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MICROSTRUCTURE OF IDLI

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Abstract

The microstructure of idli prepared from seeds of common beans (*Phaseolus vulgaris*) and rice, and Indian black gram seeds (*Vigna mungo*) and rice in the ratio 1:2 was examined. Intact starch granules and protein bodies were observed in the unfermented idli batter. Starch granules disappeared as fermentation time increased to 18 hours and 36 hours. The surface of idli prepared from 36-hour fermented batter was cohesive, dense and sponge- or foam-like. The microstructure of idli prepared from common beans and rice was similar to the microstructure of idli prepared from Indian black gram and rice. Common beans can be successfully substituted for Indian black gram in preparing comparable and acceptable steamed idli.

Key Words: *Phaseolus vulgaris*, *Vigna mungo*, fermentation, dehulled beans, scanning electron microscopy.

Introduction

Fermented foods prepared from legume and cereal combinations contribute substantial quantities of calories, proteins and vitamins to the diets of people in Southeast Asia, the Near East and parts of Africa (Rajalakshmi and Vanaja, 1967; Ramakrishnan, 1979; Reddy *et al.*, 1981; Sathe *et al.*, 1986). Due to favorable organoleptic qualities, fermented foods are becoming common in the diets of the Western world (Reddy *et al.*, 1982a; Steinkraus, 1983; Sathe *et al.*, 1986).

Idli is a naturally fermented steamed food originating in 1100 AD (Ramakrishnan *et al.*, 1976), prepared from rice and dehulled black gram cotyledons (Rajalakshmi and Vanaja, 1967; Chavan and Kadam, 1989). Idli is a common breakfast item in South India and to some extent in Sri Lanka (Reddy *et al.*, 1981; Steinkraus, 1983). The proportion of rice to black gram can vary from 2:1 to 4:1 in preparation of idli batter (Desikachar *et al.*, 1960; Mukherjee *et al.*, 1965; Steinkraus *et al.*, 1967; Padhye and Salunkhe, 1978; Sathe and Salunkhe, 1981a). However, the most commonly used and acceptable ratio of rice to dehulled black gram cotyledons is 4:1 if the traditional grinding stone is used, or 2:1 if an electric blender is used for the grinding process. The quantity of water added to the ingredients varies from 1.5 to 2.2 times the weight of the dry ingredients (Reddy *et al.*, 1982a). The microorganisms responsible for fermentation are the natural flora in the starting materials (Hesseltine and Wang, 1979). Black gram plays a major role in idli fermentation both as a source of microorganisms and as a fermentation substrate (Radhakrishnamurthy *et al.*, 1961; Venkatasubbaiah, 1984).

Many investigators have studied the physicochemical and microbiological changes occurring during fermentation of idli batter (Desikachar *et al.*, 1960; Mukherjee *et al.*, 1965; Ramakrishnan *et al.*, 1976; Padhye and Salunkhe, 1978; Reddy and Salunkhe, 1980a; 1980b; Soni and Sandhu, 1989). Acidification and leavening are the two important changes that occur during fermentation due to microbial activity (Reddy *et al.*, 1982a). The major microorganism responsible for fermentation was identified as *Leuconostoc mesenteroides* (Mukherjee *et al.*, 1965; Steinkraus *et al.*,

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1967), although other microorganisms such as *Streptococcus faecalis*, *Lactobacillus fermentum*, and *Saccharomyces cerevisiae* are reported by others (Venkatasubbaiah *et al.*, 1984; Soni and Sandhu, 1989).

Idli has a soft and spongy texture and pleasant sour flavor. Steamed idli is served with a sauce prepared from fresh coconut, and with sambar, a thin soup made of red gram dhal (pigeon peas) with vegetables and spices. Idli is served as a weaning food for infants and also served in South Indian hospitals for feeding patients requiring soft food (Ramakrishnan, 1979; Reddy *et al.*, 1982a, 1986).

