An Assessment of the Iron and Free Fatty Acid Content of Production Oil from Various Palm Oil Mills

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RINGKASAN

Satu kajian dijalankan di lima buah kilang minyak sawit. Hasil kajian menunjukkan bahawa Kilang A dan B berupaya menghasilkan minyak dengan kandungan ferum yang rendah walaupun minyak tidak ***disalurkan melalui perangkap magnet. Kilang C, yang sebahagian jenteranya diperbuat daripada keluli tahan karat, juga berupaya menghasilkan minyak sawit dengan kandungan ferum yang rendah. Kilang D*** *dan E menghasilkan minyak dengan kandungan ferum yang tinggi dan tidak sekata.*

Didapati bahawa tiada kaitan konsisten di antara kandungan ferum dan asid lemak bebas dalam minyak sawit mentah.

INTRODUCTION

Iron is an important parameter to monitor because its presence is known to affect the oxidative and bleachability of crude palm oil (Ab. Gapor & Ong, 1982). Although the natural iron content of crude palm oil ranges from 0.5 - 1 ppm the crude oil received by the Malaysian refineries ranges from 1.2 - 9.8 ppm (Chong & Gapor, 1983). Thus, from this observation, it can only be deduced that the extra iron content is picked up along the way either during the harvesting process, transportation or in the mill itself during processing or storage.

A number of mills have taken measures to reduce the iron content by installing magnetic traps in the oil to the storage pipeline, while stainless steel piping, pumps or other machinery are slowly being incorporated in the mills to prevent iron contamination during processing. Efforts are also being made to avoid bruising of the fruits as this causes an increase in the free fatty acid which indirectly may solubilize some of the iron from the machinery in the mill. Some of the other precautions taken to suppress the oxidative effects of iron or other metals are the coating of storage tanks and the adding of anti-oxidants. Finally, bad practises such as mixing of production oil with sludge oil should be strictly discouraged.

Although iron appears to be a very important parameter from the qualitative aspect it is seldom routinely monitored. This may be due to the fact that the test involves expensive instruments such as the ultraviolet or the atomic absorption spectrophotometer. Some of the mills under big corporations occasionally measure the iron content but this practice tends to be completely neglected by the individual private millers. Another reason could be attributed to the fact that unlike free fatty acid and other parameters, the iron content is not a contractual specification.

In view of the importance of iron in crude palm oil, a study was proposed to determine the effectiveness of the current technology introduced in some mills to reduce this contaminant as compared to the conventional mills.

METHODOLOGY

Five mills A,B,C,D and E were selected for the study. Mills A and B have magnetic traps installed while the majority of Mill C oil processing machineries and oil piping are made from stainless steel. Mills D and E, with no known special precautions taken to avoid iron contamination, were also selected for comparison purposes.

An intensive sampling of the production oil was carried out at the start of the morning shift until evening when at least seven samples had been collected for the day. Approximately 200 ml of crude palm oil pumped in to the storage tank were collected at fifteen minutes interval. The hourly composite sample was then analysed for its total iron, filtrable iron and free fatty acid content based on PORIM's test methods (1986).

The total iron is taken as the iron content of the sample as collected while filtrable iron is the iron determined from the filtrate after the crude palm oil has been filtered through a Whatman 4 filter paper in an oven at 60° C. The filter paper is able to retain coarse and gelatinous precipitate.

Sampling was carried out every three months for a day for a year.

RESULTS AND DISCUSSION

The results from the four rounds of crude oil collected before and after the magnetic traps from Mill A indicated no reduction in the total or filtrable iron content (*Table 1*). In fact there seemed to be a slight increase in the iron content in most of the samples.

Samples of oil collected from Mill B before and after it passed through the magnetic trap indicated a minimal reduction of iron after having passed through the magnetic trap (*Table 2*).

The overall data of Mills A and B indicated that magnetic traps are not very effective in reducing either the total or filtrable iron present in crude palm oil. The magnetic traps may not be effective if the initial total iron content is very low.

