

Chemistry of Deep-Fat Frying Oils

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ABSTRACT: Deep-fat frying produces desirable or undesirable flavor compounds and changes the flavor stability and quality of the oil by hydrolysis, oxidation, and polymerization. Tocopherols, essential amino acids, and fatty acids in foods are degraded during deep-fat frying. The reactions in deep-fat frying depend on factors such as replenishment of fresh oil, frying conditions, original quality of frying oil, food materials, type of fryer, antioxidants, and oxygen concentration. High frying temperature, the number of fryings, the contents of free fatty acids, polyvalent metals, and unsaturated fatty acids of oil decrease the oxidative stability and flavor quality of oil. Antioxidant decreases the frying oil oxidation, but the effectiveness of antioxidant decreases with high frying temperature. Lignan compounds in sesame oil are effective antioxidants in deep-fat frying.

Keywords: deep-fat frying, frying oil quality, hydrolysis, oxidation, polymerization

Introduction

Deep-fat frying is one of the oldest and popular food preparations. The economy of commercial deep-fat frying has been estimated to be \$83 billion in the United States and at least twice the amount for the rest of the world (Pedreschi and others 2005). Fried foods have desirable flavor, color, and crispy texture, which make deep-fat fried foods very popular to consumers (Boskou and others 2006). Frying is a process of immersing food in hot oil with a contact among oil, air, and food at a high temperature of 150 °C to 190 °C. The simultaneous heat and mass transfer of oil, food, and air during deep-fat frying produces the desirable and unique quality of fried foods. Frying oil acts as a heat transfer medium and contributes to the texture and flavor of fried food.

Frying time, food surface area, moisture content of food, types of breading or battering materials, and frying oil influence the amount of absorbed oil to foods (Moreira and others 1997). The oil contents of potato chips, corn chips, tortilla chips, doughnuts, French fries, and fried noodle (*naryssu*) are 33% to 38%, 30% to 38%, 23% to 30%, 20% to 25%, 10% to 15% (Moreira and others 1999a), and 14% (Choe and others 1993), respectively. The absorbed oil tends to accumulate on the surface of fried food during frying in most cases (Moreira and others 1999b) and moves into the interior of foods during cooling (Moreira and others 1997).

Foods fried at the optimum temperature and time have golden brown color, are properly cooked, and crispy, and have optimal oil absorption (Blumenthal 1991). However, underfried foods at lower temperature or shorter frying time than the optimum have white or slightly brown color at the edge, and have ungelatinized or partially cooked starch at the center. The underfried foods do not have desirable deep-fat fried flavor, good color, and crispy texture. Over-fried foods at higher temperature and longer frying time than the optimum frying have darkened and hardened surfaces and a greasy texture due to the excessive oil absorption.

Deep-fat frying produces desirable or undesirable flavor compounds, changes the flavor stability and quality, color, and texture

of fried foods, and nutritional quality of foods. The hydrolysis, oxidation, and polymerization of oil are common chemical reactions in frying oil and produce volatile or nonvolatile compounds. Most of volatile compounds evaporate in the atmosphere with steam and the remaining volatile compounds in oil undergo further chemical reactions or are absorbed in fried foods. The nonvolatile compounds in the oil change the physical and chemical properties of oil and fried foods. Nonvolatile compounds affect flavor stability and quality and texture of fried foods during storage. Deep-fat frying decreases the unsaturated fatty acids of oil and increases foaming, color, viscosity, density, specific heat, and contents of free fatty acids, polar materials, and polymeric compounds (Figure 1).

Frying temperature and time, frying oil, antioxidants, and the type of fryer affect the hydrolysis, oxidation, and polymerization of the oil during frying. This review focuses on the chemical reactions of frying oil and improvement of the oxidative stability and flavor quality of frying oil during deep-fat frying.

Chemical Reactions of Oil during Deep-Fat Frying

Hydrolysis of oil

When food is fried in heated oil, the moisture forms steam, which evaporates with a bubbling action and gradually subsides as the foods are fried. Water, steam, and oxygen initiate the chemical reactions in the frying oil and food. Water, a weak nucleophile, attacks the ester linkage of triacylglycerols and produces di- and mono-acylglycerols, glycerol, and free fatty acids. Free fatty acids contents in frying oil increase with the number of fryings (Chung and others 2004) as shown in Figure 2. Free fatty acid value is used to monitor the quality of frying oil. Thermal hydrolysis takes place mainly within the oil phase rather than water-oil interface (Lascanay 1949). Hydrolysis is more preferable in oil with short and unsaturated fatty acids than oil with long and saturated fatty acids because short and unsaturated fatty acids are more soluble in water than long and saturated fatty acids. Water from foods is easily accessible to short-chain fats and oils for hydrolysis (Nawar 1969).

