

Comparison of monounsaturated and polyunsaturated oils in continuous frying

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SUMMARY

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Some work carried out by the Turbitak Marmara Research Centre and the Yildiz Technical University in Istanbul, in collaboration with the Palm Oil Research Institute of Malaysia, involved large scale laboratory frying trials of two monounsaturated oils (olive oil and palm olein) and two polyunsaturated oils (sunflower and soyabean) on potato chips (French fries). The oils were tested in parallel in separate 6-litre fryers on five consecutive days of eight hours and 14 batches of 150g potatoes each. At the end of each day the fryers were cleared of any sediment and topped up with fresh oil (about 250g). The performance of the oils was assessed by 11 physical and chemical tests viz. colour, smoke-point, foam height, free fatty acid content, fatty acid composition, iodine value, peroxide value, anisidine value, totox, polymer content and polar compounds.

The monounsaturated oils scored higher in most tests and were clearly superior but in some tests such as colour and FFA the polyunsaturated oils scored higher. Single, simple tests as practised in many commercial establishments can be misleading and multiple tests need careful interpretation. The shelf-life of the chips was not assessed as this food is normally eaten within a short time of preparation. But the tests indicate that fried products intended for longer storage and wide distribution, will have a better shelf-life if fried in monounsaturated oils.

KEY-WORDS: Comparison of the oils – Continuous frying – Monounsaturated oil – Polyunsaturated oil.

INTRODUCTION

This paper gives a brief account of some extensive frying trials carried out jointly in Turkey by the Turkish Marmara Research Centre, The Yildiz Technological University in Istanbul and the Palm Oil Research Institute of Malaysia (PORIM). The oils chosen were: olive oil (OO), sunflower oil (SFO), soya bean oil (SBO) and palm olein (POo).

Because palm olein is much more saturated than the other oils, it becomes semi-solid in the winter months in Turkey and the main purpose of these trials was to find suitable blends which gave good frying performance while remaining fully liquid. For the sake of simplicity however, this paper only deals with the straight oils and it can be taken that the blends gave approximately proportional results.

MATERIALS AND METHODS

Oils

Samples of refined olive oil, sunflower oil and soyabean oil were obtained from local sources while palm olein was supplied by PORIM. The initial characteristics of the oils are given in Table I and their fatty acid composition in Table II.

Table I
Characteristics of the frying oils used

Parameter	POo	OO	SFO	SBO
Colour				
Red	1.0	1.0	0.7	0.5
Yellow	7.2	8.2	2.0	3.3
PV (meq/kg)	0.7	6.3	1.6	3.3
FFA (%)	0.6	4.3	0.4	0.5
IV	59.6	84.1	128.8	130.4
Induction Period (h)	40.0	12.3	8.2	10.0
Smoké Point (°C)	220	195	230	229
Polar Compds (%)	9.0	9.1	5.8	7.1

Table II
Fatty acid compositions of frying oils

FAC	POo			OO			SFO			SBO		
	0	3	5	0	3	5	0	3	5	0	3	5
C12:0	0.4	0.5	0.4	–	–	–	–	–	–	–	–	–
C14:0	1.3	1.3	1.3	–	–	–	–	–	–	0.1	0.1	0.1
C16:0	40.3	43.1	43.9	13.0	13.2	13.3	6.3	7.8	8.1	10.7	11.4	11.8
C16:1	0.1	0.1	0.1	0.5	0.4	0.3	0.1	0.1	0.1	–	–	–
C18:0	3.2	3.5	3.6	2.6	2.6	2.6	4.0	4.7	4.9	3.1	4.1	4.1
C18:1	43.5	42.6	42.1	71.2	72.9	73.5	19.2	24.0	23.7	18.9	18.7	19.3
C18:2	10.6	8.3	8.0	12.1	10.6	10.1	70.0	63.0	62.9	61.1	60.1	59.7
C18:3	0.2	0.2	0.2	0.6	0.3	0.2	0.1	0.1	0.1	6.1	5.6	5.0
C20:0	0.4	0.4	0.4	–	–	–	0.3	0.3	0.2	–	–	–
C18:2 C16:0	0.26	0.19	0.18	0.93	0.80	0.76	11.10	8.10	7.76	5.71	5.27	5.06
Percent drop	30.8%			18.3%			30.1%			11.4%		

Potatoes

Fresh potatoes were peeled, cut to 1 x 1 x 4cm size, blanched by steam for 30 seconds and then cooled, dried and weighed into 150g batches.

