

FEATURE

Reprinted from *Lipid Technology*, Vol.17, No.5, Pages 101–106, May 2005, with permission from the publisher, ©PJ Barnes & Associates, Bridgwater, UK; e-mail: sales@pjbarnes.co.uk; web: www.pjbarnes.co.uk

Performance of *trans*-free vegetable oils in shortenings and deep-fat frying

Frank T. Orthoefer

Frank T. Orthoefer, FTO Technology Consultant, 9346 Grove Hollow Lane, Germantown, TN 38139, USA; tel: +1-901-309-1447; fax: +1-901-309-1447; email: forthoefer@cs.com

Summary

A high-oleic, low-linolenic canola (rapeseed) has been created using conventional, non-transgenic, plant breeding methods. The oil from this canola seed contains 70% oleic acid, less than 3% linolenic acid and less than 7% saturated fatty acids. It is oxidatively stable without hydrogenation, is free of *trans* fatty acids and is among those oils with the lowest levels of saturated fatty acids. As a frying oil, it has an extended fry life and produces the desirable flavour of fried products. The oil is also good replacement for the *trans*-containing fats used for baking and margarine applications.

Introduction

Alternatives to partially-hydrogenated oils are being marketed that possess a natural stability to oxidation without the need for hydrogenation. These are the high-oleic, low-linolenic acid oils from canola (rapeseed), sunflower and peanut. The high-oleic, low-linolenic (HOLL) canola oil has received the most attention because of its general availability, functionality and competitive pricing (1). HOLL canola oil produces excellent fried food flavour, has an extended fry life and products made with HOLL canola oil have an improved shelf-life. This oil is easily blended or interesterified to produce shortenings that meet the speciality needs of fried-food producers, food-service operators, bakeries and margarine formulators.

Partially-hydrogenated oils

By using partial hydrogenation, food oils are produced that have increased oxidative stability. Many also have higher melting fractions that contribute to functionality or structural requirements of products such as plastic shortenings and margarines. Increased stability occurs through partial hydrogenation of the most highly unsaturated fatty acids present in the oil. These hydrogenated components generally have higher melting points. The hydrogenation process provides consumers with the preferred taste, crisp texture and a better shelf-life. However, hydrogenation leads to formation of *trans* fatty acids that are believed to be bad for health.

It has been estimated that over 40% of all foods produced contain *trans* fatty acids. Research has shown that *trans* fatty acids elevate the LDL (bad) cholesterol and reduce the HDL (good) cholesterol,

thus increasing the risk of heart disease (2). A diet high in *trans* fats may also be linked to Type 2 diabetes. The US Food and Drug Administration has ruled that from January 2006 food companies must include, in the nutrition facts panel, the *trans* fat content for all products. Partially-hydrogenated oils may contain up to 45% *trans* fatty acids. Deep-fat frying oils and many bakery shortenings contain very high levels of *trans* fatty acids, mostly to satisfy the need for oil stability during frying and to produce functional higher melting fats.

One short-term alternative to partial hydrogenation is to use lauric or tropical oils. Coconut and palm kernel oils, however, contain nearly 80–90% saturated fatty acid. Commodity palm oil and fractionated palm oil contain 40% or more saturated fatty acids. While they have the potential to replace partially-hydrogenated oils containing *trans* fatty acids, the saturated fatty acids in these oils are unhealthy because they raise blood cholesterol levels.

A modified high-oleic sunflower oil was marketed initially in the 1980s. This non-hydrogenated, zero *trans* fatty acid oil met the requirement for oxidative stability but its price prohibited wide-scale use in many products. Also, the oil was not readily available, limiting its use to speciality applications.

Commodity oils

Alternatives to the low-priced, hydrogenated commodity oils do not meet the stability or availability requirements of producers of fried foods or baked goods. Oils from soybean, corn (maize), cottonseed, sunflower, peanut, rice and canola oil are among these alternatives. Some oils are by-products and their availability depends on the demand for their primary

Table 1. Content of oleic (18:1), linoleic (18:2), linolenic (18:3) and total saturated (Sats) fatty acids in commercially-available vegetable oils (% of total).

