# A Scanning Electron Microscopy Study of Japanese Noodles[1]

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**ABSTRACT**

A scanning electron microscope was used to study changes in dough structure during Japanese noodle preparation (32% absorption) for a Japanese commercial soft wheat flour and a durum wheat flour of comparable protein content. The flour and sheeted dough from the Japanese flour had a more open structure than the durum sample. The starch granules of the Japanese flour were more conspicuous and more loosely held within the gluten protein matrix. For both flours, there was a progressive change in dough structure during noodle preparation up to the third sheeting. Examination of sheeted doughs of higher water content (up to 55% absorption), however, demonstrated that full gluten development is not achieved at noodle dough absorptions. The presence of 2% salt in the doughs resulted in a smoother and more uniform gluten structure than that observed for unsalted doughs, and strengthened farinograph dough properties. When cooked, the internal structure of the better cooking quality product, Japanese flour noodles, exhibited less evidence of breakdown than the durum flour noodles.

Although numerous studies have reported on the microstructure of wheat and wheat products, very few have dealt with pasta and noodles. Light microscopy (Frey and Holliger 1972) and scanning electron microscopy (SEM) (Dexter et al 1978) have been used to study cooked pasta structure and SEM has been employed to investigate changes in pasta dough structure during spaghetti processing (Matsuo et al 1978). Light microscopy has been used to examine Japanese noodle structure (Ogawa 1974a,b), but so far as the authors are aware there have been no reports on cooked noodle microstructure. In this investigation, SEM has been employed to examine structural changes in Japanese noodle doughs at various stages of noodle processing, and during cooking.

## MATERIALS AND METHODS

Three wheat flours of comparable protein content possessing differing noodle-making characteristics were selected for the study:

(a) A Japanese commercial flour milled at Nisshin Flour Mills that consisted of a blend of U.S. Western White, Australian Standard White, and Japanese domestic wheats.

(b) A red spring cultivar (Pitic 62) from the 1976 crop, which was milled in a commercial Bühler-Miag mill at the Canadian International Grains Institute.

(c) A low protein sample of a Canadian amber durum wheat cultivar (Wakooma) from the 1975 crop, which was milled in an Allis-Chalmers laboratory mill at the Grain Research Laboratory. Some quality data for the three flours are given in Table I. Protein contents were determined by the Kjeldahl method as modified by Williams (1973), ash was determined as described previously (Dexter and Matsuo 1978), and starch damage was determined by the method of Farrand (1964).

Although no quantitative tests were performed on the cooked noodles, it was readily apparent that cooked noodles from the Japanese flour were firmer than cooked durum flour noodles and exhibited less of a tendency to disintegrate. The Pitic 62 noodles appeared to have a cooking quality slightly inferior to the Japanese flour noodles.

### Noodle-Making

Unless otherwise stated, the noodles were prepared at 32% absorption (14% moisture basis) with 2% salt (w/w). Flour (500 g) was premixed in a Hobart C-100 mixer, equipped with a flat beater mixing paddle, at the lowest speed for 12 min. The loose friable dough was transferred to a laboratory-type noodle-making machine (Ohtake Noodle Machine Manufacturing Co.) and sheeted at a roller setting of 1.6 mm. The sheeted dough was developed further by passing it through the rollers twice more at the same setting, folding the dough in half prior to passing it through each time. Before each of the next three passes, the clearance between the rolls was reduced slightly, the final setting being 0.8 mm. On the final (sixth) pass, the dough was cut with a No. 18 noodle cutter. Wet noodles were cooked shortly after preparation.

### Sample Preparation

Samples were taken at all stages of the noodle-making process and after cooking. In each case they were frozen in liquid nitrogen, freeze-dried, and fractured to expose inner surfaces. Specimens were attached to stubs with silver conducting paints and were coated with a layer of gold approximately 20–25 nm thick in a Balzers sputter coater. The entire specimen surface was scanned with a Cambridge 'Stereoscan' MK IIa scanning electron microscope at 10 kV, and a representative area was photographed on 35 mm Kodak Panatomic X film.

### Farinograms

Farinograms were obtained for 50-g samples (14% moisture basis) in a small stainless-steel farinograph bowl (59 rpm drive) at 30°C as described by Irvine et al (1961).

## RESULTS AND DISCUSSION

### Structural Changes During Noodle-Making

Since the Japanese flour and the low protein durum flour represented the two extremes in noodle-making quality, they were chosen for a detailed study of structural changes during noodle-making. As noted previously by other workers (Hoseney and Seib

**TABLE I**
**Some Quality Data for the Flours Used in This Study**

| Property[a] | Flour Description: Japanese | Pitic 62 | Wakooma |
|---|---|---|---|
| Protein[b], % | 8.0 | 9.4 | 9.1 |
| Ash, % | 0.38 | 0.55 | 0.70 |
| Starch damage, Farrand Units | 25 | 24 | 59 |

[a] Expressed on 14% moisture basis.
[b] Expressed as % N × 5.7.

