Versatility of Palm-based Oils for Industrial Frying

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INTRODUCTION

Frying is extensively employed in the domestic and industrial sectors to process food. In principle, this cooking technique is essentially a dehydration process that involves rapid heat and mass transfer when the food is immersed into hot oil at a temperature above the boiling point of water. Interaction between the frying oil and the food causes vigorous water vapour release from the product and at the same time, the oil starts to penetrate into the food structure (Bouchon and Pyle, 2004; Dueik *et al.*, 2010).

Basically, frying has similar principle as baking where a brownish crust layer is formed on the food surface that contributes to a distinctive fried flavour. However, the former generally cooks faster than the latter, and this can be further explained by the efficiency of heat transfer (Berger, 2005). For this reason, frying has gained popularity to produce highly desirable products possessing novel sensory properties which make the food more palatable and desirable (Ahmad and Ismail, 2007). Furthermore, its operational simplicity, convenience and economic viability have resulted in extensive sales of a large variety of fried products.

PALM-BASED OILS AS FRYING MEDIA

In recent years, more than 20 million tonnes of world annual cooking oil production is used for frying (Dana and Saguy, 2006; Gertz, 2004) for which 30% of the total production is sourced from palm oil (Ismail, 2006). The position of palm oil is even pronounced in terms of its share of vegetable oil exports where it accounts for almost 60% of the global exports (Carter *et al.*, 2007). This is contributed by the techno-economic advantages of palm oil against other vegetable oils and thus often regarded as a heavy duty frying oil with stronger resistance at high frying temperatures (Ahmad Tarmizi and Ismail, 2008; Nallusamy, 2006).

With respect to stability, palm oil or particularly its liquid fraction, palm olein, contains a balance proportion of saturated and unsaturated fatty acids. It is a known fact that oil stability is associated with the ability of the oil to withstand high temperatures, and therefore the degree of saturation is of importance for choosing the right oil for frying. Oil containing higher amount of saturated fatty acids is likely to be more stable as opposed to soft or liquid oils. It is also worth noting that oils that contain more than 2% of linolenic acid will not be used for industrial frying (Gupta, 2005).

Thus, it is not a surprise that palm olein – either in its pure form or blends with other vegetable oils – is extensively used in frying sectors like domestic or household cooking, fast food outlets, mass catering and industrial frying (Matthäus, 2007; Ismail, 2001). Indeed, consistent supply of palm olein at

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competitive price also contributes to wide usage for frying purposes (Ahmad Tarmizi and Ismail, 2008). This can be depicted from *Table 1* which clearly shows that palm oil and palm oil products tend to command lower price than other vegetable oils. Cheaper cost of production of palm oil is one of the key reasons for its success in capturing market to provide a sustainable basis for its relatively low price.

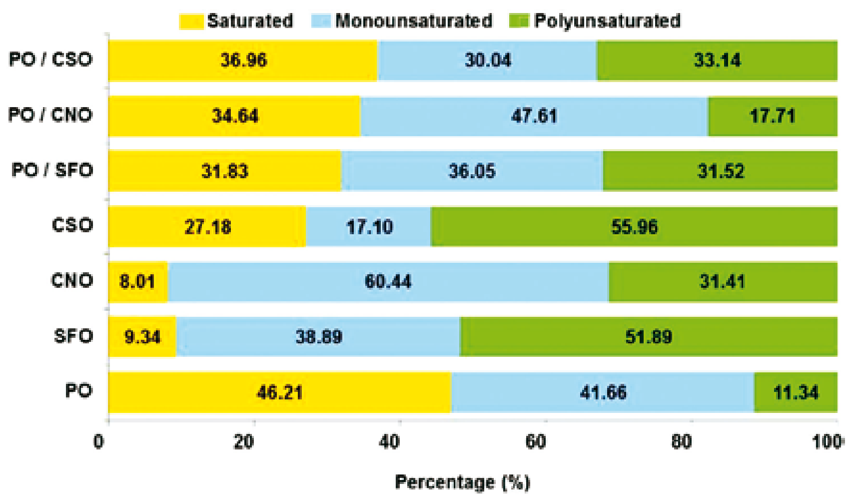
INDUSTRIAL FRYING OF SNACK FOOD

The term 'snack food' often describes food eaten between regular meals – breakfast, lunch or dinner. Amongst varieties of snack food produced in the market, potato chips are one of popular consumer snack foods worldwide (Matthäus, 2007). In most cases, potato chips are produced in mass quantities under continuous frying conditions that require large volumes of oil as frying media. The performance of vegetable oils for frying is extensively discussed in many publications. Nevertheless, most of these studies were carried out under intermittent (discontinuous) frying, and many of which involved frying of potato-based products such as potato chips and French fries. Publications related to continuous frying, however, are somewhat limited, and only restricted to frying potato chips and/or pre-fried French fries.

