The Effect of a Yeast Protein Concentrate and Some of Its Components on Starch Extrusion[1]

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ABSTRACT

A protein concentrate extracted from brewers' yeast was fractionated. The fractions were added to wheat starch and extruded under high temperature and pressure. Expansion, breaking strength, and bulk density of the extrudates were measured and related to the amounts of intact and fractionated yeast protein added. Results indicated that breaking strength of extrudates could not be related to expansion. Also lipids bound to the yeast protein were found to be functional components in the extrusion of wheat starch and yeast protein concentrate.

The use of extrusion cooking as a method of food fabrication has increased during the past few years. This increase is due to a growing demand for snack-type convenience foods and the advantages extrusion cooking offers over other production methods (Lawton et al 1972, Mercier 1977, Faubion and Hoseney 1982a). High-temperature, short-time (HTST) extrusion is an important and versatile cooking method, however, literature concerning basic studies of HTST extrusion is limited. Most papers on extrusion describe a particular machine and its applications (Anderson et al 1969; Conway 1971a,b; Smith 1975; Maga and Lorenz 1978) and rarely report experimental conditions and specific data. Effects of operating conditions or moisture content on extrusion cooking of various starch and cereal flours have been reported (Anderson et al 1969; Moore 1973; Stearns 1974; Mercier and Feillet 1975; Mercier 1977; Mercier et al 1979; Meuser et al 1982, 1984), but there are few studies of the effect of ingredients combined with starch before extrusion.

Mercier and Feillet (1975) reconstituted corn starch by blending varying amounts of waxy (high amylopectin) and high-amylose corn. They reported that, except for material extruded at 225° C, amylose reduced expansion and water solubility of extruded starch. They also found that increasing extrusion temperature increased the water solubility of extruded starch. Cabrera-Lavedre (1978) reported that surfactants reduced expansion of extruded starch and that varying pH through a range of 4–9 had no effect on expansion. However, when the pH of pure wheat starch was reduced below pH 4, the expansion of extrudates was greatly reduced. Faubion and Hoseney (1982a) found that adding wheat gluten greatly influences the extrusion properties of starch, that both flour lipids and wheat gluten decrease the expansion and force required to shear through or break extruded starch, and that the effect of added soy protein on extrudate properties depends upon the level added. The findings of Cabrera-Lavedre (1978) and Faubion and Hoseney (1982a,b) indicate that additives can be used to modify expansion and texture of starch-based extruded snack foods.

Protein and polysaccharides have important carrier and protective functions for aromatic compounds that allow flavor chemicals to withstand high temperature (Krukar 1980). Yeast protein is a high-quality protein that can be added to extrusion-made snack foods as a nutritional fortifier and possibly a flavor carrier.

Previous research (Faubion and Hoseney 1982a,b) indicates that the effect of added protein on properties of extruded starch depends on the source of protein. The purpose of this study was to determine the effect of yeast protein concentrate (YPC) on mixtures of extruded starch and YPC.

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MATERIALS

Yeast Protein Concentrate (YPC)

YPC was prepared (by Miller Brewing Company, Milwaukee, WI) as outlined in Figure 1. It was frozen and shipped under refrigeration to the Department of Grain Science and Industry at Kansas State University, lypholized on receipt, and stored at 2° C until used.

Starch

Prime wheat starch was obtained from Midwest Solvent Co., Inc., Atchison, KS.

METHODS

Moisture Determination

Moisture was determined according to AACC method 44-19 (1983).

Free Lipids Determination

Free lipids were determined according to AOAC method 30-25 (1983).

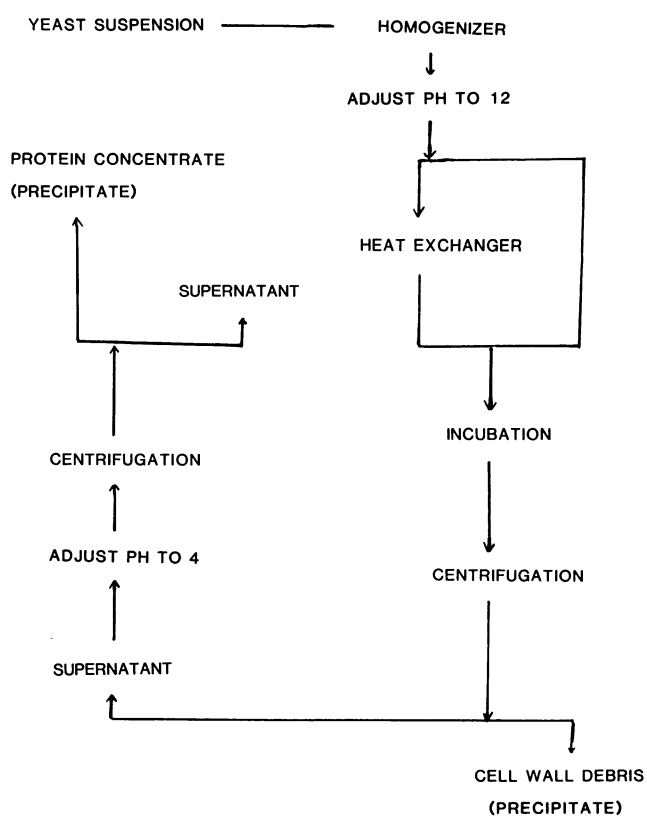

Fig. 1. Production process for yeast protein concentrate (YPC).

Bound Lipids Determination

A 5-g sample of YPC was suspended in 200 ml of water-saturated butanol. The suspension was allowed to stand 30 min with occasional stirring. The suspension then was centrifuged and the supernatant decanted. The precipitate was extracted with an additional 200 ml of water-saturated butanol for 30 min. This process was repeated three times (Fig. 2). The combined supernatants were evaporated in a reduced-pressure rotary evaporator at 30° C. The residue was dissolved in 40 ml of petroleum ether and transferred to a tared beaker. The rotary evaporator flask was rinsed with an additional 10 ml of petroleum ether, which also was added to the tared beaker. The solvent was removed by drying at 100° C for 30 min. Bound lipids content was defined as the weight of material extracted as a percentage of the sample weight on an "as is" basis.