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1973), the appearance of soft wheat and durum wheat flours under the SEM was strikingly dissimilar (Fig. 1A,B). The Japanese flour (Fig. 1A) was comprised of a wide range of particle sizes including individual starch granules and small proteinaceous fragments. Starch granules were clearly visible on the surface of the larger particles. In contrast, the durum flour (Fig. 1B) possessed few small particles and had a much more compacted appearance. Starch granules were completely encased in an amorphous protein matrix. In general, the appearance of the durum flour in this study corresponded closely to previously published micrographs of durum wheat semolina (Dexter et al 1978, Matsuo et al 1978), although the semolina had a larger and more variable particle size.

Premixing in the Hobart mixer resulted in a considerable change in structure for both flours (Fig. 1C,D). The individual flour particles had coalesced into large, loosely held heterogeneous particles. The surface of the premixed dough particles from the Japanese flour (Fig. 1C) was smooth. Starch granules were still much in evidence but appeared to be cemented within an enveloping protein network. The premixed dough particles from the durum flour (Fig. 1D), on the other hand, exhibited a very discontinuous surface structure. The protein was now comprised of jagged isolated pieces. Starch granules had become more conspicuous and in some cases appeared to be virtually free of the protein matrix.

As expected, the repeated passes through the sheeting rolls greatly modified the microstructure of the doughs. Once the dough had been sheeted three times, there was little evidence of further structural change for either flour. This corresponded to the point at which a homogeneous dough with good strength was first obtained. The structural changes observed during sheeting are illustrated by micrographs of dough cross-sections following the first and fifth passes through the sheeting rolls (Fig. 2A–D, Fig. 3A,B). The montage of the Japanese flour dough following the first sheeting (Fig. 2A) revealed a very porous dough possessing jagged discontinuous protein fragments. Some fibrillar-like protein was observed adhering to the starch granules, but did not appear to be firmly held within the main protein matrix. This is shown more clearly in an enlarged view of the once sheeted dough (Fig. 2C). Following the fifth sheeting, the Japanese flour dough had become less porous (Fig. 2B). The protein had become smoother and more continuous, and the starch granules now appeared to be more firmly held (Fig. 2D).

Although a similar pattern of change was observed in the internal structure of the durum wheat flour doughs during sheeting (Fig.