Oil	18:1	18:2	18:3	Sats
High-oleic oils				
Canola				
High-oleic	74	14	3	<7
Low-linolenic	65	22	4	7
Commodity	60	20	10	7
Sunflower				
High-oleic	82	10	<1	8
Mid-oleic	56	33	<1	9
Commodity	20	65	<1	10
Others				
High-oleic safflower	75	14	<1	7
High-oleic soybean	83	2	3	12
Olive	75	8	<1	14
Lauric Oils				
Coconut	6	2	–	92
Palm kernel	15	3	–	82
Commodity Oils				
Cotton	17	56	–	27
Soybean	23	51	7	15
Corn	26	60	1	13
Palm	39	10	<1	50

products. Corn oil, for example, depends upon the demand for starches and sweeteners. Cottonseed depends on the demand for fibre, peanut oil on regulated peanut crushing, and rice oil on oil extraction capacity.

An alternative oil

The principal use of canola seed is the production of oil for food applications and meal for feeds. Canola oil is one of the cheapest commodity oils. Commodity canola oil, similar to soybean oil, does not meet the stability and functionality requirements necessary for frying or baking. Following on the functionality results obtained with high-oleic sunflower oil, a search was made using the tools of modern biotechnology to isolate the genetic material for the production of a high-oleic, low-linolenic acid content canola oil (HOLL-canola).

Using conventional plant breeding methods, a non-transgenic canola oil was developed. This oil is naturally stable without hydrogenation, is free of *trans* fatty acids and is among those with the lowest levels of saturated fatty acids. As a frying oil, it has an

extended fry life and produces the desirable fried flavour. Production of HOLL-canola is estimated at 180 000 tonnes (400 million pounds) for 2005, extending to 900 000 tonnes (2 billion pounds) in 2008.

The typical fatty acid composition of HOLL-canola oil is: palmitic acid 3.6%, stearic acid 2%, oleic acid 73%, linoleic acid 15%, linolenic acid < 3% and arachidic acid 0.7 %.

Compared to olive oil, HOLL-canola oil contains more oleic acid, a cholesterol-neutral fatty acid, and only half the saturated fatty acid content. HOLL-canola oil matches or exceeds the healthy fatty acid composition of other high-oleic oils (**Table 1**). The AOM (active oxygen method) value is 42–44 hours, an oxidative stability equivalent to that of many partially-hydrogenated oils (**Figure 1**).

Using HOLL-canola oil for frying

HOLL-canola oil is a *trans*-free replacement for partially-hydrogenated frying oils where resistance to the stress of frying and extended shelf-life are required. Applications where it is currently used are:

- snack and grill frying;
- food service frying;
- pan sprays;
- spray oil coatings;
- bakery shortenings;
- nutritional bars;
- sauces and dressings.

Various frying trials have been performed comparing the performance of HOLL-canola to other oils. Emphasis has been placed on the assessment of hydrolysis, oxidation, and polymerization of the oil during prolonged frying. Analysis has included total polar materials (oil breakdown), polymer formation, free fatty acids (hydrolysis), and colour. Production of total polar compounds was compared to that from partially-hydrogenated canola, canola, low-linolenic canola, partially-hydrogenated soybean oil and high-oleic sunflower oil. Only high-oleic sunflower produced less total polar materials after 56 hours of frying than HOLL-canola (**Figure 2**).

Only partially-hydrogenated canola had less colour development than HOLL-canola after 70 hours of frying (7R versus 6.5R). Less *trans* fatty acids were formed during frying with HOLL-canola (5%) compared with palm olein (8%) and partially-hydrogenated rapeseed oil (16%). The HOLL-canola showed less of an increase in viscosity due to less polymerization during frying.

In an early frying study that compared the stability of soybean oil with that of canola which had a modified fatty acid composition, all oils with reduced linolenic acid content produced less room odour intensity than the standard oils (3). Free fatty acids, polar compounds, and foam height during frying were significantly less with the modified oils. Flavour quality of French fries was improved.

