Thermal stability of Australian canola oil varieties

Randy Adjonu[1*], Paul D. Prenzler[1], Chris L. Blanchard[1], Jamie Ayton[2]

[1]ARC Industrial Transformation Training Centre for Functional Grains and the Graham Centre for Agricultural Innovations, Charles Sturt University, Wagga Wagga, 2650, raadjonu@csu.edu.au, pprenzler@csu.edu.au, cblanchard@csu.edu.au.

[2] NSW Department of Primary Industries, Wagga Wagga Agriculture Institute, 2650, jamie.ayton@dpi.nsw.gov.au.

ABSTRACT

The objective of this study was to investigate the frying performance of canola oil types processed by various processors in Australia. The scope of oils tested were: refined canola oils obtained after cold-mechanical-pressing (CmpCO); hot-mechanical-pressing of canola seeds (HmpCO-I and HmpCO-II); and a generic canola oil (GenCO – blend of canola oil from other extraction techniques). Samples were selected from the 2016/2017 production season to ensure limited variation in the fatty acids composition of the oils. The canola oil samples were used to fry fresh cut potato chips, and the oil degradation was monitored by measuring the total polar materials (TPM), free fatty acids (FFA) and tocopherols content. It was found that the HmpCO-I sample exhibited better thermal stability than other oils tested. Tocopherols retention during frying also improved the thermal stability of canola oils. Overall, the oils exhibited different degrees of thermal stability, which highlighted inherent differences in canola oils – as a function of the crude oil processing method. The outcome of this study will provide insight to processors on the thermal stability of their canola oils and could serve as a platform for further optimisation of their processes to produce the best quality products for domestic and international markets.

Key words: Extraction technique; Frying life; Canola oil; Total polar material; Tocopherols.

INTRODUCTION

Frying is a popular method of food preparation and it is applied on small to large scales in various industries (Rudzińska et al., 2018). Various types of oils, including soybean, palm and palm kernel, olive, coconut and other modified and blended oils are used to fry food (Aladedunye & Przybylski, 2014; Przybylski, Gruczynska, & Aladedunye, 2013). The attractiveness of fried foods owes to the array of chemical reactions that occur in the frying medium (oil and food), leading to attributes such as crispiness, flavour, taste, and golden colour of fried foods, which are desirable to consumers.

The selection of oil type for frying is influenced by the economics of the process, mainly the frying life and the cost of purchasing the oil. The frying life of the oil is determined by the source of oil, fatty acids composition, presence of minor bioactive components (e.g. tocopherols, polyphenolic compounds) and reactions that occur in the oil during extraction and refining (e.g. Maillard reactions, polymerization, hydrolysis etc). Frying practices and the food type being fried also affect oil stability and frying life. Whereas processors will be focused on the frying life of the oil and associated oil costs, the physicochemical and sensorial attributes of the fried food is important to end-users and consumers. Therefore, oil manufacturers and fried food producers must combine these factors into their processes to produce products that can satisfy adequately, all of these factors.

Canola oil is an economically important oil owing to its unique fatty acids profile (Ghazani, García-Llatas, & Marangoni, 2014) – saturated fatty acids <8%, monounsaturated fatty acids of 55 - 67% and polyunsaturated fatty acids of 23-31%. Over the past 4 decades, canola has grown in popularity globally as the third edible oil by volume after palm and soybean oil (Lin et al., 2013). The refined oil has significant quantities of tocopherols and phytosterols, which together with the high monounsaturated fatty acids are believed to affect cardiovascular health – by regulation of plasm lipids and lipoprotein, susceptibility of low-density lipoproteins oxidation and insulin sensitivity (Lin et al., 2013).

Extensive research has been conducted on canola oil frying qualities, looking at fatty acid compositions (Przybylski et al., 2013), frying temperature and quality changes in oil during frying (Aladedunye & Przybylski, 2009). However, little has been done to investigate the effects of the crude oil extraction techniques on the thermal stability of the refined oils, although anecdotal evidence exists of differences in the functionalities (Warner & Dunlap, 2006). Thus, more research is needed to understand the compositional and functional differences between refined canola oils obtained by the different extraction techniques.

In Australia, canola oil processing involves the crude oil extraction (cold-mechanical pressing, hot-mechanical pressing, pre-pressing followed by solvent extraction and 100% solvent extraction), followed by refining, either chemically, physically or both. Differences exist in oil yield and the crude oil quality indices between the different extraction techniques (Ghazani et al., 2014). Generally, solvent extracted oils are darker in colour, high in free fatty acids, gums, and chlorophyll. The proportions of minor components also varies considerably between the different extraction techniques. For example, solvent-extracted crude canola oils has been shown to have higher tocopherols and phytosterols content than mechanical-pressed crude canola oil (Ghazani et al., 2014; Van Hoed, Ali, Slah, & Verhé, 2010).