Realising the importance of understanding the behaviour of oil under such frying conditions, the Malaysian Palm Oil Board (MPOB) has taken steps to assemble a 200-litre capacity pilot plant scale continuous fryer aimed to simulate the industrial frying of potato chips. To date, MPOB has conducted several frying studies pertaining to continuous frying conditions. In this article, we discuss on the performances of three binary blends of palm olein (PO) with sunflower oil (SFO) at 60:40, PO with cottonseed oil (CSO) at 50:50 and PO with canola oil (CNO) at 70:30; this is to be compared with that of pure PO. Potato chips were processed continuously at the rate of 50 kg hr^{-1} over 8 hr daily for seven days. Ratios of the first two blends were selected so that the oils could give more or less equivalent level of saturated, monounsaturated and polyunsaturated fatty acids (*Figure 1*). In the case of PO/CNO, the linolenic acid content did not exceed 2%.

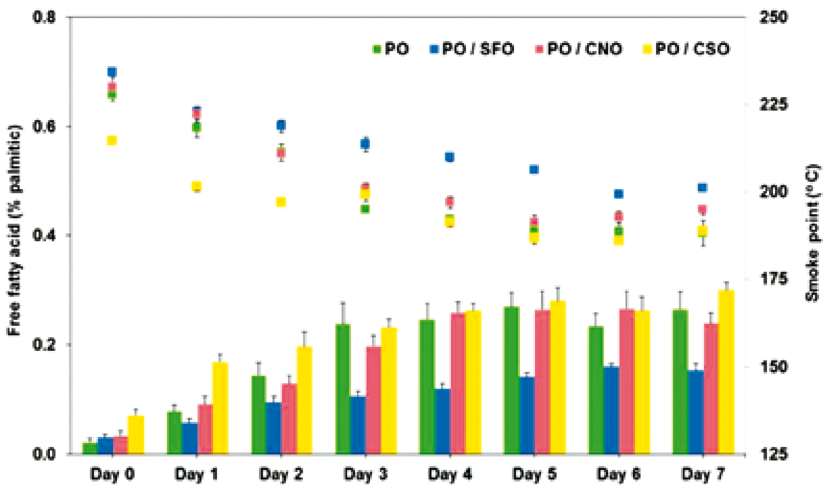
Exposure of oil at frying temperature in the presence of air and moisture leads to a complex reactions involving hydrolysis, oxidation and polymerisation (Dueik and Bouchon, 2011; Karoui *et al.*, 2011; Bensmira *et al.*, 2007). Hydrolysis mainly takes place when leached water from food reacts with triacylglycerol (TAG) and consequently splits into diacylglycerol (DAG), monoacylglycerol (MAG), glycerol and free fatty acid (FFA) (Dueik and Bouchon, 2011; Choe and Min, 2007).

In this study, FFA which normally measures the degree of hydrolysis, appears to be one of the frequently used parameters by food processors to evaluate oil quality (Maskan and Bagci, 2003; Ahmad Tarmizi and Siew, 2008). *Figure 2* shows that the FFA reached a steady state after the third day for PO (average FFA = 0.25%), fourth day for PO/CNO (average FFA = 0.26%) and PO/CSO (average FFA = 0.28%), and fifth day for PO/SFO (average FFA = 0.15%). It is important to note that the consistency in FFA level is achievable when the oil inside the fryer – which is absorbed by fried product and lost during frying – is continuously replenished with freshly prepared oil that contains lower FFA value (Ahmad Tarmizi and Ismail, 2008). The discard point for FFA differs depending on the nature of product being fried. In this particular case, 0.5% is regarded by snack



Source: Ahmad Tarmizi *et al.* (2013).

Figure 1. Fatty acid composition of single and blended oils.



Source: Ahmad Tarmizi *et al*. (2013).

