Effect of Whole Yeast and Various Fractions on Some Properties of Extruded Starch[1]

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ABSTRACT

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Whole yeast and some major fractions of whole yeast were added individually to starch and extruded under controlled conditions. Comparison of extrudate parameters of breaking strength, expansion, shear strength, and visual morphology indicated that differences exist in the effects of the various components on starch extrusion. Data indicate that the breaking strength of extruded material may be altered independently of the degree of expansion. It also appears that small differences in the quantities of yeast or yeast fractions added to a starch extrudate have relatively large effects on extrusion parameters.

Yeast protein is high-quality protein containing much lysine, the first limiting amino acid in cereals. It is thus logical to use yeast protein as a nutritional additive as well as a texture modifier for extruded, cereal-based snack foods. Adverse nutritional effects resulting from ingestion of high levels of bakers' yeast have been reported. Nucleic acids and cell wall materials were believed responsible (Reed and Peppler 1973, Reed 1981). However, adverse effects resulting from ingestion of brewers' yeast (or brewers' yeast protein isolate) have not been reported. In any case, the quantities of yeast used in extruded products are likely to be far below levels of concern.

High-temperature, short-time (HTST) extrusion is a popular processing method in the food industry. Despite the popularity and importance of this cooking method, little work has been done on the mechanism of HTST. Faubion (1980) mentions two concepts, the traditional melt theory and a modification that involves the retention of starch granule hila as focii for expansion as material leaves the extruder die. In this study we investigated changes in starch extrudates resulting from addition of other materials, which may shed some light on general extrusion mechanisms while providing useful information for incorporation of specific ingredients into extruded products.

MATERIALS AND METHODS

Dried Whole Yeast

Intact brewers' yeast (provided by the Miller Brewing Company, Milwaukee, WI) was shipped frozen to the Department of Grain Science and Industry at Kansas State University. It was lyophilized upon receipt.

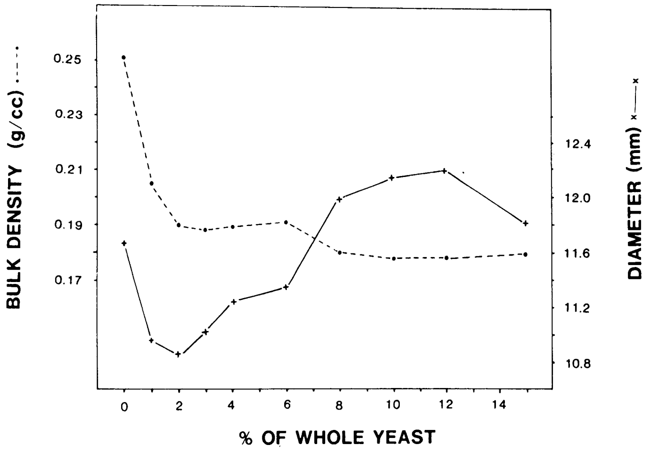

Fig. 1. Effect of added dried whole yeast on diameter and bulk density of extruded starch.

Homogenized Yeast

Yeast homogenate was supplied by the Miller Brewing Company. Homogenate material was removed following the initial homogenization in a proprietary separation scheme. The homogenized yeast was removed from the separation system at pH 12. This material was frozen, shipped to our laboratory, and lyophilized on receipt.