In this study, the thermal stabilities of refined bleached and deodorised cold-mechanical-pressed, hot-mechanical-pressed, and a generic canola oils were investigated. The behaviour of the oils with heating when frying provides insight into the thermal stability and frying life of the different oil variants.

MATERIALS AND METHODS

Four canola oil types were obtained from Australian processors. Canola oils were drawn from the 2016/2017 production season and included a cold-mechanical-press (CmpCO), two hot-mechanical-pressed (HmpCO-I and HmpCO-II) and a generic refined canola oil (GenCO). Fresh potato chips were purchased from a local processor. All other chemicals and reagents were of analytical and research grade.

Frying exercise: Frying was conducted in a 5 L capacity stainless steel double pan deep fryer (Model FFA2002, Anvil Double Basket Benchtop Fryer, Anvil Axis, South Africa). Canola oil (4 L) was heated at 180 ± 5°C for 9 hours daily (1 hour preheating + 8 hours of frying). Each frying cycle had 400 g potato chips fried for 8 minutes, every hour for 8 hours each day – for 7 days. The oil was filtered before frying on day 3 and 5, and oil volume was not topped-up. At the end of frying each day, 50 mL of oil was collected in a 50 mL centrifuge tube, wrapped in aluminium foil and kept at -20 °C for further analyses.

Monitoring oil quality: Peroxide value (AOCS Cd 8b-90, 2011) and free fatty acids content (AOCS Ca 5a-40, 2011) of unfried and fried canola oils were determined as per AOCS official methods of analysis. The total polar material (TPM) of the oils was measured before frying and after each frying cycle for 8 hours each day for the 7 days. TPM was measured with the Frying Oil Monitor DOM-24 (ATAGO Co., Ltd, Tokyo, Japan). Tocopherols content, oxidative rancidity index (OSI), and fatty acids composition were determined by in-house methods of the NSW Department of Primary Industries Oils Research Laboratory, which are based on ISO methods.

RESULTS

HmpCO-I, HmpCO-II and GenCO had low initial FFA content, ~0.05%. The CmpCO had very high initial FFA (0.52%) and peroxide value (~8.8 mEq/kg oil), as well as the lowest initial oxidative stability index (~5.8 hours) and total tocopherols content (~548 mg/kg)) when compared to the other three canola oil types (Table 1). The two hot-mechanical-pressed canola oils (HmpCO-I and HmpCO-II) had similar tocopherols content, however, the HmpCO-I recorded a higher initial peroxide value (1.8 mEq/kg Oil) than HmpCO-II (0.8 mEq/kg Oil). The GenCO had the highest tocopherols content of 707 mg/Kg. The GenCO is typically an aggregated blend of oils obtained by the different extraction techniques which, depending on the proportions of different oils blended, can affect the levels of minor components such as tocopherols, as well as the overall quality indices. The HmpCO-I, HmpCO-II and GenCO had comparable oxidative stability index (Table 1). The fatty acids composition of all the four canola oils were typical and were very similar for HmpCO-I, HmpCO-II and GenCO. The CmpCO sample had higher oleic acid and lower linoleic and linolenic acid contents of all the oils. This trend in CmpCO fatty acids composition is also reflected by a higher MUFA and lower PUFA and iodine value.

Table 1: Pre-frying oil quality and fatty acids composition of canola oils.

Parameters	HmpCO-I	HmpCO-II	CmpCO	GenCO
FFA as Oleic (%)	0.051±0.02	0.048±0.01	0.51±0.00	0.052±0.00
Peroxide Value (mEq/Kg Oil)	1.8±0.07	0.8±0.03	8.8±0.12	1.13±0.08
Oxidative Stability (h)	8.0±0.09	8.6±0.05	5.8±0.07	8.7±0.07
Tocopherols (mg/kg)	668±0.6	647±2.7	548±1.5	707±1.9
Fatty Acid composition (% total fatty acids)				
Palmitic acid (C16:0)	4.0±0.00	4.0±0.00	4.1±0.01	4.1±0.01
Stearic acid (C18:0)	1.9±0.00	1.9±0.00	2.0±0.00	1.9±0.00
Oleic acid (C18:1)	61.7±0.03	62.4±0.00	64.5±0.01	62.1±0.02
Linoleic acid (C18:2)	19.4±0.00	19.2±0.00	17.9±0.00	19.4±0.00
Linolenic acid (C18:3)	10.3±0.03	9.9±0.01	8.8±0.00	9.8±0.01
SFA	7.0±0.00	7.0±0.00	7.3±0.01	7.2±0.01
MUFA	63.3±0.03	63.9±0.00	66.0±0.01	63.7±0.02
PUFA	29.7±0.03	29.1±0.01	26.7±0.00	29.1±0.01
Iodine Value	114.7±0.10	113.8±0.02	110.6±0.02	113.6±0.03