Bound Lipids Extraction

Bound lipids were extracted by the same scheme used for their determination, except the sample to solvent ratio was reduced to 1:6. Defatted YPC was recovered by centrifugation. Residual solvent was removed by evaporation at room temperature. Bound lipids were recovered either by evaporating the solvent at room temperature under N_2 or by adding starch and evaporating solvent under vacuum at room temperature.

Preparation of YPC Starch

Appropriate amounts of dry starch (moisture content [mc] about 11%), wet starch (about 21% mc), and YPC or subfractions were blended to give a 200-g sample of the desired moisture (19.5%). Mixtures were allowed to equilibrate overnight in a double-sealed plastic bag. Moisture content of the mixtures was checked after preparation and again prior to extrusion.

Preparation of Starch and Lipids Mixture

Direct addition method. For the direct addition method, 100 g of starch (12.4% mc) was put in a Stein mill cup (Fred Stein Laboratories, Atchison, KS) and an appropriate amount of lipids added and ground for 30 sec. This mixture was added to the remainder of the dry starch (12.4% mc), ground for 30 sec in a Stein mill, then blended with an appropriate amount of wet starch to make the desired lipids-starch mixture at 19.5% mc.

Premix method. A premix was made by suspending starch in petroleum ether containing an appropriate amount of bound lipids. The solvent was removed at room temperature under vacuum. The desired mixture of lipids and starch was made by blending appropriate amounts of wet and dry starch with the premix.

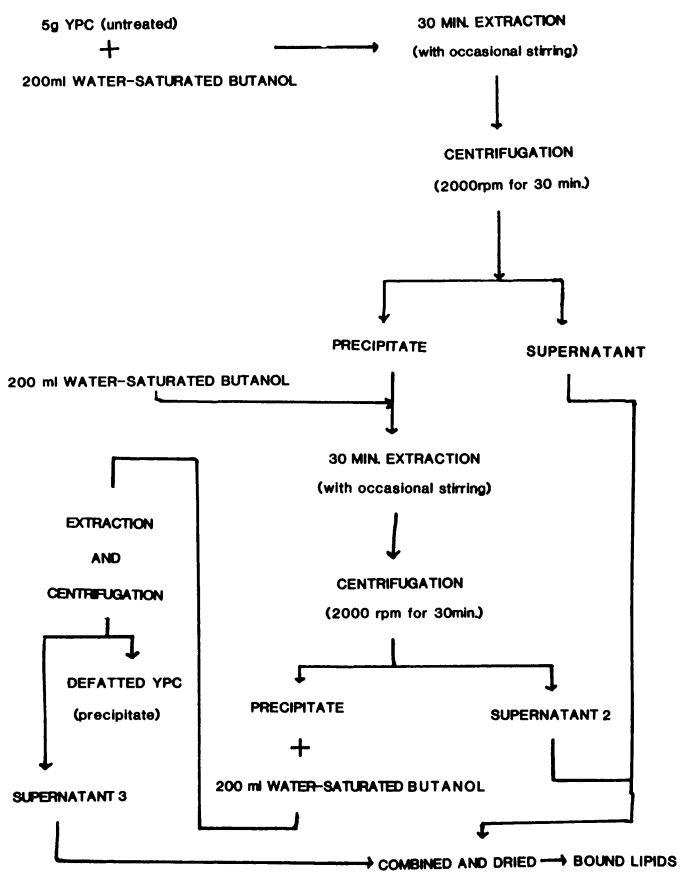

Fig. 2. Extraction scheme for bound yeast lipids.

Preparation of Reconstituted YPC

Reconstituted mixtures of YPC and starch were made by blending an appropriate amount of starch-lipid mixture (prepared by one of the two methods described) with defatted YPC.

Extrusion

All studies were done with a laboratory-sized, single-screw extruder (model 2403, C. W. Brabender Instruments, Inc., South Hackensack, NJ). The extrusion process was carried out as described by Faubion (1980) except that wet corn grit (about 25%

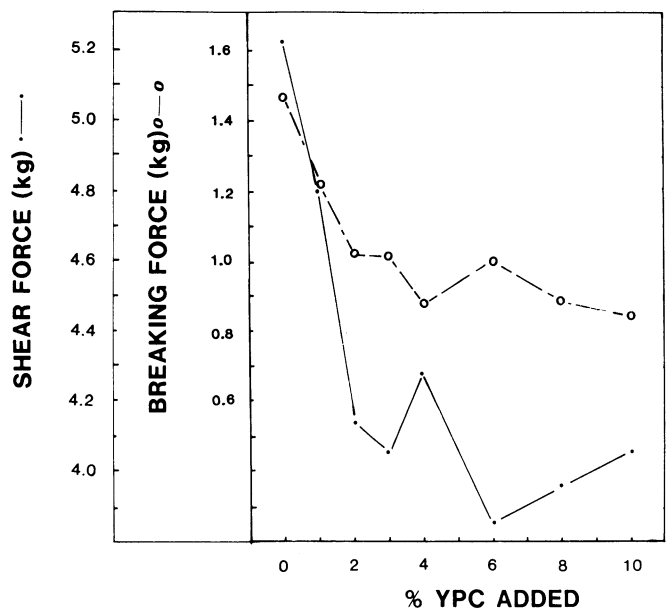

Fig. 3. Shear force and breaking force of extrudates containing graded amounts of yeast protein concentrate.

