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UNPLEASANT ODOURS OF RAPESEED OIL HEATED TO FRYING TEMPERATURES

by

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Unpleasant Odours of Rapeseed Oil Heated to Frying Temperatures

Abstract

Both rapeseed oil (RSO) and soybean oil have been criticized for unpleasant odours when they are heated to deep fat frying temperatures. Sensory studies by 7-9 trained judges using a linear scale indicate that RSO and hydrogenated RSO when heated to 190C and smelled at 55C had significantly stronger odours than soybean oil, corn oil, safflower oil and sunflower oil. When RSO and hydrogenated RSO varieties were held at 190C for extended periods of time the odour intensity values (OIV) and thiobarbituric acid values (TBA) increased to a peak at approximately 10 minutes then plateaued. No significant changes in fatty acid patterns were found between unheated oils and oils held for 40 minutes at 190C. Hydrogenation effect on RSO odour, tested over three experiments, was never significantly different but did consistently lower the heated OIV of RSO. The OIV's of heated low glucosinolate RSO were more similar to heated soybean oil odour than were the heated OIV's of high glucosinolate oils. High and low erucic acid RSO varieties from 3 processors were compared with chemical odour standards for buttery, sweet, sulfurous, painty, and fishy. High erucic acid RSO's were significantly lower in fishy odour ($P < 0.01$) and tended to be lower in painty ($P < 0.10$) and sulfurous odour ($P < 0.10$). The oils from one processor were consistently, but not significantly, lower in all odour parameters than the oils from the other two processors. Serial dilutions of a masking agent in heated RSO showed that 11.35 ppm significantly reduced heated OIV's; however, more extensive testing with the optimum level of masking showed no significant reduction of OIV. The significance of heated RSO to consumers was assessed with a telephone survey of 400 Manitobans who fried foods more than once monthly. Sixty-five percent of the respondents had heard of RSO while 41% had used it at some time and 11% were using it currently. Most respondents used RSO because of economy and had no complaints about the oil. However, 13-18% of RSO users associated unpleasant sensory characteristics with RSO. Further, 28% who had discontinued using RSO described the kitchen odour as unpleasant while 24% described taste as unpleasant. Some significant correlations between RSO use and family size, occupation, and economical food shopping behaviour were evident.

INTRODUCTION

Rapeseed is an oil-bearing seed from plants of the Brassica genus. The oil produced from these seeds has been known in Europe and the Orient since ancient times. It was used in the middle ages as a lamp oil. By the 16th century rapeseed oil (RSO) had gained wide acceptance as an edible oil as well as for lighting purposes. At the present time RSO accounts for 10-11% of the world's edible oil production (Canadian Department of Industry, Trade and Commerce, 1974).

Rapeseed was first introduced on the Canadian prairies in 1943 as a wartime effort to produce oil for industrial needs. Exploration of the edible qualities of the oil by Lips et al. (1948) led to the first commercial extraction in 1956. From this small beginning RSO has become Canada's major oilseed crop. The production of RSO increased from 42% to 58%* between 1971 and 1973 while the production of soybean oil fell from 54% to 37%* in the same period (Canadian Department of Industry, Trade & Commerce, 1974).

If RSO is to achieve its full potential in the market place there must be maximum satisfaction with important consumer qualities. These qualities are both nutritional and functional in nature. The functional qualities include physical properties, which appear to offer very little problem at this time, and the sensory properties of taste and odour. Sensory properties directly affect consumer acceptance of foods. For example Pilgrim et al. (1963) have shown that food preference accounted for 31% of the variability in food choices made by some 200 army personnel in a cafeteria eating situation. The odour of a food is a part of its overall flavour impression and is one of the first parameters which the consumer notices when using a product.

*of total oil production in Canada.

In the development of the RSO industry the emphasis has been on developing a bland flavour-stable product. However, unpleasant odours associated with heated RSO were documented by Niewiadomski (1970) in a report to the Oils and Fats Group of the Society of Chemical Industry in London. He suggested that the odour was caused by unfavourable changes in the seeds during storage, which was probably the oxidation of unsaturated fatty acids. In 1969 a consumer survey was carried out by the Department of Foods and Nutrition, University of Manitoba, to see if RSO and soybean oil were the same or different in odour pleasantness at frying temperatures. It was found that 52 out of 74 subjects preferred the odour of hot soybean oil to that of hot RSO. However, when the oils were compared at room temperature their odours were equally well liked. The unpleasant odour of RSO when heated to frying temperatures could be a problem to the cook and the customers in a restaurant when frying odours transfer to the dining area. Odour could also be a problem in homes where the kitchen and dining areas are often joined.

Consumer concern with these odour properties and their definition in laboratory tests are the focus of this study.

REVIEW OF LITERATURE

Varieties of Canadian Rapeseed

The varieties of rapeseed grown in Canada (Table 1) vary according to climatic conditions. Varieties have been deliberately developed which are low in erucic acid and in glucosinolates. Erucic acid has been implicated in nutritional problems with RSO while glucosinolates in rapeseed meal cause toxicity when it is used above certain levels for animal feeding. The oil presently on the market is from the low erucic, high glucosinolate varieties. However, a low erucic, low glucosinolate strain has recently been developed and is now in commercial production (Stefansson, 1974).

The fatty acid patterns of RSO are altered when the level of erucic acid is reduced (Table 2). When the C20:1 and C22:1 fatty acids are reduced there is a dramatic increase in oleic acid, C18:1, and a slight increase in linoleic and linolenic acids, C18:2 and C18:3.

In most of the available literature, RSO from high erucic acid varieties of rapeseed has been used. Where studies have used low erucic acid RSO, which has only been available since 1971, it will be specifically noted.

Nutritional Problems

The nutritional quality of RSO is of concern to consumers. Nutritional problems with RSO were reported at the International Conference on the Science, Technology and Marketing of Rapeseed and Rapeseed Products in 1970 at Ste. Adele by several workers (Beare-Rogers, 1970; Rocquelin and Martin, 1970; Abdellatif and Vles, 1970). Beare-Rogers (1970) reported that fatty deposits accumulated in the heart tissue of rats fed high erucic RSO on a short term basis while in longer

Table 1. Classification of Canadian Rapeseed Varieties (Weinberg, 1972 and Stefansson, personal communication).

Characteristic	B. napus	B. campestris
High erucic acid High glucosinolate	Target Turret	Echo* Polar* Arlo*
Low erucic acid High glucosinolate	Oro Zephyr	Midas Span Torch
High erucic acid Low glucosinolate	Bronowski**	
Low erucic acid Low glucosinolate	Tower (S-71-940) N-71-1788***	

*more recently considered intermediate erucic acid varieties (5% - 40% erucic acid).

**grown in Canada for experimental purposes only (intermediate erucic acid).

***experimental strain.

Table 2. Fatty Acid Composition of RSO from High and Low Erucic Acid Varieties of Rapeseed (Weinberg, 1972).

	Percent of Methyl Esters			
	B. napus		B. campestris	
	Target	Zephyr	Echo	Span
16:0	5	5	4	4
18:0	1	1	1	1
18:1	24	60	36	55
18:2	17	20	20	21
18:3	9	10	10	10
20:1	13	2	10	4
22:1	32	1	20	5

term experiments necrotic lesions on the heart developed. A voluntary change-over from high erucic to low erucic varieties of rapeseed was recommended by J.A. Campbell (1970) as a policy statement of the Canadian Food and Drug Directorate. In 1973 a stronger statement from the Canadian Health Protection Branch was forthcoming. A number of laboratories had confirmed the early report of fatty deposition on the heart muscle, inhibited growth in young animals, and finally longer term focal necrotic lesions leading to fibrotic changes in the heart muscle (Anon., Food in Canada, 1973(a)).

With this information the Canadian Health Protection Branch and the food processors voluntarily agreed to reduce the content of C22 monoenoic fatty acids in processed edible fats and oils to 5%, effective December 1, 1973. The 5% restriction necessitated a change in production from high erucic rapeseed varieties to the new low erucic varieties developed by Agriculture Canada (Anon., Food in Canada, 1973(b)).

Functional Properties

Consumers appreciate food products of high quality which function in a manner appropriate to the market form. RSO compares favourably with other popular oils on the market in functional properties.

In margarine formulation a fat that will remain stable in the beta-prime crystal form is preferred. If it transforms easily to the beta crystal form the margarine will become grainy on storage (Weiss, 1970). Rapeseed and marine oils which have high levels of C20 and C22 fatty acids form small beta-prime crystals and perform quite satisfactorily in margarine formulation (Weiss, 1970). However, Teasdale et al. (1970) reported that his results did not agree with his earlier tests for graininess of low erucic RSO in a margarine formulation.

In shortenings and compound cooking fats a broad range of plasticity and good emulsifying properties are desirable. Riiner and Ohlson (1971) report, in a review, that Tremazi found hydrogenated RSO to have a broader plastic range than hydrogenated cottonseed oil; however plastic range can vary with the processing. Linteris et al. (1958) found that hydrogenated RSO performed satisfactorily in standard yellow layer cakes. Teasdale (1970) also concludes that low erucic RSO should be satisfactory for use in blended shortenings.

Liquid oil is sold to the consumer for use in salad dressings and for frying. As a salad oil, viscosity is the important property to consider. Fresh RSO was found to be more viscous than sunflower and corn oils (Vaisey and Shaykewich, 1969), and less viscous than peanut oil (Snyder and Moore, 1969), which coincides with early work on RSO by Lips et al. (1948) who found similar viscosity differences between corn oil and RSO. However, Lips et al. (1948) also found that a taste panel was unable to detect any significant differences in mouthfeel between these oils. One might conclude that slight viscosity differences are not as important as believed.

The significant physical properties of frying fats are colour, smoke point and viscosity patterns after re-use. The oil should be light in colour, maintain a smoke point well above the deep fat frying temperature after successive fryings and should not become much more viscous on re-use. Vaisey and Shaykewich (1969) reported that the smoke points of two brands of RSO (236.7C) were within $\pm$ 0.56C of the smoke points of corn oil (236.7C) and sunflower oil (237.2C) and approximately 11.7C higher than soybean oil (226.1C). After 12 fryings of doughnuts the smoke points of corn, sunflower and RSO dropped

approximately 12C, but were still well above the temperature commonly used for frying (190-195C).

There has been some conflicting evidence reported as to viscosity patterns of re-used RSO. Vaisey and Shaykewich (1969) found no increase in viscosity of re-used RSO. However, Cobden (unpublished data, University of Manitoba, 1973) found that the apparent viscosity estimated in centipoises at 50 rpm increased from 35% to 60% when low erucic acid RSO was heated to 190C for 40 hours. Snyder and Moore (1969) also found that the viscosity of RSO and peanut oil increased after successive re-use. From these and the other findings cited it can be concluded that overall, RSO and low erucic acid RSO are quite comparable to other popular vegetable oils with regard to functional properties.

Flavour Properties

Flavour of the oil and foods prepared with it.

While early work by Lips in 1949 showed that unheated RSO had a blander flavour than corn oil, doughnuts fried in RSO had a stronger less desirable flavour than those fried in corn oil. However, more recent work by Vaisey and Shaykewich (1969) showed that doughnuts fried in RSO received flavour ratings comparable to doughnuts fried in corn, sunflower and soybean oils. Moreover, the flavour of doughnuts fried in fresh RSO was not significantly different from doughnuts fried in oil used 6 times. The improved performance found by the latter researchers is probably due to improved oil processing and deodorizing techniques over the past 25 years.

Flavour stability during storage.

Flavour stability of stored RSO has been investigated and compared with other oils. The terms reversion and oxidation are

frequently used in connection with oil stability. Reversion is defined by Weiss (1970) as "the return of the flavour that the particular oil had before it was deodorized", whereas oxidative rancidity is defined as "the overall flavour defect noted when an oil first becomes oxidized". Badings (1970) explains that during the oxidation of an unsaturated fatty acid one quantum of energy displaces one hydrogen atom adjacent to a carbon-carrying double bond to give a free radical (Figure 1). Molecular oxygen can then unite with the carbon which carries the free radical to form activated peroxide. The activated peroxide can then displace a hydrogen atom from another unsaturated fatty acid to form hydroperoxides, which are mostly tasteless and odourless but which rapidly break down to form ketones, alcohols, aldehydes and other oxidation products which have strong disagreeable flavours and odours. Forss (1972) concludes that linoleic, linolenic, and arachidonic acids are probably the most important unsaturated fatty acids from the flavour and odour standpoint because they readily form these hydroperoxides.

Badings (1970) compiled a list of known autoxidation breakdown products some of which are shown in Table 3. The flavour threshold values reported for these oxidation products are quite low and the descriptive terms used are reminiscent of oxidized oil flavours and odours. Badings concludes that the oxidation of lipids leads to a large number of flavour compounds with low flavour threshold values. Therefore even limited autoxidation can cause flavour defects. It seems to the author that although reversion and oxidation are treated as different flavour problems by the literature they may simply represent degrees of the oxidation process.

Figure 1. Oxidation of an unsaturated fatty acid. (adapted from Badings, 1970).

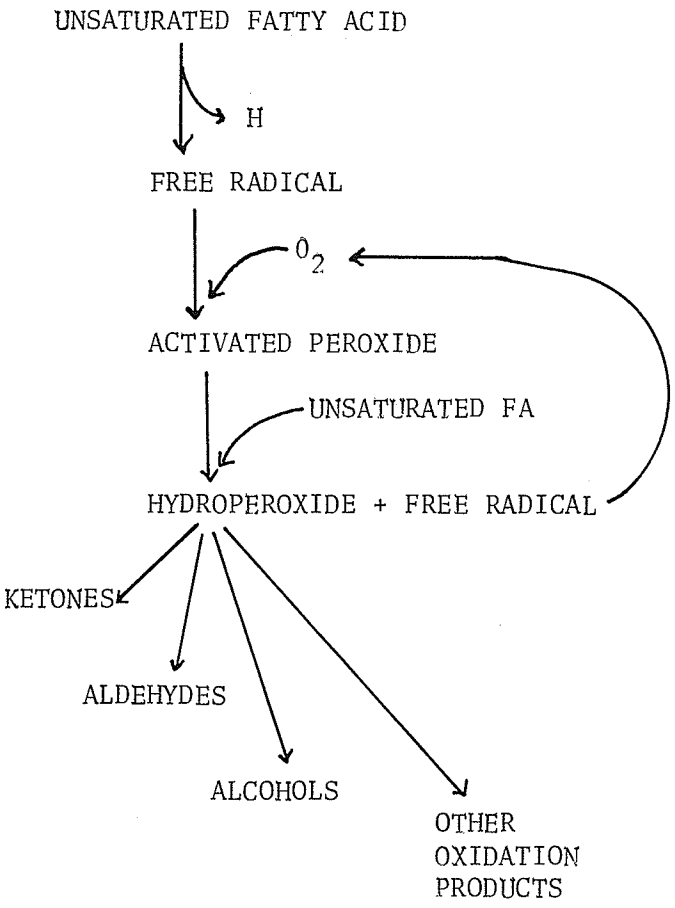


Table 3. Volatile components which contribute to autoxidation off-flavours in fats and oils (adapted from Badings, 1970).

Compound		Threshold Value* (in ppm)	Description of Flavour
Type	Name		
alkanals	hexanal	0.08	green
	octanal	0.04	fatty
2-alkenals	2 cis-pentenal	0.80	sharp, fatty
other alkenals	4 trans-heptenal	0.10	putty
2,4 alkadienals	2 trans, 4 cis-heptadienal	0.04	frying odour
other alka-dienals	2 trans, 6 cis-nonadienal	0.0015	fresh cucumber
1-alken-3-ones	1-penten-3-one	0.003	sharp, fishy
1-alken-3-ols	1-octen-3-ol	0.0075	mushroom

*Threshold values in water.

In order to assess flavour stability Moser et al. (1965) held soybean, crambe, mustard and RSO for 4 days at 60C and found that all the oils developed similar off-flavours usually found in soybean oil . These 4 oils were compared because they all have similar linolenate content which these researchers believe is the cause of the off-flavour in soybean oil. The off-flavours were described as rancid, beany, grassy and painty. The addition of citric acid, an antioxidant, definitely improved the off-flavour scores of both fresh and aged oils and reduced the frequency and quality of flavour descriptors. For example crambe was described as rancid rather than painty. The soybean, mustard seed and RSO were described as buttery, beany and grassy rather than rancid.

Vaisey and Shaykewich (1969) reported an accelerated storage test using 2 market brands of RSO, soybean, corn, and sunflower oil, which were aged for 8 days at 60C. One brand of RSO remained unchanged in odour as did corn and soybean oil. However the other brand of RSO was less stable than corn and soybean oil but more stable than sunflower oil. Generally it seems that RSO which is protected from autoxidation by antioxidants is comparable in flavour stability to other oils on the Canadian market.

The possibility of masking the unpleasant flavour and odour compounds related to oxidative rancidity has been attempted by flavour companies. One patent by Feenstra and Keppler (1972) proposes to counteract the odour by adding a mixture of aldehydes which have organoleptically acceptable polar groups. The flavour counteractant would have the representative structure R - CH = CH - CH = CH - Z in which R is an alkyl group containing up to 9 carbon atoms and Z is the

polar group. To prolong odour stability on storage a precursor of the counteractant would be added which would convert to the counteractant during storage. The combination and concentration of aldehydes used would be determined by the particular odour compounds being masked. This approach seems to have interesting possibilities.

Room odour at frying temperatures.

While the flavour of RSO during storage and as a food ingredient has been investigated to some extent there are almost no in-depth evaluations of RSO odour when it is being used for frying. Niewiadomski (1970) commented that RSO gave forth an odour when used for frying that was probably caused by oxidation of unsaturated fatty acids. Unpublished tests at the University of Manitoba, Department of Foods and Nutrition, documented the hot RSO odour problem in 1968. When the odour of hot soybean oil was compared to that of hot RSO at 204C, 52 out of 74 subjects preferred the odour of hot soybean oil. In contrast the odours of unheated oils were equally well liked when the oils were compared at room temperature.

In the study mentioned earlier by Vaisey and Shaykewich (1969) the odours of RSO, corn, sunflower and soybean oils in which doughnuts had been fried were compared with their unheated counterparts at room temperature. The used oils had significantly stronger odours than their unheated counterparts. When the oil species after one frying were compared at room temperature with each other soybean oil had the best odour, RSO and sunflower were intermediate, and corn oil was the least desirable.

Note that all of the oils in the latter study were examined at room temperature. Greater differences might have been apparent if the

oils had been evaluated at 50C, the AOCS standard temperature for oil evaluation (Smouse, 1972).

Soybean Oil: A Model

Since little work on the cause of RSO odour has been reported, a model is needed which has been more thoroughly studied. A suitable model should have similar chemical and flavour properties.

Table 4 compares the fatty acid composition of several popular cooking oils with RSO and low erucic acid RSO. The RSO's and soybean oil are very similar in linolenic acid content. This is a significant similarity since linolenic acid has been mentioned by several researchers (Meijboom et al., 1972; Badings, 1960; Moser et al., 1965; Evans et al., 1971, 1972) as a possible cause of flavour and odour reversion. Moser et al. (1965) concluded that soybean oil and RSO developed similar oxidative off-flavours and suggested that comparisons between the two would be useful in studying oxidative changes.

Researchers at the Northern Regional Laboratories in Peoria, Illinois, have been concerned with hot soybean oil odour for some years. They have carried out extensive room odour tests on soybean oil and a variety of other oils. Their tests are conducted in a closed insulated room which has a controlled air-conditioning system that can completely change the air in the room in seven minutes. The judges enter the room through three buffer doors so that there is little possibility of outside air contamination. The oil is heated to 195C in an electric saucepan. The judge stands 5 feet away from the counter where the oil is being heated and observes the room odour. A 10-point linear scale is used to assess the quality of the room odour (Table 5). In addition descriptive terms are reported by judges with intensity ratings for each term the

Table 4. Fatty Acid Composition of Popular Cooking Oils.

