University of Alberta

Sensory and Chemical Characterization of Canola Oil Extracted by Supercritical Carbon Dioxide

by

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Abstract

The quality of canola oil extracted by supercritical carbon dioxide ($SCCO_2$) was evaluated by chemical analyses, a trained sensory panel, a large-scale consumer survey, and focus panels. $SCCO_2$-extracted canola oil may be less stable than refined or crude canola oil due to its higher free fatty acid content and polyunsaturated fatty acid level. However, it requires less refining to remove undesirable compounds such as chlorophyll pigments. Quantification of total phytosterol and tocopherol levels suggest a healthier oil than refined oil. The descriptive sensory profile of $SCCO_2$-extracted canola oil was distinctly different from those of crude and refined oils and was defined by strong flavour attributes and bright, intense colour. Although consumers initially responded negatively to the intense yellow-orange colour, most panellists liked the flavour and were more willing to accept and purchase the $SCCO_2$-extracted canola oil if they were given nutritional and/or processing background information about the oil.

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This thesis is dedicated with love and respect to my grandfather Ying Po (Paul) Mak
(September 1913 – August 2006)

He was a staunch supporter of life-long education and was an inspiration to me and his many students

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Chapter 1: Introduction and background

1.1. Introduction

The focus of this thesis is the quality assessment of $SCCO_2$-extracted canola oil through descriptive sensory evaluations, consumer surveys, focus panels, and chemical analyses. Canola oil production, $SCCO_2$ extraction, chemical analyses, and sensory assessment methods are briefly reviewed in this introductory chapter.

Chapter 2, "Chemical and Sensory Descriptive Analysis of Canola Oil Extracted by Different Methods", presents the results of quality tests and the development of a trained panel sensory profile of $SCCO_2$-extracted canola oil. Characteristics of this oil are compared with those of canola oil extracted conventionally and with CO_2-assisted pressing. The content of this chapter is presented in the style of the Journal of Food Science.

Chapter 3, "The Effect of Information on the Acceptance of Canola Oil Extracted by a Novel Method", summarizes consumer acceptance of $SCCO_2$-extracted canola oil. The content of this section is presented in the format of Food Quality and Preference. As such, an extensive review of the impact of information on consumer acceptance of foods is provided in its introduction.

The final chapter of this thesis summarizes the two studies and suggests directions and rationale for future research.

1.2. Supercritical fluid extraction

Supercritical fluid behavior has been studied since the early 1800's (McHugh and Krukonis 1994). At a specific temperature and pressure combination, a chemical substance reaches its critical point above which it flows like a gas, but has the solvating properties of a liquid. The conditions at which carbon dioxide (CO_2) reaches its critical point are 73.8 bar and 31.1 ^{o}C (McHugh and Krukonis 1994). Thus, the potential exists to extract compounds at low temperatures only a few degrees above ambient. CO_2 is non-flammable, non-toxic, and inexpensive (McHugh and Krukonis 1994), making it an ideal solvent choice. Currently, $SCCO_2$ extraction is used in applications such as decaffeinating coffee and extracting hops and spices (McHugh and Krukonis 1994).

The $SCCO_2$ process occurs over two steps: extraction and separation. A vessel containing the material to be extracted is pressurized and heated to enable conditions in which CO_2 may reach its critical point. $SCCO_2$ then flows through the material, taking the extract along with it. To recover the extracted material, the vessel is depressurized, releasing the solvent in gas form. The solubility of compounds in $SCCO_2$ vary according to extraction time and/or conditions. Higher levels of phospholipids, sterols, tocopherols, and fatty acids have been found in later fractions during soybean oil extractions (Friedrich, List, and Heakin 1982). Thus, the potential exists to modify the composition of extracts by manipulating processing conditions.

Due to the need to depressurize the extraction vessel after each run, the $SCCO_2$ extraction process is currently a batch process (McHugh and Krukonis 1994). This leads to high operating costs which has limited the uses of the $SCCO_2$ technology to extracting high value products. However, a recently constructed continuous screw press is capable of introducing liquid CO_2 at high pressures to enhance the efficiency of the press (Crown Ironworks Inc., MN, U.S.A.). Although this equipment is currently unable to maintain high enough pressures to sustain the existence of CO_2 in its supercritical state, with modifications, a continuous $SCCO_2$ extractor could be made in the future. Therefore, commodity oilseeds such as canola may also be extracted by $SCCO_2$ in an economically feasible manner. In addition, recent environmental regulations have restricted the level of hexane emissions from oilseed processing facilities (EPA 2001). Therefore, oilseed processors are looking for alternative more environmentally friendly methods to extract oil from oilseeds.

1.3. Canola oil overview

Canola (*Brassica napus* and *Brassica campestris*) was developed in Canada in the 1970s from rapeseed. It differs from rapeseed in that it has low amounts of erucic acid (C22:1) in the oil, and glucosinolates in the meal. These characteristics are important since erucic acid has been known to be responsible for fatty acid deposits in the heart, skeletal muscles and adrenals of rodents in addition to impairing growth (MacDonald 2002). The hydrolyzed products of glucosinolate in the canola meal (isothiocyanates and other sulphur-containing compounds) interfere with the uptake of iodine by the thyroid gland, contribute to liver disease and reduce growth and weight gain in animals (MacDonald 2002). Although not relevant to humans, canola meal is used as animal feed; therefore, the presence of glucosinolates are detrimental to animal health.

The oil extracted from canola seed is consumed all over the world, although many regions have not adapted the name "canola". Canada produces over 1 million tons of canola oil per year and exports over 70% of the yearly yield to markets such as the European Union, United States, and Asia (Statistics Canada 2006). Currently canola oil is the third most consumed oil in the world after soybean and palm oils (USDA 2006) and accounts for nearly 75% of the vegetable oil production in Canada (Malcolmson and Vaisey-Genser 2006).

Canola oil is one of the healthiest cooking oils available on the market. It has a good proportion of mono- and polyunsaturated fatty acids (60% and 32%, respectively), and the lowest amount of saturated fatty acids (7%) among the common cooking oils (McDonald 2002). In addition, canola oil has a beneficial proportion of n-3 to n-6 fatty acids ratio (McDonald 2002).

The lack of flavour and colour of this oil has lent itself well as a versatile oil to many food applications. In addition to salad oil, canola oil is also incorporated into items such as baked goods, margarines, shortenings, and coffee whiteners (McDonald 2004).

1.4. Canola oil extraction and refining

Currently, canola oil is extracted from the seed by means of an expeller to physically express oil, followed by hexane extraction. Hexane is a flammable organic solvent. Many organic compounds are soluble in hexane; consequently, it is often used to extract oils from oilseeds. Since many undesirable compounds are extracted along with the oil, the crude oil is refined in several steps. Compounds that are of particular concern are phospholipids, free fatty acids, odor/flavor compounds and pigments (Booth 2004). The refining steps serve to remove impurities and to extend the shelf life of the oil.

Phospholipids are removed from the oil since they otherwise settle and form a sludge upon storage. Water and acid degumming methods as well as alkali refining are used to remove phospholipids (Booth 2004). The latter method also removes free fatty acids from the oil. Phospholipids are not readily soluble in $SCCO_2$ (Temelli 1992); as a result, oil extracted by $SCCO_2$ does not require degumming.

Following the removal of phospholipids, the degummed oil is bleached to remove chlorophyll and carotenoids. These compounds are removed to produce a visually-pleasing product. More importantly however, the pigments are removed to improve the oxidative stability of the oil (Przybylski 2003; Booth 2004). Oils extracted by $SCCO_2$ have been lighter and clearer than oils extracted by hexane (Bernardo-Gil and others 2002; Oliviera and others 2002) suggesting that lower amounts of pigments such as chlorophyll are extracted along with the oil in the former method. Due to increasingly stringent regulations regarding the disposal of bleaching clays (Booth 2004), the reduced refining requirements of $SCCO_2$-extracted oil is beneficial to the canola oil producer.

The last refining step is deodorization, which removes volatile odour/aroma compounds that may negatively influence the organoleptic quality of the canola oil by forcing steam through the canola oil. Since deodorization takes place at high temperatures of over 200 °C (Booth 2004), some nutritive compounds are lost in this refining step.

1.4.1. Beneficial compounds lost during conventional canola oil refining

The bleaching and especially the deodorization steps of oil refining remove some sterols that are naturally present in the oil (Bortolomeazzi and others 2003). Sterols have been of interest due to their ability to reduce serum cholesterol levels (Moreau and others 1999; Wester 2000; Hicks and Moreau 2001; Yankah and Jones 2001). Therefore, sterol consumption may decrease the risk of coronary heart disease. Plant-derived sterols have been found to be more biologically effective than sterols from animal sources (Wester 2000); therefore, sterols found naturally in canola oil may prove to be valuable. Thus, since canola oil extracted by $SCCO_2$ does not need to be refined as much as conventional hexane-extracted oil, sterols remain in the oil where they may be consumed.

Tocopherol (more commonly known as Vitamin E) levels are also largely reduced by processing and refining of canola oil. Losses of 10% were detected during the alkaline refining and bleaching steps of conventional rapeseed oil processing, while deodorization further decreased the tocopherol content by another 23% (Gogolewski and others 2000).

Tocopherols are physiologically important because they are antioxidants and have been shown to decrease the risk of atherosclerosis (Kamal-Edin and Appelqvist 1996; Herrera and Barbas 2001). Four isomers of tocopherols exist: α-, β-, γ-, and δ-, but the activity of the four isomers are not equal. Biologically, the isomer strength of antioxidant activity follows the order $\alpha > \beta > \gamma > \delta$, while the reverse order is seen in vitro (Kamal-Edin and Appelqvist 1996). Due to their in vitro antioxidant properties, tocopherols are believed to hinder the development of oxidative rancidity (Kamal-Eldin and Appelqvist 1996). Therefore, in addition to its nutritive qualities, there is interest in its quality-preserving properties. Since $SCCO_2$-extracted canola oil does not require as much refining as hexane-extracted oil, tocopherols that are extracted remain in the oil.

1.5. Comparison of hexane extraction with $SCCO_2$ extraction of edible oils

Much work exists in the literature comparing the quality of oils extracted conventionally by organic solvent with those extracted by $SCCO_2$. In general, the latter product requires less refining since $SCCO_2$ is more selective towards the triacylglycerol fraction than organic solvents. Oil extracted by $SCCO_2$ from olive husk required less refining based on acidity value, peroxide value and phosphorus content (Lucas and others 2002). In contrast, $SCCO_2$-extracted carrot root oil had higher peroxide value and free fatty acid (FFA) content than hexane-extracted oil (Ranalli and others 2004). However, FFA content in $SCCO_2$-extracted oil may be dependant on temperature and pressure conditions; compared to mid-temperature and pressure conditions, wheat germ oil had higher FFA content only at low temperature/pressure and at high temperature/pressure extraction conditions (Gomez and de la Ossa 2000). As mentioned previously, since phospholipids are not soluble in $SCCO_2$, oils extracted by this method do not have to be degummed.

Oils extracted by $SCCO_2$ appear to contain higher levels of polyunsaturated fatty acids (PUFA) and lower levels of monounsaturated fatty acids (MUFA) than their hexane-extracted counterparts. This was true for carrot root oil (Ranalli and others 2004) and hazelnut oil (Bernardo-Gil and others 2002). Fatty acid composition of fennel oils extracted by the two methods were only slightly different, with $SCCO_2$-extracted oil containing slightly higher amounts of linolenic (C18:3) acid (Simandi and others 1999). Although the higher level of PUFAs in $SCCO_2$-extracted oil indicate that these oils are more susceptible to oxidative degradation, it should also be noted that PUFAs are valued for their nutritive benefits.

There are varying conclusions as to the comparative levels of nutritive compounds extracted by the two methods. Hazelnut (Bernardo-Gil and others 2002) and walnut (Oliviera and others 2002) oils extracted with $SCCO_2$ contained more tocopherols than oils extracted with hexane. $SCCO_2$-extracted wheat germ oil also had higher total tocopherol levels, but it was in the proportion of lower α- and higher δ- tocopherol isomers (Gomez and de la Ossa 2000). This indicates that although wheat germ oil extracted by $SCCO_2$ may be reasonably resistant to oxidative degradation, it is less biologically effective with respect to potential health benefits. $SCCO_2$-extracted millet bran oil had similar tocopherol levels to hexane-extracted oil (Devittori and others 2000), while carrot root oil extracted by $SCCO_2$ had significantly lower levels of tocopherols (Ranalli and others 2004). The relative amounts of tocopherols extracted by the two methods may be dependant on the commodity that is extracted as well as the extraction conditions used. With respect to sterols, levels in $SCCO_2$-carrot oil were nearly 17 times higher than that in hexane-extracted carrot oil (Ranalli and others 2004), while those of millet bran oil were similar between the two extraction methods (Devittori and others 2000).

Extraction of oilseeds by $SCCO_2$ have also been studied. Soybean, corn and cotton seed oils had slightly lower tocopherol levels and demonstrated lower oxidative stability than their hexane-extracted counterparts (List and Friedrich 1988). This is consistent with the trend of $SCCO_2$-extracted oils containing higher levels of PUFAs. $SCCO_2$-extracted soybean oil hade higher levels of linoleic acid (C18:2) (Nodar and others 2002) and higher peroxide value (Friedrich and List 1982), but was otherwise similar to refined oil (Friedrich and List 1982; Nodar and others 2002).

There is limited work in the literature concerning the sensory properties of $SCCO_2$-extracted oils. Hazelnut (Bernardo-Gil and others 2002) and walnut (Oliviera and others 2002) oils extracted by $SCCO_2$ were clearer in appearance than hexane-extracted oil. Oil extracted with hexane from juniper berry contained a smaller amount of volatile compounds than oil extracted with $SCCO_2$ (Damjanovic and others 2003). However, sensory evaluation of fennel oil extracted by $SCCO_2$ revealed that this oil was more intense in odour and taste than hexane-extracted fennel oil (Simandi and others 1999), suggesting that a greater amount of volatile compounds existed in the $SCCO_2$-extracted oil.

1.6. Methods used to test the quality of canola oil

1.6.1. Chemical/Instrumental tests

Many testing methods are available to determine the quality of edible oils. Standardized analytical methods have been developed by the American Oil Chemists Society (AOCS), the Association of Analytical Chemists (AOAC), the International Standards Organization (ISO) and the International Union of Pure and Applied Chemistry (IUPAC). Peroxide value is a titration method used to indicate the amount of preliminary oxidative degradation while the thiobarbituric acid test measures the level of secondary oxidation products by spectrophotometry (AOCS 1998). Free fatty acid content indicates the level of degradation by quantifying fatty acids released from their glycerol backbones (Ratnayake and Daun 2004). Gas chromatography analyses of oil sample headspace are capable of measuring and identifying volatile decomposition compounds. The smoke point of an oil is a useful indicator of its suitability as a cooking oil. Canadian edible oil standards state that a minimum smoke point of 200 ^{o}C is required for an oil to be a good cooking oil, while a smoke point below 170 ^{o}C indicates an oil unfit for use in cooking (Canola Council of Canada 2005). A myriad of chemical and instrument tests are available to evaluate the quality of edible oils; however, one test cannot encompass the complexity of decomposition products that may be present since each method can only test for a single group of chemical compounds (Kristott 2001). Chemical and instrumental tests are limited by their specificity, but when used in concert may generate a profile of oil quality.

1.6.2. Sensory evaluation

Although it is important to test the quality of edible oils by chemical or instrumental methods, the most sensitive analyses involve the human senses. Sensory evaluation has been employed to evaluate many food products since humans can often detect aromas and flavors at levels below those detectable by chemical or instrumental methods (Desrochers and others 2002). Volatiles that are present in high concentrations are not necessarily the main contributors to oil aroma since threshold levels for different compounds vary in humans (Angerosa 2002). Furthermore, since many instrumental/chemical methods measure individual components in a sample, they cannot compensate for the human ability to sense a combination of stimuli simultaneously (Servili and others 1995). The human senses process complex interactions between multiple stimuli that cannot be imitated by instruments. Sensory evaluation of oil has been used largely for product grading (van Bruggen and others 1995; Angerosa 2002), shelf life studies (Malcolmson and others 1994; Broadbent and Pike 2003), and quality control (Kristott 2001). For these applications, descriptive sensory analyses panels are used to develop in-depth profiles of the product in question.

1.6.2.1. Descriptive sensory analysis

Trained descriptive panel procedures are thoroughly reviewed in sensory literature (Lawless and Heymann 1998; Meilgaard and others 1998; Stone and Sidel 2004) and are briefly summarized here.

Descriptive analysis was first developed in the 1940s and 50s by Arthur D. Little Inc. (Lawless and Heymann 1998; Meilgaard and others 1998). The process, called Flavor Profile™, is a consensus method whereby after familiarization with product attributes and evaluation scales, the moderator leads panelists to agree on a flavor profile. Quantitative Descriptive Analysis (QDA®) builds upon the Flavor Profile method by producing data that may be statistically analysed. Rather than a consensus method, panelists individually evaluate products following extensive training in terminology and line-scale use. A possible weakness to this method is the fact that panelists develop their own approach to using the 15 cm line scale on which responses are recorded (Meilgaard and others 1998). Similar to QDA, Free-Choice Profiling allows panelists to use the rating scales in any manner they like, using individually-generated descriptive terms. Although this method saves time and money by reducing panelist training time, complex General Procrustes Analyses have to be applied to the data obtained (Lawless and Heymann 1998; Meilgaard and others 1998). Gail Civille developed the Sensory Spectrum® technique, which standardizes terms, definitions, and reference standards for specific product categories. As a result, evaluations of a product performed by different groups are believed to be comparable. In general, aspects of descriptive analysis that are common among the different techniques are: panellist selection, refining and training of descriptive terms, training in the use of line scales and reference standards, repeated product evaluation, and statistical analysis of panel data.

1.6.2.2. Standardized assessment of oils by trained panelists

In conducting a trained panel, it is important to consider the presentation of the test product. Carriers are commonly used with foods that are not normally consumed on their own. However, panellists have found that evaluating oils in the form of an emulsion no more or less palatable than evaluating oil on its own (McMullen 1988). Stone and Hammond (1983) concluded that sensory results obtained from oils evaluated as emulsions differed significantly from direct evaluations of the product. Although it could be beneficial to provide carriers to evaluate some food items, edible oils do not require these.

Standard oil evaluation methods stipulate that edible oils be evaluated on their own. The most established sensory evaluation methods of oils are those for olive oil. The International Olive Oil Council and the European Union have established regulations for determining the grade of olive oil based on the sensory qualities of the oil (Aparicio and others 2000). Organizations such as the American Standards for Testing of Materials (ASTM), the International Standards Organisation (ISO), and the American Oil Chemists' Society (AOCS) have established methods for the sensory evaluation of edible fats and oils in general. These methods involve heating the oil in covered vials to temperatures ranging between 50 °C to 60 °C and directly smelling and tasting the product.