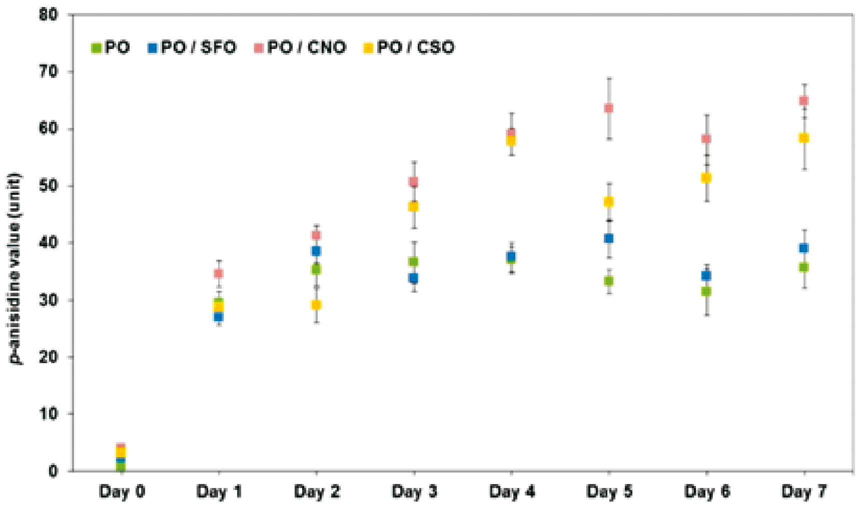
Figure 2. Transients of FFA and smoke point in PO and its blends during frying.

food producers as the benchmark for potato chips. This further attested that the usability of these oils can be extended for more than seven days of frying.

Development of FFA is often associated to smoke point where the amount of smoke release from the heated oil is proportional to the decomposition of low-molecular weight constituents such as FFA and volatile compounds (Matthäus, 2006). Increase in the FFA inversely changed the smoke point of oils across frying times: (1) 228°C to 188°C for PO; (2) 234°C to 201°C for PO/SFO; (3) 230°C to 195°C for PO/CNO; and (4) 215°C to 189°C for PO/CSO (*Figure 2*). Nevertheless, these values are still above the frying temperature (180°C) and have well exceeded the minimum smoke point allowance of 170°C (Ismail, 2001; Berger, 2005).

Oxidation is known as the precursor of oil breakdown during heating and frying. It essentially involves interaction between unsaturated fatty acids and air (oxygen). This deleterious reaction has raised concerns associated to product quality and health, by affecting the sensory properties and nutritional values of fried product (Dana and Saguy, 2001). Generally, the number of double bonds in oil structures distinguishes the extent of oil oxidation, where oil containing higher amount of polyunsaturated fatty acids is likely more susceptible to oxidative reactions as opposed to oil having higher saturation level (Gupta, 2005).

One of the ways to address the integrity of oil resistance during frying is *p*-anisidine value (AnV). This parameter basically measures the formation of aldehydes when heated oil is exposed to air. *Figure 3* shows the level of AnV of PO and its blend before and after frying. A sudden increase was detected at the early stage of frying and consistently retained the values until the end of the frying course. It was noted that PO and PO/SFO reached steady states after the second day of frying whereas PO/CNO and PO/CSO attained their optimum values toward the end of frying. At the end of the process, the first two oils displayed the lowest and similar trend of AnV profiles. On the other hand, the PO/CNO and PO/CSO gave the highest AnV values at similar frying time. This can be explained from the basis of newly developed aldehydes that are more or less levelled off by degradation of former aldehydes as a result of advanced stage of oxidation and polymerisation (Tsaknis *et al.*, 2002).



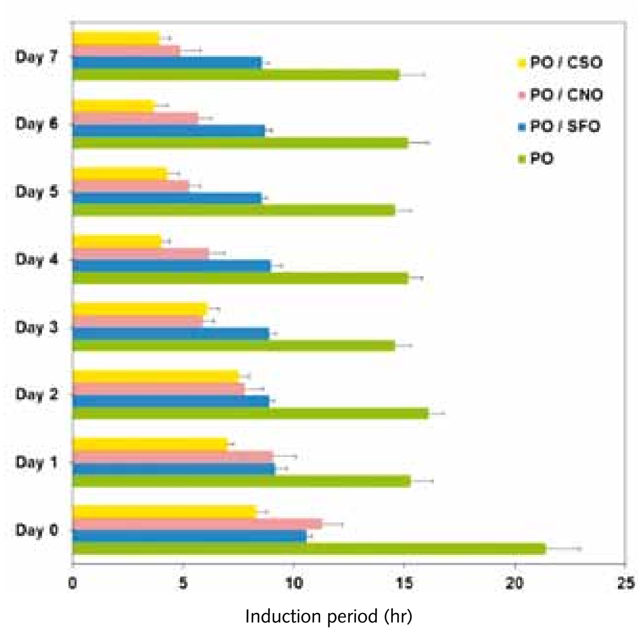
Source: Ahmad Tarmizi *et al.* (2013).

