Alkali Debranning of Corn to Obtain Corn Bran

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ABSTRACT

An alkali-debranning process was developed for yellow dent corn to obtain corn bran without disintegrating or splitting the kernel. Sodium hydroxide was found to be the most effective alkali for loosening the pericarp of the kernel and subsequently separating it in a hydroabrasor, leaving the kernel absolutely free of pericarp. The pericarp obtained was dried and expressed as bran yield on a corn dry-solids basis. Three variables significantly affecting bran yield were alkali concentration from 4 to 10%, treatment time from 5 to 12 min, and treatment temperature from 46 to 68°C. A maximum bran yield of 4.68% on dry-corn basis (standard deviation = 0.014%) occurred at 6% alkali concentration, 9-min treatment time, and 57°C. Corn bran contained 92.1% dietary fiber, which constituted 95.5% of the total dietary fiber present in the pericarp. Corn drying temperature and endosperm hardness had no significant effect on the bran yield. The bran obtained by the alkali-debranning process was more purified than the commercial corn brans produced by wet- and dry-milling processes.

Corn bran, a valuable source of dietary fiber, has become a significant ingredient in many health and diet foods today. Corn bran is a by-product of the dry- and wet-milling industries. The pericarp of the corn, which is separated during the corn-milling process, is processed and purified to obtain corn bran containing approximately 91% dietary fiber.

Alkali cooking of corn to loosen and separate the pericarp has long been practiced by native Americans to render corn more suitable and palatable as food. Today, many corn-based snack products and specialty Mexican foods are prepared using a similar alkaline treatment (Eytinge 1965, Katz et al 1974, Bedolla and Rooney 1982, Serna-Saldivar et al 1988) that involves cooking corn at 90–100°C in an alkaline solution for an extended time to achieve considerable softening of the corn kernels (Khan et al 1982). This corn is then suitable for dough or masa production.

Less severe alkaline processes have been developed to loosen and separate the pericarp and to use the pericarp-free corn for further processing in wet or dry milling. An improvement in starch

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manufacturing was made by including alkali treatment for corn (Wagner 1940, 1942). An alkaline soak treatment was developed to make parched corn by frying the alkaline-treated pericarp-free corn in oil (Holloway and Goodin 1940). Hansen (1949) developed an alkaline pretreatment to remove the pericarp from the corn and to improve the corn's dry- and wet-milling properties. Weinecke (1962) invented a pretemper step that involved soaking the corn kernels in dilute alkali before dry milling to obtain improved yields of the large grits and oil. A chemical dehulling process was developed by Blessin et al (1970) that completely dissolved the pericarp to obtain dehulled corn. Alkali debranning treatment has been applied to cereals like wheat, barley, rye, rice, and oats to provide new, more attractive ready-to-eat cereal products (Barta et al 1966).

The pericarp obtained from the above alkali processes was discarded as a by-product and no effort was made to study the quality and quantity of the pericarp. The objective of this work was to develop a modified alkali-debranning process for yellow dent corn. We wanted to obtain high-quality corn pericarp as corn bran at maximum possible yields without disrupting and damaging the corn kernel; to optimize the processing parameters of alkali concentration, temperature, and time to obtain maximum bran yield; and to compare the composition of the alkali bran with commercially available brans.

MATERIALS AND METHODS

Corn Samples

Yellow dent corn of a medium hard variety was obtained locally and consisted of a mixture of five different hybrids from the 1988 crop year (Pioneer 3737, Trisler 2995, Vineyard 530, Great Lakes 585, and Agrigold 6445). The samples, free of broken corn and foreign material, were dried using a forced-draft oven (Blue-M model POM-256C-2, Blue-M Electric Co., Blue Island, IL, airflow 80 ft/min) at 25°C. The initial moisture content was 12.5% (wet basis). High- and low-temperature dried corn was obtained by rehydrating the corn to a 20% moisture content and then drying in a forced-draft oven at temperatures of 37.7, 48.9, 60, 71.1, 82.2, 93.3, and 105°C to a final moisture content of 12.5%. Corn samples with soft (84% floaters), average (65% floaters), and hard (50% floaters) endosperm corn were obtained locally, dried, and stored at low moisture in a similar fashion. Floaters test was performed using the method followed by Paulsen and Hill (1985).

Alkali-Debranning Process

Preliminary laboratory studies were done using three different types of alkali: calcium hydroxide, potassium hydroxide, and sodium hydroxide. Sodium hydroxide loosened the bran in less than 10 min at concentrations from 5 to 10%, while the other two alkalies required more than 30 min at the same or higher alkali concentration. Sodium hydroxide was chosen as the source of alkali for the rest of the investigation.