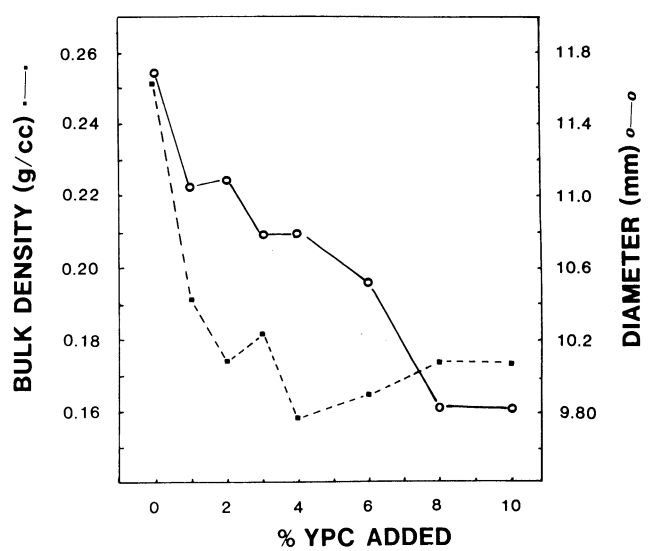

Fig. 4. Expansion and bulk density of extrudates containing yeast protein concentrate.

mc) was extruded before each test sample and a hand-operated feeder was used. The extrusion conditions were: screw speed 120 rpm; heating zone 1, air cooled; heating zone 2, 110° C; heating zone 3, 175° C; die diameter 6.35 mm; compression ratio of screw 5:1. Feed rate was adjusted to maintain a constant 9 amps to the motor.

Texture Analysis

Texture was studied with an Instron model 1130 Universal Texture Analyzer. Shear force, defined as the maximum force needed to cut through two-thirds of the extrudate, was measured using a Warner-Brazler shear apparatus to cut across the extrudate rod at a right angle to its long axis. Breaking force was measured by using a round, vertically driven anvil 1 cm in diameter to break a sample supported at both ends with a 9.25-cm free span. Deformation distance was defined as the distance the anvil traveled between touching the sample and breaking it; the measured time was defined as the deformation time.

Operating conditions of the texture studies were as follows. For shear force determination: blade speed 5 cm/min; chart speed 10 cm/min; load cell 50 kg; calibration range, calibrated at range 5 using a 5-kg weight; operation range, either range 5 or 10. For breaking force and deformation distance: anvil speed 2.5 cm/min; chart speed 50 cm/min; calibration range, calibrated at range 10 using a 1-kg weight; operation range, either range 5 or 10.

Extrudate Diameter Determination

Expansion of the extruded product was determined by measuring its diameter with calipers. Ten pieces of extrudate, each 15-cm in length, were selected from each run. Five measurements of diameter were taken at equal intervals on each piece.

Extrudate Density

Extrudate density (g/cc) was calculated from the weight of extrudate samples and the volume calculated from average diameter and length.