In the mills, separators are used to separate the crude oil from the slurry of water and solids. The high centrifugal force would have effectively separated any particulates that are more dense than the crude palm oil. Theoretically, the magnetic trap is only effective for trapping particulate iron. If the iron was in a soluble or compounded form it is doubtful whether the magnetic trap would be effective in reducing these components.

The crude oil from Mill C has an iron content ranging from 1.5 - 4.5 ppm (*Table 3*). The installation of the stainless steel tanks, piping and certain machinery in Mill C are not devices designed to remove the iron content in the oil but rather as a preventive measure to avoid iron pick-up during the process. It is doubtful that with such a short residence time in the tanks or piping that a significant amount of iron could possibly be picked up by the crude palm oil. The wear and tear of the process machinery, which is caused by the abrasive action of the sand and fibre, could possibly result in a high iron content being present in the crude palm oil while in storage (Bek-Nielsen, 1987). However, the weight of iron present in the crude palm oil while in storage is minimal when compared with the total weight of iron lost by the processing machinery. Possibly a large proportion of this iron finds its way into the sludge discharge. Figures as high as 1757 ppm iron on dried basis have been recorded (Yeong, 1982). Oil from Mill D was found to contain iron content ranging from 3.5 - 9.3 ppm (*Table 4*). Mill E produces oil with the greatest range of iron content ranging from 3.2 to 10.4 ppm (*Table 5*).

TABLE 1. FREE FATTY ACID AND IRON CONTENT OF CRUDE PALM OIL FROM MILL A

ROUND 1

Sample (hourly)	Free Fatty Acid (%)	Iron (ppm) Before Trap Total	Before Trap Filtrable	After Trap Total	After Trap Fitrable
1	1.17	1.2	1.1	1.3	1.2
2	1.31	1.3	0.9	1.8	1.1
3	1.22	1.5	1.1	1.2	1.1
4	1.13	1.0	1.1	1.4	1.4
5	1.10	1.4	1.0	1.0	1.0
6	1.05	1.4	1.0	1.3	1.0
7	0.96	1.0	1.0	1.5	1.1
8	0.99	1.0	0.9	0.9	0.8
9	0.96	1.5	1.3	1.3	1.1
Mean	1.10	1.3	1.0	1.3	1.1
S.D.	0.11	0.21	0.12	0.26	0.16
C.V. (%)	10.43	16.89	11.83	20.35	14.84

ROUND 2

Sample (hourly)	Free Fatty Acid (%)	Iron (ppm) Before Trap Total	Before Trap Filtrable	After Trap Total	After Trap Filtrable
1	1.22	1.8	0.5	2.5	1.5
2	1.23	2.7	1.0	2.6	0.6
3	1.35	2.2	1.0	2.3	0.8
4	1.43	1.8	1.0	2.7	0.7
5	1.42	2.2	1.0	2.6	0.7
6	1.51	1.4	0.8	2.4	1.3
7	1.58	2.0	1.0	2.2	0.7
8	1.06	1.2	0.5	1.5	0.6
9	1.04	1.6	1.1	1.8	0.8
10	1.03	1.4	1.5	2.1	0.5
Mean	1.28	1.8	0.9	2.3	0.8
S.D.	0.20	0.46	0.29	0.38	0.32
C.V. (%)	15.63	24.9	30.9	16.87	39.33

ROUND 3

Sample (hourly)	Free Fatty Acid (%) Before Trap	Iron (ppm) Before Trap Total	Iron (ppm) Before Trap Filtrable	Iron (ppm) After Trap Total	Iron (ppm) After Trap Filtrable
1	1.25	2.2	1.3	2.4	1.6
2	1.25	2.2	1.0	2.3	1.6
3	1.26	2.2	1.2	2.2	1.2
4	1.24	2.0	1.0	2.2	1.4
5	1.25	1.7	1.0	1.8	1.2
6	1.27	1.5	1.0	1.8	1.0
7	1.28	1.5	1.0	1.9	1.2
8	1.23	1.5	1.0	1.6	1.0
9	1.41	1.5	1.0	1.7	1.2
10	1.35	1.6	1.1	2.0	1.2
Mean	1.28	1.8	1.1	2.0	1.3
S.D.	0.06	0.35	0.10	0.27	0.21
C.V. (%)	4.45	19.58	10.14	13.7	16.5

