EVALUATION OF COTTONSEED OIL AND HYDROGENATED CANOLA OIL IN A COMMERCIAL SCALE UNIVERSITY FOOD SERVICE OPERATION

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF MASTER OF SCIENCE

IN THE GRADUATE SCHOOL OF THE

TEXAS WOMAN'S UNIVERSITY

DEPARTMENT OF NUTRITION AND FOOD SCIENCES

COLLEGE OF HEALTH SCIENCES

BY

JULIA ANNE SHEAFFER, B. S.

DENTON, TEXAS

AUGUST 1998

TEXAS WOMAN'S UNIVERSITY

DEPARTMENT OF NUTRITION AND FOOD SCIENCES

COLLEGE OF HEALTH SCIENCES

23 April 1998

Date of Final Defense

To the Associate Vice President for Research and the Dean of the Graduate School:

I am submitting herewith a thesis written by Julia Anne Sheaffer entitled: "EVALUATION OF COTTONSEED OIL AND HYDROGENATED CANOLA OIL IN A COMMERCIAL SCALE UNIVERSITY FOOD SERVICE OPERATION." I have examined this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master's of Science, with a major in Food Science.

Clay C. King, Ph.D.
Major Professor

We have read this thesis
and recommend its acceptance:

Accepted:

Associate Vice President for Research
and Dean of the Graduate School

DEDICATION

To my children,

Anne E. and Walter A. Sheaffer, III,

who have learned a great deal by my pursuance of this

thesis, who may have suffered a little by lack of my presence, but

who can hopefully continue to appreciate the importance of education and

persistence.

ACKNOWLEDGMENTS

I would like to express my sincere appreciation and thanks to my entire committee.

To Dr. Clay C. King, advisor and committee chairman, for his expert guidance.

To Dr. Elizabeth Christian, adjunct professor, for her patience and knowledge and for taking personal time to help me with this project.

To Mr. Richard Metivier, Research and Development at Frito-Lay, for his expert knowledge and assistance.

In addition I would like to thank the following for their assistance:

To Dr. Carolyn Bednar, Chair of the Department of Nutrition and Food Sciences, for her continuing support, critique and suggestions. To the Texas Food and Fiber Commission for their support throughout this joint project. To the employees at the University of North Texas and Clark Hall Grill who have endured my presence in their kitchen during busy preparation times and who have given me a great amount of information based on their expertise of frying in a commercial setting. To the National Cottonseed Producers Association for the funding of this project and the generous supply of cottonseed oil they provided. Lastly, I would like to thank the graduate students, who worked along side me on similar projects, for all their individual expertise, help and enthusiasm.

My appreciation goes out to everyone of you, for all your encouragement in helping me to finish this project.

Evaluation of Cottonseed Oil and Hydrogenated Canola Oil in a Commercial Scale University Food Service Operation

Julia Anne Sheaffer

August 15, 1998

ABSTRACT

The frying performance of cottonseed oil (CSO) and partially hydrogenated canola oil (PHCO (23.3% trans)) was compared in a university food service operation. French fries (FFs)were fried in the oils over a 10 day period, and the quality of the FFs and the oils were evaluated. The only other food fried was chicken fried steak. Amount of food fried and oil used were recorded.

There was no significant difference in fat absorption and food to oil ratios. Differences in sensory acceptability, peroxide value, alkalinity, and polar matter results obtained for the two oils were not significant.

This indicates that CSO compared favorably from both a performance, and a sensory and quality standpoint, but with the nutritional advantage of using a non-hydrogenated oil product for frying applications.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

FIGURES PAGE

CHAPTER I

INTRODUCTION

Although the general public, nutritionists, restaurants, food service facilities and food manufacturers are focusing on low fat or no fat foods, there is positive evidence that the frying of foods in oil is an important part of the diet and will remain a popular preparation method in the food service industry as well as in our homes. Deep-fat foods contribute a substantial amount to the American diet (Gamble, Rice, and Selman, 1987). Prepared fried products contribute to a large part of food service sales (Richardson, 1985). Fat contributes texture, flavor and palatability to the fried food and is accepted readily by consumers (Varvela, 1988).

The damage done by frying is no greater, or even may be considerably less, than that caused by other methods, possibly due to the absence of oxygen during frying. There are only small nutritional food losses during frying (Varvela, 1988). Consumers rank nutrition second to taste in importance for food selection. However, fat selection is the most important nutritional concern, overwhelmingly ranked at 65% (McMahon, 1995).

French fries (FFs) are part of our culture; they go hand in hand with hamburgers, ranking second and first in menu incidence respectively (Johnson, 1997). Therefore, french fries would be difficult to remove from our lives. Also, in this quick paced world we live in, many people tend to eat convenience and fast food items no matter what the health ramifications may be. Consumption of fast foods continues to increase in the U.S.A (Smith et al., 1985).

Current Dietary Guidelines recommend that total fat contribute no more than 30% to the daily diet, and that saturated fat contribute only 10%. There are currently no guidelines for trans fatty acids (TFAs) in the diet, although labeling requirements may occur soon due to recent research in the area (Stauffer, 1996). Many oils when hydrogenated, including canola oil, are transformed into a high level of saturated fat. Some of the fatty acids undergo a configuration change from cis to the more thermodynamically stable trans isomers. Although stability and functionality are increased in the oil, potential health problems are also increased. TFAs have been shown to cause heart disease (Castelli, 1987).

TFAs may influence the rate of oxidation of substrate in heart mitochondria, the synthesis of prostaglandins and the fluidity of the lipid phase in cell membranes. Whether any or all of these observations are significant to the development of heart disease is a question requiring additional research (Perkins, 1983). The body cannot incorporate these isomers into the cell membranes, causing a chain reaction of imbalances in the body. Cis isomers are curved and accepted by the body readily. Trans isomers have been found to clog arteries, affect tumor growth in cancers, and to degenerate body tissues (Herman, 1991). The subject of trans is one of the most controversial areas in both food science and nutritional science today (Perkins, 1983).

Due to the complexities of fatty acids, their positioning on a fat molecule, potential of isomers forming, and varying affects on body metabolism, it is extremely hard to make a claim to the health benefits of avoiding trans-isomers in the diet. The process of hydrogenation alone: the choice of metal catalysts, selectivity of double bond on the least unsaturated chain, protocols of agitation, pressure and temperature all contribute to variations in the products of hydrogenation. Although, Proctor & Gamble tried to get sole rights to the hydrogenation process, they were was invalidated, which led the way to multiple variations (Perkins, 1983). Depending upon the process used in hydrogenation, there will be different affects on the type of isomers formed in the fat molecule. Specifically, the lack of linolenic, an essential fatty acid, in the finished product has been shown to cause the most harm and can create the most problems with trans (Perkins, 1983). Oleic isomers seem to have a neutral effect.

Until it has been verified substantially that trans-isomers have such a negative impact on the heart, food scientists should use caution when making these claims. Any fatty acid studied under unbalanced, severe scientific conditions would show adverse effects. (Perkins, 1983). Nutritionists agree that instead of looking at fat negatively, people should control their calorie intake, and limit their fat (Deis, 1997). Oils are necessary for bodily functions. Oils contribute essential fatty acids. They provide an efficient energy source by contributing 9 kcal per gram of fat instead of the 4 kcal from protein and carbohydrates. They also serve as carriers for fat soluble vitamins, phosopholipids and cholesterol. Another important purpose of fat is to provide satiety for enjoyment during a meal.

Canola oil has been erroneously touted as a healthy oil when used in a frying application. It has a healthy aura due to all the positive press and written articles in recent years (Deis, 1997). To stabilize it for frying, canola oil must be hydrogenated or otherwise processed (Mounts 1979; Blumenthal 1976; Dobbs 1978). Off flavors or other fishy and or metallic flavors are formed when the linolenic fatty acids (18:3) break down during high cooking temperatures. Flavor reversion is related to linolenic (18:3) and other unsaturated fatty acids (Weiss, 1978). There is approximately 10% linolenic fatty acid in canola oil. A product's susceptibility to oxidation tends to be influenced most by the presence of linolenic acid (18:3) and linoleic acid (18:2 (Erickson, 1994)).

Although cottonseed oil (CSO) naturally contains 27% of the saturated fatty acid, palmitic (16:0), not all saturated fats have a negative impact on health (Deis, 1997). CSO has a healthy fatty acid profile, is high in polyunsaturates such as linoleic (18:2) and Oleic (18:1). Oleic has the greatest stability of the unsaturated fatty acids. Oleic also has been found to lower LDL cholesterol (bad) and increase the HDL cholesterol (good). Its low linolenic acid values also contribute to its stability.

Research has indicated that for Americans, between 37-42% percent of their calories are contributed by fat. Sixteen % of total calories in the diet come from saturated fat. (Castelli, 1987). Americans get 3.5% of their calories from TFA. (Stauffer, 1996).

Watkins (1998) has reported that the level of calories from dietary trans is within the range of 2 to 4%. Focusing on decreasing the TFAs in the diet would be beneficial to our health. There is evidence to suggest that a positive relationship exists between TFA intake and increased cardiovascular risk (Jonnalagadda et al., 1996). In our diets, TFA comes mostly from hydrogenated oils (ASCN, 1996). Hydrogenation of oils is done to increase heat and flavor stability and to prolong the life of the oil. Decreasing the trans in the diet by avoiding hydrogenated products might be beneficial in reducing our country's heart problems. Research has shown that CSO is naturally heat stable due to its low levels of linolenic acid (18:3) and hydrogenation is not necessary. Nutritionally, cottonseed has high levels of unsaturated fatty acids oleic (18:1) and linoleic (18:2) with no appreciable trans. It would be an advantage to consumers as well as to food service operations to have CSO available on the supermarket shelves. Besides CSO's healthy fatty acid profile consisting of high levels of polyunsaturates, it has high levels of natural antioxidants that increase its stability. CSO also imparts a desirable characteristic bland, slightly nutty flavor to foods. With the demand for healthier cooking oils, CSO should be recognized as one of the best oils to use for deep-fat frying. Research must be completed to show the stability of the oil, its positive flavor attributes, nutritional qualities and its versatility in the marketplace.