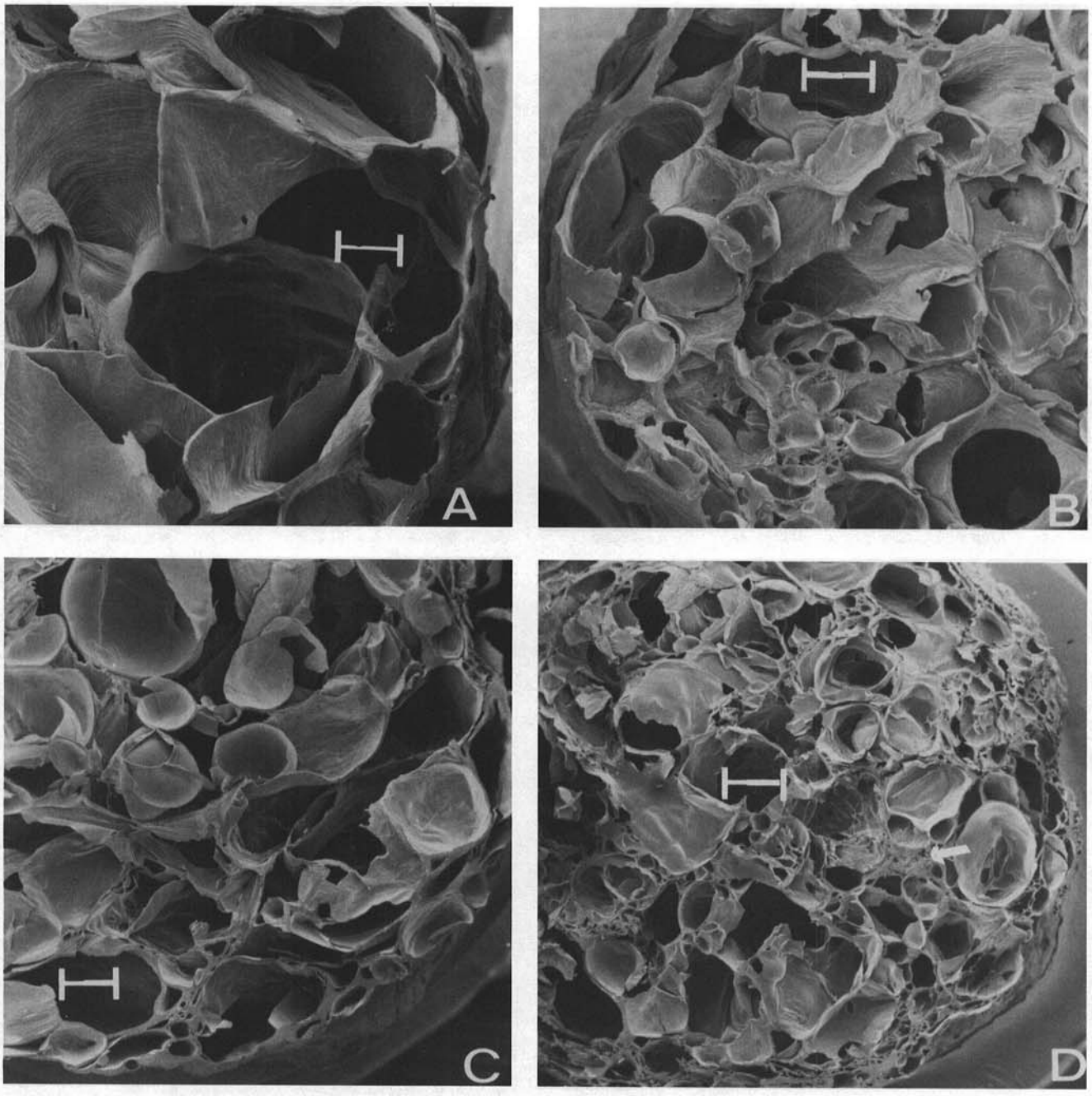

Fig. 5. Scanning electron micrographs of extrudate containing **A,** 0%; **B,** 1%; **C,** 6%; and **D,** 10% YPC (bars = 500 μm).

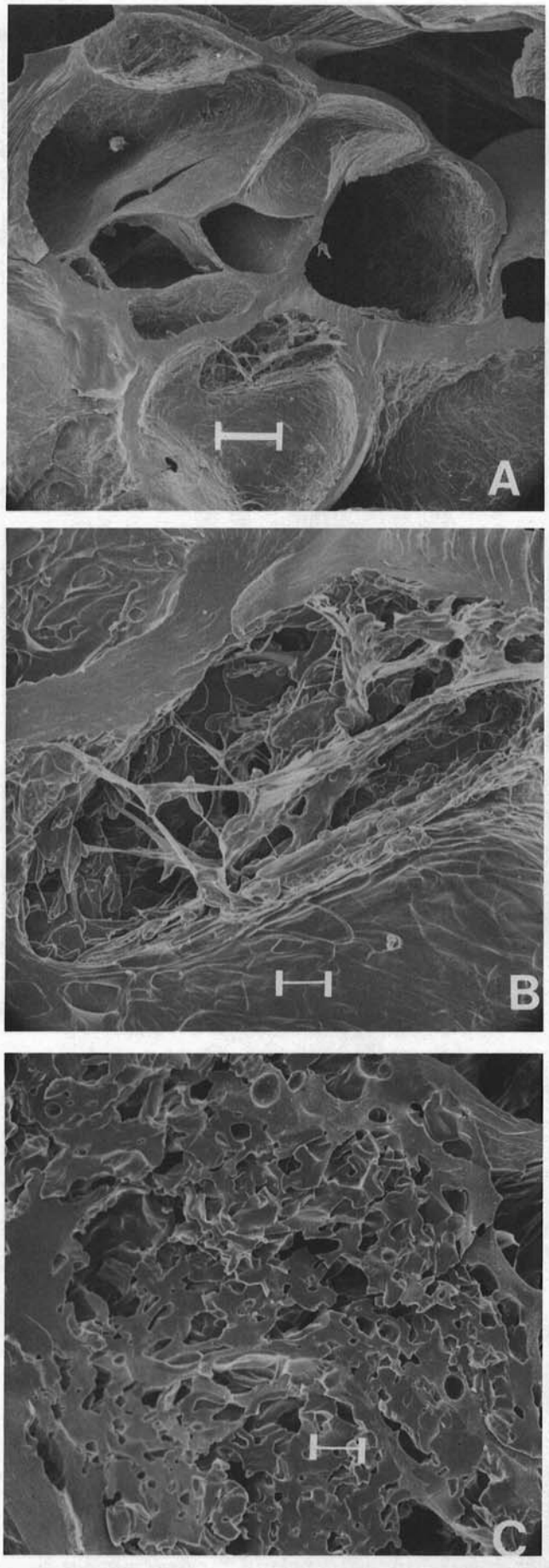

Fig. 6. Enlarged view of **A,** dense areas (bar = 100 μm); **B,** thread-like structure (bar = 20 μm); and **C,** solid chunk-like materials found in extrudates containing yeast protein concentrate (bar = 20 μm).