ROUND 4

Sample (hourly)	Free Fatty Acid (%) Before Trap	Iron (ppm) Before Trap Total	Iron (ppm) Before Trap Filtrable	Iron (ppm) After trap Total	Iron (ppm) After trap Filtrable
1	1.93	3.4	2.1	3.8	2.7
2	1.83	4.0	1.9	3.8	2.7
3	1.39	2.6	1.6	2.9	1.8
4	1.36	2.5	1.6	2.9	1.9
5	1.53	2.6	1.3	2.8	1.8
6	1.37	2.3	0.9	2.5	1.7
7	1.28	2.5	1.3	2.8	1.2
8	1.08	3.4	1.2	3.0	1.2
9	0.94	1.9	1.2	1.8	1.3
10	1.16	1.8	1.0	1.9	1.4
Mean	1.39	2.7	1.4	2.8	1.8
S.D.	0.31	0.69	0.38	0.66	0.55
C.V.(%)	22.41	25.83	27.25	23.51	31.07

TABLE 2. FREE FATTY ACID AND IRON CONTENT OF CRUDE PALM OIL FROM MILL B

ROUND 1

Sample (hourly)	Free Fatty Acid (%)	Iron (ppm) Before Trap Total	Iron (ppm) Before Trap Filtrable	Iron (ppm) After Trap Total	Iron (ppm) After Trap Filtrable
1	3.14	3.2	1.4	2.3	1.3
2	2.73	2.2	1.3	2.0	1.4
3	2.79	4.0	1.2	2.3	1.1
4	2.51	3.0	1.1	1.9	1.5
5	2.08	2.4	1.1	2.0	1.4
6	2.45	3.0	1.2	2.0	1.3
7	2.54	2.4	1.2	2.2	1.5
Mean	2.61	2.9	1.2	2.1	1.4
S.D.	0.33	0.62	0.11	0.16	0.14
C.V. (%)	21.62	21.49	8.80	7.78	10.30

ROUND 2

Sample (hourly)	Free Fatty Acid (%)	Iron (ppm) Before Trap Total	Iron (ppm) Before Trap Filtrable	Iron (ppm) After Trap Total	Iron (ppm) After Trap Fitrable
1	2.60	3.5	2.7	2.8	2.0
2	2.39	3.1	1.7	3.3	1.6
3	2.34	3.0	2.8	2.8	2.0
4	1.78	2.6	2.4	2.9	1.6
5	1.85	2.5	2.0	2.5	1.9
6	1.91	2.2	2.3	2.2	1.9
7	2.51	2.0	1.5	1.8	1.7
8	2.53	2.5	2.0	2.6	2.0
Mean	2.24	2.7	2.2	2.6	1.8
S.D.	0.33	0.49	0.46	0.46	0.18
C.V. (%)	14.03	8.50	21.11	17.53	9.62

ROUND 3

Sample (hourly)	Free Fatty Acid (%)	Iron (ppm)			
		Before Trap		After Trap	
		Total	Filtrable	Total	Filtrable
1	2.15	4.0	2.5	2.0	1.0
2	1.95	2.2	1.7	2.0	1.0
3	1.92	2.1	1.0	2.2	1.1
4	1.85	2.0	1.1	2.2	1.2
5	1.86	1.7	1.0	1.7	1.1
6	1.93	2.0	1.1	1.9	1.1
7	2.09	2.2	1.1	2.0	1.2
8	1.97	2.2	1.0	2.0	1.2
Mean	1.96	2.3	1.3	2.0	1.1
S.D.	0.10	0.71	0.53	0.16	0.07
C.V. (%)	5.29	30.7	40.6	8.02	6.29

