Evaluation of Palm Oil Quality: Correlating Sensory with Chemical Analyses

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Palm oils of various qualities were used in this study. Chemical analyses included determination of free fatty acids, peroxide value and *p*-anisidine value. Sensory evaluations included scoring and descriptive tests. Fresh, crude palm oil of high quality with a maximum score showed a zero peroxide value, a zero *p*-anisidine value and a free fatty acid level of 0.2%. It had a strong, pleasant, sweet caramel-like flavor. The levels of free fatty acids were higher in samples that had been stored for a long time. Their *p*-anisidine values were also higher compared to fresh oils. Flavor intensity of red palm oil did not necessarily indicate quality. Its quality was dependent on the type of flavor, pleasant or otherwise. For refined, bleached and deodorized oil, there was an inverse relationship between flavor intensity and quality with a correlation coefficient of r = −0.87. There was some correlation between overall quality rating by sensory method and quality evaluation by chemical analyses, such as free fatty acids (r = −0.69), peroxide value (r = −0.57) and *p*-anisidine value (r = −0.49).

KEY WORDS: Free fatty acid, palm oil, peroxide value, quality, sensory evaluation.

The acceptability of a fat or oil depends partly on the extent that deterioration has occurred. Common quality deteriorations that may occur to oils and fats are oxidation, hydrolysis, cross contamination between grades of products and contamination with foreign substances (1-3). Some criteria for assessing the extent of deterioration are necessary. Sensory assessment is one of the methods in evaluating quality of oils (4). Although oil quality can be determined by analytical techniques, such as ultraviolet absorption or gas chromatography (3), the extent of chemical changes occurring in oils and fats is usually measured by chemical procedures, such as measurement of peroxide value, *p*-anisidine value and free fatty acids. Quite often, however, oil suppliers are faced with the problem of their oil being rejected based on flavor criteria (off-flavor). Thus, sensory evaluation is important because it is the ultimate test of oil quality. The peroxide value is a common measurement of lipid oxidation; however, it might not serve as a true indicator of the actual state of oxidative rancidity of an oil or fat (5). Good correlation between peroxide values and flavor scores was found (6), but other workers (7) indicated that the peroxide value is not reliable as an index of flavor quality. This paper reports on correlation between quality evaluation of palm oil by chemical analyses and sensory methods.

MATERIALS AND METHODS

Nineteen samples of red palm oil and refined, bleached and deodorized (RBD) palm oils of various qualities were used in the study. They were all commercial samples obtained from different mills and refineries, except samples A and B, which were prepared in the Palm Oil Research Institute of Malaysia's (PORIM) laboratory. The age of the samples ranged from 4 days to 60 months. The samples were stored at different temperatures (10, 15 and 23°C). Information on the oils tested is summarized in Table 1. Specific processing conditions for the commercial samples were not known. However, crude (red) palm oil is normally processed by standard procedures, as shown in Figure 1. Figure 2 shows steps in the physical refining process to obtain RBD palm oil. Sample A was obtained as follows—crude (red) palm oil, 3 kg, was degummed by adding 3 g of phosphoric acid (85% concentration). Degumming was carried out in a glass vessel at 80°C for 15 min. Neutralization was carried out by adding 75 mL of 4 N NaOH and the mixture was stirred continuously for 15 min. The sample was then washed with hot water. The degummed and neutralized red palm oil was deodorized by distillation at a temperature of 160°C and a pressure of 30×10^{-3} torr, to yield a refined red palm oil.

Sample B, which was crude palm oil prepared in the laboratory, was obtained with the following steps. Palm fruits were sterilized in a Mini Sterilizer (Estell Hearson, London, U.K.) at 130°C and pressure of 1.8 psi for 2 hr. After sterilization, the nuts were manually separated from the mesocarp. The oil was extracted from the mesocarp with a hydraulic press (Apex Construction Ltd., London, U.K.) to yield a crude red palm oil.