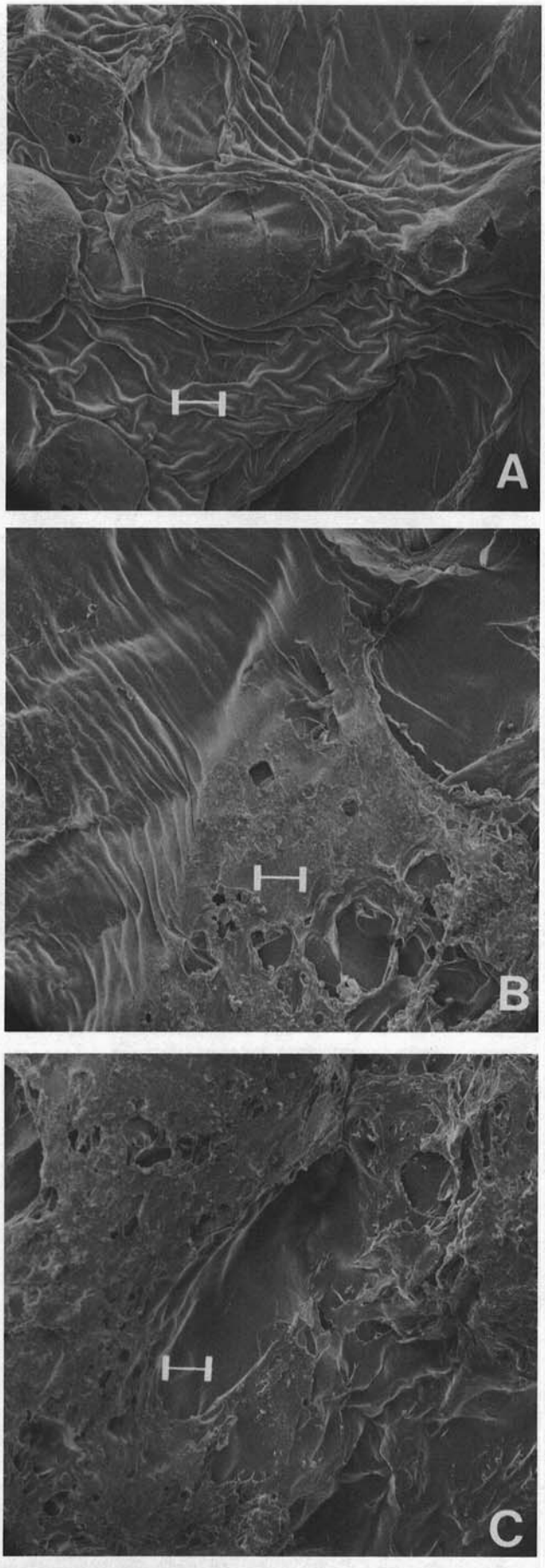

Fig. 7. Scanning electron micrographs of extrudates surface of **A,** control (starch); **B,** starch and 1% yeast protein concentrate (YPC); and **C,** starch and 10% YPC (bars = 100 μm).

Scanning Electron Microscopy

Sample preparation for scanning electron microscopy was as described by Faubion and Hoseney (1982a).

Statistical Analyses

Mean, standard deviation, and least significant difference (Snedecor and Cochran 1964) were calculated for each sample property tested.

RESULTS AND DISCUSSION

Effects of YPC on Extrudate Properties

Varying amounts of YPC were added to wheat starch and extruded. The effects of adding YPC were determined as changes in expansion, bulk density, breaking force, and shear force of the extrudates. All these factors tended to decrease as the amount of YPC increased (Figs. 3 and 4). Bulk density of extrudates containing YPC reached a minimum with a 2% addition and remained constant with higher levels of addition ($P = 0.05$) (Fig. 4). The fact that a decrease in expansion was not accompanied by an increase in bulk density indicates that production rate was altered.

The addition of 2% YPC decreased both breaking force and shear force of the extrudate. Addition levels greater than 2% (Fig. 4) did not affect either parameter.

Figure 5 (A–D) shows the ultrastructure of extrudates with 0, 1, 6, and 10% added YPC. All pictures were taken at the same magnification (×10). It appears that added YPC reduced cell size. The decrease in cell size is roughly proportional to the amount of

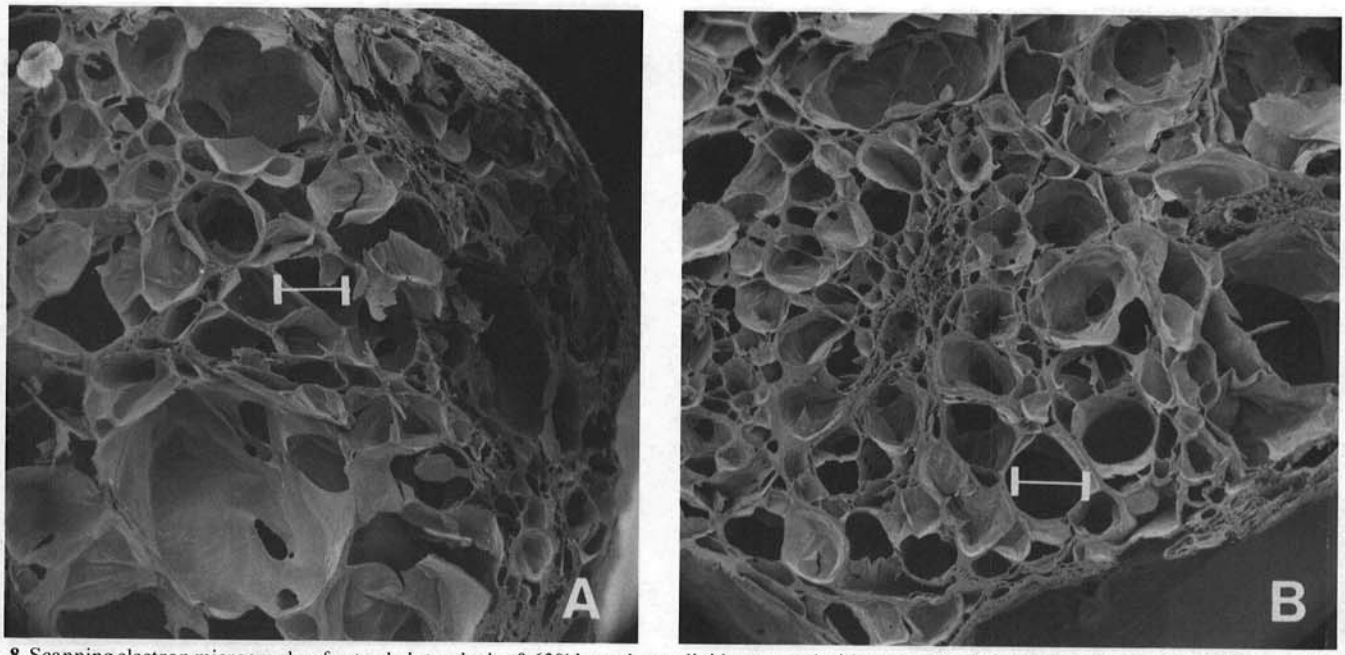

Fig. 8. Scanning electron micrographs of extruded starch plus 0.63% bound yeast lipids prepared with **A,** the premix method, or **B,** the direct addition method (bars = 50 μm).