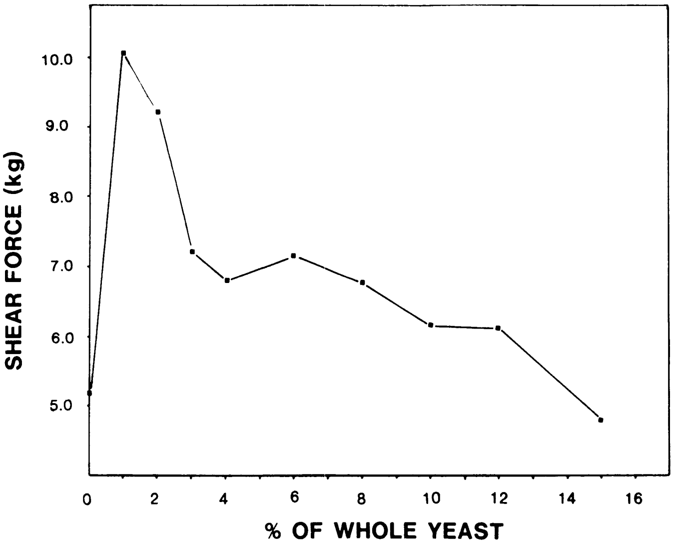

Fig. 2. Effect of added dried whole yeast on shear force of extruded starch.

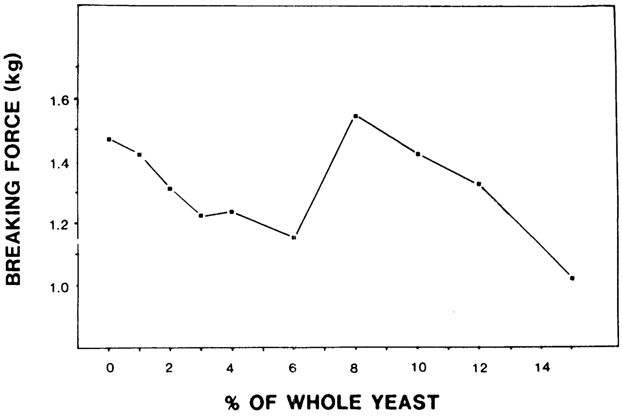

Fig. 3. Effect of dried whole yeast on breaking force of extruded starch.

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TABLE I
Effect of Cell Wall on Extrusion

Treatment	Diameter[a] (mm)	Bulk Density[b] (g/cc)	Breaking Force[c] (kg)	Shear Force[d] (kg)
Control	11.66 ± 0.96[e]	0.251 ± 0.022	1.740 ± 0.306	(a) 5.222 ± 0.837
10% Whole yeast	12.14 ± 0.79	0.178 ± 0.009	1.420 ± 0.353	(a) 6.166 ± 0.947
6% Yeast protein concentrate	10.53 ± 0.69	0.167 ± 0.017	1.009 ± 0.195	(a) 3.855 ± 0.618
10% Yeast cell homogenate	10.71 ± 0.65	0.163 ± 0.012	1.043 ± 0.230	...
1% Cell wall	10.74 ± 0.84	0.209 ± 0.014	1.498 ± 0.189	(b) 8.820 ± 0.681
2% Cell wall	10.30 ± 0.67	0.167 ± 0.017	1.298 ± 0.160	(c) 7.350 ± 1.344

[a] LSD (0.05) = 0.41; $n = 50$.
[b] LSD (0.05) = 0.016; $n = 10$.
[c] LSD (0.05) = 0.181; $n = 17$.
[d] LSD (0.05) = 0.42; (a) $n = 30$, (b) $n = 14$, (c) $n = 25$.
[e] Values are average ± standard deviation.

