Original Article

Palm oil and palm olein frying applications

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Several million tonnes of palm oil and palm olein are used annually in the world for frying. This paper will discuss their frying performances in three major applications - industrial production of potato chips/crisps, industrial production of pre-fried frozen French fries and in fast food outlets. In the first study, about four tonnes of potato chips were continuously fried 8 hours a day and five days a week. The palm olein used (with proper management) performed well and was still in excellent condition and usable at the end of the trial. This was reflected in its low free fatty acid (FFA) content of around 0.23%, peroxide value of 4 meq/kg, anisidine value of 16, low polar and polymer contents of 10% and 2%, respectively, induction period (OSI) of 21 hours and high content of tocopehrols and tocotrienols of 530 ppm even after >1900 hours. In the second study in which an average 12 tonnes pre-fried frozen French fries were continuously fried a day for 5 days a week, palm oil performed excellently as reflected by its low FFA of 0.34%, food oil sensor reading of 1.1, low polar and polymer contents of 17% and 2.8%, respectively, over the 12 days of trial. In the third study in which palm shortening, palm oil and palm olein were simultaneously used to intermittently fry chicken parts in the laboratory simulating the conditions in fast food outlets, the three frying oils also performed very satisfactorily as reflected by their reasonably low FFA of <1%, smoke points of >180ºC, and polar and polymer contents of <25% and <6%, respectively, after 5 days of consecutive frying. All the quality indicators did not exceed the maximum discard points for frying oils/fats in the three applications, while the fried food product was well accepted by the in-house train sensory panel using a-nine point hedonic score.

Key Words: palm oil, palm olein, industrial frying, batch frying

Introduction

Since making inroads into the world market in the early 1980's, palm oil and palm olein have been increasingly used in frying due to their techno-economic advantages over other oils/fats. It is estimated that several million tonnes of palm oil/palm olein, in their natural forms, in blends with other oils or after specific processing, are used annually for domestic and commercial frying.

Frito Lay, the world's largest snack food company, have, over the years used more than 90,000 tons of palm olein annually in their operations outside the USA.[1] It was estimated that in 2000 the EU used 170,000 tonnes of frying fats, which included palm oil, for production of 3.32 million tonnes of frozen French fries.[2] There are 600 instant noodle factories of all sizes in China consuming about one million tonnes of palm oil/palm olein a year.[3] In the fast food sector, Malaysia, starting from way back in 1978/79, has convinced all the familiar giant fast food companies, like A & W, McDonalds and KFC, to switch to palm oil products as their frying media.[4] There are now close to 1,000 fast food outlets in Malaysia and Singapore using 40,000 tonnes of palm olein and shortenings a year.[5]

The fast food outlets in Indonesia, Thailand, Hong Kong, Philippines, India, etc. also use large quantities of palm oil products. In future, more palm oil products are expected to be used by the fast food outlets because of economic liberalization, especially in the ex-communist bloc countries, change in lifestyle and the more affluent society. The frying performance of palm oil products in the three major frying sectors - industrial frying of potato chips/crisps, industrial frying of pre-fried frozen French fries and batch frying in fast food outlets - will be discussed.

Study I: Industrial frying of potato chips using palm olein

This study was carried out in collaboration with a local potato chip production plant. The main objective was to establish a proper oil management system so that the PV of palm olein can be maintained at ~4 units for the longest use of the oil.[6] The plant is equipped with modern A – Z units processing as shown in Figure 1. Its large fryer holding ~2,000 litres oil can fry four tonnes of potato chips every eight hours. Raw potatoes (Atlantic variety with specific gravity of 1.080) were automatically washed, peeled, sliced into wavy chips and rewashed. After passing the inspection conveyor, the chips were dropped into the hot oil at 180ºC. The frying was continuous for 8 hours a day. The fried chips were then seasoned and packed in another continuous operation. During the frying, the oil was continuously being filtered and recycled back to the fryer and the losses (mainly from absorption by the chips) automatically made up with fresh oil from a storage tank. As a maximum 0.5% FFA is

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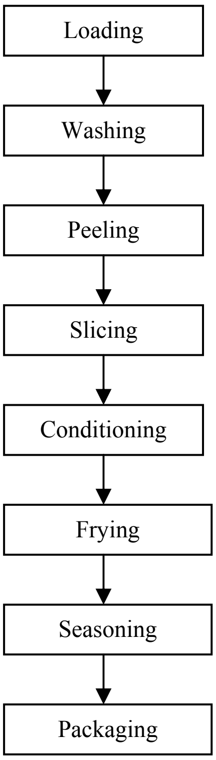


Figure 1. Flow chart of Industrial production of potato chips.