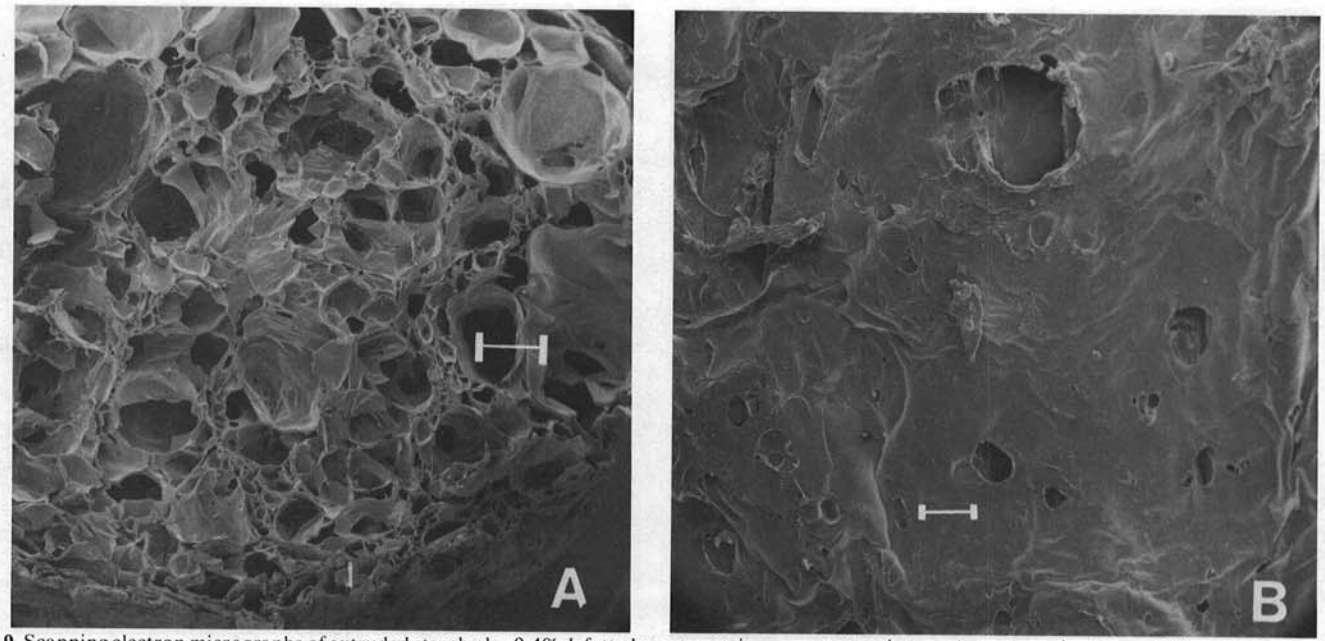

Fig. 9. Scanning electron micrographs of extruded starch plus 9.4% defatted yeast protein concentrate mixture. **A,** cross section (bar = 500 μm); **B,** extrudate surface (bar = 100 μm).

YPC added. The cell wall of extruded starch appears rougher than that of extrudates containing YPC. The addition of YPC also changed the distribution of cell sizes of extruded starch. Peripheral cells in the extruded starch and extrudate containing 1% YPC were relatively expanded and/or elongated, whereas those in extrudates containing high levels of YPC (6 and 10%) were small and round. Dense areas seen scattered throughout extrudates containing the higher amount of YPC are composed of groups of small cells. In addition to the dense areas, some essentially solid materials also were seen in extrudates containing YPC (arrow in Fig. 5D). Under higher magnification these materials appeared to be of cells that expanded poorly (Fig. 6C). The small round cells may be the hila of starch granules (Fig. 6C). Faubion (1980) suggested that the starch hilum may be the nucleation site for water vaporization as material exits the die.

We occasionally found some thread-like materials bridging the cell wall of poorly expanded cells of extrudates containing YPC (Fig. 6A) that appeared similar to those reported by Faubion and Hoseney (1982b). Under higher magnification, these thread-like materials appeared to be fibrous, with granules, probably starch, embedded in them (Fig. 6B). Figure 7 shows the surface of extrudates with (7B and C) or without (7A) added YPC. As reported by Stearns (1974) and Faubion and Hoseney (1982a), domes, ripples, and pits are present on the surface of extruded starch (Fig. 7A). Stearns (1974) hypothesized that domes indicate the existence of well-expanded cells that set before cell collapse. Ripples were considered signs of cell collapse. Our data are consistent with this hypothesis. From Figure 5A, we can see that some peripheral cells are relatively large and round, but others are partially collapsed (elongated). For extrudates containing high levels of YPC, severely torn regions also were seen (Fig. 7B). As the YPC addition level increased, torn regions became predominant. Domes were seen rarely in extrudate containing 10% YPC; the surface of this sample appeared to be rough and torn (Fig. 7C).