Percent of methyl esters	RSO (Weinberg 1972)	Low erucic acid RSO (Weinberg 1972)	Soybean oil (Cowan 1973)	Corn oil (Craig 1970)	Sunflower oil (Craig 1970)
16:0	5	5	11	12	10
18:0	1	1	4	2	4
18:1	24	60	23	29	16
18:2	17	20	54	56	73
18:3	9	10	8	1	-
20:1	13	2	-	-	-
22:1	32	1	-	-	-

Table 5. Ten-Point Linear Scale used to Assess Room Odour Quality Used at Northern Regional Laboratories.

Name _____ Date _____

Please indicate the score by placing a check mark (✓) in the space opposite the value.

Score		Sample I	Sample II
Very good	10		
Good	9		
	8		
Fair	7		
	6		
Poor	5		
	4		
Bad	3		
	2		
Very bad	1		

Please indicate intensities of odours by placing check marks opposite the odour description. ✓ = weak, ✓✓ = moderate, ✓✓✓ = strong.

Odor description	Sample I	Sample II

judges use; 1 = weak odour, 3 = strong odour. However, 25% of the judges must report the same descriptive term before its presence is regarded as important. These weighted descriptive terms are called the odour intensity value (OIV). The variables which have been investigated by researchers at the Northern Regional Laboratories will be discussed in the following sequence:

oil species

heating times

prior oxidation

antioxidants and antifoam agents

hydrogenation

catalysts used in hydrogenation.

From tests with several different oil species purchased from local markets, Evans et al. (1971) reported that corn oil and safflower oil were given the best room odour scores, olive oil and peanut oil the poorest, with soybean and cottonseed oils intermediate in room odour pleasantness. The temperature ranged from 185C to 202C. Three soybean oils (8% linolenate, 1.2% linolenate, 8% linolenate with added anti-oxidant) were used and in all but one case the odour became less pleasant as the temperature increased.

The consequence of heating a second time was assessed by heating and evaluating several oils, then storing them for one week at room temperature in the dark and evaluating the room odour again. The room odour scores improved on the second heating which indicated to Evans et al. (1971) that odour is not strongly dependant on prior oxidation, but that the odour volatiles may be considerably modified by heat and oxygen during the heating process.

An antioxidant, Tenox 6 (10% BHA, 10% BHT, 6% citric acid), and a silicone antifoam agent were added to two samples of soybean oil. Improvement in room odour was observed for both samples. However, when the antifoam agent was used alone, at 5 ppm, the room odour was improved as much as when the two additives were used together. These findings further substantiated Evans' theory that the odour is the result of heat and oxygen on the volatilizing substances at the time of heating rather than the effect of prior oxidation (Evans et al., 1971).

If unsaturation is implicated as one cause of soybean oil and RSO room odours one would expect hydrogenation to reduce the room odour problem. Conflicting results regarding the effects of hydrogenation on room odour have been reported by Northern Regional Laboratories. In one test (Evans et al., 1971), hydrogenated soybean oil with 1.8% linolenic acid gave significantly better room odour scores than a sample of soybean oil with 8% linolenic acid. However in two later papers by Cowan et al. (1973) and Evans et al. (1972), hydrogenated soybean oil produced other novel unpleasant odours which had not been noticed in the original oil.

The type of catalyst used in hydrogenation has been reported to affect room odour. Cowan (1970) reported that copper hydrogenated soybean oil received significantly better room odour scores than nickel hydrogenated soybean oil. The odour character of the oils was different. The nickel hydrogenated oil received a larger OIV for "fishy" while the copper hydrogenated oil received higher "hot oil" and "rancid" responses. It seems that a copper catalyst which selectively hydrogenates linolenic acid improves the room odour of soybean oil. These results were further substantiated by Cowan et al. (1973).

Since it is felt that the products of fatty acid oxidation are the cause of many undesirable odours and flavours in cooking oils, Evans et al. (1972) added a number of these chemicals to a bland cottonseed oil to check the room odour response (Table 6). These chemicals did not cause a different odour to the oil even when added at levels which were far above their flavour thresholds. Only one score was significantly different from the control. If these compounds are, in fact, responsible for the room odour observed one can surmise that considerable oxidation must take place during frying to reach the concentrations needed to impart off-odours to the room. Possibly the high heat caused the added chemicals to change to less odourous compounds.

Another possible source of odour in RSO may be the sulfur compounds introduced into the oil from the meal during oil extraction. The amount of sulfur in the seed depends upon the seed type and growing conditions. While the refining process removes most of the sulfur compounds from the oil, Daun (1975) reported that RSO contained 1-57 ppm sulfur depending upon the stage of refinement (Table 7). The sulfur content of finished, refined, bleached oil ranges from 1-7 ppm which seems minimal compared to the unrefined oil. However, the detection threshold in air of isothiocyanates, one class of sulfur-containing compounds found in RSO, is reported to be approximately 0.2 ppm (Stahl, 1973).

Moser et al. (1965) found that crambe, mustard, and RSO, which all contain glucosinolates, developed rubbery flavours often accompanied by a garlic or onion-like flavour, which soybean oil did not. These novel flavours were only noticed when the oils were stabilized with

Table 6. Effect of Addition of Fatty Acid Oxidation Products on the Room Odour Score of Hot Cottonseed Oil (Evans et al., 1972).

Compound	Concentration, ppm	Odour Scores	Odours OIV Index
cis-4-Heptenal	5	6.0	Rancid 0.3, hot oil 0.2
cis-4-Heptenal	100	5.5	Rancid 0.6, hot oil 0.4
1-Octene-3-ol	25	6.2	Hot oil 0.6, burnt 0.4
1-Octene-3-ol	50	6.5	Hot oil 0.5, rancid 0.4
1-Decyne	25	7.0	Hot oil 0.4, rancid 0.4
1-Decyne	50	6.4	Hot oil 0.5, rancid 0.3
2,4-Decadienal	50	5.8	Rancid 0.5, burnt 0.3
2,4-Decadienal	200	6.4	Hot oil 0.4, rancid 0.3
3,4-Decadienal	100	6.5	Rancid 0.6, hot oil 0.4
2,4-Dodecadienal	100	5.7	Rancid 0.5, fishy 0.3
2,4-Dodecadienal	200	4.3*	Rancid 0.6, fishy 0.6
Control cottonseed oil	-	6.4	Hot oil 0.6, rancid 0.4

*Significantly different from control.

Table 7. Effect of Processing on the Sulfur Content of RSO (adapted from Daun, 1975).

Processed Oil Sample	Total Sulfur (ppm)
Expelled	19-25
Extracted	10-57
Crude	5-30
Degummed	9-16
Refined	4-9
Bleached	0.5-8
Deodorized	1

citric acid and exposed to fluorescent light. The authors suggested that the unusual flavours in the oils may have been due to a reaction involving sulfur compounds.

The researchers at Northern Regional Laboratories (Evans et al., 1971, 1972; Cowan et al., 1973) have attempted to correlate flavour panel scores of oxidized oils with objective chemical tests in order to quantify their results. Evans et al. (1971) added an antioxidant (Tenox 6) to soybean oil then carried out both odour panel evaluation and peroxide value tests, by the active oxygen method (AOM). They found that the addition of the antioxidant affected the AOM value but did not have a significant effect on room odour scores. Evans et al. (1972) oxidized soybean oil to four different peroxide levels and found that there was negligible change in room odour scores or character after oxidation. They conclude that "the slight change on repeated heatings would indicate that prior oxidation, as measured by peroxide value, does not have much direct effect on room odor". Cowan et al. (1973) also found that oxidative stability as measured by the peroxide value did not correlate with room odour scores.

Chemical Tests for the Extent of Oxidation

There are several chemical tests that have been used to evaluate the extent of oxidation in oils. These tests fall into two broad categories: colorimetric methods and gas liquid chromatography (GLC) methods of analysis.

The colorimetric methods are distinguished by the reagents they employ:

thiobarbituric acid (TBA)

benzidine

anisidine

peroxide.

Thiobarbituric acid tests measure oxidative rancidity by indicating the relative amount of unsaturated aldehydes, thought to be mainly malonaldehyde, and other 3 carbon derivatives similar to malonaldehyde (Patton, 197). The pink pigment read at 532 mu has been found to be a useful indicator of lipid oxidation (Patton, 1973). However, Fioriti et al. (1974) found that TBA readings did not correlate well with sensory findings on flavour changes in aged soybean oil and beef tallow, while Biggar et al. (1975) reported good correlation between TBA values and oxidative flavour deterioration in canned whitefish. Patton (1973) suggests that the complex factors leading to the pigment production make it essential that the test results be considered with sensory evaluation and other suitable chemical tests.

The benzidine test has been found to be an excellent indicator of past oxidation but only gave fair correlation with soybean oil flavour scores (Smouse and Maines, 1971). Fioriti (1974) found poor correlation with oil flavour scores and concluded that the test was more indicative of oil type than degree of oxidation.

The anisidine test has been used by List et al. (1974) instead of benzidine because the benzidine reagent has been found to be carcinogenic. The test is similar to the benzidine test except that isooctane is used as the fat solvent. List et al. (1974) found that the ansidine test scores correlated well with flavour scores of freshly processed soybean oil from sound beans but not with aged oil or oil from damaged beans.

Peroxide values are measures of the primary oxidation products of oil degradation, hydroperoxides. Fioriti et al. (1974) found that peroxide values correlated well with pentane values, which is predictable since pentane is formed by the thermal decomposition of hydroperoxides.

Test methods which rely on GLC to elucidate various representative oxidation products are:

oxygen absorption

pentane values

octanoic acid values.

The oxygen absorption method measures the amount of oxygen used up in the headspace gas of a sealed bottle of oil. A measured amount of the headspace gas is injected into a gas chromatograph and the percent of oxygen in the headspace is obtained. Fioriti et al. (1974) found that the oxygen absorbed during storage correlated with peroxide and pentane values but that the time required to carry out the test limited its usefulness.

Pentane values are also derived from GLC analysis. Pentane is formed by thermal decomposition of hydroperoxides. Scholz and Ptak (1966) found that this method was sensitive to the detection and quantification of oxidative changes in oils. The method minimizes manipulation of the sample and avoids altering the products of oxidation. Scholz (1966) found that the results correlated well with panel tests of cottonseed oil.

Octanoic acid values also estimate the extent of oxidation of an oil by measuring the production of octanoic acid. However, Fioriti et al. (1974) found that the correlation with flavour scores using a variety of fats and oils (beef tallow, lard, soybean oil, safflower oil and corn oil) were poor and that the values at the end of the oxidation period were not significantly different from those at the beginning of the period. This method also proved to be very time-consuming.

Summary

In summarizing the possible causes of undesirable room odour from heated RSO the weight of the evidence points toward the poly-unsaturate content of the oil and more specifically toward the linolenate content as the main source of odorous compounds. From the work with soybean oil it has been shown that various treatments such as hydrogenation, addition of stabilizing agents, aging and temperature of heating affect the magnitude and, to some extent, the quality of the odours. Another possible source of odour is the trace of sulfur from isothiocyanate or oxazolidinethione compounds in the seed. The influence of most of these variables on the odour of hot RSO has not yet been assessed; therefore few conclusions about hot RSO odour can be drawn at this time.

EXPERIMENTAL METHODS

Experimental Design

This project was divided into two distinct phases.

A. Recognizing that top quality oil should be bland under all conditions of use, a series of laboratory studies were done to define the scope of the "hot" odour problem in rapeseed oil (RSO) using both chemical and sensory techniques. In the laboratory tests of the effect of heating for periods up to 40 minutes were examined among several oil variables. These variables included:

Species - The differences in odour produced by RSO and other popular oil species were examined.

Varieties - The differences between high and low erucic acid RSO varieties and between high and low glucosinolate RSO varieties were assessed.

Hydrogenation - The effects of hydrogenation on odour development were examined in several of the RSO varieties.

Commercial masking agent - Preliminary studies were done with a commercial masking agent as a possible solution to the odour problem.

These variables were investigated through a series of separate experiments using both odour panel evaluations and chemical measurements in which various oils and heating treatments were evaluated. Table 8 summarizes the specific oils and treatments that were used in each experiment.

B. A telephone survey of 400 Manitoba households was carried out to determine the extent of consumer use of RSO and to identify any flavour or odour problems which may have been obvious to consumers.

Table 8. Summary of Laboratory Experiments*.

Exp.#	Title	Oil Type**	Heat Treatments	Exp. Treatments
1	Comparison of high and low erucic acid oils from three different processors	a) High erucic RSO b) Low erucic RSO	a) unheated b) 190C for 0 min.	a) 3 processors b) 2 oil types c) 2 heat treatments = 12
2	Comparison of popular oil species.	a) RSO - high glucosinolate b) Hydrogenated RSO - high glucosinolate c) Soybean oil d) Corn oil e) Sunflower oil f) Safflower oil	a) unheated b) 190C for 10 min.	a) 6 oils b) 5 heat treatments = 30
3	Detection threshold of heated RSO in mineral oil.	a) Mineral oil b) RSO - high glucosinolate	RSO heated for 10 min. at 190C	10 levels of RSO = 10
4	Comparison of odour changes during prolonged heating of oils.	a) RSO - high glucosinolate b) Hydrogenated RSO - high glucosinolate c) Soybean oil	a) unheated b) 190C for 0 min. c) 190C for 10 min. d) 190C for 20 min. e) 190C for 40 min.	a) 3 oils b) 5 heat treatments = 15
5	Comparison of odour changes during prolonged heating of low glucosinolate rapeseed oils.	a) RSO - strain S-71-940 (Tower) b) Hydrogenated RSO - strain S-71-940 (Tower) c) RSO - strain N-71-1788 d) Hydrogenated RSO - strain N-71-1788 e) Soybean oil	As in Experiment 4.	a) 5 oils b) 5 heat treatments = 25

continued

Table 8 - continued - Summary of Laboratory Experiments*.

Exp.#	Title	Oil Type**	Heat Treatments	Exp. Treatments
6	Assessment of effect of odour masking compound at 1135 ppm on odour development of heated oil.	a) RSO - high glucosinolate b) Hydrogenated RSO - high glucosinolate c) Soybean oil	a) unheated b) heated for 10 min. at 190C	a) 3 oils b) 2 heat treatments c) 2 mask levels (0 and 1135 ppm) = 12
7	Identification of the appropriate level of masking agent in heated oil.	RSO - high glucosinolate	Heated for 10 min. at 190C	5 masking levels (0, 1.135, 11.35, 113.5 and 1135 ppm) = 5
8	Assessment of effect of odour masking compound at 11.35 ppm on odour development of heated oil.	a) RSO - high glucosinolate b) Hydrogenated RSO - high glucosinolate c) Soybean oil	a) unheated b) heated for 10 min. at 190C.	a) 3 oils b) 2 heat treatments c) 2 masking levels (0 and 11.35 ppm) = 12

* All experiments were replicated 3 times.

**Only low erucic oil was used except in Experiment 1.

Materials Used

All rapeseed oil materials used in these experiments were obtained directly from the processor. While processors varied (Table 9), all oils were finished for the consumer market, i.e. alkali refined, deodorized and bleached, commercial antioxidants were added.

A mixture of 0.01% butylated hydroxyanisole (BHA) and 0.01% butylated hydroxytoluene (BHT) was used by Canada Packers as the antioxidant. It is assumed that the same mixture was the antioxidant used by the other processors. The RSO and hydrogenated RSO obtained from Canada Packers and used in experiments 2-4 and 6-8 was known to have been prepared from Zephyr oil. In experiment 2 the other oil species were market brands of oil purchased from local grocery stores. Soybean oil and mineral oil used as reference standards were purchased on the local market. All of the oils used in the experiments were sealed under nitrogen and stored at 4.5C in refrigerators except for the oils used in experiment 1. These oils were stored at -40C.

An imitation olive oil flavour which is sold as a flavour masking agent was obtained from Polack Frutal Works (PFW). PFW was consulted for appropriate levels of addition of their masking agent but their information was appropriate only for lipids to be used without heating. An appropriate level was approximated from their information and from Unilever patents for similar compounds (Feenstra and Keppler, 1972).

Oil Heating Method

In experiments 1 through 5 the oils were heated, 400 ml at a time, in 1 quart pyrex saucepans on a Corningware #PC351 hot plate. The oils were heated to 190C$\pm$5C which corresponds to commonly recommended deep fat frying temperatures. The oils were held at this temperature for

Table 9. Processors of Experimental Oils.

Processor	Experiment
A	1
B	1
C	1, 2, 3, 4, 6, 7, 8
D	5

varying lengths of time. Samples were removed at appropriate times for both sensory and chemical tests. All of the samples were flushed with nitrogen, capped and stored at -40C until needed for sensory and chemical evaluation. In experiments 6 through 8, 50 ml samples of oil with the appropriate level of masking agent added, were heated in red pyrex glasses on the Corningware #PC351 hot plate to 190C$^{+}_{-}$5C for 10 minutes. The samples were then cooled to 55C and presented to the sensory panel for evaluation.

Sensory Evaluation

Evans et al. (1971) approached the study of hot soybean oil odour by heating a sample of oil in a deep fat fryer in a closed room and having the panelists simply judge the odour of the room. A room which could be exclusively devoted to oil odour evaluation was not available for these studies; therefore a method was devised to preheat samples which could be stored and evaluated in booths in a conventional sensory testing room.

A 6 to 9 person trained panel evaluated the odour of the oils in a standard sensory testing room with separate booths, slight positive atmospheric pressure and controlled light. Fifty milliliters of oil were presented in red pyrex glasses and examined at 50C, the AOCS standard temperature for oil odour testing (Smouse, 1972). To maintain a constant temperature the red glasses were placed in water baths on small electric warmers in each panel booth (Figure 2). When more than four samples were to be tested several of these arrangements were set up in adjacent booths and panelists moved from booth to booth in random order to evaluate all the treatments.

In the first odour study, the oils were evaluated in relation to

Figure 2. Warming arrangement for sample presentation.

chemical odour standards which seemed to be similar to the odour qualities in heated RSO (Table 10). These odour standards were selected, after considerable discussion and examination of the oil along with compounds which were considered, by the prospective judges, to be similar to the various components of the oil odour. When using these standards the panelists were instructed to consider each odour standard separately and to rate each oil in relation to each standard using the method of magnitude estimation (Table 11).

The sensory task in experiments 2 through 8 was to decide how strong the overall odour of each sample was in comparison to the unheated soybean oil reference. In these studies a semi-structured scale was used to evaluate the odour intensity of the oil with unheated soybean oil always used as the bland reference sample (Table 12). There were no set divisions in the scale except the beginning and end point, leaving the panelist free to place his mark anywhere along the line. A numerical value was derived by measuring the distance in centimeters from the bland reference point to the panelist's mark. In all tests a coded unheated soybean oil was included as an internal check on the panelists' performance.

Panelist Selection and Training

A seven to nine member panel consisting of faculty, staff members and graduate students of the Departments of Foods and Nutrition and Plant Science were selected to participate in the study on the basis of their interest and availability. Eighteen initial sessions were designed to acquaint the candidates with the techniques of oil odour evaluation. These sessions were conducted in an air-conditioned laboratory around a large table to facilitate group discussion.

Table 10. Oil Odour Standards used in Experiment 1.

Odour Quality	Chemical	Concentration*
buttery	diacetyl (Chem.Service Media, Pa.)	10 ppm
sweet	trans-7-hexanol (unidentified source)	10 ppm
sulfurous	dimethyl disulfide (K.& K. Laboratories)	5 ppm
fishy	trimethylamine (Chem.Service Media, Pa.)	40 ppm
painty	linseed oil (used in absence of a pure chemical)	5% by volume

*All chemicals were diluted in mineral oil.