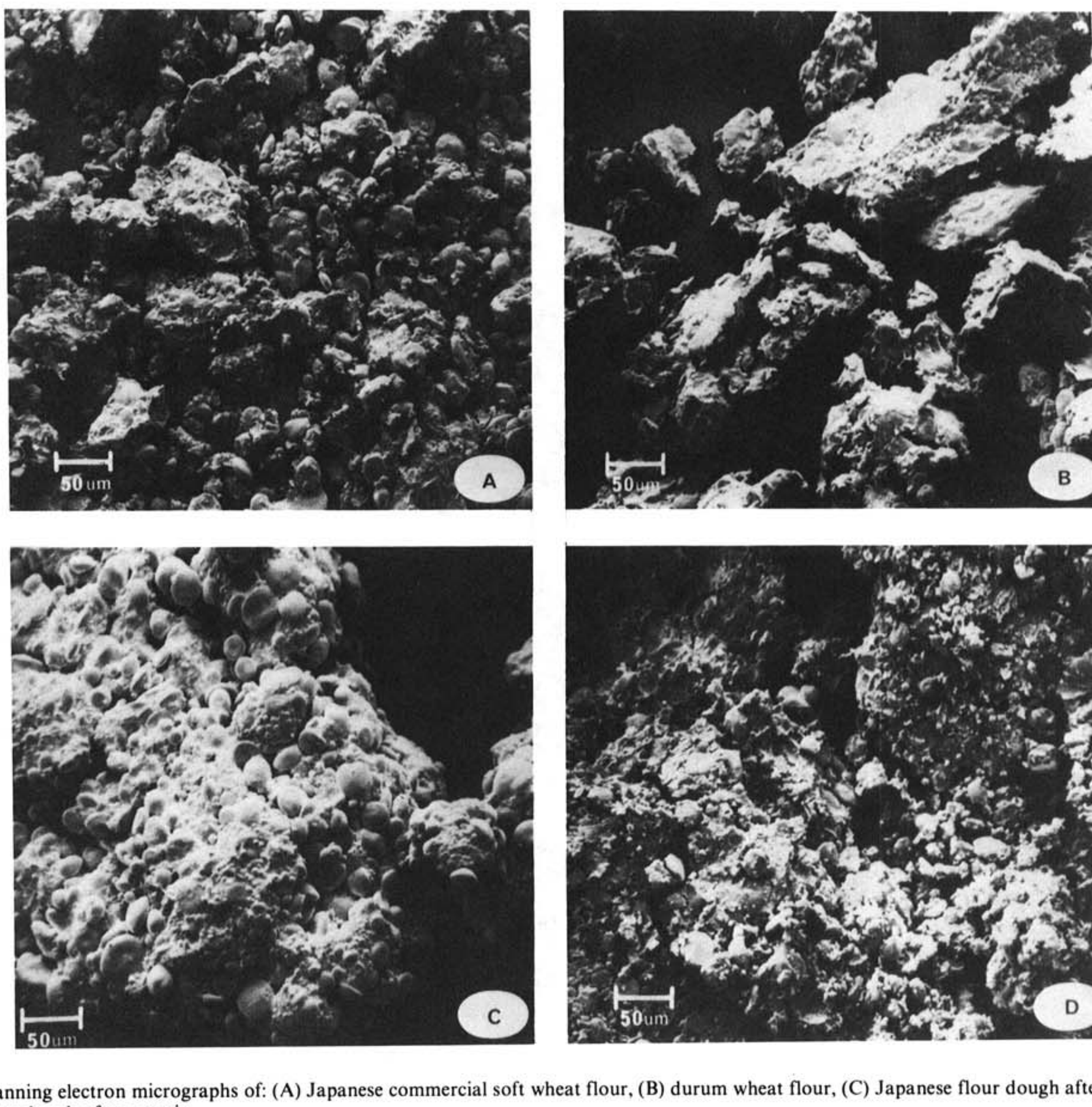


Fig. 1. Scanning electron micrographs of: (A) Japanese commercial soft wheat flour, (B) durum wheat flour, (C) Japanese flour dough after premix, (D) durum flour dough after premix.

3A,B), some noticeable differences in structure between the durum and Japanese flour doughs were observed. The starch granules in the durum flour doughs appeared to be more completely covered by the gluten matrix at each stage examined. During the initial stages of dough development, the protein matrix within the durum dough (Fig. 3A) was less interrupted and less jagged than for the Japanese flour dough (Fig. 2A). In contrast, following the fifth sheeting, the protein in the Japanese flour dough (Fig. 2B) was noticeably smoother than that in the durum dough (Fig. 3B).

In a recent SEM study of pasta processing (Matsuo et al 1978), we observed that the large lens-shaped starch granules within pasta dough became aligned in the direction of flow during extrusion. The pasta dough protein network also appeared aligned. Since noodle doughs are stretched unidirectionally during sheeting, it might be anticipated that alignment would also be observed in this study. This was not the case, however, as the random orientation of the granules in the micrographs of cross-sectioned noodle doughs clearly showed (Fig. 2A–D, Fig. 3A,B). This confirmed a previous report by Ogawa (1974a,b), who showed that machine processed noodles such as the ones used in this study did not exhibit any unidirectional orientation under the light microscope. He did observe, however, that traditional hand-strectched noodles showed a definite alignment of the gluten network along the direction of the strands.

The outer surface of the doughs prepared from the Japanese flour and the durum flour appeared very similar following the first pass through the sheeting rolls (Fig. 4A,C). In each case, the starch granules on the surface were partially covered by a nonuniform amorphous protein coating. Following the fifth sheeting, however, their appearance had become quite different (Fig. 4B,D). For the durum dough (Fig. 4D), there appeared to be a slight increase in the continuity of the protein coating. In contrast, the outer surface of the Japanese flour dough (Fig. 4B) was characterized by a less conspicuous protein film that did not cover the large starch granules on the surface to anywhere near the same extent as that observed for the durum dough.

Previously we (Dexter et al 1978) showed that spaghetti appeared to be coated by a thin protein film, and we postulated that the extent and strength of the film may be important factors in spaghetti cooking quality. Assuming this is the case, one would have expected to observe a more prominent protein film on the surface of the Japanese flour noodles, the better cooking quality sample, compared with the durum wheat flour noodles. However, micrographs of the outer surface of the cut edge of both noodles (micrographs not shown) revealed a structure essentially the same as that previously observed for cross-sections of the fifth pass noodle doughs (Fig. 2B,D, Fig. 3B), being devoid of any enveloping protein film. This discontinuity of surface structure would tend to

