NOTE

Effect of Chlorination on the Hydrophobicity of Wheat Starch

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ABSTRACT

Aqueous suspensions of wheat prime starch chlorinated at various levels and containing isoamyl alcohol were vigorously shaken, and the volume and stability of the bubbles formed were measured. Bubble volume and stability increased with chlorination rate. Microscopic observation showed that chlorinated prime starch hydrophobically associated with isoamyl alcohol droplets, however, nonchlorinated prime starch did not. These observations showed the increased hydrophobicity of the surface of wheat starch caused by the action of chlorine gas.

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Seguchi and Matsuki (1977) reported improvements of pancake textures such as increased springiness and reduced gumminess from chlorination of wheat flour. Seguchi (1984, 1985) suggested that those improvements were caused by lipophilic modification by chlorination of the protein on the surface of starch granules. However, a link between the improving effect of chlorination and the increased hydrophobicity of wheat starch was not shown.

Hydrophobic powders such as lead sulfide (PbS) and chalcopyrite ($CuFeS_2$) make rigid and stable bubbles in water after vigorous shaking with a bubbling agent. These hydrophobic powders bind to the surface of air bubbles. Ore floatation techniques make use of this phenomenon.

Tomie and Okubo (1984) compared the hydrophobicity of some materials, such as cotton, acryl, polyvinylchloride (PVC), silk, and nylon, and the ability of those materials to catch bubbles in water. They suggested that bubble-catching ability increases with hydrophobicity.

Those reports suggest the possibility that chlorinated wheat starch may also retain air bubbles in cake batter, and possibly stabilize it, at least at room temperature. A model experiment was designed to measure the bubble-catching ability of chlorinated wheat prime starch. The bubbling agent isoamyl alcohol was added to a starch-water suspension throughout the experiment.

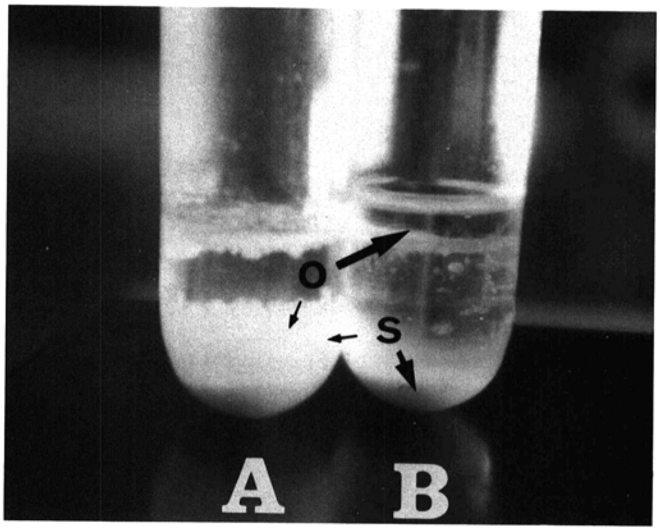

Fig. 1. Mixtures of (**A**) chlorinated starch (2.0 g of Cl_2 gas/kg of wheat flour) or (**B**) nonchlorinated starch with oil in water. **O** = oil, **S** = starch.

MATERIALS AND METHODS

Materials

A patent, commercially milled, U.S. western white wheat flour was utilized, having respective protein and ash contents of 7.6 and 0.35%. Chlorination of wheat flour and its fractionation were performed as described by Seguchi and Matsuki (1977). The prime starch fraction was suspended in water (12%) and frozen until used. Protein (N × 6.25) of the prime starch was determined by the method of Smith (1964). Other reagents were purchased from commercial sources. Wheat prime starch fractions were obtained from chlorinated wheat flour (0.0, 0.5, 1.0, 1.5, and 2.0 g of Cl_2 gas/kg of flour). Proteins of these prime starch samples were 0.1–0.2%, and no increase or decrease by chlorination was observed.

Preparation of Starch-Water Suspensions

Aqueous (5.0%) suspensions of wheat prime starch (500 mg) containing various concentrations of isoamyl alcohol were prepared in 25-ml calibrated test tubes (15 × 150 mm) with glass stoppers, and shaken with an up and down motion by a shaker (Miyamoto Riken Kogyo Co. Ltd., MW-S) at 4,700 rpm for 30 min at room temperature. Photographs of the volume of the bubble