Deep-fat frying is a popular method of cooking and the products fried in oil are highly acceptable and desirable. Consumers have become more aware of the impact of oils on their health and their choices have resulted in the production of new blends or varieties. CSO has been used in the commercial industry for a long time because of its unique fatty acid profile and cooking properties. It also imparts a pleasant flavor to the finished product. It is widespread in many commercial products and does not require hydrogenation to be heat stable. A newly developed product made from canola oil, Extend®, has been created by hydrogenation to allow its use in the oil industry for deep-fat frying purposes. Canola oil needs to be hydrogenated, or otherwise altered, to change the fatty acid profile to make it more stable for frying at high temperatures over extended periods.

STATEMENT OF PROBLEM

Deep-fat frying is a popular method of cooking and the products fried in the oils are highly acceptable and desirable. Consumers have become more aware of the impact of oils on their health and their choices have resulted in the production of new blends or varieties. CSO has been used in the commercial food industry since the early 1900's because of its unique fatty acid profile and cooking properties. CSO also imparts a pleasant flavor to the finished product. It is found widespread in many commercial products. Extend® (Wilsey Foods, City of Industry, CA.) oil has been recently developed to allow the use of the rapeseed in the oil industry in a productive, healthy and economical manner. This canola oil product made from rapeseed needs to be processed by hydrogenation or other means to change the fatty acid profile to make it stable at high temperatures. This research will compare the benefits of frying in CSO to a partially hydrogenated canola oil.

PURPOSE OF THE STUDY

The purpose of this study was to compare and evaluate the inherent stability of CSO to a canola product called Extend® that has been partially hydrogenated to increase stability. Due to hydrogenation, Extend® oil has high levels of TFA that have been shown to cause health risks. The comparison will help to determine if CSO, with substantially less processing and positive health benefits, could be substituted for the highly processed oil product, Extend®.

OBJECTIVES

Overall Objective: To compare the frying performance of CSO and a partially hydrogenated canola oil in a university food service operation.

Specific objectives of the study were to:

1) Compare french fries deep-fat fried in CSO and partially hydrogenated canola oil (Extend®) from a University of North Texas (UNT) commercial frying operation.

2) To compare FFs fried side - by - side in CSO and EXTEND at TWU

3) To evaluate the quality of fries using sensory analysis and fat absorption

4) To evaluate quality of the oil using analytical tests: Peroxide Values (PV), Polar and Alkaline Contaminant Materials (PCM and ACM), Fatty Acid Profiles and Trans analysis

5) To determine fry life of CSO and EXTEND

6) To determine the economical and nutritional benefit of using CSO in a commercial food service operation

NULL HYPOTHESIS

1) There are no significant differences between the two tested oils in fry life stability.

2) There are no significant differences between the FFs that were fried in the two oils in total oil and moisture content, before and after deep-fat frying.

3) There are no significant differences in sensory evaluation results between the fries fried in either oil, at any age of oil.

4) There are no significant differences in fatty acid profile changes between the two used oils at any point in between the endpoint and startpoint.

LIMITATIONS

1) The quantity of the sample analyzed was small (four FFs) which would limit significance and may not be representative of the entire batch.

2) The panel size for each sensory evaluation is limited. Forty panelists were used. Experience and or data indicates a panel of sixty is optimal to reach significance.

3) Surveys done at Clark Hall, UNT were limited to population demographics. College students could have given erroneous responses based on inexperience or motivation toward the reward and not in giving correct responses.

4) It was difficult to monitor the consistency of preparation due to real world applications. The logistics of serving a hot product to many people in panels leads to variations in temperature and freshness that could influence results and comments made by panelists.

5) The day to day operations of a food service facility can not be consistently maintained and therefore fluctuations in data collected would limit responses.

6) Packaged, frozen FFs may vary in waxyiness or mealyiness. The oils they are pre-fried in can vary in source and type of oil. These variations could affect fatty acid profiles, flavor and oil absorption.

7) Fries vary in size, shape and surface texture which could influence fat uptake.

8) Temperature of the oil and variations in temperature of the fries at the time of frying could affect frying time and therefore, fat uptake or sensory evaluation.

CHAPTER II

LITERATURE REVIEW

A. THE DEEP-FAT FRYING PROCESS AND HOW FOOD FRIES

Frying is a simple and quick way to cook satisfying food. Frying is one of the oldest cooking methods in existence, originating in olive-growing countries because of the availability of olive oil (Varvela, 1988). Fried foods are well accepted for the texture, characteristic flavor, the color imparted to the food and ease of eating, as well as the speed and convenience of the process. However, frying is one of the least understood cooking systems, considered more of an art than a science (Grob, 1990). Deep fat frying, says the Joy of Cooking, "is an art itself -- an art in which experience is the best teacher." Depending on the oil and the food fried in it, they both can be a source of nutrients. The oil contributes to the fried food flavor, brown color, crust and texture of the food.

During deep-fat frying, foods are cooked by immersion into an oil or fat at high temperatures. Deep-fat frying is quite complex, with the food and oil both undergoing a series of changes during the many simultaneous reactions. Optimal frying involves balancing many variables that are constantly changing, yet yields a product that has a crispy, non-greasy exterior and a moist, tender interior. Rapid heat transfer sets the coating or surface of the food to be fried, allowing for minimum moisture loss (Kulp, et al., 1996). The optimum temperature range for deep-fat frying is from 356 °F to 374 °F

(180 ° C to 190 ° C (Stauffer, 1996)). Another frying range using lower temperatures of 325-340 ° F (161-171 ° C) has been demonstrated when stabilizers are added regularly to the oil (Miroil, a). The temperature of the food being fried depends on the type of food fried and the time of frying to achieve the optimum result. The highest temperature should be 20 ° C below the initial smoke point of the oil (Varvela, 1988). If the temperature is too low, the food takes longer to fry and increased fat absorption results. Too high a temperature results in excessive browning and moisture loss.

Deep-fat frying is a major component of the American diet (Gamble, Rice, Selman). Potatoes are blanched, peeled and sliced into FFs for deep-fat frying. The potatoes fried in oil contribute dietary fiber, minerals and energy as complex carbohydrate to our daily diets. Cooking and salad oils come from vegetables and they do not contain cholesterol. Most data has been published to reflect how raw oil affects health, however most oils are not used raw (Varvela, 1988). Cooking changes the fatty acid profiles.

Oils can be monounsaturated, polyunsaturated, saturated or a mixture. The more saturated the oil is, the more double bonds it has, which makes it more susceptible to reactions. Therefore, the more saturated the oil, the faster and easier it is to deteriorate. All oils have their own fatty acid profiles that define the oil. These profiles can be enhanced to attain the best results through biotechnology and other technologies. Molecular biologists are developing strains to find an optimum oil, while others are trying to find the perfect blend of oils.

Extend® was created to give canola oil some stability. Pure canola oil is highly unstable because it has a large portion of the fatty acid, linolenic acid (18:3) which has three double bonds and is very likely to oxidize. Another factor affecting health is the hydrogenation process itself where the cis-fatty acids are converted to trans-fatty acids. TFAs have been associated with heart disease in some cases. A major concern during deep-fat frying, is that when the oils are exposed to high temperatures, oxygen, moisture or batter, the oil becomes abused and the fatty acid profile changes. The once healthy oil may become unhealthy by saturation or other means. Mono and polyunsaturated oils, which are considered the healthiest of fatty acids, because they may lower total cholesterol, can become more saturated. Recent research has demonstrated that it is the degree of saturation and the position of the isomer that can determine the healthiness of the oil.

It is not only the type of the fatty acid, but its location on the molecule that is also important in determining its functional properties. Not all saturated or trans acids will be the same, depending on this fact. What fatty acid is involved is an important factor; elaidic acid appears to be the culprit (ASCN, 1996). Oil stability is important. If the oil cannot withstand heat and oxygen, than it is not only costly to discard, but it can develop polymers, contribute to cholesterol formation in the body and become unpalatable to eat. The breakdown of the oil depends on four major factors: the temperature of the fat or oil, the degree of exposure to the air or oxygen, the turn-over rate of the fat, and the amount of non-fat ingredients that may contaminate the fat (Richardson, 1985).

In addition, the process of deep-fat frying itself increases the lipid content of the fried food. A small portion of the oil is absorbed into the food as the moisture or water content decreases as it escapes as steam during the deep-fat frying process. The oil contributes greatly to the fried food flavor we associate with the food being fried, but the oil also can be an important factor to your health. Besides all the current data on health, flavor still remains the most important factor in choosing oils, not the fatty acid composition. Food service operations still consider cost most important (Hauman, 1996). The dynamic processes during deep fat-frying are shown in (Figure 1).

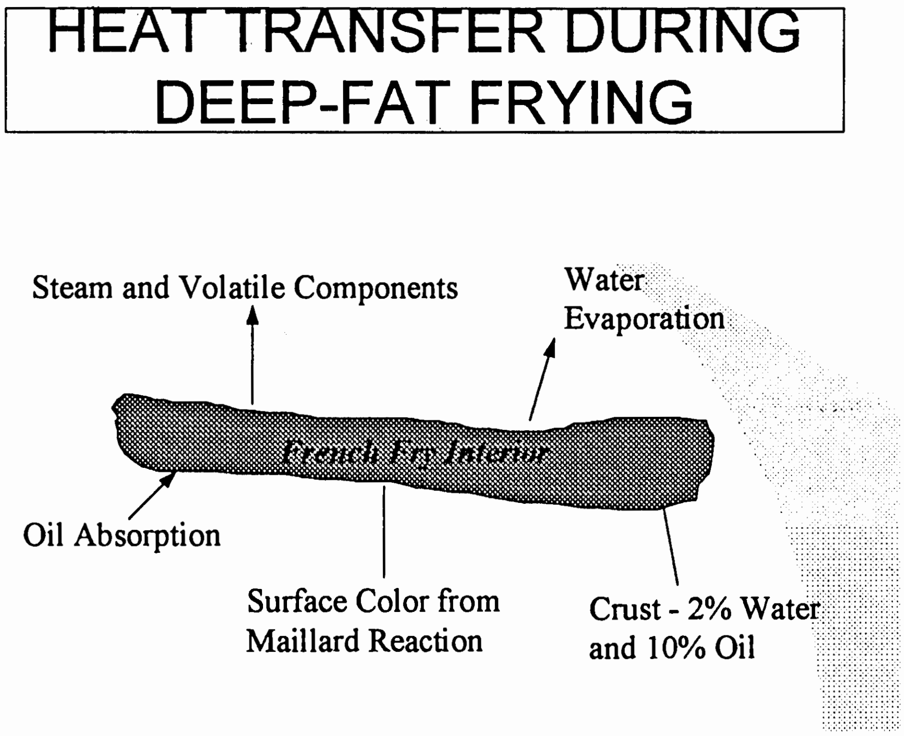

Figure 1. Heat Transfer (Adapted from Varvela, 1988)

B. HEAT TRANSFER AND MASS TRANSFER

Deep-fat frying involves surrounding the food in hot oil. As this occurs, water, pigments, lipids and other compounds of the food itself is released into the fat or oil. A small portion of the oil is absorbed into the food as the moisture content decreases and the water escapes as steam in the process of deep-fat frying. Mass transfer is also called oil uptake or fat absorption. The food absorbs the oil while releasing some of its water vapor. These two simple processes of evaporation and absorption determine the quality of the food fried (Stauffer, 1996). Food is predominantly a water system and during frying, the frying oil replaces some of the water in the food. The oil acts as an effective heat transfer medium, and becomes a component of the food (Deis, 1997).