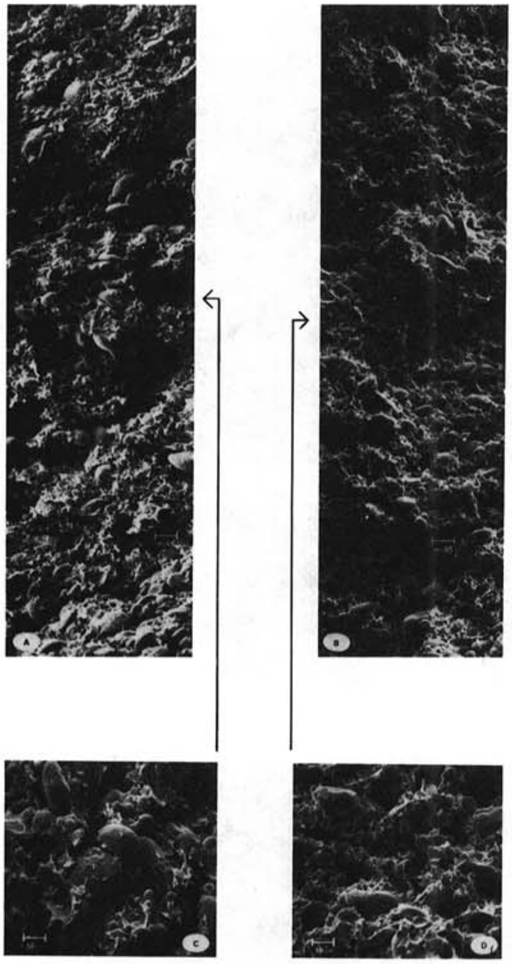


Fig. 2. (A) Scanning electron micrograph of a cross-section of Japanese flour noodle dough after first sheeting, (B) scanning electron micrograph montage of a cross-section of Japanese flour noodle dough after fifth sheeting, (C) close-up of dough after first sheeting, (D) close-up of dough after fifth sheeting.

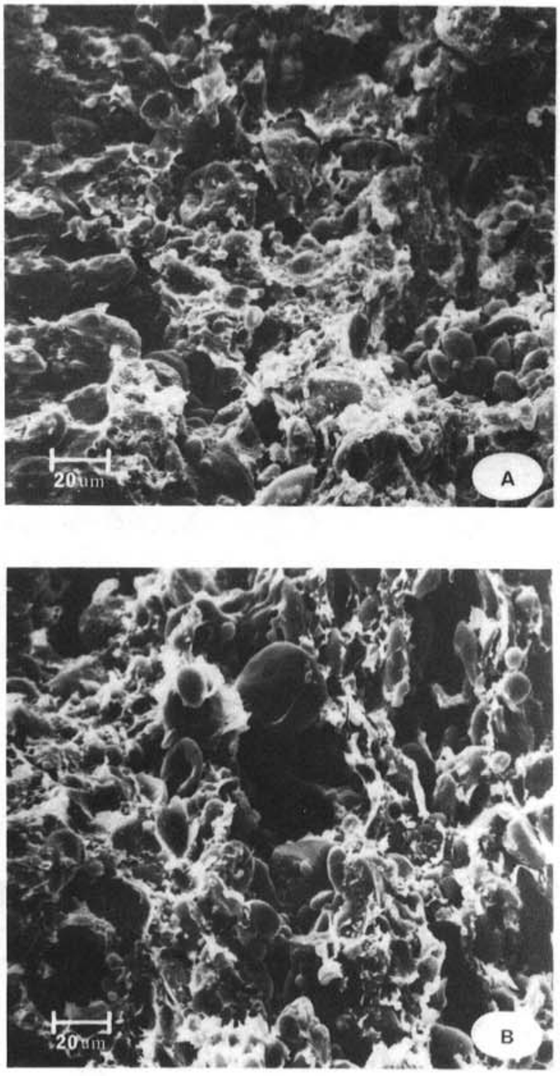


Fig. 3. Scanning electron micrographs of cross-section of durum flour dough after (A) first sheeting and (B) fifth sheeting.

minimize the importance of the role played by the outer protein film in slowing structural breakdown for noodles during cooking.

