Dehulling of Palm Kernel of Oil Palm (*Elaeis guineensis*) to Obtain Superior-Grade Palm Kernel Flour and Oil

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A novel method has been developed for the removal of the thin, dark-brown skin, called testa, from the palm kernel of the oil palm (*Elaeis guineensis*) by chemical treatment. Studies carried out for this purpose included physical or mechanical means, dry or wet heat, solvents and other chemicals. Of the procedures tried, treatment with hydrochloric acid (HCl) resulted in complete removal of the testa, producing a pearl-white palm kernel. All other treatments were found to be ineffective. Based on our laboratory studies, semi-large-scale trials were made with 4N HCl for continuous dehulling of palm kernel in an abrasive peeling machine for the preparation of superior-grade kernel flour and oil.

KEY WORDS: Dehulling, hydrochloric acid, pearl-white palm kernel, peeling, testa.

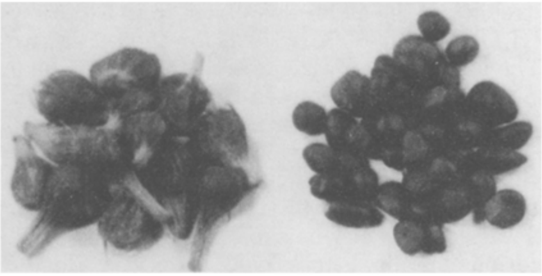

FIG. 1. Oil palm seed/nut and palm kernel (undehulled).

Palm kernel, the by-product of the oilpalm industry, has great potential as a source of dietary protein and oil (1). Global production of palm oil has increased considerably over the years and is likely to increase more, resulting in large quantities of palm kernel. Little use is made of the palm kernels at present. Palm kernel oil is akin to coconut oil in its fatty acid composition, but its use for human consumption, particularly in India, is presently restricted (2–4). This is mainly due to the presence of undesirable phenolic constituents, which impart dark color to the palm kernel meal and oil (5–14).

Palm kernel has a thin, single seed coat weighing 3–5% of the kernel. The layer of gum/lignin that binds the seed coat to the kernel appears to be thin (15–22). The testa is so strongly attached to the kernel that its removal by dehulling processes normally used is extremely difficult. The dehulling process usually practiced, such as water soaking (23), treatment with various chemicals, such as soda ash or lime, sodium bicarbonate, sodium carbonate, sodium borate, sodium hypochlorite, alkali or a combination of alkali-acid (24–28), are difficult and ineffective. Systematic investigations were therefore undertaken to find the most effective method for removal of the testa from the palm kernel.

EXPERIMENTAL PROCEDURES

Palm kernels (*Elaeis guineensis*) containing 5–6% moisture were used for all the experimental work (Central Plantation Crops Research Institute, Agricultural Research Station, Palode, Kerala State, India). The kernels were bold with a dark-colored, thin, brown skin (Fig. 1). Sample size was 250 g in all experiments unless otherwise specified. Results presented are averages of six replicates. Fifteen samples collected from 15 different lots were subjected to the following treatments under the conditions of the test. Several approaches for the removal of testa were made, including physical or mechanical means, use of heat, solvents or chemicals.

Physical or mechanical means. The kernels were given a physical scouring action on a wire mesh and on a grater. They also were given mechanical abrasive action by running them in a rice polisher or dehuller with extra clearance for the kernel.

Dry and wet heat treatment. For the dry heat treatment, kernels were subjected to various temperatures (from 80 to 160°C) in an air oven for 1–6 h. Kernels wetted with water for 2 h also were subjected to similar heat treatment. Wet heat treatment trials were carried out by autoclaving the kernels from 0 to 120 min, keeping the water level constant throughout the experimental period.

Hot water treatment. Kernels were boiled with water (1:1.5, wt/vol) for various periods from 0 to 120 min, keeping the water level constant throughout the experimental period.