The water is the heat transfer medium within the food. The heat process itself is both convective (from the surrounding fluid oil to the solid food) and conductive (through or within the food). The rate of heat transfer is influenced by the thermal properties of the food. In a solid food such as a french fry, steam can only escape to the fat phase, therefore energy is not transmitted completely to the center of the fry. This also can occur in a doughnut that has internal voids. These variables also include heat diffusivity, thermal conductivity, density and specific heat of the food being fried (Moreira, et al., 1995). The vigorous movements of the water vapor bubbles escaping from the surface of the food create complicated surface interactions by creating considerable turbulence within the oil. (Singh, 1995). Also, efficient heat transfer is usually interrupted by water vapor bubbles that are entrapped on the underside of the food, preventing interaction between the oil and the food. Floating food near or in the foaming bubbles at the surface of the oil further prevents efficient heat transfer from the oil to the top portion of the food. (Levine, 1990b). This creates uneven browning in the fried food. In addition, as the moisture decreases in the frying food, the water vapor bubbles also decrease as the frying time increases, contributing to a drier fried food product and/or charring of the surface.

C. WATER TRANSFER

Water has many purposes during the frying process. First, as water migrates out of the food, it leaves voids on the surface along which fat migrates, thus enhancing heat transfer. Steam can then only escape to the fat phase. Steam also acts as an insulator in the initial stages of frying because its conductivity is lower than that of fat. Water carries off the thermal energy from the hot oil and the food interface, preventing charring of the food's exterior due to excessive dehydration. The steam blanket surrounding the food will be at the heat of vaporization temperature of 212 °F (100 °C), although the frying oil can be as high as 360 °F (180 °C). The food will not burn or char as long as the steam blanket of water vapor is still intact. Thus, maintaining temperatures at a constant, high rate will insure consistency in a fried food. Due to this fact, adequate oil temperature recovery, in which temperature falls when food is added but rises again quickly, is an important factor in choosing a fryer. Furthermore, water is the best conductor of heat in a food system. Water conducts heat better than fat, protein or carbohydrates. The bound water in the interior of the food is responsible for the transfer of heat energy that allows for the cooking of the interior of the food. Starch gelatinization and protein denaturation also occur in the interior of the food.

D. CHEMISTRY OF FRYING

Reactions During Frying

Oxidation occurs in the oil due to the exposure to heat, air, moisture and the characteristics of the food being fried. The rate of the reactions double as the temperature is increased 50 °F (10 °C (Stauffer, 1996)). Good frying practices suggest that fryers be turned down to 150 ° - 200 °F (66-94 °C) when not in use (Wilsey Foods, 1997). Also, as free fatty acid concentration increases due to degradation of the oil, the temperature of the smoke point decreases. Constant heat exposure causes many other reactions, such as auto-oxidation, hydrolysis, thermal decomposition and the creation of by-products. If water is available, hydrolysis will likely occur. Hydrolysis involves splitting of the ester linkages in triglycerides to produce free fatty acids. Oxidation involves the addition of oxygen at double bond sites in the fatty acid chain. Hydroperoxides result and further breakdown into aldehydes, ketones and alcohols with distinct rancid odors and flavors. This results in fishy or painty odors. Exposure to undesirable by products such as oxidized lipids are a potential health hazard. Unpleasant off flavors are formed during auto-oxidation rancidity due to the by-products of aldehydes and ketones. Flavor, color and texture of the finished product can be affected.

Most importantly, the oil itself needs to have thermal oxidation stability for prolonged cooking and repetitious frying (Erickson, 1994). Fatty acid profiles help to determine the stability of the oil. High levels of linoleic acid (18:2) and linolenic (18:3) have both been found to decrease fry life of oils. (Saguy, 1995). Flavor reversion has been related to linolenic acid (18:3 (Weiss, 1983)).

Polymerization can also occur. Only enough energy to replace the energy involved in heat and mass transfer is required for a frying system. Any energy input more than that will result in increased degradation, leading to increased polymer content of the oil and hardening of the food. Raising the temperature of a frying system does not necessarily cook the food faster. The rate of the chemical reactions and the products formed from these reactions vary depending on the oil and the food fried in the oil. According to Fritsch (1981), decomposition products during frying can be divided into two main areas, 1) volatiles and 2) nonvolatiles. (Figure 2) Most volatile products are removed during frying due to steam distillation as a result of food dehydration (Escher, 1997). During vaporization, steam, smoke and antioxidants are removed. These volatiles present four main concerns. First, identification of the volatiles helps to identify the nonvolatile products formed within the frying system. Also, the volatiles are inhaled by the kitchen personnel that could create health implications. Third, volatiles associated with desirable flavors in foods such as unsaturated lactones can be identified (May et al., 1978). Lastly, the volatiles can be retained in the fried foods (Chang et al., 1978).

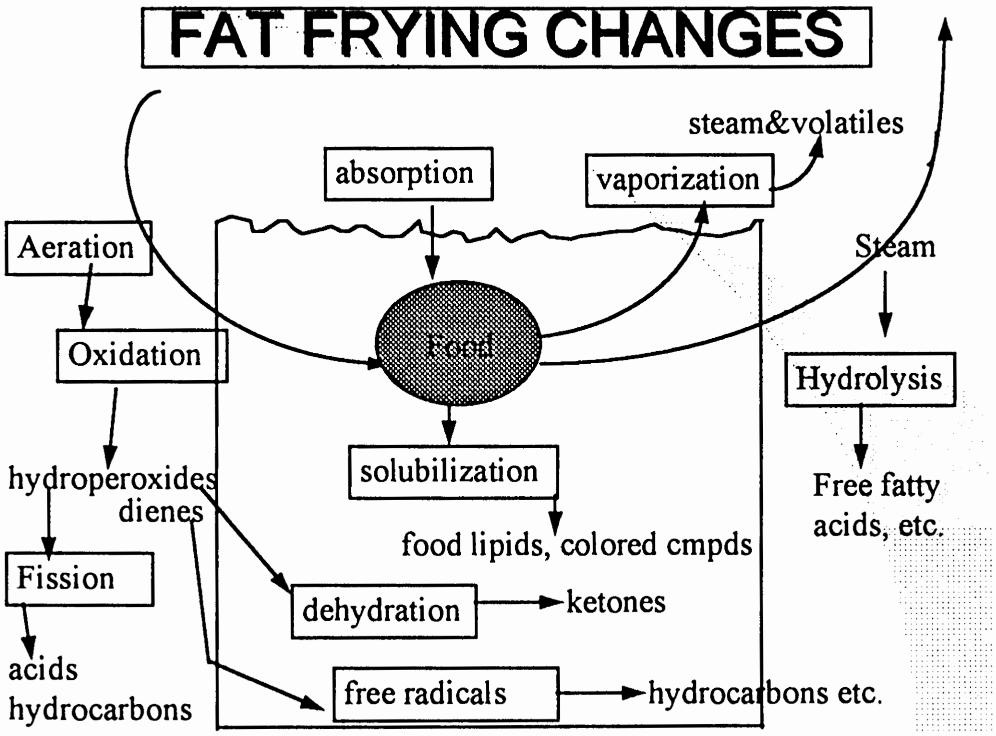

Figure 2. Changes During Deep-Fat Frying (Adapted from Fritsch, 1981)

Nonvolatile decomposition products are formed primarily due to thermal oxidation and polymerization of the unsaturated fatty acids present in the frying oil and the food. These products not only may be retained in the food, but they may also be degraded further. Nonvolatile decomposition products affect physical changes in frying oil such as increased viscosity, color darkening and excessive foaming which in turn affect the quality of the fried product. Increased formation of polymers can sometimes be attributed to the chemical changes that occur due to formation of volatile compounds such as free fatty acids, carbonyl values, hydroxl content and saponification values. (Perkins, 1967). Chemical and physical changes occur such as color changes due to pigment solubilization. Solubilization of the lipids could cause fatty acid profile changes in the oil. When there is aeration, air is introduced as the steam escapes causing oxidation to occur. Diffusion at the surface of the product also introduces fat into the system. Air can also be introduced into the oil by splashing when fresh oil or product is added to the fryer or through the continuous filtration system.

Quality of the oil can be affected by the filtering process itself, and by the filter paper, filtering aid and fry powders used. The outcome of the oil quality can be influenced by the addition of chemicals, variations in pH, or adsorbent material interactions. Adsorbent materials used in filtration have been shown to remove oil degradation products (Naylor, 1992). Some of the materials used for this function include crystalline silica, diatomaceous earth, perlite, porous pumicite and synthetic silicates. Each of these removes varying types and amounts of degradation products, according to its nature and properties (Miroil, a). Continuous use of Frypowder® achieved lower levels of ACM (alkaline contaminant material) between filtration, therefore protected the oil by decreasing degradation. Frypowder® contains citric acid that has antioxidant qualities. Polar contaminate material (PCM) was not removed by the Frypowder® because free fatty acids (FFA) and similar materials cannot be removed from the oil. (Naylor, 1992). PCM is the sum of all breakdown products in the oil. A level between 25-27% has been established as too much. (Miroil, b). Alkaline contaminant materials (ACM) are defined as soap and soap like surfactants that form at the surface of the oil. These products are destructive to oils and affect them in three important ways:

1) they effect the rate of degradation of the oil.

2) they affect how much oil is absorbed by increasing the oleophobic effect. The oil penetrates the food interior easier.