Figure 3. Change of AnV in PO and its blends during frying.

Another method that is used to monitor the stability state of oil is the induction period – the expression of time needed for oil to resist oxidation at high temperature (Matthäus, 2006). In this test, air is firstly passed through the heated oil inside a reaction vessel. This leads to the production of organic acids and hence the conductivity of water is increased. The interval at which the water conductivity starts to change is denoted as the induction period. From *Figure 4*, it is obvious that the induction periods of fresh oils were significantly different despite some of the oils – PO/SFO and PO/CSO – exhibited comparable fatty acid profiles (*Figure 1*). The PO, which has the largest induction period, was able to retain almost 70% of its initial value (21.4 hr) after seven days of frying. With respect to blended oils, PO/SFO exhibited only a marginal drop in the induction period whereby the other two blended oils lost more than half of their origins (10.6, 11.3 and 8.3 hr for PO/SFO, PO/CNO and PO/CSO, respectively) upon completion of the frying operation.

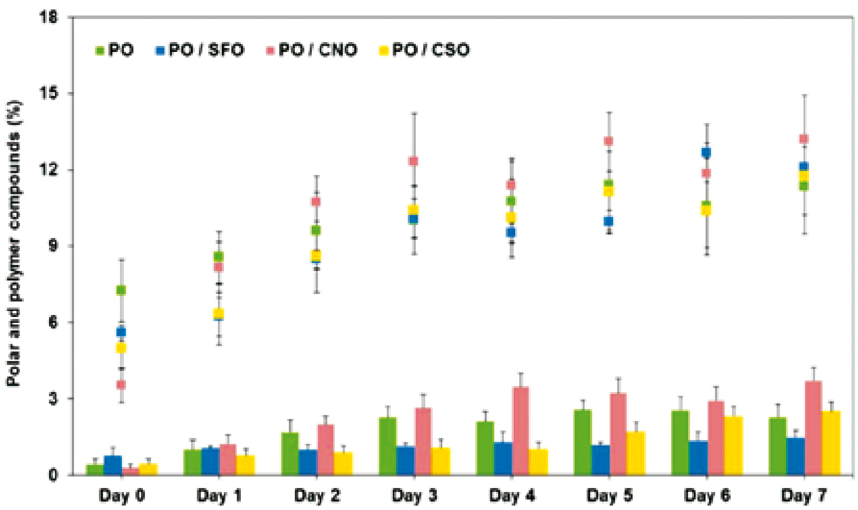
Polymerisation occurs when the heated oil undergoes the advanced stage of oxidative reaction and/or thermal alteration of TAG structures (Ahmad Tarmizi and Ismail, 2008). As consequence higher molecular weight constituents, known as polymer compounds, are being developed. These polymer compounds are responsible for the change in oil viscosity, tendency of foaming during frying, and they impart bitterness to the fried product (Ahmad and Ismail, 2007; Samah and Fyka, 2002; Tseng *et al.*, 1996). Indeed viscosity could affect the oil content in fried product (Maskan 2003). The results shown in *Figure 5* indicate a moderate increase in polymer compounds with the progression of frying. The PO/SFO only exhibited a minor change in the polymer compounds of not more than 2% while PO/CNO gave the highest value (3.7%) after the seventh day of frying. The concentration of polymer compounds seemed similar in that of PO and PO/CSO. Nevertheless, the amount of polymer compounds of all oils were much lower than the discard point of 10% to 16%, which varies between countries (Ahmad and Ismail, 2007; Berger, 2005).

Quantification of polar compounds is also crucial and reliable



Source: Ahmad Tarmizi *et al*. (2013).

Figure 4. Profile of induction period in PO and its blends during frying.



Source: Ahmad Tarmizi *et al.* (2013).

Figure 5. Evolution of polar and polymer compounds in PO and its blends during frying.