Figure 1 shows the changes in TPM of the four canola oil types during frying. The TPM correlated with frying time and increased as the frying cycle / time increased. TPM increased in the order, HmpCO-II (3.0 – 19.5%) > HmpCO-I (3.5 – 24.3%) = GenCO (4.0 – 22.5%) > CmpCO (3.5 – 28.0%).

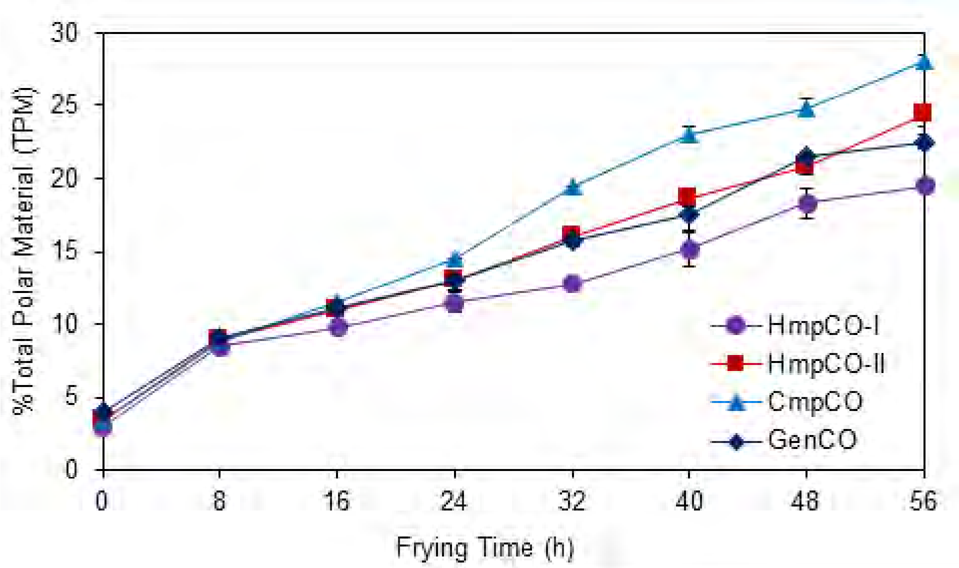

Figure 1: Changes in total polar materials of different canola oil types during frying. Legends: HmpCO-I and HmpCO-II = hot-mechanical-pressed; CmpCO = cold-mechanical-pressed GenCO = generic refined canola oil.

The formation of FFA during frying is presented in Figure 2. Again, FFA was well correlated with frying time and increased in a 2nd order polynomial fashion. The three canola oils HmpCO-I, HmpCO-II and GenCO displayed similar trends in data, however as shown in Figure 2, the CmpCO was well distinguished from the rest of the oils due to the unusually high initial FFA content.

