The Effect of Fruit Storage on Palm Oil Bleachability

W.L. Siew* and **N. Mohamad**
Palm Oil Research Institute of Malaysia, 43650 Bandar Baru Bangi, Selangor Darul Ehsan, Malaysia

Storage of oil palm fruits resulted in crude oil that was difficult to bleach, especially from bruised fruits. Fruits stored in the shade were less affected than those exposed to sun and rain. Surprisingly, oil from fruits stored at 5°C was highly hydrolyzed and difficult to bleach.

KEY WORDS: Color, DOBI, hydrolysis, oxidation, palm oil bleachability.

The intense red color of crude palm oil is due to carotenoids. These are easily removed during adsorptive bleaching and deodorization. The amount of carotenoids present does not generally determine the residual color of refined oil. The residual color is attributed to unknown high-molecular weight compounds (1).

Refining is carried out by a degumming *cum* bleaching step followed by deodorization. The resultant product is usually a clear, transparent golden-yellow oil of about 2.0–2.5 R in a 5.25-inch Lovibond cell. The major problem has been bleachability during processing and, on some occasions, a difficult-to-bleach oil is encountered.

A simple analytical method was proposed as a relevant method for the Deterioration-of-Bleachability Index (DOBI) (2). The procedure is a spectrophotometric assay of crude palm oil dissolved in a solvent. The ratio of the absorbance at 446 nm to 269 nm gives a good indication of the bleachability of the oil. Ratios of 3–4 are found for the best grades of crude palm oil, while oils with values of 2–3 may yield an acceptable color upon refining. Oils with values less than two are not refinable under normal processing conditions.

Lipoxygenase activity is a possible cause for deterioration of fruits that results in bleaching problems (3). Oxidation of the oil during heat treatment might be another factor.

This paper examines some of the factors involved in the development of color problems in palm oil refining and the extent of degradation from these factors.

EXPERIMENTAL PROCEDURES

Three series of experiments were carried out.

Series No. 1. Ripe bunches (20 wk after anthesis) were harvested and chopped into spikelets that were distributed into four groups for the following treatments:

F1: Fresh, sterilized immediately, followed by oil extraction of the mesocarp *via* hydraulic press;
F2: As above, except that the mesocarp was boiled with the nuts for 30 min prior to oil extraction;
S1: Fruits stored for four days. After sterilization, the oil was extracted from the mesocarp *via* hydraulic press;
S2: As in S1, except that the mesocarp was boiled with the nuts for 30 min prior to oil extraction.

*To whom correspondence should be addressed at Palm Oil Research Institute of Malaysia, No. 6, Persiaran Institusi, 43650 Bandar Baru Bangi, Selangor Darul Ehsan, Malaysia.

The pressed oil was warmed to 60°C to prevent crystallization and centrifuged to remove nonoil solids and fibers.

Series No. 2. Ripe bunches (20 wk after anthesis) were harvested and chopped into spikelets that were divided into five groups for the following treatments:

Fresh (FF): Fresh fruits were sterilized immediately followed by oil extraction of the mesocarp *via* hydraulic press;
SO (NB): Undamaged fruits were stored in the open for four days before being sterilized and the oil was extracted as above;
SO (B): Damaged fruits (by bruising) were stored for four days in the open and the oil was extracted;
SS (NB): Undamaged fruits were stored under shaded conditions. Oil extraction was carried out as indicated for the fresh fruits;
SS (B): Damaged fruits (by bruising) were stored under shaded conditions. Oil extraction was carried out as indicated for the fresh fruits.

Series No. 3. Ripe bunches were harvested and cut into spikelets that were grouped into three lots for the following treatments:

Fresh (F): The fruits were sterilized immediately and the mesocarp was pressed;
Stored Ambient (A): The fruits were stored at ambient temperature in the laboratory for one day prior to processing as above;
Stored (5°C) (C): The fruits were stored at 5°C in a cold room for one day prior to processing as above.

Heated oils. Three other oils were processed as follows:

HF: The crude palm oil extracted from (F) above was heated at 60°C in an oven for 7 h each day for 2 wk.
HA and HC: Similar heating treatment was carried out on the crude oils (A) and (C).

The oils extracted from the three experimental series were analyzed for peroxide value (PV), free fatty acids (FFA), carotene content, DOBI, tocopherols, extinction coefficient at 233 and 269 nm, and bleachability (4).