The formation of polymeric compounds in HOLL-canola oil was comparable to that of palm olein and partially-hydrogenated rapeseed oil after 72 hours of frying, with less of a change in viscosity and less darkening in colour (4). In a French fries study that compared HOLL-canola with rapeseed oil, partially-hydrogenated rapeseed oil and sunflower oil, the modified canola oil showed greater resistance to peroxide development and colour formation, and less foaming. In a comparison of HOLL-canola oil with palm olein, partially-hydrogenated rapeseed, and high-oleic sunflower oil, the HOLL-canola, after 72 hours frying, was reported as the oil with the best performance criteria (4). HOLL-canola was compared to commodity canola, low-linolenic canola oil, mid-oleic sunflower oil, partially-hydrogenated canola and soybean oil. HOLL-canola gave better performance during frying than the other oils tested (5). In comparing partially-hydrogenated soybean oil to HOLL-canola and canola oil for polar materials, the partially-hydrogenated soybean oil reached the discard point (24% polar compounds) after 14 hours of frying. HOLL-canola reached the same discard point after 40 hours of frying.

A perfect frying oil is defined as having high oxidative stability, healthy composition (low saturates, low *trans* fatty acids) and producing high-quality fried foods with excellent taste (4). Frying with HOLL-canola oil was equivalent or superior to partially-hydrogenated rapeseed oil, high-oleic sunflower oil, and palm olein in development of free fatty acids, oxidative stability, polar compound

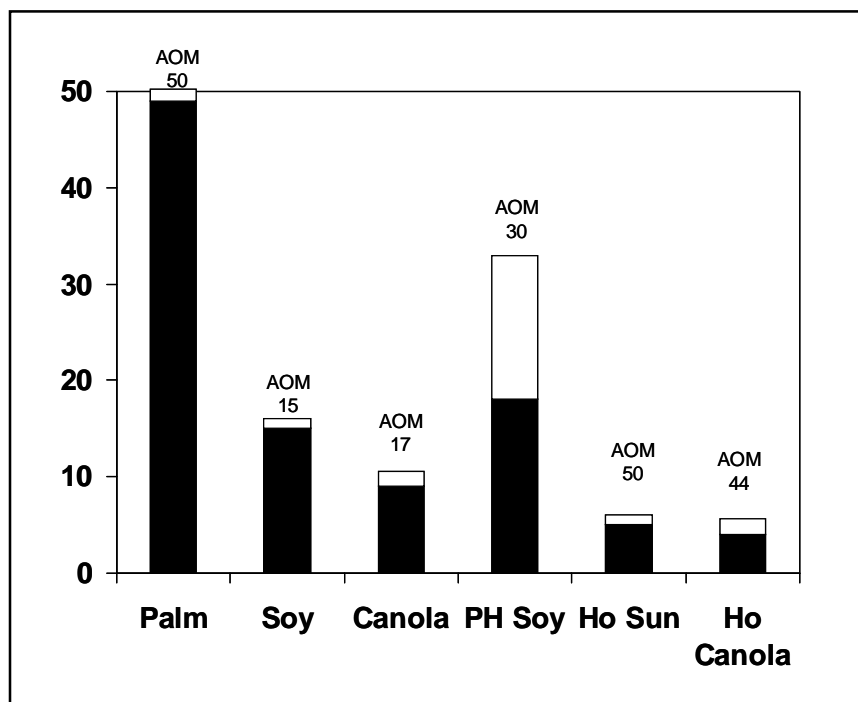


Figure 1. Oxidative stability of six major vegetable oils (AOM values shown) and their % content of *trans* fatty acids (white bars) and saturated fatty acids (black bars). Ho = high-oleic.