Table 1. Conditions in industrial frying of potato chips

Temperature	180 ± 2ºC
Time	2 minutes
Frying Interval	Continuous
Filtration	Continuous
Replenishment	Continuous
Fryer Capacity	2,000 liters
Oil Consumption	1,600 – 1,800 liters/day
Oil Turnover Time	8 hours (typical)
Heating Method	Indirect (heat-exchanger)
Production of Potato Chips	4 tonnes / 8 hours/day
Bench-Mark to Stop Frying	Maximum 0.5% FFA
Duration of Study	1900 hrs (in 48 weeks)

normally the point of total discard of the oil, the frying would have been stopped if the FFA reached the level.

The processing conditions are given in Table 1. At the end of every frying session, the oil was filtered and stored overnight in the used oil tank, and pumped back into the fryer the next day. About 500g of fresh oil were sampled (in duplicate). Daily, the used oil was also sampled (in duplicate) from the fryer (immediately after filtration), put in amber bottles, sparged with nitrogen and stored at -20ºC for subsequent analysis. The analyses for the key quality parameters were done by the Malaysian Palm Oil Board (MPOB) and AOCS official methods.

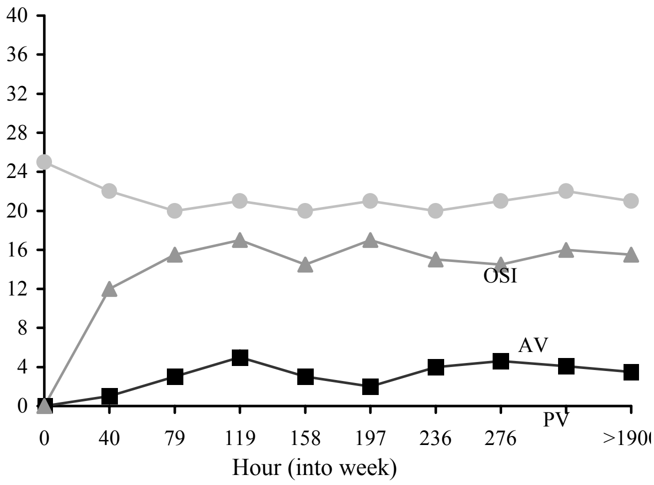
Results and Discussion

Table 2 show the characteristics of the palm olein, including its major fatty acids, used in the experiment. It was of very high quality as per its low PV, AV, Totox, FFA content and high smoke point, long induction period and very high content of total tocopherols. The changes in its key quality parameters from 0 hour to 40 hours (Week 1), 316 hours (Week 8) and >1900 hours (Week 48) are given in Table 3 and Figure 2. Table 3 shows that the FFA increased moderately from 0.04 to 0.21% in the first week. But, thereafter, to 316 hours and then >1900 hours, it only further increased marginally to 0.20% and 0.24%. This meant that an equilibrium had been reached with the higher FFA oil taken up by the fried chips and lost being replaced by the lower FFA fresh oil added. In other words, the palm olein was continuously being re-conditioned. However, a recent study[7] in which an equally good quality palm olein fortified with 46 ppm TBHQ and used for industrial frying of potato chips, showed a different result. The initial FFA content of 0.03% rose sharply to 0.41% in 30.5 hours when the frying was stopped. This difference could be, *inter alia*, due the fact that the replenishment was with a used palm olein of 0.31% FFA (leftover from the previous week's frying) and that the plant did not have a filtering unit. It is known that oil oxidation is auto-catalytic, and an oxidized oil will promote the oxidation of fresh oil.

Table 2. Characteristics of fresh palm olein used in industrial frying of potato chips.

FFA (%)	0.04
M&I (%)	<0.1
IV (WIJS)	59
PV (meq/kg)	0.28
AV	0.40
Totox (2PV + AV)	0.96
Color (Lovibond, 5.25”)	2.1R
Smoke Point (ºC)	220
Polymer Compounds (%)	<0.5
Polar Compounds (%)	6.0
Total Tocopherols (ppm)	810
Induction Period (hrs, OSI at 110ºC)	24
Major Fatty Acids (%)	
Myristic (C14:0)	1.0
Palmitic (C16:0)	38.0
Stearic (C18:0)	3.7
Oleic (C18:1)	44.2
Others	1.4