3) they affect how the oil cooks the food by changing the boundary layer conductivity between the food and the oil. High levels of ACM cause the heat to be delivered in higher intensity (water requires energy to escape as steam resulting in the interior not cooking due to the lack of temperature increase).

Any type of metal ions catalyzes oxidization reactions and their use should be avoided (Stauffer, 1996) Stainless steel is suggested for vat lining, baskets and frying tools (Davis, 1992). In addition, high temperatures will accelerate oxidation. During hydrolysis, which occurs with the release of steam during vaporization, and during oxidation and cleavage of double bonds, free fatty acids can also be formed. Oxidation results in the formation of hydroperoxides or conjugated dienes that are converted to other products. Fission reactions create alcohols, aldehydes, acids and hydrocarbons which in turn contribute to poor flavor and dark oil. As an example, the alcohol product, hexanol, can be formed which is associated with rancid flavor. If the hydroperoxides undergo dehydration also, they may produce ketones. Hydroperoxides can further breakdown into dimers, trimers, epoxides, alcohols and other hydrocarbons.

Heating of the oil itself creates dimers and cyclic compounds. Polymers are formed between carbon-carbon and/or carbon-oxygen linkages among several fatty acids. Diels-Alder reactions also contribute to polymerization. Polymerization increases the viscosity of the oil and contributes to gumming, hardening of the food and darkening of the oil color that all have negative effects on the fried product. Cyclic monomers in abused oils have also been associated with toxic effects (Van Twisk et al., 1997a).

Generally, the greater the degree of unsaturation of the oil, the greater the chemical reactivity, therefore the faster the rate of the reactions. For instance, oleic acid (18:1) with one double bond, is the least likely to oxidize, linoleic (18:2), is second to oxidize and linolenic (18:3) is usually first to oxidize.

E. FOUR BASIC STAGES OF FRYING

1. INITIAL HEATING begins when the surface of the submerged food heats to the temperature of the surrounding liquid. The mode of transfer is due to convection movement of the liquid.

2. SURFACE BOILING is when the vaporization process occurs and the crust begins to form at the surface of the food. The convection changes from natural to forced due to the turbulence of the oil the food is fried in and the temperature of the oil while frying.

3. FALLING RATE begins when the internal moisture rapidly leaves the food and the core temperature rises to the boiling point. The rate of frying (heat transfer) decreases as the frying progresses. The skin or crust continues to form and thicken until the vapor transfer at the surface eventually decreases over time. Physiochemical changes occur internally as the food cooks. Gelatinization (swelling of the starch granules) occurs here if the food is a carbohydrate or starch. Protein foods undergo denaturation.

4. BUBBLE END POINT occurs at the time the rate of moisture leaving the product diminishes and the crust thickens (Singh, 1995). There are no more bubbles on the surface. The crust continues to thicken. As more water evaporates from the outer parts of the product, the temperature of the dried areas rises above the boiling point.

F. FRIED FOOD STRUCTURE

1. THE INNER ZONE, or, ZONE #1, relates to the cooked, moist interior of the fried food; starch gelatinization and protein denaturation occur here.

2. ZONE #2. Maillard, non enzymatic browning and caramelization reactions that occur on the food surface result in the brown color. The deepness of the color depends upon time and temperature as well as the chemical composition of the food (Stevenson, 1984).

3. ZONE #3 is the final, crisp outer shell or crust of the fried food produced by dehydration. Time, temperature and surface structure are the three major factors that effect the degree of the browning, not the oil itself. The crust begins to form at 100 °C or 212 °F. The crust is the most important factor in determining popularity of fried foods, and sets fried food apart from other forms of cooking (Robertson, 1967, Guillaumin, 1988).

G. FAT UPTAKE

Frying oil absorption is a major health concern for frying operations. The frying process itself can increase the lipid content of the fried food, therefore, the fatty acid profile of the oil is important in addressing health concerns. Current data show that consumers want healthier foods that do not contribute to obesity (Haumann, 1996).

To be more profitable, food service facilities do not need to waste oil uselessly due to unnecessary fat loss because of absorption. There are several factors effecting oil uptake or fat absorption. Fry temperature, time, product shape, porosity and composition, oil quality and pre-fry treatments are all influences (Pinthus, 1993). Oil penetration is influenced by frying time, oil type and oil quality (Steir et al., 1990). The most highly correlated factors include high surface area exposed to the oil, low fry temperatures and/or overloading the fryer, and low smoke point of the oil (Orthoefer et al., 1996). Surface roughness also increases oil uptake (Saguy, 1995). Other suggestions to decrease fat uptake involve practicing proper frying techniques.

Oil needs to be hot or it takes longer to cook the fries. Do not thaw the fries because they get mushy and take in more oil. Fill the baskets half full to get evenly cooked fries. Diminish number of fries cooked at one time, because too many dropped in at once decrease the temperature too rapidly, and increases the recovery time and the frying time. Drain fries well so that excess oil does not adhere to the fries (Johnson, 1997). Factors affecting initial and final moisture content make it hard to determine the fat uptake. Increasing temperatures may work to conserve moisture loss therefore oil absorption may be decreased. Product weight usually decreases with frying time because of greater moisture loss.

1) Oil drainage: Evidence has shown that oil uptake occurs during product drainage, not frying. As the product is removed from the fry vat, the oil adheres to the surface. Neither fry time nor temperature has a large affect on oil uptake. When drainage pressure and/or drainage temperature increased, oil uptake decreased. Drainage pressure had the biggest affect on uptake. Because excess browning can occur when increasing

these two limits, drainage temperature and pressure must be balanced to achieve the optimum effect (Escher, 1996).

2. Surface Area: The surface of the fried food contributes to fat absorption. Generally, the greater the surface area, the greater the lipid absorption. Large, flat fries (home fries) absorb the least amount of fat with approximately 3.6 g of fat. Slender, shoe string fries absorb the most because there is more surface area (about 5 g of fat per serving). Crinkle cut fries offer more surface area creating more places for the fat to adhere. Surface roughness also increases surface area, resulting in increased fat absorption (Saguy, 1995). A linear relationship exists between the surface area and the amount of oil uptake (Gamble, et al., 1988b). Another element to oil uptake is the porosity of the food. Porosity increases with frying time. Oil absorption is significant only in the early stages of frying. Crust formation is also involved. Oil uptake correlated linearly with initial product porosity. (Saguy, 1995). Effects of fluctuating freezing on poor porosity has been indicated and may also affect oil absorption.

3. Time and Temperature of Frying: The higher the fryer temperature, the less oil is absorbed within limits of suggested frying temperatures. Sometimes increasing the oil temperature is not beneficial because excessive browning may occur and the crust may become too crisp. Although, certain foods may benefit from the higher temperatures, the hardened crust may inhibit moisture loss and oil absorption. To get the desired brown color, lowering the temperature tends to increase cooking time. This in turn theoretically should increase fat absorption because the longer the food is in the oil the more oil is

absorbed. Very Low temperatures cause excess oil absorption due to the longer time the food is in contact with the oil. However, in a previous study, changing cooking temperatures showed no difference in oil absorption, yet showed significant differences in browning (Lowe et al., 1940). This is most likely due to the hardened crust not letting the oil into the food. According to another study, frying time is independent of oil temperatures in the 305-400 °F. (155 to 200 °C) range. Also, the amount of oil absorbed is independent of frying temperature (Gamble et al., 1987). A higher surface-to-mass ratio of the food increases oil absorption. Freezing FFs before frying also decreases fat uptake (Saguy, 1995).

4. Composition and Nature of the Food: Fat containing foods such as meats may lose lipids while cooking. The greater the initial fat content of the food, the less fat is absorbed (Makinson, et al., 1987). Differences in the absorbing power of the potatoes themselves, rather than the fat, explains the slight differences in fat absorption between batches (Woodruff, et al., 1919).

5. Moisture: Oil absorption occurs as moisture is removed from the food during frying. Also, moisture loss is proportional to the square root of frying time (Varvela, 1988). A higher initial moisture content results in a higher fat uptake with a linear relationship between initial moisture content and oil uptake (Gamble et al., 1988a). A high moisture content in the product will usually result in a lower fat content (Gamble et al., 1987). A lower initial moisture content would most likely result in lower fat absorption due to a lower internal volume that is occupied by oil during the frying process.

6. Batters: Batter and breading influence fat absorption by reducing moisture loss during frying. Batters, however, contaminate the oil and increase the rate of oxidation and change the oil composition. Pieces of food, batter and debris left in the oil over time can cause burning, smoking, excessive color darkening, charring and unpleasant off flavor development (Varvela, 1988).

H. OIL COMPOSITION, QUALITY AND FRYING CHARACTERISTICS:

Oil choice is an important factor with nutrition, sensory, cost, and rate of turnover of the oil. Temperatures at which the food fries and storage of the oil are also considerations. Superior oil is often more cost effective in the long run due to quality of end product fried and customer satisfaction. The oil will last longer and will not have to be replaced as often. Oil turnover reflects the amount of oil replaced over a time. Turnover rate is a function of the oil absorbed by the food being fried and losses of oil due to filtration or spattering. Fresh oil added to the vat to compensate for loss of oil due to oil absorption or filtering helps to counter loss of performance brought by heat, moisture and chemical reaction (Meyer, 1988). Greasiness in the food somewhat depends on the type of fat used, but much more on the temperature a certain type of food cooks (Williams, et al., 1918). Foods eaten at room temperature will have a greasy mouthfeel if highly hydrogenated oils are used. Lower melting point oils give a better mouthfeel (Stevenson, et al., 1984).

saturates to increase, as evidenced by gas chromatography (GC (Varvela, 1988)). Not only will the oil degrade more quickly with polymerization and oxidation, but there will be health ramifications. Some types of dietary fats are shown to be important factors in the development of cardiovascular disease. The fatty acid profile of the oil or fat can ultimately determine the affect on your health. Mono and polyunsaturated oils are the healthiest, tending to be less injurious to the heart. A joint expert committee from the Food and Agriculture and the World Health Organization established new guidelines for fat and oil consumption that included a directive to the food industry to reduce levels of trans fatty acids (TFAs) in the food supply (Food & Agriculture, 1994).

