Bleaching Effect of Acid on Pearl Millet[1]

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Cereal Chem. 56(4):287-290

ABSTRACT

Soaking millet grain (*Pennisetum typhoides*) overnight in solutions containing sour milk or tamarind pods markedly reduced the color of the grain. This process is traditionally practiced by some Nigerian villagers to improve the appearance of the flour. Decolorization was pH-dependent and was duplicated with 0.2*N* HCl or citric acid. Acid entered whole millet very slowly only through areas around the embryo but penetrated scarified millet rapidly through areas where the hull had been broken. The rate of acid bleaching of the grain, monitored by reflectance spectroscopy, increased dramatically with the degree of dehulling. Typically, at a degree of dehulling of 10%, soaking times of 5–10 min in 0.2*N* HCl were required to bleach millet to a color comparable to the traditional sour milk soaked product. Considerable variation was found in the effectiveness of the acid soaking treatment among different varieties of millet grain.

In 1973 the International Development Research Centre (IDRC) established a village-scale mill in Maiduguri, Nigeria (Anonymous 1976). This dry-milling facility incorporated cleaners, a dehuller, hammer mill, sifter, and a packaging facility. The grains that were initially processed included maize, sorghum, and millet. Although consumer acceptance was excellent for maize and sorghum products, millet flour met with considerable consumer resistance because of its gray color. Since consumers in the area were accustomed to a creamy-white flour, this color problem forced the mill to stop processing millet.

An IDRC survey (Rolston 1975) of millet growing regions in Nigeria indicated that millet grains are dehulled in the traditional mortar and pestle fashion. In some areas, particularly around Maiduguri, the grains are then often soaked overnight either in water or water containing sour milk or tamarind pods. When millet from the latter two treatments is ground into a paste, it is creamy-white in color in comparison to the objectionable gray color obtained when mill millet flour from the dry-milling process is used directly to prepare the paste. The marked improvement in color due to the sour milk or tamarind pod soaking treatment was attributed to fermentation during this soaking process (Rolston 1975). The survey determined that this practice was used throughout northern Nigeria predominantly by members of the Kanuri and Hausa tribes, but that it was not a general practice.

[1]Issued as NRCC 17567.

0009-0352/79/000041$3.00/0

The objectives of this investigation were to study the phenomenon of millet bleaching and to determine an alternate procedure to the traditional sour milk or tamarind pod soaking treatment.

MATERIALS AND METHODS

Grain Samples and Processing Procedure

Millet grain (*Pennisetum typhoides*, early season variety) was obtained from Maiduguri, Nigeria, in June, 1975. Unless indicated otherwise, all work reported in this paper was done using this variety. The grain was scarified with a Strong-Scott laboratory pearler and the degree of dehulling was determined by the amount of fines passing through a 20-mesh screen. Initial moisture content of the grain was 7.4%.

Small samples of five millet cultivars grown in Nigeria in 1976 and 11 cultivars grown in the same field in India in 1976 were obtained. Varieties from Nigeria included: Nigerian composite $(S_1)C_1$, Maiwa composite, World composite $(S_1)C_1$, Ex-Borno $(S_1)C_1$, and Senegal dwarf synthetic. Varieties from India included: NHB-3, PHB-14, ICH-118, Ancouters, Serere 2A-9, and six varieties referred to only by their color—white, yellow, brown, deep slate, purple, and deep purple.