1.6.2.3. Consumer acceptance

In the various stages of product development, it is important to determine consumer acceptance of a product. The two main categories of consumer acceptance testing are preference (a product is chosen over others) and acceptance (the degree of liking). Acceptance data can also be interpreted from a preference point of view and contain more insight into consumer opinion (Lawless and Heymann 1998). Large numbers of panelists are required in preference and acceptance testing to ensure validity of the data and reasonable representation of the potential consumer base.

Qualitative research techniques range from simple focus group discussions to in-depth one-on-one interviewing involving laddering techniques and conjoint analyses. Vast generalizations of data obtained by these methods should be limited due to the small sample size of panelists. However, this is offset by the quality of data generated by qualitative methods.

Although $SCCO_2$ extraction has been in use for many years, it is still unfamiliar to the general population (McHugh and Krukonis 1994). Therefore, it is crucial to investigate consumer perception of this "novel" technology applied to a familiar commodity. In considering a product such as canola oil extracted by $SCCO_2$, it is important to assess the consumer response to this product since a significant amount of money would be invested in the manufacturing of the oil.

1.7. Potential placement of $SCCO_2$-extracted canola oil in the market

Canola oil extracted by $SCCO_2$ may find a niche in the market of health oils, boosted by consumer interest in "designer" oils. In the United States, products boasting high levels of phytosterols have been introduced to fill the consumer demand for these healthy oils. Such products have included spreads such as *Benecol* and *Take Control*, the sterol food ingredient Phytrol™ , and naturally sterol-rich corn fibre oil (Hicks and

Moreau 2001). Proctor and Gamble was the first company to market a phytosterol-enriched cooking oil (*CookSmart*™), while Forbes MediTech Inc. developed an oil that incorporated Phytrol™ (Hicks and Moreau 2001). Since canola oil extracted with $SCCO_2$ may require less refining than conventionally-extracted canola oil, it may contain high levels of sterols and tocopherols. Therefore, this oil may be marketed as containing nutritionally beneficial compounds without the processing such as that required by the existing high-sterol "designer oils". This may also appeal to consumer demand for minimally-processed foods.

Canola oil extracted by $SCCO_2$ is of interest due to its anticipated higher amounts of healthy compounds since less refining of the oil may be required. The sensory aspects of $SCCO_2$-extracted oils need to be explored more extensively since this information is lacking in the literature. Chemical and sensory analyses working in tandem may aid to form a complete profile of the canola oil extracted by $SCCO_2$.

1.8. Research Objectives

The objectives of the current research were three-fold:

A. To determine and compare the chemical and instrumental profiles of refined, unrefined hexane-extracted, $SCCO_2$-extracted, and CO_2-assisted pressed canola oils (Chapter 2),
B. To determine and compare the sensory profiles of refined, unrefined hexane-extracted and $SCCO_2$-extracted canola oils (Chapter 2), and
C. To determine the effect of information on consumer acceptance of the concept and sensory qualities of $SCCO_2$-extracted canola oil by way of a survey and a focus panel (Chapter 3).

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Chapter 2: Chemical and sensory descriptive analysis of canola oil extracted by different methods[1]

2.1. Introduction

Canola (*Brassica napus* and *Brassica campestris*) oil is one of the healthiest oils available in the market, containing a favourable fatty acid profile (Canola Council of Canada 2006). It is the second most consumed oil in the United States (Canola Council of Canada 2006). Currently, canola oil is extracted from the canola seed with hexane and refined before marketing. With increasing government environmental regulations on solvent use, alternative extraction solvents are being explored.

Supercritical carbon dioxide ($SCCO_2$) extraction is a good alternative since CO_2 is affordable, available at high levels of purity, non-toxic, non-flammable and is easily removed from the extracted media (McHugh and Krukonis 1994). The processing temperature required for $SCCO_2$ extraction is low and thermal degradation reactions are minimized during the process (Gomez and de la Ossa 2000; Lucas and others 2002; Oliveira and others 2002). In addition, since CO_2 is a more selective solvent than hexane, it extracts fewer undesirable compounds with the oil (McHugh and Krukonis 1994). Consequently, $SCCO_2$ oil may be marketed with minimal refining and processing.

Currently, $SCCO_2$ technology is used to extract spices and hops (McHugh and Krukonis 1994), to decaffeinate coffee (McHugh and Krukonis 1994), and to extract high-value specialty oils (Damjanovic and others 2003). Despite the fact that the overall $SCCO_2$ extraction process is simpler compared to conventional hexane extraction and refining processes, the high equipment costs of the $SCCO_2$ process make it difficult to adapt to high volume processing of oilseeds. However, developments in equipment design will enable the handling of large volumes of oilseeds continuously. A recently developed system that injects high pressure liquid CO_2 into a screw press (CO_2-assisted pressing) may lead to the development of $SCCO_2$ extraction being a continuous high-volume process. This process has not previously been tested with canola seed.

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[1] A version of this chapter will be submitted to the Journal of Food Science for consideration for publication.

Previous studies on the quality of $SCCO_2$–extracted oils have included that of carrot root (Ranalli and others 2004), fennel seed (Simandi and others 1999), soy bean (Friedrich and List 1984), poppy seed (Bozan and Temelli 2003), hazelnut (Bernardo-Gil and others 2002), and walnut (Gomez and de la Ossa 2000). Several studies have explored the extraction of canola oil by $SCCO_2$ (Bulley and others 1984; Dunford and Temelli 1997; Pryzbylski and others 1998). Quality parameters of $SCCO_2$-extracted canola oil that have been explored by these researchers include quantification of free fatty acids (FFA), peroxide value (PV), fatty acid composition, unsaponifiables, phospholipids, tocopherols, and sterols. However, information on the sensory characteristics of $SCCO_2$-extracted canola oil does not exist in the literature.

The objectives of the current study were to:

A. Determine the chemical composition of $SCCO_2$-extracted and CO_2-assisted pressed canola oil and compare them to those of crude and conventional hexane-extracted canola oil.
B. Identify and quantify the sensory attributes of $SCCO_2$-extracted canola oil and compare them to the sensory characteristics of crude and refined canola oil obtained by the conventional hexane extraction process.

Information from such studies may benefit canola growers and processors who are interested in this technology and may aid in future marketing of the technology and product.

2.2. Materials and Methods

2.2.1 Materials

The methods of canola oil extraction evaluated in this study may be divided into three groups: refined and unrefined, $SCCO_2$-extracted, and CO_2-assisted pressed. A major canola oil processor provided the refined canola oil, the unrefined canola oil and the canola flakes used for $SCCO_2$–extractions and CO_2-assisted pressing. $SCCO_2$ extraction was conducted by Norac Technologies, a division of Newlyweds Foods

(Edmonton, AB, Canada). A summary of the canola oil samples and their extraction conditions may be found in Table 2-1. Upon receipt, all oil samples were divided into amber glass bottles, flushed with nitrogen, capped with Teflon-lined caps and frozen at -30 °C. The unrefined canola oil consisted of oils from various steps of the conventional hexane extraction process (stripper, decanter, and crude). CO_2-assisted pressed oils from canola flake and cake were also included in the analyses since these oils were extracted in conditions similar to, but not reaching the pressures of supercritical fluid extraction.

2.2.2. Chemical analyses

All analyses were performed in triplicate, unless otherwise indicated.

2.2.2.1. Basic oil quality analyses

All basic oil quality analyses were performed according to standard methods of the American Oil Chemists Society (AOCS, 1998). Peroxide value (PV) of each oil sample was determined as per method Cd 8-53 and reported as milliequivalents of peroxide per 1000 g sample. Free fatty acids (FFA) were analysed as per method Ca 5a-40 and expressed as % oleic acid. Unsaponifiable content (Ca 6a-40) was reported as a percentage w/w. Smoke point determination was adapted from method Cc 1A-48. Chlorophyll content was analysed according to method Ch 4-91 and reported as mg of chlorophyll per 1000 mg oil sample.

2.2.2.2. Sterols

Sterols were identified and quantified by a modified method of Mounts and others (1996). A 0.05 g aliquot of each oil was weighed to 1 mg accuracy into test tubes. To each tube, 0.5 ml of KOH (50 % w/w), 2 ml of 95% v/v ethanol and 1 ml ethanol containing 2.5 mg dihydrocholesterol (Sigma-Aldrich, St. Louis, MO, U.S.A.) internal standard were added. Samples were heated at 70 °C for one hour. To each test tube, 15 ml cyclohexane and 5 ml deionised water were added, then vigorously vortexed and centrifuged at 121 g for 10 min. The cyclohexane layer was washed with deionised water, then evaporated at room temperature under a stream of nitrogen. To each tube, 0.25 ml each of pyridine and silyation agent (BSTFA + TMCS, 99:1, Supelco, Bellefonte, PA, U.S.A.) was added and samples were incubated at 70 °C for 30 min. Silyated samples were diluted with hexane and immediately analyzed by gas chromatography.

For sample analysis, a Varian 3400 gas chromatograph (Walnut Creek, CA., U.S.A.) equipped with a flame ionization detector (FID), a Varian 8100 autosampler and a J & W Scientific DB-5 fused silica capillary column (30 m x 0.25 mm i.d., 0.1 mm film thickness, Agilient Technologies, Palo Alto, CA., U.S.A.) was used. Helium was the carrier gas at a head pressure of 1.72 bar. The initial injector temperature of 80 °C was held for 0.2 min, then increased at 150 °C /min to 280 °C. The detector temperature was set at 280 °C. An initial column temperature of 70 °C was held for 0.2 min, then ramped to 250 °C at 20 °C /min. A final temperature of 280 °C was reached at 15 °C /min and held for 17 min. Data acquisition and peak integration was conducted with Shimazdu Class VP software (Version 4.2, Shimazdu Scientific Institute, Inc., Columbia, MD, U.S.A.). All sterol forms were quantified using an internal standard with the same response factor of 1.0. Peaks were identified by comparing retention times to external standards.

2.2.2.3. Tocopherols

Tocopherols were analysed according to Kramer and others (1997). Approximately 0.25 g of oil were dissolved in 750 μl hexane and directly injected (25 μl) into the HPLC for analysis. Standard mixtures of α-, β-, δ-, and γ- tocopherols (Sigma Chemical Co., St. Louis, MO, U.S.A.) and tocotrienols (EM Science, Gibbstown, NJ, U.S.A.) were prepared in several concentrations (0-289 μg/ml). Full sets of standards were run at the beginning, middle and end of each set of samples for identification and quantification.

Analyses were performed with a Shimadzu HPLC system (Shimadzu Scientific Instruments, Inc., Columbia, MD, U.S.A.) equipped with a Shimadzu RF535 fluorescence detector set at 295 nm for excitation and 330 nm for emission. The column was a Supelco LC-Diol column, (4.6 mm x 25 cm, 5 μm particle size, Supelco, Inc., Bellefonte, PA, U.S.A.). The autosampler was a Hewlett Packard 1050 (Agilent Technologies, Palo Alto, CA, U.S.A.). Samples were eluted under isocratic conditions with a 99.4:0.6 v/v mixture of hexane:isopropanol as the mobile phase at a flow rate of 1 ml/min using a Varian 9010 solvent delivery system (Varian Associates, Sugarland, TX, U.S.A.). Calibration curves were prepared for the eight external standards and used for quantification. The response factor for each component was greater than 0.99.

2.2.2.4. Fatty acid composition

The canola oil fatty acid composition method was adapted from AOAC official method 41.1.28 (AOAC, 2000). Samples were run in duplicate. Approximately 0.01 g of each oil was weighed into individual test tubes. A mixture (5 ml) of 35% (v/v) BF_3/methanol (14% BF_3/MeOH, Supelco, Bellefonte, PA, U.S.A.), 45% (v/v) MeOH, and 20% (v/v) hexane was added into each test tube. Each tube was then sealed with a Teflon-lined screw cap and heated in a water bath at approximately 100 °C for 45 min with occasional shaking. After cooling to room temperature, 5 ml of a 5% sodium chloride solution were added to each tube, shaken, and allowed to phase separate. An aliquot of the hexane layer was taken for gas chromatography analysis.

GC analysis of fatty acids were conducted using a Varian 3400 gas chromatograph (described above). The column was a SP-2560 (Supelco, Bellefonte, PA, U.S.A.) with a 0.25 mm internal diameter and 50 m length. The detector was set at 230 °C. The initial injector temperature of 60 °C was held for 0.2 min, increased at 150 °C /min to a final temperature of 230 °C and held for 42 min. The initial column temperature of 45 °C was held for 4 min, then ramped to 175 °C at 13 °C /min and held for 10 min. A final temperature of 215 °C was reached by increasing the temperature by 4 °C /min and held for 11 min. Peaks were resolved with Varian Galaxie Workstation software version 1.8.504.1 (Palo Alto, CA, U.S.A.). Peaks were identified by comparison of retention times with those of external standards (NuChek Prep, Elysian, MN, U.S.A.).

2.2.3. Sensory evaluation

All sensory testing protocols were approved by the Faculty of Agriculture, Forestry and Home Economics Research Ethics Board.

2.2.3.1. Canola oil samples

The trained panel evaluated canola oil extracted by three different methods (Table 2-1): refined, $SCCO_2$-extracted, and hexane-extracted (crude). Frozen samples were thawed at 4 °C the day before each evaluation session.

2.2.3.2. Panellists

Ten panellists (9 female, 1 male, age range 22-30 yr) were selected from staff and students at the University of Alberta following a screening session (See Appendices 1-5 for screening tools used). Three of the selected panellists had previous trained panel experience with other food products. The screening was based on activities described by Meilgaard and others (1998). Panellists were instructed not to eat or drink for at least one hour before each session.

2.2.3.3. Sensory method

Canola oil was evaluated using generic descriptive analysis (Meilgaard and others 1998). Over a period of 12 one-hour sessions, panellists were trained to evaluate aroma, flavour, and appearance attributes of canola oil. The first five sessions were dedicated to generating descriptive terms, refining the definitions, choosing reference standards and placing the standards on 15 cm unstructured line scales (Table 2-2). A rinsing protocol was also chosen. During the last seven sessions, panellists were presented with a range of canola oil samples modified to exhibit varying degrees of the 13 attributes to be evaluated. In these sessions, panellists were also familiarized with the computerized data acquisition system (Compusense *five*, version 4.2, Compusense Inc., Guelph, ON, Canada). Panellist performance was evaluated during two half hour sessions to ensure that each judge was using the line scales and reference standards correctly.

2.2.3.4. Sample preparation

Ten ml aliquots of each type of canola oil were distributed into individual 20 ml amber glass vials, covered with Teflon-lined screw caps and heated in a 50 °C water bath for 10 minutes (ASTM Standard E 1346, West Conshohocken, PA, U.S.A.). During sample evaluation, sample vials were kept warm in individual evaluation booths in

Corningware double boiler systems (World Kitchen Inc., Endicott, NY, U.S.A.) heated at 50 °C on Salton hot trays (Lake Forest, CT, U.S.A.). Reference standards were presented at room temperature in 30 ml lidded containers.

2.2.3.5. Sample Evaluation

Sensory testing was conducted over three days with one session per day. Each panellist evaluated all three samples at each session. All three coded canola oil samples were presented to panellists at the same time and were evaluated in a randomized complete balanced block design. All attributes were evaluated on 15 cm unstructured line scales labelled with "Not at all" on the left and "Very" on the right for each attribute. A paper copy of the line scales may be found in Appendix 6. Oil evaluation techniques were adapted from ASTM Standard E 1627 (West Conshohocken, PA, U.S.A.). Participants were instructed to first swirl the capped vials of oil. Then, holding the vial under the nose, panellists uncapped the vials and took three short "bunny" sniffs to evaluate the aroma attributes of the sample. If required, panellists smelled their glass of rinse water to "zero" their noses. Oil flavour was evaluated by taking half of the amount of the oil in the vials (about 5 ml) into the mouth, swishing for 5 seconds then inhaling through the mouth and exhaling through the nose to enhance the perception of volatile aromatic compounds. Expectoration cups were provided since panellists were instructed not to swallow the samples. Panellists waited one minute between samples during which they cleansed their palates with water crackers (Western Family, Overwaitea Food Group, Langley, BC, Canada) and warm (50 °C) distilled water. For visual assessments, oil samples were placed in clear plastic Petri dishes (60 × 15 mm, Fisher Scientific, Ottawa, ON, Canada) to a depth of one cm and presented under controlled lighting conditions (Macbeth Skylight at Daylight setting, Kollmogen Corp., Newburgh, NY, U.S.A.). Colour and lightness/darkness of the oils were evaluated. Colour references were taken from a Pantone Colour Guide (1982, Pantone Inc., Carlstadt, NJ, USA).

2.2.4. Statistical analyses

Analysis of variance (ANOVA) was performed on all data using the PROC MIXED procedure of the Statistical Analysis System (Ver. 9.1, SAS Inst., Cary, NC, U.S.A.). For trained panel analyses, replicate was a random effect and panellist and sample were fixed effects. Tukey's honestly significant difference (HSD) was applied where appropriate for means comparison at $P \leq 0.05$.

2.3. Results and Discussion

2.3.1. Chemical analyses

2.3.1.1. Basic oil quality analyses (Table 2-3)

$SCCO_2$–extracted canola oil and CO_2-assisted pressed oils had significantly higher ($P \leq 0.05$) PV and FFA content, indicating these oils may be less stable than both crude (except stripper oil) and refined canola oils. The values for the refined oil used in this study are within Canadian standards for fresh refined canola oil of a maximum of 0.05% free fatty acid by mass and a maximum peroxide value of 2.0 meq/1000g sample (Canola Council of Canada 2005). The Canadian standard for the maximum acceptable amount of free fatty acid in crude canola oil is 1.0% by mass (Canola Council of Canada 2005). While the decanter and crude oils met this level, the stripper oil did not. Previous studies have indicated that the free fatty acid content of $SCCO_2$–extracted oil is the same or lower than that of hexane-extracted oil (Friedrich and List 1982; Gomez and de la Ossa 2000; Bernardo-Gil and others 2002), but this varies depending on the type of oil and the extraction conditions (Gomez and de la Ossa 2000).

The higher peroxide value of CO_2-assisted pressed and $SCCO_2$ oils may be explained by the fact that these oils have not been refined to increase stability. Yet, the three unrefined hexane-extracted canola oils had relatively low peroxide values. Since oils samples were either frozen or analyzed upon receipt, the time for decomposition was minimized. Decomposition may have occurred at the producer end during extraction due to high temperature conditions. Additionally, phosphatides, which help to stabilize edible oils, are not as soluble in $SCCO_2$ as in hexane and are therefore not present in oils extracted by $SCCO_2$ (Friedrich and List 1982; Eggers and Sievers 1989; Temelli 1992). These results demonstrate the need to handle the $SCCO_2$-extracted oils in such a manner as to prevent oxidative degradation.

Unsaponifiables content of the samples tested ranged from 1.28% w/w (stripper oil) to 0.99% w/w (refined oil). Although the amount detected in the stripper oil was significantly ($P \leq 0.05$) higher than the rest of the samples, the unsaponifiable contents of the remaining samples was generally similar. This is consistent with literature findings that indicated little variation in unsaponifiables content between hexane-extracted and $SCCO_2$-extracted oils (Friedrich and List 1982; Christianson and others 1984; Devittori and others 2000).