In this study, CSO was compared to a partially hydrogenated canola oil, Extend®, to test for fry life and quality of the finished product. Both oils have similar additives. CSO appears to be more stable due to its natural saturation and other properties. Canola oil is promoted as a healthy oil but can not be used in frying without hydrogenation. Canola oils are suited for edible-oil products such as margarine and salad dressing without added processing because of their lack of hydrogenation and hence, low stability. Low saturation, although more healthy for the consumer, provides low stability for cooking purposes (Erickson, 1994).

Peroxide Values were done regularly on the oils. The method was implemented because of its standard use in the food industry, even though it has not been shown to be accurate in monitoring frying oils. Peroxides decompose readily during storage and heating. PV measurement may not measure the extent of the oil oxidation (Jones, 1996).

interaction with the hot oil and food in the presence of air. Those products reduce the surface tension at the oil-food interface. During heat transfer, viscosity and surface tension react with the pressure gradient, and the oil's ability to cling to the food surface. Frying ability of the oil depends on the surfactants that form when oil reacts with the food being fried (Steir, et al., 1990). The surfactants need to reach an optimum level in order to give a quality fried product.

The flavor and texture are also greatly effected during the frying process. As the oil ages, the interior and exterior texture of the food product also suffer. FFs fried in a fresh oil gives a pale yellow color, a starchy interior and a crispy exterior. As oil ages, the french fries reach their optimum acceptability after a few days. They have a golden brown color, a crispy exterior and a moist interior. FFs cooked in an older oil gets progressively oilier, develops a drier interior, a darker exterior and becomes limp. Much later, these fries develop rancidity.

I. NUTRITION AND HEALTH CONCERNS

Oils contribute necessary fatty acids to our diets and therefore fats and oils are essential nutrients for our bodies. Limiting fat in its entirety can not be done without creating health issues because many life processes require fat and essential fatty acids. Fat is vital for the function and integrity of cell membranes, protection of vital organs, insulation of the body, and transport and absorption of fat-soluble vitamins. It provides unsaturated essential fatty acids necessary for metabolic reactions. The amount and type of fat appear to be more important in cardiovascular health (Castelli, 1995). Oils are important because they serve as carriers for cholesterol, fat soluble vitamins and phospholipids. Oils also provide an efficient source of energy by contributing 9 kcal per gram of fat while carbohydrates and protein merely contribute 4 kcal per gram. During a meal, fats and oils provide satiety to further the enjoyment of your eating experience.

The suggested amount of fat to ingest per day is 30%, or, 20% unsaturated fats and 10% saturated fats in our daily diets. According to USDA disappearance data, Americans derive 42% of their calories per day from fat! More recent information suggests that consumption is closer to 37% of calories. Some health organizations suggest reducing fat to below the 30% level and replacing fat with complex carbohydrates. The average diet consists of 16% saturated fat and 7% of total calories and is made up of polyunsaturates, specially linoleic acid. Current guidelines suggest keeping polyunsaturates at 10% of calories (Castelli, 1987).

The process of frying increases the lipid content of the fried food. Therefore, the fatty acid profile of the oil is important in addressing health concerns. Saturated fats and trans unsaturated fatty acids can elevate blood serum cholesterol. The body tends to react to trans isomers the same way as saturated fats (Deis, 1996). Hydrogenation, which creates trans unsaturated fatty acids, can affect the heart and cholesterol levels. The current estimate of trans in a typical daily diet is 8 g/day, or 3.5% of the daily caloric intake. (Stauffer, 1996). Other research reported an average daily amount of trans of 2-

4% of total calories, compared to saturated which is 12-14% of the diet (Watkins, 1998). On the average, fat contributes from 37 to 42% of total calories to the diet.

Monounsaturated fats appear to have the healthiest influence. Oleic acid (18:1) is a monounsaturated fatty acid found in many oils. It is hypolipidemic and hypocholesterolemic, which can reduce both cholesterol and low density-triglycerides (LDL - bad - stores cholesterol) without decreasing high density-lipoprotein (HDL - good - carrier for cholesterol) in humans. On the other hand, a saturated fatty acid, such as stearic acid (18:0), found mostly in animal fat, is hyperlipidemic and hypercholesterolemic, and is thought to increase cholesterol levels in humans. However, if the molecules that make up saturated fats are in their natural form, such as those found in CSO, they fit neatly into the cell membranes of the human body. This natural shape refers to the cis-configuration.

When chemically prepared vegetable oils, such as a partially hydrogenated canola oil, are developed to increase their heat stability, the double bonds are hydrogenated. Other bonds undergo a configuration change from the natural cis form to the thermodynamically more stable trans isomer. These trans isomers have been shown to increase cardiovascular disease. The hydrogenated vegetable oils become more saturated and usually contain palmitic and stearic saturated fatty acids, which are mildly hypercholesterolemic. The shape no longer is curved and natural, but becomes more of a zigzag shape. The trans are found on opposite sides of the molecule. The body cannot incorporate these TFAs into the cell membranes causing a chain reaction of imbalances in the body. Trans fatty acids (TFA), as found in these chemically prepared vegetable oils, are shown to clog arteries, affect tumor growth in cancers, and to degenerate body tissues (Hermann, 1993). They tend to elevate the LDL (bad) levels, putting us at risk for coronary heart disease.

There have been studies that suggest that frying of food should be decreased to follow the American Health Associations Dietary Guidelines set forth in 1990 (Castelli, 1987). The suggestion is to decrease the amount of fats in our diets, not to totally avoid it. Also, there has been controversial evidence submitted by the 1995 International Life Sciences Institute (ILSI) stating that trans may not be linked to heart disease (Deis, 1996). The main source of TFA continues to come from hydrogenated vegetable oils (Watkins, 1998). Still, after all the negative health warnings by the USDA and other researchers, FFs are a popular and plentiful item on most institutional menus.

J. POTATOES AND FRENCH FRIES

Potato consumption has remained unchanged and a great portion of their use is for FFs in restaurants (O'Neill, 1997). The french fry is a perfect food for frying because it has little fat to interfere with the frying process. This makes it even better for scientific research applications because there are minimal interactions in the vat between components. The french fry was not discovered in France, after all. However, it is a universal food prepared in many countries. It is believed they were called FFs because an American first saw them in France. Simplot invented the frozen pre-fried french fry to find another way to make potatoes more convenient. Previous preparation involved too much time cutting, washing and cooking in the kitchen (Davis, 1992). The potatoes themselves contain negligible fat and are a good source of carbohydrates. They also supply energy, minerals, vitamins and fiber. At 100 grams per serving, they provide only less than 1 percent fat before frying. The manufacturing process includes pre-frying the potatoes in varying blends of available oils. This not only leads to an increase of total oil content, but possibly can change the fatty acid profile of the oil. Pre-fried FFs usually range from 2-7% fat. After frying, FFs content on the 10-12% fat. Because the packaging on the fries used in this study stated "partially hydrogenated soybean oil and/or canola oil," one has no way of knowing what oil is in each fry unless fatty acid profiles were done on every package. It is the cooking method that results in the french fry being considered an unhealthy food due to high fat absorption (Woolfe, 1987). Although baked fries will be less oily and lower in calories and therefore healthier, the appeal and sensory aspects are not associated with baking. To get the flavor, mouthfeel, texture and aroma we associate with the french fry, they need to be cooked or fried in an oil product (Varvela, 1988).

Storage conditions and growing conditions effect the nutritional content of the potato. Half the Vitamin C is lost after six months. The longer the potato is stored, the more sugar it develops which can create too much browning due to caramelization. A potato tuber is 78% water and 18% starch (complex carbohydrates). The dry matter (DM) of a potato relates to specific gravity. The higher the specific gravity the higher the dry matter (Lulai, 1986). FFs need a higher DM because oil uptake decreases with higher solids. Specific gravity is measured by weighing the potatoes in air and then water, using a hydrometer, and then dividing the density of the potato by the density of water. This will shows how much heavier the potato is than water (Lulai, 1979). This information suggests that knowing the source of the potato is an important factor in determining fat uptake. DM adds an additional variable to the absorption of fat. How and how long the potatoes are stored before processing into FFs will also affect the fat uptake and finished quality of the fries. Potatoes need to be stored at 45-50 °F. and should be used within 4 to 9 months. Refrigeration should be avoided because excess sugars develop which causes too much browning during cooking. They also should be stored in the dark to prevent greening which can occur in light caused by formation of toxic alkaloids. Greening creates a bitter and sometimes toxic potato (Woolfe, 1987). After freezing, frozen fries need to be kept constantly at 0 °C to insure moisture loss or gain is remains at a minimum. Ice crystals can effect the frying process by adding excess moisture to the oil, increasing the rate of oxidation and degradation of the oil. Thawed products effect the finished product by the increase of fat absorption.

K. FRYING OILS AND THEIR ANALYSIS

Oil is one of the important choices when frying because the oil itself has its set of desirable or functional qualities. Oil stability should be the chief concern. The goal of industry is to develop fats and oils that are low in saturation and high in stability (Erickson, 1994). Frying causes polyunsaturate content to fall and the percentage of saturates to increase, as evidenced by gas chromatography (GC (Varvela, 1988)). Not only will the oil degrade more quickly with polymerization and oxidation, but there will be health ramifications. Some types of dietary fats are shown to be important factors in the development of cardiovascular disease. The fatty acid profile of the oil or fat can ultimately determine the affect on your health. Mono and polyunsaturated oils are the healthiest, tending to be less injurious to the heart. A joint expert committee from the Food and Agriculture and the World Health Organization established new guidelines for fat and oil consumption that included a directive to the food industry to reduce levels of trans fatty acids (TFAs) in the food supply (Food & Agriculture, 1994).

In this study, CSO was compared to a partially hydrogenated canola oil, Extend®, to test for fry life and quality of the finished product. Both oils have similar additives. CSO appears to be more stable due to its natural saturation and other properties. Canola oil is promoted as a healthy oil but can not be used in frying without hydrogenation. Canola oils are suited for edible-oil products such as margarine and salad dressing without added processing because of their lack of hydrogenation and hence, low stability. Low saturation, although more healthy for the consumer, provides low stability for cooking purposes (Erickson, 1994).

Peroxide Values were done regularly on the oils. The method was implemented because of its standard use in the food industry, even though it has not been shown to be accurate in monitoring frying oils. Peroxides decompose readily during storage and heating. PV measurement may not measure the extent of the oil oxidation (Hui, 1996).