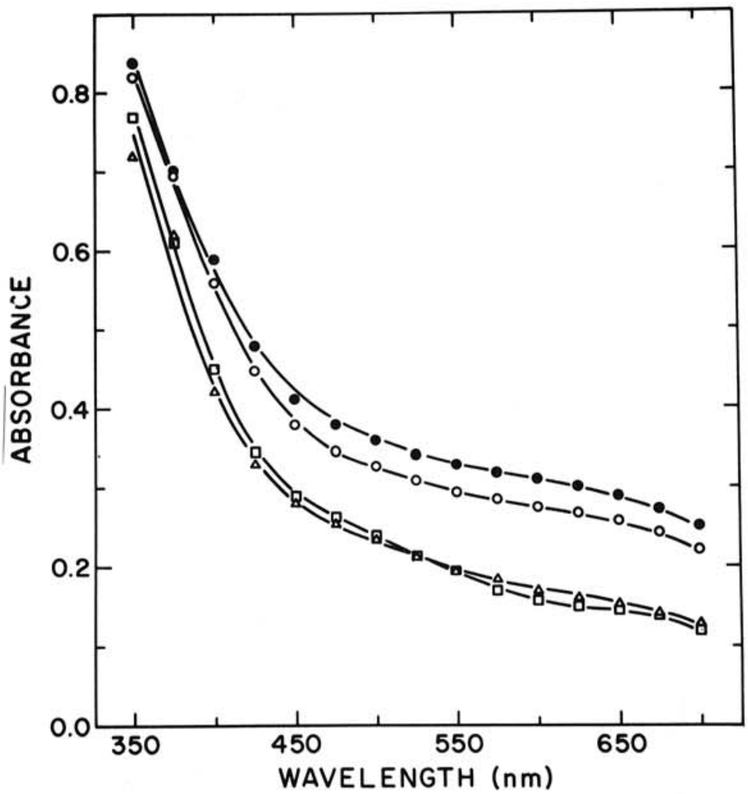

Fig. 1. Reflectance spectra of scarified millet (4.6% dehulling) (●), soaked in water (○), sour milk (△), and 0.2*N* HCl (□). Spectra are of dried flours.

Soaking Treatment

Scarified millets were treated with sour milk or tamarind pods in proportion to quantities used in the Maiduguri area. Sour milk was prepared by leaving milk at room temperature for 16 hr. The pH dropped from 6.8 to 4.3. Tamarind pods (fruit of the tamarind tree *Tamarindus indica* L.) obtained from Maiduguri were ground to approximately 0.5-cm pieces in a mortar and pestle. Sour milk (2.5 ml) or tamarind pods (4.6 g) were added to 25-g samples of scarified millet. Distilled water (50 ml) was immediately added to these samples and to untreated scarified millet. Fifty milliliters of 0.2*N* HCl was added to another 25-g sample of scarified millet. These were well stirred and left at 32°C for 16 hr. The solutions were drained (tamarind pods discarded) and the treated seeds washed 3 times with 30 ml of distilled water.

All treated millets were dried in vacuo at room temperature for 16 hr, ground to flour in a CRC micro-mill, and reflectance measured on the dry flour.

Millet varieties obtained from India and Nigeria were soaked in an excess of 0.1*N* HCl for 48 hr at room temperature. The effect of acid soaking on grain color was visually assessed after air drying the seeds.

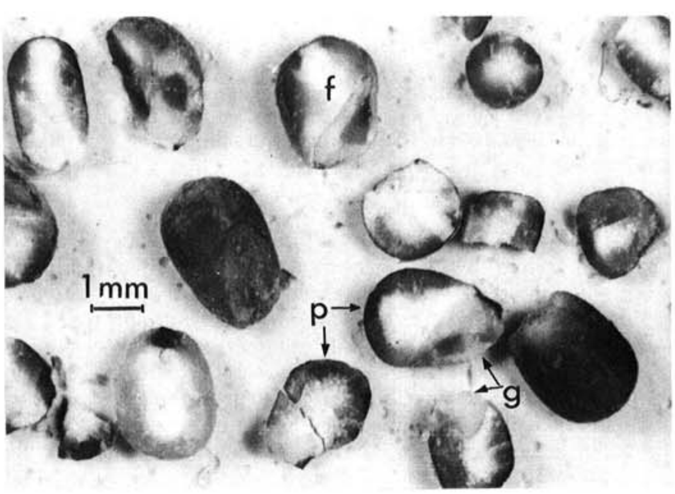

Fig. 2. Photomicrograph of cracked millet illustrating dark gray peripheral regions of (**p**) the endosperm, (**f**) the light-colored central region, and (**g**) the germ.