Chemical analyses. The level of free fatty acids was determined according to AOCS Method Ca-5a-40 (8). Peroxide value was determined according to AOCS Method Cd-8-53 (8). Determination of the *p*-anisidine value

TABLE 1

Sample Identification and Storage Conditions

Sample code	Type of oil	Storage time	Storage temperature
A	Refined (red) palm oil	20 days	23°C
B	Crude (red) palm oil	4 days	23°C
C(REF_1)	Crude (red) palm oil	12 months	10°C
D	Crude (red) palm oil	18 months	23°C
E	Crude (red) palm oil	30 months	23°C
F	Crude (red) palm oil	36 months	23°C
G	Crude (red) palm oil	60 months	23°C
H	RBD palm oil	6 months	23°C
I	RBD palm oil	4 months	23°C
J(REF_2)	RBD palm oil	20 months	10°C
K	RBD palm oil	45 months	23°C
L	RBD palm oil	50 months	23°C
M	RBD palm oil	45 months	10°C
N	RBD palm oil	12 months	10°C
O	RBD palm oil	5 months	15°C
P	RBD palm oil	3 months	23°C
Q	RBD palm oil	18 months	10°C
R	RBD palm oil	24 months	10°C
S	RBD palm oil	50 months	10°C

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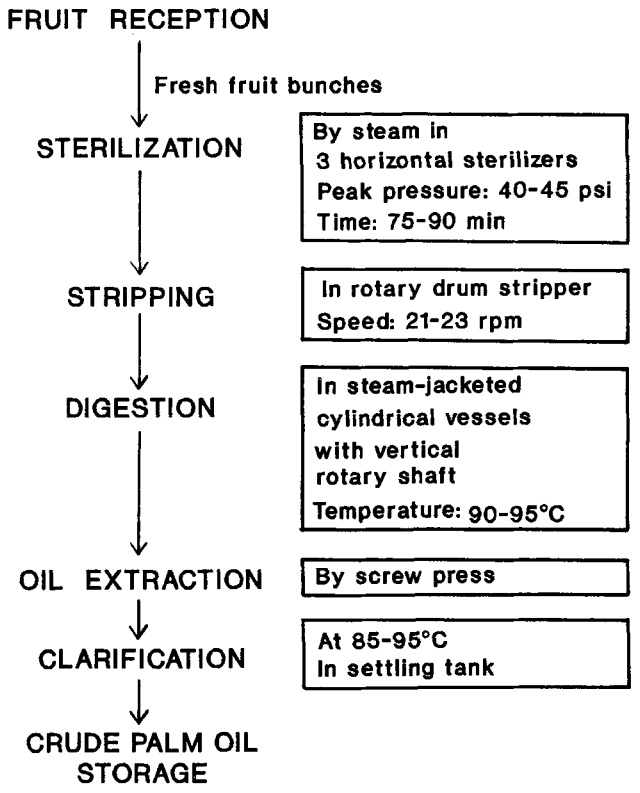

FIG. 1. The process of obtaining crude palm oil.