Frying experiments

An outline of the frying procedure is given in Table III. Six litres of each of the four oils were put into separate electric fryers and heated to 180°C when the potatoes were introduced and fried for 2.5 minutes. The oil was maintained hot and 14 batches of potatoes were fried during 8 hours per day for five days, making a total of 70 batches in each oil. At the end of each day, the oil was cooled, filtered and a 250g sample taken for testing.

Table III
Frying conditions

Quantity of oil (per fryer)	: 6l
Frying temperature	: 180 ± 2° C
Frying time (per batch)	: 2.5 min
Quantity of fresh potatoes (per batch)	: 150 g
Frying frequency/day	: 14 batches
Total frying time/day	: 8 hours
Total frying time	: 40 hours

The fryers were cleaned without removing any adhering gum and topped up with 1.5 litres of fresh oil ready for the next day.

Tests

The oil samples taken at the end of each day were submitted to the following tests: colour, FFA, smoke point, foam height, fatty acid composition, iodine value, peroxide value, anisidine value, totox, polymer content and polar compounds, using the methods given in Table IV.

Table IV
Methods of analyses

Colour (USING LOVIBOND TINTOMETER WITH 1" CELL)
Fatty Acid Composition (IUPAC, 1979)
Peroxide Value (PORIM TEST METHODS, 1990)
Anisidine Value (PORIM TEST METHODS, 1990)
Free Fatty Acids (PORIM TEST METHODS, 1990)
Smoke Point (OAC OFFICIAL METHODS Cc 9a-48)
Iodine Value (WIJ'S METHOD)
Polymer Content (M. PEELED, 1975)
Polar Compounds (IUPAC 2.507, 1989)
Totox Value = 2 x PV + AV
Foam Height (A. DIEFFENBACHER <i>et al.</i>)

RESULTS AND DISCUSSION

The household and catering users judge the end of the useful life of an oil mostly by colour and smoke point, while industry relies most on FFA and occasionally foaming tendency. These tests are therefore considered first.

1. Colour

In these trials, the colour of the oil was measured initially and at the end of every day and the results are shown in Figure 1. The least colour was in soybean oil in all five days. Olive oil was almost as good up to day two but then started darkening quickly. Palm olein darkened quickly and

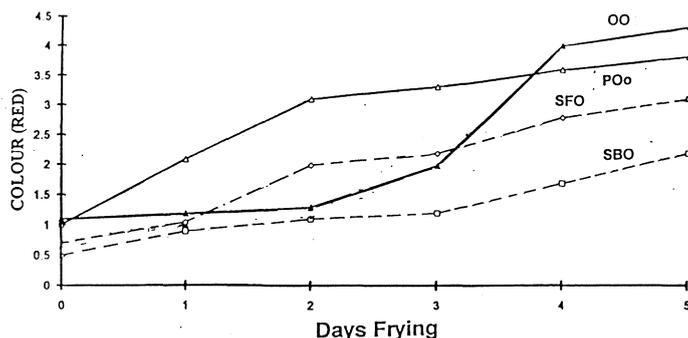


Figure 1
Colour of Frying Oils During Frying 1" Lovibond cell

appreciably.

But colour rise means different things for different oils. PORIM researchers found that the darkening of palm oil products due to the presence of trace phenolic compounds and that of olive oil is probably due to the same cause. In any case, darkening to the extent found here did not affect the colour of the chips.

Clearly colour change is not a good test for assessing the quality of different frying oils, although it is probably good for estimating the amount of use a given oil has had.

2. Free Fatty Acid Content (FFA)

The FFA is the most widely used test in industry but it has come under criticism from various quarters on scientific grounds. Oils in frying develop acidity due not only to oxidation and decomposition which are highly relevant, but also due to hydrolysis which

is not. Different oils have different rates for these two reactions and the starting values also affects the results. The FFA level in the fryer represents the equilibrium between the rate of formation and the rate of its removal by distillation.