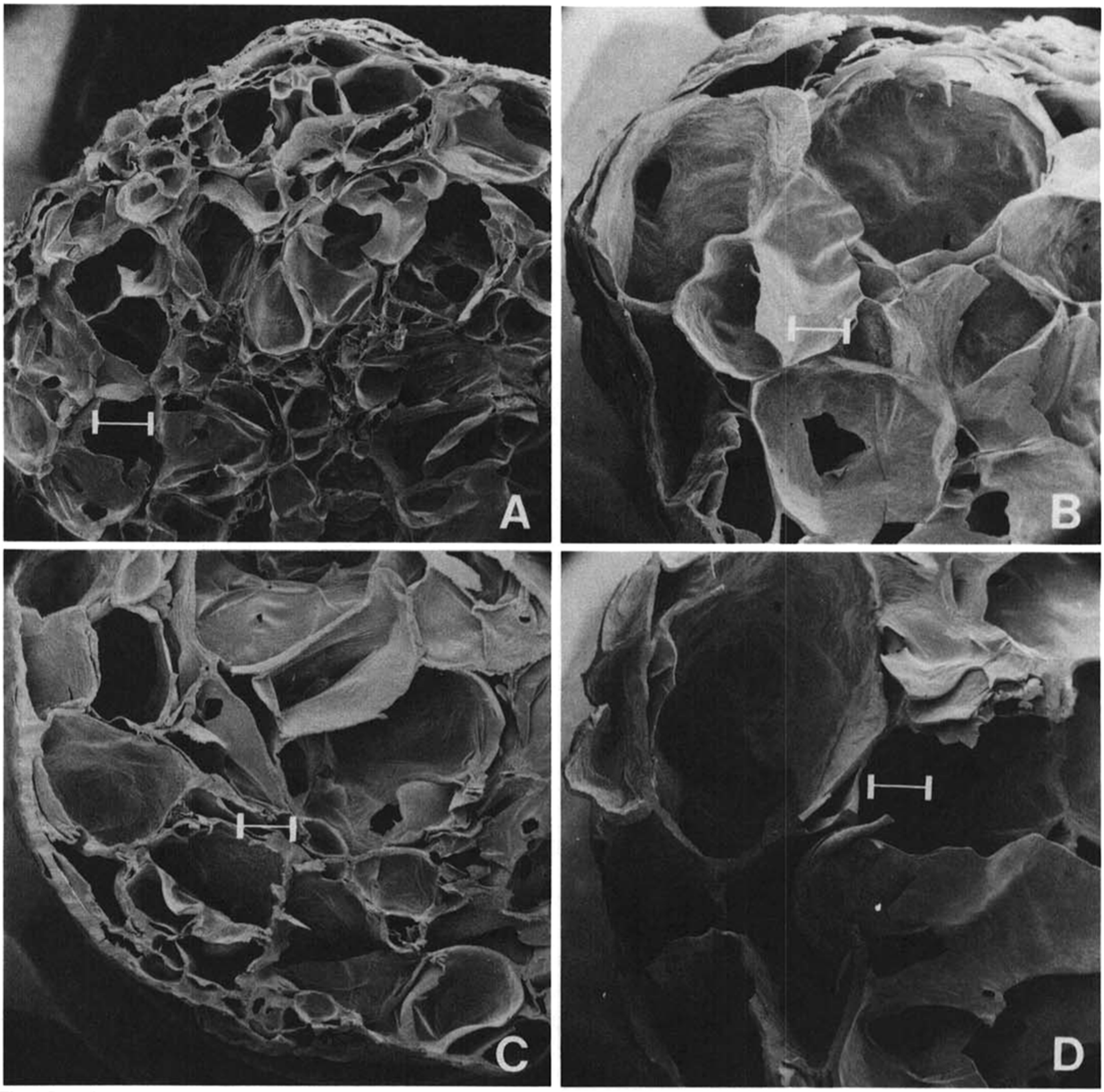

Fig. 4. Scanning electron micrograph of extruded starch cross sections containing (**A**) 1%, (**B**) 8%, (**C**) 12%, and (**D**) 0% yeast protein concentrate (bars = 500 μm).

Cell Wall Material

Cell wall material (supplied by the Miller Brewing Company) was recovered by centrifugation of the pH 12 yeast cell homogenate as part of a proprietary yeast separation scheme. The material was frozen, shipped to our laboratory, and lyophilized on receipt.

Starch

Prime wheat starch was donated by Midwest Solvent Company, Atchison, Kansas.

Moisture Determination

Moisture contents (mc) were determined according to AACC Method 44-19 (AACC 1980).

Tempering

Starch was tempered by adding sufficient water to bring the moisture content to about 21%. Water was added as a fine mist while the starch tumbled in a rotating drum. The moist starch then was packed in double-walled plastic bags and allowed to equilibrate for at least 24 hr at 5° C. Before use, the moist starch was remixed in a rotating "V" blender.