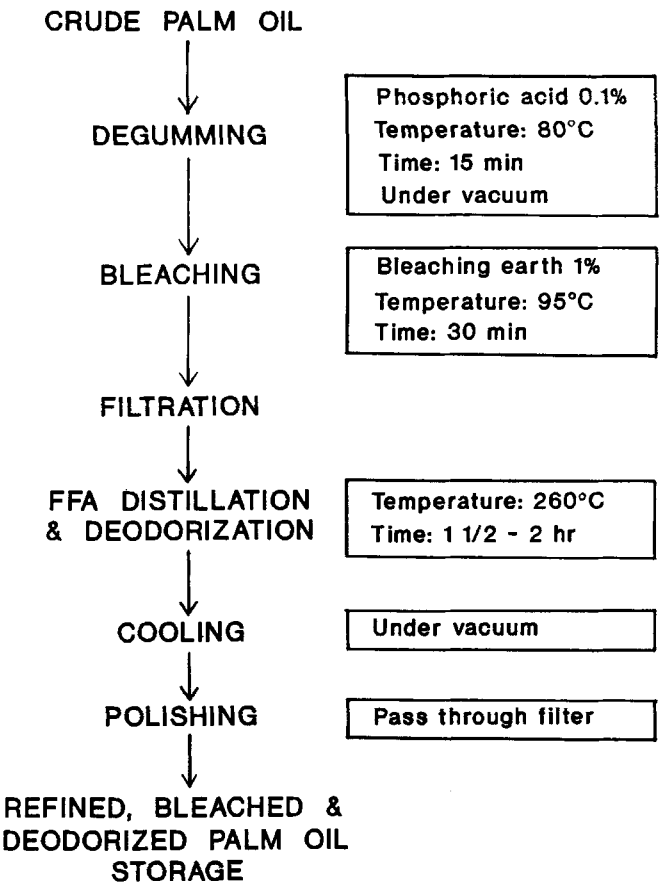

FIG. 2. The physical refining of palm oil.

was carried out by means of IUPAC Method 2.504 (9). Totox value was calculated based on peroxide value and *p*-anisidine value by using the following equation (10):

$$TV = 2\ PV + p\text{-}AV\ TV$$

where TV, totox value; PV, peroxide value; and *p*-AV, *p*-anisidine value.

Sensory evaluation. An analytical sensory test was designed to determine flavor intensity and overall quality of the oil, based on a five-point scoring system.

The sensory test was conducted in an air-conditioned sensory laboratory equipped with 10 individual booths. The lighting system consisted of fluorescent red and blue lights. The red light was used to mask any color difference among samples. A total of 10 trained panelists served as judges. They had been selected based on their ability to discriminate small differences in oil quality (11). Prior to the evaluation, they had undergone 12 training sessions, which had been held with the objective of familiarizing them with various sensory test methods and techniques of evaluating various products, including oils and fats.

Oil samples were melted and 25 mL was transferred into clear, narrow-mouth glass bottles (30 mL capacity) and then covered with screw caps. Three-digit random numbers were used to code each sample. Samples were evaluated in three sets, and panelists evaluated the three sets at three different times. The first set consisted of selected red palm oil, while the second and third sets were comprised of RBD palm oil. A scoring test was used to evaluate flavor intensity and overall quality of the oils. The scores ranged from 1 to 5. For flavor intensity, the scores were: 1, bland; 2, trace; 3, moderate; 4, strong; and 5, extreme. For overall quality, the scores were: 1, very poor; 2, poor; 3, fair; 4, good; and 5, very good. In the first set, a duplicate of sample C was presented as the reference sample (REF_1) with a given flavor intensity rating of 4 and an overall quality rating of 3. In the second and third sets, a duplicate of sample J was presented as the reference sample (REF_2) with given flavor intensity and an overall quality rating of 3. Panelists were asked to sniff and evaluate the flavor intensity and overall quality of the coded (unknown) samples against the reference sample. Lastly, a descriptive test was done by the same panelists on selected samples.

Statistical analysis. The data obtained were subjected to linear and stepwise multiple regression to find the relationship between sensory and chemical analyses.

RESULTS AND DISCUSSION

Table 2 shows results of chemical analyses while Table 3 shows sensory evaluation results of selected red palm oil samples. Sample A was a refined red palm oil that had been treated to reduce its free fatty acids content and other impurities while retaining its carotene content. Sample A was aged for 20 days and had a peroxide value of 0.19. Sample B was fresh crude (red) palm oil and had a

TABLE 2

Free Fatty Acids, Peroxide Value, *p*-Anisidine Value and Totox Value of Selected Red Palm Oil

Sample code	Free fatty acids (%)	Peroxide value	*p*-Anisidine value	Totox value
A	0.13	0.19	0.72	1.10
B	0.20	0.00	0.00	0.00
C	1.38	1.34	0.80	3.48
D	2.50	3.78	1.12	8.68
E	3.37	19.57	4.78	43.96
F	5.02	14.96	7.13	37.05
G	6.90	28.99	8.99	66.97