Chlorophyll content of the $SCCO_2$–extracted samples (3.3 and 3.9 mg/kg oil) were relatively low and closer to those of refined canola oil (none) than unrefined hexane-extracted canola oil (13.7 – 15.7 mg/kg oil). Chlorophyll content of CO_2-assisted pressed canola oil, although high, was significantly lower ($P \leq 0.05$), than those of the unrefined canola oils. Since chlorophyll in the oil aids oxidation with exposure to light (Przybylski 2003), these pigments should be removed from the oil to prevent product degradation. The low levels of chlorophyll in $SCCO_2$-extracted oils indicate that less refining to remove chlorophyll is required for this oil than is needed for either unrefined hexane-extracted oil or CO_2-assisted pressed oil.

The smoke point of the refined canola oil was the highest ($P \leq 0.05$) of the oils tested, which was expected since this oil is refined to increased stability. Smoke points of $SCCO_2$–extracted oil (181–182 °C) were comparable to those of hexane-extracted and CO_2-assisted pressed canola oils (171–183 °C). However, other than the refined canola oil, the smoke points of all the oils tested were below the minimum value of 232 °C for canola oil as set by the Canadian General Standards Board (Canola Council of Canada 2005). This indicates that without refining, these canola oils may not function as well as refined oil for cooking purposes.

2.3.1.2. Sterols

Beta-sitosterol, brassicasterol and campesterol were the major sterol compounds found in the canola oil samples analysed. Of the oil samples tested, sterol content (Table 2-4) was lowest in refined canola oil ($P \leq 0.05$). The rest of the oil samples contained significantly ($P \leq 0.05$) higher levels of individual and total sterol levels. This was expected since these oils were not refined; up to 40% of sterols are removed during the edible oil refining process, particularly during the deodorization step (Przybylski 2003). Within this group of oil samples, the unrefined hexane-extracted canola oils tended to have the highest levels of individual sterols, except campesterol, of which $SCCO_2$–extracted oil contained the most ($P \leq 0.05$). These findings are in agreement with the sterol analyses of walnut oil (Oliviera and others 2002) and rice bran oil (Ramsay and others 1991), where greater amounts of sterols were detected in oil extracted by $SCCO_2$ than in hexane-extracted oil.

2.3.1.3. Tocopherols

The four tocopherol isomers were detected in the canola oils tested, but no tocotrienols were found. α-Tocopherol content (Table 2-5) of $SCCO_2$-extracted oils were similar ($P > 0.05$) to that in refined canola oil. The hexane-extracted canola oils had significantly ($P \leq 0.05$) higher amounts of α-tocopherol than refined canola oil and levels were comparable to oils extracted by CO_2-assisted pressing at 138 bar. The CO_2-assisted pressed oil that was processed at 207 bar contained similar α-tocopherol levels to the $SCCO_2$–extracted oils. Higher amounts of α-tocopherol have also been found in hexane-extracted walnut (Oliviera and others 2002) and wheat germ (Gomez and de la Ossa 2000) oils than in their $SCCO_2$-extracted counterparts. The level of α-tocopherol is of interest since it is believed to be the isomer that has the most biological activity (Kamal-Eldin and Appelqvist 1996). However, in terms of quality-preserving properties, γ- and δ-tocopherols are the most potent isomers (Kamal-Eldin and Appelqvist 1996). Of the samples tested, the unrefined hexane-extracted canola oils had the highest levels of γ-tocopherol, followed by the CO_2-assisted pressed oils and then the $SCCO_2$–extracted oils. Refined canola oil had the least amount of γ-tocopherol ($P \leq 0.05$).

Total tocopherol levels were generally the highest ($P \leq 0.05$) in unrefined hexane-extracted canola oil (653-746 mg/kg oil). $SCCO_2$-extracted and CO_2-assisted extracted oils had significantly ($P \leq 0.05$) greater total tocopherol levels (447-593 mg/kg oil) than refined while refined canola oil had the lowest level of total tocopherols (380 mg/kg oil). Recent research now indicates that a mixture of tocopherol isomers has greater physiological significance than any single isomer (Liu and others 2003). Therefore, more nutritional benefits could be gained from consuming $SCCO_2$-extracted canola oil than from refined canola oil.

The findings of the current study concur with studies on soybean, corn, and cottonseed oils of List and Friedrich (1988) who determined that tocopherol levels of $SCCO_2$-extracted oils were slightly lower then levels found in hexane-extracted oils. In contrast, hazelnut (Bernardo-Gil and others 2002) and walnut (Oliviera and others 2002) oils extracted with $SCCO_2$ contained more total tocopherols than oils extracted with hexane. However, it may be surmised that oil extraction from nuts may differ from extraction from oilseeds. In addition, Friedrich, List, and Heakin (1982) determined that greater amounts of phytosterols and tocopherols were present in soybean oil at later stages of $SCCO_2$ extraction; therefore, concentration of compounds in $SCCO_2$-extracted oils are also dependant on extraction parameters.

2.3.1.4. Fatty acid composition (Table 2-6)

No significant differences were found in the proportions of saturated fatty acids (SFA) among the oils samples studied (Table 2-6). Although the $SCCO_2$–extracted canola oil had a significantly ($P \leq 0.05$) lower proportion of monounsaturated fatty acids (MUFA), the proportion of polyunsaturated fatty acids (PUFA) was significantly higher ($P \leq 0.05$) than the other oils tested. A significantly greater proportion of omega-3 fatty acids was detected in the $SCCO_2$–extracted canola oil than in the other samples tested. Refined canola oil had the lowest proportion of PUFA. There have been varying conclusions in the literature regarding fatty acid compositions of oils extracted by $SCCO_2$ and by hexane. The current findings do not agree with studies that have found millet bran (Devittori and others 2000), soybean (Friedrich and List 1982), and wheat germ oils (Gomez and de la Ossa 2000) extracted with $SCCO_2$ to have similar fatty acid profiles as hexane-extracted oil. However, similar to this study, Cheung and others (1998) found that PUFA levels in seaweed oil extracted with $SCCO_2$ were higher than levels found in hexane-extracted oil. Canola oil extracted at 414 bar and 40 °C contained a higher level of PUFAs at early stages of the run than at later stages. (Lee, Kim, and Przybylski 1998). Not only do temperature and pressure conditions have an effect on PUFA content, the extraction stage at which the extract is obtained has an effect as well.

Oils with greater proportions of unsaturated fatty acids are more susceptible to oxidation. Fatty acid composition analysis of the oils show that $SCCO_2$-extracted canola oil has a higher proportion of polyunsaturated fatty acids. This may partially explain the relatively high peroxide value of $SCCO_2$–extracted oil compared to conventional and crude oil and suggests that this oil should be stored in such a way as to minimize oxidative degradation. Although the higher PUFA level found in $SCCO_2$-extracted canola oil may pose issues with shelf-life, the high level of omega-3 essential fatty acid indicates that this oil has a nutritional advantage over refined canola oil.

2.3.2. Sensory Evaluation

Significant differences ($P \leq 0.05$) were found among the three evaluated oils (refined, $SCCO_2$-extracted, and crude) for all attributes except for rubbery aroma in which no significant differences were found between refined and $SCCO_2$-extracted oils (Figures 2-1 and 2-2). ANOVA main effects and LSMean values of each attribute are tabulated in Appendix 7. Compared to refined canola oil, $SCCO_2$–extracted canola oil was more intense in all attributes except buttery aroma and flavour. Compared to crude canola oil, $SCCO_2$ canola oil was less nutty and rubbery, but more intense in pickle aroma, mustard aroma and mustard flavour. In general, $SCCO_2$–extracted canola oil was distinguished from the other two oils by sharp, distinct attributes such as pickle, pine and mustard aromas, and mustard and pine flavour. Although the crude canola oil was rated as having the strongest flavour and aroma intensities ($P \leq 0.05$), $SCCO_2$–extracted canola oil was also rated significantly ($P \leq 0.05$) more intense than refined canola oil in these attributes. Sensory evaluation of fennel oil extracted with $SCCO_2$ was demonstrated to have more intense flavour and odour than the same oil extracted with hexane (Simandi and others 1999). The $SCCO_2$–extracted canola oil evaluated in this study was also intensely flavoured, but less so than crude canola oil. Instrumental identification of flavour and aroma compounds by gas chromatography would increase understanding of the sensory characteristics of canola oil extracted by $SCCO_2$.

Canola is the only known edible oilseed that contains sulphur fatty acids (Przybylski 2003; Ratnayake and Daun 2004). Although their presence was not tested, sulphur-containing compounds may account for some of the unique flavours of the

$SCCO_2$–extracted canola oil. Since these compounds are not extracted into the oil or removed in the conventional refining process, it may be possible that these compounds were extracted by $SCCO_2$. Future research into the presence of these compounds may help to explain the unique flavour of $SCCO_2$-extracted canola oil.

In terms of the appearance attributes, refined canola oil was rated as light and yellow, $SCCO_2$–extracted oil was darker and orange, and crude canola oil was darkest and orange-brown. Previous studies have shown that hazelnut oil extracted by $SCCO_2$ was clearer than oil extracted conventionally by hexane (Bernardo-Gil and others 2002). It has been shown that $SCCO_2$–extracted oil is lighter in color than unrefined hexane-extracted hazelnut oil (Bernardo-Gil and others 2002; Oliviera and others 2002). The same result was observed here.

Consumer acceptability of the $SCCO_2$-extracted canola oil should be assessed, particularly since its sensory attributes are so different from refined oil. However, due to the small volumes of oil obtained by the pilot scale $SCCO_2$-extractor used in this study, there were insufficient quantities of oil for this type of evaluation. A consumer survey of the appearance, and focus panel evaluation of the flavour of $SCCO_2$-extracted canola oil was conducted and is reported elsewhere (Mak and others 2006).

2.4. Conclusions

Levels of chemical constituents of canola oils extracted by $SCCO_2$ were generally intermediate relative to those of refined and unrefined hexane-extracted canola oils. $SCCO_2$-extracted canola oil had a greater proportion of omega-3 fatty acids and a higher amount of sterols compared to the other oils, indicating that this oil may have a nutritional advantage over refined canola oil and that extracted by other methods. However, it should be noted that the composition of $SCCO_2$-extracted oil is dependant on extraction conditions. $SCCO_2$-extracted canola oil may not be as shelf-stable as refined, CO_2-assisted pressed or unrefined hexane-extracted canola oil. Canola oil extracted with $SCCO_2$ has distinctly different and more intense sensory attributes than either refined or crude canola oil. These distinct aromatics should be identified in future research to better explain the unique nature of the oil. For the creation of a marketable product, sensory testing and storage analyses are required. Therefore, future studies on the shelf life and consumer acceptability of $SCCO_2$-extracted canola oil are necessary to ensure a stable and acceptable product.

2.5. Tables

Table 2-1. Canola oil samples and their descriptions.

Sample Name	Sample Abbreviation	Extraction Description
Refined canola oil[a]	Ref	Canola salad oil from major oil supplier
Unrefined canola oil		
Stripper Oil	Str	Hexane-extracted, some desolventization
Decanter Oil	Dec	Pressed oil, some clarification
Crude Oil[a]	Cr	Combination of stripper and decanter oil, degummed and dewatered
CO_2-assisted pressed canola oil		
Cake oil at 138 bar	C138	CO_2–assisted pressed oil from canola press cake using CO_2 at 138 bar
Flake oil at 138 bar	F138	CO_2–assisted pressed oil from canola flakes using CO_2 at 138 bar
Flake oil at 207 bar	F207	CO_2–assisted pressed oil from canola flakes using CO_2 at 207 bar
Supercritical CO_2 ($SCCO_2$)–extracted canola oil		
$SCCO_2$ Batch 1[a]	SCB1	Extracted for 3 h at 300 bar/51 °C and collected in a separator set at 120 bar/56 °C
$SCCO_2$ Batch 2[a]	SCB2	Extracted for 3 h at 300 bar/59 °C and collected in a separator set at 120 bar/56 °C

[a] Food-grade samples evaluated by trained panel. The two batches were combined.

Table 2-2. Sensory attributes and scale placements of reference standards used in descriptive sensory analysis of refined, unrefined, and $SCCO_2$-extracted canola oil.

Sensory attribute	Reference	Placement on 15cm line scale
Aroma		
Pickle	Gherkins (Western Family Foods, Vancouver, BC, Canada)	10.5
Mustard	Prepared yellow mustard (French's, Toronto, ON, Canada)	10.5
Buttery	Melted unsalted margarine in canola oil, 10% v/v (Fleischmann's, ConAgra Foods Inc., Omaha, NE, U.S.A.)	9.5
Nutty	Untoasted sunflower seeds, crushed	2.5
	Toasted sunflower seeds, crushed (Save on Foods, Edmonton, AB, Canada)	12.0
Pine	Galbanum oil in canola oil, 1% v/v (Hilltech Canada Inc. Vankleek Hill, ON, Canada)	13.5
Rubber	New rubber tubing (Fisher Scientific, Ottawa, ON, Canada)	8.0
Flavour		
Buttery	Melted unsalted margarine in canola oil, 10% v/v (Fleischmann's, ConAgra Foods Inc., Omaha, NE, U.S.A.)	10.0
Nutty	Untoasted sunflower seeds, crushed	4.5
	Toasted sunflower seeds, crushed (Save on Foods, Edmonton, AB, Canada)	10.0
Mustard	Aftertaste of prepared yellow mustard (French's, Toronto, ON, Canada)	7.0
Pine	Pine nuts, crushed (Save on Foods, Edmonton, AB, Canada)	5.0
Appearance		
Yellow-Brown	Pantone colour paper selector #22-27 (Pantone Inc., Carlstadt, NJ, U.S.A.)	2.1, 4.2, 6.3, 8.4, 10.5, 12.6
Light-Dark	Water (mental reference)	0.0
	Red Wine (mental reference)	15.0

Table 2-3. Free fatty acid content, peroxide value, unsaponifiable content, chlorophyll content and smoke point of refined, unrefined, CO_2-assisted pressed, and $SCCO_2$-extracted canola oils.

Extraction Method	FFA (as % oleic acid w/w)	PV (meq peroxide/1000g oil)	Unsaponifiable value (% w/w)	Chlorophyll (mg/kg oil)	Smoke Point (°C)
Refined	0.02g	1.39e	0.99bc	0.0g	251a
Unrefined					
Stripper	1.23a	3.58d	1.28a	15.6a	178c
Decanter	0.78f	3.78d	1.04b	13.7b	181b
Crude	0.89e	3.52d	1.10b	15.7a	183b
CO_2-assisted pressed					
Cake 138 bar	1.09c	6.57b	0.94c	12.5c	181b
Flake 138 bar	1.10c	6.66b	1.01bc	12.5c	171d
Flake 207 bar	1.15b	17.17a	0.95c	12.0d	179c
$SCCO_2$-extracted (300 bar)					
SCB1 (51 °C)	1.03d	5.45c	1.07bc	3.9e	181b
SCB2 (59 °C)	n/a	n/a	1.11b	3.3f	182b
SEM[z]	≤0.01	0.07	0.02	≤0.02	≤0.40

[abc] Values within a column followed by different letters are significantly different ($P \leq 0.05$). Values are least square means of 3 replicates.

[z] Standard error of the mean

Table 2-4. Sterol content of refined, unrefined, CO_2-assisted pressed, and $SCCO_2$-extracted canola oils (mg/kg oil).

Extraction Method	**Sterol (mg/kg oil)**			
	Brassica-	**Campe-**	**Sito-**	**Total**
Refined	610d	2117e	3561e	6304c
Unrefined				
Stripper	1077a	2984c	5011ab	9072a
Decanter	941c	2746d	4531cd	8217b
Crude	1027b	3071bc	4860abc	8957a
CO_2-assisted pressed				
Cake 138 bar	934c	2694d	4401d	8029b
Flake 138 bar	945c	2710d	4470d	8125b
Flake 207 bar	933c	2608d	4454d	7996b
$SCCO_2$ (300 bar)				
SCB1 (51 °C)	927c	3224ab	4684bcd	8835a
SCB2 (59 °C)	962c	3338a	5028a	9327a
SEM[z]	**10.5**	**37.54**	**69.72**	**110.83**

[abc] Values within a column followed by different letters are significantly different ($P \leq 0.05$). Values are least square means of 3 replicates.
[z] Standard error of the mean

Table 2-5. Tocopherol content of refined, unrefined, CO_2-assisted pressed, and $SCCO_2$-extracted canola oils (mg/kg oil).

Extraction Method	**Tocopherols (mg/kg oil)**				
	α-T	**β-T**	**γ-T**	**δ-T**	**Total**
Refined	110.7d	42.4de	227.0e	0.0b	380.0g
Unrefined					
Stripper	193.5a	82.6a	457.2a	12.8ab	746.0a
Decanter	159.5bc	59.4bc	421.5b	13.2ab	653.6bc
Crude	175.3ab	69.2b	424.0b	11.9ab	680.4b
CO_2-assisted pressed					
Cake 138 bar	153.5c	50.6cd	368.2c	5.6b	577.9d
Flake 138 bar	160.4bc	46.8d	368.0c	18.5ab	593.6cd
Flake 207 bar	100.4d	34.2e	344.4cd	25.3a	504.2e
$SCCO_2$–extracted (300 bar)					
SCB1 (51 °C)	102.5d	6.2f	323.8d	15.0ab	447.5ef
SCB2 (59 °C)	109.7d	7.0f	333.3d	10.5ab	460.4ef
SEM[z]	**3.4**	**1.8**	**5.4**	**3.4**	**10.8**

[abc] Values within a column not followed by the same letter are significantly different ($P \leq 0.05$). Values are least square means of 3 replicates.
[z] Standard error of the mean.

Table 2-6. Fatty acid composition of refined, unrefined, CO_2-assisted pressed, and $SCCO_2$-extracted canola oil expressed as a % of fatty acids.