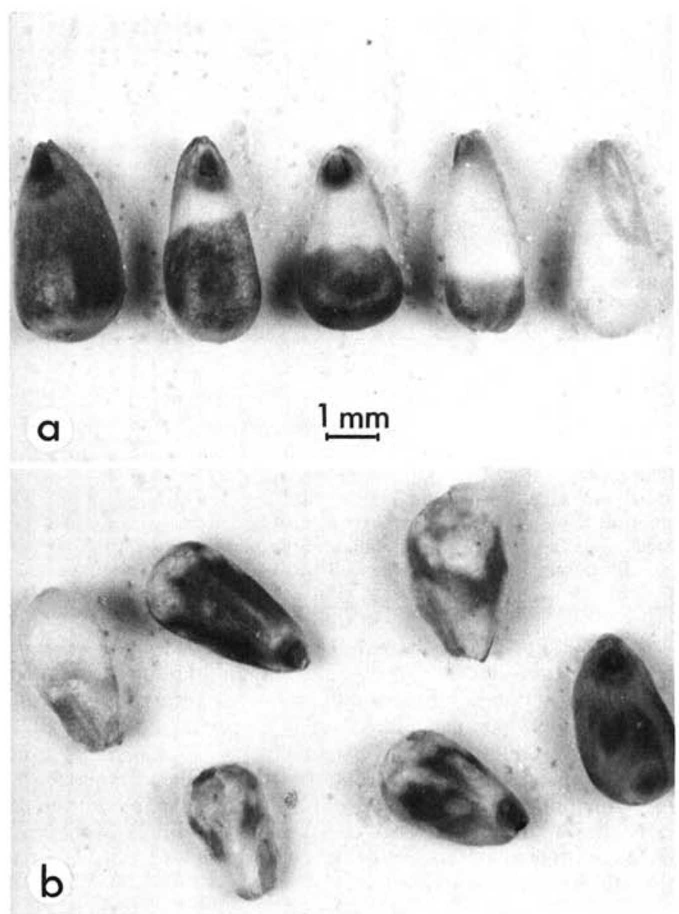

Fig. 3. Photomicrographs of whole and scarified millet absorbing 0.2*N* HCl. (**a**) Whole millet, (**b**) scarified millet (2.4% dehulling).

Photomicrographs

Photomicrographs were obtained on a Wild Heerbrugg model M7 microscope. Samples were mounted on two-sided sticky tape and attached to filter paper. Millet seeds were cracked in a mortar and pestle to reveal the peripheral and floury endosperm regions of the grain.

Measurement of the Relative Rate of Acid Absorption into Millet Grains

The rate of bleaching millet was investigated using 0.2*N* HCl. Whole or scarified millet (100 g) was immersed in 600 ml of 0.2*N* HCl and slowly stirred at room temperature. The large quantity of acid used in the reaction ensured that initial and final concentrations of acid were nearly equal. At 1, 3, 5, 10, 15, 30, and 180 min, approximately 10 g of the seeds was removed and immediately immersed in 500 ml of distilled water. The seeds were washed with another 6 × 500 ml of distilled water before drying the seeds in a vacuum oven at room temperature for 16 hr. The dried seeds were ground to flour in a CRC micro-mill for 2 min. Flour-water paste reflectance measurements at 600 nm indicated the relative rate of acid absorption into the millet grains.

Reflectance Measurements

Dry flour measurements were taken on a Hitachi-Perkin Elmer spectrophotometer equipped with a diffuse reflectance attachment (Reichert and Youngs 1976). Paste measurements were taken on flour + water mixtures (5 g + 4.5 ml), which were stirred into a smooth, creamy paste with a spatula.