Peroxide tests are better used for initial oil quality, before degradation begins, and are helpful in predicting oil stability

L. HYDROGENATION

Hydrogenation is a reaction that reduces a double bond to a single bond by the addition of hydrogen atoms in the presence of a metal catalyst (Seager, 1994). Double bonds of an unsaturated acid are reduced to single bonds to yield a saturated fat. Partial hydrogenation is essential in keeping the fat pliable and creamy. If the reaction is completed, the resulting product is hard and waxy (Seager, 1994). Positional selectivity is an intriguing process based on the rate of hydrogenation and depending on its position on the triglyceride molecule (Dijkstra, 1997). Hydrogenation is performed to change the physical and chemical qualities of an oil to make it more semi solid at room temperature, to be less susceptible to oxidation, and to become more thermally stable under high frying conditions (Lichtenstein, 1995). The fatty acid acyl chains of unsaturated oils change in a three step process. The degree of saturation increases by producing more saturated fatty acids. Next, double bonds migrate along the acyl chain and create geometric isomers. Last, cis bonds convert to unnatural trans isomers during intermolecular rearrangement (Lichtenstein, 1995). Regulating hydrogen pressure, temperature, speed of agitation and concentration or type of catalyst, will result in a particular product being formed (Beckmann, 1983).

M. COTTONSEED OIL AND CANOLA OIL

Canola oil is made from rapeseed, was originally raised solely for its oil and was developed through crop breeding in the 1970's. Varieties with less than 2% erucic acid are termed "canola" (Canada oil low acid). It naturally has only 6-7% saturation but has to be hydrogenated to increase the stability of the omega 3 fatty acids, to inhibit formation of fishy off flavors during high heat applications. After hydrogenation, canola oil typically has 51% hydrogenation. Some varieties have been bred to enhance the fatty acid profiles, such as to decrease the heat unstable linolenic acid (18:3). The hydrogenation process is usually chosen for frying oils because it is cheaper than genetic modification and the oils are more readily available. Genetic modification and breeding are time consuming and expensive processes to undertake and are still being developed to yield quality frying oils. Canola oil is bland and slightly buttery when fresh, but develops off-flavors quickly as it deteriorates as in frying (Hui, 1996). These off-flavors are often referred to as painty, fishy and metallic.

Cottonseed oil (CS0), has a natural saturation of 27% and does not need hydrogenation to stabilize it. Besides its beneficial fatty acid profile with 55% monunsaturation and 19% polyunsaturation, it inherently has heat stable antioxidants that allow it to remain stable at high temperatures. The antioxidants naturally present in canola oil do not appear to benefit its stability because of the interference of sulfur compounds in the molecule (Hui, 1996).

N. SENSORY EVALUATION TECHNIQUES

Sensory evaluation is essential for research and development and gives a reliable indication of acceptability and consumer preferences (Charley, 1982). Sensory evaluations are necessary for product development, for monitoring the flavor or likeability of a new product, and in pointing out differences. It is the ultimate method for determining flavor quality of oils (Hui, 1996). Sensory is subjective evaluation done by humans, as opposed to objective evaluations done by instruments or machines. All five senses are used during the evaluation of food. Sensory tests focus on texture, color, flavor, and aroma of a food. When consumers talk about a product's quality, the discussion usually revolves around that product's sensory attributes. Preference and quality judgments are usually used interchangeably. When making a judgment about a food, visual color and appearance attributes are followed by flavor and aroma attributes (Stone et al. 1991).

Several sensory tests and their usefulness are as follows:

1) DIFFERENCE TEST would probably be utilized when testing new products in order to find out what was different and if it was noticed.

2) LIKEABILITY OR PREFERENCE TEST would be used for consumer acceptance. Do you like it, or which product do you prefer?

3) DESCRIPTIVE ANALYSIS TEST allows panelists who are trained to recognize a particular group of attributes in a specific food. These panelists are more analytical because they have to be able to rate the attributes and sometimes offer suggestions of terminology.

4) TRIANGLE TESTS are discrimination tests. The question in a triangle test is - which two are the same and which is different? (Moskowitz, 1988). A panelist may have to describe why the odd one is different. You are not asked to rate attributes. These tests are useful when a small change has been made to a product, and it needs to be determined if it can be noticed. Colored lights, specially the use of red lights, mask any obvious differences there might be. This test is a good one because you do not necessarily have to like the product you are tasting, however, some people have a hard time telling that there is a difference.

5) DUO-TRIO TESTS are not as much concerned with looking for differences, but instead is asking the panelist to match a reference. There may be more bias when deciding which one is different. A panelist focuses more on which two are alike.

When setting up a sensory test, you need to follow a series of steps regarding the particular test and answer the following questions (Lawless et al., 1993):

1) what test should be used?
2) type panelists required?
3) statistical tests to use?
4) what is the experimental design?
5) sample presentation?

However, it is of most importance that no bias is inadvertently introduced into the test procedures. Statistic procedures are identified with each particular sensory test. Parametric statistics are used for scaled responses and binomial statistics are usually used for choice based tests. Last, sensory tests are conducted in controlled conditions, usually with minimal distractions. Sensory booths are set up to minimize bias by controlling for sound, color, lighting, and temperature.

CHAPTER III

METHODS AND MATERIALS

Cottonseed oil and Extend®, a partially hydrogenated canola oil; were compared for stability and quality during a matching fry life study between the University of North Texas (UNT) and Texas Woman's University (TWU), both in Denton, Texas. The study was divided into seven main parts:

PART I - pilot study with side by side frying and aging of oil at TWU.

PART II - commercial frying at Clark Hall, UNT.

PART III - consumer sensory evaluation of FFs from both TWU and UNT.

PART IV - sensory quality surveys and bench topping at TWU and UNT.

PART V - descriptive evaluation of frying oils used in the study.

PART VI - physical analysis looking at sensory quality

1. total oil and moisture content
2) food to oil ratios

PART VII - oil quality and fry life using analytical testing

1. PV
2. GC (fatty acid profiles and trans)
3. ACM & PCM

PRODUCTS: At both UNT and TWU

Frosty Acres brand 3/8" crinkle cut french fries (FFs) product code 27643)), pre-fried with partially hydrogenated soybean and/or canola oils were ordered from CD Hartnett, a wholesale food service distributor in Fort Worth, Texas. In addition, QTF homestyle breaded beef fritters (chicken fried steak, CFS (product code 204)) was fried at UNT.

A. SAMPLE MANUFACTURE AT TWU

EQUIPMENT USED AT TWU

1) stainless steel utensils
2) twin Super Chef™ (model E414) 5 pound electric fryers
3) identical digital thermometers with probes, (Oakton model # 90080)
4) food service heating lamps
5) glass partition

PROCEDURES AT TWU

Before testing, fryers at TWU were cleaned thoroughly before using (ASTM method E-1346). Frymaster seapowder was made into a cleaning solution and added to the fryers before boiling for at least 30 minutes. NaOH and distilled water were used to rinse the fryers in the final step. The fryers were checked for sheeting action to insure no polymers or contaminants were left on the fryers. Fryers were then dried thoroughly. One gallon of oil less 500 ml was placed in each fryer to prevent boiling over. Each day, both oils were heated at TWU in fryers for 8 hours per day. Continuous heating began at about 9 AM and fryers were turned off at about 5 PM. The fryers were covered at night. A total of ± 3.5 pounds (1.5 ± 0.1 kg) of FF were fried in each fryer on sample days. Six (6) ounce portions (170 ± 0.1 grams) were fried at a time in each fryer to prevent temperature fluctuations and food crowding. Frozen french fries were measured and fried for 4 minutes until golden brown. Fries were kept under heating lamps until served. On non-sensory evaluation days, 100 ± 0.1 grams of fries were fried every 3 hours to ensure constant stress of the oil. After many trial runs, temperatures in the fryers were found to equalize best by raising the temperature to 370°F. This caused the temperature to drop and then to recover quickly during the 3 minute frying time. A timer was used to precisely monitor the pre-determined ideal frying time of 3 minutes ± 10 seconds for each batch of 100 grams (± 3.5 ounces). No fresh oil was added to the fryers. A glass wall was inserted between the two vats to prevent crossover spattering. No filter aids were used in either vat, although food particles were skimmed at the same time daily. Temperatures were monitored and maintained at 350°F ± 5°F throughout the day. Fryers were allowed to heat up for one hour before any frying began to stabilize proper temperatures. Temperatures were held as best as possible by monitoring them on the hour and making adjustments if necessary. Temperatures tended to decrease by 25° F immediately after dropping in the frozen FFs, but rebound within 1 minute. These oils were placed in fryers and brought up to 370° F (180°C.) for 30 minutes to stabilize temperature.

B. SAMPLE MANUFACTURE AT UNT:

EQUIPMENT USED AT UNT

1). A brand new dual vat commercial Frymaster fryer model 9706610046 (total 105 lb. capacity) maintained temperatures accurately and had the ability to filter automatically.

2) 1.5 jugs of oil (35# per jug) were poured into the vats (52.5 lb. each).

3) Filter Magic part No. 8030170 filters.

4) filter aid (diatomaceous earth) supplied by Frymaster

PROCEDURES AT UNT

Vats were filtered at about 8:30 AM and 3:30 PM, one vat right after the other, two times per day. One cup of frypowder was adding to the oil before filtering. Fryers were filtered six times (about every 3 days) before changing filter paper. Fryers were cleaned thoroughly after boiling with cleaning solution and then washed in an electric dish washer. Temperatures were set at 360 °F (±180 °C) as directed by the manufacturer. FF were usually drained by shaking the fry basket over the fryer, then pouring the fries into a stainless steel pan for carrying to the food service line. Then they were dumped into serving pans and placed over dry heat until eaten, or discarded if held too long. FFs were cooked for 3 to 3.5 minutes and CFSs were cooked for about 3.5 to 4 minutes on an average.

SAMPLE HANDLING AT BOTH OPERATIONS

Daily oil samples were taken using stainless steel tools for transfer to amber bottles before being transported to TWU labs for later analysis. All samples were frozen at 0 ° C. All samples were clearly marked to insure reliability. Day 10 endpoint oil samples were retrieved from at oil change time and taken in plastic jugs to TWU for sensory evaluation purposes. French fry samples were taken from the first morning frying, allowed to cool and placed in plastic, freezer zip-lock bags for transfer to the lab for moisture and oil analysis. Samples were then frozen and stored.