	Refined oil	**Unrefined oils**			**CO_2-assisted pressed oils**			**$SCCO_2$-extracted oils**		
Fatty Acid	**Refined**	**Stripper**	**Decanter**	**Crude**	**C187**	**F187**	**F207**	**SCB1**	**SCB2**	**SEM[w]**
C16:0	4.39ab	4.42a	4.29abc	4.31abc	4.22c	4.26bc	4.33abc	4.26bc	4.29abc	≤0.04
C16:1cis	0.24b	0.28a	0.20c	0.23b	0.23b	0.22bc	0.23bc	0.21bc	0.21bc	≤0.01
C18:0	1.72	1.92	1.77	1.50	1.69	1.58	1.78	1.84	1.85	≤0.29
C18:1cis9	60.24a	59.03b	60.63a	60.25a	60.47a	60.96a	60.69a	57.39c	57.32c	≤0.23
C18:1cis7	2.96b	3.27a	2.65c	2.95b	2.86bc	2.79bc	2.88bc	3.00ab	3.01ab	≤0.07
C18:2	19.34de	20.19a	19.59cd	19.74bc	18.99f	19.11ef	19.24ef	19.92ab	19.92ab	≤0.08
C18:3	0.66a	0.00b	0.00b	0.00b	0.00b	0.00b	0.00b	0.00b	0.00b	≤0.01
C18:3w3	7.55e	9.12c	9.08cd	9.19bc	9.41b	9.14c	8.86d	12.03a	12.01a	≤0.06
C20:0	0.72a	0.66ab	0.70ab	0.69ab	0.69ab	0.69ab	0.70a	0.62b	0.62b	≤0.02
C20:1w12	0.69a	0.00b	0.00b	0.00b	0.00b	0.00b	0.00b	0.00b	0.00b	≤0.01
C22:0	0.38	0.38	0.35	0.39	0.36	0.35	0.36	0.33	0.33	≤0.01
others	0.36a	0.09b	0.09b	0.09b	0.04b	0.08b	0.09b	0.06b	0.03b	≤0.04
Total SFA[x]	**7.19**	**7.35**	**7.09**	**6.91**	**6.94**	**6.86**	**7.16**	**7.06**	**7.09**	**≤0.28**
Total MUFA[y]	**64.10a**	**62.56c**	**63.45b**	**63.39ab**	**63.53ab**	**63.96ab**	**63.76ab**	**60.61d**	**60.55d**	**≤0.19**
Total PUFA[z]	**27.54f**	**29.30b**	**28.66cd**	**28.93bc**	**28.39cde**	**28.24cd**	**28.08ef**	**31.95a**	**31.93a**	**≤0.14**

[abc] Values within a row followed by different letters are significantly different ($P \leq 0.05$). Values are least square means of 3 replicates.

[W] Standard error of the mean

[x] Saturated fatty acids

[y] Monounsaturated fatty acids

[z] Polyunsaturated fatty acids

2.6. Figures

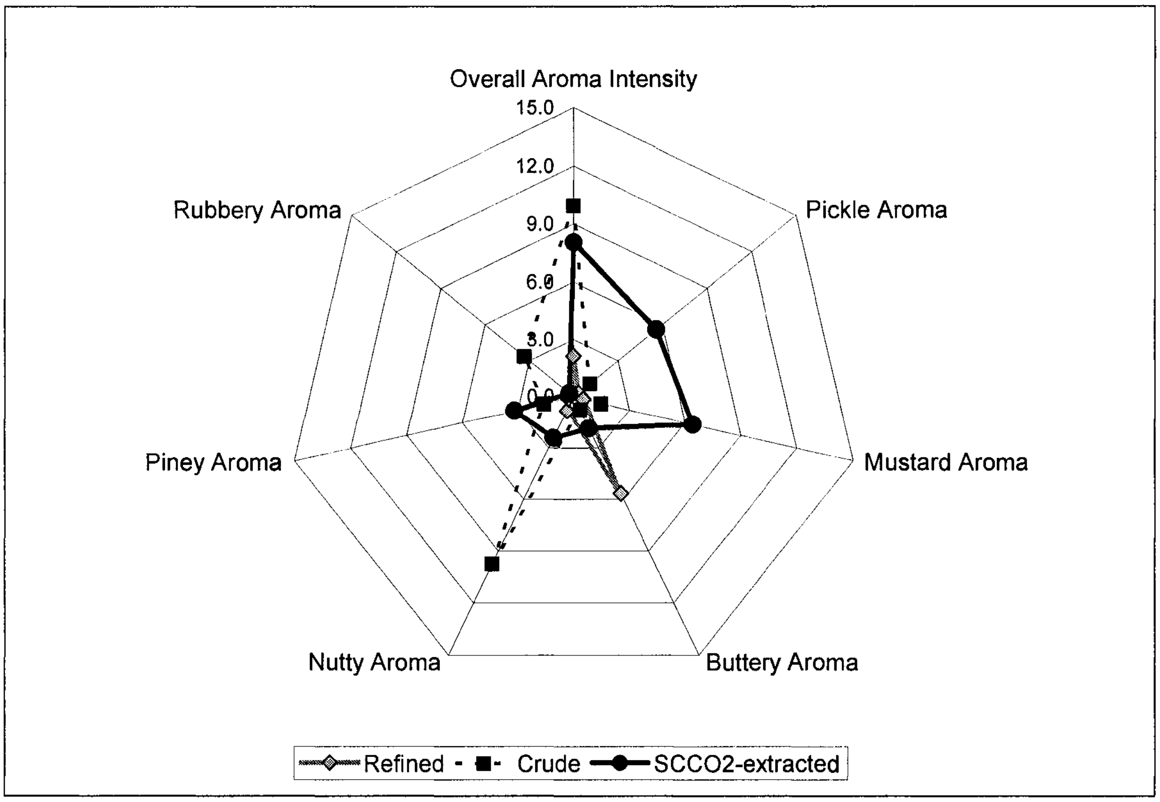

Figure 2-1. Spider diagram of the mean intensity ratings for the aroma attributes of refined, crude and $SCCO_2$-extracted canola oil rated by the trained panel on 15 cm unstructured line scales. Means are from the responses of 10 panelists and 3 replications.

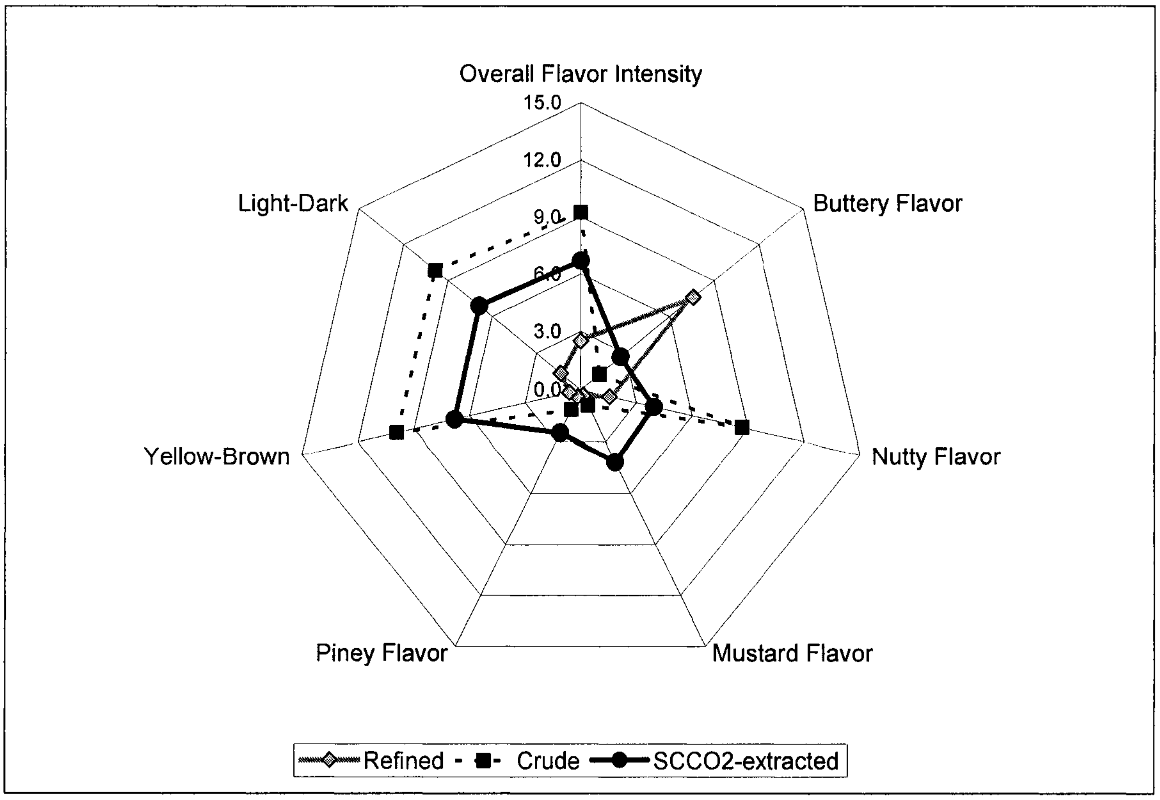

Figure 2-2. Spider diagram of the mean intensity ratings for the flavor and appearance attributes of refined, crude and $SCCO_2$-extracted canola oil rated by the trained panel on 15 cm unstructured line scales. Means are from the responses of 10 panelists and 3 replications.

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Chapter 3: The effect of information on consumer acceptance of canola oil extracted by a novel method[2]

3.1. Introduction

When purchasing a new food product, consumers do not have prior sensory experience to aid the purchase decision. Extrinsic cues such as label information, brand, store name and price are used by consumers to judge product quality (Deliza and MacFie 1996; Jaegar 2006). Tuorila and others (1998b) suggested that acceptance of a new product is strongly influenced by a consumer's experience with foods in the same product category and relies little on label information. When considering the purchase of a food product, consumers rely on three types of attributes to make their purchase decision (Wansink and others 2004): experience attributes (characteristics of the product that may be evaluated when the product is sampled), search attributes (such as appearance and price), and credence attributes (such as manufacturing process or nutritional information). The latter two attributes can be determined without prior experience with the product.

The effect of information on product acceptance and willingness to buy food products have been studied by several researchers. For example, the term "transgenic" incorporated into a label had a negative influence on willingness to buy soybean oil when assessed with price while nutritional information and brand name had no effect (Carneiro and others 2005). Consumers were increasingly willing to buy spelt when precise rather than general information was given about the product's origin (Stefani and others 2006). The sooner consumers were exposed to nutritional information prior to experiencing the product, the greater the acceptance of a low-fat spread product (Kähkönen and others 1996b). Levin and Gaeth (1988) concluded that if consumers have prior sensory information about ground beef, fat level information has less of an effect on current acceptance and purchase intent. Focus groups about probiotic bacterial cultures (Bruhn and others 2002) revealed that product information is more credible if it aligns with existing beliefs. Similarly, label information is more effective if the message is consistent with consumers' beliefs (Aaron and others 1994); consumers who were more accepting

[2] A version of this chapter is to be submitted to Food Quality and Preference for consideration for publication.

of reduced fat products demonstrated greater acceptance of a product labelled as low-fat. From these studies, it may be seen that ample information given before a consumer forms an opinion about a product may have the most impact in their subsequent acceptance of the product.

Numerous studies have explored the influence of nutritional information on product acceptance. Consumers who had positive attitudes towards reduced-fat spreads perceived the sensory characteristics of a labelled reduced-fat spread to be more acceptable than consumers who had positive attitudes towards full-fat spreads (Aaron and others 1994). Similarly, respondents gave higher liking ratings to a juice with an off-flavour when they were presented with health information about the juice compared to a control group that did not receive any information when assessing the same juice (Tuorila and Cardello 2002). Pleasantness ratings and buying probability of reduced-fat frankfurters and margarine increased when reduced-fat information was given (Kähkönen and Tuorila 1999). However, in the same study, reduced-fat chocolate bars were rated lower in pleasantness and buying probability when consumers were given the same information. In a study involving commercial corn chips, consumers demonstrated that taste has a larger influence on purchase intent than health considerations (Tepper and Trail 1998). Although much of the literature shows that consumers generally have a positive attitude towards nutritious foods, some foods are accepted to be inherently unhealthy and are perceived negatively when health-promoting information about the product is presented.

The influence of processing related information on product acceptance has also been studied. Tomatoes that were labelled as ecologically grown elicited more positive hedonic responses than conventionally grown tomatoes (Johansson and others 1999). However, when environmental concern (an altruistic motive) was compared with health concern (an egoistic motive), the latter was found to be a better predictor of organic food purchase (Magnusson and others 2003). Information about novel or unfamiliar processing technologies has been presented to consumers to gage product acceptance. Consumers were more likely to accept and express positive purchase intention when greater amounts of processing information were given about a juice processed by a non-conventional high-pressure technology than when little or no information was given (Deliza and others 2003). Information about brewing technologies using ingredients that were described as genetically modified, organic or traditional influenced labelled evaluations of beer, but sensory characteristics also had a strong effect on acceptance (Caporale and Monteleone 2004). Although it has been observed that nutritional or health messages constitute important pre-purchase information, processing information is also influential. This may be especially true if the manufacturing process is a novel one.

Supercritical carbon dioxide ($SCCO_2$) extraction is a novel process for extracting canola oil from canola seeds. At present, canola oil is extracted with the organic solvent hexane and then refined to remove undesirable compounds. With increasing environmental government regulations on hexane use in the United States (EPA 2001), alternative extraction solvents are being explored. Supercritical carbon dioxide ($SCCO_2$) extraction is a good alternative extraction solvent to hexane since CO_2 is affordable, non-toxic, non-flammable, and less harmful to the environment (McHugh and Krukonis 1994). Currently, this technology is used to extract spices and hops (McHugh and Krukonis 1994), decaffeinate coffee (McHugh and Krukonis 1994), and to extract high-value specialty oils (Damjanovic and others 2003). Since this new process, based on the solvating properties of compressed CO_2, does not extract as many undesirable compounds along with the oil, the oil does not need to be refined to the same extent to create a marketable product. Thus, some nutrients such as plant sterols and vitamin E that are removed in the conventional refining process remain in the $SCCO_2$–extracted canola oil. It is anticipated that the $SCCO_2$–extracted canola oil will be positioned in the market as a high quality oil product comparable to high-end virgin olive oil. Thus far, there have been no studies to determine either consumer attitudes of canola oil processed using this extraction method or to compare this novel product to conventionally extracted canola oil.

The purpose of the this study was to evaluate the influence of information presented about $SCCO_2$ extraction of canola oil on both the appearance acceptability of $SCCO_2$ canola oil compared to conventional canola oil and on willingness to buy $SCCO_2$ canola oil. Focus panels allowed for direct sampling of the oils to build upon information gained in the appearance acceptance study. To avoid the negative connotations that may be associated with the unfamiliar terms "supercritical" or "$SCCO_2$", this oil was referred to as "alternative canola oil" in both the consumer survey and the focus group and the oil and its process are referred to as "alternative" throughout this paper. The information obtained from this study will be important for canola oil processors who may be interested in the $SCCO_2$ extraction technology.

3.2. Materials and Methods

3.2.1. Consumer survey

3.2.1.1. Products and sample presentation

Canola flakes used for $SCCO_2$ oil extractions and conventional canola oil were provided by a major canola oil processor in Canada. $SCCO_2$ extraction was conducted at Norac Technologies, a division of Newlyweds Foods, Edmonton, AB, Canada.

A sample of each oil was placed in a clear glass container under a Macbeth Skylight (Kollmogen Corp., Newburgh, N.Y., U.S.A.) at "Daylight" setting and photographed. The two photographs were shown to panellists in a balanced complete block design to minimize presentation order effects. Only appearance was evaluated in this survey since sufficient amounts of food grade $SCCO_2$ oil were not available due to the small scale pilot runs performed in this study. The colour photographs shown to panellists are depicted in Figure 3-1.

About one-third of respondents (n=107) (control group) were presented with a set of identical photographs of conventional oil instead of a photograph of each of the two oils. These control pictures were presented to observe the influence of the information itself on any changes to appearance acceptance ratings without an actual difference in the appearance stimuli.

3.2.1.2. Consumers

All consumer testing protocols were approved by the Faculty of Agriculture, Forestry and Home Economics Research Ethics Board of the University of Alberta.

Consumers (n=300) were recruited from grocery stores and farmers' markets (54%) and from staff and students (46%) at the University of Alberta. Grocery store and university participants were recruited on weekdays between 8 a.m. and 5 p.m. The farmers' market was held on a Saturday between 8 a.m. and 3 p.m. Participants were screened to ensure purchase and use of canola oil. Informed consent (Appendix 8) was collected from qualified and interested panellists.

3.2.1.3. Questionnaire

Figure 3-2 illustrates the sequence of questionnaires, canola oil photograph evaluations and information presentation to consumer panellists. Initially, frequency of canola oil use was rated on a 5-point category scale ranging from 'more than once a day' to 'never'. Panellists were asked how they used canola oil. Photographs of the two canola oils, labelled with random 3-digit codes to blind their identities, were evaluated for overall acceptance of appearance on 9-point hedonic scales (Peryam and Pilgrim 1957).

Panellists were then asked, "How important is it for you to buy foods that are minimally processed/refined?" and "How important is it for you to buy foods with proven health benefits?". They were then given one of three different information types in paragraph form (described in section 3.2.1.3.1.). After reading the information provided, panellists rated overall appearance acceptability of the same photographs as before, but this time they were labelled correctly as "conventional" and "alternative" canola oils. Following this, panellists were asked to indicate their willingness to buy the alternative canola oil if its price was comparable to or higher than that of canola oil currently on the market given its appearance and the information provided. Each of these questions were answered on a 5-point category scale ranging from 'definitely will buy', 'probably will buy', 'may or may not buy', 'probably will not buy', and 'definitely will not buy'. Panellists were than asked if they would be willing to pay a given random price for the alternative canola oil. Finally, demographic information was obtained. The questionnaire presented to panellists is replicated in Appendix 9.

3.2.1.3.1. Information presented to consumers

Information presented to panellists was written by the investigators based on a literature review of the $SCCO_2$ extraction process. Elements of the $SCCO_2$ process were divided into nutritional and processing aspects and expressed in informational paragraphs. The nutrition information (N) indicated, "since the alternative canola oil does not need to be processed as much as conventional oil, nutrients such as Vitamin E and sterols remain in the oil where they may be consumed". The processing information (P) stated that unlike the conventional process, "the alternative extraction uses carbon dioxide instead of hexane, which is more environmentally friendly, non-toxic, and does not leave residues in the oil". A third information paragraph incorporated a combination of both the nutritional and processing information (C). Each information type was presented to panellists in paragraphs of approximately 100 words (See Appendix 10).

3.2.1.4. Response measures

The four response measures were 'overall appearance acceptance', 'willingness to buy at a comparable price', 'willingness to buy at a higher price' and 'willingness to pay at a given price level'. For the last measure, one of 15 possible prices ranging in $0.50 increments from $3.00 to $10.00 for a litre of canola oil was randomly presented as a hypothetical asking price for a bottle of the alternative canola oil. A survey of local grocery stores indicated that $4.00 was the average price of a one-litre bottle of canola oil; this information was provided with the question.

3.2.1.5. Data analyses

The Catmod (chi-square) procedure of SAS version 9.1 (SAS Institute, Cary, NJ, U.S.A.) was used for comparisons of categorical demographic and response variable data. The McNemar chi-square test was used to compare the number of respondents who liked the appearance of the samples tested during pre-and post-information conditions. Pre- and post information hedonic ratings of the appearance of the oil pictures were compared using repeated measures analysis of variance (ANOVA) (repeated factor: evaluations of oil pictures before and after receiving information). The source of between-subjects variance was the information type received. To clearly observe the impact of presented information on appearance ratings, the difference between labelled and blind hedonic ratings (response shift) was calculated for each oil and information type (Bower and others 2004). These values were also subjected to ANOVA with information type as a between subjects factor. Tukey's honestly significant difference (HSD) was used for means separation where applicable.