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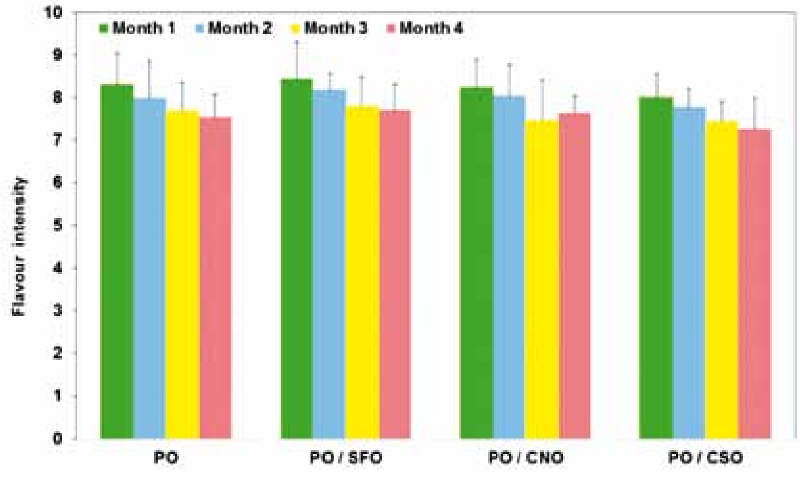
method to examine the extent of oil deterioration in used oil (Warner and Gupta, 2003). The fractions of polar compounds include polymerised and oxidised TAGs, DAG and FFA (Dobarganes *et al.*, 2003). From *Figure 5*, it is clearly shown that the level of polar compounds was more pronounced during the first three days of frying, followed by a gradual increase afterwards. It is important to note that the rate of polar compounds formation in PO was the lowest albeit its initial level was the highest (7.3%). This is because PO inherently contains a higher level of DAG as compared to other vegetable oils (Berger, 2005). Nonetheless, the level of polar compounds in the four oils was more or less comparable across frying intervals and way below the maximum allowance of 25%.

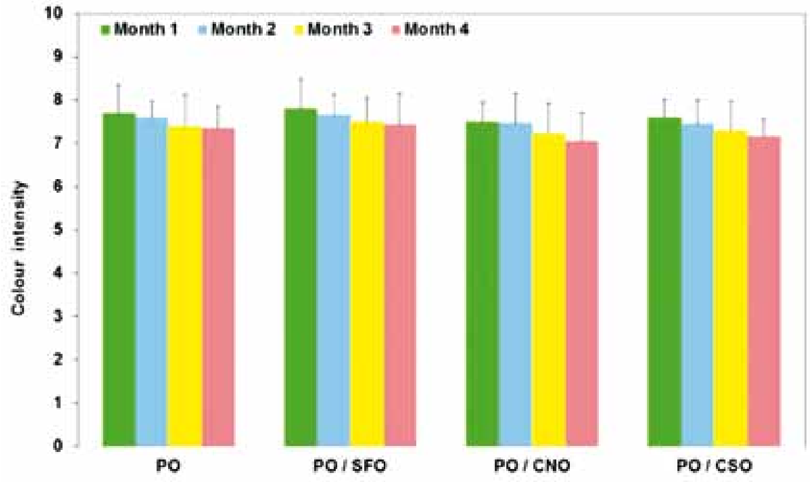
The stability of frying oil also influences the sensory properties of fried product. Sensory is a subjective method to evaluate food products through human senses. The results in *Figures 6* to *9* illustrate the sensory attributes – *i.e.* flavour, colour, crispness and taste – of potato chips fried in different oils. Regardless of the frying medium, insignificant difference in potato chips attributes were confirmed by means of sensory test scores, albeit the value slightly decreased over storage time. This demonstrates that blending PO with soft oils, to some extent, produced potato chips with comparable shelf life stability as those obtained from PO alone.

From the basis of a 10-point scale used to distinguish the intensity of the perceived sensory attrib-



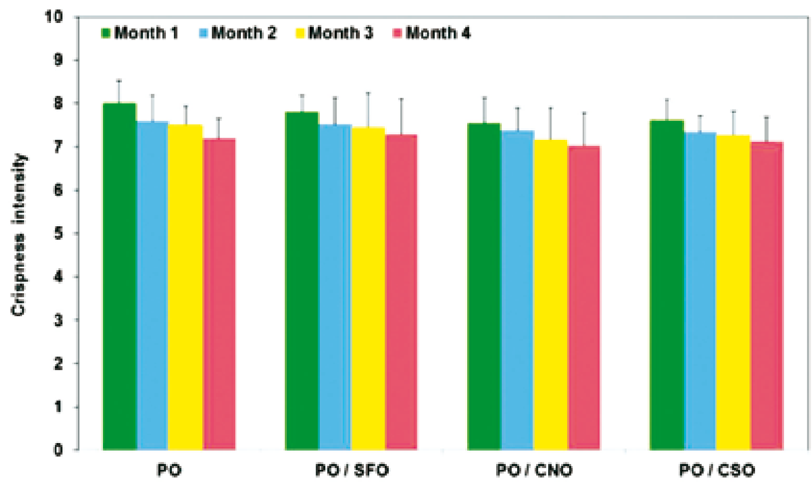
Source: Ahmad Tarmizi *et al*. (2013).