ROUND 4

Sample (hourly)	Free Fatty Acid (%)	Iron (ppm)			
		Before Trap		After Trap	
		Total	Filtrable	Total	Filtrable
1	2.39	2.9	1.3	2.3	1.3
2	2.74	2.4	1.3	2.0	1.1
3	2.28	2.4	1.2	2.0	0.8
4	2.20	2.4	1.3	2.2	1.2
5	1.87	2.9	1.0	2.4	1.9
6	1.88	2.0	1.3	2.1	1.2
7	2.11	2.2	1.3	2.0	1.1
8	2.04	2.8	1.6	1.9	1.0
9	2.76	3.8	1.7	1.8	0.8
10	2.72	2.6	1.4	1.9	0.7
Mean	2.29	2.6	1.3	2.1	1.1
S.D.	0.34	0.50	0.19	0.18	0.34
C.V. (%)	14.96	19.08	14.58	9.21	30.63

TABLE 3. FREE FATTY ACID AND IRON CONTENT OF CRUDE PALM OIL FROM MILL C

ROUND 1

Sample (hourly)	Free Fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	3.09	2.0	1.0
2	2.84	2.0	1.0
3	2.71	1.6	1.0
4	2.48	2.8	1.0
5	2.45	1.5	1.0
6	2.68	3.5	1.0
7	2.68	3.0	1.0
8	2.52	3.0	1.3
Mean	2.4	2.5	1.04
S.D.	0.74	0.69	0.10
C.V. (%)	8.09	28.63	9.56

ROUND 2

Sample (hourly)	Free Fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	2.49	2.5	2.3
2	2.49	2.8	2.1
3	2.14	2.0	0.8
4	2.25	2.2	1.6
5	2.19	2.0	0.7
6	2.14	2.4	2.2
7	2.39	2.2	2.0
8	3.01	2.8	2.6
9	2.91	3.0	1.8
10	2.73	2.6	1.9
Mean	2.5	2.45	1.8
S.D.	0.35	0.33	0.57
C.V. (%)	12.81	13.57	32.58

ROUND 3

Sample (hourly)	Free Fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	2.19	2.0	1.0
2	2.33	1.7	0.6
3	2.44	2.2	1.1
4	2.42	2.1	1.1
5	2.41	1.8	1.2
6	2.22	2.0	1.2
7	2.25	2.3	1.2
8	2.02	1.8	1.0
9	1.94	1.8	1.0
10	2.05	1.7	0.8
Mean	2.23	1.9	1.0
S.D.	0.18	0.21	0.19
C.V. (%)	7.98	10.92	18.94

ROUND 4

Sample (hourly)	Free Fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	1.70	4.3	1.8
2	1.59	4.5	1.9
3	1.73	3.4	1.1
4	1.80	2.8	1.9
5	1.93	3.0	1.2
6	1.84	2.5	1.4
7	1.80	2.6	1.0
8	1.81	3.2	2.2
9	1.79	2.7	1.0
10	1.74	2.7	1.1
Mean	1.77	3.2	1.5
S.D.	0.09	0.70	0.43
C.V. (%)	5.11	22.3	29.31

TABLE 4. FREE FATTY ACID AND IRON CONTENT PALM OIL FROM MILL D

ROUND 1

Sample (hourly)	Free Fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	5.11	6.1	3.8
2	5.33	6.4	2.6
3	5.41	8.5	2.8
4	5.64	6.0	2.6
5	5.03	5.0	4.3
6	4.78	5.5	4.5
7	4.56	5.2	5.0
8	4.59	6.6	4.8
9	4.42	5.1	4.3
10	4.38	6.6	3.5
Mean	4.93	6.1	3.8
S.D.	0.44	1.10	0.91
C.V. (%)	9.02	18.08	23.20