**Effect of Salt on Noodle Dough Structure**

Aside from the effect it has on noodle taste, addition of 2 or 3% salt to noodle dough has been claimed to impart a number of other benefits to noodle quality (Anonymous 1975, Naka 1974, Sawabe and Sakurai 1971). These include the tightening of gluten structure to give it astringency and improved viscoelastic properties, the increasing of water permeability during cooking thereby accelerating water uptake, the preventing of cracking during drying, and the suppressing of lactic acid and alcoholic fermentation. Therefore, it was decided to investigate the effects of various levels of salt on noodle dough structure and farinograph mixing characteristics. The Pitic 62 flour was used for this study. All noodles were prepared at 35% absorption (14% moisture basis). In agreement with the previous reports (Anonymous 1975, Naka 1974, Sawabe and Sakurai 1971), the addition of 2% salt appeared to strengthen the dough properties, as reflected by an increase in farinograph mixing time and a decrease in tolerance index (Fig. 5A,B). In addition, at 2% added salt, the internal structure of the Pitic 62 dough following the fifth pass exhibited a smoother and more uniform appearance than that found in the dough prepared with no added salt (Fig. 5A,B). When the level of salt was increased to 5%, the dough still handled well during sheeting, although it was slightly dry. Dryness was reflected by a very long farinograph mixing time (Fig. 5C), and the presence of a more jagged discontinuous protein matrix within the sheeted dough. When 10% salt was added, the sheeted dough became quite dry and lacked strength. At this level of added salt (Fig. 5D), dough formation would not occur in the farinograph and the internal structure of the sheeted dough revealed a very undeveloped gluten structure. From these results, it appears that addition of about 2% salt can have a favorable effect on dough characteristics, whereas addition of higher levels of salt causes a deterioration in dough properties in the absence of additional water.

**Effect of Absorption of Dough Structure**

A previous SEM study showed that under spaghetti processing conditions (27% absorption, 50° C), there did not appear to be sufficient water to form a uniform developed gluten network (Matsuo et al 1978). The sheeted noodle doughs formed in this study (Figs. 2B, 3B, 4C,D, 5B), however, seemed to have a smoother and more uniform gluten structure than spaghetti doughs. Comparison of the internal structure of unsalted Pitic 62 doughs that had been sheeted five times at 45% absorption (Fig.