RESULTS AND DISCUSSION

Figure 1 illustrates the effect of soaking (16 hr) scarified millet in water, sour milk, and 0.2*N* HCl solutions on dry flour color. Water soaking slightly reduced the absorbance of the flour; however, the flour was still gray. The flours produced from sour milk soaked and 0.2*N* HCl soaked grains were creamy-white and nearly identical in color. Millet flour from grains soaked in a solution containing tamarind pods, which contain tartaric acid, were also nearly identical in color to sour milk or 0.2*N* HCl soaked grains. These results indicate that the bleaching effect is simply pH dependent and can easily be reproduced with dilute HCl solutions. Citric acid reduced the color of millet when it was mixed at the 1–2% level with the flour prior to preparation of a porridge.

Figure 2 illustrates the dark gray peripheral regions of the endosperm that can be bleached with acid. Also illustrated are the germ and the central region of the seed, which are lighter in color.

Unscarified millet grains decolorized slowly in 0.2*N* HCl because the solution entered the grain only through small regions around the embryo and then slowly migrated toward the opposite end (Fig. 3a). The pericarp is apparently impervious to penetration of 0.2*N* HCl. In many of the seeds, a distinct boundary marked the progress of the acid. After soaking whole millet seeds in excess 0.2*N* HCl solution for 6, 15, 21, and 24 hr, the approximate percentage of seeds that was completely whitened was 12, 51, 70, and 86%, respectively. Acid penetrated scarified millet (degree of dehulling of 2.4%) mainly through areas where the pericarp had been broken (Fig. 3b). This resulted in rapid bleaching; after soaking in 0.2*N* HCl for 1 and 2 hr, 55 and 89%, respectively, of the seeds were completely bleached.

The mechanism of water absorption into whole millet and wheat is similar. After prolonged immersion, water enters wheat grains mainly through the bran adjacent to the embryo (Ziegler and Greer 1971). The testa layer of the seed coat of wheat is apparently resistant to entry of water (Hinton 1955). The millet used in this study did not have a testa layer.

The relation between the degree of dehulling and the rate of bleaching millet grain with 0.2*N* HCl is illustrated in Fig. 4. Following the soaking treatment, the seeds were dried and ground to flour and reflectance measurements (600 nm) were obtained on flour-water pastes. The change in absorbance of the paste was greater than that of dry flours. The decolorizing rate increased dramatically with the degree of dehulling. The horizontal line represents the color of a traditionally dehulled and overnight sour milk soaked sample. Combinations of suitable scarification and soaking treatments that could be used to duplicate the bleaching effect of the sour milk soaking treatment are shown in Table I. Moisture contents of the treated grains ranged from 29.2 to 33.2%; the pH of 25% suspensions of the dried flours in water ranged from 4.1 to 5.1. The pH of a 25% suspension of the traditionally dehulled and sour milk soaked product was 4.4.

The effect of acid (0.1*N* HCl) soaking on grain color of 16 varieties of pearl millet is shown in Table II. The color of all varieties was improved to some extent; however, only five varieties produced white-colored grains. Reflectance measurements of flour-water pastes at 450 and 600 nm verified that these five varieties were lightest in color. The majority of the treated grains were yellow. Two brown-seeded varieties of millet showed only slight improvement. In general, it appears that the gray pigmentation is readily acid bleached, whereas the brown pigmentation is not bleached at all in some varieties and in others it is bleached to yellow. A distinct boundary marking the progress of the acid from the embryo to the opposite end of the seed was observed in some seeds from each variety.