Table 3 also shows low formation of polar and polymer compounds. There were no increasing trends and they varied, respectively, within narrow ranges of 9.8 - 11.0% (average 10%) and 1.7 - 2.4% (average 2%) from 40 to >1900 hours. This was also the case with total tocopherols. Starting with about 800 ppm, there was no trend (increasing or decreasing) and the content varied from 519 – 556ppm (average 530 ppm). The changes in PV, AV and OSI are shown in Figure 2. As expected, PV fluctuated within a narrow range of 3 - 4.4, and was ~4 units at >1900 hours. AV increased sharply from 0.4 to 12 units at 40 hours, after which it only increased moderately to about 17 units where it stabilized. The OSI started with 42 hours, then dropped to about 21 hours after 79 hours and thereafter fluctuated between 19.8 – 22.5 hours, and was 21 hours at >1900 hours. This excellent frying performance of palm olein was achieved largely because of proper oil management and good maintenance of the plant machinery.[6]



N.B.: Part of the results from this study was presented in the AOCS Meeting & Expo, USA, 2001

Figure 2. Changes in Peroxide, Anisidine and OSI values of palm olein during industrial frying of potato chips.

Table 3. Changes in quality parameters of palm olein during industrial frying of potato chips

Frying Time (Hours in weeks)	FFA (%)	Polar Compounds (%)	Polymer Compounds (%)	Total Tocopherols (ppm)
0	0.04	5.8	<0.5	810
40 (Week 1)	0.21	10.1	1.9	556
79	0.23	11.0	1.7	519
119	0.22	9.8	1.8	533
158	0.24	10.4	1.9	540
197	0.21	10.2	2.4	520
236	0.19	9.9	1.9	529
276	0.23	10.3	1.6	530
316 (up to Week 8)	0.20	10.0	1.8	548
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
. >1900 (upto Week48)	0.24	11.0	2.3	527

N.B.: Part of the results from this study was presented in the AOCS Meeting & Expo, USA, 2001

Study II: Industrial frying of pre-fried frozen french fries using palm oil

The industrial frying was done 5 days/week for two weeks (12 days).[8] The pre-fried frozen French fries were produced from the Bintje and Rekord varieties by a multi-step, continuous process including two-phase blanching of the chips and three-phase drying. The chips were flash-fried for 30 seconds in palm oil (176 - 181ºC) and then frozen. The production process for the pre-fried frozen French fries is shown in Figure 3.

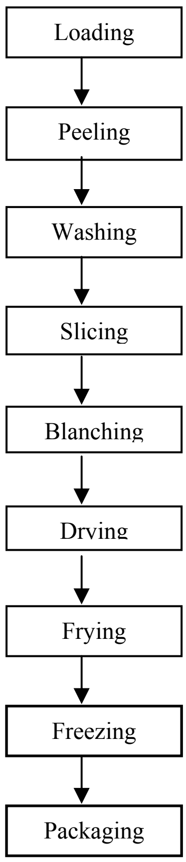


Figure 3. Flow chart of industrial production of pre-fried frozen French fries

The test started off with fresh palm oil with more of the oil automatically added to keep the level constant in the fryer. Records were kept on the quantities of raw materials and final product, as well as the processing parameters. The daily production (Table 4) varied with the orders received, but ranged from 6.5 tonnes on Day 12 to 17.8 tonnes on Day 10. A total of 121 tonnes of French fries were produced, with about 8.75 tonnes of palm oil added. A maximum 1.0% FFA was set as the end point of the frying. Samples of the oils and pre-fried French fries were taken daily, and their qualities assessed by the Official Methods and Food Oil Sensors.

Table 4. Quality changes of palm oil during industrial of frying of frozen french fries[10]

Day of Frying	Production (tons)	FFA (%)	Food oil sensor (unit)
0	-	<0.05	-
1	8.3	0.14	0.6
2	9.5	0.27	1.3
3	10.7	0.24	1.1
4	15.4	0.39	1.3
5	10	0.41	1.4
8	12.7	0.45	1.5
9	17.5	0.39	0.8
10	17.8	0.41	1.4
11	12.6	0.33	1.0
12	6.5	0.40	1.3

Results and Discussion

Table 4 shows that the palm oil experienced a moderate increase in FFA - from <0.05% initially to 0.14% on Day 1 and 0.27% on Day 2, but thereafter fluctuation between 0.24 to 0.45%. Over the 12 days of study, it averaged 0.34%. Thus, the FFA level remained well below 1.0%, making the oil suitable for frying throughout the experiment. There were also small increases in polar and polymer compounds, averaging 17% and 2.8%, respectively, over the 12 days (Table 5). This was supported by the results from the rapid test by the Food Oil Sensor, which hovered around 1.1 units, way below the discard limit of 4 units. Similar results were also obtained from the lipid extracted from the French fries which, with the sen-sory evaluation, showed that the pre-fried frozen French fries, as well as the palm oil, were of good quality with the latter's frying performance excellent.