Alkali treatment was performed by soaking 100 g of corn in 200 ml of sodium hydroxide solution held in a constant-temperature water bath. After treating the corn sample for a specific time, the corn was rinsed with tap water to remove any excess alkali from the surface of the kernel and cooled to room temperature to terminate the alkali reaction. A hydroabrasor (Fig. 1), consisting of a plastic bristle brush rotating at 160 rpm over a 4.0-mesh, 150-mm-round screen containing corn, was used to remove the loosened pericarp from the kernels. The pericarp peeled off because of the abrasive action and fell onto the 150-μm screen below. A continuous spray of recirculated wash water on the top screen helped move the bran from the top to the bottom screen. When all of the loose pericarp on the top screen was washed to the lower screen (2–3 min), the corn and the pericarp were removed from the hydroabrasor. The solids content of the pericarp was determined using a vacuum oven at 60°C (AOAC 1980) and was called corn bran. Bran yield was calculated from the amount of dry pericarp solids obtained per 100 g of dry corn.

Experimental Design and Statistical Analysis

The independent test variables were alkali concentration, temperature, and time. A sodium hydroxide concentration of 6% was initially selected and compared at seven times (5, 6, 7, 8, 9, 10, and 12 min) and five temperatures (46, 52, 57, 63, and 68°C). After determining an optimum temperature of 57°C, bran yield was obtained for alkali concentrations from 4 to 10% and compared with the same seven times.

An SAS (1984) statistical program was used to analyze the data for variance using Duncan's multiple range test. Least significant differences of the mean bran yield were obtained at a 5% significance level. A statistical graphics system (STSC 1987) was used to obtain regression coefficients and a model regression equation for response surface analysis of bran yield.

A total-solids balance was obtained on the debranning process and evaluated for losses during the process. Pure pericarp of corn was obtained by carefully hand-peeling dissected soaked corn with a razor blade. The hand-peeled pericarp obtained from 100 g of corn (dry basis) was dried to determine yield and analyzed for dietary fiber content. Each set of experiments was run in duplicate and an average value of bran yield presented. The standard deviation of the duplicate measurement was ± 0.01–0.02%.

Sample Analysis

Untreated yellow dent corn, debranned corn, and bran samples were obtained at the optimal treatment parameters, sealed in bags, and sent to a commercial analytical laboratory for determinations of moisture, protein, fats-oils, ash, fiber, and starch (AOAC 1980).

RESULTS AND DISCUSSION

Figure 2 shows the effect of temperature (46–68°C) on bran yield at a 6% alkali concentration. The maximum bran yield occurred at 57°C for all of the treatment times studied. As the temperature decreased, the pentosan and hemicellulose were less susceptible to alkali attack, which left most of the pericarp attached to the kernel. Increasing speed or abrasion time did not increase the bran yield. At higher temperatures the action of alkali dissolved the pericarp, resulting in lower bran yield.

The response surface plot of bran yield against alkali concentration at 57°C (Fig. 3) showed maximum bran yields at lower alkali concentrations and at higher times. Lower bran yields occurred at very low and very high levels of both treatment times and alkali concentrations. Underexposure to alkali, i.e., at lower times, resulted in incomplete action by the alkali on the bonds holding the pericarp to the kernel. Increasing the speed or abrasion time of the hydroabrasor did not offset the lower alkali exposure.

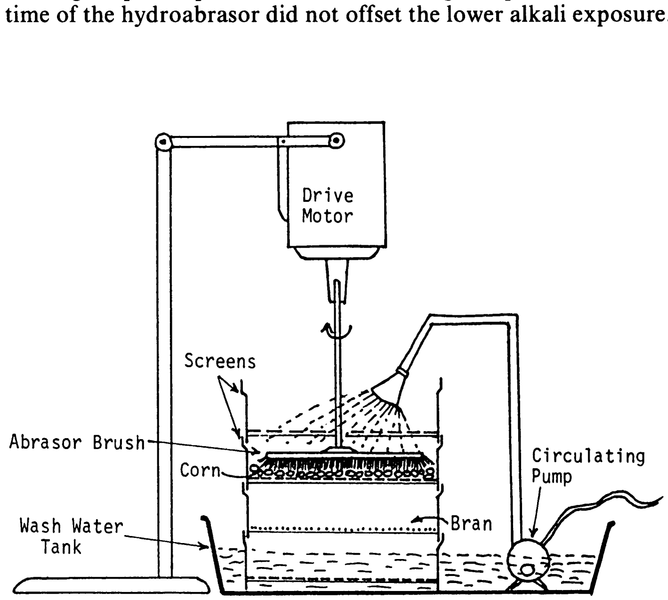

Fig. 1. Hydroabrasor apparatus designed and constructed in the laboratory to debran alkali-treated corn.