Use of solvents. Kernels were soaked with different solvents or mixtures of solvents for 16 h. Solvents used were hexane, methanol, water, chloroform, methanol/water (90:10, vol/vol) and hexane/methanol/water (44:40:16, vol/vol/vol). The solvent was then drained off and kernels were air-dried.

Sulfuric acid treatment. The kernels (250 g) were treated with H_2SO_4 (375 mL) of varying normality (1–8N). The temperature of the contents was raised to 95°C and maintained at this level for varying periods from 0 to 30 min.

Phosphoric acid and acetic acid treatment. Kernels were subjected to treatment with phosphoric acid and acetic acid under conditions similar to those described for H_2SO_4 treatment. The strength of the acid in each case varied from 5 to 60% (vol/vol). Glacial acetic acid and 85% phosphoric acid were used to make various dilutions.

Hydrochloric acid treatment. Hydrochloric acid of varying strength (1N to 8N) was used. The temperature was maintained at 95°C. The period of treatment varied from 0 to 30 min. In another trial, the concentration of HCl was kept constant at 4N and the temperature of treatment was varied from 70 to 95°C.

Treatment with sodium and potassium hydroxide. Various strengths of sodium hydroxide (from 1N to 6N) were used at a constant temperature of 95°C, and the time

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of treatment was varied from 0 to 30 min. Conditions for potassium hydroxide were identical to those for sodium hydroxide.

Other alkalies. Other alkalies, such as ammonium hydroxide, calcium hydroxide and barium hydroxide, also were tried in the same manner as described for NaOH. The strength of the alkali was varied from 5–50% (vol/vol) for NH_4OH and 5–50% (wt/vol) for the other two alkalies. The effect of the various treatments on the loosening of the testa was assessed by scouring action.

Chemical treatment. After the laboratory studies, semi-large-scale trials were carried out with 4N HCl at 95°C for 6 min. The 4N HCl solution (5 L) was heated in a 10-L Corning-glass beaker to 95°C, and 3 kg of cleaned palm kernel was added. The whole mass was drained after a contact period of 6 min. Excess cold water was added to cool down the kernel and also to wash off the acid in contact with the kernel. Ten such identical unit operations were carried out in a day and pooled to collect 30 kg of treated kernels.

Removal of testa and pigments. An abrasive peeling machine fitted with a cylindrical sieve with 1/16″ perforations was used for the continuous dehulling of treated palm kernel. The machine was fitted with a hopper with a regulating valve at the bottom (Fig. 2) to control the flow of kernels. Complete removal of testa was accomplished in a single pass by regulating the feed rate and proper setting of the nylon brushes inside the sieve. The dark liquid along with the testa from the peeling machine was centrifuged, and the overflow and the sedimented wet testa were collected for a separate study.