Substitution of black gram with oilseeds such as soybeans and peanuts, or dry beans (Great Northern beans) in the preparation of idli has been reported (Steinkraus *et al.*, 1967; Ramakrishnan *et al.*, 1976; Susheelamma and Rao, 1980; Sathé and Salunkhe, 1981a; Soni and Sandhu, 1989). Research on idli fermentation and nutritive value was carried out in the United States at Cornell University, Utah State University and Washington State University. However, research on the microstructure of idli is limited. Therefore, this study was undertaken to study the microstructure of idli prepared from whole white beans, dehulled white beans, dehulled black beans (*Phaseolus vulgaris*), or dehulled Indian black gram (*Vigna mungo*) in combination with rice.

Materials and Methods

Idli preparation

Whole black beans (cv. Black Turtle Soup), whole white beans (cv. Great Northern) (*Phaseolus vulgaris*), and long grain rice were purchased from a local market in Pullman, WA. Dehulled Indian black gram (*Vigna mungo*) was purchased from an Indian grocery store in Chicago, IL. Whole black and whole white beans were soaked separately in water equal to three times the weight of the beans for 4 hours, and the hulls were removed by hand to obtain approximately 150 grams of dehulled beans for idli preparation. Rice was also soaked in water equal to 1.5 times the weight of the rice for 4 hours. The proportion of rice to dehulled beans was 2:1 on dry weight basis for preparing idli. Rice and beans for each variety of beans were ground separately in a blender to obtain a batter of semithick consistency, and mixed together. Half of the batter was poured into a container with a tight fitting lid and incubated at 30°C for 18 hours or 36 hours. The fermented batter was mixed well and a spoon of batter was dished into an idli pan containing individual cups with a diameter of 3 inches (7.6 cm) and a depth of 1 inch (2.5 cm) with 25 perforations. The perforations were necessary for the easy entry of steam into the idli during steaming. The pan with batter was placed in a steamer and steamed for 7 minutes at 100°C. The pan was removed from the steamer, cooled and the individual steamed idli were removed. The procedure was repeated for unfermented batter.

Scanning electron microscopy (SEM)

Unfermented idli batter was frozen in liquid nitrogen, lyophilized, mounted on aluminum stubs using carbon tape and Tempfix wax, sputter coated with 30 nm gold using a Technics Hummer V sputter coating unit (Anatech Ltd., Alexandria, VA) and viewed with a Hitachi S570

scanning electron microscope (Hitachi Instruments, San Jose, CA) operated at 20 kV.

Small portions of steamed idli were fixed with 3% glutaraldehyde in 50 mM piperazine-N,N'-bis(2-ethanesulfonic acid) for 15 hours at 4°C, post-fixed in 1% osmium tetroxide for 4 hours at ambient room temperature and dehydrated for 10 minutes in each solution of a graded series of 30, 50, 70, 95 and 100% ethanol. After dehydration, the idli pieces were freeze-fractured in liquid nitrogen and critical point dried in carbon dioxide (Tousimis Samdri-PVT-3B; Tousimis Research Corp., Rockville, MD); mounted on aluminum stubs using double sided tape and Leit-C-Plast plastic conductive carbon cement, and sputter coated and examined in SEM as described above.

Results and Discussion

The scanning electron micrographs of unfermented idli batter and unfermented, 18-hour fermented, or 36-hour fermented, steamed idli prepared from whole white beans in combination with rice are presented in Figures 1-4. Intact starch granules, approximately 26-30 μm in diameter and protein bodies, approximately 4-6 μm in diameter are clearly visible in unfermented whole white bean and rice idli batter (Fig. 1). Intact, but smaller starch granules and protein bodies were also observed in unfermented idli batter prepared from dehulled black gram and rice. Steaming caused disappearance of starch granules but clumps of protein bodies persisted in unfermented and 18-hour fermented idli prepared from whole white beans and rice (Figs. 2 and 3). The surface of the idli was more cohesive and sponge-like in appearance after 36-hour fermentation (Fig. 4) than for unfermented idli or idli fermented for 18 hours (Figs. 2 and 3). The disappearance of starch granules and most protein bodies in Figures 2-4 may be due to the gelatinization of starch granules and denaturation of protein bodies during steaming of idli (Hughes and Swanson, 1989).