RESULTS

Qualities of crude palm oils extracted from freshly sterilized fruits (series 1) are shown in Table 1 and were excellent as indicated by low peroxides and secondary oxidation products. Excellent refinability was indicated by the bleachability test of 0.3 R. As a comparison, commercial crude palm oil showed an average bleachability test value of 2.0–3.0 R. Thus, certain processing factors contribute toward the increase in residual color. Post-harvest

TABLE 1

Quality Deterioration of Oil Palm Bunches During Storage[a]

Fruit condition	PV (meq/kg)	FFA (%)	$E^{1\%}_{233}$	$E^{1\%}_{269}$	Carotene (ppm)	DOBI	Tocopherol (ppm)	Bleachability (5.25-inch cell)	
								R	Y
F1	0.19	0.45	0.93	0.04	555	4.77	1111	0.3	8
F2	0.19	0.50	0.89	0.05	507	4.65	1132	0.3	8
S1	0.16	1.73	1.05	0.14	501	3.48	919	0.7	16
S2	0.28	1.35	1.07	0.14	515	3.52	980	0.7	9.4

[a]PV, peroxide value; FFA, free fatty acids; DOBI, Deterioration-of-Bleachability Index. F1, F2: Fresh oil palm bunches; S1, S2: Oil palm bunches, stored for 4 d.

storage periods, which may vary from several hours to a week, are important factors contributing toward the color increase. In general, palm fruits are processed immediately or within a day or two. However, there may be occasions for longer storage due to poor climatic conditions.

An increase from 0.3 R to 0.7 R was observed in the oil after four days of storage (Table 1). During this period the DOBI decreased from 4.77 and 4.65 to 3.48 and 3.52, respectively. In series 2 (Table 2) there was no increase in color with storage. Neither was there any drop in the DOBI values. This is to be expected because the DOBI gives an indication of the bleachability of the oil. Thus, storage of fresh fruits may or may not result in a decrease in the bleachability of the oil. If oxidation has occurred during the storage period, poorer bleachability is expected.

In addition to the increase in residual color on refining, storing fruits also increases free fatty acids and secondary oxidation products. The increase in free fatty acids is due to the high lipolytic activity of palm fruit lipase (5,6). The slight decrease in carotenoids in the oils from fruits could be due to lipoxygenase activity (3). The increase in oxidation as shown by increased peroxides, $E^{1\%}_{233}$ and $E^{1\%}_{269}$, provides further support to this theory.

Another factor affecting palm oil bleachability is the condition of the fruits during the post-harvest period prior to sterilization, as shown in Table 2. Good-quality, unbruised fruits showed relatively little deterioration during storage in both shaded and exposed conditions. Bruised fruits, however, showed rapid deterioration. The free fatty acids increased 26-fold when the fruits were kept in the sun, and only 14.7-fold when stored in the shade. Peroxides in the oil extracted from the SO (B) and SS (B) bruised fruits were more than double that found in the oil from fresh fruits. Secondary oxidation products at $E^{1\%}_{269}$ were also higher in oil from bruised fruits. Some carotenoids were destroyed during storage, which was reflected in the DOBI values. Storage of bruised fruits in the sun was more detrimental to the oil's bleachability performance compared to similar fruits stored in shaded conditions. This was also indicated from the lower DOBI value of 3.9 compared to 4.2 in the oils from fruits stored in the shade.

Fruits stored at ambient laboratory temperatures (25°C) were compared to those stored at 5°C (Table 3). Although it is not the practice for palm fruits to be kept in such cold conditions, changes occurred in the fruits that resulted in severe hydrolysis and oxidation. The most significant changes occurred in the free fatty acid content, phosphorus content and bleachability. The free fatty acids in the oil increased to 35.5% after overnight storage of fruits at 5°C. Phosphorus in the oil was 88.8 ppm compared to 5.4 ppm and 6.0 ppm in oils from fresh fruits and fruits stored at ambient conditions. respectively. A 12.5-fold increase in color upon refining was obtained in the oil when fruits were stored at 5°C.

Another factor affecting the bleachability performance of crude palm oil is the result of heat treatment (Table 3). Heating crude oils caused oxidative and color deterioration. Rapid hydrolysis also occurred with the HC sample when heated. The rate of oxidation was faster for the HC sample compared to HA and HF. The color of the refined oils increased in the heated samples (HF and HA) from 0.4 R to 1.0 R in a 5.25-inch Lovibond cell. For the HC

TABLE 2

Effect of Fruit Condition on the Keepability of Oil Palm Fruits[a]

Fruit condition	PV (meq/kg)	FFA (%)	$E^{1\%}_{233}$	$E^{1\%}_{269}$	Carotene (ppm)	DOBI	Bleachability (5.25-inch cell)	
							R	Y
FF	0.3	0.31	0.99	0.09	962	4.6	1.1	20
SO (NB)	0.3	0.46	0.96	0.10	810	4.4	1.0	13
SO (B)	0.8	8.13	1.14	0.18	867	3.9	2.2	31
SS (NB)	0.3	0.24	1.00	0.12	862	4.3	0.9	10
SS (B)	0.7	4.56	1.05	0.14	845	4.2	1.5	18

[a]See Table 1 for abbreviations. FF, fresh fruits; SO (NB), undamaged fruits stored for 4 d; SO (B), damaged fruits stored for 4 d; SS (NB), undamaged fruits stored under shaded conditions; SS (B), damaged fruits stored under shaded conditions.