Bran yield decreased at higher treatment times due to the excessive action of alkali on the pericarp, resulting in the disintegration of pericarp to soluble components that could not be separated from the wash water. Higher bran yields were obtained at alkali concentrations of 5–8% for most of the treatment times from 8 to 12 min.

Bran yield obtained at different alkali concentrations, times, and temperatures varied significantly ($\alpha = 0.05$) (LSD = 0.010%). Maximum bran yield of 4.68% occurred at 57°C, 6% alkali concentration, and 9 min.

A statistical model equation to predict bran yield at 57°C for alkali concentrations from 4 to 10% and treatment times from 5 to 12 min was obtained using the Statgraphics program ($R^2 = 0.93$):

$$\text{Percent bran yield} = -3.42 + 1.05\,(\text{conc}) + 0.88\,(\text{time}) + 0.04(\text{conc}^2) - 0.03(\text{time}^2) - 0.05(\text{conc} \times \text{time})$$

Debranning of soft, average, and hard endosperm corn gave 4.69, 4.67, and 4.68% bran yield, respectively, using 6% alkali concentration at 57°C for 8 min. The standard deviation of the bran yield for all three types of corn was 0.011%. Corn dried at seven temperatures from 38 to 105°C showed bran yield variation from 4.66 to 4.69% (standard deviation for the average of all drying temperatures was ±0.014%). Thus, the endosperm hardness and drying temperature had no significant effect on the maximum obtainable bran yield.

Debranned corn had approximately half the dietary fiber content of the untreated corn (5.10 vs. 11.15%). The protein and oil content were reduced after debranning from 10.93 to 10.71% and from 3.76 to 2.72%, respectively. The ash content increased from 1.44 to 1.56% due to the absorption of alkali by the corn. The solids balance obtained from the debranning process showed that 91.3% of the corn solids were retrieved as whole debranned corn and 4.68% as corn bran. The rest of the corn solids were partially dissolved in the alkali solution and partially in the wash water. This loss was mainly attributed to some dissolution of pericarp and tipcap and to leaching of sugars and other solubles from the germ.

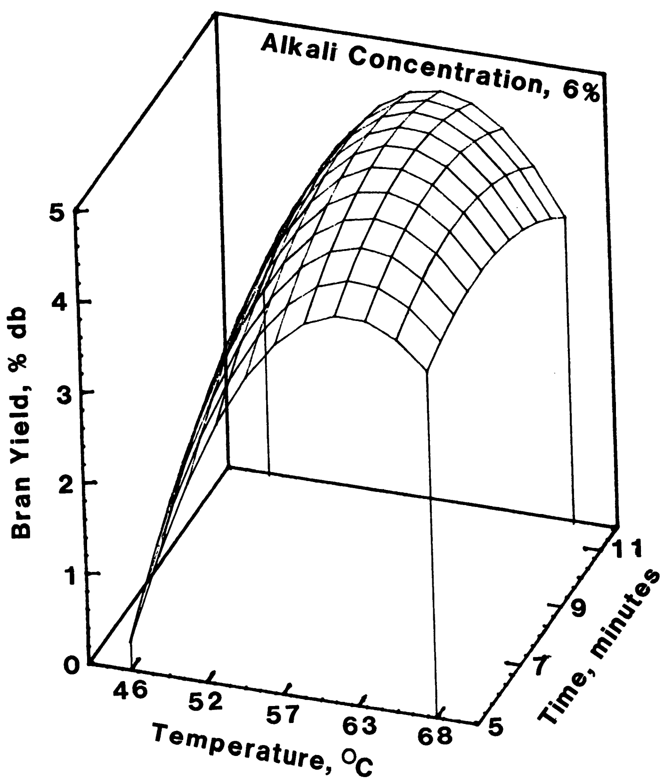

Fig. 2. Response surface plot of bran yield with interaction effects of treatment time and temperature at 6% alkali concentration.

The pericarp yield of the untreated corn obtained by hand-dissecting soaked corn was 5.93% and contained 76% dietary fiber. The bran obtained by alkali debranning was 4.68% of the corn solids and had 92.1% dietary fiber. Therefore, on a 100-g untreated corn-solids basis, out of 4.51 g of dietary fiber in the untreated pericarp, more than 4.31 g was obtained in the bran by alkali debranning (95.5% recovery).