Preparation of Dried Whole Yeast and Starch Mixture

Appropriate amounts of wet starch (about 21% mc), dry starch (about 11% mc), and dried whole yeast were blended to give a 2-kg sample mixture with 19.5% mc. Varying amounts of dried whole yeast (from 0 to 15%) were added to starch and extruded.

Extrusion processing, product evaluation, and statistical analysis were carried out as described by Lai et al (1985).

RESULTS AND DISCUSSION

Effect of Dried Whole Yeast

The effect of dried whole yeast depended on the amount added. Adding low levels of dried yeast (up to 4%) reduced the diameter of extruded starch (Fig. 1). This reduction in diameter was maximal at the 2% addition level, and from 2–8% the extrudate diameter increased. Adding more than 8% dried whole yeast did not further increase extrudate diameter, however, the increase in diameter above that of the control was significant ($P < 0.05$).

Adding dried whole yeast at the 2% level decreased the bulk density of extruded starch. Levels above 2% produced little or no additional effect (Fig. 1). Changes in expansion at addition levels greater than 2% were not accompanied by a change in bulk density, indicating a change in rate of material flow through the extruder with addition of dried whole yeast.

The addition of low levels of dried whole yeast substantially increased the shear force required to cut extruded starch (Fig. 2). Shear force doubled between 0 and 2% added yeast, then declined sharply at the 4% level. At levels above 4%, a gradual decline in shear force was noted until at the 15% level shear force values were equal to the control. Adding low levels of dried whole yeast (up to 6%) slightly decreased the breaking force of extruded starch (Fig. 3). The breaking force of the extruded yeast-starch mixture fell to a minimum at 6% added yeast. An increase in breaking force was noted between 6 and 8% added yeast. This was followed by a gradual decline in breaking force between 8 and 15% added yeast (Fig. 3).

TABLE II
Effect of pH Adjustment on Extrusion Cooking of Mixtures of Cell Wall and Starch and of Yeast Cell Homogenate and Starch

Treatment	Diameter[a] (mm)	Bulk Density[b] (g/cc)	Breaking Force[c] (kg)
1% Cell wall			
pH 7	12.23±0.84[d]	0.219±0.019	2.061±0.224
pH 9	10.74±0.84	0.209±0.017	1.498±0.189
10% Homogenate			
pH 7	11.29±0.71	0.212±0.007	0.914±0.196
pH 9	10.71±0.65	0.163±0.012	1.043±0.230
6% Yeast protein concentrate	10.53±0.69	0.167±0.017	1.009±0.195

[a] LSD (0.05) = 0.44; $n = 50$.
[b] LSD (0.05) = 0.014; $n = 10$.
[c] LSD (0.05) = 0.146; $n = 17$.
[d] Values are average ± standard deviation.

Sound reasons for the observed effects of small amounts of dried whole yeast on starch extrudates were not obvious from this study. However, the changes in extrudate diameter, shear force, and bulk density that occurred with the addition of 2% dried whole yeast were significant ($P < 0.05$) and repeatable, as were the changes in diameter and breaking force that occurred with additions of 6–10% dried whole yeast.

Figure 4 shows cross sections of extrudates with and without added dried whole yeast. The cells of extrudates containing 1% dried whole yeast (Fig. 4A) appeared to be smaller and shallower than those of the control (Fig. 4D). As the addition level increased, cell size and depth increased (Fig. 4 A–C). For the 8–12% levels, the ultrastructure of extruded yeast-starch mixtures resembled that of extruded starch (Fig. 4D). At all addition levels, added dried whole yeast did not affect morphology of cell walls (Fig. 4A–D).