The results obtained in this trial are shown in Figure 2. The polyunsaturated oils gave the lowest FFA, with soyabean oil first and sunflower oil second. The value obtained from olive oil is mostly due to its higher initial level and probably also to its higher content of partial glycerides. These are also

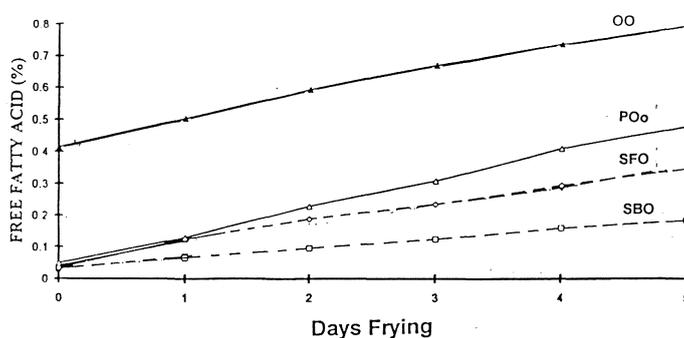


Figure 2
FFA Content of Oils During Frying

responsible for the palm olein performance.

These results confirm what we have found repeatedly in industry, that the FFA is a very misleading test when used unthinkingly for comparing different oils, but very useful for assessing the quality of different batches of the same oil, or for deciding the rejection point of a given oil, because it increases smoothly with frying time and is easy to carry out.

3. Smoke Point

The smoke point is certainly an important characteristic for restaurants and housewives in deciding when to change their frying oil.

The smoke point depends almost entirely on the FFA and molecular weight of the fatty acids but since most frying oils are based on only C16 and C18 fatty acids, the FFA is the controlling factor.

The values obtained in this trial are shown in Figure 3 and not surprisingly reflect those on FFA with the oils are in the same but reverse order. The two polyunsaturated oils had the highest (best) values. Olive oil had the lowest value because it started with the highest FFA.

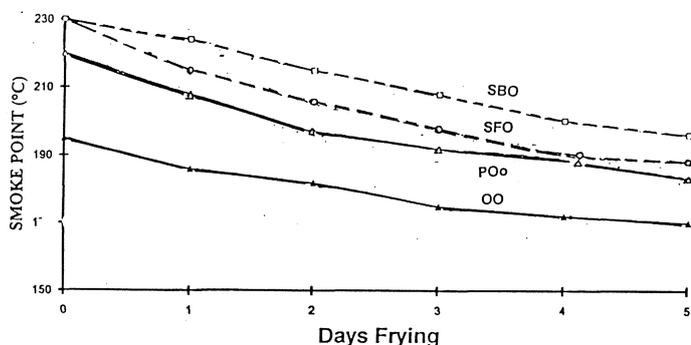


Figure 3
Smoke Point of Oils During Frying

4. Foam Height

Excessive foam in a frying pan or in an industrial fryer is at best a nuisance and in extreme cases it can be a fire hazard necessitating change of the oil. What causes oil to foam is not well understood but depends on many parameters such as viscosity, emulsifiers and stabilisers formed in the breakdown of the oil.

Typically, foam height reaches an early maximum value and then settles quickly to much lower levels. The worse foam type is the one composed of small, dense bubbles which persist throughout the frying period. In this trial as expected, foam height increased from the first to the fifth day and Figure 4. gives the results obtained on the fifth day. The best results by far were given by the monounsaturated oils palm olein and olive oil.

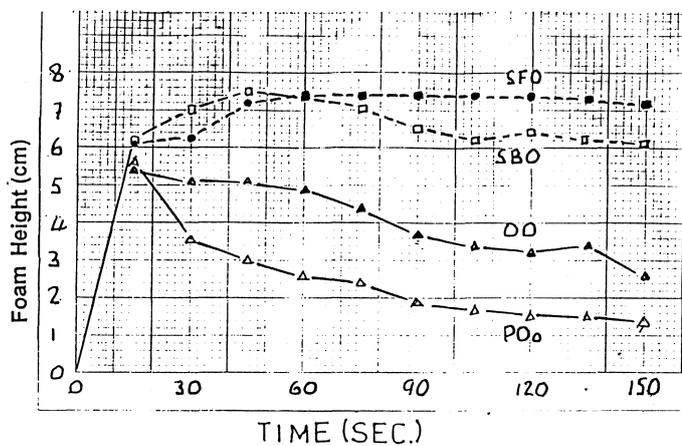


Figure 4
Foam Height of Oils During Frying

In my experience, the resistance of an oil to foam correlates well with its overall frying qualities, but the test is time-consuming and has not yet been standardised.

5. Fatty Acid Composition

Change in C18:2 & C18:3

The decrease in linoleic and linolenic acid content of oils during frying, is due to their destruction by oxidation, polymerisation, etc., and should therefore be a meaningful test of oil performance. The problem is that it seems to have a large experimental error and so small differences between oils are not significant.