Linear regression models were applied to determine the variables that had a significant effect on the response measures (dependant variables). All non-continuous variables were coded with dummy variables as follows: gender (female=1, male=0), age in years, education (postsecondary education=1, less than postsecondary education=0), income (1 if the tax bracket applied to the respondent, 0 if the tax bracket did not apply), location (1 for the location where the respondent was queried, 0 if the respondent was not queried at that location), frequency of canola oil use (≥2 times/week=1, <2 times/week=0), willingness to buy questions (probably and definitely would buy=1, maybe, probably and definitely would not buy=0). SPSS version 14.0 (SPSS Inc. Chicago, IL, U.S.A.) was used for linear regression analyses. All tests of significance were calculated at $P \leq 0.05$.

3.2.2. Focus panel method

3.2.2.1. Subjects

Two focus panels were conducted to allow consumers to sample the canola oils. The first group (n=9, 1 male, 8 females, age range 25-70) consisted of participants from the consumer survey who expressed an interest and were available to participate in the focus panel. The second group (n=7, 3 males, 4 females, age range 21-55) consisted of people recruited on campus and were largely from the student population. Interested individuals were screened to ensure purchase and use of canola oil. Participants were given a $25 gift certificate upon completion of the focus panel.

3.2.2.2. Procedure

The focus panels were held in the focus group room of the Human Ecology Building on the University of Alberta campus. Each session lasted 60 to 90 minutes and was videotaped. Panellists were presented with one of each of the canola oils (conventional and alternative) in clear 20 ml capped vials, two small dishes and pieces of French bread as oil carriers.

At the beginning of each session, the moderator (moderator guide may be found in Appendix 11) explained the project and the participants provided informed consent. Participants told the group what kinds of oils were in their cupboard and for what they were used. Following this, all sensory aspects of the canola oil samples were discussed. The concept of the $SCCO_2$ (alternative) extraction method was presented. Both the nutritional and the processing aspects of the alternative extraction process were compared with those of the conventional extraction process. Information presented to focus panel members was the same as that presented to consumer survey participants as described earlier. Reactions to this information and subsequent willingness to buy were discussed. Finally, group members were asked about potential uses and markets for the alternative canola oil.

Videotapes of each focus panel session were transcribed verbatim. Similar discussion ideas were grouped together and statements that were the most common or that elicited the most panellist agreement were reported.

3.3. Results

3.3.1 Consumer survey results

3.3.1.1. Demographic data (Table 3-1)

Of the people surveyed, 56% were female. There was a significant location by gender effect ($\chi^2 = 41.41$, d.f. = 11, $P < 0.0001$). This was reflected by a higher proportion of female respondents at grocery stores and farmers' markets, while the reverse was observed at on-campus locations. Income levels were significantly different across locations ($\chi^2 = 31.29$, d.f. = 6, $P < 0.0001$). Most respondents from campus locations indicated yearly individual income levels of $35,595 CAD or less, the lowest 2004 Canadian income bracket. The majority (64%) of respondents had a post-secondary education or greater. Education levels of respondents by location were significantly different ($\chi^2 = 47.48$, d.f. = 6, $P < 0.001$), which may be expected since 46% of the surveys were conducted on a university campus.

The combination of on- and off-campus locations resulted in a relatively even distribution of participants across age categories, with slightly greater numbers of on campus respondents belonging in the age 18-34 groups. There was a significant age by education interaction ($\chi^2 = 392.17$, d.f. = 10, $P < 0.0001$) with a decrease in education level in the higher age groups (>65 y). There was also an age by income interaction ($\chi^2 = 173.77$, d.f. = 10, $P < 0.0001$) with the higher incomes earned by participants in the 35-65 age range.

A significant interaction was found between age and self-reported importance of consuming foods with health benefits ($\chi^2 = 66.34$, d.f.= 8, $P < 0.0001$). Although most participants indicated that it was important for them to buy foods that are healthy, 20% of the respondents in the 18-24 age group were indifferent or stated that it was not important for them to consume foods with health benefits. In contrast, all respondents above 65 years thought it was important to consume healthy foods. The older demographic tended to be more concerned about purchasing foods that are minimally refined or processed, but the age by importance interaction was not significant.

Over half of the respondents used canola oil 3 times a week or more. The most common use of canola oil was for frying. Non-food applications such as skin moisturizer, biodiesel for cars, and as a lubricant were suggested by 5.3% of respondents. Reasons for consuming canola oil were mainly that the consumer believed that it is healthy (65%), affordable (52%), familiar (45.3%) and because of its flavour (35%). Only 11.3% of panellists purchased canola oil for its appearance.

Over 70% of respondents claimed that they read food labels always or frequently. The information that most people gleaned from labels were nutrition and ingredient information (86% and 85%, respectively).

3.3.1.2. Overall appearance acceptance

Control pictures

There was no significant difference in the pre-information hedonic ratings of the appearance of the two control canola oil photographs; this was expected as the two photographs were identical. In addition, there was no significant difference between the pre- and post-information appearance acceptance of the control oil picture whether labelled as "conventional oil" or as "alternative oil" and for all information types presented. Thus, it can be concluded that consumers did not express any information influences as non-existent differences in appearance. The control panellists were excluded from further analyses of hedonic appearance measures.

True pictures

Blind (pre-information) hedonic ratings

The appearance acceptance of the two unlabelled oil pictures was significantly different [F (1,384) = 103.02, $P < 0.001$]. On average, the appearance of the conventional canola oil was initially "liked slightly" to "liked moderately", while the appearance of the alternative canola oil was initially "neither liked nor disliked" (Table 3-2). Consumers commented that the alternative oil looked "used", "dirty", and "heavy" while the conventional oil appeared "clean", "light" and "like the kind of oil I normally use".

Labelled (post information) hedonic ratings

Regardless of the type of information received, appearance ratings of the labelled alternative oil were significantly higher [F(3, 380) = 4.20, $P = 0.006$] than the corresponding blind ratings (Table 3-2). In contrast, consumers who received either processing or combined information liked the appearance of the labelled conventional canola oil significantly less than its blind counterpart [F(3, 380) = 3.79, $P = 0.01$]. Although the consumers who received only nutrition information also rated the labelled conventional oil lower than blind ratings, the difference was not statistically significant. The appearance of both labelled alternative and conventional oils were in the range of "liked slightly" on the hedonic scale.

Whereas appearance liking of the blinded conventional oil was rated significantly higher than the alternative, the appearance liking of the two labelled oils were no longer significantly different after either combined or processing information was presented (Table 3-2). For consumers who were presented with these information types, liking of the conventional oil appearance decreased while that of the alternative oil increased, bringing the post-information appearance ratings of the two oils closer in magnitude. Consumers who received only nutrition information still liked the appearance of the conventional oil significantly more than the appearance of the alternative oil after reading the information [$F(1, 138) = 11.06$, $P < 0.001$].

The distribution of hedonic responses among "neutral" or "dislike" (1-5 on the hedonic scale) and "like" (6-9 on the hedonic scale) were examined (data not shown). Initially, 61% of the panellists were neutral or disliked the appearance of the alternative canola oil, while only 23% disliked or were neutral with respect to the appearance of the conventional oil. The McNemar chi-square test was used to observe the effect of information on liking (Siegel 1956). Regardless of the information type presented, a significantly greater number of people increased their hedonic appearance ratings (shifted from "disliking" or "neither like nor dislike" to "liking") compared to the number of people who decreased their hedonic appearance ratings (shifted from "like" to "dislike" or neutral) ($\chi^2 = 4.08$ to 6.75, d.f. = 1, $P < 0.05$). It is interesting to note that of the people presented with combined information, a significant number of people also changed their opinion of conventional oil from "like" to "dislike" or "neither like nor dislike" ($\chi^2 = 6.75$, d.f. = 1, $P < 0.05$).

After viewing the labelled pictures, some respondents changed their ratings of the pictures positively or negatively by at least two scale points but not to a different region of the hedonic scale as described in the preceding paragraph. After presentation of combined ($\chi^2 = 6.72$, d.f. = 1, $P < 0.05$) and processing ($\chi^2 = 6.67$, d.f. = 1, $P < 0.05$) information, significantly more people increased than decreased their ratings of the labelled alternative oil. Significantly more people decreased their ratings of the labelled conventional oil compared to those whose ratings increased if they received combined information ($\chi^2 = 5.4$, d.f. = 1, $P < 0.05$).

There was a trend for combined and processing information to result in a greater change in hedonic responses than nutrition information, although information type did not have a significant effect on hedonic response shifts (labelled-blind values) for either oil sample (Table 3-3).

Based on multiple linear regression analyses (Table 3-4), conventional oil response shifts of consumers who received only nutritional information were 0.4 higher than those who received either processing or combined information. Conventional oil response shifts of females with postsecondary education were 0.9 lower than everyone else (females without postsecondary education, males), with information type held constant. The same model run for the response shift of the alternative oil showed that none of the variables had significant effects. Therefore, when consumers were presented with photographs of conventional and alternative canola oil and three types of information, the effect of information was reflected in the form of a negative response shift towards conventional canola oil, rather than a positive response shift towards the alternative canola oil.

It cannot be confidently assumed that the visual evaluations of each oil sample were completely independent of one another. Therefore, the difference in relative ratings, DRR (Table 3-3) was determined by calculating the difference in ratings between the conventional and alternative oils and subtracting the pre- and post- information differences from each other (Stefani and others 2006) (Eq. 1):

$$\text{Difference in relative ratings (DRR)} = (\text{ConvBlind-AltBlind})-(\text{ConvLabelled-AltLabelled}) \quad (1)$$

This data transformation allows the observation of the total impact of information received by combining the changes in hedonic ratings of the two samples into one variable. A difference greater than zero indicates that after reading the information provided, panellists increased their acceptance of the appearance of the alternative oil and/or decreased their acceptance of the conventional oil. Conversely, a difference of less than zero indicates that panellists' acceptance of the appearance of the oils shifted unfavourably relative to the alternative oil and/or favourably towards the conventional oil after reading the provided information. A difference of zero means the panellists did not change their opinion of either oil after reading the information or changes in ratings were in equal magnitude in the same direction for both samples.

As with the response shifts, the DRRs were not significantly different in value among the three information types presented when analysed by ANOVA (Table 3-3). No variable had a significant effect on DRRs when analysed by multiple linear regression. However, Chi-square comparisons show that a significant difference exists ($\chi^2 = 13.78$, d.f. = 4, $P = 0.008$) in the proportions of negative, zero and positive DRRs among information types. For each of combined and processing information groups, greater than 50% of the difference in relative ratings (DRR) were positive (Figure 3-3). These respondents increased their acceptance of the alternative oil appearance, decreased their acceptance of the conventional oil appearance, or changed in both aspects after receiving information. In contrast, only 34% of consumers who received nutrition information showed positive DRRs, while 51% did not change their minds after receiving the information. Therefore, fewer consumers who received nutritional information increased their acceptance of the labelled alternative oil compared to those who received processing or combined information.

3.3.1.3. Willingness to Buy (WTB)

The control group evaluations were included with willingness to buy analyses in order to make comparisons with true picture evaluations since it is possible that the appearance of the alternative oil would resemble that of conventional oil after further processing.

3.3.1.3.1. Willingness to buy at a price comparable to canola oil on the market

Information and picture type (control or true) received by the panellists influenced the proportion of consumers that were willing to buy the alternative oil ($\chi^2 = 13.17$, d.f. = 5, $P = 0.02$). Assuming that the alternative canola oil was comparable in price to canola oil currently on the market, more panellists who received control pictures indicated that they were willing to buy the alternative oil. Of the consumers who received processing or nutritional information along with control photographs, 95% and 91%, respectively, of these panellists indicated that they would be willing to buy the alternative oil if there were no price premium (Figure 3-4). In comparison, 79% and 77% of consumers who received the same information types, respectively, along with true pictures were willing to buy the alternative oil. Nearly the same percentage of consumers given combined information and control (84%) or true (83%) pictures indicated positive WTB responses.

The results of multiple linear regression models showed that consumers who received control pictures were 10% more likely to indicate willingness to buy the alternative oil without a price premium than consumers who received true pictures (Table alternative oil without a price premium than consumers who received true pictures (Table 3-5). While the type of information received did not have a significant effect on WTB responses, post-information appearance ratings of the alternative oil had a significant positive effect (Table 3-6). Response shifts in appearance liking of the alternative oil and DRRs also had significant positive influences on WTB, but these effects were not large. Thus, willingness to buy the alternative oil without a price premium is influenced by the hedonic liking of the appearance of the alternative oil after receiving any of the information types.

3.3.1.3.2. Willingness to buy at a price higher than canola oil on the market

The percentage of people willing to buy the alternative oil at a price higher than that of conventional canola oil decreased in comparison to WTB responses for alternative oil without a price premium (Figure 3-4). Although a larger proportion of panellists presented with control pictures were willing to buy the alternative oil at a comparable price to conventional canola oil, about the same percentages of the participants who received control pictures and true pictures were willing to pay a premium for the alternative oil. The influence of information and picture type was not significant. In both the control and true picture situations, more panellists who received processing (56% and 50%, respectively) or combined (53% and 52%, respectively) information were willing to buy the alternative oil with a price premium than panellists who received only nutritional information (41% and 43%, respectively). Gender and income levels did not affect WTB.

3.3.1.3.3. Willingness to buy at a given price

Price had a significant ($p<0.001$) effect on willingness to buy the alternative canola oil at a given price (Table 3-7). As the price increased by $1.00 per 1 litre bottle of oil, the likelihood of a consumer agreeing to purchase the alternative oil decreased by 11.9%. As with WTB without a price premium, the appearance ratings of the alternative oil had a significant, albeit small influence on WTB at a given price.

Since the type of information presented did not have a significant effect on WTB at a given price, the responses of panellists who were given true pictures were compiled;

the same was done for those who were given control pictures. Figures 3-5 and 3-6 show the percentage of panellists for each WTB response price. While true pictures appeared to elicit many positive WTB responses at lower price levels, panellists were not willing to pay the two highest prices ($9.50 and $10.00). In contrast, those presented with control pictures were willing to pay the highest proposed prices to purchase alternative canola oil. However, control pictures did not exert a significant influence on WTB at a given price as determined by a linear regression model (Table 3-5).

Further regression analyses of willingness to buy evaluations were performed and are discussed elsewhere.

3.3.2. Focus panel results

3.3.2.1. Oils used by panellists

Almost every participant used extra virgin olive oil in addition to canola oil. Canola oil was used in all cooking applications while extra virgin olive oil was used mainly for vinaigrettes and dips. Only a few people used olive oil for frying and cooking.

3.3.2.2. Sensory characteristics

Initial impressions of the appearance of the oils indicated that the conventional canola oil was "lighter" in both flavour and colour and "cleaner", which elicited perceptions that this oil was healthier than the alternative oil. The darker colour of the alternative canola oil led some panellists to comment that it looked "like what you take out of your deep fryer after you're done", was "less refined", "looked heavier" in colour and density, and was possibly stronger tasting. Participants also noted that it looked like the alternative oil "stained the bottle" in which it was presented and therefore must not be as healthy because it might "stick to your arteries". However, several panellists likened the relatively darker alternative canola oil to that of extra virgin olive oil, which is darker than its refined counterpart. As such, these panellists believed that the darker alternative canola oil would be wholesome, have a stronger flavour, and be more expensive than conventional canola oil.

The flavour and aroma of the alternative oil was perceived favourably by more than half of the panellists, who liked the nutty flavour of the oil and thought the flavour to be "interesting". Most commented that the alternative oil did not smell or taste like canola oil and likened its flavour and aroma to that of peanut, sunflower and hemp oil. The panellists who perceived the sensory attributes of the oil unfavourably ("old", "medicinal" and "a bit off-putting") did not like the overall strong, lingering flavour of the oil as they were accustomed to odourless, flavourless canola oil. Most participants commented on the bright yellow colour of the alternative oil.

3.3.2.3. Applications

Due to the strong flavour and the darker colour of the alternative canola oil, many panellists foresaw themselves using this oil as they would use extra virgin olive oil. Such "specialty purposes" included salad dressings, in oil and vinegar-type dips and for dishes in which a unique flavour would be enjoyed.

3.3.2.4. Reaction to processing technology

Participants were unaware of current canola oil extraction techniques; many were unpleasantly surprised to learn of the use of hexane as the extraction solvent and that some nutrients are lost during refining of conventional canola oil. Therefore, panellists reacted favourably to the processing and nutritional aspects of the alternative extraction process. In particular, panellists responded to the words "environment" and "health benefits".

3.3.2.5. Willingness to buy

Most panellists who were willing to buy the alternative canola oil were willing to pay about as much as what they would pay for extra virgin olive oil. However, several participants expressed doubt as to whether or not they would buy the alternative canola oil instead of extra virgin olive oil due to its intense colour and unusual flavour.

Discussions from both groups were similar in all aspects except for reasons as to why panellists would be willing to buy and pay more for the alternative oil. Members of Group 1 were willing to buy the alternative canola oil because it would contain more nutrients than conventional canola oil. Many in this group were concerned with their health and had modified their diet in favour of healthier habits. In contrast, while most members of Group 2 were also willing to pay about as much as Group 1 for the alternative oil, fewer people in Group 2 were concerned about nutrition. Many group members stated that because of their younger age, they were not yet worried about what they eat since they lead an active lifestyle. In addition, a few members believed that oil in general was "a bad part of my diet". However, they expressed interest in the alternative canola oil because of the environmental implications of using CO_2 rather than hexane as an extraction solvent. Members of both groups were willing to buy the alternative canola oil "to try it out", but stated that they would probably not replace conventional canola oil with the alternative oil.

3.3.2.6. Marketplace application

Participants agreed that due to the unique flavour and colour of the alternative oil and its perceived lack of versatility, it would replace neither olive oil (or the specialty oil they currently use) nor conventional canola oil. Thus, the product would most likely occupy a niche market. Suggestions for marketplace success of this oil included campaigns to educate consumers on the benefits of the alternative canola oil, recipe ideas, and packaging in dark bottles to disguise the bright colour of the oil.

3.4. Discussion

The obvious immediate attribute of the alternative canola oil is its un-conventional appearance, which negatively influenced consumer hedonic appearance scores. The oil's dark colour was the most discussed attribute in the focus panel, although the strong flavour and aroma of the oil was also a concern. In testing of a "health beverage" with off-flavours, Tuorila and Cardello (2002) suggested masking the offending attribute. Although the focus panels suggested marketing the oil in coloured bottles, the true nature of the oil would be revealed as soon as the consumer pours the oil. As suggested by the current study, providing information with the oil will increase acceptance of this novel product.

The presentation of the information to panellists in this study was unique in that it was presented in paragraphs of approximately 100 words. Many studies have provided information in the form of simple labels or brand names (Levin and Gaeth, 1988; Prescott and Young 2002; Di Monaco and others 2005; Stefani and others 2006). It has been suggested that excessive information may bore consumers and it is questionable exactly how much information is retained by the reader (Salaun and Flores 2001), thus the length of the information presented in his study may have had an impact not quantified. However, it would be difficult to format the information as a simple label as the manufacturing technology employed is new and unfamiliar to most consumers. In fact, when the focus panel was queried as to their previous knowledge of oil extraction methods, the consensus was that there was no existing knowledge. Therefore, it was necessary to provide adequate background information for this study.