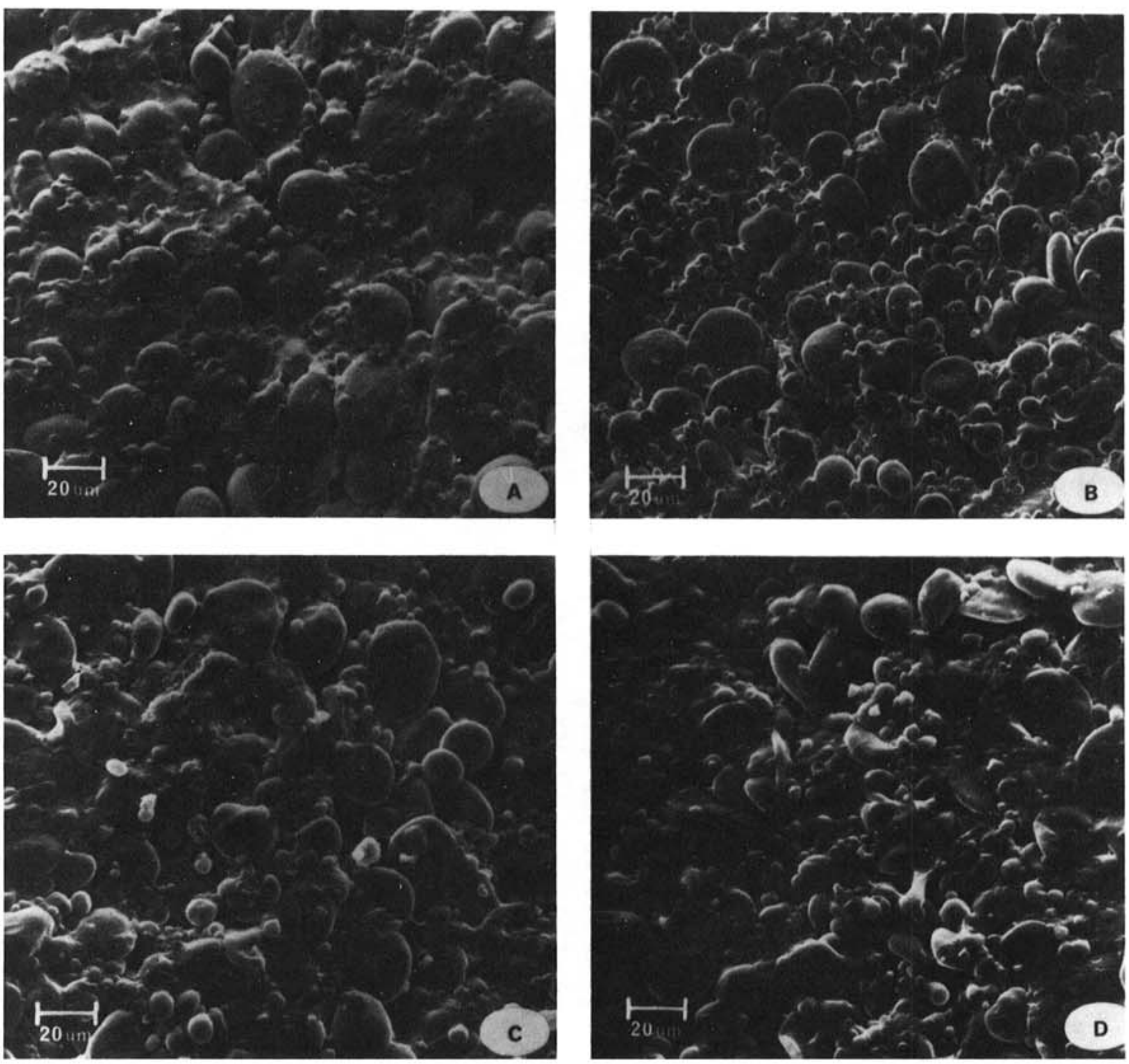


Fig. 4. Scanning electron micrographs of outer surfaces from Japanese flour dough after (A) first sheeting and (B) fifth sheeting; and of durum flour dough after (C) first sheeting and (D) fifth sheeting.

6A) and at 55% absorption (Fig. 6B) to micrographs of the Pitic 62 doughs sheeted at 35% absorption without salt (Fig. 5A) and with 2% salt (Fig. 5B) clearly illustrated that there was further modification of the gluten network with the addition of increasing amounts of water. Thus, under Japanese noodle processing conditions, full gluten development was not attained, although development appeared to proceed beyond that experienced during pasta processing. This may be partially due to the high mechanical efficiency of sheeting rolls (Kilborn and Tipples 1974) that would result in a significantly greater work input during noodle processing compared with spaghetti processing.

**Cooked Noodle Structure**

Wet noodles prepared from both the Japanese and durum flours were cooked for various times and their structures compared. Figure 7 shows the outer surface of the uncut edge of Japanese flour noodles after cooking for 6 min. The surface was characterized by smooth areas with some small openings where the protein film had remained relatively intact (Fig. 7B), some open areas interconnected by fibrils comprised of gluten protein, and material leached from starch granules during gelatization (Chabot et al 1976, Dexter et al 1978, Miller et al 1973). As cooking time was increased, the open areas became progressively more extensive. The cut edge of the noodles had a much more open structure than the uncut edge at all stages of cooking. The outer surface of the durum noodles (not shown) exhibited essentially the same appearance as the Japanese flour noodles. In general, the outer surfaces of both the Japanese flour noodles and the durum noodles retained their integrity to a lesser degree than that observed previously for cooked spaghetti (Dexter et al 1978).

The internal structure of cooked noodles (Fig. 8) was similar to that described previously for cooked spaghetti (Dexter et al 1978), consisting of an open filamentous network near the outer surface where starch gelatization was complete, an ungelatized region near the core, and an intact core where cooking water had not yet penetrated. As expected, the superior cooking quality of the Japanese flour noodles (Fig. 8A) was reflected by less evidence of structural breakdown near the outer surface compared with the durum wheat noodles (Fig. 8B) after equivalent cooking times.