SENSORY ANALYSIS

1) CONSUMER PANEL

Duo-Trio consumer tests were conducted at TWU using endpoint oils taken from the UNT. There were two tests conducted on two dates on these ten day oils comparing both CSO and Extend® oil using a reference test design and requesting preference of sample. Another test was conducted on another 10 day set of oils asking no preference. In addition, there were two duo-trio tests run on the fresh oils themselves, and on the 10 day oils from the side by side study conducted at TWU. Oils were tested at day "0" while fresh, and day "10," the endpoint. In the case of consumer testing, as many panelists were seen as close together as possible to assure that the fried products were cooked, held and served under the same conditions. Triangle and Paired Preference and Duo-Trio tests were developed and implemented at TWU's consumer testing laboratory to determine likeability, difference and preference. Consumer panels consisted of TWU staff, researchers, students and professors who were semi-trained to trained through previous experience at TWU. Gender was not a factor in choosing panelists. Means, percentages and graphs were done using Lotus 1-2-3 software or Microsoft Excel programs. A statistical table was used to determine significance (Roessler, 1978). Because of the small number of panelists of 40 or less, a decision was made not to run standardized statistical analysis on the sensory evaluations. A minimum of 40 panelists was used for each test. FFs were fried in CSO and Extend® oil at varying ages of the oils. Samples were kept under a heat lamp until served. FFs were cooked on an ongoing basis to keep them fresh and hot, so that differences in serving procedure would not effect the results. References were randomized so that all FFs were served an equal number of times. This was done by altering the reference every five ballots between CSO and Extend® oil. This insured that all products were kept at the same age and temperature and no one product was used more or less than another. Three digit codes were assigned to each product to avoid identification. Three samples were paired with the FFs and presented to each panelist in order for them to make a choice, or guess if they could not match the reference. Semi-trained panel members were professors, undergraduate and graduate students, from TWU who regularly visit the sensory laboratory. Each panel member was asked to evaluate each product selection and determine sensory characteristics that best described each sample. Comments were encouraged. While implementing the triangle test, panelists were asked to make a choice between 3 samples and to pick the odd sample. Red lights were used to mask any visual difference in colors of the fries. Triangle tests were determined inappropriate due to their nature of looking for a difference, and duo-trio tests were selected instead because matching to the reference was more appropriate than looking for the difference. Comments were asked freely and recorded.

2) BENCH TOP EVALUATIONS

Bench topping was done on a regular basis to monitor quality of the oils and quality of the food fried in them by several Food Science graduate students and professors at TWU. This was considered a semi-trained to trained panel. In addition, food service personnel often assisted by filling out the ballots based on their expertise. Six, seven, ninth and tenth days were analyzed for both CSO and Extend ®oil by using an eight question ballot with a comment section involving more in depth thought. This procedure was followed in order to verify survey results made by untrained panelists

3) SURVEYS

At Clark Hall Grill, surveys were done on the third and tenth day of frying for both oils. Tests consisted of four questions; three attributes and one likeability question. The means were done on all four tests. Original ballots contained fifteen attributes and were found to be too lengthy and detailed. Questions were shortened to three attributes and likeability on a 1-9 point hedonic rating scale. Surveys were conducted to narrow down attributes for on going consumer testing at TWU and to determine preference, if any. The consumer sensory tests were developed from the UNT surveys. Nine scale rating likeability tests using hedonic scales were developed for a three attribute test. Degrees of likeability ranged from 1-extremely dislike to 9-extremely like. Attributes were narrowed down to greasiness, fried flavor and crust crispiness. Greasiness was ranked from 1-not greasy to 9 very greasy. Crust crispiness was ranked from 1-very soggy to 9-very crispy. Fried flavor was ranked from 1-flavorless to 9-strong flavor. Panelists for the surveys were students at UNT who had no experience in sensory evaluations. Potential Clark Hall panelists entered the food service buffet line, where signs were placed to alert them of the test. As the clients exited the line, they were asked to fill out a survey, for which they would receive a prize for their efforts. Small candy bars were displayed in baskets with a sign in an attempt to gain interest, and later used as prizes for their participation in the research. Panelists were asked to read the ballots in detail, to answer the four questions by tasting the FFs without condiments, seasonings or gravy. They were also asked to eat their fries while hot and before they had anything else on their palettes. After they finished filling out the ballot, they were given a prize. Surveys also screened for age and gender. Forty panelists were required on each survey day.

4) DESCRIPTIVE FRYING OIL EVALUATION

Oils were evaluated for attributes that related to age of the oils by a panel in training in order to correlate changes in the oils with changes in the foods. Sensory evaluation mainly looks at the foods themselves. Time limitations and constraints made this aspect of testing merely a trial basis.

PHYSICAL ANALYSIS RELATING TO SENSORY QUALITY

OIL ABSORPTION AND MOISTURE CONTENT

The Goldfisch extractor was used to determine fat content of the FFs. Numerous runs of the Goldfisch apparatus, using at least three replications per run yielded variable results. Each Goldfisch operation took 24 hours for completion, so it was necessary to toggle the testing and to accurately time various stages of the analysis. Since the optimum day of frying was determined as day 3 with subsequent bench topping, samples of FFs were taken on this day and analyzed. Days 6, 9, and 10 were determined to be the other most obvious days for analysis and the Goldfisch was run on these days too. No significant differences were observed, therefore, oil absorption analysis was not done on a daily basis.

A. Total oil content and moisture content were analyzed before and after deep-fat frying of samples taken from both operations. Within the hour after collection, a 50 gram representative sample of FF was ground for 1 minute in a Black and Decker food grinder to prepare them for the fat analysis procedure. The leftover portion of fries was placed in the freezer for future analysis. All samples were run in at least triplicate, and all results were averaged.

B. MOISTURE METHOD. AACC Method 44-40 - Per cent moisture

1. Weigh well mixed sample in pre-weighed thimbles, put in partial vacuum oven having a pressure equivalent to 25 mm Hg or less. Heat at 238°F (100°C) for 6 hours. Admit dry air into vacuum to bring to atmospheric pressure.

2. Allow to cool and weigh as soon as it reaches room temperature

3. Weight is reported as percent moisture in the following calculation

% moisture and volatile matter = loss of moisture X 100/weight of sample

C. FAT EXTRACTION METHOD. AACC Method 30-25

1. After prepared sample is weighed for moisture, place thimble in 50 ml beakers with petroleum ether as the solvent and attach to Goldfisch apparatus.

2. After 14-16 hours of extraction, the petroleum ether is driven off into collection tubes and the sample is placed in a dessicator containing $CaSo_4$ for 6 hours to continue driving off moisture and/or petroleum ether.

3. The extracted fat (oil) is calculated by difference.

CHEMICAL ANALYSIS OF THE OILS

A. FATTY ACID PROFILES. Gas chromatography analysis was conducted to determine and monitor initial and continuous fatty acid profile changes (AOCS Method CE1-62). Methyl ester samples were prepared for the GC using AOCS Method Ce 2-66 and put in vials on the autosampler. Each oil sample was heated in the presence of methanol with a commonly used catalyst, borontriflouride, to transesterify the fatty acids to methyl esters for free fatty acid analysis comparisons (AOCS Methods Cs 8-53, Ce 2-66). The gas chromatograph was run on day 0 (fresh oil), day 3 (optimum oil) and day 10 (endpoint oil) on both oils taken from UNT.

B. TRANS FATTY ACIDS. Since the column at TWU would not support trans fatty acid elution, it was determined that an outside laboratory be utilized. Samples were sent out to Woodsen-Tenent Laboratories, Inc. Memphis, TN. for TFA analysis. They used a Hewlett-Packard 5890 gas chromatograph, HP 7673 GC/SFC injector, HP 5890-3396 integrator, Supelco column 2-4023 60 m X 0.25 mm sp 2340, 0.20 um fused silica capillary, Smalley Trans series check control with internal standard C13. Woodsen-Tenent were sent fresh and 10 day samples from Clark Hall Grill, food service facility at UNT. Both CSO and Extend® oils were collected in 2 sets of 2 gram amber bottles and sent by air to the laboratory for analysis.

C. ALKALINE CONTAMINANT MATERIALS. AOCS Method Cc 17-79 was adapted by Miroil Oil Process Systems (Allentown, PA.) to determine ACM in the oil using a hand held color chart. A mixture of oil and reagent is compared to a color chart for degradation products.

D. POLAR CONTAMINANT MATERIALS. Hand held colorimetric test kits were used to monitor changes in PCM (AOCS Method 28-074). A small amount of oil is dropped into a small amount of reaction fluid in a test tube. Results are verified by matching color charts.

E. PEROXIDE VALUE. Initial oxidation products were analyzed by using the Titration Method (AOCS Method Cd 8-53). Acetic acid-chloroform solution was first mixed with ± 5 grams of sample and swirled until dissolved. Saturated potassium iodide was added by pipet and allowed to stand for 1 minute. Distilled water and a starch indicator solution were then added. The solution is titrated with sodium thiosulfate until the blue color is gone. PV is determined by calculation.

CHAPTER IV

RESULTS AND DISCUSSION

Demographics

Sensory testing at both UNT and TWU involved mostly young students. As would be expected at TWU, panelists participating in consumer testing involved a large percentage of young female students (52%) within the ages of 18-29. At UNT, the opposite occurred for survey participation. There were (47%) males between the ages of 18-29. (Figure 3) It would be reasonable to assume a large percentage of females would enroll in woman's university. More males would most likely be eating in an all-you-can-eat establishment because they tend to eat more during this particular age span of growth and development than females. Females tend to be more concerned with gaining weight. Not only does this correspond with young college age students being in a university setting, but it correlates with ballot comments indicating high preference for FFs.