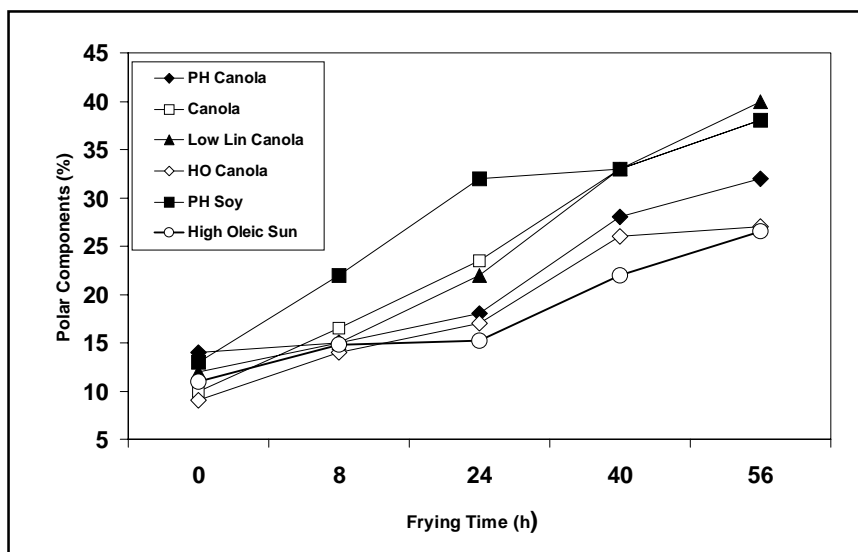


Figure 2. Oxidative stability of six major vegetable oils measured as production of total polar compounds (HO Canola = HOLL-canola).

Table 2. Typical solid fat content (SFC) profile for an all-purpose shortening.

SFC at °F	at °C	% solids
50	10	28 ± 3
70	21	20 ± 2
80	27	17 ± 1
92	33	13 ± 1
104	40	7 ± 1

Table 3. Solid fat content (SFC) profile for high-oleic, low-linolenic (HOLL) canola blended with increasing amounts of fully-hydrogenated oil (hardfat).

Blend (% hardfat)	% solids at temperature					
	50 10	70 21	80 27	92 33	100 38	104°F 40°C
Soy hardfat						
10	11.5	10.2	9.7	8.4	7.7	7
20	22.5	20.9	19.5	17.6	16.1	15.6
30	33.2	31.6	29.6	27.5	25.4	24.7
Cottonseed hardfat						
10	11.3	10.3	9.3	7.9	7	6.8
20	21.6	20.8	19.2	17.4	15.6	14.9
30	32.3	31.4	29.6	27.3	25.1	24.1
Palm hardfat						
10	10.9	9.7	8.3	6.9	5.6	4.9
20	21.3	19.8	18.2	16	13.9	12.8
30	31.3	30.3	28.5	25.9	23.2	21.9

formation, oligomer production, sensory quality and development of hexanal during frying. Hexanal is a breakdown product resulting from oxidized fatty acids. Overall, HOLL-canola was considered the best of the oils tested.

Together, the frying studies demonstrate that HOLL-canola has greater fryer stability when compared with partially-hydrogenated oils and is nearly equivalent to the high-oleic sunflower oil shortenings, which contain 80% oleic acid.

Shortenings

Many foods require not only oxidative stability for shelf-life but also semi-solid fats for functionality or structural performance. Examples include common bakery or all-purpose shortening, puff pastry shortening and margarine oils.

All-purpose bakery shortenings contain solid fats that aerate the dough during creaming of sugar and flour. Aeration of the dough ultimately provides the

Table 4. Solid fat content (SFC) profile for interesterified high-oleic, low-linolenic (HOLL) canola blended with increasing amounts of fully-hydrogenated oils (hardfat).

Blend (% hardfat)	% solids at temperature					
	50 10	70 21	80 27	92 33	100 38	104°F 40°C
Soy hardfat						
10	1.4	0.6	0.1	0	0	0
20	5.4	4.5	2.6	0.9	0.2	0
30	12.7	12.6	10.7	4.8	2.4	2
Cottonseed hardfat						
10	5.1	2	1.4	0.6	0.4	0.1
20	5.9	4.3	2.2	0.6	0.1	0
30	11.4	11.1	8.9	3.9	1.8	1
Palm hardfat						
10	7.9	5.8	5	3.6	2.3	1.3
20	19.7	17.3	15.9	13.6	10.8	9.7
30	29.7	25.9	23.7	19.9	16.2	14.5

structure of the finished baked product. The solids present in the shortening must extend over a wide temperature range to produce the desired plasticity for creaming. An example of a desirable solid fat content (SFC) for an all-purpose shortening is shown in **Table 2**.