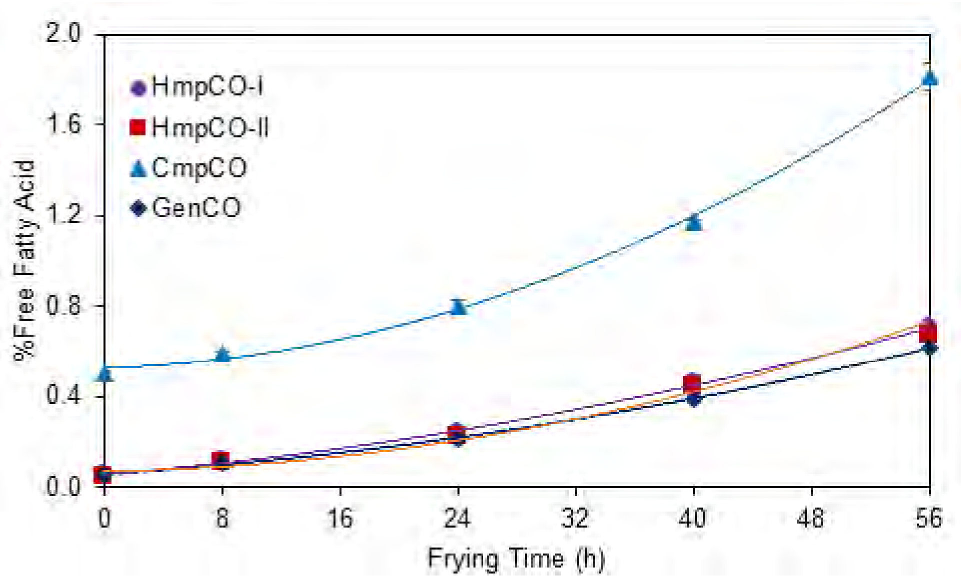

Figure 2: Free fatty acids evolution during frying. Legends: HmpCO-I and HmpCO-II = hot-mechanical-pressed; CmpCO = cold-mechanical-pressed GenCO = generic refined canola oil.

The percent loss in tocopherols during frying is shown in Figure 3. At the end of the 7th day, tocopherol losses were 68.5%, 82.5%, 92.6% and 78.8% for the HmpCO-I, HmpCO-II, CmpCO and GenCO, respectively. The CmpCO had the greatest loss in tocopherols over the frying period.

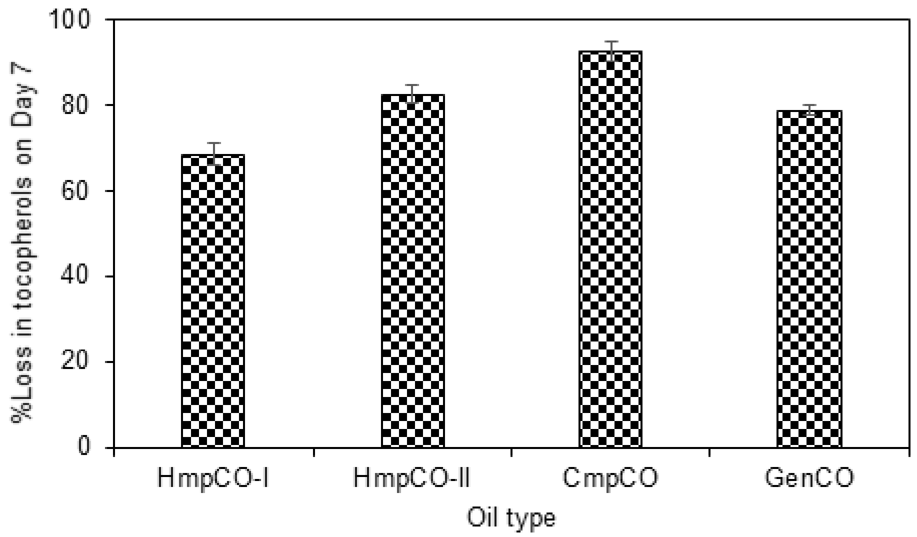

Figure 3: Tocopherols loss end of day 7 of frying. Legends: HmpCO-I and HmpCO-II = hot-mechanical-pressed; CmpCO = cold-mechanical-pressed GenCO = generic refined canola oil.

DISCUSSION

The current study focused on the effect of various processing techniques as applied to crude oils on the frying performance of four canola oil types. The fatty acids composition of the unfried canola oils was typical of the 2016/2017 canola oil production season. The CmpCO had the least amount of tocopherols, which can be attributed to the cold-pressing technique used for the crude oil extraction, which tends to extract less tocopherols into the oil (Ghazani et al., 2014), whereas the very high initial FFA resulted from the refining process applied to the oil. Most likely, the refining process did not reduce the initial FFA content in the crude oil especially during the neutralisation and deodorisation steps.

Canola oil deterioration during frying was monitored by measuring the TPM, FFA and tocopherol loss. TPM measurement is an accurate index to evaluate oil deterioration during frying (Przybylski et al., 2013) and, together with the FFA and tocopherols, can provide estimations on oil performance and frying life. Generally, oil is considered degraded when the TPM value reaches 24%. The effect of frying on TPM and FFA evolution correlated with frying time (Figures 1 and 2) – increasing with number of frying cycles. As shown in Figure 1, the CmpCO presented the lowest frying life and reached the TPM cut-off for frying oils by the end of day 6. The HmpCO-I recorded the best stability followed by the GenCO and the HmpCO-II. This underscores the intrinsic and performance differences between canola oils obtained by the different extraction methods and by different processors.