TABLE 3

Effect of Storage Conditions on Oil Palm Fruits and Oil Quality upon Thermal Treatment[a]

	PV (meq/kg)	FFA (%)	$E^{1\%}_{233}$	$E^{1\%}_{269}$	Carotene (ppm)	P (ppm)	Bleachability 5.25-inch cell R	5.25-inch cell Y	1-inch cell R	1-inch cell Y
Fruit condition										
Fresh (F)	0.0	0.31	0.95	0.09	650	5.4	0.4	10	0	1.9
Stored at ambient (A)	0.0	0.40	0.92	0.10	600	6.0	0.4	10	0	1.9
Stored at 5°C (C)	0.7	35.50	0.95	0.24	580	88.8	5.0	54	1.1	9.1
Heated oils										
Fresh (HF)	5.0	0.35	1.65	0.12	395	5.4	1.0	10	0.3	2.1
Stored at ambient (HA)	5.8	0.49	1.50	0.15	380	6.0	1.0	10	0.4	4.0
Stored at 5°C (HC)	1.5	50.80	1.70	0.68	101	88.8	—[b]	—[b]	12.0	14.0

[a]Abbreviations as in Table 1. [b]Oil is not sufficient for color test in 5.25-inch cell.

sample, almost 50% of the oil had been distilled off as free fatty acids in the bleachability test. This amount of oil was not sufficient for a color reading in a 5.25-inch cell. Instead, a color reading in a 1-inch cell indicated a dark-brown oil of 12 R.

Peroxides increased 5-fold when fresh samples were heated. Although peroxides in the HC sample appeared low, the $E^{1\%}_{269}$ showed a higher extent of oxidation. Much of the carotenoids were also destroyed in the HC sample.

Bleachability problems in crude palm oil can also be attributed to oxidation of the oil. In this case, oxidation occurred during storage at 60°C (Table 3). Oxidation of hydrolyzed oils obtained from damaged fruits occurred sooner compared to oils with lower free fatty acids.

DISCUSSION

Our findings show that fruit condition is an important parameter in oil quality. Oils from fruits that are harvested at the correct ripeness period and are undamaged show little deterioration if processed within a few days. Damaged or bruised fruits should be processed immediately for minimum deterioration in oil quality. Over-ripe fruits or loose fruits should also be processed immediately because hydrolysis occurs rapidly in such fruits. Lipase activity in palm fruits increases during ripening (7).

Damage caused by exposing palm fruits to cold was extensive. Because the oil palm is a tropical crop, palm fruits are never subjected to such cold conditions. However, it is an interesting phenomenon, and further investigations may reveal information on fruit keepability and oil bleachability.

High lipase activity in oil palm fruits subjected to cold was reported (8). Phosphorus levels of oil extracted from such fruits were also high. Strong correlations exist between FFA levels and phosphorus and between FFA levels and bleachability of the oil (9). However, no correlation exists between phosphorus and bleachability, indicating that phosphorus compounds are not a cause of bleachability problems; the high free fatty acid content in the oil may have solubilized other polar compounds from the fruits during extraction to cause bleachability problems.

Keepability of fruits is affected by the extent of fruit damage. Thus, bruised fruits resulted in deterioration in bleachability (from 1.1 R to 2.2 R) during storage but did not affect the color if the fruits were processed immediately. Oxidation, which occurs during prolonged heating and storage, further aggravated the problem. Good-quality oils when heated for 2 wk at 60°C showed deterioration of 0.6 R units (Table 3). Hydrolyzed oils are more prone to oxidation, resulting in further deterioration of their bleachability. This could be the result of β-carotene and linoleate being co-oxidized during thermal treatment to form stable yellow pigments (10).

REFERENCES

1. Fraser, M.S. and G. Frankl, *J. Am. Oil Chem. Soc. 58*:926 (1981).
2. Swoboda, P.A.T., *PORIM Bulletin No. 5,* Kuala Lumpur, 1982.
3. Ames, G.R., W.D. Raymond and J.B. Ward, *J. Sci. Food Agric. 11*:194 (1960).
4. *Palm Oil Research Institute of Malaysia Test Methods,* Kuala Lumpur, 1990.
5. Abigor, D.R., F.I. Opute, A.R. Opoku and A.U. Osagie, *J. Sci. Food Agric. 36*:599 (1985).
6. Arumughan, C., C. Mohankumar and R. Kaley Saraj, *Proceedings of the PORIM International Development Conference Module II Agriculture,* Kuala Lumpur, 1989, pp. 92–100.
7. Henderson, J., and J.J. Osborne, *Phytochemistry 30(4)*:1073 (1991).
8. Sambanthamurthi, R., C.L. Chong, K.C. Oo, K.H. Yeo and P. Rajan, *J. of Exp. Bot. 42(242)*:1199 (1991).
9. Gee, P.T., S.H. Goh and S.L. Tong, in *Proceedings of Workshop on Quality in the Palm Oil Industry,* Kuala Lumpur, 1983.
10. Wong, K.C., in *Proceedings of International Developments in Palm Oil,* edited by D.A. Earp and W. Newall, The Incorporated Society of Planters, Kuala Lumpur, 1976.

[Received May 26, 1992; accepted October 6, 1992]