Table 11. Magnitude Estimation Ballot for Oil Odour Evaluation.

Name _____

Date _____

MAGNITUDE ESTIMATION

You have been given a Standard Sample plus Coded Samples. The task is to rate the intensity of the odour in relation to the intensity of the Standard. If the sample seems 5 times as strong give it a score of 5, if it seems half as strong score it as 1/2. There is no limit to the values of the factors or fractions that you can use as scores. Please rest for 30 seconds before sniffing the next sample.

Standard	Sample	Magnitude Estimation Score
buttery		
sweet		
sulfurous		
fishy		
painty		

Table 12. Semi-Structured Scale for Odour Evaluation.

Name: _____ Booth # _____ Date: _____

You have been given a BLAND reference sample. Smell the reference and then smell each of the other samples. Mark the intensity of the overall ODOUR of each sample.

CODE: _____	bland	⊢——————————⊣	strong
_____	bland	⊢——————————⊣	strong
_____	bland	⊢——————————⊣	strong
_____	bland	⊢——————————⊣	strong

At this time the various odour qualities of the oil were identified by the panel. Some of the descriptors used were: buttery, burnt, sulfurous, sweet, fishy, metallic, beany and painty. These parameters were narrowed down to five: buttery, sweet, sulfurous, fishy and painty. The panelists were in agreement that the "character impact" of the oil was dominated by the painty odour. In subsequent discussion periods several chemical compounds were examined to determine the most appropriate chemical standard for each odour quality. After the panel had agreed on the odour standards and their respective concentrations the judging was moved to panel booths to carry out individual evaluation.

After experiment 1 was completed using this evaluation technique, it was the opinion of the panel and the experimenter that the evaluation technique was too intensive and tedious, and caused too much odour fatigue among the panelists. Therefore a simpler evaluation method was devised in which the panelists rated the overall strength of the sample oil in comparison to a bland soybean oil reference, using a semi-structured scale (Table 12). Since the panel was already trained in odour evaluation a relatively short training period was required to adjust to the new method.

Experiment 2 was used to assess the panelists' ability to discriminate between heated and unheated oils and between degrees of the heated oil odour. To establish confidence in the panelists' discriminatory ability, Kendall's coefficient of concordance was used to measure scoring consistency of each panelist and of the panel as a whole. The coefficient of concordance is a linear function of the average of the coefficients of rank correlation for all pairs of

rankings (Gibbons, 1971). It is a measure of agreement between observers or replications by the same observer which ranges between 0 and 1. Zero means no agreement and 1 means perfect agreement.

Formulae:

k = observers or replications

n = objects

R = ranks

S = sum of squares of deviations of all ranks around the average rank

$$S = \sum_{j=1}^{n} \left[R_j - \frac{k(n-1)}{2} \right]^2$$

W = ratio of S to its maximum value

$$W = \frac{12S}{k^2(n^3-n)}$$

Test for significance based on W may be approximated using χ^2.

$\chi^2 = k(n-1)W$ with n-1 df.

Table 13 shows the coefficient of concordance for each panelist for 3 replicates of experiment 2. The panelists showed significant concordance ($P < 0.005$) with their own scores over all replications. Table 14 shows the coefficient of concordance among panelists in three replications of experiment 2. The panelists showed significant concordance ($P < 0.005$) among their own scores in each of the three replications. The χ^2 are larger for replications than for panelists indicating that the panelists were more in agreement with each other on a particular day than they were with themselves on successive days. Taken together the coefficient of concordance for each panelist and for each replicate established confidence in the judges' discriminatory ability. However, if only the coefficient of concordance for each panelist were considered it would be possible for each panelist to rate

Table 13. Coefficient of Concordance for each Panelist over Three Replications for Experiment 2.

Panelist	W	χ^2 (11df)*
1	.689	38.39
2	.746	41.02
3	.619	34.05
4	.814	44.77
5	.749	41.20
6	.732	40.26
7	.794	43.67
8	.737	40.54
9	.804	44.22

*All χ^2 values were significant ($P < 0.005$).

Table 14. Coefficient of Concordance for each Replication, for all Panelists, for Experiment 2.

Replications	W	χ^2 (11df)*
I	.73	72.27
II	.70	69.30
III	.67	66.33

*All χ^2 values were significant ($P < 0.005$).

the oils in different orders. If the judges were rating the oils in different orders the coefficient of concordance within a replicate would not be significant. The experimenter would then be able to eliminate judges who were not in agreement with the majority of the panel until a significant coefficient of concordance is reached.

Chemical Tests

Thiobarbituric acid (TBA) tests were carried out in duplicate for oil samples from all treatments in experiments 2, 4 and 5. The TBA method was adapted from work published by Vyncke (1970). Because the method was originally used with fish some modifications were necessary including: elimination of trichloroacetic acid (TCA); addition of a solvent; and elimination of heating to develop maximum colour.

Modified TBA Procedure:

1. Accurately weigh 0.5 gm of oil into a 15 ml screw cap glass tube.
2. Add 5 ml hexane to each tube and also to one blank tube. Cap tubes and mix vigourously for 15 seconds.
3. Accurately add 5 ml TBA* solution to each tube. Cap tightly and shake tubes well.
4. Place tubes in a dark cupboard for 15 hours.
5. Aspirate all of the hexane layer off the top.
6. Pipette sufficient solution into cuvettes and read on a Unicam SP 600 spectrophotometer at 528 mu using the "hexane TBA blank" to zero the instrument.

*TBA solution: dissolve 0.283 gm of TBA reagent in 100 ml distilled water. Prepare fresh daily.

TCA was eliminated in the modified method because there was no protein present in the oils to be precipitated. Hexane was added to dissolve the oil and eliminate problems with emulsion formation. The heat treatment was not used because Tarladgis (1964) found that standing the samples at room temperature for 15 hours achieved comparable colour development.

Consumer Survey

A questionnaire was constructed as an instrument to determine the extent of use of rapeseed oil by Manitoba consumers and to define any problems in the use of rapeseed oil which may have been noticed by these consumers.

The questions were divided into six sections (Appendix I).

1. Questions 1 and 2 assessed the frequency and method used to fry foods. If the respondent used frying as a food preparation method less than once a month the interview was terminated at this point.
2. Knowledge and opinions about RSO were queried in question 3; e.g., Where did you hear about RSO? What have you heard about it?
3. Questions 4 and 5 determined the type and brand of oil or fat that the respondent used for frying.
4. Assessment and descriptions of RSO sensory characteristics were asked in questions 6-11. These questions were answered only by respondents who used RSO.
5. Economy oriented food shopping behaviour characteristics were determined in questions 12-14.
6. Demographic data of respondents and their families were

gathered in questions 15-19.

Interviews by telephone were conducted during August 1974 by the author and three trained summer students employed by the Department of Foods and Nutrition at the University of Manitoba. Four hundred Manitobans were surveyed using this instrument. Since approximately half of the population of Manitoba lives in Winnipeg, half the survey sample was chosen randomly from the Winnipeg telephone directory and half was chosen randomly from the rural Manitoba telephone directory. In order to qualify for the survey the respondent had to do most of the cooking for the family, and had to use frying as a method of food preparation more than once a month. A total of 400 telephone surveys were completed.

Statistical Treatment

Analysis of variance was used to identify the sources of variation in all the sensory evaluation tests. Multiple range tests were used to identify samples and treatments which were judged significantly different in odour intensity.

In experiment 1, some additional manipulation of the data had to be carried out before analysis of variance was possible because a magnitude estimation rating technique, which is a multiplicative scale, was used. In order to carry out analysis of variance an additive scale is required, therefore the magnitude estimation scores were transformed to their log values before analysis of variance.

The coefficient of correlation and simple linear regression was computed to indicate the strength of the linear relationship between the odour intensity values and the TBA scores in experiments 4 and 5.

In the consumer survey cross-comparisons were made to determine if there was a relationship between the use of RSO, shopping behaviour

and demographic characteristics. Also the relationship between continued use of RSO, and the sensory qualities and demographic characteristics and the relationship between the reason for first trying RSO and shopping behaviour were investigated by cross-comparisons. The significance of these relationships were assessed by computing the appropriate chi-square (χ^2).

RESULTS

Sensory Evaluation of Heated Oil Odours

The variables examined in the following experiments were:

Oil varieties

erucic acid levels

glucosinolate levels

Processors

Prolonged heating

Hydrogenation

Masking agents

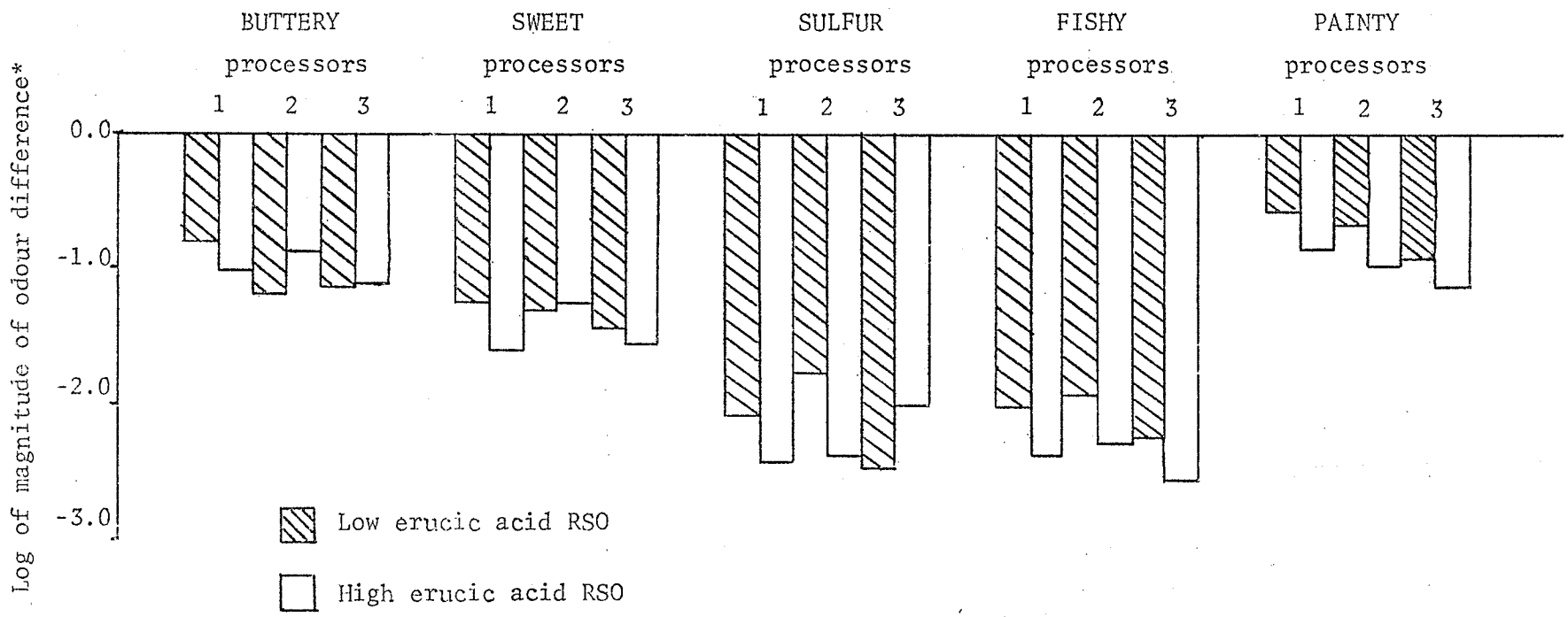
These variables were examined in various combinations within experiments; therefore the results of each experiment will be presented followed by a discussion of the variables across experiments and in light of the literature.

Comparison of high and low erucic acid oils from three different processors (Experiment 1).

The odour profile (Figure 3) demonstrates that all of the parameters, buttery, sweet, sulfur, fishy, and painty, were present in all the oils.

Figure 3 shows the log value of the mean magnitude of the difference between each oil and the chemical standard which was scored at 1. All of the oils were scored less intense than the standard; therefore when these values were converted to logs they became minus numbers. The lower the minus number the less odour was perceived. The differences in odour intensity among the various parameters is not meaningful in terms of their relative significance in the oil; rather they reflect intensity differences among the standards used. This approach to the analysis of oil odour enabled the

Figure 3. Odour profile of high and low erucic acid RSO from three processors (Experiment 1).



*Standard scored at 1, therefore logs of odour difference which were less than 1 become minus numbers.

judges to describe the qualities in heated RSO odour which makes it unpleasant. The fishy, sulfurous, and painty notes were seen by the judges as the dominating unpleasant characteristics of the heated oil odour. Analysis of variance of the odour scores (Table 15) showed that there were no significant differences among the oils in the buttery and sweet parameters. High erucic oils had significantly less intense fishy odour ($P < 0.01$) than low erucic oils and tended to have less intense sulfur and painty odours ($P < 0.10$). The mean scores over all processors for high and low erucic oils for these odour parameters were:

	Sulfur	Fishy	Painty
Low erucic acid	-2.11	-2.11	-0.63
High erucic acid	-2.37	-2.42	-0.83

Although there were no significant differences between oils from different processors, the mean scores for processor III were consistently lower over all the odour parameters. The mean scores were:

	Buttery	Sweet	Sulfur	Fishy	Painty
Processor I	-0.93	-1.46	-2.28	-2.25	-0.73
Processor II	-1.03	-1.28	-2.07	-2.11	-0.68
Processor III	-1.13	-1.49	-2.37	-2.43	-0.79

These scores suggest that techniques used by Processor III favour the production of RSO which has a lower overall odour intensity. Further, the significant processor x erucic acid level interaction ($P < 0.05$) in the sulfur parameter was due to a lower odour level in low erucic acid than high erucic acid oils from Processor III.

High judge variability represented by the coefficients of variation (Table 15) led to the

Table 15. Summary of Analyses of Variance for Comparison of Odour Parameters of High and Low Erucic Acid RSO from Three Processors (Experiment 1).

Sources of Variation	df	Mean Sqaures from each Analysis of Variance				
		Buttery	Sweet	Sulfur	Fishy	Painty
Replications	2	0.83	0.14	0.63	1.60	1.40
Processors	2	0.35	0.44	0.84	0.93	0.10
Erucic Acid Level	1	0.08	0.65	1.90*	2.59***	1.13*
Pro x Erucic	2	0.59	0.49	1.63**	0.03	0.05
Judges	5	3.94***	7.49***	4.48***	7.55***	5.72***
Error	95	0.39	0.55	0.50	0.37	0.38
Total	107					
Coefficient of Variation (%)		61.54	54.55	29.79	27.60	89.34

*,**,*** $P \leq 0.10$, 0.05 and 0.01, respectively.

conclusion that the sensory task was more extensive than desirable. The judges felt that the unpleasant odour characters of the oil, sulfur, fishy, and painty, could be embraced in an overall odour intensity score which would reduce the three parameters to one. As a result of this decision the simple semi-structured scale technique was used for the balance of the experiments.

Comparison of popular oil species (Experiment 2).

The effect of heating on the odour of oils from a variety of popular oil species was evaluated using the odour intensity scale method, where higher values represent stronger odours. Figure 4 shows that the odour intensity value (OIV) for all the oils except corn increased when heated to 190C, with RSO and hydrogenated RSO (HRSO) showing the most increase in odour intensity. In contrast, corn oil had a high unheated odour that decreased slightly when heated, substantiated by the significant ($P < 0.01$) oil x heating interaction (Table 16). The oil x heating interaction also is indicative of the greater rate of increase in odour of RSO and soybean oil as compared to safflower and sunflower oils; this observation is demonstrated by the different slopes of the lines in Figure 4.

In experiment 2 the judges showed some inconsistency in the order and magnitude of their judgments and some oils behaved atypically, which caused significant heat treatment x judge, oil x judge, and oil x heat treatment x judge interactions. In order to explain these interactions the atypical oil, corn oil, and the most atypical judges were consecutively removed and new analysis of variance were calculated after each removal. The main effects were not significantly changed with these manipulations, but the interactions were reduced somewhat. This

Figure 4. Comparison of odour changes after heating popular oil species to 190C for 10 minutes (Experiment 2).

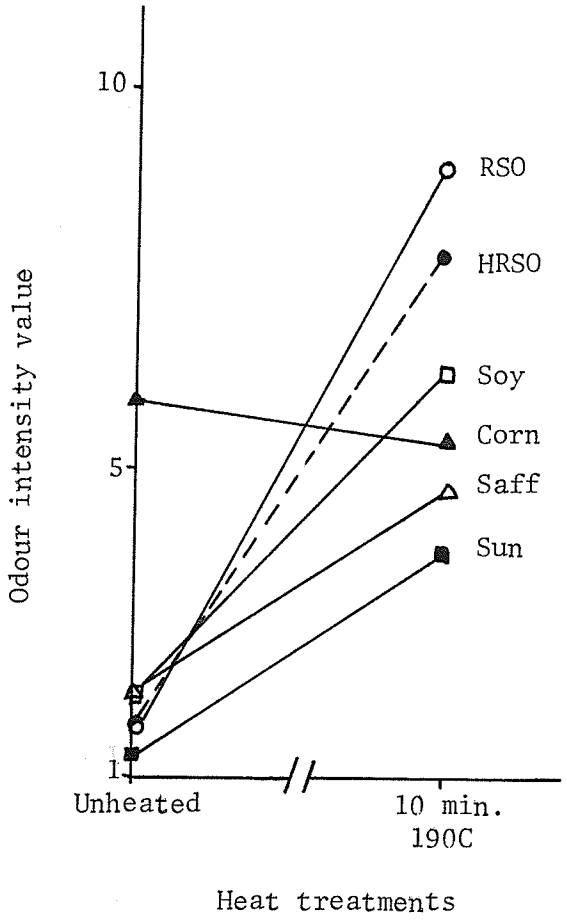


Table 16. Analysis of Variance for Comparison of Popular Oil Species (Experiment 2).