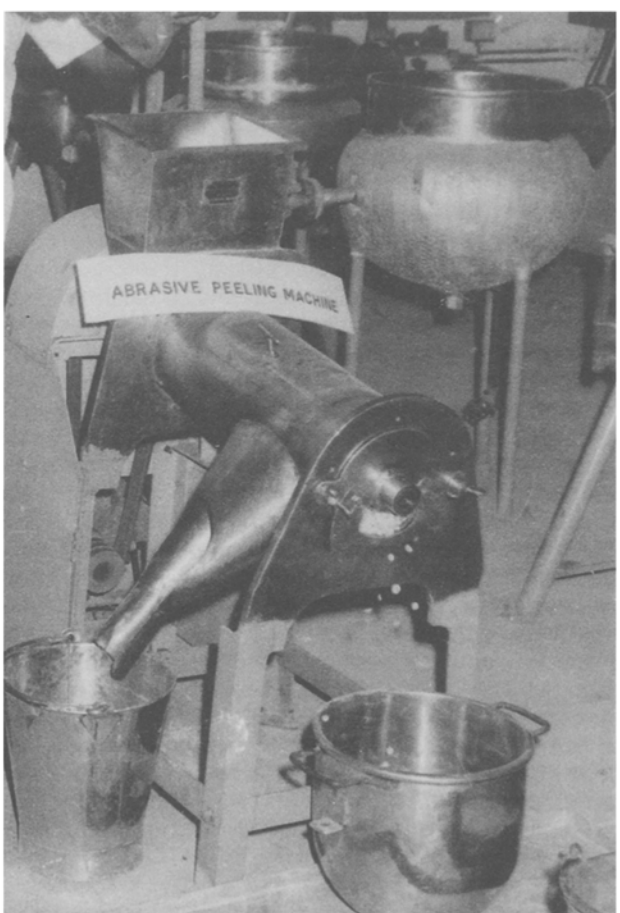


FIG. 2. Abrasive peeling machine.

Washing and drying. The treated kernels were washed with water in a 60-L plastic bin and drained. The treated kernels had a moisture content of 12–15% and were dried in a through-flow drier for 2 h at 45°C to a moisture content of 5–6%.

Preparation of fat-free, superior-grade palm kernel flour. Dehulled kernels (50 kg) were ground in a plate mill to pass through a 44 mesh screen, and extracted with hexane in a batch solvent extractor. The defatted palm kernel flour was air-dried and stored in airtight containers at 10°C until further use. The kernel meal/flour obtained by this method was superior in its quality characteristics and had an appealing appearance.

RESULTS AND DISCUSSION

The kernels did not show any marked loosening of the testa when subjected to physical or mechanical abrasive action. A significant portion of the kernels were obtained as powder after these treatments.

Dry and wet heat treatment. Dry and wet heat treatment of the kernels, with or without wetting, at temperatures ranging from 80 to 160°C for 1–6 h had no effect at all on loosening of the testa. Similarly, autoclaving of the kernels at 15 psi for periods from 5 to 30 min was not effective for any perceptible removal of the testa, although similar treatments proved effective in removal of the seed coat from a number of oilseeds and legumes, such as groundnut, soybean, fieldbean and green gram (25). However, palm kernel proved to be extremely resistant to the heat treatment.

Hot water treatment. Dipping of the kernels in hot water at different temperatures, ranging from 85°C to boiling, for 1/2 to 2 h, followed by air or oven drying, did not have any effect on loosening of the testa.

Mere soaking in water at room temperature, followed by drying, has been effective to loosen the seed coat of winged bean, soybean and black gram (26). The endosperm shrinks more on drying than the hull in these cases, resulting in a bubbled seedcoat, which can be removed easily by the shearing action of the shelling machine. But this method, even when augmented by treatment with boiling water, did not prove effective for palm kernel.

The impermeability of palm kernel to water, even on protracted boiling, is due to a continuous, hard layer of gum/lignin on the caps of the palisade cells, as well as to the presence of quinones in a continuous layer of cells around the seed, both in the lumen and the cell wall. Lignification and presence of gum could be possible causes for the difficult-to-mill seed coat, which results in decreased adsorption of water. Lignification of the cell wall is mainly due to cross-linking of the hydroxypropyl residues in proteins to lignin.

Use of solvents. Solvents, such as hexane, methanol, chloroform, 90% methanol or methanol/hexane/water (44:40:16 vol/vol/vol), proved ineffective at room temperature. These experiments were carried out with the hope of selectively extracting certain waxy materials of the testa, so that the testa may get detached from the endosperm.

Use of chemicals. A host of chemicals were tried in an attempt to remove the testa, with varying degrees of success. Dehulling of palm kernel by sulfuric acid treatment was only 25%, even at the concentration of 8N H_2SO_4 for 30 min. The kernel got damaged when it was given a scouring action against a wire mesh after treatment with even the lowest strength of sulfuric acid. In the kernels that have not undergone dehulling, the seed coat exhibited strong binding. Only the surface of the testa appeared to be affected and there was no loosening to any appreciable extent. It is possible that only surface dehydration of the testa is brought about by sulfuric acid. Also, phosphoric acid and acetic acid were unsatisfactory for loosening the testa.