Effect on Cell Walls

The effects of dried whole yeast were quite different from those of yeast protein concentrate (YPC) added to the same system (Lai et al 1985). YPC was found to decrease both expansion and textural strength at 10% additions. Examination by scanning electron microscopy of extrudates containing dried whole yeast showed some intact yeast cells embedded in the extrudate cell wall (Fig. 5). Possibly, yeast cell walls encapsulated the cytoplasmic material and prevented it from interacting with starch. To explore this possibility, lyophilyzed yeast cell homogenate equivalent to 10% dried whole yeast was added to starch and extruded. Adding homogenized yeast cells in place of intact yeast resulted in decreased expansion, breaking force, and bulk density of the extrudate (Table I). Extrusion parameters of extrudates containing homogenized yeast were similar to extrudates containing 6% YPC. About 60% of the homogenized yeast is recovered as YPC, thus, addition of 6% YPC is equivalent to addition of 10% homogenized yeast. The ultrastructure of extrudates containing homogenized yeast was very similar to that of extrudates containing 6% YPC (Figs. 4 and 6A). This supports the hypothesis that yeast cytoplasmic materials are responsible for the effects of YPC and that these materials are not released during extrusion processing of whole yeast combined with starch.

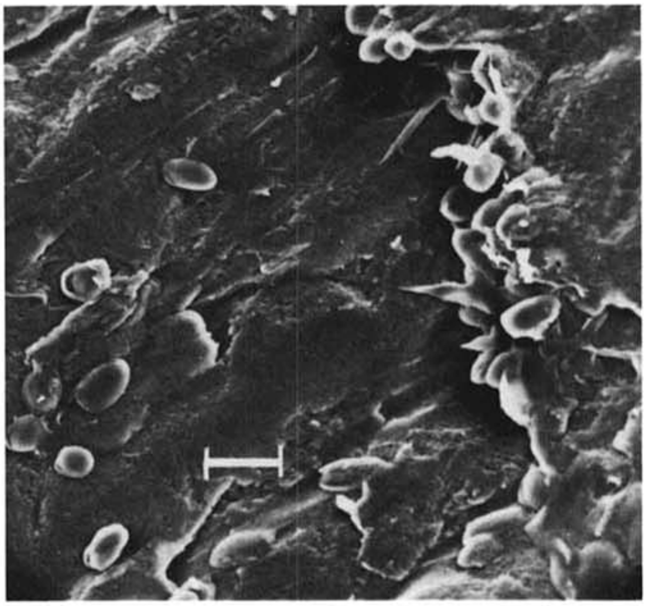

Fig. 5. Scanning electron micrograph of extruded starch containing 8% dried whole yeast (bars = 10 μm).