Sources of Variation	df	MS	F
Replications	2	2.70	
Oils	5	68.71	8.08**
Heating	1	1101.34	129.49**
Oil x heat	5	104.97	12.34**
Judges	8	54.62	6.42**
Experimental error	88	8.50	
Replication error	214	2.66	
Total	323		
Coefficient of variation (%)	37.66		

**P <0.01.

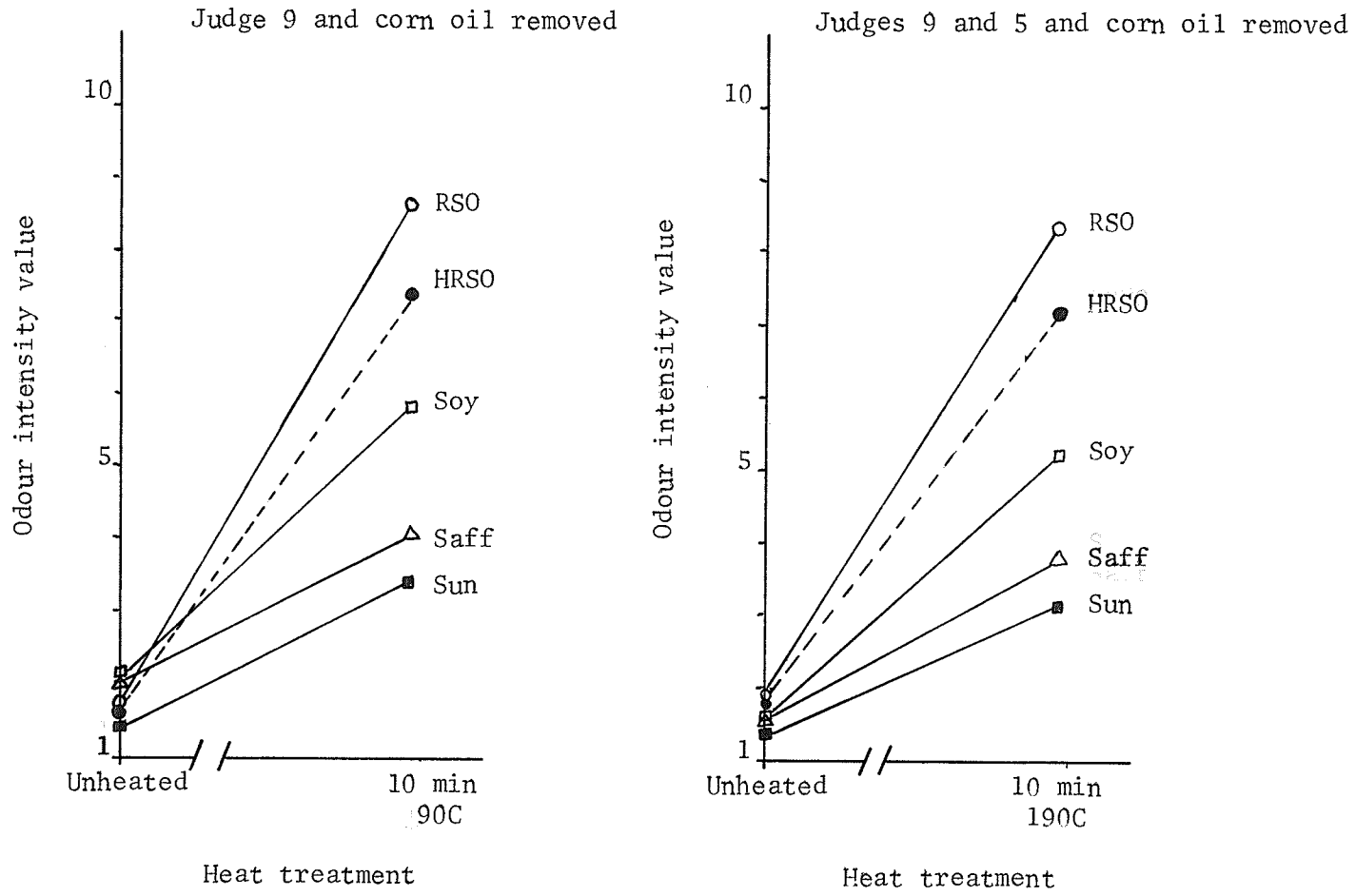
can be seen by comparing the two graphs in Figure 5 which show the oil x treatment interaction, excluding corn oil scores, after the removal of judge 9 and after the removal of judges 9 and 5. The order of the unheated oils changed so that there were fewer cross-overs after the two judges were removed but the different rates of odour increase, which also caused some interaction, were essentially unchanged. These interactions, treatment x judge, oil x judge, and oil x treatment x judge, were combined into an experimental error term and used to test the F values of the main effects (Table 16). Note that this is a more stringent test of F values than the replication error term since there are fewer degrees of freedom.

Since the judges showed similar inconsistencies in the order and magnitude of their scores in experiments 3 to 8, the procedure of pooling the judge interactions for an error term was applied throughout this series of studies.

Detection threshold of heated RSO in mineral oil (Experiment 3).

Data in Figure 6 show that the heated RSO odor intensity increased as its concentration in mineral oil increased up to 20% by volume. Increments beyond 20% gave erratic OIV's reflecting high judge variability (Table 17). A comparison of mean intensity values showed that a 10% dilution of RSO in mineral oil was not statistically different from 0, and 20% was not different from 100% as evidenced by the multiple range test:

Figure 5. Changes in interactions after removal of atypical oil and judges (Experiment 2).



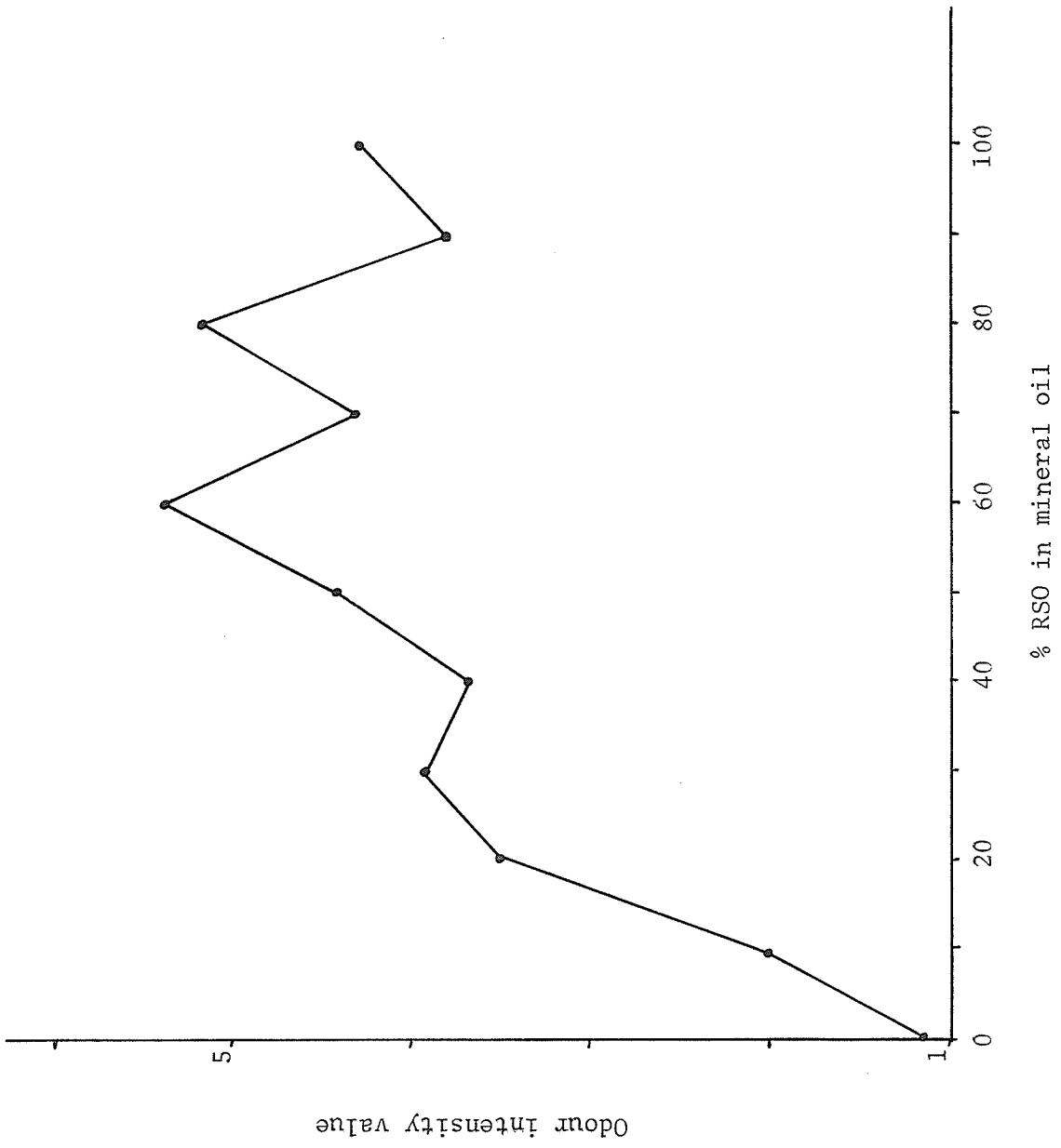


Figure 6. Detection threshold of heated RSO in mineral oil (Experiment 3).

Table 17. Analysis of Variance of Detection Threshold of Heated RSO in Mineral Oil (Experiment 3).

Sources of variation	df	MS	F
Replications	2	3.98	
Dilutions of RSO	10	33.27	6.37**
Judges	6	28.24	5.41**
Experimental error	60	5.23	
Replication error	152	4.58	
Total	230		
Coefficient of Variation (%)	56.40		

**$P < 0.01$.

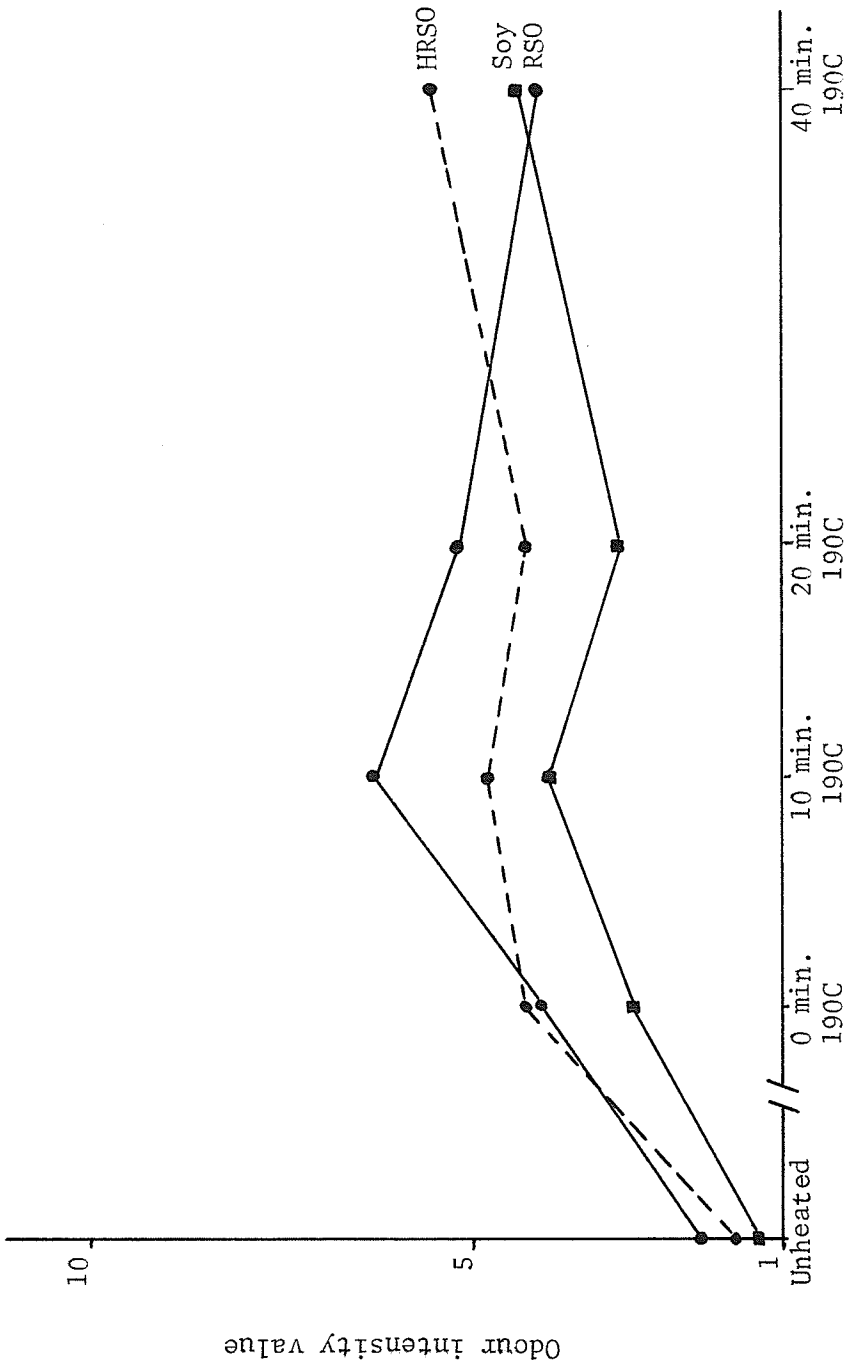
Mean Scores*	% RSO in mineral oil
1.14	0
2.01	10
3.50	20
3.71	40
3.81	90
3.91	30
4.28	100
4.28	70
4.45	50
5.20	80
5.41	60

*Means connected by a continuous vertical line are not statistically different ($P < 0.05$).

Comparison of odour changes during prolonged heating of oils (Experiment 4).

Progressive heating was used to determine if Zephyr RSO, a high glucosinolate, low erucic acid species, increased in odour intensity as heating time was extended. The RSO odour scores increased to a peak after 10 minutes at 190C, then tended to plateau (Figure 7). The unheated OIV was significantly lower than the heated OIV as shown by the multiple range test:

Figure 7. Comparison of odour changes during prolonged heating of high glucosinolate RSO (Experiment 4).



Mean OIV*	Heat Treatments (over all oils)
1.68	unheated
3.81	0 min at 190C
4.21	20 min at 190C
4.74	40 min at 190C
5.05	10 min at 190C

*Means connected by continuous vertical line are not significantly different from each other ($P < 0.05$).

Ten minutes heating at 190C produced the average peak for the three oils. However Figure 7 shows that the OIV for hydrogenated RSO continued to incerase to 40 min. Soybean oil OIV was also slightly higher at 40 minutes of heating time demonstrating that the OIV peak at 10 minutes was mainly caused by the high odour response to RSO.

The analysis of variance (Table 18) shows a significant ($P < 0.01$) difference in OIV's among the three oils. The multiple range test demonstrates that RSO and hydrogenated RSO were not different from each other but they were both significantly stronger than soybean oil:

Mean OIV*	Oils (over all heat treatments)
4.42	RSO
4.12	Hydrogenated RSO
3.15	Soybean oil

*Means connected by a continuous vertical line are not significantly different from each other ($P < 0.05$).

Hydrogenation tended to reduce the hot oil odour but did not significantly affect the problem.

Table 18. Analysis of Variance of Odour Changes During Prolonged Heating of High Glucosinolate Oils (Experiment 4).

Sources of Variation	df	MS	F
Replications	2	24.35	8.7
Oils	2	59.05	8.77**
Heating Times	4	143.41	21.31**
Oils x heating	8	9.58	1.42
Judges	8	44.71	6.64**
Experimental error	112	6.73	
Replication error	268	4.17	
Total	404		
Coefficient of Variation (%)	52.41		

** $P < 0.01$.

Comparison of odor changes during prolonged heating of low glucosinolate RSO (Experiment 5).

Rapeseed oils from low glucosinolate, low erucic acid species developed strong odours on heating regardless of prior hydrogenation (Figure 8). The differences in OIV's between RSO and soybean oil were marginally significant ($P < 0.05$) (Table 19). In fact, only one RSO (940) was significantly stronger than soybean oil as demonstrated by the multiple range test:

Mean OIV*	Oil (over all heat treatments)
4.25	940 RSO
4.15	1788 RSO
3.63	940 HRSO
3.43	Soybean oil
3.39	1788 HRSO

*Means connected by continuous vertical line are not significantly different from each other ($P < 0.05$).

The two RSO's showed a slightly higher OIV than their hydrogenated counterparts again suggesting that hydrogenation may effect a slight improvement in oil odour. Note that at the 40 minute heating time the hydrogenated RSO's and soybean oil were judged equal in OIV.

The difference between heated and unheated oil odour was again confirmed ($P < 0.01$). The OIV tended to peak at 10 minutes heating at 190C and then it plateaued or dropped from 10 to 40 minutes.

Assessment of effect of odour masking compound at 1135 ppm on odour development of heated oil (Experiment 6).

When the masking compound was added at the suggested level (PFW, personal communication), the OIV's of the unheated masked samples (Figure 9) were significantly higher due to fruity, floral odours of the

Figure 8. Comparison of odour changes during prolonged heating of low glucosinolate RSO (Experiment 5).

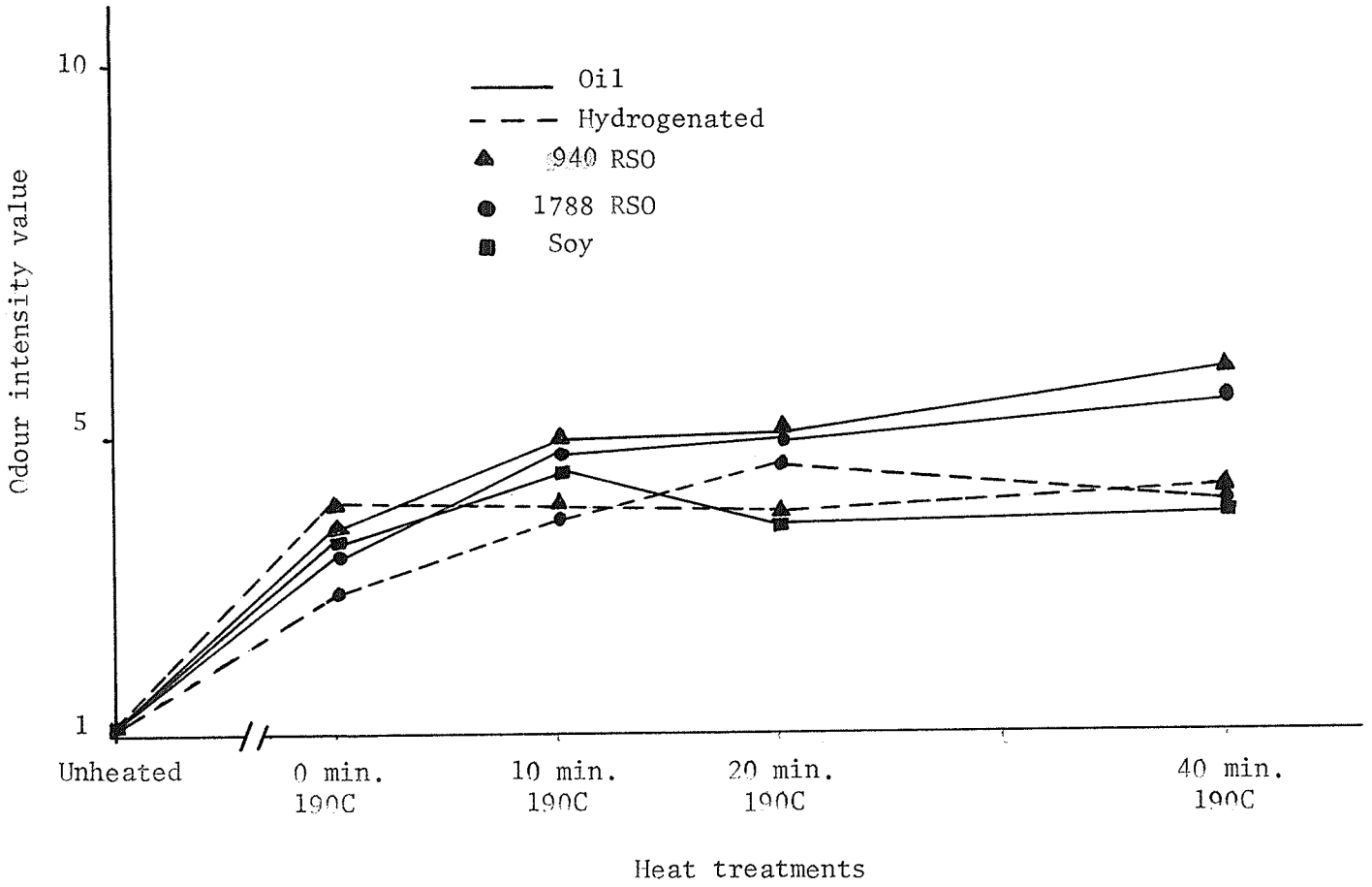
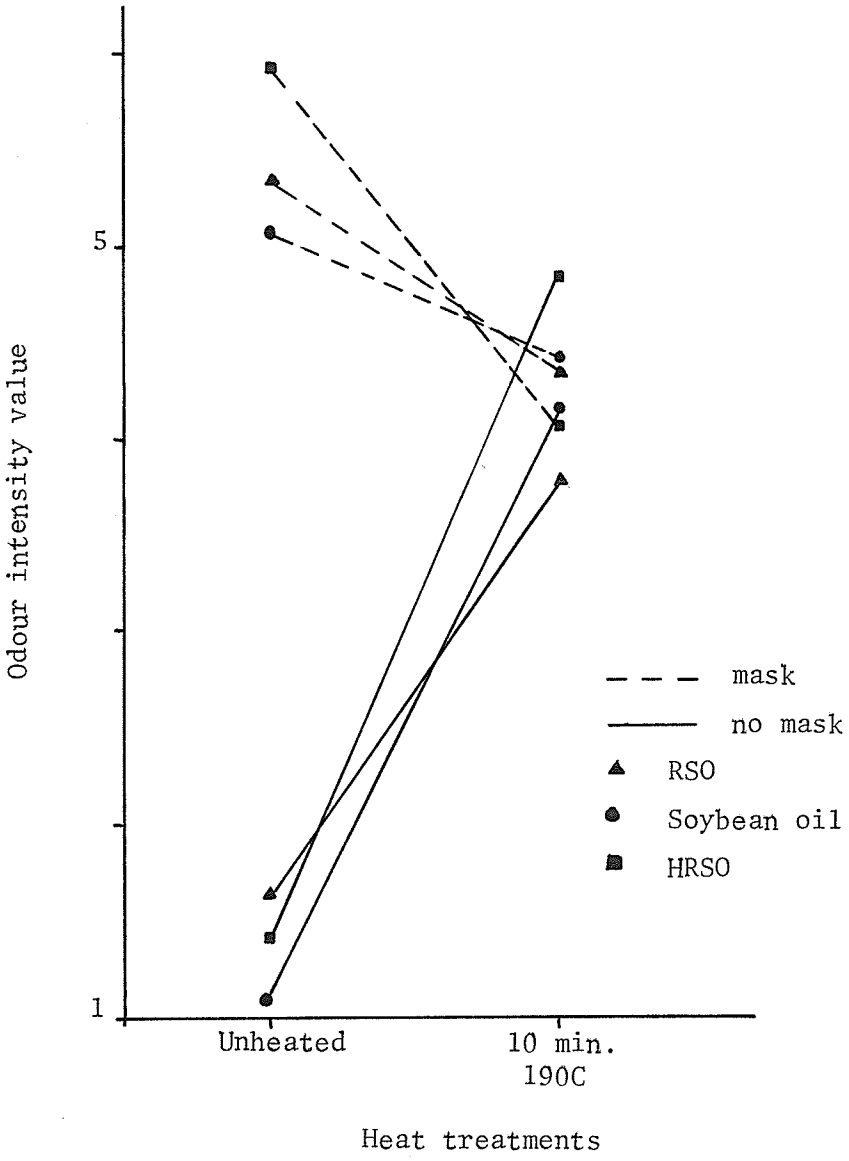


Table 19. Analysis of Variance of Comparison of Odour Changes During Prolonged Heating of Low Glucosinolate Oils (Experiment 5).