Typically, all-purpose shortenings are blends of 85–90% partially-hydrogenated oil with 10–15% of a fully hydrogenated fat such as cottonseed or palm oil. The fully hydrogenated component is selected based upon its crystalline behaviour. A beta prime crystal is preferred. *Trans* fatty acid content ranges from 20% to 30%, and is all derived from the partially-hydrogenated component. Fully-hydrogenated hard fats contain zero *trans* fatty acids.

The preparation of alternative all-purpose shortenings began by blending HOLL canola oil with 10, 20, and 30% hard fats (soybean, cottonseed or palm oil) (**Table 3**). Blends were also interesterified using either chemical or enzymatic methods (**Table 4**). Interesterified fully-hydrogenated palm stearin (30% of product) gave solids profiles most like the targeted all-purpose shortening. Conversion of the blends to traditional plastic shortenings is performed using swept surface votation equipment.

Harder fats used for Danish puff pastry or roll-in applications are also possible by addition of fully-hydrogenated palm or cottonseed hard fats to the HOLL-canola oil. A potential benefit of using fully-hydrogenated fats in blends with HOLL-canola is the increase in oxidative stability as measured by OSI (**Figure 3**).

Margarines

Margarine oils vary depending upon the specific type of margarine being produced. Soft stick and tub margarine are the most common types. The solid fat index (SFI) of these products is shown in **Table 5**. Fully-saturated cottonseed oil or palm stearin at 10% are acceptable blends with HOLL canola oil (Tables 3 and 4). Interesterified blends are preferred for better melting. Palm at about 10% with HOLL-canola gives a preferred ingredient. Others have used palm kernel oil also to improve melt and flavour release.

Intesterified blends of higher solids content with up to 30% fully hydrogenated palm oil have been investigated for production of stick margarines. Combinations of the interesterified base (up to 30% fully-hydrogenated soybean oil interesterified with

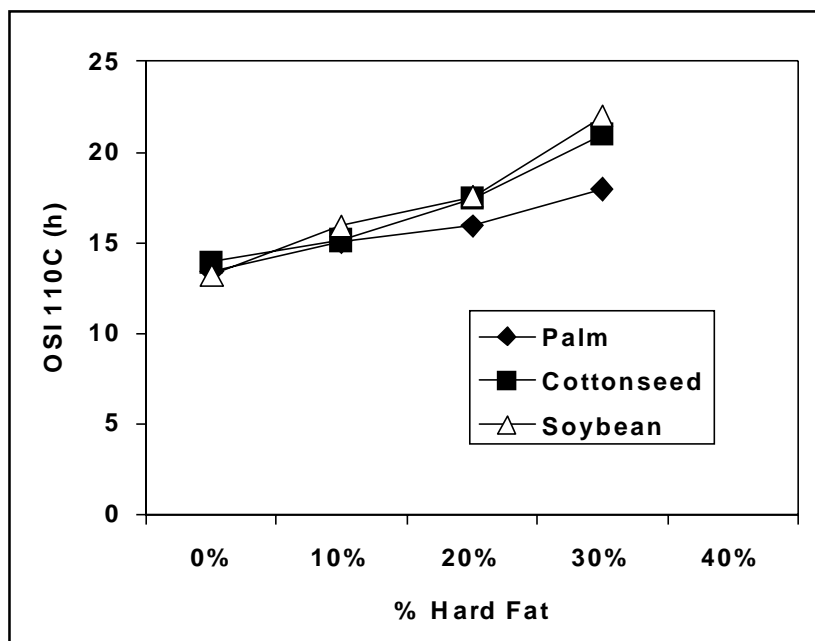


Figure 3. Oxidative stability index values (OSI) for blends of high-oleic, low-linolenic (HOLL) canola oil with fully-hydrogenated palm, cottonseed and soybean oils.

70% HOLL canola) with liquid oil also are being investigated.

Conclusions

Studies have shown that two-thirds of the risk of heart attack may be attributed to high serum cholesterol level and smoking. Dietary *trans* fatty acids have been shown to increase LDL (bad) cholesterol and decrease HDL (good) cholesterol. An estimate showed that *trans* fats may be responsible for 30 000 or more deaths per year (6). Saturated fats are an unsatisfactory alternative to hydrogenated oils because they increase total blood cholesterol. The *trans* fatty acids can be minimized through formulation and processing. The new US dietary guidelines recommend that dietary *trans* fats should be as low as possible and consumers should limit their intake of saturated fats to 10% of calories (7).