ROUND 2

Sample (hourly)	Free Fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	3.19	4.4	4.1
2	3.36	6.7	4.4
3	3.29	6.4	4.6
4	3.28	6.4	5.2
5	2.89	6.5	5.2
6	3.43	6.7	5.4
7	3.13	6.6	5.2
8	3.21	5.4	4.7
9	2.82	5.9	4.5
10	3.46	5.5	4.7
Mean	3.21	6.1	4.8
S.D.	0.21	0.75	0.42
C.V. (%)	6.62	12.39	8.89

ROUND 3

Sample (hourly)	Free Fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	3.25	6.0	4.5
2	3.35	6.8	4.4
3	3.30	5.2	3.7
4	3.27	5.8	3.5
5	3.01	5.6	3.5
6	2.91	4.8	2.6
7	2.58	5.0	2.6
8	2.80	3.7	2.7
9	2.77	3.5	2.8
10	2.66	4.2	3.0
Mean	2.98	5.1	3.3
S.D.	0.28	1.04	0.71
C.V. (%)	9.55	20.69	21.38

ROUND 4

Sample (hourly)	Free Fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	2.91	7.1	6.0
2	2.87	7.0	6.5
3	2.94	7.1	6.2
4	3.02	8.2	8.0
5	3.32	7.0	6.6
6	3.32	9.0	7.9
7	3.19	9.3	8.2
8	3.37	9.2	8.1
Mean	3.12	7.8	7.2
S.D.	0.20	1.03	0.94
C.V. (%)	6.60	15.14	13.12

TABLE 5. FREE FATTY ACID AND IRON CONTENT OF CRUDE PALM OIL FROM MILL E

ROUND 1

Sample (hourly)	Free Fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	4.03	6.4	5.0
2	3.98	7.0	5.9
3	4.05	7.0	6.0
4	3.99	7.2	6.0
5	4.23	8.0	5.0
6	4.23	7.4	5.2
7	4.91	8.5	6.5
8	5.08	8.0	7.5
Mean	4.20	7.4	5.9
S.D.	0.33	0.68	0.85
C.V. (%)	7.83	9.20	14.42

ROUND 2

Sample (hourly)	Free fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	4.63	9.1	4.0
2	4.59	8.8	7.0
3	4.55	10.4	7.7
4	4.49	9.0	7.4
5	4.38	10.1	6.4
6	4.39	4.0	4.4
7	4.12	6.2	4.1
8	4.09	6.1	4.1
9	4.28	4.4	4.3
Mean	4.08	7.6	5.5
S.D.	1.13	2.29	1.5
C.V. (%)	27.7	30.25	27.42

ROUND 3

Sample (hourly)	Free Fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	2.19	3.3	2.4
2	2.61	3.8	3.3
3	2.28	3.6	3.2
4	2.72	3.7	2.4
5	2.22	4.0	3.4
6	2.59	3.8	2.4
7	2.54	3.8	2.6
8	2.41	3.8	2.7
9	2.44	3.2	2.5
10	2.35	3.4	3.2
Mean	2.44	3.6	2.8
S.D.	0.18	0.26	0.39
C.V. (%)	7.31	6.75	14.01

ROUND 4

Sample (hourly)	Free Fatty acid (%)	Iron (ppm)	
		Total	Filtrable
1	2.67	9.5	7.4
2	2.81	8.7	5.1
3	3.25	8.4	5.4
4	3.11	9.5	7.2
5	4.13	8.4	7.9
6	2.21	6.7	5.9
7	3.15	6.6	5.4
8	3.06	7.6	5.2
9	2.70	7.4	5.5
10	2.70	7.4	5.5
Mean	2.98	8.1	6.1
S.D.	0.51	1.03	1.03
C.V. (%)	17.0	12.74	17.01