Large amounts of water hydrolyze the oil rapidly (Dana and others 2003). Water hydrolyzes the oil faster than steam (Polkorny 1989). Large contact between the oil and the aqueous phase of food increases hydrolysis of oil. Mono- and diacylglycerols in cottonseed oil during frying of potato chips at 155 °C to 195 °C increased initially

MS 20070005 Submitted 1/23/2007, Accepted 3/10/2007. Author Choe is with the Dept. of Food and Nutrition, Inha Univ., Incheon, Korea. Author Min is with the Dept. of Food Science and Technology, The Ohio State Univ., 2015 Pyffe Rd., Columbus, Ohio. Direct inquiries to author Min (E-mail: min.2@osu.edu).

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L Darling-Hammond



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Research Awards Index , **Research Grants Index** National Institutes of Health (U.S.). Division of Research Grants,1969 **Food and Nutrition Information and Educational Materials Center Catalog** Food and Nutrition Information and Educational Materials Center (U.S.),1973 **Agrindex** ,1992 **Deep Frying** Michael D. Erickson,2015-08-08 Since the first edition of Deep Frying was published in 1996 there have been many changes to the U S Dietary Guidelines and nutritional labeling laws and improvements in frying technology and practices have made a significant impact on the industry This book covers everything you need to know to create fat and oil ingredients that are nutritious uniquely palatable and satisfying Focuses heavily on the physical characteristics of oils during frying including odor and flavor components and oxidized sterols Includes practical information on the dynamics of frying from many perspectives including foodservice and industrial Addresses regulatory issues environmental concerns and nutritional aspects **Book of Abstracts** American Chemical Society. Meeting,American Chemical Society,1985 Bibliography of Agriculture ,1996 *Deep Frying* ,2007 Since the first edition of Deep Frying was published in 1996 there have been many changes to the U S Dietary Guidelines and nutritional labeling laws and improvements in frying technology and practices have made a significant impact on the industry This book will cover everything you need to know to create fat and oil ingredients that are nutritious uniquely palatable and satisfying **Frying of Food** Dimitrios Boskou,Ibrahim Elmadfa,1999-07-21 This important resource concentrates mainly on two factors that influence the deterioration of a fat at elevated temperatures the nature of the heated fat and the presence of oxidation retardants especially those naturally occurring in oils or obtained from natural sources Discussions include important biologically active ingredients present in oils and fats and minor constituents which appear to affect the performance of a heated oil and or may also be categorized as functional Frying of Food also discusses olar phenolic compounds which have an impact on the stability of oils at high temperatures *Frying Technology and Practices* Monoj K. Gupta,Kathleen Warner,Pamela J. White,2004-06-30 This book is a unique compilation of theoretical discussions on oil chemistry the mechanism of oil breakdown and the practical aspects related to frying Topics include basic frying oil chemistry and the techniques for the protection of the frying oil frying techniques for coated foods food safety and regulatory aspects related to frying package issues and the proper techniques required for the day to day operation of a frying process *Flavor Chemistry of Fats and Oils* David B. Min,Thomas H. Smouse,1985 **A Study of the Chemical Changes of Fats During Deep-fat Frying** Dorothy Frances Burch,1937 **Recent Advances in Chemistry and Technology of Fats and Oils** R. J. Hamilton,2012-12-06 Since we produced Fats and Oils Chemistry and Technology in 1980 the trend we anticipated to up date the classical texts of oils and fats has manifested itself Bailey s famous textbook has been completely revised and a second edition of Bernardini s work has been produced The present text is an attempt to provide some insight into the current state of the art Chapter 1 discusses the physical properties of oils and fats with special reference to those properties

which can be monitored to give an indication of the suitability of fats for chocolate production The physical properties of the fats are often determined by the order in which the fatty acids are attached to the glyceride molecule Ram Bhati in the last article he wrote before his death showed how mass spectrometry and chemical methods could be used to determine the sequence of fatty acids Ram's essentially practical approach to the problem is exemplified by the section dealing with the experimental details of the techniques Chapter 3 outlines some of the problems which can arise in industry when the lipid part of a foodstuff undergoes oxidation whilst in Chapter 4 Patterson describes the major technique hydrogenation which is used to circumvent the problems caused by oxidation of the unsaturated fatty acids In Chapter 4 the essentials of the theory are given to enable the reader to appreciate the design features of the apparatus Chapter 5 deals with the analysis mainly chromatographic of lipids