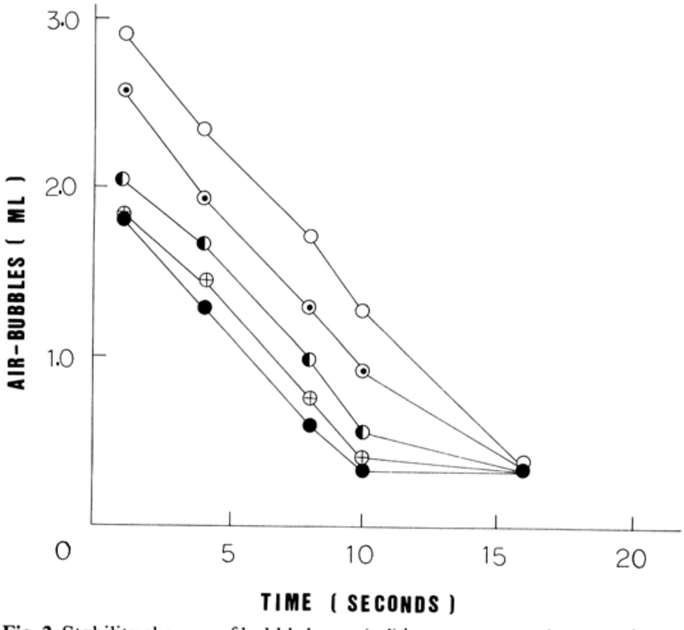

Fig. 2. Stability changes of bubble layers (ml) in aqueous starch suspension. Chlorination level of starch samples were ● = 0.0, ⊕ = 0.5, ◐ = 1.0, ⊙ = 1.5, and O = 2.0 g of Cl_2 gas/kg of wheat flour.

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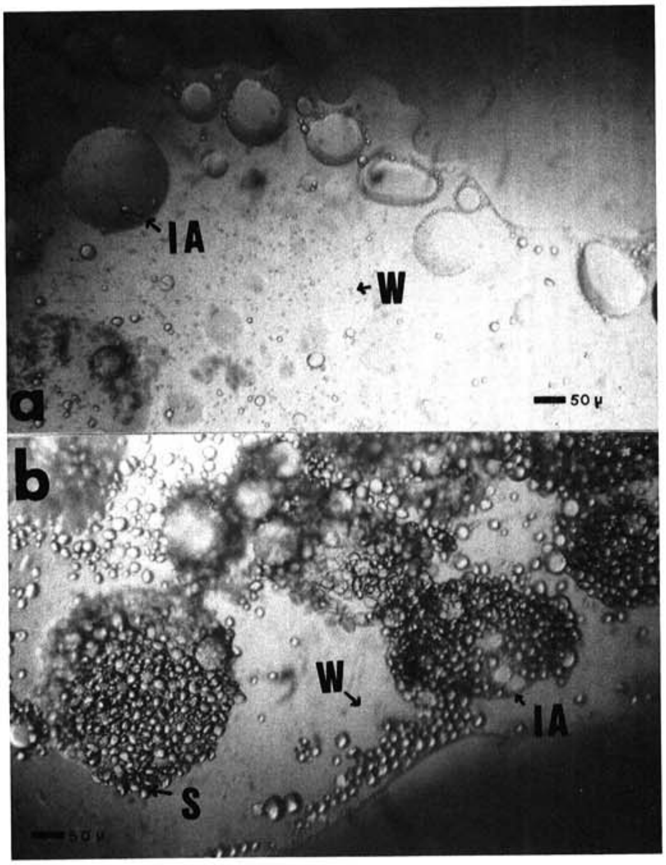

Fig. 3. Photomicrographs of nonchlorinated starch (**a**) and (**b**) chlorinated starch (2.0 g of Cl_2 gas/kg of wheat flour) suspended in water containing 2.0% isoamyl alcohol. **S** = Starch granule, **W** = water, **IA** = isoamyl alcohol.

layers were made just after stopping the shaking action and intermittently thereafter, and bubble volumes were measured from those photographs. Experiments were replicated three times. Standard deviations of this method were 2–4%. A preliminary investigation showed that optimum bubble formation occurred at a concentration of 2% isoamyl alcohol. After shaking, a few drops of the starch-water suspensions containing isoamyl alcohol were placed on a slide and observed by microscopy.

RESULTS AND DISCUSSION

Chlorinated prime starch showed the oil-binding ability (Fig. 1A) reported previously (Seguchi 1984), indicating that lipophilic (hydrophobic) properties at the surface of chlorinated starch granules had been imparted by chlorine gas. Various concentrations of starch-water suspensions containing 2.0% isoamyl alcohol were prepared by shaking simultaneously. Bubbles were very unstable, and all bubbles disappeared within a short time; even at the highest chlorination level (2.0 g of Cl_2 gas/kg of wheat flour), bubbles disappeared within 16 sec (Fig. 2). The volume of bubbles increased with chlorination (Fig. 2). It is assumed that the chlorinated starch granules concentrate in the bubble membrane increasing bubble stability at the temperature of measurement. Microscopic examination revealed that nonchlorinated prime starch granules did not bind to isoamyl alcohol (Fig. 3a), whereas chlorinated granules did bind (Fig. 3b), certainly by a lipophilic attraction. This demonstrated how chlorinated starch can associate in the bubble (air-water) membrane and increase bubble stability. In relation to pancake baking, wheat proteins and lipids may act like the bubbling agent, isoamyl alcohol, and the hydrophobic, chlorinated starch granules may function as bubble stabilizers. Chlorine gas affects most, if not all, flour constituents, and further study is necessary to determine whether the increased stability of bubbles (up to 16 sec) after chlorine treatment observed in a model system is involved in the improvement of heated cake batters.

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