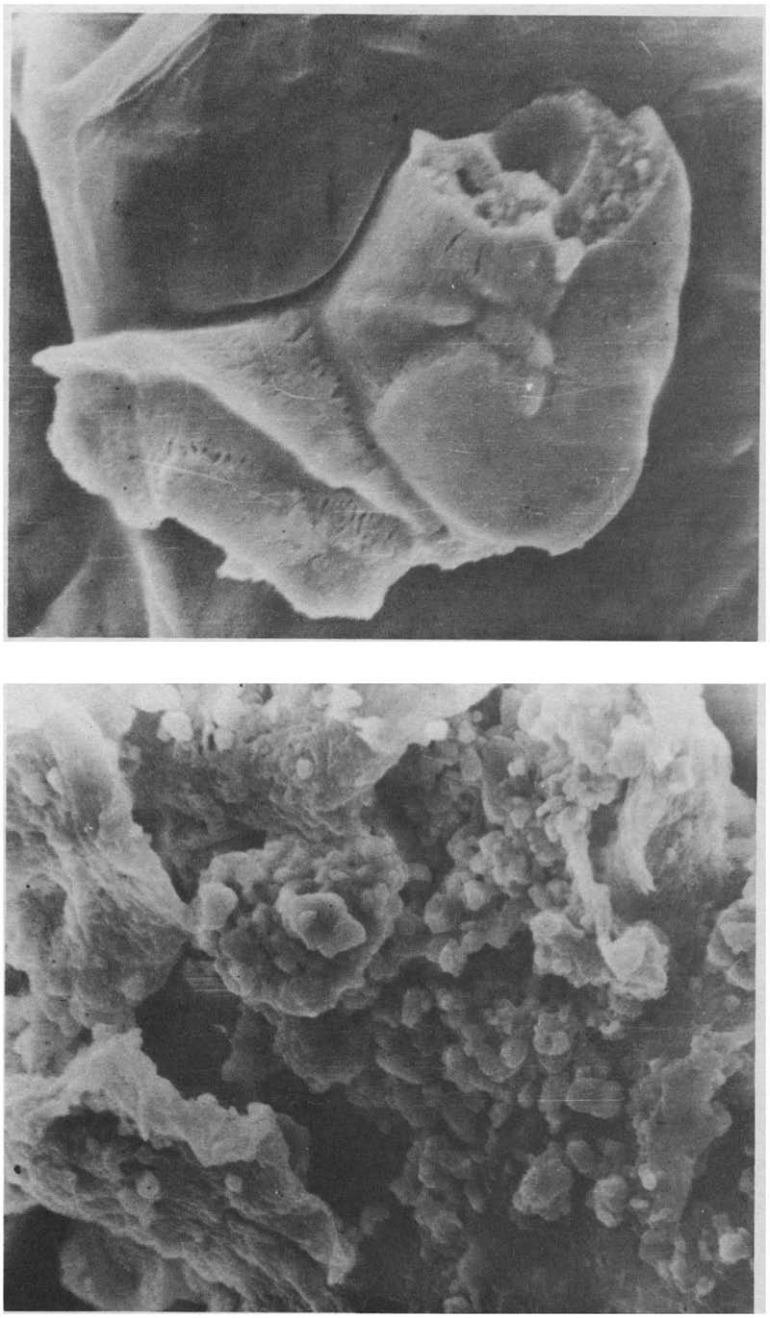
Fig. 6. SEM micrographs of (a) blanched and (b) baked sweet potato; both cooked for 20 min (× 1500).