TABLE 6. CORRELATION COEFFICIENT (R) BETWEEN DIFFERENT PARAMETERS

Mill	Parameter	Total iron vs Free Fatty Acid	Filtrable Iron vs Free Fatty Acid	Total Iron vs Filtrable Iron
A	Round I	0.43ns	0.35ns	0.52ns
	Round II	0.63ns*	0.26ns	0.26ns
	Round III	0.32ns	0.17ns	0.86**
	Round IV	0.85**	0.90***	0.78**
	Overall	0.65***	0.68***	0.66***
B	Round I	0.66*	0.40ns	0.58ns
	Round II	0.00ns	0.26ns	0.17ns
	Round III	0.00ns	0.24ns	0.37ns
	Round IV	0.54ns	0.62ns	0.88***
	Overall	0.23ns	0.04ns	0.35*
C	Round I	0.2ns	0.26ns	0.32ns
	Round II	0.84*	0.57ns	0.69ns
	Round III	0.66*	0.24ns	0.66*
	Round IV	0.73*	0.28ns	0.52ns
	Overall	1.51***	0.08ns	0.26ns
D	Round I	0.79*	0.55*	0.47*
	Round II	0.26ns	0.31ns	0.73*
	Round III	0.26ns	0.13ns	0.33ns
	Round IV	0.07**	0.19ns	0.58ns
	Overall	0.53***	0.46**	0.04ns
E	Round I	0.37ns	0.75**	0.57*
	Round II	0.00ns	0.0ns	0.66*
	Round III	0.22ns	0.85**	0.81**
	Round IV	0.64ns	0.62ns	0.94***
	Overall	0.46**	0.55***	0.63***

Correlation pooled over 4 rounds of samples adjusted for individual round effect

*** for statistical significance at 0.1%
** for statistical significance at 1 %
* for statistical significance at 5%-10%

The different levels of iron content found in these mills could possibly be explained by their location and sources of fresh fruit bunches. Mill A, B, C and D process fruits from their own neighbouring estates while Mill E, being a private miller, purchases fruits from many variable sources. The soil around Mills A and B are known to be alluvial soil while the soil around Mill C is a mixture of alluvial and peat. The region around Mill D contains laterite soil which has a high iron content which possibly explains its highly variable and high iron content of the oil although it processes only fruits from its own estates. The varied fresh fruit bunches processed by Mill E possibly explains its highly variable iron content.

Mill A was able to produce oil of the lowest free fatty acid of 1.26% while Mill B and C produced oil of 2.28% and 2.23% free fatty acid respectively. Similar to the trend in iron content, Mill D and E produced oil of higher free fatty acid that is greater than 3%

Linear regression statistical analysis indicated that there was no consistent correlation between the amount of free fatty acid versus the total or filtrable iron content in the crude palm oil (*Table 6*). It was also found that there were no consistent correlation between the amount of total and filtrable iron in the crude palm oil. The data merely indicated that there are at least two unrelated classes of iron compounds in the oil as defined by the experimental method, that is, one class is soluble in oil at 60°C and thus filtrable through a Whatman 4 filter paper while the remainder is infiltrable.

CONCLUSION

Mills A and B produced crude palm oil of low iron content before it passed through the magnetic trap and therefore magnetic traps appear to be ineffective in reducing the iron content of oils of low iron content. Although Mill C had certain machineries and pipes made of stainless steel the iron content of the oil produced was not as low as that from Mill A. Mills D and E tend to produce crude oil containing higher iron and free fatty acid when compared with the other three mills.

The iron content of the crude oil from each mill was found to be quite consistent within the day of processing but it varied from day to day and from mill to mill. This variability could possibly be due to the quality or sources of the fruits delivered to the mill.

From the study made at Mill A it would appear that to produce oil of low iron content and free fatty acid it is essential to have short harvesting rounds, effective handling of the fresh fruit bunches to avoid damage and/or bruising of the fruits and to process with the minimum delay.

Further studies are needed to determine the nature of iron in palm oil in order to further plan any useful experiments regarding the exact role of the metal in relation to processing or to the quality of oil.

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