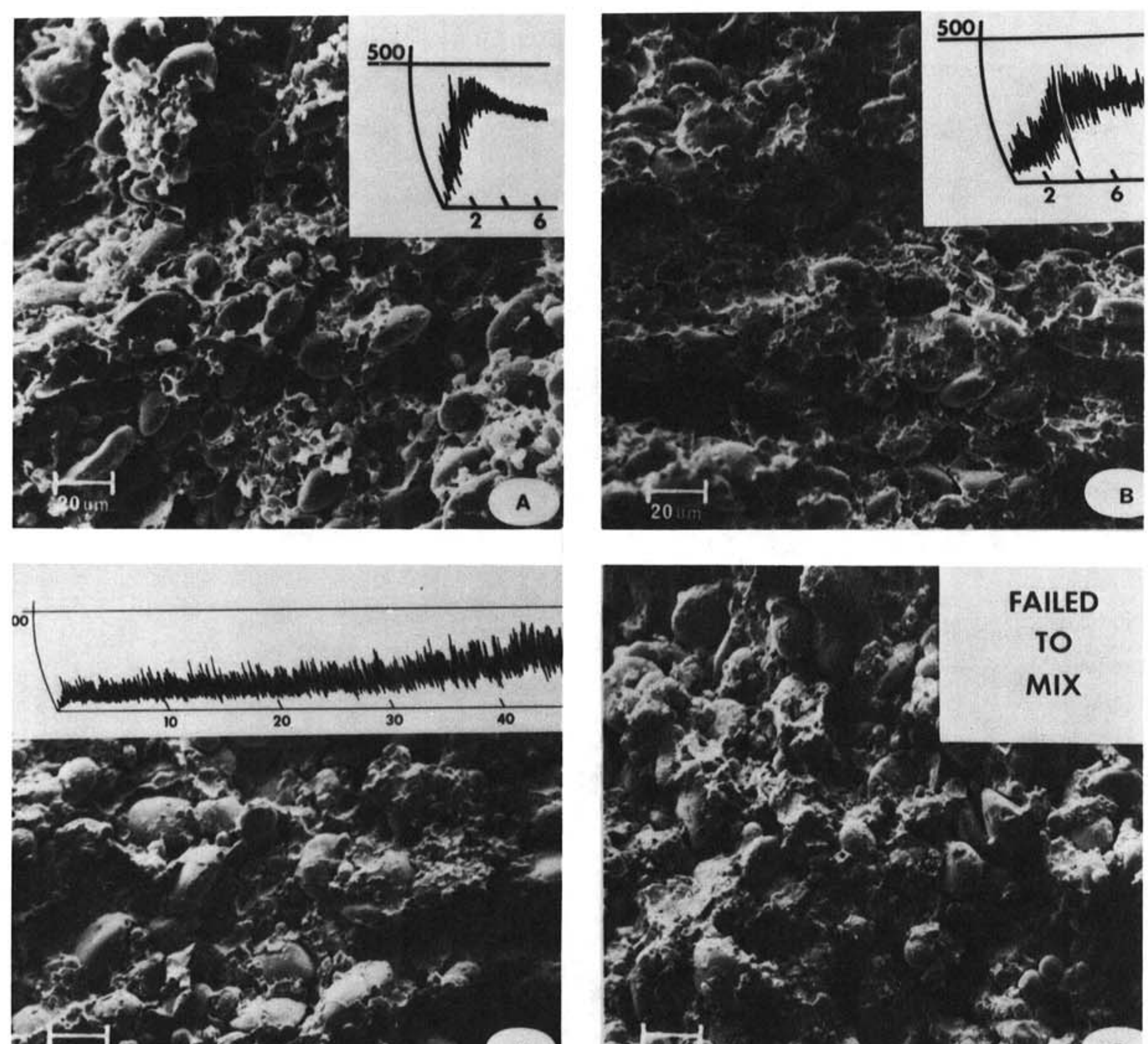


Fig. 5. Scanning electron micrographs of cross-sections of Pitic 62 noodle doughs prepared at 35% absorption, sheeted five times, and prepared with (A) no salt, (B) 2% salt, (C) 5% salt, (D) 10% salt. Farinograms obtained by the method of Irvine et al (1961) shown in upper right corner.

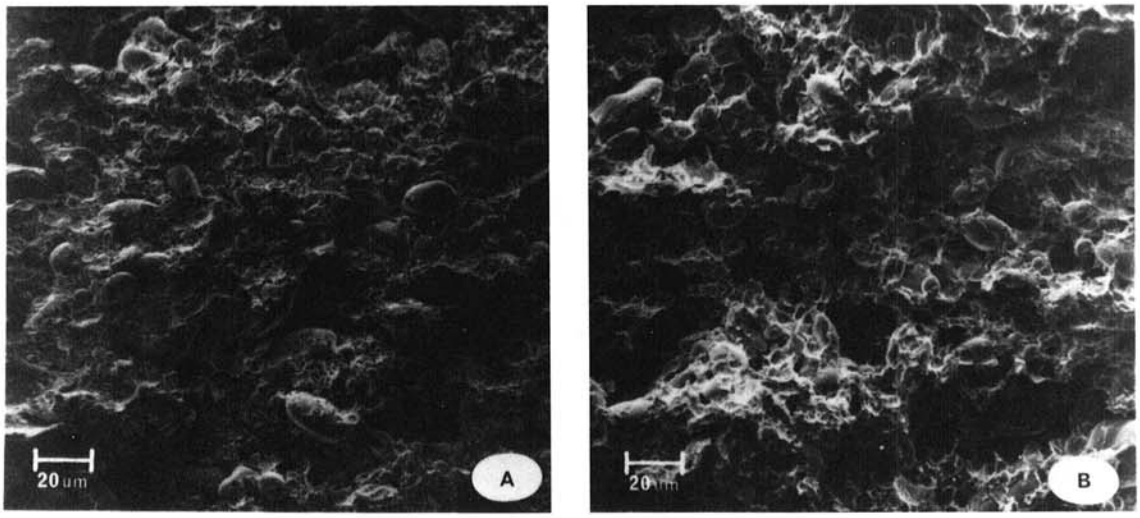


Fig. 6. Scanning electron micrographs of cross-sections of Pitic 62 doughs sheeted five times and prepared at (A) 45% absorption and (B) 55% absorption.