On initial examination of the data, the type of information received by the panellists did not influence change in hedonic appearance acceptance; significant differences existed between blind and labelled ratings regardless of the information type received. However, when examining the distribution of consumers among DRR segments of negative, zero or positive changes, nutritional information elicited a smaller proportion of positive shifts and a larger proportion of zero shifts compared to either processing or combined information. Thus, a nutritional message alone was not as influential as either a processing message, or a combination of both. Nutritional information does not always increase the acceptance of a food product (Kähkönen and others 1996a; Carneiro and others 2005). Previous work has shown that health-related information has less effect on hedonic responses than on behavioural intentions (Tuorila and others 1998a; Tuorila and Cardello 2002; Bower and others 2003; Stein and others 2003; Di Monaco and others 2005). The current study also reflects this: although nutritional information was less effective than processing or combined information in eliciting positive hedonic responses to the alternative oil, the proportions of positive WTB responses from panellists who received only nutritional information were nearly the same as those of the other two information types.

Some participants in the focus panel suggested that oil is generally not regarded as a healthy food since it is a form of fat. Thus, for these members of the focus panel, canola oil was not seen as a carrier of functional ingredients. Similar conclusions were reached in a study involving a functional chocolate bar (Di Monaco and others 2005) in which consumers suggested that chocolate was not an appropriate base product for healthy ingredients. Furthermore, consumers are more receptive to information that is in line with their existing beliefs (Bruhn and others 2002). This may explain in part why a nutritional message was not as effective in promoting the alternative oil as messages that included environmental benefits.

Response shift and post-information liking of the alternative oil appearance significantly influenced WTB responses. This result was expected as other studies have shown that hedonic responses are positively and strongly related to purchase intent (Solheim and Lawless 1996; Lange and others 2002; Stefani and others 2006). However, it would be oversimplifying to state that willingness to buy was only influenced by hedonic responses since purchase intent involves more value components (Stefani and others 2006).

Values and attitudes are likely predictors of behaviour. Dreezens and others (2005) determined that those who tend towards the value "power" were in favour of "human domination over the natural environment". On the other hand, people who opposed human interference over the environment were in line with the value "universalism". The former group were in favour of genetically modified foods, while the latter preferred organic foods. Although the current study did not have tools to test the attitudes of the consumers, discussion during the focus group revealed some consumers were strongly in support of preserving the environment. Further studies that incorporate attitudinal analyses tools would likely yield clearer relationships between consumer values and the type of information that would strongly influence their opinions of the alternative oil.

Results from the focus groups suggest that the younger demographic is not as interested as the older demographic in maintaining their health through food. This is in agreement with Wandel and Bugge (1997), who found that while respondents in younger age groups based their purchase habits on environmental concern and animal welfare, respondents in older demographics purchased foods based on considerations for their own health. Females have been found to have a higher level of concern with regards to nutrition for themselves and their families (Solheim and Lawless 1996; Guinard and

Marty 1997; Bower and others 2003). While educated females in this study were found to be more likely to produce positive response shifts for the appearance of the alternative oil, this factor was not significant when it came down to purchase intention. However, since acceptance of the appearance of the alternative oil was influential in purchase intent, it may still be surmised that older educated females could be a target audience for health-related marketing of the alternative oil.

In the current study, willingness to buy the alternative oil was inversely related to price. Females have been observed to be more sensitive to price in other studies (Solheim and Lawless 1996; Di Monaco and others 2005), but no gender effects on willingness to pay were found in the current study. Di Monaco and others (2005) also found that consumers with a higher degree of involvement with chocolate bars were less sensitive to price. This was not found in the current canola oil study. It may be that since canola oil is used mainly as a cooking aid or ingredient, consumers are not aware of its presence when consuming it. It should be noted that self-reported behavioural intentions (ie, willingess to buy and/or pay) do not necessarily reflect actual behaviour (Tuorila and Cardello 2002). As such, results in this study involving self-prediction of future behaviour should be viewed within this context. Further study perhaps in an auction-type setting may be better predictors of actual behaviour.

Lange and others (2002) compared the impact of information on liking and purchase intent of Champagnes under two settings; a Vickrey auction and a hedonic test. The authors concluded that auctions are suited for studies in which the extrinsic value of a product is of interest, while hedonic evaluations are suited to evaluations of the intrinsic value of a product. However, both situations were effective in discriminating among products. Since previous consumer research has not been conducted on the oil studied in the current project, it was useful to obtain hedonic (intrinsic) impressions of the product.

In a real buying situation, the influences of aroma and flavour of the product in question would only apply to repeat buyers. First-time buyers would have only appearance and label information upon which to base their purchase intentions. Therefore, this study may be considered as a partial simulation of a real-life buying situation. However, limitations exist since samples were not presented in bottles with information portrayed in the labels as would occur in a real purchasing situation. Brand name is included on labels and commonly observed by consumers; however, this factor was not tested in this study. Lusk and others (2002) showed that college students were more likely to purchase corn chips made from genetically altered corn if they were marketed by a brand with a high level of loyalty or reliability even if a competing brand with less loyal following sold non-genetically modified chips. Brand, therefore, had a stronger influence on willingness to buy than the use of a relatively novel technology in manufacturing the food. Although the current study shows that consumers responded well to the novel oil processing method, a truer reflection of attitudes would be better observed with the incorporation of a known canola oil brand. Nonetheless, since consumer research on the oil extraction method in this study does not exist, this preliminary research is a useful starting point for further research.

Both chi-square comparisons and multiple-linear regressions were used to analyse the current data. In some cases, results found in one analysis method were not found in another method. This could be expected due to the different approaches of the two methods. The chi-square analysis was used with categorical data and compared to expected and observed counts. The limitation of this analytical method is that it does not control for as many variables as the linear regression method.

It is acknowledged that the use of linear regression models has limitations when used to analyse binary response variables. In this study, willingness to buy/pay responses were analysed as binary response variables in the form of yes/no responses. In these cases, an incremental change in an independent variable is reflected in a change in the probability of the dependant variable being a positive response (willing to buy/pay). However, applying linear analyses to this type of data has disadvantages; fitted probabilities can be less than 0 or greater than 1, and the usual assumption of a constant standard error (homoscedasticity) is violated (Wooldridge 2003; Studenmund 2005). Logistic regression (logit) models largely correct for these issues. However, it should be noted that in most cases (the current one included) the magnitude and statistical significance of the coefficients determined by linear regression analyses are similar. Thus, it is acceptable to use linear regression to analyse binary response variables (Wooldridge 2003). To ensure the validity of the linear regression model in this study, logit models (not shown in this thesis) were run with the current data and the same conclusions were drawn.

3.5. Conclusions

The results of this study showed that processing or a combination of nutritional and processing information had a greater effect on hedonic evaluations of appearance than nutritional information alone. This effect was not observed on willingness to buy evaluations. Focus panellists suggested that although most consumers consider nutritional content when purchasing foods, the younger demographic was more inclined towards the environmental merits of a new product. Since the sensory attributes of the canola oil processed by the alternative method are distinctly different from conventional canola oil, most consumers indicated that the alternative oil would not replace conventional oil. Therefore, this oil may appeal to a niche market. Further studies involving consumers of all types of oils would broaden the data obtained in the current study. In addition, studies that include attitude diagnostic questionnaires may increase understanding of the type of consumer that would be interested in canola oil extracted by this alternative technology.

3.7. Tables

Table 3-1. Demographic profile of consumers who participated in the consumer survey (n=300)

Characteristic	Response Categories	Frequency (%)
Gender	Female	56
	Male	44
Age	18-24	17
	25-34	28
	35-44	12
	45-54	18
	55-64	11
	65+	14
Education	Some high school	3
	High school diploma	7
	Some undergraduate	26
	Undergraduate degree	32
	Some postgraduate	7
	Postgraduate degree	25
Income (individual annual)	<$35,595/year	49
	$35,595-71,190/year	36
	>$71,190/year	15
Frequency of canola oil consumption	Once a day or more	18
	2-3 times a week	50
	4-6 times a month	23
	Less than 4 times a month	9
Uses of canola oil	Frying/cooking	91
	Baking	63
	In salad oils	51
	Other	5
Frequency of reading food labels	Always	37
	Frequently	39
	Sometimes	16
	Occasionally	6
	Never	1
Information observed on food labels	Brand	45
	Nutritional information	86
	Price	63
	Processing information	29
	Ingredients	85
	Health claims	56
	Other	8

Table 3-2. Mean appearance acceptance scores (9-point hedonic scale) of conventional and alternative canola oil under blind and labelled conditions by information type

	Mean Hedonic Scores			
	Conventional Oil		Alternative Oil	
Information Type	Blind	Labelled	Blind	Labelled
Nutritional	6.67^{a} (0.20)	6.43^{a} (0.20)	4.90^{y} (0.23)	5.40^{x} (0.23)
Processing	6.77^{a} (0.22)	6.17^{b} (0.22)	4.92^{y} (0.25)	5.75^{x} (0.25)
Combined	6.87^{a} (0.21)	6.10^{b} (0.21)	5.11^{y} (0.24)	5.84^{x} (0.24)

$^{ab,\,xy}$ Blind and labelled values within an information and oil type not followed by the same letter superscript are significantly different ($p \leq 0.05$). Values in parentheses are standard error of the means.

Table 3-3. Response shifts and difference in relative ratings of the alternative and conventional oils after presentation of each information type.

	Response Shift (Labelled - blind hedonic ratings)		**Relative Difference of Appearance Ratings (conventional-alternative)**		**Difference in Relative Ratings (DRR)**
Information Presented	**Conventional Oil**	**Alternative Oil**	**Blind**	**Labelled**	
Combined	-0.78 (0.19)	0.73 (0.20)	1.76 (0.31)	0.25 (0.37)	1.51 (0.32)
Processing	-0.60 (0.19)	0.82 (0.20)	1.85 (0.31)	0.43 (0.38)	1.42 (0.30)
Nutritional	-0.24 (0.18)	0.50 (0.19)	1.77 (0.29)	1.03 (0.35)	0.74 (0.33)

Values in brackets are standard errors of the means. No significant differences were found among information types.

Table 3-4. Multiple linear regression analyses of conventional and alternative oil hedonic appearance response shifts.

Dependant Variable	**Conventional oil Response Shift**	**Alternative oil Response Shift**
R-squared value	0.045	0.049
Constant	-0.886***	0.506
Independent Variables (variables in parentheses are the base cases)		
Information type presented		
Nutrition only	**0.446*** (0.222)	-0.268 (0.236)
Demographics		
Female (male)	0.372 (0.355)	-0.151 (0.377)
Postsecondary Education (no Postsec)	0.457 (0.329)	0.277 (0.350)
Female*Postsec	**-0.877*** (0.445)	0.545 (0.472)

Values in parentheses are standard error of the means.
* p<0.05
**p<0.01
***p<0.001

Table 3-5. Multiple linear regression analyses of willingness to buy the alternative canola oil at a price comparable to conventional canola oil if presented with control pictures (no difference in appearance between conventional and alternative canola oil)

Models	WTB no price premium	WTB at a given price
R-squared value	0.016	0.254
Constant	0.801***	1.210***
Variables in parentheses are the base cases		
Price	-	**-0.114*** (0.012)
Information type presented		
Nutrition only (processing only, combined)	-0.008 (0.045)	-0.069 (0.053)
Pictures Received		
Control (true pictures)	**0.099*** (0.045)	-0.061 (0.052)

Numbers in parentheses are standard error of the means.
* p<0.05
**p<0.01
***p<0.001

Table 3-6. Three multiple linear regression analyses models (A, B, and C) of willingness to buy the alternative canola oil at a price comparable to conventional canola oil.

Models	A	B	C
R-squared value	0.035	0.031	0.166
Constant	0.764***	0.764***	0.242
Variables in parentheses are the base cases			
Information type presented			
Nutrition only (processing only, combined)	-0.002 (0.06)	0.001 (0.06)	0.011 (0.056)
Hedonic Ratings			
Post-info Conventional	-	-	0.011 (0.015)
Post-info Alternative	-	-	**0.086*** (0.014)**
Conventional Labelled-Blind	-0.013 (0.021)	-	-
Alternative Labelled-Blind	**0.042* (0.020)**	-	-
Difference in Relative Ratings (DRR)	-	**0.028* (0.011)**	-

Numbers in parentheses are standard error of the means.
* $p<0.05$
** $p<0.01$
*** $p<0.001$

Table 3-7. Three multiple linear regression analyses models (A, B, and C) of willingness to buy the alternative canola oil at a given price.

Models	A	B	C
R-squared value	0.271	0.274	0.290
Constant	1.242***	1.287***	1.022***
Variables in parentheses are the base cases			
Price	**-0.120*** (0.014)**	**-0.118*** (0.015)**	**-0.117*** (0.014)**
Information type presented (nutrition only)			
Nutrition only (processing only, combined)	-0.057 (0.064)	-0.063 (0.065)	0.043 (0.064)
Demographics			
Female (male)	-	0.016 (0.063)	-
Postsecondary Education (less than PS)	-	0.033 (0.065)	-
Age	-	-0.002 (0.002)	-
Hedonic Ratings			
Post-info Alternative	-	-	**0.035* (0.016)**

Numbers in parentheses are standard error of the means.
* p<0.05
**p<0.01
***p<0.001

3.8. Figures

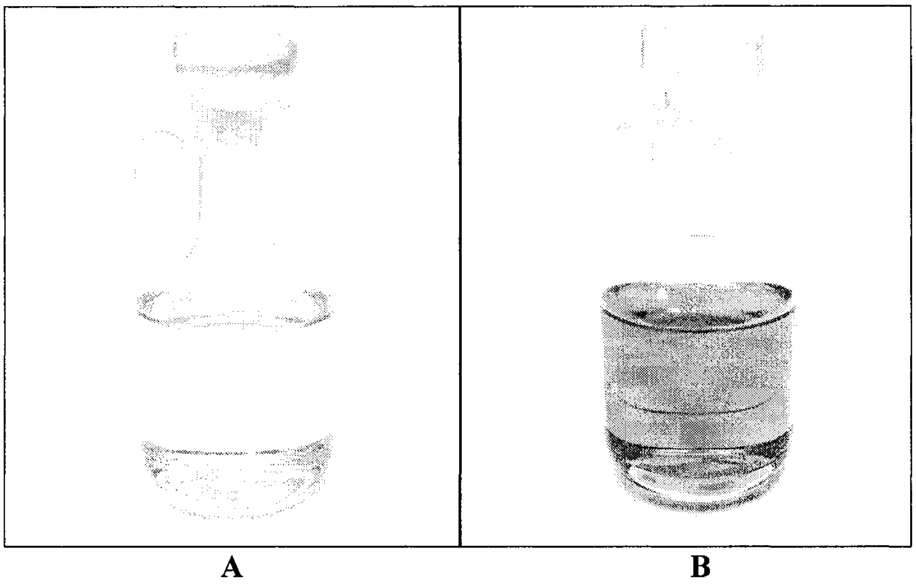

Figure 3-1. Canola oil photographs presented to consumer survey participants. Photograph A is conventional canola oil, while photograph B is the alternative canola oil.

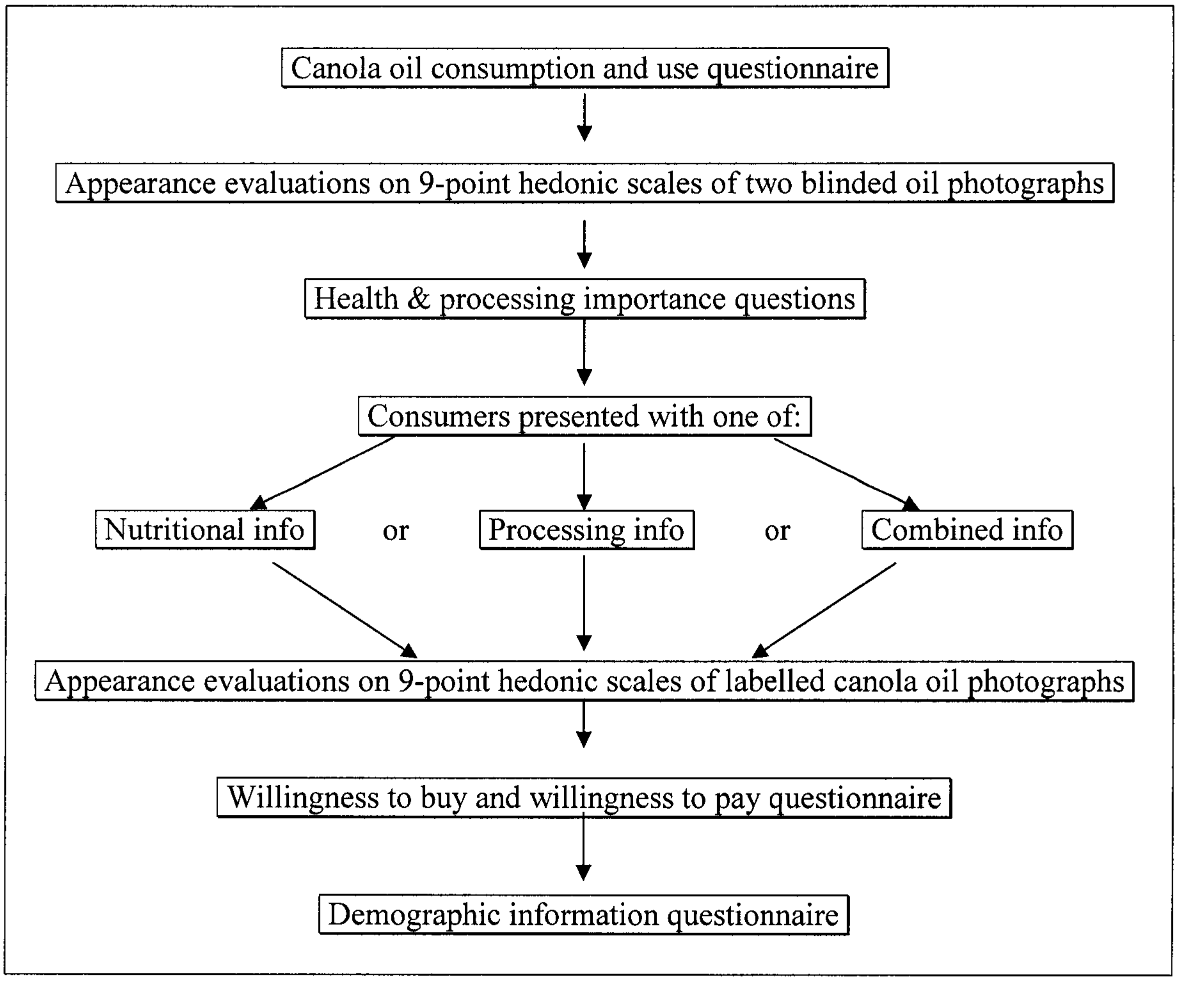

Figure 3-2. Sequence of questionnaires, acceptance evaluations, and information presentation to consumer panellists for blinded and labelled evaluation of photographs of canola oil extracted by conventional and alternative methods.