Some technologists only consider the reduction in the linoleic acid and this is clearly illogical. Others consider the relative change rather than the absolute change and this is also wrong.

The results obtained here are shown in Figure 5. where it is seen that all the oils gave quite similar results except for the sunflower oil which gave much higher values and this was rather surprising.

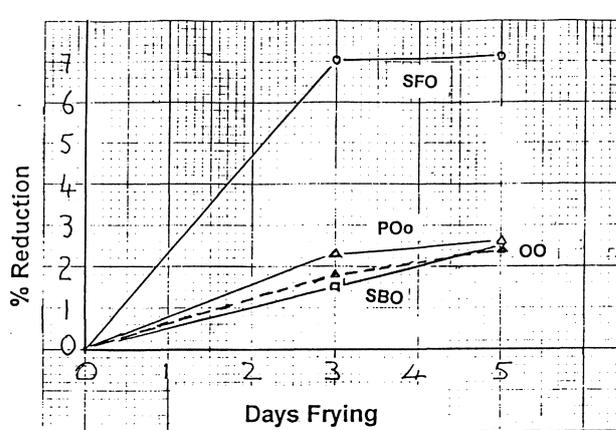


Figure 5
Reduction of Linoleic & Linolenic Acid During Frying

Changes in Total Unsaturation

The picture changes drastically when we consider the reduction in total unsaturates (see Figure 5A). Now olive oil clearly gives the lowest (best) values and palm olein the highest. Clearly the results obtained depend on which fatty acids we consider. The experimental error seems to be too high and to obscure the true picture.

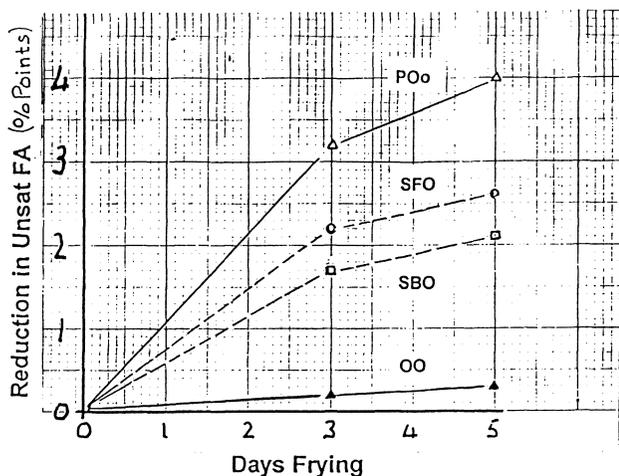


Figure 5A
Reduction in Total Unsaturated FA During Frying

6. Iodine Value (IV)

The reduction in IV during frying is often taken as a measure of deterioration. The test is analogous to that for unsaturated FA reduction but gives much more weight to higher unsaturation. Some people calculate the relative reduction in IV but I think that is wrong. It is the absolute reduction that is significant.

Determination of the Wijs IV probably has a lower experimental error than the sum of various fatty acids by GLC because this test normally gives more consistent results.

The result obtained in the trial for day 0 and day 5 are shown in Figure 6 and are in ascending order, olive oil, palm olein, soyabean oil and sunflower oil. The monounsaturated oils had far lower values.

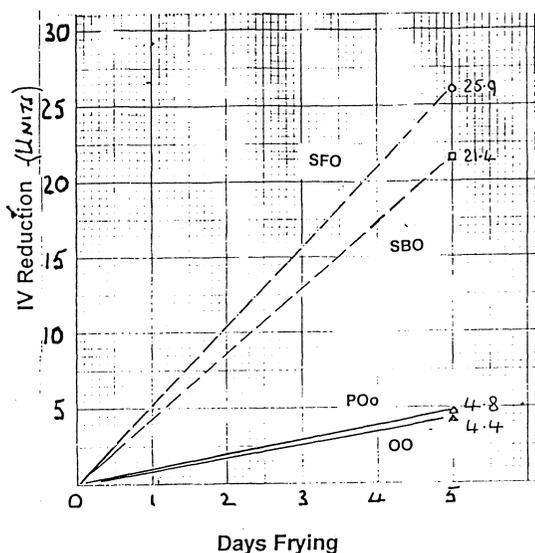


Figure 6
Reduction in IV During Frying

7. Peroxide Value

The peroxide value is a good measure of oxidation under normal conditions, but when used on oils during frying, it can be very misleading. Peroxides are destroyed under frying conditions and the PV only rises during the subsequent cooling, sampling and storage of the samples.