Table 5. Quality changes in palm oil and lipid extracted from frozen french fries during industrial frying[10]

Day	Frying Oil		Lipid Extracted from French Fries		
	Polar (%)	Polymers (%)	Lipids	Polar (%)	Polymers (%)
Fresh Oil	13.5	0.4	0.2	-	-
1	13.4	1.4	5.7	10.2	0.7
2	17.9	1.3	6.0	16.0	5.1
3	18.5	3.5	5.0	16.6	3.0
4	21.2	4.7	5.0	14.2	4.9
5	23.4	4.2	5.1	15.0	3.6
8	17.8	5.2	5.1	16.6	6.3
9	19.9	3.3	5.6	14.6	1.2
10	16.3	4.5	5.6	15.8	4.4
11	19.6	3.7	6.2	19.1	3.8
12	21.8	1.0	5.3	16.3	2.9

Study III: Batch frying of fried chicken using palm oil, palm olein and palm shortening

In this study 9, chicken parts were simultaneously and inter-mittently fried in the laboratory using palm shortening, palm oil and palm olein, simulating the conditions in a fast food outlet. The initial qualities of the oils were very good and almost similar - each with FFA level of about 0.05%, PV <1meq/kg, AV <1%, polymer compounds <0.05%, polar compounds averaging 6.5% and smoke point of 210ºC. The fresh chicken parts were coated and intermittently fried at 175 ± 5ºC, 8 hours/day for 5 consecutive days, in electrically heated Valentine open fryers of 4 liters oil capacity. The fried chicken was sensory evaluated twice daily, within 7 – 10 minutes of frying. After each frying session, the oils were filtered and topped up with <10% of their fresh equivalents and covered for the next day's frying. The oils were sampled after the filtration, sparged with nitrogen and stored at –20ºC for subsequent analysis.

Results and Discussion

Figures 4-7 show the changes in FFA, smoke point, polar and polymer compounds of the three oils. The FFA of all three after 5 days of frying were <1.0%, well below the discard level of 2–2.5%. Similarly, the polar and polymer compounds only increased to 24% and 6%, below the discard points of 25–27% and 10–16%, respectively. The smoke points of all three on Day 5 dropped to about 180ºC which was higher the discard point of 170ºC.[9] It is clear that after the five consecutive days of frying, the three palm oil products were still good for further frying. This conclusion was supported by the sensory panel which members still found the product acceptable on Day 5 (Fig. 8) after considering the attributes of colour, smell, crispiness, taste, etc.

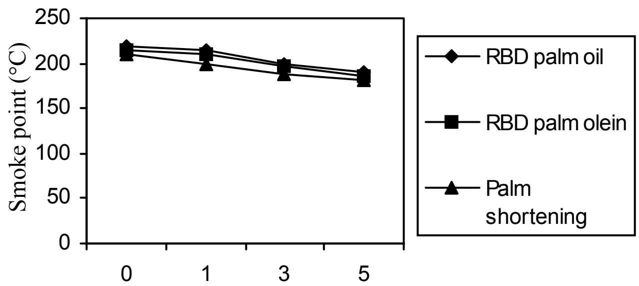


Figure 4. Changes in smoke point of frying oils during batch frying of chicken.

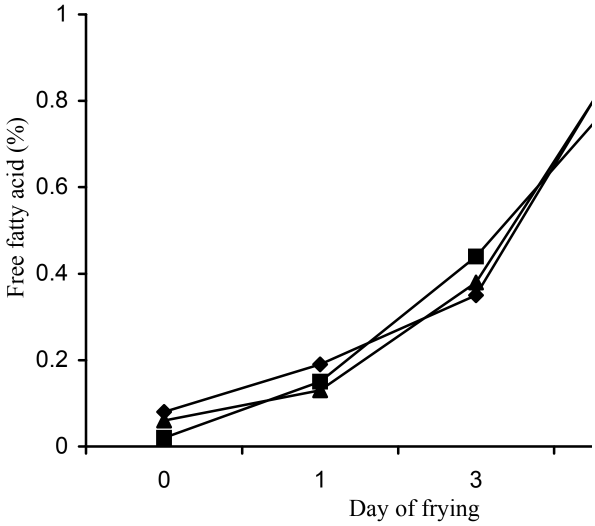


Figure 5. Changes in free fatty acid of frying oils during batch frying of chicken.