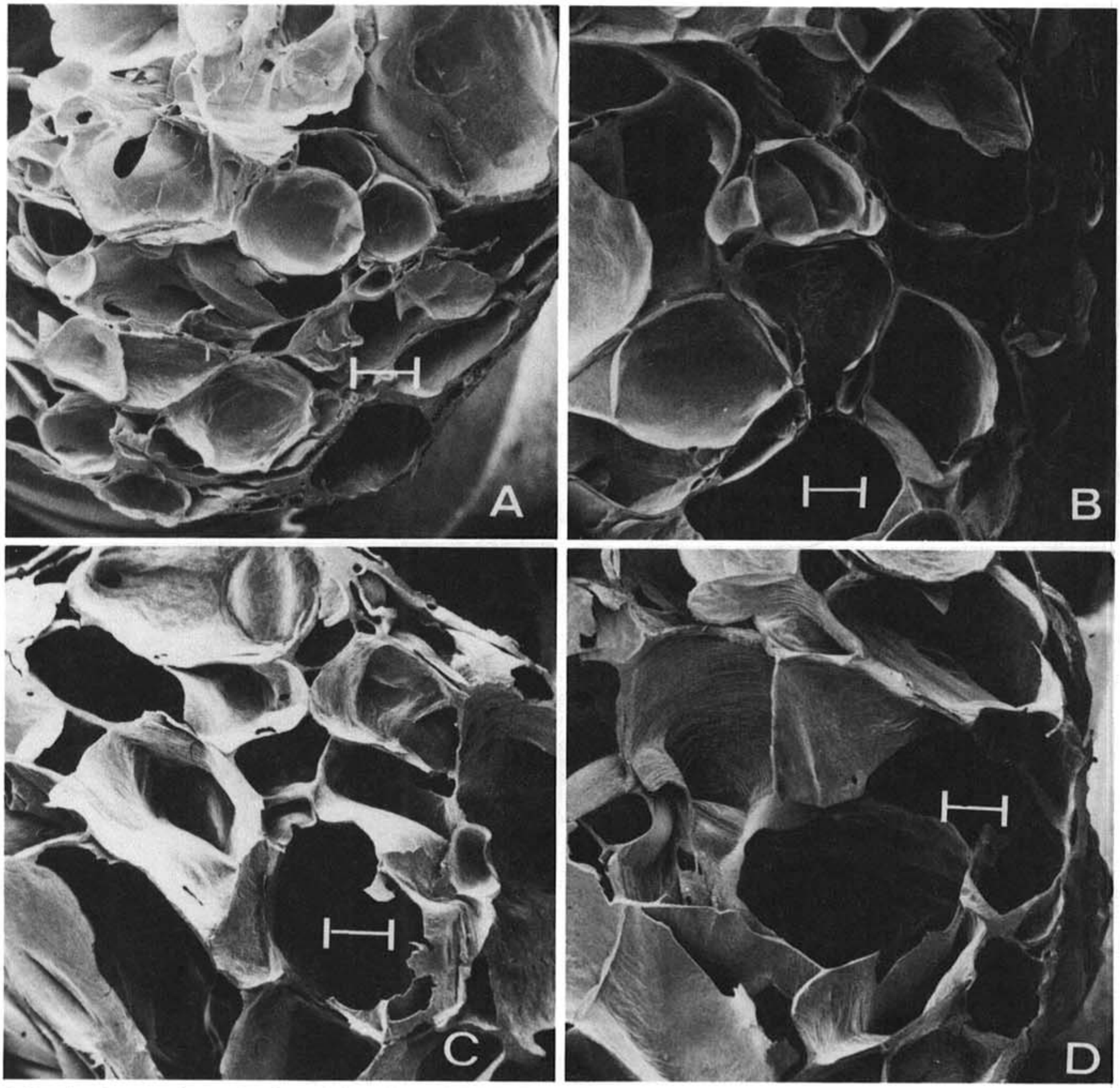

Fig. 6. Scanning electron micrographs of extruded starch containing (**A**) 10% homogenized yeast cells, (**B**) 10% neutralized, homogenized yeast cells, (**C**) 1% cell wall material, and (**D**) 1% neutralized cell wall material (bars = 500 μm).

Given this hypothesis, the effects of dried whole yeast should be duplicated by isolated yeast cell wall, so 1 and 2% cell wall material isolated from yeast cell homogenate were added to starch and extruded. Results are summarized in Table I. Cell wall materials did not duplicate the effects of whole yeast; the extruded mixture of cell walls and starch had less expansion but was slightly higher in shear force. That these effects were not duplicated might be caused by cytoplasmic contamination of cell wall materials during isolation. The unusually high pH (determined by the method of Cabrela-Lavedre 1978) of the various fractions, resulting from the fractionation scheme used to separate them, was also considered as a possible cause. The pH values for extrudates containing 1 and 2% cell wall and 10% homogenized yeast were, 9.2, 9.35, and 9.5, respectively.

Neutralizing the cell wall fraction and yeast homogenate significantly changed their effects on some extrusion parameters but not all. The data in Table II show that both materials had a significant effect on extrudate diameter. However, neutralization affected bulk density only of the extrudates containing homogenized yeast, and only affected the force required to break extrudate of the cell wall materials and not that of the homogenized yeast. Invariably, extrudates containing high-pH material were more similar to extrudate containing 6% YPC than were those containing neutralized material.

Explanations for these observations were not evident from this study. However, it appears that the dependence of breaking strength of an extrudate on its degree of expansion, which was true for the starch and YPC mixture reported by Lai et al (1985), is not true for starch combined with other fractions of yeast. This observation indicates that the extrudate parameters of expansion and breaking strength are not necessarily interdependent, which may be of interest to both researchers in the area of extrusion processing and to producers of extruded products such as snack foods.

ACKNOWLEDGMENT

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