A modified high-oleic, low-linolenic acid modified canola oil (HOLL-canola) is now produced containing 70% oleic acid, < 3% linolenic acid and less than 7% saturated fatty acids. This oil meets the 2005 US Dietary Guidelines and, because of natural stability, is

Table 5. Solid fat index (SFI) of margarine oils.

SFC at °F	at °C	Soft stick	Tub
50	10	12–20	8–12
70	21	8–17	6–8
92	33	1.0–3.0	3 max

an excellent replacement for *trans*-containing fats used for frying, baking and margarine applications.

Reference

1. Dzisiak, D. (2004) New oils reduce saturated and *trans* fats in processed foods. *Cereal Foods World*, 49, (6), 331–333.
2. Ascherio, A. *et al.* (1999) *Trans* fatty acids and coronary heart disease. *N. Engl. J. Med.*, 340, 1994.
3. Warner, L. and Mounts, T.L. (1993) Frying stability of soybean and canola oils with modified fatty acid compositions. *J. Am. Oil Chem. Soc.*, 70, 983–988.
4. Matthaus, B. (2005) Use of different oils unusual for deep-fat frying. 5th International Symposium on Deep Frying. 20–25 February 2005, San Francisco, California, USA.
5. Przybylski, R. *et al.* (1999) Frying performance of modified canola oils. Proceedings of the 10th International Rapeseed Congress, Canberra, Australia. www.regional.org.au/au/gcirc/
6. Willett, W.C. and Ascherio, A. (1994) *Trans* fatty acids: are the effects only marginal? *Am. J. Pub. Health*, 84, 5722–5724.
7. Dietary Guidelines Committee Report (2004). Center for Nutrition Policy and Promotion. Washington, DC, USA.



THE OILY PRESS

Books on fats, oils and other lipids

PJ Barnes & Associates, PO Box 200, Bridgwater, TA7 0YZ, England

Tel: +44-1823-698973

E-mail: sales@pjbarnes.co.uk

Fax: +44-1823-698971

Web site: www.pjbarnes.co.uk

LIPIDS: STRUCTURE, PHYSICAL PROPERTIES AND FUNCTIONALITY

Written by Kåre Larsson, Peter Quinn, Kiyotaka Sato and Fredrik Tiberg
ISBN 0-9531949-9-X, 280 pages, published in 2006. Vol. 19 in The Oily Press Lipid Library.

LIPID OXIDATION — SECOND EDITION

Written by Edwin N. Frankel
ISBN 0-9531949-8-1, 2005, 486 pages, 152 tables, 148 figures, 87 equations, 849 references. Vol. 18 in The Oily Press Lipid Library.

BIOACTIVE LIPIDS

Edited by Anna Nicolaou and George Kokotos
ISBN 0-9531949-7-3. September 2004, 294 pages, 21 tables, 47 figures, 1127 references. Volume 17 in The Oily Press Lipid Library.

For more details see:

www.pjbarnes.co.uk/op/books.htm

ADVANCES IN LIPID METHODOLOGY — FIVE

Edited by Richard O. Adlof
ISBN 0-9531949-6-5, November 2003, 384 pages, 24 tables, 110 figures and 929 references. Vol. 16 in The Oily Press Lipid Library.

LIPID ANALYSIS — THIRD EDITION

Written by William W. Christie
ISBN 0-9531949-5-7, 2003, 416 pages, 25 tables, 84 figures, 644 references. Vol. 15 in The Oily Press Lipid Library.

CONFECTIONERY FATS HANDBOOK

Written by Ralph E. Timms.
ISBN 0-9531949-4-9, 2003, 441 pages, 90 tables, 146 figures, 725 references. Vol. 14 in The Oily Press Lipid Library.

LIPIDS FOR FUNCTIONAL FOODS AND NUTRACEUTICALS

Edited by Frank D. Gunstone.
ISBN 0-9531949-3-0, 2003, 322 pages, 65 tables, 44 figures, 1183 references. Vol. 13 in The Oily Press Lipid Library.