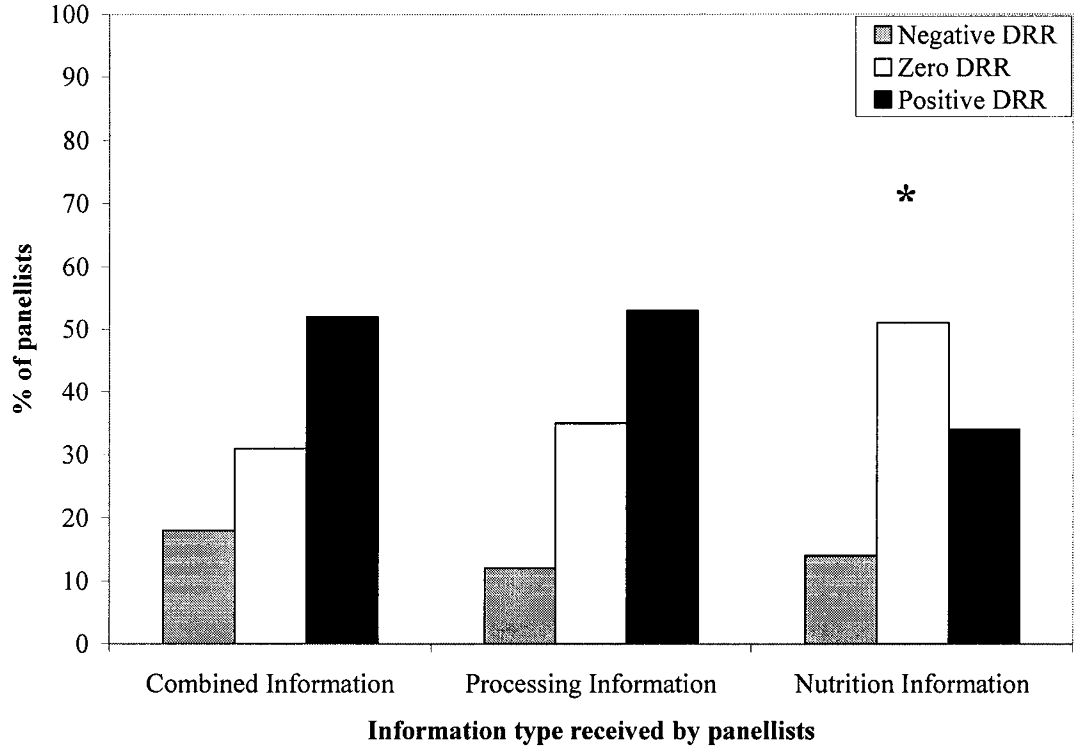

Figure 3-3. Distribution of panellists among negative, zero, or positive Difference in Relative Ratings (DRR).

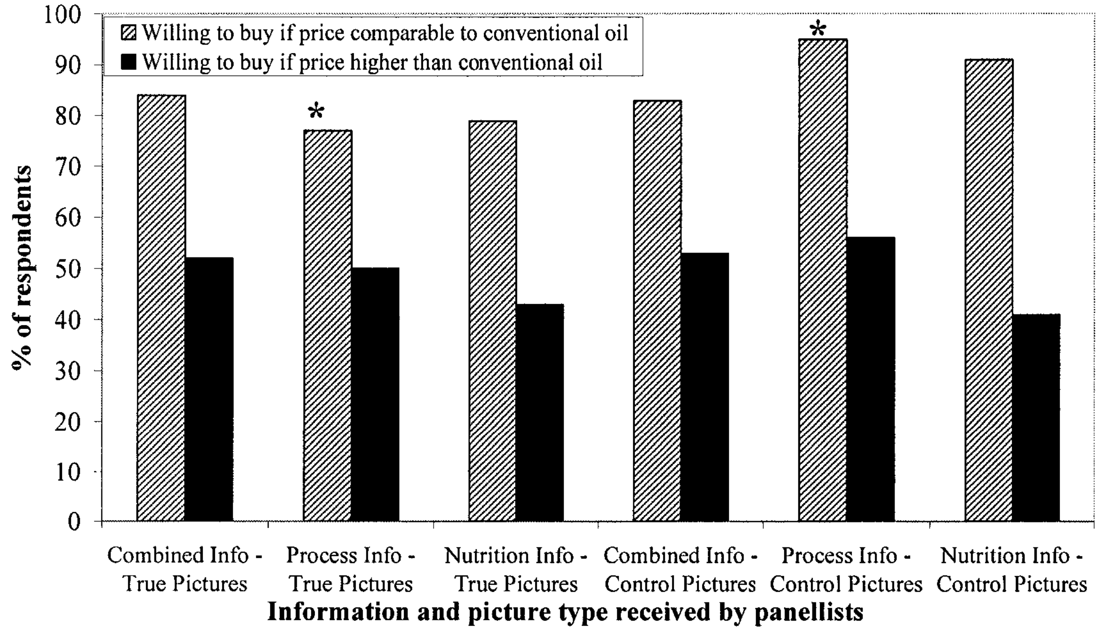

Figure 3-4. Percentage of consumers within each information and picture group willing to buy the alternative canola oil at price conditions of comparable to and higher than that of conventional canola oil. Significant differences in willingness to buy exist between true and control pictures, within processing information.

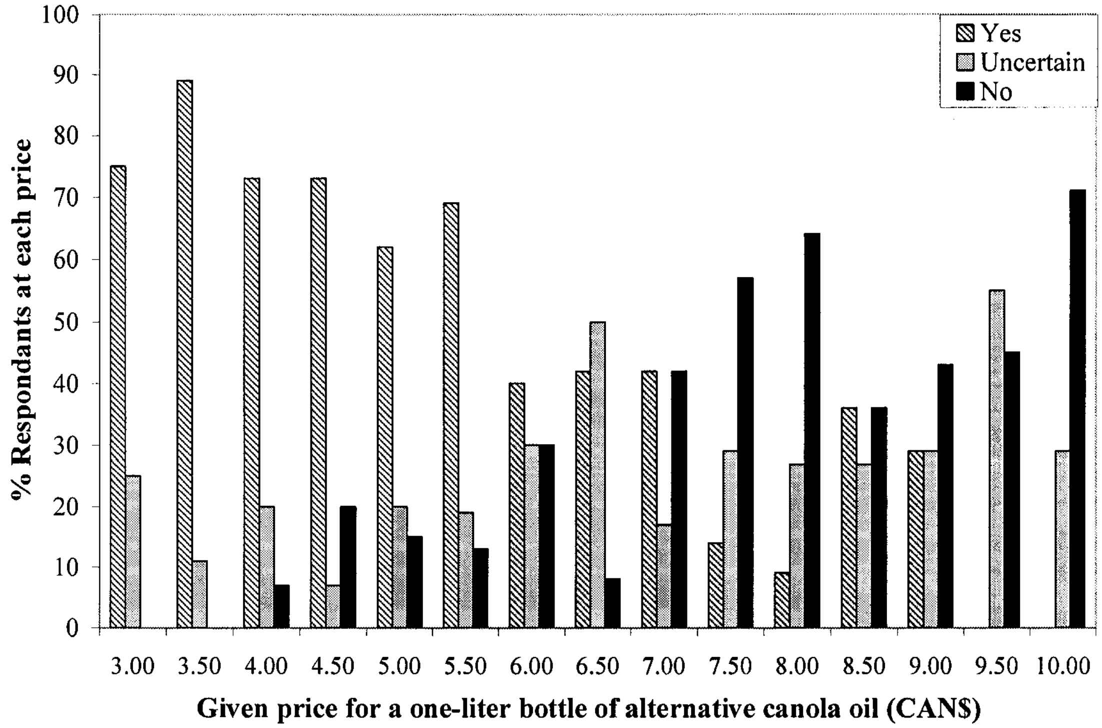

Figure 3-5. Percentage of consumers presented true pictures willing to buy the alternative canola oil at each given price. The average price of a one-litre bottle of conventional oil is $4.00.

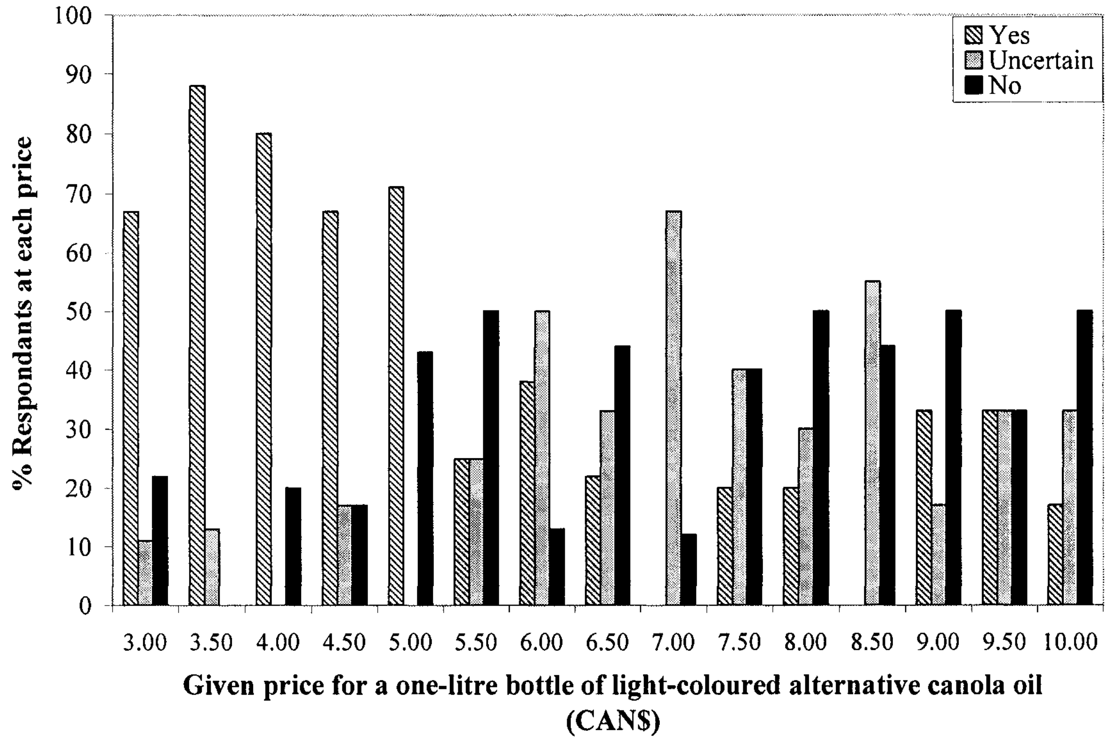

Figure 3-6. Percentage of consumers presented control pictures willing to buy the alternative canola oil at each given price. The average price of a one-litre bottle of conventional oil is $4.00.

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Chapter 4: Summaries, Conclusions, and Recommendations

4.1 Summaries

4.1.1. Sensory and chemical characterization of canola oil extracted by various methods

The chemical profiles of refined hexane-extracted oil, unrefined hexane-extracted oil, $SCCO_2$-extracted oil, and CO_2-assisted pressed oil were determined and compared. In addition, the sensory profiles of the first three canola oils were developed and compared.

Basic quality tests indicated that $SCCO_2$-extracted canola oil may require some minor refining to attain the same quality as refined hexane-extracted canola oil. Free fatty acids and peroxide value of $SCCO_2$-extracted and CO_2 assisted-pressed oil are higher than those of refined oils. However, unsaponifiables content was similar among the samples tested, with the exception of unrefined hexane-extracted oils, which had significantly higher unsaponifiables content. Whereas the chlorophyll content of the CO_2-assisted pressed and unrefined-hexane extracted oils were relatively high, that of $SCCO_2$-extracted oils, although significantly higher, was similar to the low levels found in conventionally refined canola oil. Therefore, canola oil extracted by $SCCO_2$ might only require minor refining to remove free fatty acids and may not have to undergo the bleaching process due to its chlorophyll level.

The nutritional content of both $SCCO_2$–extracted and CO_2-assisted pressed oils may be superior to that of refined canola oil since they contain greater amounts of total sterols and tocopherols. $SCCO_2$-extracted oil likely only requires minimal refining; therefore these nutritional compounds remain in the oil and may be consumed. In addition, the proportion of essential omega-3 fatty acid is significantly higher ($P \leq 0.05$) in $SCCO_2$-extracted canola oil than in the other oils tested. Thus, canola oil extracted by $SCCO_2$ may be healthier than canola oils extracted by other methods.

The sensory attributes that distinguished $SCCO_2$-extracted canola oil from refined and crude canola oils consisted of mustardy, piney, and pickle aromas and flavours. $SCCO_2$-extracted oil was orange and medium toned in comparison to refined canola oil, which was rated as nearly colourless, and crude canola oil, which was evaluated as the darkest of the three samples and brownish in colour.

4.1.2. Consumer acceptance of canola oil extracted conventionally and by $SCCO_2$

Consumer acceptance of $SCCO_2$-extracted canola oil was compared with that of refined canola oil. Initially, a survey ($n = 300$) assessed the appearance acceptance of the two oils before (blind) and after (labelled) information about the $SCCO_2$ extraction process was presented. Three information types were presented: nutritional, processing, and a combination of nutritional and processing. Blind evaluations of the oil appearances revealed that consumers did not like the dark appearance of the $SCCO_2$-extracted canola oil. However, acceptance shifted in favour of this oil after presentation of processing and combined information, while acceptance of the appearance of conventional oil decreased. Presentation of nutritional information did not elicit as large of an acceptance shift. When consumers were presented with photographs of conventional and $SCCO_2$-extracted canola oil and the three types of information, the significant ($P \leq 0.05$) effect of information was reflected in the form of a negative response shift towards conventional canola oil, rather than a positive response shift towards the alternative canola oil.

Panellists who received control pictures were more willing to purchase ($P \leq 0.05$) the $SCCO_2$-extracted canola oil without a price premium than panellists who received true pictures, regardless of information type received. When price was taken into consideration, the picture type received did not have an effect on willingness to buy at a given price. As the prospective price of a one-litre bottle of $SCCO_2$-extracted canola oil increased by \$1.00, the likelihood of a panellist agreeing to purchase the oil decreased by 11.9%.

Focus panel reactions to the appearance of the $SCCO_2$-extracted oil were that the oil was darker than they are used to for canola oil. The flavour and aroma of the oil was received positively by more than half of the participants. It was evident to the panellists that $SCCO_2$-extracted canola oil did not resemble conventional refined canola oil in appearance or flavour. Therefore, they noted that it was unlikely that this SCCO2-extracted canola oil would replace conventionally-extracted canola oil. However, after receiving background information on the $SCCO_2$ extraction process, panellists indicated that they would be willing to buy the $SCCO_2$-extracted canola oil for its health and environmental benefits. However, there existed some panellists that did not believe that oil could be considered as healthy food and were not interested in the product.

4.2. Conclusions and Recommendations

Chemical characterization of $SCCO_2$-extracted canola oil indicates that this oil may not be as stable as conventional refined canola oil. This conclusion has also been found for other oils extracted by $SCCO_2$ (List and Friedrich 1989) and is logical since the oil has not been refined to increase its stability. However, the results of the first study indicate that $SCCO_2$-extracted oil likely does not need as much refining as crude hexane-extracted oil. Furthermore, decreased refining allows a greater amount of nutritive compounds to remain in the oil where they may be consumed. Nonetheless, it would be beneficial to conduct shelf-life studies to determine the stability of $SCCO_2$–extracted canola oil.

The sensory profile of canola oil extracted by $SCCO_2$ is distinctly different from both crude and refined canola oil. The existence of a flavour profile of $SCCO_2$-extracted canola oil lends itself as a future reference or to further profile refinement. To enhance the overall knowledge of the sensory characteristics of this oil, identification of key volatile aroma compounds responsible for sensory characteristics should be considered. In addition, the presence of sulphur-containing fatty acids should be explored to help explain the unique attributes of this oil.

The sensory quality of the $SCCO_2$ oil indicates that the oil does not require refining to be deemed acceptable by consumers. In the focus panel conducted in this study, consumers were initially taken aback by the bright hue of the $SCCO_2$-extracted oil. However, the flavour attributes of the oil were accepted by most respondents. Features of the oil such as the environmentally friendly processing technique and greater content of nutrients than conventional oils make the $SCCO_2$-extracted canola oil appear to be an attractive addition to the oils that consumers currently use.

The small pilot scale on which the $SCCO_2$ oil samples were manufactured for this study did not allow for large-scale consumer tasting of the product. As a result, only the small group of focus panel members was able to provide consumer insights into the flavour of the novel $SCCO_2$-extracted canola oil. However, data were obtained for a large sampling of people with regard to the appearance of the oil. This information is important since the appearance of the product, along with any label information, is an extrinsic clue that consumers use to aid purchase decisions (Deliza and MacFie 1996; Jaegar, 2006). Future consumer research should involve consumer tasting of the product on a larger scale to expand on the focus group results of the current study and to further define the potential target market segment.

Technological improvements on the current equipment to make $SCCO_2$ extraction into a continuous process will alleviate the economic strain that is currently limiting the application of $SCCO_2$ extraction from commodities such as canola. CO_2-assisted pressing produced oil that was very similar in quality to unrefined canola oil. Further refinement of this equipment is needed to attain conditions that will allow for the existence of $SCCO_2$ and to extract oil that is comparable to that obtained by $SCCO_2$ batch processes.

The current study involving chemical, sensory and consumer assessments provides the foundation for future research in this previously unexplored area of $SCCO_2$ extraction of canola oil.

4.3. Literature Cited

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Appendix 1: Basic taste scorecard used to screen potential trained panellists

Basic Taste Identification Scorecard

Name: ____________________ Date: __________

On the tray there are five water solutions; four each of the basic tastes plus one of water.

Please taste the samples in the order indicated. **DO NOT SWALLOW THE SAMPLES.** "Swish" the samples around the mouth, then expectorate into the large coloured cup provided. Identify the taste you experience. Rinse your mouth with water between samples and wait one minute before proceeding to the next sample. Continue testing in the same manner until all samples have been tasted. Record your initial reaction and **DO NOT** go back to re-taste or change your answer.

Sample Code	***Identity***
468	
251	
983	
575	
832	

Thank you!