TABLE 3

Flavor Intensity[a] and Overall Quality[b] Mean (n=10) Scores of Selected Red Palm Oils as Rated by Trained Panels

Sample code	Flavor intensity	Overall quality
A	1.8	4.2
B	3.3	3.8
C (duplicate of "REF_1")	3.2	3.3
D	4.5	1.3
E	4.3	3.1
F	3.9	2.8
G	3.5	2.7

[a]Bland, 1; extreme, 5.

[b]Very poor, 1; very good, 5.

zero peroxide value. Its free fatty acid content was low (0.20%). Since a light deodorization technique (to an iodine value of 53) was applied to sample A, its free fatty acids content was lower (0.13%) than that of sample B. The light deodorization technique resulted in low flavor intensity (mean score = 1.8), and the quality of the oil was rated very good (mean overall quality rating = 4.2). Sensory quality of sample B was very good (mean overall quality score = 3.8). It had a strong, pleasant, sweet caramel-like flavor.

Samples C and E were rated as fair with overall quality scores of 3.3 and 3.1, respectively. Their free fatty acid contents were 1.38 and 3.37%, while peroxide values were 1.34 and 19.57, respectively. These values were higher than those of samples A or B. However, sample D was rated as poor (overall quality score=1.3) even though its free fatty acid content (2.5%) and peroxide value (3.78) were lower than that of sample E. The poor quality of sample D probably was due to the presence of strong metallic and sour flavors. On the other hand, samples F and G had been stored for 36 and 60 months, respectively, and developed grassy flavor (sample F) and rancid flavor (sample G) with high free fatty acids content, and high peroxide, *p*-anisidine and totox values.

Sensory analyses indicated that samples H, I, N, O and P were good-quality RBD oils with mean flavor intensity scores ranging from 1.6 to 2.9, and mean overall quality ratings ranging from 3.6 to 4.4 (Table 4). Free fatty acid contents ranged from 0.06 to 0.10%, while peroxide values ranged from 0.78 to 2.13 (Table 5). *p*-Anisidine values of the samples ranged from 1.51 to 2.23, while their totox values ranged from 3.48 to 6.49. Samples J, Q and R were

TABLE 4

Flavor Intensity and Overall Quality Mean (n=10) Scores of Selected Palm Oils as Rated by the Trained Panels[a]

Sample code	Flavor intensity	Overall quality
H	2.1	3.6
I	2.2	3.8
J (duplicate of "REF_2")	2.9	3.5
K	3.2	2.3
L	3.9	2.5
M	3.7	2.5
N	2.9	3.6
O	2.3	3.7
P	1.6	4.4
Q	3.5	2.4
R	2.6	3.9
S	3.4	2.1

[a]Ratings as in Table 3.

TABLE 5

Free Fatty Acids, Peroxide Value, *p*-Anisidine Value and Totox Value of Selected RBD Palm Oils

Sample code	Free fatty acids (%)	Peroxide value	*p*-Anisidine value	Totox value
H	0.07	0.78	1.92	3.48
I	0.06	1.00	1.51	3.51
J	0.07	5.79	2.02	13.60
K	0.16	20.54	3.74	44.82
L	0.31	45.90	5.65	97.45
M	0.41	3.39	1.04	7.82
N	0.09	2.13	2.23	6.49
O	0.10	1.54	2.12	5.20
P	0.06	1.80	1.60	5.20
Q	0.34	3.84	2.64	10.32
R	0.32	5.98	2.56	14.52
S	0.58	7.10	2.86	17.06

of fair quality with mean flavor intensity scores of 2.9, 3.5 and 2.6, respectively. Their mean overall quality ratings were 3.5, 2.4 and 3.9. Sample J had lower free fatty acid content but slightly higher peroxide and *p*-anisidine values than sample Q (Table 5). Refined, bleached and deodorized palm oil samples K and L, which had been stored at 23°C for 45 and 50 months, respectively, showed higher peroxide and *p*-anisidine values and, consequently, higher totox values as compared to other RBD palm oils that were stored for a shorter period of time and at a lower temperature. It is likely that quality deterioration had occurred during the 45–50 months of storage at 23°C, resulting in formation of a strong, rancid flavor. These samples received quality ratings of 2.1 to 2.3, which designates poor quality.