Structural integrity of many protein bodies was maintained in the unfermented dehulled white beans and rice combination idli upon steaming (Fig. 5), compared to the 18-hour fermented idli (Fig. 6). The surface of idli became more cohesive and foam-like with an increase in fermentation time (Fig. 7).

The microstructure of idli prepared from dehulled white beans and rice (Figs. 5-7) is similar in appearance to the idli prepared from dehulled black beans and rice (Figs. 8-10). Gas cells of the foam-like structure are clearly evident in Figure 10. The structure of idli prepared from unfermented dehulled Indian black gram and rice (Fig. 11) was similar to the structure of unfermented idli prepared from dehulled black and dehulled white beans with rice. Structural integrity of many protein bodies was maintained in the unfermented idli. Loss of protein body structure began after 18-hour fermentation (Fig. 12) and structural integrity was almost completely lost after 36-hour fermentation of idli prepared from dehulled Indian black gram and rice (Fig. 13) due to the activity of microbial enzymes such as amylases and proteases (Reddy and Salunkhe, 1980a; Soni and Sandhu, 1989). After 36-hour fermentation, no structural differences were observed among the idli prepared from dehulled white beans, dehulled black beans, or dehulled black gram (Figs. 7, 10 and 13) with rice. Except

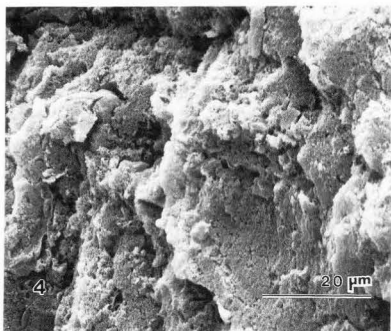
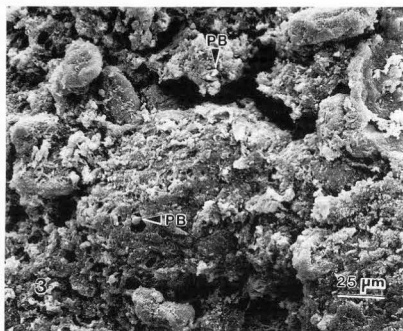
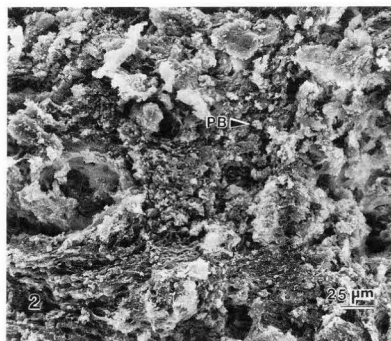
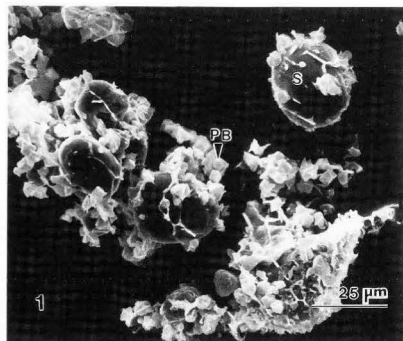