Sources of Variation	df	MS	F
Replications	2	1.23	
Oils	4	14.81	2.56*
Heating times	4	192.70	33.30**
Oils x heating	16	3.82	0.66
Judges	5	187.11	32.33**
Experimental error	120	5.78	
Replication error	298	2.67	
Total	449		
Coefficient of Variation (%)	43.35		

*,** $P \leq 0.05$ and ≤ 0.01, respectively.

Figure 9. Assessment of effect of odour masking compound at 1135 ppm on odour development of heated oils (Experiment 6).



masking agent ($P < 0.01$) than the unheated samples without the masking agent (Table 20). For this reason it was concluded that the concentration of the masking agent was too high. The OIV of the masked samples dropped on heating whereas the OIV of the samples without masking agent increased causing a significant ($P < 0.01$) heat x mask interaction (Table 20). The fruity, floral odours were also evident in the heated, masked oils.

Identification of an appropriate level of masking agent in heated oil (Experiment 7).

Serial dilution appeared to be an effective technique to establish the optimum level of masking agent. With no masking agent the usual high odour level of heated RSO was perceived (Figure 10), but an appropriate concentration (11.35 ppm) of the masking agent significantly ($P < 0.01$) decreased this odour (Table 21). At higher concentrations the odour of the masking agent, which was fruity and floral, dominated and increased the OIV. No unheated soybean oil control was included in this experiment as a check on the panelists' scores, although the RSO's were evaluated against an unheated soybean oil control.

Assessment of effect of odour masking compound at 11.35 ppm on odour development of heated oil (Experiment 8).

Experiment 6 was repeated using 11.35 ppm of the masking agent, the optimum level indicated by the serial dilution experiment. Figure 11 shows that this low level of masking agent was not obvious in the unheated oil; however it did not have any effect on the odour intensity of the heated oils. The analysis of variance for these data (Table 22) failed to show the interaction which would be expected if oil heated in the presence of the masking agent behaved atypically. These findings

Table 20. Analysis of Variance for Assessment of Effect of Odour Masking Compound at 1135 ppm (Experiment 6).

Sources of Variation	df	MS	F
Replications	2	9.86	
Oils	2	3.49	0.54
Heating	1	46.64	7.14**
Oil x heat	2	3.07	0.47
Masking	1	262.94	40.28**
Oil x mask	2	0.48	0.07
Heat x mask	1	257.03	39.37**
Oil x heat x mask	2	6.57	1.01
Judges	6	61.41	9.41**
Experimental error	66	6.53	
Replication error	166	2.47	
Total	251		
Coefficient of Variation (%)			

** $P < 0.01$.

Figure 10. Identification of appropriate level of masking agent in heated RSO (Experiment 7).

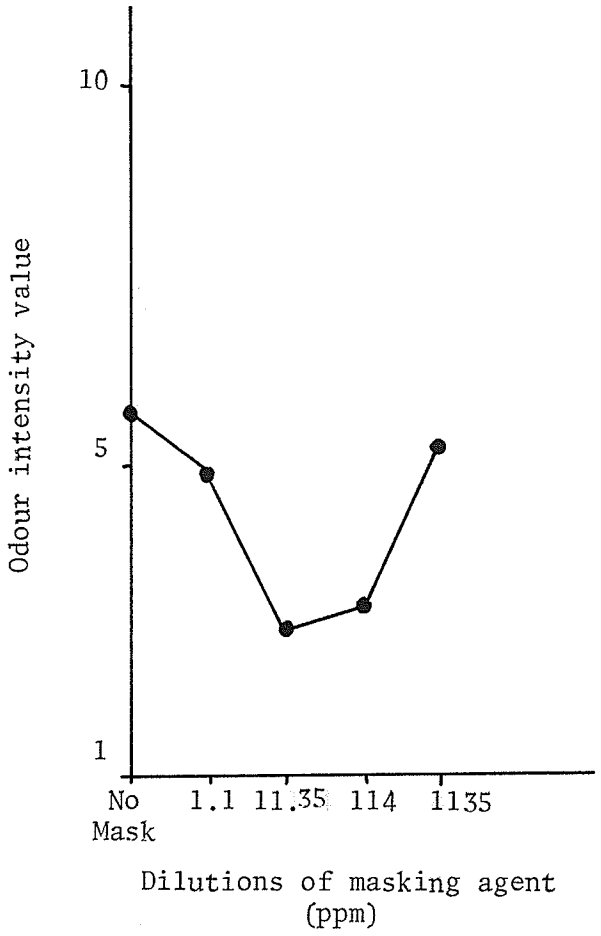


Table 21. Analysis of Variance of Identification of Appropriate Level of Masking Agent in Heated Oil (Experiment 7).

Sources of Variation	df	MS	F
Replications	2	10.92	
Dilutions of masking	4	28.95	6.90**
Judges	5	89.98	21.44**
Experimental error	20	4.20	
Replication error	58	2.41	
Total	89		
Coefficient of Variation (%)	35.40		

** $P < 0.01$.

Figure 11. Assessment of effect of odour masking compound at 11.35 ppm on odour development of heated oil (Experiment 8).

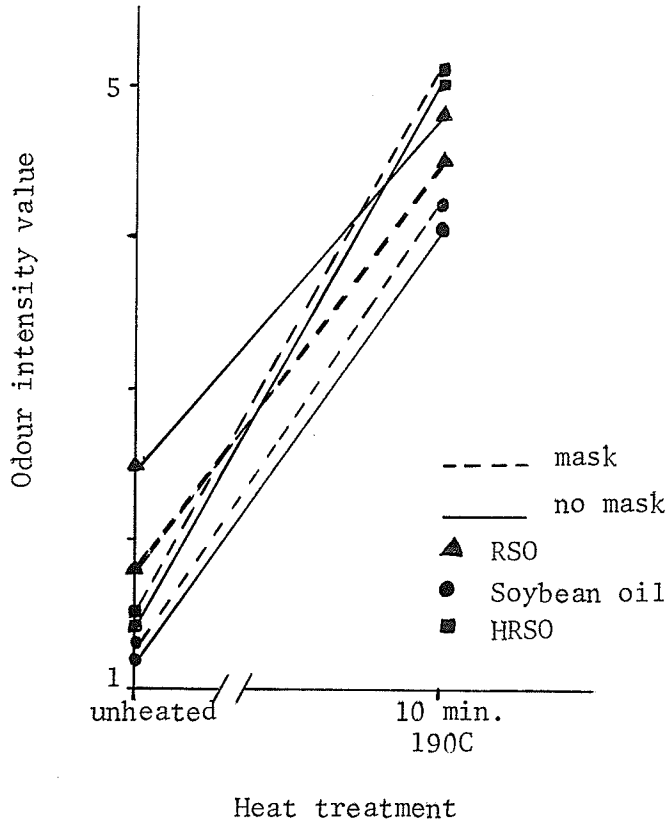


Table 22. Analysis of Variance of Effect of Odour Masking Compound at 11.35 ppm on Odour Development in Heated Oil (Experiment 8).

Sources of Variation	df	MS	F
Replications	2	25.52	
Oils	2	9.53	2.10
Heating	1	493.39	108.77**
Oil x heat	2	5.08	1.12
Masking	1	0.58	0.13
Oil x mask	2	1.86	0.41
Heat x mask	1	0.22	0.05
Oil x heat x mask	2	0.40	0.09
Judges	5	43.55	9.60**
Experimental error	55	4.54	
Replication error	142	2.60	
Total	215		
Coefficient of Variation (%)	51.02		

** $P < 0.01$.

appear in direct contradiction with those of the masking agent dilution test. Contamination of the glassware might have been suspected had the scores for the unheated oils not containing the masking agent been unusually high. However this was not the case; therefore it appears that 11.35 ppm of the masking agent was a level of addition insufficient to mask heated oil odour.

Chemical Tests

Fatty acid analysis.

The fatty acid composition of the oils used in experiment 2 (Table 23) shows that RSO has the highest linolenic acid (C18:3) content. Soybean oil would be expected to have similar levels of linolenic as RSO; however commercial soybean oil had been partially hydrogenated, reducing the C18:3 fatty acids. The linolenic content of hydrogenated RSO was also reduced. Corn, safflower and sunflower oils had similar levels of linoleic (C18:2) and oleic (C18:1) acids.

The main differences in the fatty acid content of RSO species used in experiments 3 through 8 are due to hydrogenation (Table 24) which reduces the proportion of linolenic and linoleic acids and increases oleic acid.

Table 25 shows that there is very little change in fatty acid composition of either RSO or soybean oil after the oils were held at 190C for 40 minutes. Extended heating very slightly reduced 18:3 and increased 18:2 and 18:1 fatty acids but not significantly as these differences were less than expected between duplicate samples.

TBA tests.

Figure 12 shows that popular oil species heated to 190C for 10 minutes increased in TBA value. A significant difference between oils ($P < 0.01$), heating treatments ($P < 0.01$), and a significant oil x

Table 23. Fatty Acid Composition of Popular Oil Species (Experiment 2).

No.of carbons: No.of double bonds	% Methyl Esters					
	RSO	HRSO	Soy-Bean	Corn	Saf-flower	Sun-flower
14:0	0.1	0.1	0.1	-	0.1	-
16:0	3.6	5.6	9.5	11.2	6.9	7.0
16:1	0.2	0.5	0.1	-	0.1	-
18:0	1.7	6.5	4.1	1.7	4.7	4.6
18:1	52.9	75.3	47.3	25.7	16.4	18.3
18:2	21.6	8.6	35.0	60.8	70.1	69.1
18:3	11.0	1.1	3.2	0.4	0.7	0.5
20:1	3.8	1.5	-	-	0.2	-
22:0	-	0.1	-	-	-	-
22:1	5.0	0.4	0.2	-	0.8	-

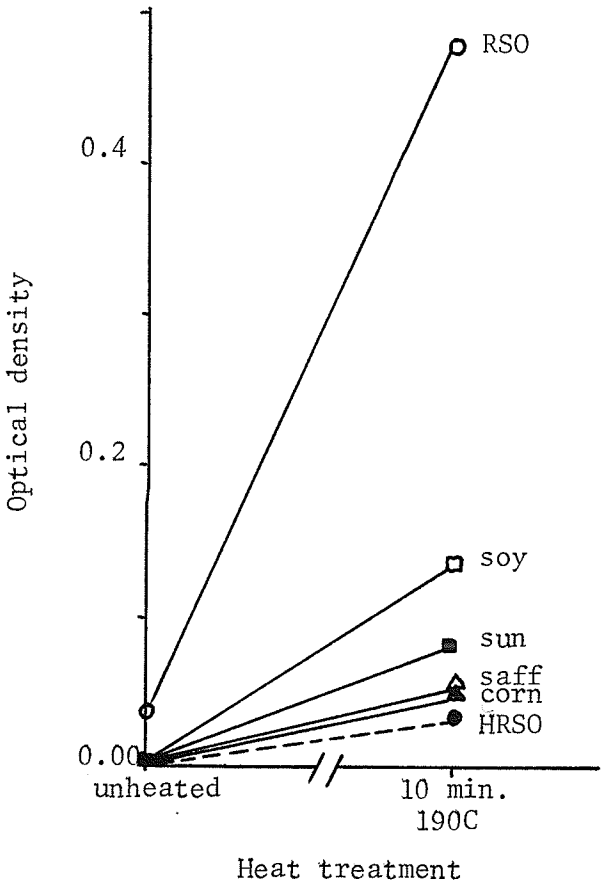
Table 24. Fatty Acid Composition of Low Erucic, Low Glucosinolate and Low Erucic, High Glucosinolate RSO Varieties (Experiment 5).

No.of carbons: No.of double bonds	% methyl esters					
	Low erucic acid High glucosinolate		Low erucic acid Low glucosinolate			
	Zephyr		1788		940	
	HRSO	RSO	HRSO	RSO	HRSO	RSO
14:0	0.2	0.1	0.1	tr	0.1	-
16:0	5.6	4.8	4.4	3.6	4.7	4.4
16:1	0.5	0.4	-	-	0.3	0.2
18:0	6.5	2.6	16.4	1.6	20.9	1.7
18:1	75.3	59.8	64.1	59.1	65.2	58.5
18:2	8.6	20.5	4.4	18.9	3.5	21.3
18:3	1.1	9.0	1.6	8.1	1.3	9.5
20:1	1.5	1.7	4.8	5.0	2.4	2.8
22:0	0.1	0.2	-	tr	-	0.3
22:1	0.4	0.7	3.7	3.7	1.3	1.3

Table 25. Comparison of Fatty Acid Composition of Heated and Unheated Oils from Experiment 4.

No.of carbons: No.of double bonds	% methyl esters					
	Soybean oil		Low erucic, high glucosinolate RSO			
			RSO		HRSO	
	unheated	heated 190C, 40 min.	unheated	heated 190C, 40 min.	unheated	heated 190C, 40 min.
14:0	0.1	-	0.1	-	0.2	0.2
16:0	9.5	9.5	4.8	4.9	5.6	5.7
16:1	0.1	-	0.4	-	0.5	0.4
18:0	4.1	3.7	2.6	2.2	6.5	5.9
18:1	47.3	48.0	59.8	63.7	75.3	78.6
18:2	35.0	36.0	20.5	20.9	8.6	7.8
18:3	3.2	2.0	9.0	8.4	1.1	0.6
20:1	-	-	1.7	-	1.5	-
22:0	-	-	0.2	-	0.1	0.9
22:1	0.2	-	0.7	-	0.4	-

Figure 12. TBA values of popular oil species heated for 10 min. at 190C (Experiment 2).



heat interaction ($P < 0.01$) were demonstrated (Table 26). The interaction was caused by the different rates of TBA increase, on heating, for different oils with RSO showing the steepest increase while HRSO showed the least.

In experiments 4 and 5 TBA values increased on prolonged heating (Figures 13 and 14). There was a significant difference between oils ($P < 0.01$). Values for RSO and soybean oil increased substantially while HRSO increased only slightly. There was a significant difference between heating treatments in experiment 5 ($P < 0.01$). The difference between heating treatment was not as significant in experiment 4 ($P < 0.10$). However the lower significance is probably due to a significant oil x heat interaction buried in the error term.

TBA Correlation with Sensory Tests

In experiments 4 and 5 the increase in TBA values showed high positive correlations with the odour intensity values for each oil (Figures 15 and 16). Linear regression lines show that the magnitude of odour change related to change in TBA was markedly different for each oil. The effect of hydrogenation is demonstrated by the differences in $\hat{\beta}_1$ (Figures 15 and 16). A large $\hat{\beta}_1$ indicates a dramatic increase in OIV for a small increase in TBA. Therefore, TBA tests can be used as predictors of odour increase but each oil must be considered individually.

Consumer Survey

To qualify for the consumer survey respondents had to be people who did most of the cooking for the family and they had to use either pan frying or deep fat frying more than once a month. If either of these conditions were not met the interview was terminated.

The interviews were no more than 10 minutes long and were

Table 26. Analysis of Variance of TBA Changes During Heating of Oils.

Sources of variation	Popular oil species Experiment 2		High glucosinolate oils Experiment 4		Low glucosinolate oils Experiment 5	
	df	MS	df	MS	df	MS
Duplicates	1	.00004				
Oils	5	.03295**	2	.147**	4	.178**
Heating	1	.10179**	4	.026*	4	.066**
Oil x heat	5	.02409**				
Error	11	.0016	8	.008	17	.012
Total	23		14		25	

*,**P≤ 0.10, 0.01, respectively.

Figure 13. Comparison of TBA changes during prolonged heating of high glucosinolate RSO (Experiment 4).