(b)

(a)

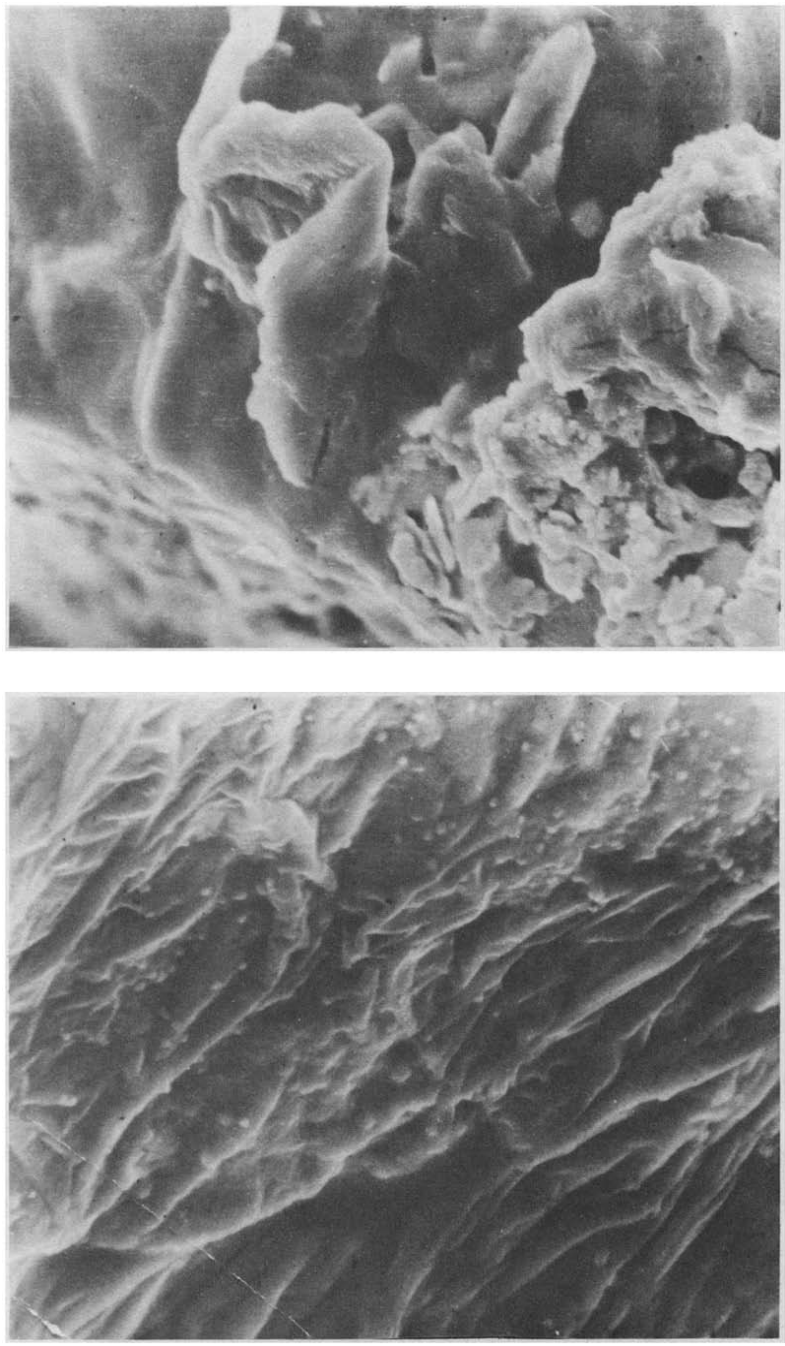
Fig. 7. SEM micrograph of (a) blanched (× 2000) and (b) baked (× 1000) sweet potato; both cooked for 30 min.