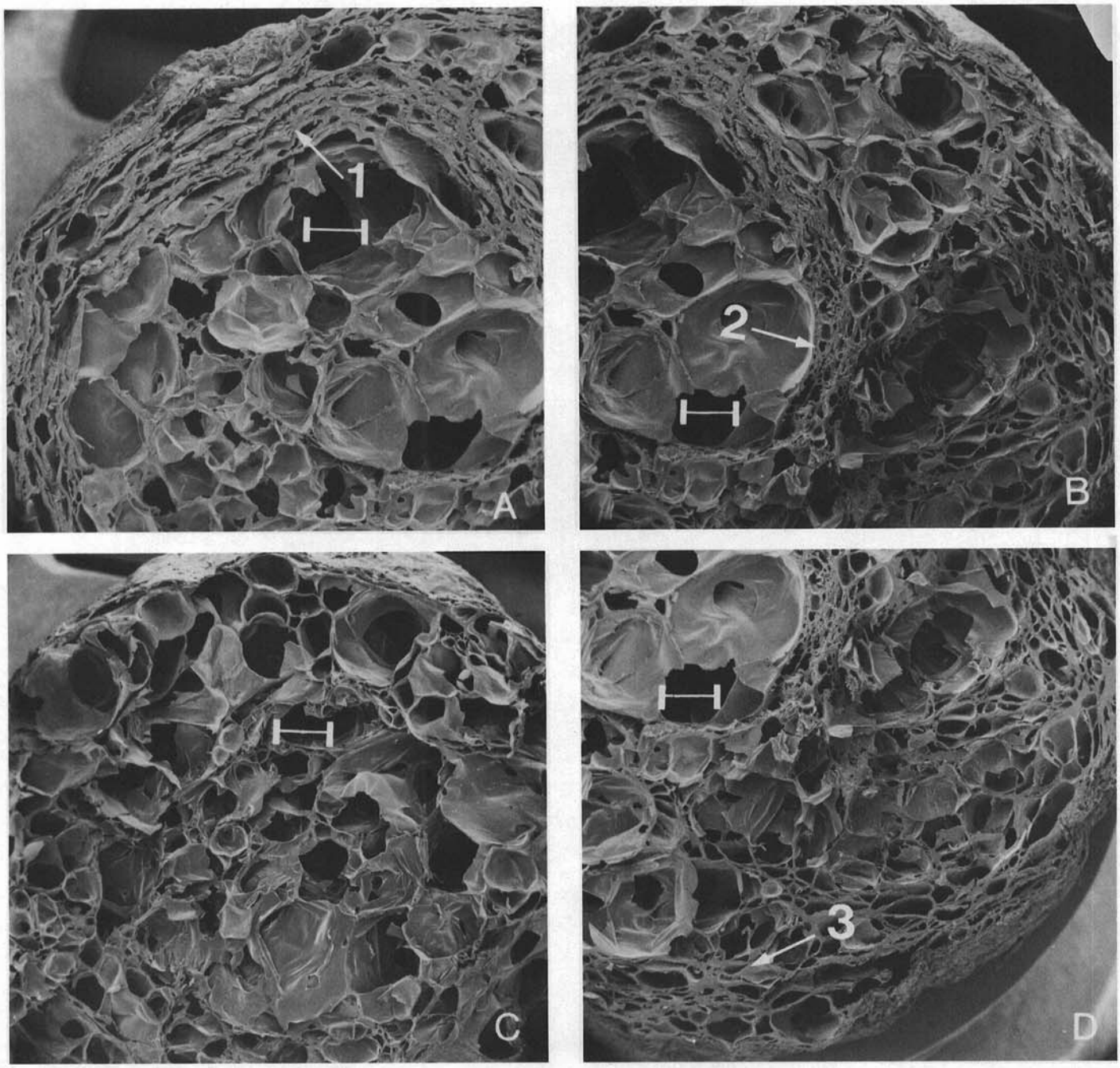

Fig. 10. Scanning electron micrographs of extruded reconstituted yeast protein concentrate (YPC) plus starch mixture. **A, B,** and **D,** from one sample of reconstituted YPC and starch, **C,** intact YPC (bars = 500 μm).

Effect of YPC Components

Faubion and Hoseney (1982b) reported that free flour lipids reduced expansion, shear force, and breaking force of extruded wheat starch. YPC was found to contain only 0.21% free lipid and 6.3% water-saturated, butanol-extractable materials. The water-saturated butanol extract was called bound yeast lipids. It was highly soluble in petroleum ether.

To determine the effects of YPC lipids, mixtures of starch and bound yeast lipids, defatted YPC and starch, and reconstituted YPC and starch were extruded. The addition of bound yeast lipids reduced expansion of extruded starch without affecting bulk density (Table I) but increased the breaking force of the extrudate. This is contrary to results of Cabrera-Lavedre (1978) and Faubion and Hoseney (1982b) for other lipids. They both reported that lipids reduced breaking force, as well as expansion, of extruded starch. Cross-sectional views of extrudates containing bound yeast lipids are shown in Figure 8 (A and B). From these figures it appears that added bound yeast lipids decrease average cell size. Otherwise, extrudates of starch with YPC and bound lipids were visually similar to starch with YPC extrudates.

Defatting YPC did not significantly influence expansion, bulk density, or breaking force of the extruded YPC and starch mixture (Table I). The ultrastructure of extrudates containing intact YPC and defatted YPC was very similar. The surface of extrudate containing 10% intact YPC (Fig. 7C) appeared to be rougher than that of extrudate containing an equivalent amount of defatted YPC (Fig. 9B).

Reconstitution of the YPC by recombining defatted YPC, extracted lipids, and starch did not restore the original effect of YPC on extrusion. When compared with the mixture of YPC and starch, the reconstituted YPC and starch mixture had higher bulk density (Table I). Examination by scanning electron microscopy of