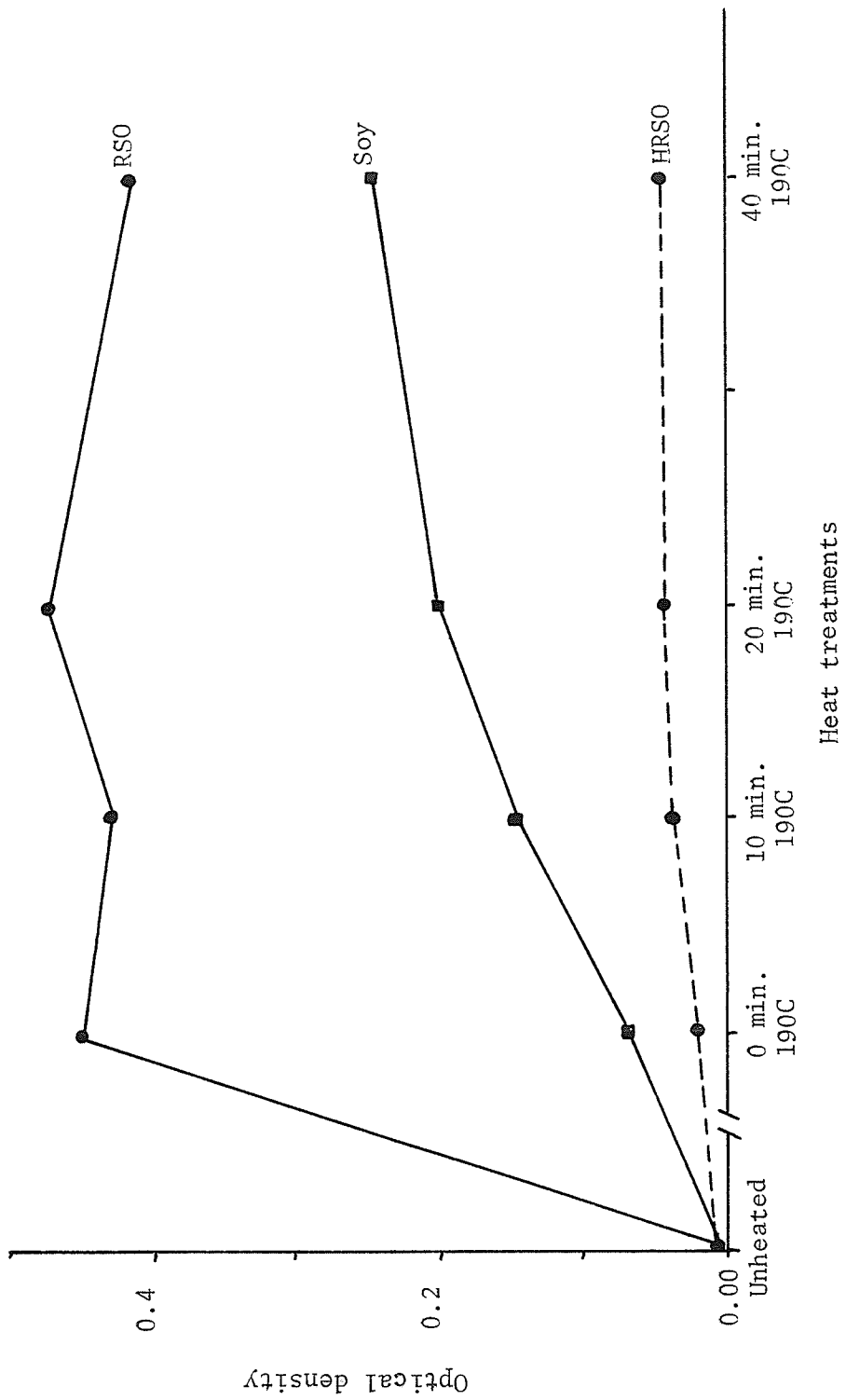


Figure 14. Comparison of TBA changes during prolonged heating of low glucosinolate RSO (Experiment 5).

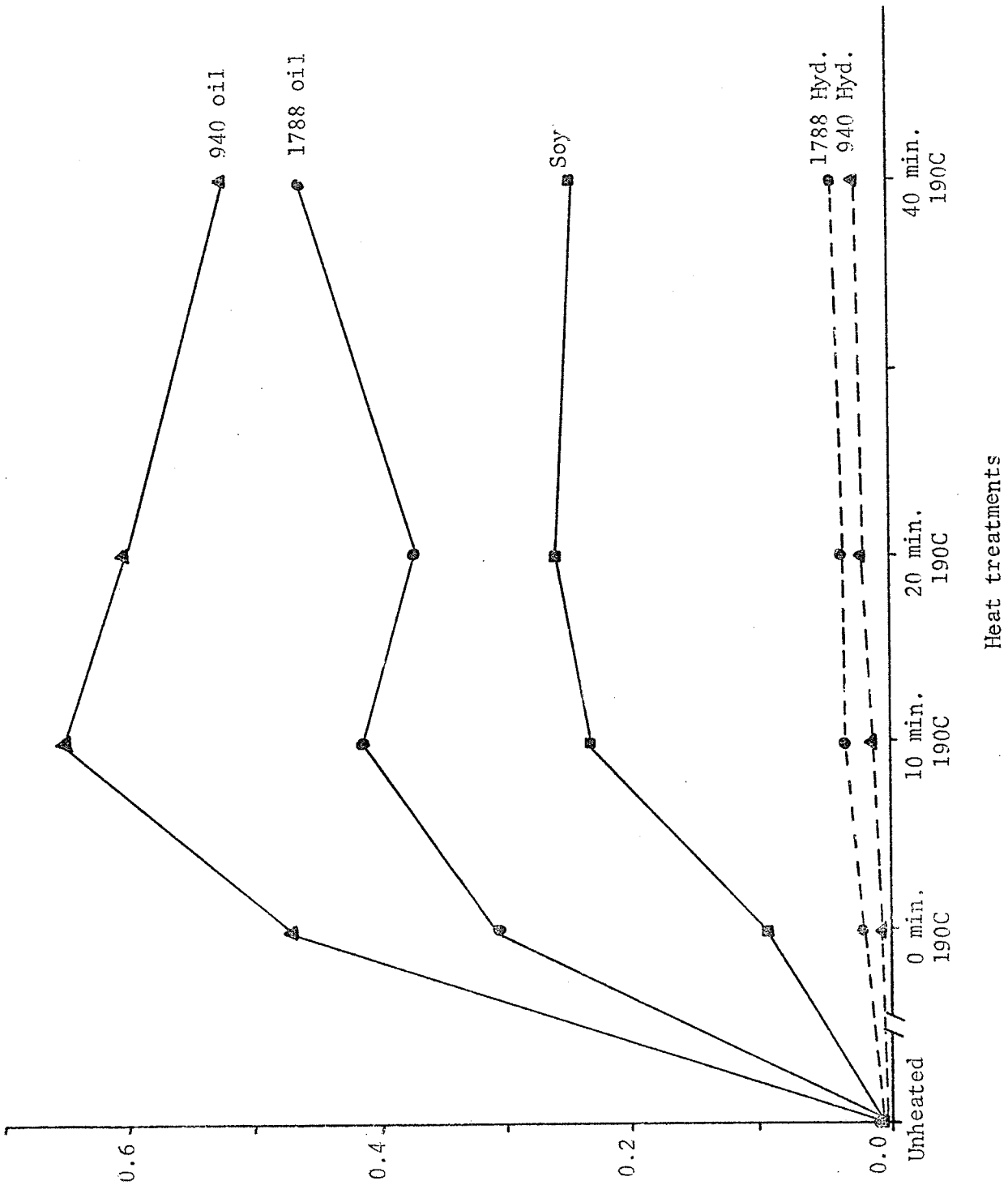


Figure 15. Relationship between TBA values (OD) and odour intensity values (OIV) of heated oils (Experiment 4).

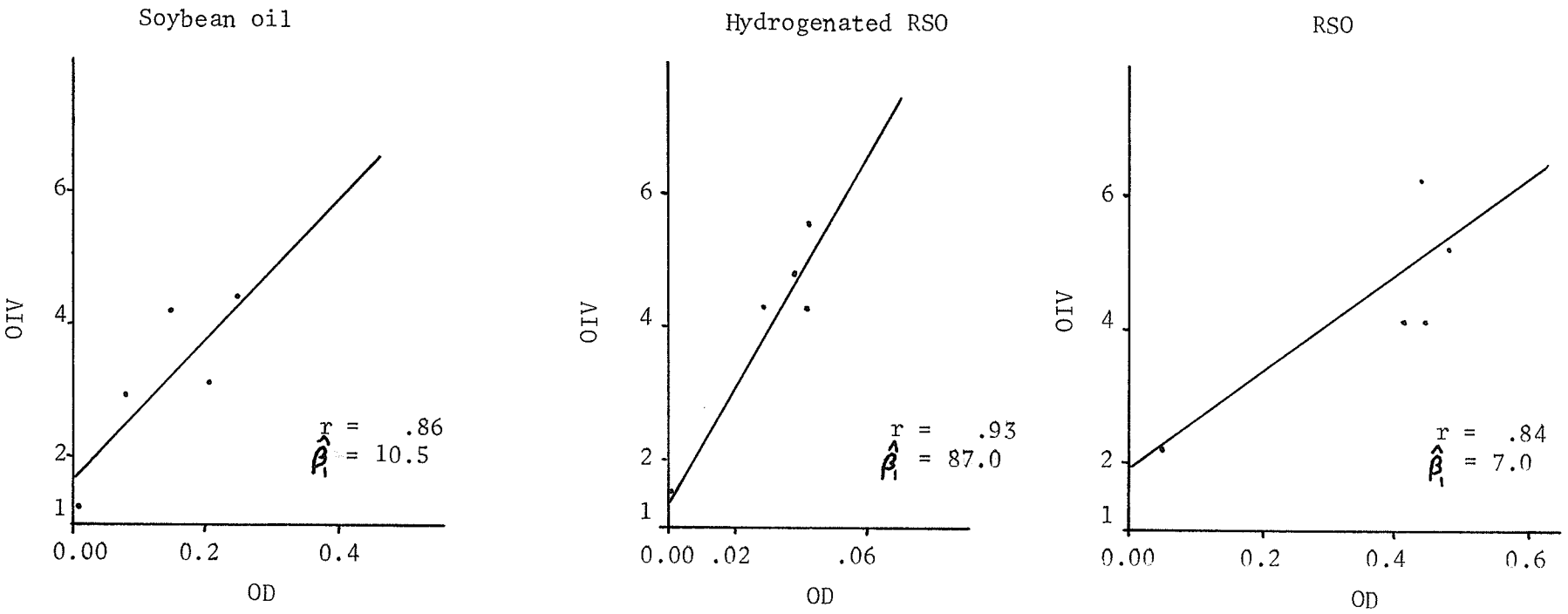
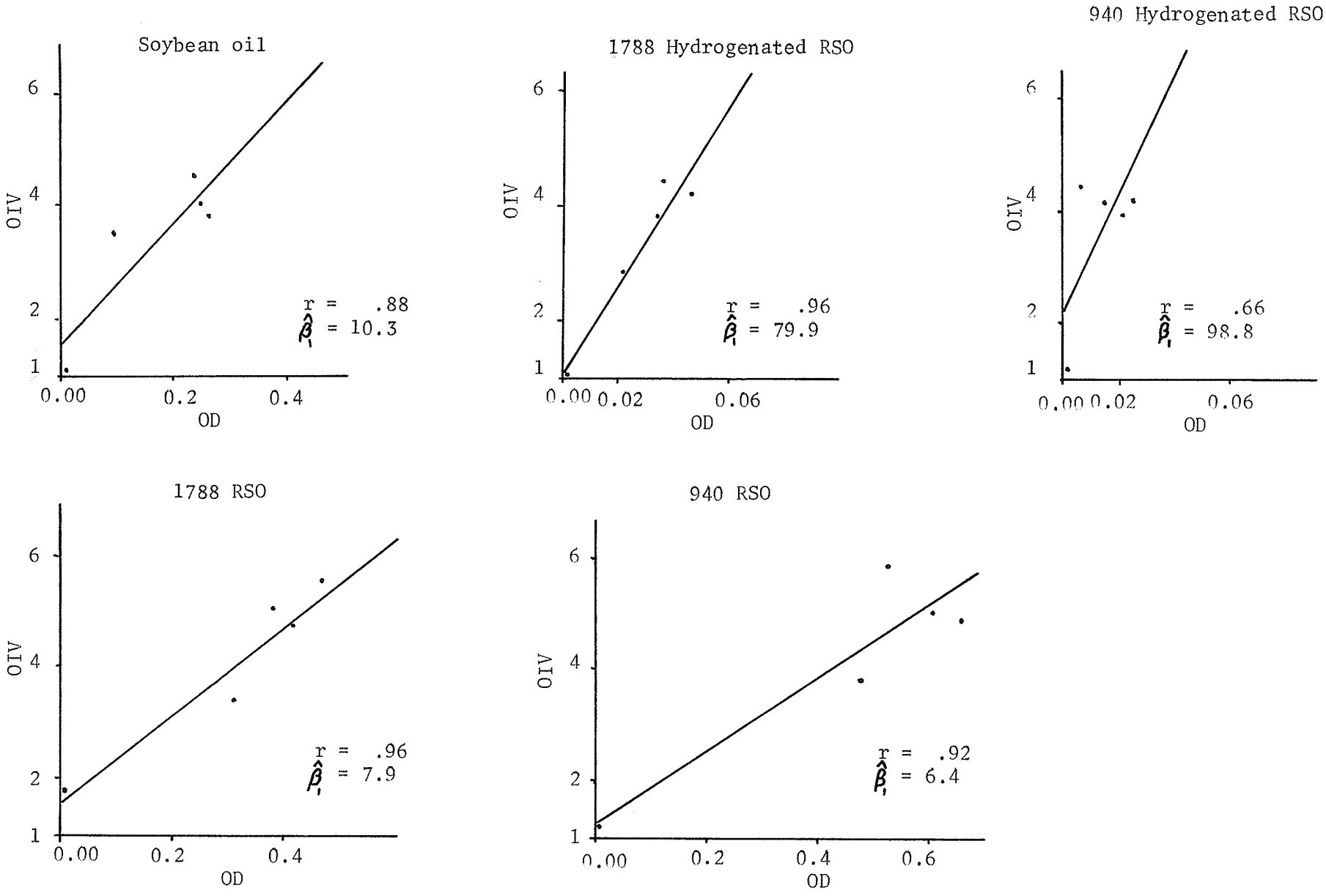


Figure 16. Relationship between TBA values (OD) and odour intensity values (OIV) of heated low glucosinolate oils (Experiment 5).



carried out in August, 1974 between the hours of 10.00 a.m. and 7.00 p.m. Most of the respondents were women and it can be surmised that the majority did not work outside the home since most calls were made during working hours.

Demographic characteristics of the respondents summarized in Table 27 show that close to 60% were between 30 and 60 years of age, while 24% were younger and 18% were older than this. Most of the respondents (72%) were members of families of 4 or less while 28% had 5 or more family members. Slightly less than half had completed high school, and 21% had some post high school training. The sample population was deliberately distributed evenly between Winnipeg and the remainder of the Province. Labourers comprised 42% of the sample population, "white-collar"workers approximately one-fourth of the sample while only 13% were farmers.

The attitudes of respondents to economy in food shopping (Table 28) shows that approximately 67% had some limit on their food spending and 84% shopped for bargains and specials sometimes or more often.

Almost all of the respondents used pan frying as a cooking method and most of them pan fried once a week or more often (Table 29). Approximately 62% also deep fat fried and one-third of them deep fat fried at least once a week.

When questioned about their knowledge of RSO, 65% indicated that they had heard of it (Table 30); however their sources of information were mixed. The largest percentage (30%) did not know where they had heard of it. The media was the specific information source for 24% of the respondents and the most frequently mentioned was the newspaper. When probed about whether they had heard good or bad

Table 27. Characteristics of Manitoba Respondents Surveyed about RSO Use.

Characteristics	Response category	% respondents (n=400)
Age	⩽ 30	23.5
	31-45	29.2
	46-60	29.3
	⩾ 60	18.0
	Total	100.0
Family size	1-2	31.5
	3-4	40.8
	⩾5	27.7
	Total	100.0
Education	< High school	51.7
	High school	26.8
	> High school	21.5
	Total	100.0
Residence	Winnipeg	50.2
	Other Manitoba city	8.8
	Small town	29.5
	Farm	11.5
	Total	100.0
Occupation of wage earner	Unskilled labour	2.2
	Semi-skilled labour	20.5
	Skilled labour	18.5
	Sales or managerial	16.5
	Professional	9.2
	Retired, unemployed or student	16.3
	Farmer	12.8
	No answer	4.0
	Total	100.0

Table 28. Attitudes of Respondents to Economy in Food Spending (n=400).

Do you have a definite limit on food spending?		Do you shop for bargains and specials?	
Response category	% respondents	Response category	% respondents
Definite limit	22.7	Often	41.5
Approximate limit	43.8	Sometimes	42.2
No limit	33.5	Seldom	16.3
Total	100.0	Total	100.0

Table 29. Frequency with which Respondents Used Pan and Deep Fat Frying Methods (n=400).

	% respondents				
	Use				
Method	Yes	No	Once a week or more	1/wk	1/mo.
Pan frying	97.8	2.3	87.7	10.0	2.3
Deep fat frying	61.8	38.2	29.6	41.3	29.1

Table 30. Respondent Knowledge of RSO.

Question	Response Category	% respondents
		(n=400)
Have you heard of RSO?	yes	65.2
	no	34.8
	Total	100.0
		(n=261)
Where did you hear about it?	newspaper	15.3
	radio	5.0
	TV	3.8
	friend	10.8
	more than one source	6.9
	don't know	29.5
	other	28.7
	Total	100.0
		(n=261)
What have you heard about it?	good	13.8
	bad	1.1
	neither good nor bad	85.1
	Total	100.0

reports about RSO most indicated that the information had been neither good nor bad. Only 3 people said they had heard anything negative about RSO.

Most respondents used liquid vegetable oil for both pan frying and deep fat frying (Table 31). The most frequently used oils were corn and soybean oil. Rapeseed oil and sunflower oil were both used by about 10% of the respondents for pan and deep fat frying. Lard was the most frequently used (7%) of the solid shortenings for pan frying with margarine, butter and hydrogenated shortening closely following. Most of the respondents answered this question by giving a brand name. When asked if they knew what kind of oil or fat they were using over half indicated that they knew the species (Table 32), and of those who answered yes,86% named the correct species.

Table 31 shows that only about 10% were currently using RSO; however,when popular brands of RSO were identified it was found that 41% had used at least one brand of RSO at some time (Table 33). Brand A (Table 33) was mentioned by 68% of the respondents who had used RSO.

Economy was a primary factor influencing RSO use (Table 34). Over half of the respondents said they would continue to use RSO and approximately half of those cited lower price as the reason. Those respondents who had tried RSO and discontinued using it generally gave a variety of non-specific reasons for this purchasing decision. However, dislike of sensory features was identified as a reason by 13% of these 71 people.

When queried about sensory properties of the oil (Tables 35 and 36) one fourth of the respondents had noticed some difference in the

Table 31. Fat Forms Currently Used by Respondents for Frying.

	% respondents (n=400)	
	Pan frying	Deep fat frying
Oils		
Corn oil	27.0	16.5
Soybean oil	25.5	17.5
Rapeseed oil	11.0	8.2
Sunflower oil	10.0	7.5
Peanut oil	1.0	1.8
Olive oil	1.0	0.8
Safflower oil	0.3	0.3
Other	4.0	2.0
Sub-total	79.8	55.1
Shortenings and Fats		
Lard	7.3	2.8
Margarine	5.8	-
Butter	4.8	-
Hydrogenated shortening	4.6	4.6
Bacon fat	2.5	0.3
Spray-on pan coating	1.3	-
Other	0.3	0.5
Sub-total	26.6	8.2
Total*	106.4	63.3

*Totals differ from those in Table 29 because some respondents indicated more than one type of oil or fat used.

Table 32. Knowledge of Species of Oil being Used by Respondents (n=400).

Question	% respondents (n=400)	
	yes	no
Do you know what type of oil or fat you are using?	53.5*	46.5

*Correct species named by 85.5% of these people.

Table 33. RSO Use by Respondents.

		% respondents
Have used RSO (N=400):		
yes		40.5
no		59.5
Brands of RSO which were used (N=162):		
A		67.9
B		16.7
C		3.1
D		3.7
More than one brand		7.4
Other		1.2
	Total	100.0

Table 34. Reasons for RSO Use of those Respondents Who Had Tried It.

First tried RSO because (n=162)		Continuing to use RSO because (n=91)		Discontinued use of RSO because (N=71)	
Less expensive	60.5	Lower price	47.2	Not satisfied	14.1
Manitoba product	4.3	Satisfied with product	31.9	Like other brand	18.3
Chance	17.9	Like flavour	1.1	Didn't like flavour	8.5
Other reasons	17.3	Don't know	6.6	Didn't like odour	4.2
		Other reasons	13.2	Don't know	16.9
				Other reasons	38.0
Total	100.0		100.0		100.0

Table 35. Difference Between RSO and Other Oils (n=162).