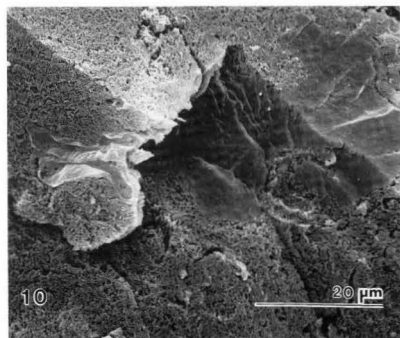
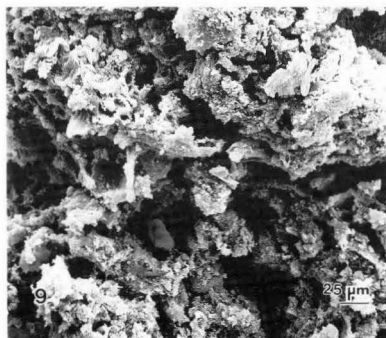
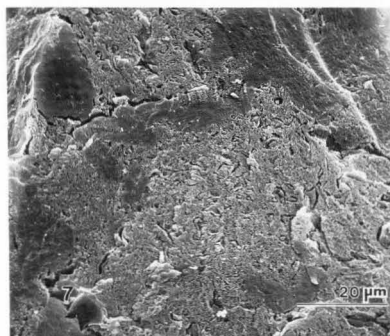
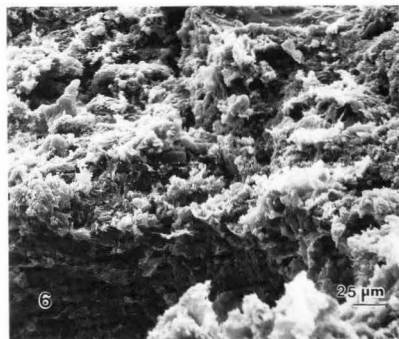
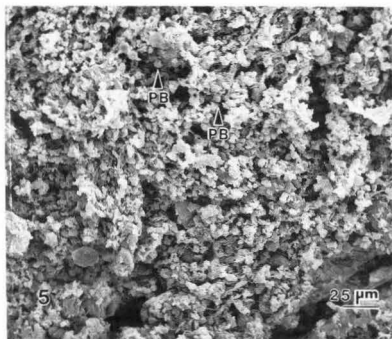
Figure 1. Unfermented idli batter prepared from whole white beans and rice exhibiting starch granules (S) and protein bodies (PB).

Figures 2 and 3. Steamed idli prepared from whole white beans and rice exhibiting clumps of protein bodies (PB), unfermented (**Figure 2**) and 18-hour fermented (**Figure 3**).

Figure 4. Steamed idli prepared from whole white beans and rice and fermented for 36 hours.

for the idli prepared from whole white beans and rice, each idli after 36-hour fermentation exhibited a cohesive, dense and foam-like structure. The surface structure of idli observed with increasing fermentation time may result from physico-chemical and microbiological changes occurring during fermentation such as an increase in soluble solids, acidity and alpha-galactosidase activity and a decrease in soluble sugars (Rajalakshmi and Vanaja, 1967; Padhye and Salunkhe, 1978; Reddy and Salunkhe, 1980b; Reddy *et al.*, 1982b; Soni and Sandhu, 1989). Susheelamma and Rao (1974; 1978a; 1978b and 1979) indicated that the smooth and porous structure of idli is due to the presence of surface active globulin proteins and an arabinogalactan in Indian black gram cotyledons. The globulin proteins of

black gram are responsible for the development of the soft, spongy texture of idli, and arabinogalactan is essential for raising and stabilizing of the spongy texture produced by the surface active globulin proteins. The arabinogalactan helps to trap and hold the leavening gases, and prevents disruption of the protein foam by heating at steaming temperatures. However, a certain degree of disruption of the network does occur resulting in disruption of susceptible areas along the protein surface by excessive stress developed during steam cooking. Although the literature on the foaming properties of common beans of *Phaseolus vulgaris* is limited, the globulin proteins and polysaccharides responsible for foaming are present in common beans as well as Indian black gram cotyledons (Satterlee *et al.*, 1975; Sosulski *et al.*, 1976; Sathe and Salunkhe, 1981b, 1981c).



Figures 5 and 6. Steamed idli prepared from dehulled white beans and rice, unfermented (**Figure 5**), and 18-hour fermented (**Figure 6**). Note many intact protein bodies (PB) are visible in **Figure 5**.

Figure 7. Steamed idli prepared from dehulled white beans and rice and fermented for 36 hours.

Figures 8, 9 and 10. Steamed idli prepared from dehulled black beans and rice, unfermented (**Figure 8**), 18-hour fermented (**Figure 9**) and 36-hour fermented (**Figure 10**).

Figure 11 (at right). Steamed idli prepared from unfermented dehulled Indian black gram and rice exhibiting many intact protein bodies (PB).