Descriptive test. Refined red palm oil was bland and, upon storage, trace flavor developed. Fresh crude palm oil had a sweet, pleasant, caramel-like flavor. Regular crude palm oil was described as being carrotty, sourish and fruity. Upon storage (at 23°C for 18 months) the sample developed a metallic flavor and became more sour (Table 6). Fresh RBD palm oil had a bland flavor. Upon storage at room temperature (23°C) for three months, trace flavor developed. Samples kept in the cold room (10°C) could

TABLE 6

Reference Standards of Palm Oil Quality

Type	Sample	Descriptor	Quality
Refined	Refined red palm oil (stored at 23°C for 20 days)	Bland	Very good
Crude	Fresh crude red palm oil	Sweet, pleasant, caramel-like flavor	Excellent
	Crude red palm oil (stored at 10°C for 12 months)	Carrotty, sourish, fruity	Good
	Crude red palm oil (stored at 23°C for 18 months)	Metallic flavor, sourish	Poor
RBD	Fresh RBD palm oil	Bland	Very good
	RBD palm oil (stored at 10°C for 24 months)	Cucumber flavor, grassy flavor	Fair

maintain the bland flavor for a period of one year. However, upon longer storage, there were developments of cucumber and grassy flavors.

Correlations between sensory scores and chemical analyses. There seems to be an inverse linear relationship between quality evaluation by sensory panels and free fatty acid content obtained by chemical analysis. The correlation was better in the case of red palm oils ($r = -0.80$) than for RBD palm oils ($r = -0.69$). The linear regression equation for predicting quality score of red palm oil was $y = 4.34 - 0.53x$, where y is the predicted quality score and x is the free fatty acid content. The linear regression equation for predicting quality score of RBD palm oil was $y = 4.41 - 4.57x$. It should be noted that RBD palm oil contained much less free fatty acid than red palm oil, because the free fatty acids were removed during the refining and deodorization processes.

Flavor intensity scores were inversely related to quality scores ($r = -0.73$ for red palm oil, significant at $P < 0.10$; $r = -0.92$ for RBD palm oil, significant at $P < 0.01$). For red palm oil, flavor intensity did not necessarily indicate quality. However, the type of flavor in the red oil had an influence on its quality rating. On the other hand, for RBD palm oil, flavor intensity significantly influenced its quality. A slightly better correlation was found between flavor intensity scores and free fatty acid content of RBD palm oils ($r = 0.61$, significant at $P < 0.05$) than for red palm oils ($r = 0.58$).

In the case of red palm oils, there were significant correlations ($P < 0.10$) between chemical parameters (peroxide, *p*-anisidine and totox values) and quality scores by sensory method. Correlation coefficients between sensory quality scores and the three chemical parameters, namely peroxide value, *p*-anisidine value and totox value, were significant at $P < 0.10$ in RBD palm oil ($r = -0.57$, $r = -0.54$ and $r = -0.50$, respectively). However, these values were lower compared to correlation coefficients of $r = -0.61$, $r = -0.61$ and $r = -0.53$, respectively, for red palm oils. On the other hand, slightly better correlations were found between the three chemical parameters and flavor intensity scores in RBD palm oils ($r = 0.51$, $r = 0.60$, significant at $P < 0.05$; and $r = 0.52$, respectively) as compared with those of red palm oils ($r = 0.50$, $r = 0.47$ and $r = 0.50$g, respectively).

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