Response category	Taste of fried foods	Odour of kitchen when frying
Not different	74.1	75.9
Different	25.9	24.1
Degree: slightly	11.7	13.0
somewhat	9.9	9.9
very	4.3	1.2

Table 36. Sensory pleasantness of RSO (n=162)

Response category	Taste of fried foods	Odour of kitchen when frying
Pleasant	34.0	11.1
Neutral	53.0	70.4
Unpleasant	13.0	18.5
	100.0	100.0

taste and odour of RSO as compared to other oils. Thirteen to nineteen percent stated that the taste or odour of RSO was unpleasant. Most of the respondents (68%) could not describe the room odour of RSO; 17% described the odour in terms usually associated with reverted or oxidized oils (Table 37).

The association of RSO use with demographic characteristics and economy-oriented shopping behaviour (Table 38) shows that the only demographic characteristic with which RSO use could be significantly ($P < 0.01$) associated was family size (Figure 17). A larger percentage of families with 5 or more members were RSO users at some time.

In relating continuation of RSO use with sensory quality characteristics (Table 39), significant dependence ($P < 0.01$) was associated with differences in taste, pleasantness of taste, and pleasantness of kitchen odour. Thirty-nine percent of those not continuing use of RSO noticed some differences in taste (Figure 18) while 24% of those not continuing use described the taste as unpleasant (Figure 19) and 28% described the kitchen odour as unpleasant (Figure 20).

The incidence of continued use of RSO was significantly associated with the occupation of the wage earner in the family ($P < 0.05$) (Table 39). The significant differences were focused within the skilled labour, sales or managerial and professional classifications (Figure 21). More skilled labourers discontinued use while more in the managerial and professional classifications continued to use RSO.

There was a significant ($P < 0.05$) association between reasons for trying RSO and economy-oriented shopping behaviour (Table 40). Three-fourths of respondents who had purchased RSO because it was less expensive had a limit on their food spending. As well almost three-fourths of those who purchased RSO by chance had a limit on their food spending

Table 37. Description of RSO Odour while Cooking (n=162).

Descriptors	% respondents
Oily	1.8
Greasy	3.1
Hot oil	6.8
Fishy	2.5
Grassy	0.6
Bland	5.6
Strong and unpleasant	9.2
No odour	2.5
Don't know	67.9
Total	100.0

Table 38. Association of RSO Use* with Demographic Characteristics and Shopping Behaviour.

Characteristics	df	x^2 (n=400)
Limit on food spending	2	0.88
Shop for bargains and specials	2	2.16
Number in household	2	9.21**
Location of residence	3	2.37
Educational level	2	1.29
Age group	3	4.11
Occupation	7	8.77

* Users (n=162) vs. Non-users (n=238).

** $P < 0.01$.

Figure 17. Association of RSO use with number in household (n=400).

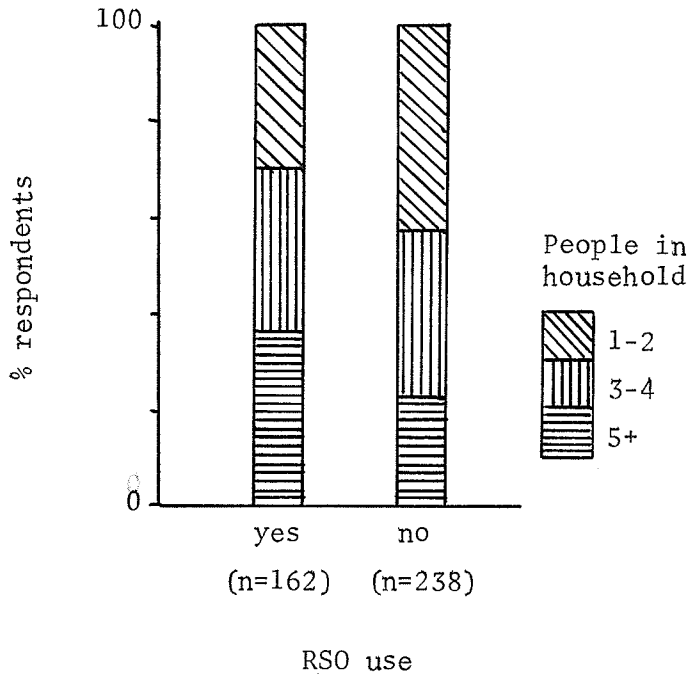


Table 39. Association of Continued Use* of RSO with Oil Sensory Quality Characteristics, Shopping Behaviour and Demographic Characteristics.

Characteristics	df	x^2 (n=162)
Difference in taste	3	12.21***
Difference in kitchen odour	3	2.16
Pleasantness of taste	2	17.97***
Pleasantness of odour	2	10.08***
Limit on food spending	2	3.56
Shop for bargains and specials	2	1.65
Number in household	2	0.51
Location of residence	3	0.25
Educational level	2	1.73
Age group	3	5.59
Occupation	7	14.53**

*Users (n=91) vs. Non-users (n=71).

,* $P < 0.05$ and < 0.01, respectively.

Figure 18. Association between continued use of RSO and difference in taste (n=162).

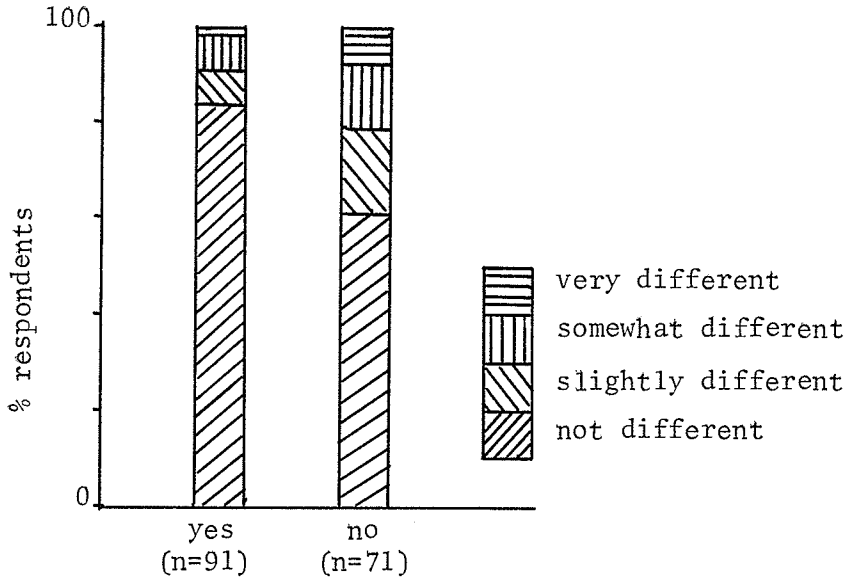


Figure 19. Association between continued use of RSO and taste pleasantness (n=162).

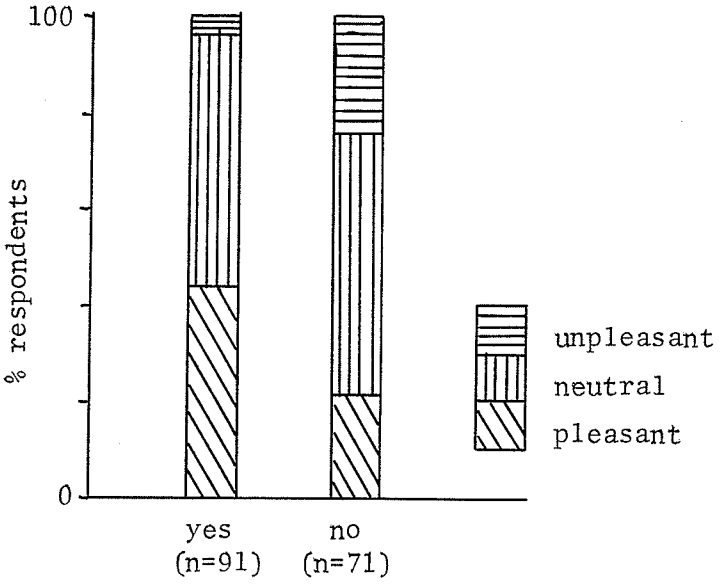


Figure 20. Association between continued use of RSO and kitchen odour pleasantness (n=162).

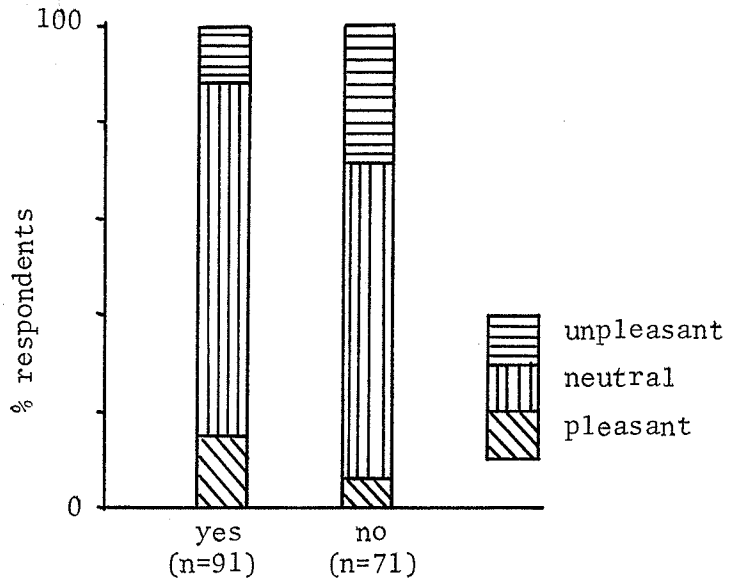


Figure 21. Association between continued use of RSO and occupation (n=162).

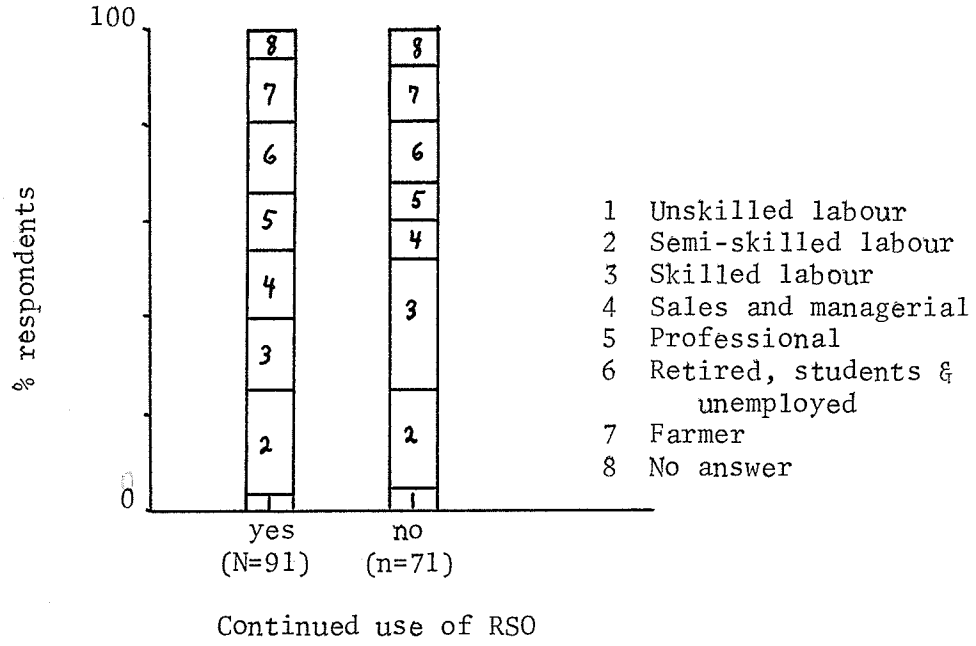


Table 40. Association of Reason for Trying* RSO with Shopping Behaviour.

Characteristics	df	x^2 (n=162)
Limit on food spending	6	12.91**
Shop for bargains and specials	6	11.09

*Reasons for trying RSO:

less expensive (n=98)

Manitoba product (n=7)

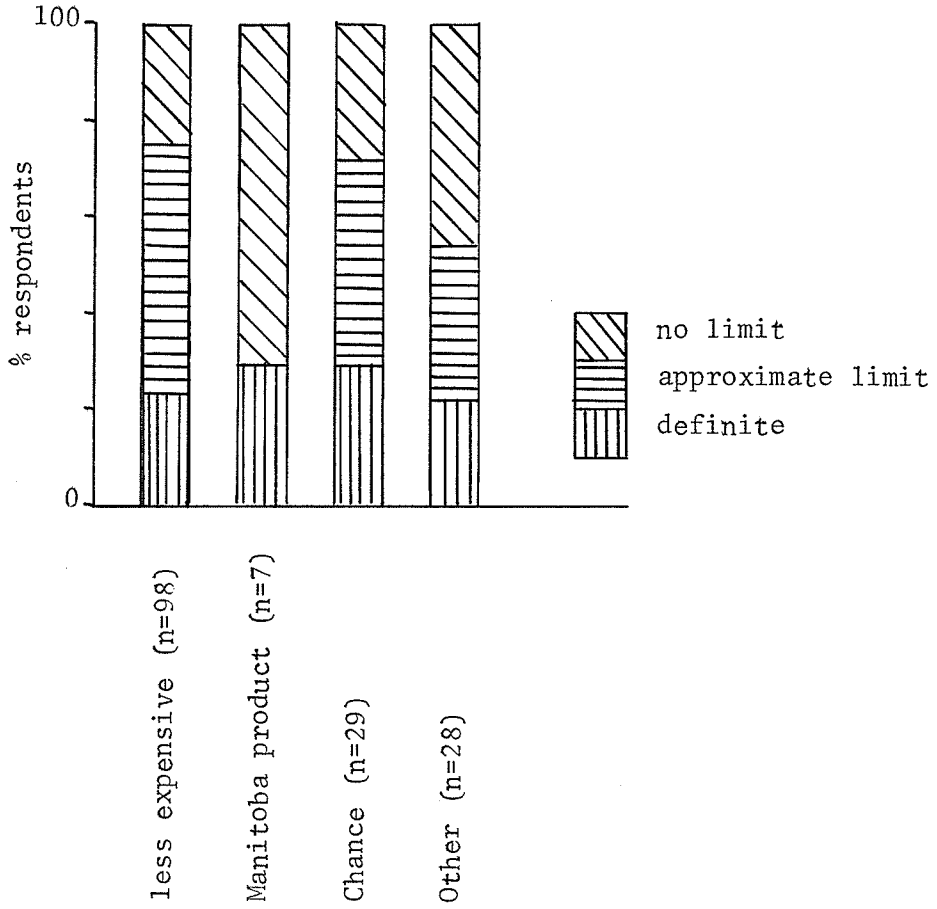
chance (n=29)

other (n=28)

**P< 0.05.

(Figure 22). However, only 29% of those who purchased RSO because it was a Manitoba product also had a limit on food spending.

Figure 22. Association between reason for trying RSO and set limit on spending (n=162).



DISCUSSION

Most of the consumers interviewed had few complaints about RSO but only 56% continued use after trying it. However nineteen percent of those who had tried RSO noticed an unpleasant kitchen odour (Table 36). The unpleasant odour was correlated with consumer purchases. Twenty-eight percent of those who discontinued RSO use found the kitchen odour unpleasant (Figure 20). Accordingly definition of the cause of the unpleasant odour of hot RSO would be worthwhile as one step toward its elimination.

Corn oil was the most frequently used oil (27%) (Table 31), yet the sensory panel found that unheated corn oil had an unusually strong popcorn-like odour which dissipated slightly when heated (Figure 4). It seems obvious that although the odour of corn oil is strong it is not unpleasant to consumers.

Soybean oil was the next most frequently used oil (25.5%) (Table 31), yet the researchers at Northern Regional Laboratories in Peoria, Illinois, have been concerned with improving soybean oil odour for some years (Evans, 1971).

The third most frequently used oil was RSO (11%) (Table 31). The sensory evaluation panel consistently found that RSO had a stronger heated odour than heated soybean oil and that the odour increased on prolonged heating to peak at about 10 minutes at 190C (Figures 4, 7, and 8). Terms used by the sensory evaluation panel for the odour parameters of heated RSO (Table 10) were similar to Evans' (1971) descriptions of heated soybean oil odour and also similar to descriptions used by Badings (1970) to describe the odour of various lipid autoxidation

products (Table 3). Some of these same descriptors, fishy, painty and grassy, were used by consumers (Table 37) to describe the room odour of RSO, although most could not describe it.

It would seem likely to expect to find a relationship between heated oil odour and oxidative change because of the similarity of descriptors used to indicate oxidative breakdown products and the odour of heated RSO and soybean oil. If oxidation explains the cause of greater odour development in heated RSO and soybean oil than in other popular oils the higher content of linolenic acid (C18:3) in these oils could account for it (Tables 23 and 25). Forss (1972) cites linolenic and linoleic as two of the most important unsaturated fatty acids in foods from the off-odour standpoint. The speed with which C18:3 breaks down as compared to C18:2 could explain the susceptibility of linolenic-containing oils to oxidative change. According to Labuza (1971) linolenic oxidizes 20-30 times faster and linoleic 10 times faster than oleic acid.

Differences in fatty acid composition between varieties may also partially explain heated odour development. High erucic RSO had consistently better, i.e. lower, odour scores than low erucic RSO for sulfur, fishy and painty parameters (Figure 3). The lower levels of C18:1, C18:2 and C18:3 in high erucic acid RSO may account for reduced odour development (Vaisey et al., 1973).

The odour intensity values of hydrogenated RSO, although not significantly different, were consistently lower than RSO (Figures 4, 7 and 8). Here again the lower C18:3 content (Tables 23 and 24) may account for the slight improvement in odour.

The increase in TBA values for all the oils on prolonged heating (Figures 13 and 14) further substantiates that

oxidative changes were taking place in the oils. TBA values also showed a high positive correlation with odour intensity values (Figures 15 and 16).

Nevertheless some of the findings in these studies indicated that oxidative change provides only an incomplete explanation of heated oil odour development. For example, few changes in fatty acid patterns were noted when RSO, hydrogenated RSO and soybean oil were heated for 40 minutes at 190C (Table 25). The changes in C18:3 and C18:2 were no greater than would be expected between duplicate samples. Therefore, if the odour produced is due to fatty acid breakdown products, only very minute quantities of the oil are responsible for the dramatic odour increase.

The magnitude of the difference between TBA values for RSO and hydrogenated RSO (Figures 12, 13 and 14) as compared to the high OIV's for both RSO forms (Figures 4, 7 and 8) further challenges oxidative change as the single cause of heated RSO odour development. Nevertheless TBA changes were highly correlated with odour change for both RSO and hydrogenated RSO (Figures 15 and 16).

The differences between high and low glucosinolate oils cannot be explained by oxidation of the fatty acids. The differences between the heated OIV's for low glucosinolate RSO and soybean oil were less than the differences between high glucosinolate RSO and soybean oil (Figures 7 and 8). In fact, heated OIV's for hydrogenated forms of low glucosinolate RSO were comparable to those for heated soybean oil (Table 8). Table 24 shows that these breeding changes do not change the fatty acid composition. The lower sulfur content of low glucosinolate rapeseed (Stefansson, personal communication) would provide less

opportunity for sulfur residues in the oil; this may account for the reduced odour of these oils.

Better processing coupled with the use of low sulfur varieties may be the key to the reduction of heated RSO odour. It has been shown by Daun (1975) that processing can reduce the sulfur content of high glucosinolate oils to 1 ppm (Table 7); however the odour threshold for sulfur compounds has been reported between 0.1 and 0.2 ppm (Stahl, 1973). The low glucosinolate varieties contain 10-fold less sulfur than the varieties reported by Daun (1975). The use of low glucosinolate varieties may reduce the sulfur content below the odour threshold. Hydrogenation of low glucosinolate varieties reduced the OIV to equal soybean oil (Figure 8). Further, in the study comparing oils from different commercial sources, the oil from one processor who is known to have a more modern process, was consistently lower in all odour parameters (Figure 3). Therefore, the combination of low glucosinolate RSO varieties, partial hydrogenation and processing by the best procedure available, should provide the best potential for production of a less odourous RSO.