With 1N HCl, seed coat separation was not possible up to a period of 10 min, but with progressive increase in time there was an increase in the extent of loosening of the testa. Treatment with 1N HCl for 45 min at 95°C resulted in 100% separation of the seed coat. With increase in the strength of the acid, the time of treatment was progressively decreased. Treatment for 30 min was adequate for complete seed coat separation when 2N HCl was used. When the strength of the acid was increased to 3N, seed coat separation was possible in about 13–15 min, while with 4N HCl complete removal of testa was achieved in about 6 to 7 min, resulting in a pearl-white palm kernel. Two-min of dipping in 6N HCl was quite enough for complete testa removal. When the concentration of this acid was increased to 7N or 8N, complete seed coat separation was achieved in about 30 s, producing a pearl-white palm kernel. The seed coat comes off easily on HCl treatment.

Taking into consideration the cost factor, treatment with 4N HCl appears to be both economical and effective. Therefore, it was decided to use HCl at this strength. To see whether or not lower temperature would be effective, treatment with 4N HCl was tried. The results indicate that complete testa removal is possible at 70, 80, 85 and 90°C in 60, 40, 20 and 15 min, respectively. This indicates that dehulling of palm kernel can be accomplished even at 70°C if the period of treatment is increased.

If kernels are exposed to HCl at 4N or higher strength for longer periods than those stated above, there was yellowish-brown discoloration of the kernel. Treatment with 4N HCl at 95°C for 6–7 min was found to be the optimum condition for dehulling in terms of color of the kernel obtained and the cost involved. The kernels came out pearl-white with no discoloration whatsoever. After this treatment, the seed coat comes off easily once a little pressure is exerted. The kernels were immediately washed with water to remove the acid and then dried in a cross-flow drier. The testa come off easily by applying physical methods (Fig. 3).

The ion common to HCl and NaCl is chloride. To assess the efficacy of chloride ion of sodium chloride (NaCl), kernels were treated with a binary mixture of 0.5 to 10% NaCl plus 1N to 3N HCl. The results obtained indicate that complete testa removal is possible at 55, 35 and 20 min for 1N to 3N HCl plus NaCl as compared to 45, 30 and 15 min when HCl alone was used. Use of NaCl was not found to be effective.

Treatment with alkali. Sodium hydroxide at 95°C, even at a low concentration of 1N, for a period of 7 to 10 min proved to be effective in loosening the testa completely. Higher concentrations of alkali decreased the treatment time (4N, 5N and 6N NaOH required 4, 3 and 2 min, respectively). Even though alkali treatment resulted in complete dehulling, its serious disadvantage was that the kernel was colored dark brown and appeared as if no dehulling had taken place.

Soaking palm kernels in various concentrations of sodium hydroxide at room temperature also was tried. To get 100% dehulling, it was necessary to soak in 6–7 N NaOH for 3 h, and the kernels were colored brown. Treatment with potassium hydroxide solution gave similar results.

In an attempt to see if the colored kernel obtained by alkali treatment can be decolorized, the alkali-treated kernels were immediately treated with hydrochloric acid of varying concentrations. Though some decolorization was observed after acid treatment, the kernels were still colored, and therefore alkali treatment was not considered desirable.

Treatment with other alkalies, such as calcium hydroxide, ammonium hydroxide and barium hydroxide, at various concentrations for different periods did not prove effective in loosening the testa.