Comparison of the composition of alkali-extracted bran with commercially available corn brans (Table I) indicated that the bran obtained by debranning had more dietary fiber than the commercial bran obtained by wet milling (refined bran) and dry milling (corn bran). The protein, oil, and starch contents were significantly lower than those of the commercial brans, indicating that the bran obtained by the alkali process may need little or no further refining. Soaking the alkali-extracted bran in 1% lactic acid solution for 1 hr reduced the ash content from 1.56 to 0.66%. Thus, the higher ash content in the alkali bran could be reduced substantially by neutralizing with a suitable acid.

The physical appearance of the debranned kernel was no different from that of the untreated kernel. However, the color

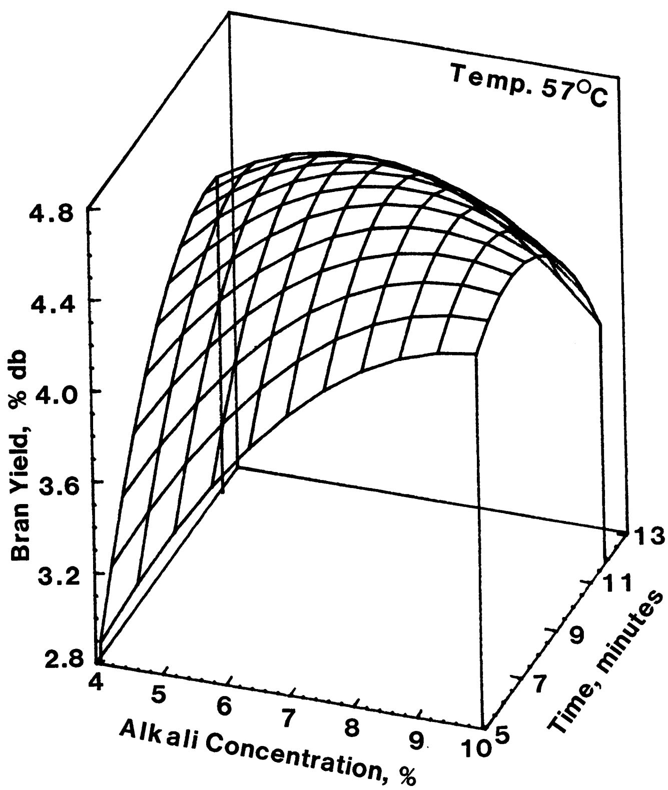

Fig. 3. Response surface plot of bran yield using a first order model equation with interaction effect of alkali concentrations and treatment times at 57°C.

TABLE I
Content[a] of Corn Bran Obtained by the Alkali-Debranning Process and of Commercially Available Corn Brans Obtained by Wet- and Dry-Milling Processes

Components	Alkali-Treated Bran	Refined Corn Bran[b]	Corn Bran[c]
Dietary fiber	92.12 ± 0.12	92	76.66
Protein	3.73 ± 0.42	4–6	7.10
Ash	1.09 ± 0.47	<0.06	. . .
Fats-oils	0.49 ± 0.02	2–4	<1.0
Starch	2.57 ± 0.15	4–6	8.26

[a] Percent dry basis.
[b] Product literature obtained from A. E. Staley Co., Decatur, IL.
[c] Product literature obtained from Lauhoff Grain Co., Danville, IL.

was slightly duller but more yellow. This is due to the absence of the smooth pericarp layer and exposure of the pigment-rich aleurone layer. Because of the nature and scope of the investigation, the debranned corn and the bran were not tested for the organoleptic characteristics. The bran was duller and darker than the commercial brans. On acid soak, the color of the alkali bran was restored and appeared similar to that of the commercial brans. The brans obtained from debranning calcium hydroxide- and potassium hydroxide-treated corns had a similar appearance.

CONCLUSIONS

An alkali (sodium hydroxide)-debranning process was developed for yellow dent corn to loosen and remove the pericarp in a hydroabrasor, leaving the kernel whole and undamaged. Bran yield was affected by time, temperature, and concentration of alkali. The highest value (4.68% on a dry-solids basis) of bran yield was obtained at 6% alkali concentration, 9 min, and 57°C. The bran obtained by the alkali-debranning process contained more than 95.5% of the dietary fiber present in the corn pericarp. The bran obtained from the debranning process was more refined than the commercially available bran samples. Corn drying temperature and kernel hardness had no significant effect on the mean maximum bran yield. Alkali debranning is a short, simple, and easy process that can be used to obtain high-quality corn bran without disintegrating the corn kernel.

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