Figure 6. Flavour intensity of potato chips fried in PO and PO blends.



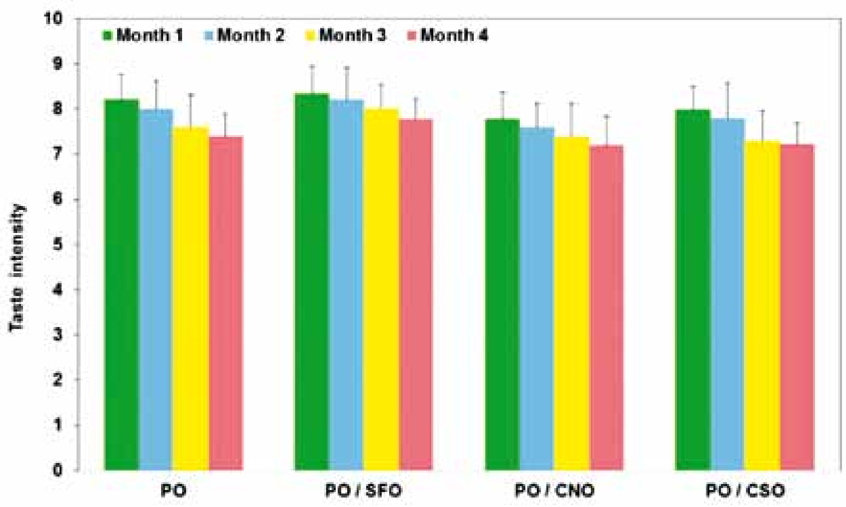
Source: Ahmad Tarmizi *et al*. (2013).

Figure 7. Colour intensity of potato chips fried in PO and PO blends.



Source: Ahmad Tarmizi *et al.* (2013).

Figure 8. Crispiness intensity of potato chips fried in PO and PO blends.



Source: Ahmad Tarmizi *et al*. (2013).

Figure 9. Taste intensity of potato chips fried in PO and PO blends.

TABLE 1. PRICE OF SELECTED VEGETABLE OILS

Oils/fats	North-West Europe Market (USD t^{-1})						
	2007	2008	2009	2010	2011	2012	2013
Crude palm oil	780	949	683	901	1 125	1 000	857
Palm oil	800	1 006	725	935	1 179	1 022	841
Palm olein	828	1 067	767	963	1 210	1 062	884
Palm stearin	789	891	678	933	1 101	988	831
Soyabean oil	881	1 258	849	989	1 299	1 227	1 057
Cottonseed oil	971	1 553	814	964	1 252	1 183	1 045
Groundnut oil	1 348	2 109	1 183	1 403	1 883	2 426	1 773
Sunflower oil	1 022	1 499	855	1 074	1 360	1 263	1 124
Rapeseed oil	969	1 329	858	1 013	1 368	1 241	1 082
Coconut oil	919	1 224	725	1 121	1 730	1 112	940

Source: http://bepi.mpob.gov.my/index.php/statistics/price/monthly.html.

utes, the limit score of the sensory acceptance was valued at 5. It is therefore noted from *Figures 6* to *9* that the overall scores of potato chips fried in PO and the blends were above seven even after four months of storage. This clearly indicates that the stored potato chips were of good stability and extending the storage period seemed possible. It is plausible that tastier potato chips are generally produced using oils with a moderate increase in FFA content (Singh and Mittal, 1997).

CONCLUSION

In consideration of the results above, PO and its blends exhibited comparable performance during continuous frying of potato chips. The stability of all oils was reflected by sensory attributes of potato chips stored for four months. Hence, this finding provides opportunities for PO to penetrate into countries or regions that have strong preference for their local oils, but at the same time have major concerns pertaining to oil stability upon frying.

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