LIMITATIONS

Conclusions from this research have been tempered in recognition of certain limitations imposed by the instruments.

Considerable judge variability was experienced in sensory panel investigation as demonstrated by high coefficients of variation which ranged from 27% to 89%, significantly different OIV's for judges and significant judge interactions exemplified in experiment 2 (Figure 5). Sensory evaluation produces high variability even under the most stringent of controls because of human variation (Ough and Baker, 1964). There is need for continuing motivation especially in a study of long duration to maintain peak performance (Henderson and Vaisey, 1970). To successfully maintain motivation, panelists should be informed of their correct responses. The present study continued 3 times per week for 6 months during which panelists were usually, but not always, informed of their correct identification of the control sample. Further, odour evaluation is sensitive and variable because odour adaptation is rapid and increases with increasing odour intensity (Amerine, 1965).

Since the detection threshold was placed between 10% and 20% of RSO by volume (Figure 6), sensory evaluation using a lower concentration of RSO might have resulted in a slower rate of adaptation (Amerine, 1965).

High and low glucosinolate RSO's were compared across experiments 2, 4 and 5, by comparing heated OIV's for the RSO's with the heated OIV's of the reference soybean oil (Figures 2, 7 and 8). This is a technique not commonly recommended in statistical methods although some valuable inferences can be derived in this way.

The TBA test, which is a measure of malonaldehyde thought to be derived from some decomposition product of oxidized unsaturated fatty acids (Tarladgis et al., 1962), has been viewed with some caution. Some researchers suspect that there are other degradation products of TBA which absorb at the same wave length (532 mu) as the TBA-malonaldehyde complex (Marcuse et al., 1973; Tarladgis et al., 1960, 1962).

In the consumer survey the order of the questions may have resulted in some bias. Questions specific to the sensory quality of RSO (#7-10) were asked before probing the reasons for continued or discontinued use (#11) of RSO.

RECOMMENDATIONS

The investigations in this study indicate the following areas for future research.

1. Comparison of the sulfur content and odour increase on heating of high and low glucosinolate oils from commercial processors.
2. Future testing of the masking agent in heated RSO at concentrations between 11.35 ppm and 113.5 ppm.
3. Odour adaptation may be reduced in future hot RSO testing by using a diluted RSO (10-20% by volume in mineral oil) and thereby reducing panel variability.
4. A GLC examination of the odour peaks of hydrogenated RSO might simplify the identification of compounds related to RSO odour, because some of the oxidative breakdown products were reduced, as demonstrated by the low TBA values, while the odour intensity of the oil remained high.

SUMMARY AND CONCLUSIONS

The investigations in this study permit the following conclusions:

1. Sensory panel evaluation showed that RSO and hydrogenated RSO were stronger in heated odour intensity than heated soybean oil which in turn was higher than corn oil, sunflower oil and safflower oil.
2. The OIV of RSO and soybean oil increased when heated to 190C and tended to plateau after about 10 minutes.
3. Hydrogenation tended to reduce heated RSO odour intensity consistently in three separate experiments although the differences between RSO and hydrogenated RSO were not statistically significant.
4. The unpleasant odour emitted by RSO on heating was described as sulfurous, fishy, and painty, by the odour evaluation panel.
5. In a comparison of RSO oil from three processors the mean scores for the oils from one processor were consistently, although not significantly, lower in all odour parameters than the oils from the other two processors.
6. Oxidation of the oils on prolonged heating was evidenced by increased TBA values of heated oils.
7. Hydrogenated RSO did not show the same dramatic increase in TBA values on heating as RSO and soybean oil.
8. High positive correlations were found between TBA values and OIV values for both unhydrogenated and hydrogenated oils.
9. High erucic RSO varieties were significantly better, i.e. lower, in fishy odours ($P < 0.01$) and tended to be lower in painty odours ($P < 0.10$) and sulfurous odours ($P < 0.10$) than low erucic RSO varieties.

10. Low glucosinolate RSO varieties had OIV's which were lower and more similar to soybean oil than high glucosinolate RSO varieties.
11. Fatty acid analysis showed that RSO had the highest content of linolenic acid followed by soybean oil and hydrogenated RSO.
12. No significant change in fatty acid content was found between unheated oils and oils held at 190C for 40 minutes.
13. When serial dilutions of a masking agent in RSO were heated to 190C for 10 minutes, 11.35 ppm of the masking agent significantly ($P < 0.01$) reduced the odour of heated RSO. However when this level of masking was tested more extensively no significant differences between masked and unmasked samples of RSO were found.

A telephone survey of 400 Manitobans permits the following conclusions:

14. 65% had heard of RSO.
15. 41% had used RSO at some time and 11% were using it currently.
16. Economy was the predominant reason for purchasing RSO.
17. Most RSO users had no complaints about it. However 13-18% associated some unpleasant sensory characteristics with RSO use.
18. Twenty-eight percent of the respondents who had discontinued using RSO described the kitchen odour as unpleasant and 24% described the taste as unpleasant ($P < 0.01$).
19. A larger percent of the families with 5 or more members than those with less than 5 members were RSO users at some time ($P < 0.01$).
20. More RSO users in the skilled labour category discontinued use of RSO than those in the managerial or professional category ($P < 0.01$).

21. Three-fourths of those who purchased RSO because it was cheaper had a limit on their food spending ($P < 0.01$).

LITERATURE CITED

Abdellatif, A.M.M. and Vles, R.O. 1970. Physiopathological effects of rapeseed oil and canbra oil in rats. Proceedings of the Intl.Conf. on the Sci., Tech. and Marketing of Rapeseed and Rapeseed Products. Ste. Adele, Quebec, Canada, Sept.20-23, 1970. p.423-434.

Amerine, M.A., Pangborn, R.M. and Roessler, E.B. 1965. Principles of Sensory Evaluation of Food. Academic Press, New York and London.

Anon. 1973(a). Long chain fatty acids restricted in processed edible fats and oils. Food in Canada 33 (8): 38.

Anon. 1973(b). Content of C22 monoenoic fatty acids to be restricted voluntarily - or otherwise. Food in Canada 33 (9): 46.

Badings, H.T. 1960. Principles of autoxidation processes in lipids with special regard to the development of autoxidation off-flavors. Neth.Milk & Dairy Journal 14: 215-242.

Badings, H.T. 1970. Cold-storage defects in butter and their relation to autoxidation of unsaturated fatty acids. Nizo-Verslagen, Nr 124, pp. 13-24. H.Veenman & Zonen, N.V., Wageningen.

Beare-Rogers, J.L. 1970. Nutritional aspects of long-chain fatty acids. Proceedings of the Intl.Conf. on the Sci., Tech. and Marketing of Rapeseed and Rapeseed Products. Ste.Adele, Quebec, Canada, Sept.20-23, 1970. p.450-463.

Biggar, C.A., Eskin, N.A.M., Vaisey, M. and Johnston, B. 1975. Oxidative deterioration of canned lake whitefish (Coregonus clupeaformis) treated with antioxidants. J.Fish.Res.Bd.Can. 32 (2): 227-232.

Campbell, J.A. 1970. Official statement from Food and Drug Directorate concerning safety of rapeseed oil for human consumption. Presented at Intl.Conf. on the Sci., Tech. and Marketing of Rapeseed and Rapeseed Products. Ste.Adele, Quebec, Canada, Sept.20-23, 1970. p.467-468.

Canadian Department of Industry, Trade and Commerce. 1974. Statistical Review of Fats and Oils Production and Trade. Presented to the Annual Meeting, Can.Comm.on Fats and Oils, National Research Council, October 17-18, Winnipeg, Manitoba.

Cowan, J.C., Evans, C.D., Moser, H.A., List, G.R., Koritula, S., Moulton, K.J. and Dutton, H.J. 1970. Flavor evaluation of copper-hydrogenated soybean oils. J.Am.Oil Chem.Soc. 47: 470-474.

Cowan, J.C., Koritula, S., Warner, K., List, G.R., Moulton, K.J. and Evans, C.D. 1973. Copper-hydrogenated soybean and linseed oils: composition, organoleptic quality and oxidative stability. J.Am.Oil Chem.Soc. 50: 132-136.

Craig, B.M. 1970. Comparative Characteristics of Canadian Rapeseed Oils. Proceedings of the Intl.Conf. on the Sci., Tech. and Marketing of Rapeseed and Rapeseed Products. Ste.Adele, Quebec, Canada, Sept.20-23, 1970. p.158-169.

Daun, J.K. 1975. Sulfur Compounds in Rapeseed Oil. Ph.D. thesis, University of Manitoba, Winnipeg, Manitoba.

Evans, C.D., Moser, H.A., List, G.R., Dutton, H.J. and Cowan, J.C. 1971. Edible oil evaluation by room odor tests: a preliminary report. J.Am.Oil Chem.Soc. 48: 711-714.

Evans, C.D., Warner, K., List, G.R. and Cowan, J.C. 1972. Room odor evaluation of oils and cooking fats. J.Am.Oil Chem.Soc. 49: 578-582.

Feenstra, W. and Keppler, G. 1972. Fatty acid products having improved flavour characteristics. British patent 1282786, 22 Aug., 1972.

Fioriti, J.A., Kanuk, M.J. and Sims, R.J. 1974. Chemical and organoleptic properties of oxidized fats. J.Am.Oil Chem.Soc. 51: 219-223.

Forss, D.A. 1972. Odor and flavor compounds from lipids. Progress in the Chemistry of Fats and Other Lipids.13 (4): 203-258.

Gibbons, J.D. 1971. Nonparametric Statistical Inference. McGraw-Hill, New York.

Henderson, D. and Vaisey, M. 1970. Some personality traits related to performance in a repeated sensory task. J. Food Sci. 35: 407-411.

Labuza, T.P. 1971. Kinetics of lipid oxidation in foods. CRC Revs. in Food Tech. 1: 355-404.

Linters, L.L. and Thompson, S.W. 1958. The use of solid triglyceride stearines as fluid shortening ingredients. J.Am.Oil Chem.Soc. 35 (1): 28-32.

Lips, H.J., Grace, N.H. and Hamilton, E.M. 1948. Canadian erucic acid oils. II. Edible use of Rape and Mustard Seed Oils. Can.J.Res. 26F: 360-365.

List, C.R., Evans, C.D., Kwolek, W.F., Warner, K. and Boundy, B.K. 1974. Oxidation and quality of soybean oil: a preliminary study of the anisidine test. J.Am.Oil Chem.Soc. 51: 17-21.

Marcuse, R., and Johansson, L. 1973. Studies on the TBA test for rancidity grading: II TBA reactivity of different aldehyde classes. J.Am.Oil Chem.Soc. 50: 387-391.

Meijboom, P.W. and Stroink, J.B.A. 1972. 2-trans 4-cis 7-cis decatrienal, the fishy off-flavor occuring in strongly autoxidized oils containing linoleic acid or W 3,6,9 etc. fatty acids. J.Am.Oil Chem.Soc. 49: 555-558.

Moser, H.A., Evans, C.D., Mustakas, G. and Cowan, J.C. 1965. Flavor and oxidative stability of some linolenate-containing oils. J.Am.Oil Chem.Soc. 42: 811-813.

Niewiadomski, H. 1970. Progress in the technology of rapeseed oil for edible purposes. Chemistry and Industry 4: 883-888.

Ough, C.S. and Baker, G.A. 1964. Linear dependency of scale structure in differential odor intensity measurements. J.Food Sci. 29: 499-505.

Patton, S. 1974. Malonaldehyde, lipid oxidation, and the thiobarbituric acid test. J.Am.Oil Chem.Soc. 51 (3): 114.

Pilgrim, F.J. and Kamen, J.M. 1963. Predictors of human food consumption. Science 139: 501-502.

Riiner, U., and Ohlson, R. 1971. A review of rapeseed oil uses for edible purposes. J.Am.Oil Chem.Soc. 48: 860-862.

Rocquelin, G. and Martin, B. 1970. Comparative physiological effects of rapeseed and canbra oils in the rat: influence of the ratio of saturated to monounsaturated fatty acids. Proceedings of the Intl.Conf. on the Sci., Tech. and Marketing of Rapeseed and Rapeseed Products. Ste.Adele, Quebec, Canada, Sept.20-23, 1970. p. 405-422.

Scholz, R.G. and Ptak, L.R. 1966. A gas chromatographic method for measuring rancidity in vegetable oils. J.Am.Oil Chem.Soc. 43: 596-599.

Smouse, T.H. 1972. Progress report of the flavor nomenclature and standards committee. American Oil Chemists' Assn.

Snyder, B. and Moore, M. 1969. Properties of rapeseed and peanut oil relative to frying qualities. Rapeseed Oil: Facts and Recipes. Published by the Rapeseed Association of Canada, p.14-16.

Stahl, W.H. (ed.) 1973. Compilation of odor and taste threshold values data. ASTM Data Series DS48, 1916 Race Street, Philadelphia, Pa. 19103.

Stefansson, B.F. 1974. Breeding exotic characteristics in oilseeds. Presented to the Annual Meeting, Can.Comm. on Fats and Oils, National Research Council, October 17-18, Winnipeg, Manitoba.

Tarladgis, B.G., Pearson, A.M. and Dugan, L.R. 1964. Chemistry of the 2-thiobarbituric acid test for determination of oxidative rancidity in foods. II Formation of the TBA-malonaldehyde complex without acid heat treatment. J.Sci.Food Agric. 15: 602-607.

Tarladgis, B.G., Pearson, A.M. and Dugan, L. Jr. 1962. The chemistry of the 2-thiobarbituric acid test for the determination of oxidative rancidity in foods. I. Some important side reactions. J.Am.Oil Chem.Soc. 39: 34-39.

Tarladgis, B.G., Watts, B.M., Younathan, M.T. and Dugan, L. Jr. 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. J.Am.Oil Chem.Soc. 37: 44-48.

Teasdale, B.F., Helmel, G.A. and Swindells, C.E. 1970. The use of canbra oil in margarine and shortening. Proceedings of the Intl.Conf.on the Sci., Tech. and Marketing of Rapeseed and Rapeseed Products. Ste.Adele, Quebec, Canada, Sept. 20-23, 1970. p.190-202.

Tremazi, S.A., Lovegren, N.V. and Feuge, R.O. 1965. Characterization and evaluation of some rapeseed oils. J.Am.Oil Chem.Soc. 42: 78-81.

Vaisey, M., Latta, M., Bruce, V. and McDonald, B.E. 1973. Assessment of the intake and digestibility of high and low erucic acid rapeseed oils in a mixed Canadian diet. J.Can.Inst.Food Sci.& Tech. 6 (3): 142-147.

Vaisey, M. and Shaykewich, K. 1969. Studies on consumer use aspects of rapeseed oil. Rapeseed Oil Facts and Recipes. Published by the Rapeseed Association of Canada. p.8-13.

Vyncke, W. 1970. Direct determination of the thiobarbituric acid value in trichloroacetic acid extracts of fish as a measure of oxidative rancidity. Fette.Siefen.Anstrichmittel 72: 1084-1087.

Weinberg, B. 1972. Processing of low erucic acid rapeseed and canbra oil. Can.Inst.Food Sci.& Tech.J. 5: (3): A57-A60.

Weiss, T.J. 1970. Food Oils and Their Uses. Avi Pub.Co., Westport, Conn.

APPENDIX I

RAPESEED OIL QUESTIONNAIRE

CODE

1. DO YOU PAN FRY FOODS? YES [ASK]

HOW OFTEN? ONCE A WEEK OR MORE ____

LESS THAN ONCE A WEEK ____

LESS THAN ONCE A MONTH ____

NO [ASK #2]

2. DO YOU DEEP FRY FOODS? YES [ASK]

HOW OFTEN? ONCE A WEEK OR MORE ____

LESS THAN ONCE A WEEK ____

LESS THAN ONCE A MONTH ____

NO [TERMINATE IF NO TO #1 AND 2 OR LESS THAN ONCE A MONTH]

3. WE ARE INTERESTED IN LEARNING ABOUT PEOPLES' EXPERIENCES COOKING WITH RAPESEED OIL. HAVE YOU EVER HEARD OF SUCH OILS?

YES [PROBE]

WHERE DID YOU HEAR ABOUT IT?

WHAT HAVE YOU HEARD ABOUT IT?

NO ____

4. WHAT PRODUCT DO YOU USUALLY USE FOR:

	OIL	SHORTENING	OTHER
A. PAN FRYING?	____	____	____
B. DEEP FAT FRYING?	____	____	____

C. DO YOU KNOW WHAT KIND OF OIL (FAT) THAT IS?

YES ____ KIND ____

NO ____ [IDENTIFY OIL FOR RESPONDENT. (See card provided for oil brand classification)]

5. HAVE YOU EVER USED ANY OF THESE (OTHER) RAPESEED OIL BRANDS?

NO _____

WEST OIL _____

CO-OP _____

CAPRI _____

CINDERELLA _____

BURNS VEGETABLE OIL _____

OTHER _____

IF RESPONDENT HAS USED RAPESEED OIL CONTINUE TO #6. IF RESPONDENT HAS NOT USED RAPESEED OIL GO TO #13 AND COMPLETE SURVEY.

6. DID YOU NOTICE ANY DIFFERENCE BETWEEN THE TASTE OF FOODS FRIED IN RAPESEED OIL AND OTHER COOKING OILS?

NOT DIFFERENT _____

SLIGHTLY DIFFERENT _____

SOMEWHAT DIFFERENT _____

VERY DIFFERENT _____

7. WAS THE TASTE PLEASANT OR UNPLEASANT? PLEASANT _____

NEUTRAL _____

UNPLEASANT _____

8. DID YOU NOTICE ANY DIFFERENCE IN THE KITCHEN ODOUR WHILE YOU WERE COOKING BETWEEN RAPESEED OIL AND OTHER COOKING OILS?

NOT DIFFERENT _____

SLIGHTLY DIFFERENT _____

SOMEWHAT DIFFERENT _____

VERY DIFFERENT _____

9. WAS THE ODOUR PLEASANT OR UNPLEASANT? PLEASANT _____

NEUTRAL _____

UNPLEASANT _____

10. CAN YOU DESCRIBE THE ODOUR OF THE RAPESEED OIL WHILE YOU WERE COOKING? _____

11. I WONDER IF YOU ARE CONTINUING TO USE RAPESEED OIL? YES ___ PROBE

WHY? _____

NO ___ PROBE

WHY NOT? _____

12. WHY DID YOU FIRST TRY RAPESEED OIL? LESS EXPENSIVE ___

MANITOBA PRODUCT ___

CHANCE ___

OTHER ___

13. DO YOU USUALLY SET A DEFINITE LIMIT ON YOUR FOOD SPENDING?

DEFINITE LIMIT ___

APPROX. LIMIT ___

NO LIMIT ___

14. DO YOU USUALLY SHOP FOR BARGAINS AND SPECIALS? OFTEN ___

SOMETIMES ___

SELDOM ___

15. HOW MANY PEOPLE ARE IN YOUR HOUSEHOLD? 1 - 2 ___

3 - 4 ___

5 & OVER ___

16. DO YOU LIVE IN

WINNIPEG _____

OTHER MANITOBA CITY _____

SMALL TOWN _____

FARM _____

17. HAVE YOU FINISHED HIGH SCHOOL? YES _____ PROBE

ANY FURTHER THAN HIGH SCHOOL? _____

NO _____

18. WHAT AGE GROUP DO YOU FALL INTO?

UNDER 30 _____

31 - 45 _____

46 - 60 _____

OVER 60 _____

19. WHAT IS THE OCCUPATION OF THE MAIN WAGE EARNER IN YOUR HOUSEHOLD? _____