(b)

(a)

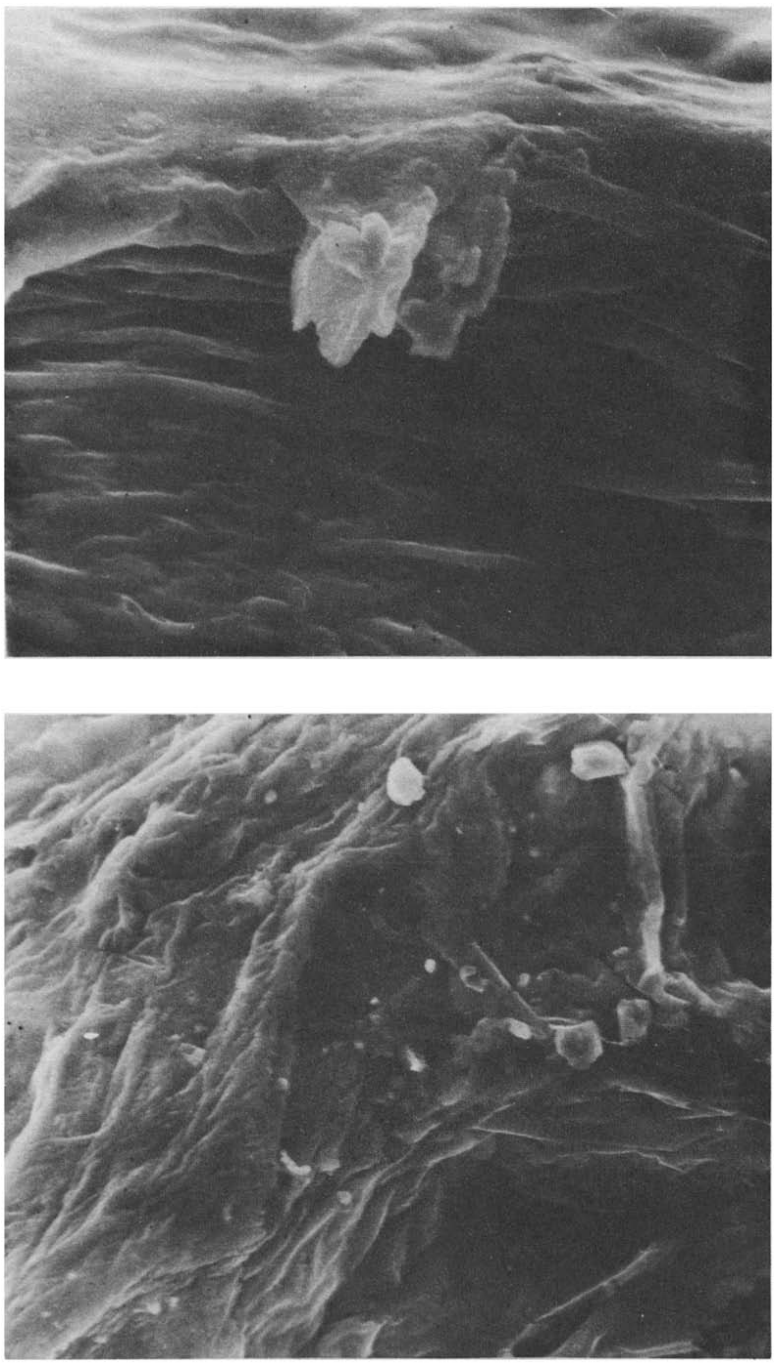
Fig. 8. SEM micrograph of (a) blanched and (b) baked sweet potato; both cooked for 40 min (× 2000).



(b)

(a)

Fig. 9. SEM micrograph of (a) blanched and (b) baked sweet potato; both cooked for 50 min (× 1500).



(b)

(a)

Fig. 10. SEM micrograph of (a) blanched (×1500) and (b) baked (×2000) sweet potato; both cooked for 60 min.

being degraded and dispersed into small fragments. In comparison, numerous irregular protuberances were observed in all starch granules of roots baked for the same time Fig. 8(b). However, a residual core of ungelatinized starch in the centre of the granules was evident. Completely gelatinized granules appearing as ghost-like structures with distinguishable walls Figs 9 and 10(a) were evident in the over-blanched sweet potato roots (50 and 60 minutes). In the roots baked for 50 min, diffusion and dispersion of starch granules as a whole occurred Fig. 9(b) and the complete deformation of the granule shape was evident after 60 minutes baking time (Fig. 10(b)).

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