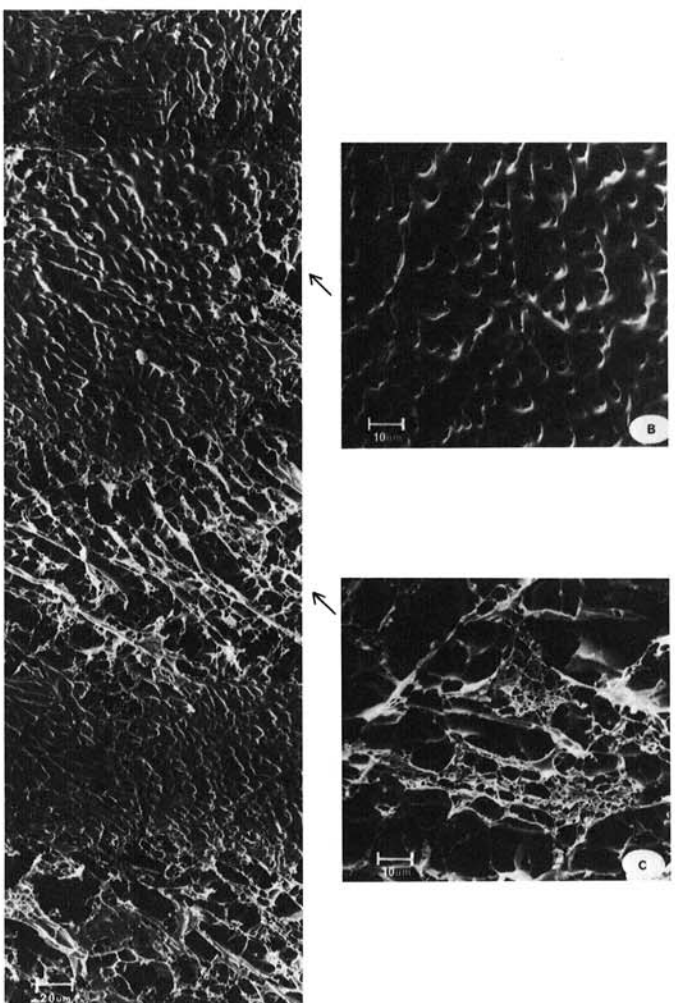


Fig. 7. (A) Scanning electron micrograph montage of the outer surface of a Japanese flour noodle cooked 6 min, (B) close-up of smooth area, (C) close-up of open filamentous area.

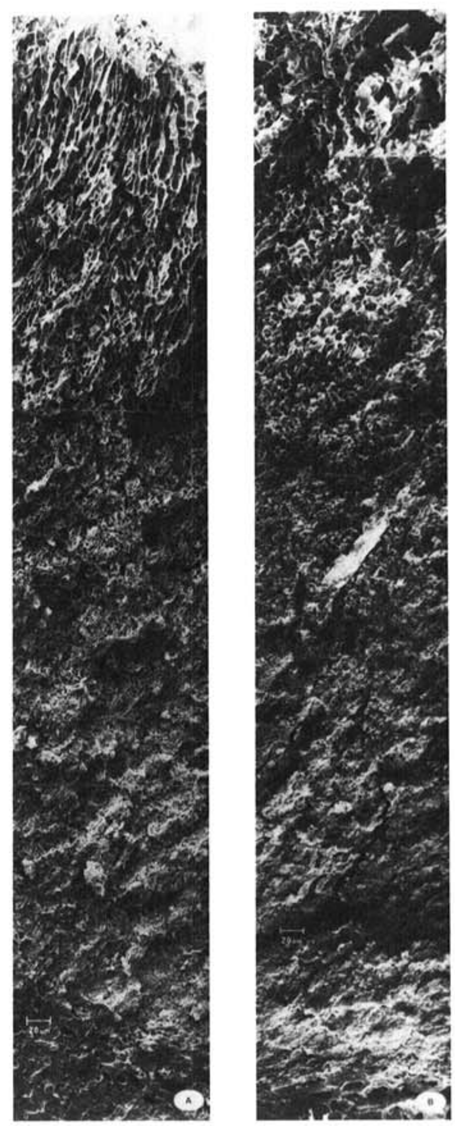


Fig. 8. Scanning electron micrograph montages of cross-sections of a noodle cooked for 6 min and prepared from (A) Japanese flour and (B) durum flour.

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