Fats and Oils Richard John Hamilton, A. Bhati, 1980

Deep-fat Frying Azmil Haizam Ahmad Tarmizi, 2012 This thesis represents a study on the application of vacuum during post frying stage with the aim of lowering oil content in fried food Using potato chips as an illustrative product several protocols were initially screened either towards the end of frying or after frying Lowering the pressure when the product was removed from the oil resulted in a significant reduction in oil uptake Applying vacuum triggered a continuous water vapour release from the product as a result of lower water saturation temperature and this prevented the surface oil from penetrating into the product structure The image generated by confocal laser scanning microscopy showed a visible boundary between the core and the crust regions and the oil distribution was only concentrated in the crust with insignificant trace of oil in the core region Despite the amount of oil being absorbed into fried food the ability of oil to withstand high temperatures at the extended frying period must also be taken into consideration Interestingly vacuum drainage significantly inhibited the free fatty acid formation while the total oxidation value was slightly lowered which in turn showed minimal reductions in the total colour difference value viscosity and polar compounds We also explored the possibility of combining moderate vacuum frying with high vacuum drainage to lower the oil uptake in fried food As expected high vacuum drainage significantly lowered the amount of oil taken by the potato chips regardless to the vacuum frying conditions applied It was also noted that the head space temperature also plays a significant role in the continuous release of water vapour from the product aside from the product temperature An attempt to develop fat free product was accomplished when sorbitol was used to substitute oil as frying medium In sorbitol fried French fries a crust was formed similarly to oil fried product and the colour and texture developments were comparable

Deep-Fat Frying of Foods BLUMENTHAL M., Michael M. Blumenthal, 1995-11-01 An international group of experts covers operations relationships between food and oils and analytical issues related to oils for this comprehensive reference on deep fat frying Chapters discuss the frying process including snack and processed food frying

Investigation on the Stability of Different Frying Oils During Frying with and Without Foods Zainal, 2010

Qualitative Analysis of Cooking Oil in Deep Fat Frying of Foods Wan Aini Ibrahim, 2009

Deep-fat Frying Characteristics of Blends of Palm and

Canola Oils Ogan Mba, 2017 Selecting an appropriate oil for deep fat frying can be challenging since oils undergo irreversible thermo degradation as frying progresses Highly saturated and trans fat oils have adverse public health consequences Virgin palm oil VPO has a balanced fatty acid composition and is rich in phytonutrients that possess health promoting functions This study investigated the stability of these phytonutrients and their migration into fried products when VPO either alone or as the major portion in blends of oils is used in deep fat frying Refined canola oil RCO was the second oil sample in the binary blends Firstly Fourier transform near infrared spectroscopy FTNIRS was used to characterize the palm canola and their blends oil samples Partial Least Squares PLS regression was used to correlate spectral data with iodine value IV free fatty acid FFA and peroxide value PV data of the oil samples obtained by reference methods First derivative and first derivative straight line subtraction spectra pre processing methods gave the most reproducible and robust predictions of the PLS NIR models developed The study simultaneously characterized the essential quality parameters of VPO RCO and their blends using the FTNIRS The VPO RCO and blend samples were used in deep fat frying of ripe and unripe plantain crisps at 180 C for different times Significant differences $p < 0.05$ were observed in the oil uptake and color properties of the crisps The unripe and ripe plantain crisps absorbed 14% and 26% less oil respectively when fried in VPO than RCO The browning index showed that the VPO crisps had greater color changes than the crisps fried using RCO The VPO RCO blends also improved the qualities of the crisps better than RCO alone The deterioration of VPO RCO and VPO RCO 1:1 w/w blend during 20 h of successive deep fat frying at 170, 180 and 190 °C was investigated Kinetics results showed that FFA and PV accumulation followed the first order reaction model while anisidine value pAV total polar compounds TPC and color index CI followed the zero order reaction model The deterioration rate constants were modeled by the Arrhenius equation The overall activation energy E_a values showed that during thermo oxidation the PV build up was the fastest while the blend oil sample was the most stable Frying potato slices at 170 °C for different times was used to assess the migration and retention of the endogenous phytonutrients from VPO RCO and blend VPO RCO 1:1 w/w The French fries produced using VPO and the blend was significantly enriched with phytonutrient over 50% of total carotenoids 40-45% of tocotrienols and 3-16% of tocopherols absorbed less oil and showed more pronounced color changes The biphasic first order model was applied as a predictor model of changes in the concentration of the phytonutrients in the French fries The thermostability of the tocopherols tocotrienols and carotenoids in VPO RCO and their blends used in deep fat frying at 170 to 190 °C for 20 h was evaluated The deterioration kinetic rate of each homolog followed a reaction order 1 The Arrhenius relationship adequately modeled the deterioration rates The E_a showed that the least stable homologs were gamma tocopherol and gamma tocotrienol while delta tocotrienol and carotenoids were the most stable The rate for alpha tocopherol alpha tocotrienol and delta tocopherol were similar and intermediate The carotenoids were more retained in VPO E_a of 71.5 kJ/mol while the tocopherols and tocotrienols were more stable in the blend oil samples This work further broadened the scientific knowledge

on the behavior of VPO alone or in blend with other unsaturated oils during deep fat frying The blended oil samples were the most stable The fried products were enriched with bioactive phytonutrients VPO and blends offer great advantages as choice frying oils and can be adopted in domestic and commercial deep fat frying protocols **Papers Pres. During the Symposium "The Chemistry and Technology of Deep-Fat Frying"** M. M. Blumenthal,R. A. Carr,1991

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