The evolution in the FFA was similar for the HmpCO-I, HmpCO-II and the GenCO, however the CmpCO was markedly distinct from the rest (Figure 2). This resulted from the unusually high initial FFA of the CmpCO compared to the other oils (Table 1). It is worth mentioning that the CmpCO, however, recorded the least relative change in FFA of 0.67 at the end of frying compared to the other oil which had increased by 1.12 – 1.13. This implied that, the high initial FFA of the CmpCO did not play any significant role in the thermal stability of this canola oil and might not be important to the overall stability. This suggested that other degradation products including dimeric and higher polymeric triglycerides, monomeric oxidized products, as well as mono- and diglycerides (Farhoosh & Tavassoli-Kafrani, 2010) most likely contributed more to oil deterioration. Thus, FFA is not the best predictor of oil degradation but TPM is, since TPM as an index combines the contributions of all the degradation products listed including FFA.

The stability of the oils with frying also correlated with tocopherols loss with greater tocopherols loss correlating with higher TPM values (Figures 1 and 3). Thus, tocopherol being a natural antioxidant protected the oils against oxidation and thermal degradation. The HmpCO-I samples although showed highest initial peroxide value and lowest initial oxidative stability index when compared to the HmpCO-II and the GenCO, had the longest frying life of the three canola oils (Figure 1 and 3). Thus, an initially high peroxide value may not necessary influence the frying life adversely and that the ability to retain tocopherols by protecting tocopherols against oxidation and thermal degradation was more important to frying life of the canola oils. The presence of Maillard reaction products has been shown to inhibit tocopherols loss and improved the frying performance of expeller-pressed refined soybean oil over solvent-extracted refined soybean oil (Warner & Dunlap, 2006).

In conclusion, the current study has demonstrated that the seed preparation and crude oil extraction techniques can influence the functionality of the refined oil and that differences exist between the different canola oil variants during frying. Further research is however needed to better understand the sources of these variations. The outcome of this study could lead to further process optimisation leading to products with improved functionalities such as longer frying life – and show canola oil as a non-commodity oil product which can command a market premium.

ACKNOWLEDGEMENTS

This work was funded by ARC Industrial Transformation Training Centre for Functional Grains Charles Sturt University. The authors also acknowledge the support of the Graham Centre for Agriculture Innovation and NSW Department of Primary Industries. Finally, the authors are grateful to oil processors who supplied samples for the project.

REFERENCES

Aladedunye, F., & Przybylski, R. (2014). Performance of palm olein and modified rapeseed, sunflower, and soybean oils in intermittent deep-frying. *European Journal of Lipid Science and Technology, 116*(2), 144-152.

Aladedunye, F. A., & Przybylski, R. (2009). Degradation and nutritional quality changes of oil during frying. *Journal of the American Oil Chemists' Society, 86*(2), 149-156.

Farhoosh, R., & Tavassoli-Kafrani, M. H. (2010). Polar compounds distribution of sunflower oil as affected by unsaponifiable matters of Bene hull oil (BHO) and tertiary-butylhydroquinone (TBHQ) during deep-frying. *Food chemistry, 122*(1), 381-385.

Ghazani, S. M., García-Llatas, G., & Marangoni, A. G. (2014). Micronutrient content of cold-pressed, hot-pressed, solvent extracted and RBD canola oil: Implications for nutrition and quality. *European Journal of Lipid Science and Technology, 116*(4), 380-387.

Lin, L., Allemekinders, H., Dansby, A., Campbell, L., Durance-Tod, S., Berger, A., & Jones, P. J. H. (2013). Evidence of health benefits of canola oil. *Nutrition Reviews, 71*(6), 370-385. doi:10.1111/nure.12033

Przybylski, R., Gruczynska, E., & Aladedunye, F. (2013). Performance of regular and modified canola and soybean oils in rotational frying. *Journal of the American Oil Chemists' Society, 90*(9), 1271-1280.

Rudzińska, M., Hassanein, M. M., Abdel-Razek, A. G., Kmiecik, D., Siger, A., & Ratusz, K. (2018). Influence of composition on degradation during repeated deep-fat frying of binary and ternary blends of palm, sunflower and soybean oils with health-optimised saturated-to-unsaturated fatty acid ratios. *International Journal of Food Science & Technology, 53*(4), 1021-1029.

Van Hoed, V., Ali, C. B., Slah, M., & Verhé, R. (2010). Quality differences between pre-pressed and solvent extracted rapeseed oil. *European Journal of Lipid Science and Technology, 112*(11), 1241-1247.

Warner, K., & Dunlap, C. (2006). Effects of expeller-pressed/physically refined soybean oil on frying oil stability and flavor of french-fried potatoes. *Journal of the American Oil Chemists' Society, 83*(5), 435-441. doi:10.1007/s11746-006-1223-x