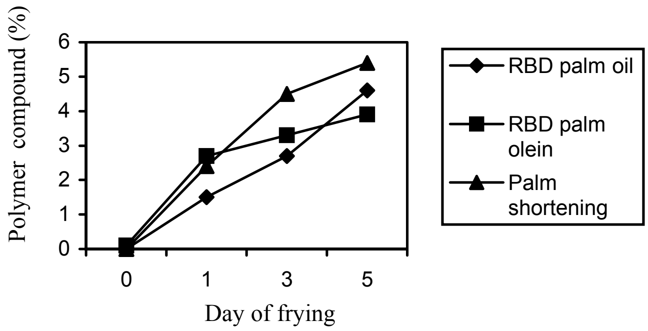


Figure 6. Changes in polymer compounds of frying oils during batch frying of chicken.

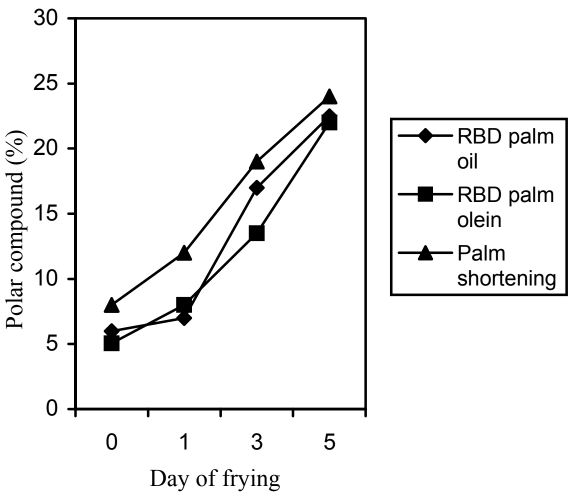


Figure 7. Changes in polar compounds of frying oils during batch frying of chicken.

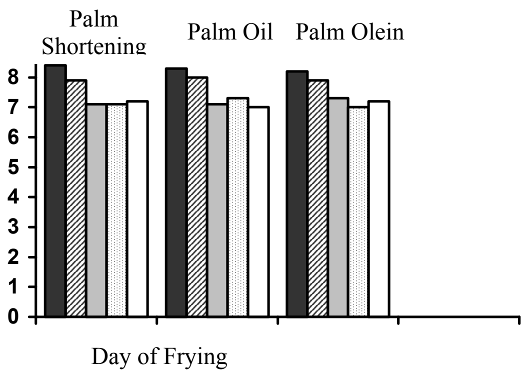


Figure 8. Overall Acceptability of fried chicken over 5 days of frying

Conclusion

Palm oil and palm olein with their proven techno-economic advantages are excellent and versatile frying media for almost all frying activities, either in fast food outlets, industrial frying of pre-fried frozen French fries, commercial production of potato chips, mass catering, hawking and general household frying.

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Palm oil and palm olein frying applications
棕榈油和棕榈液的油炸应用

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全世界每年都有上百万吨的棕榈油和棕榈液油用于煎炸。本文将讨论它们在三种主要应用中的煎炸性能-工业化生产薯条和薯片，工业化生产冷冻预炸薯条和快餐的出口加工。第一个研究，大约 4 吨的薯条每天连续炸 8 个小时，每星期炸 5 天。完成试验后，用过的棕榈油（固有化生产）性能良好，反应在 0.23%的低自由脂肪酸含量，4meg/kg 的氧化值，16 的甲氧基苯胺值，低含量分别为 10%和 2%的极性和聚合物。21 小时的诱导期和 530ppm 高含量的生育酚和生育三烯酚类甚至在大于 1900 小时之后。第二个研究，平均 12 吨冷冻预油炸薯条每天持续炸，每星期炸 5 天。超过 12 天的实验后，棕榈油还是表现优良，反映在 0.34%低自由脂肪酸，1.1 的食物油传感器读数，低含量分别为 17%和 2.8%的极性和聚合物。第三个研究在实验室以模拟快餐出口环境，起酥棕榈油，棕榈油和棕榈液油同时用于间隙炸鸡肉，连续 5 天煎炸之后，这三种油表现非常令人满意，反映在它们相当低的自由脂肪酸含量<1%，烟点>180℃，极性和聚合物含量分别<25%和<6%。所有的质量参数显示，炸油在三种食品应用中没有超出最大的丢弃点，当油炸食品被内部链感官小组使用 9 分制接受。

关键词：棕榈油，棕榈液油，工业化油炸，成批油炸