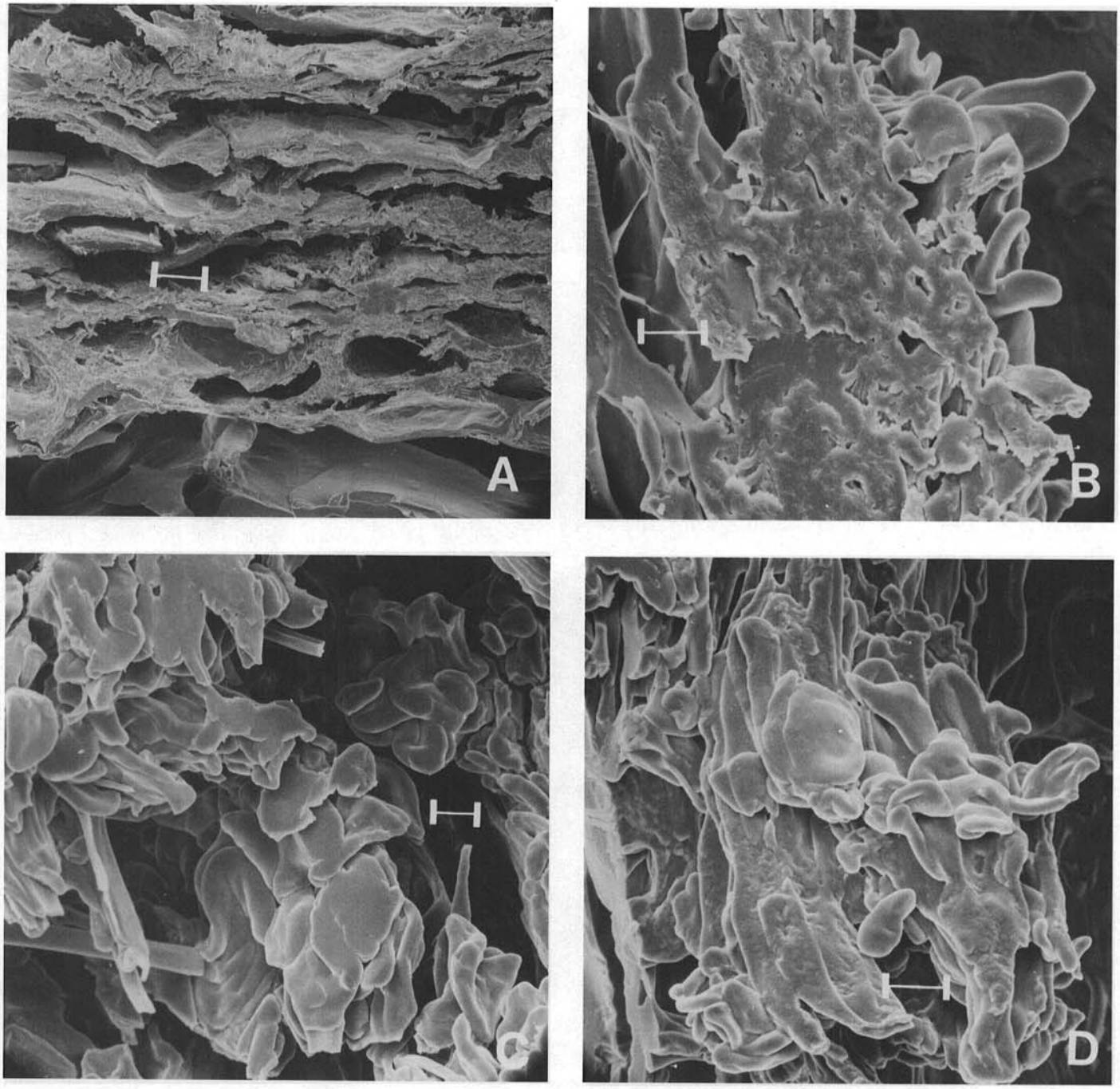

Fig. 11. Enlarged view of multiple layer in Fig. 10A, **A,** (bar = 100 μm) and **B,** (bar = 10 μm); **C,** cell wall surface of small, thick-walled cells in Fig. 10B (bar = 10 μm); **D,** cell wall surface of small elongated cells in Fig. 10D (bar = 10 μm).

TABLE I
Extrusion Parameters of Extruded Mixtures of Starch with Bound Lipids, Starch with Defatted Yeast Protein Concentrate (YPC), and Starch with Reconstituted YPC

Extruded Mixtures	Diameter[a] (mm)	Bulk Density[b] (g/cc)	Breaking Force[c] (kg)	Production Rate (g/min) $n = 3$
Control[d]	11.66 ± 0.96ca[e]	0.251 ± 0.22a	1.471 ± 0.306c	...
10% YPC	9.82 ± 0.63b	0.174 ± 0.012b	0.848 ± 0.152b	...
Defatted YPC[f]	9.51 ± 0.47b	0.194 ± 0.011b	0.627 ± 0.107b	96.5 ± 9.26
YPC-bound lipids[g]	10.75 ± 1.06	0.261 ± 0.48a	4.854 ± 1.059a	109.71 ± 9.26
Reconstituted YPC[h]	9.52 ± 0.68b	0.332 ± 0.038c	0.811 ± 0.987b	83.0 ± 3.18

[a] $n = 50$, least significant difference (LSD) (.05) = 0.32.
[b] $n = 10$, LSD (.05) = 0.03.
[c] $n = 17$, LSD (.05) = 0.49.
[d] Wheat starch.
[e] Values reported are mean and standard deviation. Values followed by the same letter are not significantly different at the 5% level.
[f] The amount of defatted YPC added was equivalent to 10% YPC.
[g] The amount of lipids added to starch was equivalent to 10% YPC.
[h] The amount of reconstituted YPC was equivalent to 10% YPC.

the ultrastructure of extrudates containing reconstituted YPC showed bands that consisted of either a multiple-layered structure (marked as region 1 in Fig. 10A) or small and thick-walled cells (2, Fig. 10B). Areas of small and elongated cells also were often seen (3, Fig. 10D). These three features were not found in extrudates containing intact YPC (Fig. 10C). At higher magnification, the multiple-layered structure appears as layers with granules, probably starch, adhering to them (Fig. 11A and B). Granules also were seen on the cell wall surface of small, thick-walled cells and small elongated cells (Fig. 11C and D). Other structures observed in extrudates containing reconstituted YPC were similar to those found in extrudates containing intact YPC.

CONCLUSION

The apparent finding in this study and that of Faubion et al (1982b) of granular starch in extrudates clouds the traditional theory that all starch granules are melted into a homogeneous plastic state in the extruder barrel. Our data also indicate that the breaking force of an extrudate is not related to its expansion (Table I), as suggested by Faubion (1980). Results of this study demonstrate that lipids bound to YPC are functional components when the YPC is extruded with wheat starch.

ACKNOWLEDGMENTS

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