These laboratory studies thus indicate that treatment with 4N HCl at 95°C for 6–7 min is the most satisfactory method to loosen the testa and to produce a pearl-

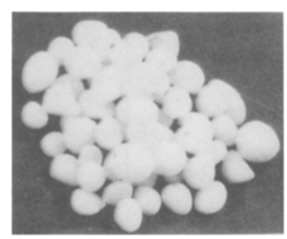
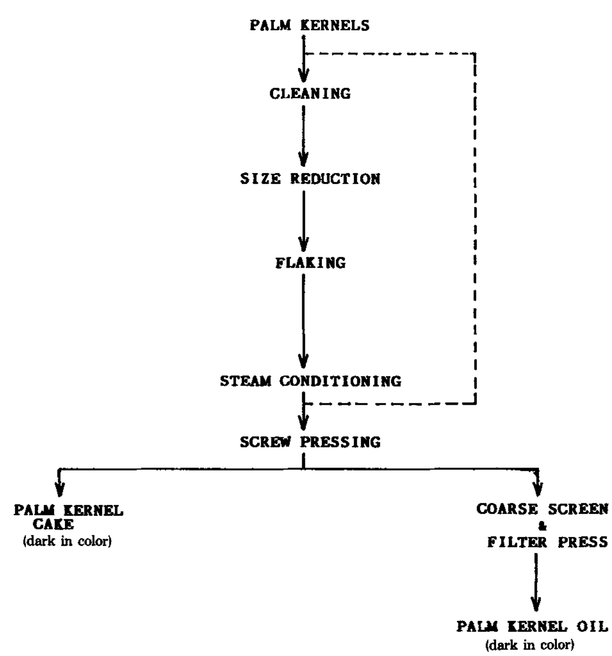


FIG. 3. Palm kernel (dehulled).

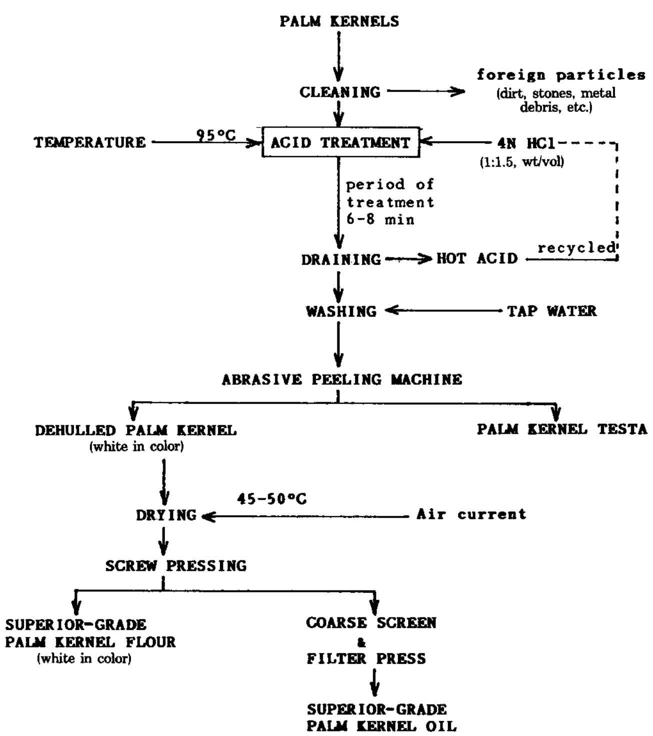


SCHEME 1

white kernel. It was therefore decided to adopt this procedure for semi-large-scale dehulling of palm kernels.

Semi-large-scale trials. Flow sheets for the continuous dehulling of palm kernels in an abrasive peeling machine for the preparation of pure, white, palm kernel flour and for the existing method are shown in Schemes 1 and 2. Scheme 1 shows the existing methodology for the extraction of palm kernel oil and cake, and Scheme 2 is the typical flow diagram for palm kernel dehulling by acid treatment. There does not appear to be any previous report on the dehulling of palm kernel, and our method was the most satisfactory approach to obtain superior-grade palm kernel flour and colorless oil.

Detailed studies on the effect of HCl treatment on different classes of proteins, the fatty acid profile and dietary fiber were not studied at this time.



SCHEME 2

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