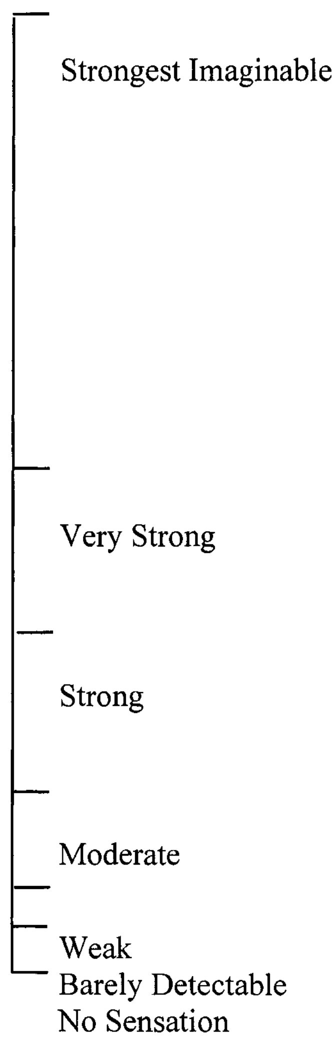
Appendix 2: PROP test scorecard used to screen potential trained panellists

PROP Test Sensation

Name: ____________________ Date: _____________

Instructions:

1. Cleanse your palate with a sip of water
2. Place the PROP solution provided in your mouth. **DO NOT SWALLOW THE SOLUTION.**
3. Swish it around in your mouth for ***10*** seconds, ***spit out the solution into the cup provided***, then rate the taste of the solution somewhere between no taste at all ***(no sensation)*** and taste which is the strongest sensation that you could imagine having in your mouth ***(strongest imaginable)***.



Thank you! Please return to room 2-35 for your candy treat.

Appendix 3: Sweetness intensity scorecard used to screen potential trained panellists

Ranking of Sweetness Intensity

Name: ___________________ Date: __________

Please evaluate and rank the five samples of sweet solutions in water according to their intensity of sweetness. Rank the samples from least sweet to most sweet. Write in the sample three-digit codes in the spaces provided.

_______________ Least sweet

____

____

____

_______________ Most sweet

Thank you!

Appendix 4: Term generation scorecard used to screen potential trained panellists

Oil Evaluation

- Please look at the two oil samples in front of you. What are some words that can describe the colour of each sample?

Sample 623: ____

____

____

Sample 465: ____

____

____

- Open the lid of each bottle and take a few sniffs. What are some words that can describe the aroma of each sample?

Sample 623: ____

____

____

Sample 465: ____

____

____

- Taste each oil sample. Please spit the samples into the red cups provided. Between samples rinse your mouth thoroughly with water and bites of cracker.

Take the oil sample into your mouth and swish it around. What are some words that can describe the flavour of each oil?

Sample 623: ____

____

____

Sample 465: ____

____

____

Appendix 5: Screening questionnaire given to potential trained panelists

Panelist screening questionnaire

Contact information:

Name: ______________________________

Phone number (business, home):______________________________

E-mail:______________________________

Availability:

1. Are there any weekdays and times (Tuesday - Friday) that you will not be available between January 18 and Febuary 18, 2005?

____
____
____

Health:

1. Do you have any of the following?
   Diabetes ____________
   Oral or gum disease ____________
   Hypoglycemia ____________
   Food allergies ____________
   Hypertension ____________
   Thyroid condition ____________
   Pregnant ____________

2. Do you take any medications which may affect your senses, especially taste and smell?

   ____

Food Habits:

1. Are you currently on a restricted diet? If yes, please explain.

____

2. What is (are) your favorite foods? ______________________________

3. What is (are) your least favorite foods? ______________________________

____

4. What foods do you not eat because of insensitivities, intolerances, allergies or dislikes?

I nsensitivities: ______________________________

Intolerances: ______________________________

Allergies: ______________________________

5. How would you rate your ability to distinguish smells and tastes?

	Smell	Taste
Better than average	______	______
Average	______	______
Worse than average	______	______

6. Does anyone in your immediate family work for a food company? ____________

____

7. Does anyone in your immediate family work for an advertising company or a marketing research agency? ______________________________

____

8. Members of the trained panel should not use heavy perfumes/colognes on evaluations days. They should also not smoke an hour before the panel meets. Would you be willing to do the above if you are chosen as a panellist? ____________

Flavour Quiz:

1. Describe some noticeable smells in a McDonald's restaurant.

____

____

2. What would you say is the difference between flavour and aroma? ____________

____

____

3. What would you say is the difference between flavour and taste? ____________

____

____

Appendix 6: Ballot used by the trained panel for oil evaluations. Ballot was presented using Compusense *five* computerized software. Reference markings are not shown.

Trained Panel Sensory Questionnaire for the Evaluation of Canola Oil.

Take a bite of cracker and sip of warm water to cleanse your palate before you begin.

Start with the first sample indicated below and evaluate it for the following attributes as described in the training session. Take ~ 5 ml of warm oil into the mouth, pull air through the oil and evaluate the odour and flavour by exhaling through the nose and swishing the sample in your mouth. Do not swallow the sample. Use the expectoration cups provided.

If necessary, refer to the reference samples provided.

Pickle Aroma

Not at all Pickley — Very Pickely

Mustard Aroma

Not at all Mustardy — Very Mustardy

Canola Meal Aroma

None — Strong

Buttery Aroma

Not at all Buttery — Very Buttery

Nutty Aroma

Not at all Nutty — Very Nutty

Piney Aroma

Not at all Piney — Very Piney

Rubbery Aroma

Not at all Rubbery — Very Rubbery

Overall Aroma Intensity

Not at all Intense — Very Intense

<u>Flavour</u>

Overall Flavour Intensity

Not at all Intense — Very Intense

Buttery Flavour

Not at all Buttery — Very Buttery

Mustard Flavour

Not at all Mustardy — Very Mustardy

Nutty Flavour

Not at all Nutty — Very Nutty

Piney Flavour

Not at all Piney — Very Piney

Colour

Yellow — Brown

Lightness/Darkness

Light (e.g., Water) — Dark (e.g., Red wine)

Appendix 7: Trained panel ANOVA main effects, interactions, and least squared means of sample evaluations

Attribute	ANOVA			LSMeans			SEM
	Treatment	Judge	Trt*Judge	Refined	$SCCO_2$	Crude	
Aroma							
Overall Aroma Intensity	***	***	***	2.14c	8.04b	9.92a	0.16
Pickle	***	NS	***	0.31c	5.58a	1.10b	0.12
Mustard	***	*	**	0.52c	6.42a	1.50b	0.19
Butter	***	**	***	5.65a	1.84b	0.75c	0.13
Nutty	***	NS	***	0.79c	2.40b	9.77a	0.18
Pine	***	**	***	0.31c	3.21a	1.60b	0.17
Rubber	***	***	***	0.24b	0.30b	3.34a	0.08
Flavor							
Overall Flavour Intensity	***	***	***	2.51c	6.71b	9.23a	0.18
Butter	***	**	***	7.61a	2.70b	1.29a	0.12
Mustard	***	***	***	0.30c	4.15a	0.88b	0.13
Nutty	***	***	***	1.56c	3.96b	8.67a	0.12
Piney	***	***	***	0.39a	2.48a	1.15b	0.14
Appearance							
Yellow-brown	***	***	NS	0.62c	6.82b	9.91a	0.16
Light-Dark	***	***	***	1.36c	6.88b	9.83a	0.16

Appendix 8: Survey participant informed consent forms

Project Information Sheet: Consumer Panel Sensory Evaluation of Canola Oil.

Purpose: The purpose of this project is to evaluate consumer acceptance of the appearance of canola oil and to gather information about consumer canola oil consumption, nutritional knowledge, purchase habits and opinions of canola oil production methods.

Consumer Panel Methods: You are being asked to participate in a consumer sensory panel to evaluate the appearance of four samples of canola oil. You will be provided with two samples of oil to evaluate, a questionnaire to complete, and two more samples of canola oil to evaluate. The session is expected to last about 15 minutes.

Confidentiality: You are not asked to provide your name on the sensory questionnaires, only your participant number. The contact information you provide on the consent form will be used only to inform you of the outcome of the study if you have requested this information and/or to contact you for participation in a future focus group if you have indicated that you are interested in participating. Your consent forms will be kept confidential and then destroyed at the end of the study.

Benefits: The results of this study may not have any direct benefits for you, but will be valuable to Alberta canola oil producers who are looking for novel methods to produce higher quality healthy canola oil. No payment is offered, however you will receive a small candy treat at the end of the session.

Risks: There are no anticipated risks in participating in this study.

Withdrawal from the Study: Even after you have agreed to participate in the consumer panel, you can change your mind at any time before or during the evaluations and withdraw from the panel. The researchers will not use any evaluations you have completed to that point.

Use of Your Information: This study is being conducted by researchers in the Department of Agricultural, Food and Nutritional Science at the University of Alberta. Your consumer panel data will be averaged with those of the other participants and these mean values will be used to generate overall appearance preferences of canola oil. Aggregate evaluations from the consumer panel will be incorporated into research reports for the funding agency and for publishing in scientific journals. The data will also be used in a Master's thesis. A summary of the research results will be e-mailed to you upon your request.

For further information about this project you may contact:

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Consent Form for Consumer Panel Sensory Evaluation of Canola Oil

Title of Research Project:

Consumer Panel Sensory Evaluation of Canola Oil.

Investigators:

- Wendy Wismer, Department of Agricultural, Food and Nutritional Science, University of Alberta
- Feral Temelli, Department of Agricultural, Food and Nutritional Science, University of Alberta
- Sandra Mak, Department of Agricultural, Food and Nutritional Science, University of Alberta

Consent: Please circle your answers:

Do you understand that you have been asked to be in a research study?	Yes	No
Have you read and received a copy of the attached Information Sheet?	Yes	No
Do you understand the benefits and risks involved in taking part in this research study?	Yes	No
Have you had an opportunity to ask questions and discuss this study?	Yes	No
Do you understand that you can quit taking part in this study before or while you are completing the questionnaires? You do not have to say why.	Yes	No
Has confidentiality been explained to you?	Yes	No
Do you understand who will have access to your data?	Yes	No
Do you know what the information you provide will be used for?	Yes	No
Do you give your consent to use the data obtained in this experiment for the explained purpose of the study, outlined in the project information sheet?	Yes	No
Do you consent to the use of your data for further analysis at a later date?	Yes	No

The persons who may be contacted about the research are:

Wendy Wismer, University of Alberta, 780-492-2923
Feral Temelli, University of Alberta, 780-492-3829
Sandra Mak, University of Alberta, 780-492-3833

This study was explained to be by: ______________________________

I agree to take part in this study.

____________________________ ____/____/______
Signature of Research Participant Date (dd/mm/yyyy)

____
Printed Name

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

____
Signature of Investigator or Designee

Summary of the research results:

Would you like to receive a summary of the results of the consumer panel research? Yes No

Participation in a focus group:

In the fall, we plan to hold a focus group to elicit discussion to generate more in-depth ideas and opinions about the oils evaluated today. Would you like to be contacted for potential participation in the focus group? Yes No

If you answered "Yes" to any of the above two questions, please fill in your phone number and /or e-mail address. Your contact information will not be used for any other reason than to contact you for the above reasons where you indicated a "Yes".

E-mail: ______________________________

Phone number: ______________________________

Appendix 9: Consumer survey questionnaire

Part 1: Canola Oil/Intro Questionnaire

1. How often do you use canola oil?
   - ☐ Once a day or more
   - ☐ 2-6 times a week
   - ☐ 4-7 times a month
   - ☐ Hardly ever
   - ☐ Never

2. How do you use canola oil? (check all that apply)
   - ☐ Frying/cooking
   - ☐ As a baking ingredient
   - ☐ In salad oils and dressings
   - ☐ Other (please specify) ______________________________

3. Why do you use/consume canola oil instead of other oils? (check all that apply)
   - ☐ Because it is healthier than other oils
   - ☐ For its flavour
   - ☐ For its appearance
   - ☐ For its stability
   - ☐ Because it is affordable
   - ☐ Because it is familiar to me
   - ☐ Other (please specify) ______________________________

4. Do you read labels on food products?
   - ☐ Always
   - ☐ Frequently
   - ☐ Sometimes
   - ☐ Occasionally
   - ☐ Never

5. If you read labels on food products, what information do you observe in the labels? (check all that apply)
   - ☐ Brand
   - ☐ Nutritional information
   - ☐ Price
   - ☐ Processing information
   - ☐ Ingredients
   - ☐ Health claims
   - ☐ Other (please specify) _____________________

Please look at the photographs of the two coded canola oil samples and evaluate their appearance using the scales on the following page.

Evaluations of Oil Appearance

Please look at the photographs of the two oil samples and evaluate their appearances on the scales below.

Sample 763
Overall, what is your opinion of the **appearance** of this canola oil sample?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please add any comments you may have:

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Sample 598
Overall, what is your opinion of the **appearance** of this canola oil sample?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please add any comments you may have:

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Please proceed to Part 2 of the survey.

Part 2

1. How important is it to you to purchase foods that are minimally refined/processed (e.g., fresh lettuce instead of pre-packaged salads)?

- ☐ Unimportant
- ☐ Somewhat unimportant
- ☐ Neither important nor unimportant
- ☐ Somewhat important
- ☐ Very important

2. How important is it to you to purchase foods with proven health benefits?

- ☐ Unimportant
- ☐ Somewhat unimportant
- ☐ Neither important nor unimportant
- ☐ Somewhat important
- ☐ Very important

3. What are some reasons that may prevent you from purchasing foods with health benefits?

- ☐ Too expensive
- ☐ Availability (lack of)
- ☐ Limited knowledge about these products
- ☐ Do not believe that the foods have the health benefits
- ☐ Other (please specify) ______________________________

Information

One of nutritional, processing or combined informational paragraphs are presented here. See Appendix 10 for details.

Please look at the photographs of conventional and alternative canola oil samples and evaluate their appearance using the scales on the following page.

Evaluations of Oil Appearance

Please look at the photographs of the two oil samples and evaluate their appearances on the scales below.

Conventional canola oil
Overall, what is your opinion of the **appearance** of this canola oil sample?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please add any comments you may have:

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Alternative canola oil
Overall, what is your opinion of the **appearance** of this canola oil sample?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please add any comments you may have:

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Please proceed to the next page of the survey.

Post-Information Questionnaire

1. Considering its appearance and what you now know about the nutritional and processing background of the alternative canola oil, how likely would you buy this alternative canola oil assuming that the its price is **comparable to** that of canola oil currently on the market?

- ☐ Definitely would buy
- ☐ Probably would buy
- ☐ Maybe/maybe not
- ☐ Probably would not buy
- ☐ Definitely would not buy

2. Considering its appearance and what you now know about the nutritional and processing background of the alternative canola oil, how likely would you buy this alternative canola oil assuming that the its price is **higher than** that of canola oil currently on the market?

- ☐ Definitely would buy
- ☐ Probably would buy
- ☐ Maybe/maybe not
- ☐ Probably would not buy
- ☐ Definitely would not buy

3. The average price of a one litre bottle of canola oil is **$4.00** a litre.

Would you pay **$x.xx** for a one litre bottle of the alternative canola oil?

- ☐ Yes
- ☐ No
- ☐ Uncertain

Demographics

1. Please indicate the age group that you belong to:
   - ☐ 18-24
   - ☐ 25-34
   - ☐ 35-44
   - ☐ 45-54
   - ☐ 55-64
   - ☐ 65 and above

2. Please indicate your gender:
   - ☐ Female
   - ☐ Male

3. Please indicate the highest level of education that you have attained:
   - ☐ Some high school
   - ☐ High school diploma
   - ☐ Some postsecondary
   - ☐ Postsecondary degree
   - ☐ Some graduate
   - ☐ Graduate degree

4. Please indicate your annual individual income level:
   - ☐ Less than $35,595
   - ☐ $35,595 - $71,190
   - ☐ $71,190 - $115,739
   - ☐ More than $115,739

Thank you for completing this survey!
☺

Appendix 10: Information presented to consumer survey participants

Information presented to consumers

One of the following information blocks was presented to consumers before they evaluated the canola oil appearances the second time.

Nutritional Information:

Canola oil is one of the healthiest oils available in the market. It contains the lowest amount of saturated fatty acids, a high percentage of monounsaturated fatty acids and is a good source of omega-3 fatty acids.

The conventional refining process that removes unwanted residues from canola oil also removes nutrients naturally present in the oil such as Vitamin E and plant sterols. Vitamin E is an antioxidant, has been shown to decrease the risk of heart disease and possibly cancer. Plant sterols have also been shown to decrease the risk of heart disease.

Recently, an alternative method was developed to extract canola oil from the same canola seed as conventional oil. This alternative canola oil does not need to be refined as much as conventional canola oil. Therefore, nutrients such as Vitamin E and sterols remain in the alternative oil where they may be consumed.

Processing Information

Canola oil is obtained from canola seed using hexane as an extraction solvent. Hexane is potentially hazardous to the environment.

Currently, an alternative method of extracting canola oil is being studied. In this method, carbon dioxide, which is normally found in the atmosphere, is used instead of hexane to obtain oil from canola seed. When the oil extraction is complete, the carbon dioxide is simply released into the atmosphere, leaving no solvent residues in the oil. The use of carbon dioxide is favoured as it is non-toxic and not as harmful to the environment as hexane.

Combined Information

Conventional canola oil is obtained from canola seeds using hexane. Hexane is potentially hazardous to the environment. When hexane is used to extract canola oil, unwanted residues are also extracted into the oil. As a result, the oil has to be refined to remove these residues. During this refining, healthy nutrients (plant sterols, Vitamin E) are also removed from the canola oil.

An alternative method of obtaining canola oil from canola seed uses carbon dioxide instead of hexane. Carbon dioxide is naturally present in the atmosphere, is non-toxic and is not as harmful to the environment as hexane. In addition, the canola oil obtained by carbon dioxide does not need to be refined as much as conventional oil. As a result, nutrients such as Vitamin E and plant sterols remain in the canola oil where they may be consumed.

Appendix 11: Focus panel moderator guide

Moderator Guide – Focus Panel Evaluation of Canola Oil

1. Moderator (S. Mak) introduces self, explain project, ground rules, mention audio taping of session and go over informed consent. Participants read and sign consent forms (10 minutes).

2. Participants introduce themselves and share "what's in the kitchen cupboard?"
   - Why participants choose canola instead of other oils, edible oils used at home, how used (10 minutes)

3. Taste samples of supercritical carbon dioxide (SC-CO_2) extracted and conventional canola oil (30 minutes). *Look at vials of oil before opening. Discuss. Open caps, smell, then pour into dishes. Dip bread into oil and taste, focusing on flavour of the oil.*
   - Discuss appearance, aroma, flavour and any other relevant attributes.
   - Discuss reasons for likes, dislikes and concerns.

4. Present concept of SC-CO_2 extraction of canola oil. Get reactions (20 minutes)
   - Explain **current** extraction process with hexane and refining required
     - Explain carbon dioxide **extraction** method, less refining involved
     - Describe **nutritional differences** between oils extracted the two ways
     - Probe **environmental and nutritional concerns**.
   - Which concern is more important? Is a combination of information a stronger impact?
     - Review SC-CO_2 concept and relate to samples tasted. Discuss.

5. Discuss willingness to buy, how much they are willing to pay and where panellists see SC-CO_2 canola in the market (15 minutes).
     - Compare to prices of conventional canola oil and olive oil.

Canola oil: $3.50 – 4.50/ litre
Refined olive oil: ~$5.00-7.50/litre
Extra Virgin cold pressed oil: ~$5.50-12.00/litre

6. Last discussions, closing, thanks and incentives distributed (5 minutes).