The observations of idli microstructure suggest that the spongy or foamy texture of idli prepared from whole white, dehulled white, dehulled black beans of *Phaseolus vulgaris* with rice may be due to the foaming of proteins and polysaccharides as observed for the idli prepared from dehulled Indian black gram with rice.

Conclusions

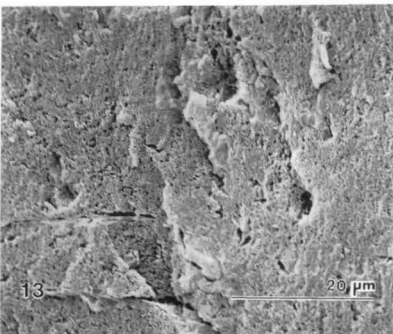
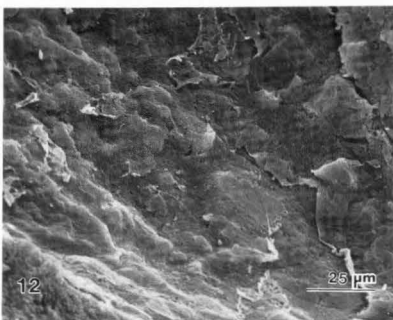
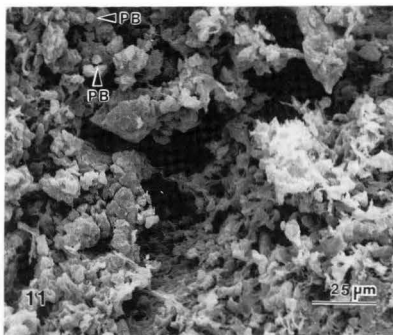
Microstructure of idli prepared from fermented beans (*Phaseolus vulgaris*) and rice was similar to the microstructure of idli prepared from fermented dehulled Indian black gram and rice. Although the traditional method of preparing idli in India uses dehulled black gram and rice, dehulled white or black beans can be used for preparing idli. When visually observed, the texture of idli prepared from whole white beans and rice was comparable to the texture of idli prepared from dehulled beans and rice. The cohesive, dense and sponge- or foam-like surface of idli obtained with increasing fermentation time may be due to the physico-chemical and microbiological changes occurring during the fermentation process as well as the presence of surface active globulin proteins and an arabinogalactan.

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Figures 12 and 13. Steamed idli prepared from dehulled Indian black gram and rice and fermented 18 hours (**Figure 12**) and 36 hours (**Figure 13**).

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Discussion with Reviewers

Om Johari: Based on your work, can you make any practical recommendations regarding: 1) selection of ingredients: kind of beans, whole or dehulled beans, and type of rice (e.g., brown, parboiled, or regular); 2) selection of grinding method: grinding stone, blender, or use of ground flours; 3) cooking time; and 4) use of an additional leavening agent such as yeast?

Authors: When using black beans or white beans, dehulled beans are better for making idli batter. The dark color of the black bean seed coat is unacceptable in idli since the color of idli is traditionally white. In India, dehulled black gram is readily available. Dehulling equipment is not readily available in the United States. The seed coat of white beans does not significantly change the color of idli and may increase dietary fiber content. However, the length of time necessary for grinding to an acceptable batter consistency may increase due to the presence of the seed coat. Any type of rice can be used for making idli batter. Parboiled rice is used in India. Brown rice also can be used to make idli, but preference for the idli may decrease due to the color contributed by the rice.

Although use of a blender is acceptable for making idli batter, the use of the traditional grinding stone is better. Grinding takes a longer time when using the grinding stone, thereby incorporating more air into the batter. Use of ground flours is unacceptable for making idli batter since less air is incorporated in mixing. The texture of idli made with ground flours is heavy and compact. Commercial idli mixes are available. However, the texture of idli made from the mixes is poor when compared to the texture of idli made from freshly ground beans and rice. Seven to ten minutes is sufficient for cooking time. Steaming the batter longer than 10 minutes may allow condensation from the steam to drip from the lid of the steamer, mar the surface of the idli, and produce an unacceptable appearance. Use of an additional leavening agent, such as yeast, is unnecessary if the temperature for fermentation is maintained at 30°C for 12-18 hours.