The results obtained in this trial are shown in Figure 7, and they were mixed. Olive oil and soyabean oil gave the lowest (best) values while palm olein and sunflower oil gave the highest. Palm olein apparently fell on the 3rd day and then rose again, while sunflower oil was on a falling trend from the second day onwards. It is evident that peroxide formation is erratic under these conditions and the test has a large experimental error.

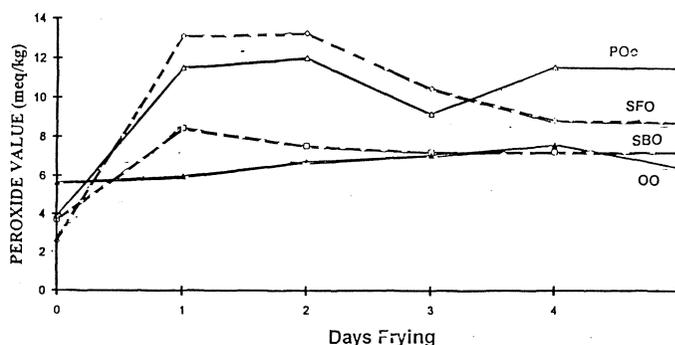


Figure 7
Peroxide Value of Oils During Frying

8. Anisidine Value

The Anisidine value is a more meaningful test than PV for oils during frying because it measures aldehydes which are less easily destroyed under these conditions.

The results obtained are shown in Figure 8. The values are much smoother and progressive than with the PV and clearly this is a better test. The monounsaturated oils olive oil and palm olein were very similar and gave much lower values than the polyunsaturated sunflower and soyabean oils. The lower values given by sunflower oil compared with soyabean oil are as one expects on theoretical grounds and the opposite of the PV test.

The AV seems to be one of the best test for frying oils, giving results compatible with theory and with practical experience.

10. Polymer Content

Good fresh oils have polymer content below 0.5% but after repeated use, values can rise to 30 or 40% (Peled 1975). In the past, this was considered a decisive test by government food inspectors, but it is laborious to carry out and is reported to have a large experimental error. In recent times it has been replaced by the test for polar compounds which is easier to carry out and is said to correlate well with polymer content.

In this trial, the values obtained during the five days frying are shown in Figure 10. On the fifth day the values of the monounsaturated oils were very similar and a little lower than the soyabean oil. The sunflower oil was equal best up to day 3 but rose steeply afterwards and this behaviour is not supported by the other tests of this trial. For example, the linoleic plus linolenic acid content remained constant between the third and fifth day, and the polar compounds do not show any sharp change Figure 11. This result therefore seems to be an artefact.

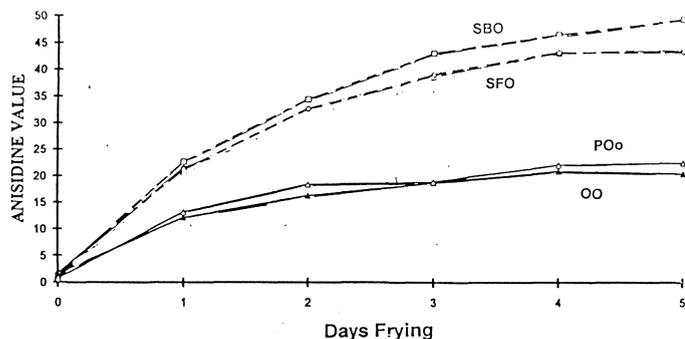


Figure 8
Anisidine Value of Oils During Frying

9. Totox Value

This value is defined as $2xPV + AV$ and so gives twice as much weight to the PV than to the AV, but in frying, the AV changes much more than the PV and this is the predominant variable.

The results obtained in this trial are shown in Figure 9. The lowest (best) values were obtained with olive oil, with palm olein clear second and sunflower oil and soyabean oil third.

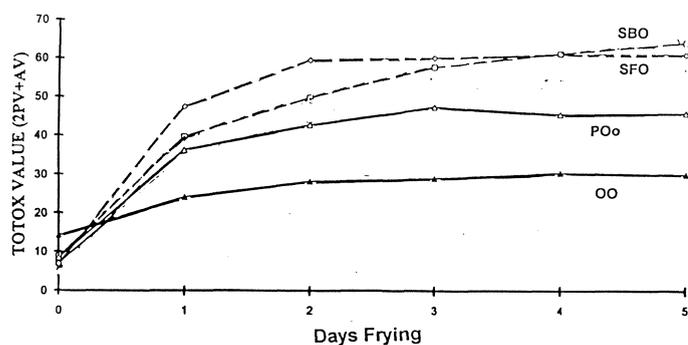


Figure 9
Totox Value of Oils During Frying

This test suffers from the objections that if under frying conditions, the PV has much higher experimental error than the AV, combining the two weakens the power of the test.