CONCLUSIONS

The bleaching effect of the traditional sour milk soaking treatment of millet grain is simply a pH-dependent effect and can be duplicated with acids such as HCl. The reduction in grain color

TABLE I
Bleaching Treatments of Millet that Produce a Color Comparable to the Traditional Sour Milk Soaked Product

Degree of Dehulling (%)	Soaking (0.2*N* HCl) Time Required (min)	Moisture Content (%)	pH of 25% Suspension of Dried Flour
4.59	26	33.2	4.1
8.37	11	32.1	4.7
13.78	4	28.8	5.0
19.23	3	29.2	5.1

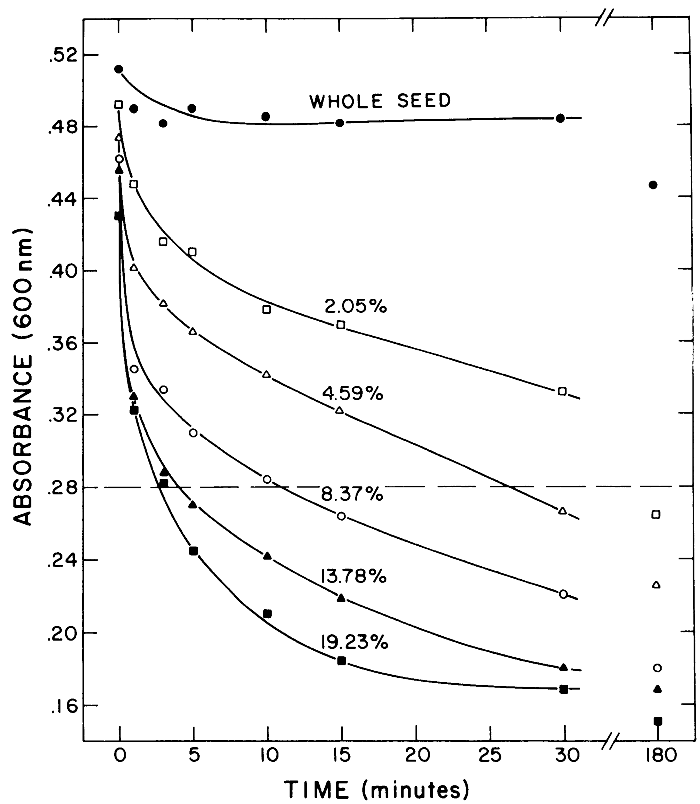

Fig. 4. Effect of degree of dehulling on the rate of decolorizing millet seeds with 0.2*N* HCl. Reflectance measurements are of flour-water pastes.

TABLE II
Effect of 0.1*N* HCl Soaking on Grain Color of Millet

Variety	Seed Color		General Effectiveness of Acid Treatment[a]
	Before Treatment	After Treatment	
NHB-3	Gray-yellow	Yellow	Good
PHB-14	Gray	White	Excellent
ICH-118	Gray-light brown	Yellow	Good
Ancouters	Brown-yellow	Yellow	Good
Serere 2A-9	Gray-green	White	Excellent
Nigerian composite $(S_1)C_1$	Gray-light brown	Yellow	Good
Maiwa composite	Yellow-gray	White	Excellent
World composite $(S_1)C_1$	Gray-light brown	Yellow	Good
Ex-Borno $(S_1)C_1$	Gray-brown	Yellow	Good
Senegal dwarf synthetic	Yellow-green	Yellow	Good
White	Yellow	White	Excellent
Yellow	Yellow-green	Yellow	Good
Brown	Light brown	Yellow	Good
Deep slate	Gray	White	Excellent
Purple	Brown	Lighter brown	Poor
Deep purple	Dark brown	Lighter brown	Poor

[a]Excellent = dramatic improvement and treated grain is white; good = moderate improvement in color but grain is yellow after treatment; poor = little improvement in color and would likely be unacceptable.

caused by acid bleaching is dependent on the variety. The rate of the acid bleaching effect is markedly dependent on the degree of dehulling. A bleaching process using HCl or an organic acid could be incorporated into a village-scale mill to circumvent the problem of gray millet flour produced by the dry-milling process.

ACKNOWLEDGMENTS

We would like to thank the IDRC for their cooperation and support of this work. We thank also F. H. Khadr, Kano Agricultural Research Station, Kano, Nigeria, and S. A. Rao, ICRISAT, Hyderbad, India, for supplying millet grains, and E. F. Lorer for technical assistance.

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[Received September 15, 1978. Accepted November 17, 1978]