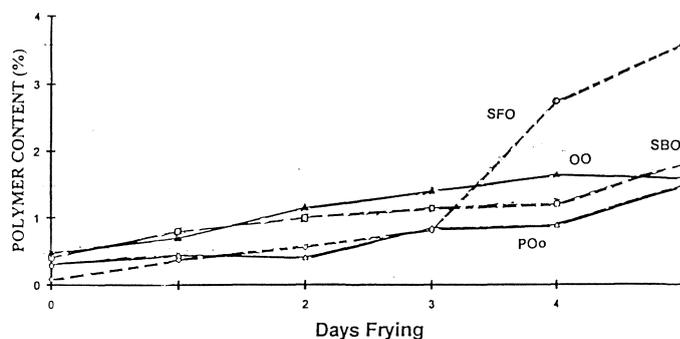


Figure 10
Polymer Content of Oils During Frying

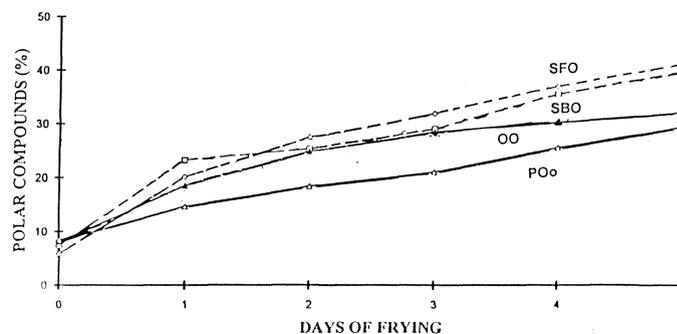


Figure 11
Polar Compounds of Oils During Frying

11. Polar Compounds

This test is now considered to be one of the most reliable for assessing oil deterioration (Wetherit 1988). Research has shown that the fraction of oxidised oil most toxic to laboratory animals is polar and in several European countries, a value of max 27% is enforced on commercial frying operations.

One weakness of the test is that some oils have inherently higher levels of polar compounds which are not the same as the harmful products formed when abusing the oil. Some people therefore advocate taking the increase in polar compounds rather than the value itself, but this procedure would be open to other objections.

The results obtained in this trial are shown in Figure 11 and it is seen that the monounsaturated oils palm olein and olive oil have lower values than the sunflower oil and soyabean oil.

SUMMARY AND CONCLUSIONS

From the results of the tests described in this paper, it is evident that different test placed the oils in different order of merit, which is a very unsatisfactory state of affairs. Table V gives a summary of all the test results and it can be seen that the monounsaturated oils scored more highly, occupying 64% of the first and second places, and more importantly, they scored higher in the more powerful tests, such as polar compounds, polymer content, foam height IV and asinidine value. Olive oil scored higher than any other oil, occupying five of the eleven first places and eight of the first or second places.

The overall conclusion is that laboratory tests can only serve as a preliminary guide in the selection of frying oils and the final decision should be made after a plant trial and storage of the fried food for the required time.

Table V
Summary of test Results

Test	Order of Performance (best oil first)			
	1	2	3	4
1 Colour (1" Lovi. Red)	SBO	SFO	POo ≈ OO	
2 FFA	SBO	SFO	POo	<u>OO</u>
3 Smoke Pint	SBO	SFO	POo	<u>OO</u>
4 Foam Height	POo	OO	SBO	SFO
5 18:2-18:3 Reduction	OO ≈ SBO	≈ POo	<u>SFO</u>	
6 IV Reduction	<u>OO</u> ≈ POo	SBO	SFO	
7 PV	OO ≈ SBO	SFO	POo	
8 AV	<u>OO</u> ≈ POo	SFO	SBO	
9 Totox	OO	POo	SFO ≈ SBO	
10 Polymer Content	POo	OO	SBO	<u>SFO</u>
11 Polar Compounds	POo	OO	SBO ≈ SFO	

———— Very different from the others

≈ Approximately equal