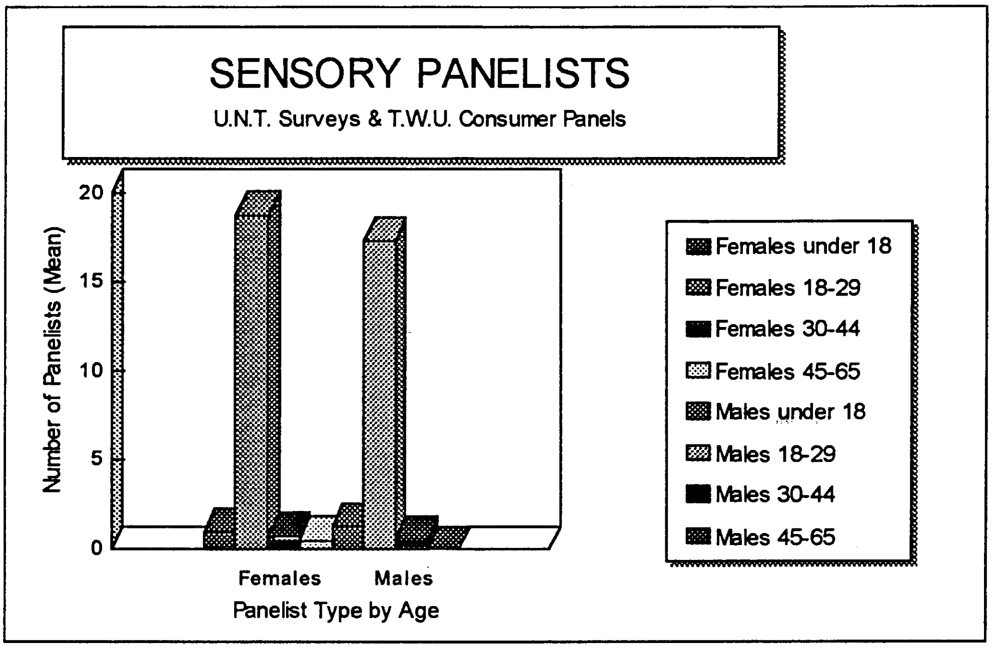

Figure 3 Sensory Survey Summary of Results

SENSORY EVALUATION

Subjective testing was done using sensory evaluations by survey and with consumer tests at both universities. At TWU, consumer testing was performed using duo-trio type tests, but little or no significance was found between fries fried in both oils, at various days of fry life using statistical tables (Roessler, 1978). Consumer surveys conducted at UNT using an hedonic scale also indicated similar values for the evaluations of attributes of the fries using the two oils.. However, a discussion of comments, observations and evaluation of the means calculated will follow.

CONSUMER SURVEYS

Figures 4 through 7 show that during day 3 and 10 of testing using CSO and Extend® (PHCO), likeability was rated closely for both oils. A mean of about 7.0 on a scale of 1 to 9, for 77% of the panelists was determined. For both oils, panelists liked the FFs equally on the optimum frying day and after prolonged frying. Greasiness means went down in both oils after 10 days. Greasiness followed the same trend for both oils indicating that there was no increase in perceived greasiness intensity. This response is inconsistent with what is to be expected. Greasiness is expected to increase with frying time. However, the difference is slight. Crispiness and fried flavor were also similar in both oils. For both oils, mean followed the same general trends.

To conclude, the sensory surveys were done to gather general information on oil choice, not to use formal sensory procedures. Experimental design was limited based on the uncontrolled environment and facilities available at UNT. Conclusions can not be derived from these evaluations and extreme statistical analysis cannot be used. The insignificance of the means indicates that either panelists were not particular in the answers they gave, or more likely, quality of the food fried in the oils was maintained by the fry cooks. Additionally, 10 days of frying time is considered a short fry life cycle, and stressing the oils past this point would be necessary to find any significance, if any.

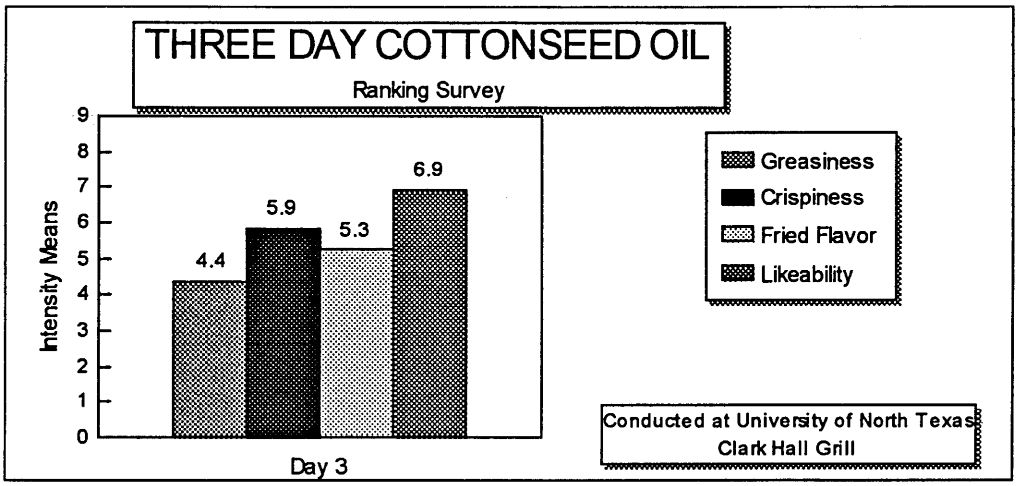

Figure 4. 3 Day Cottonseed Oil Survey

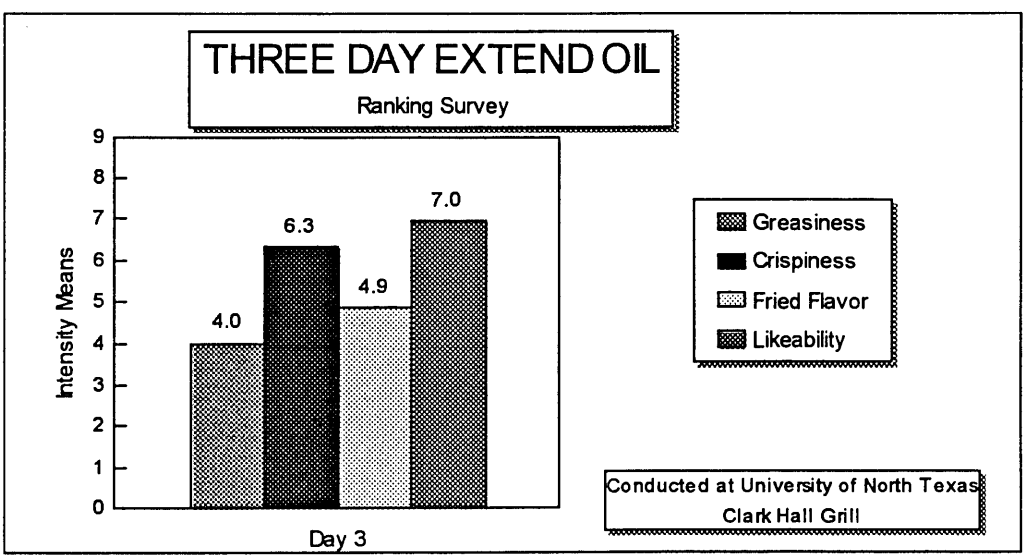

Figure 5. 3 Day Extend® Oil Survey

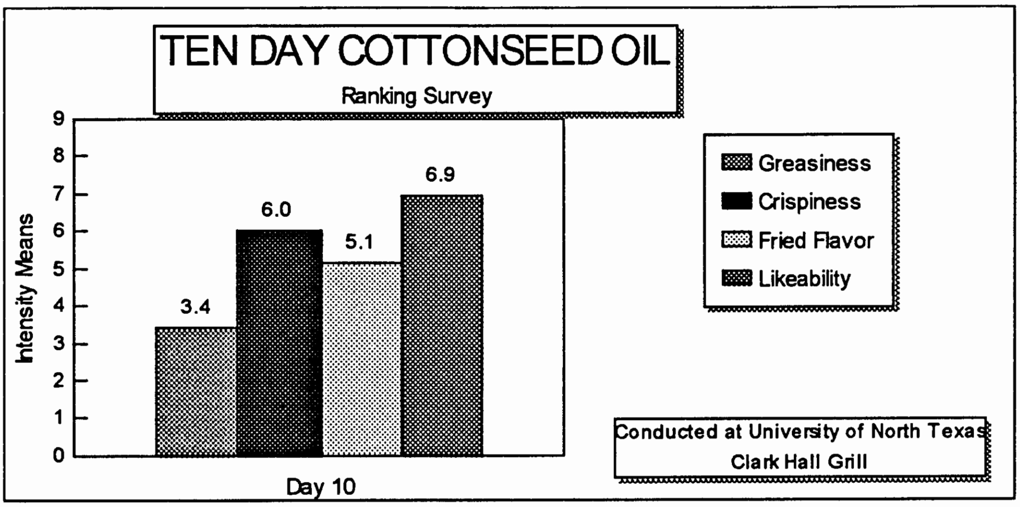

Figure 6. 10 Day Cottonseed Oil Survey

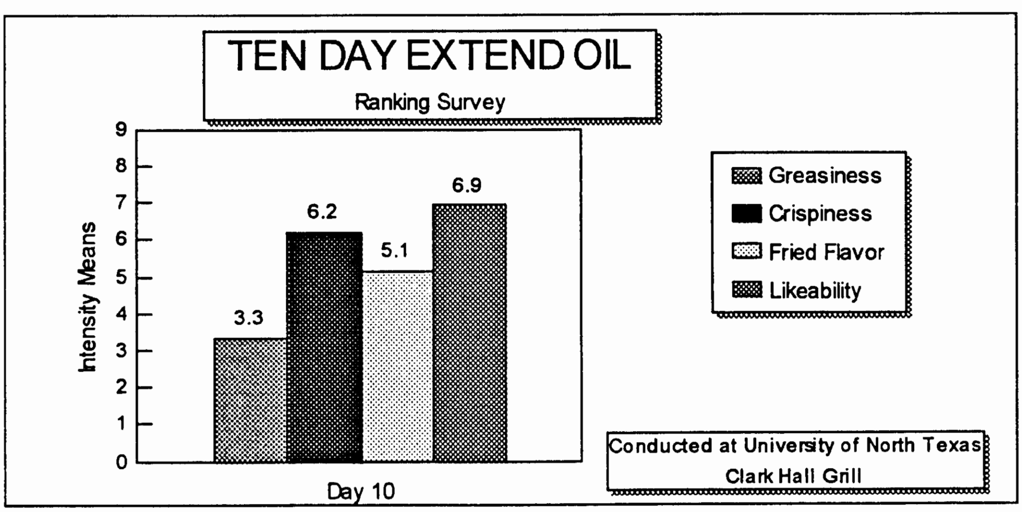

Figure 7. 10 Day Extend® Survey

BENCH TOP EVALUATIONS

In both CSO and Extend® (PHCO) results reflected variation and differences in attributes, most likely due to various degrees of knowledge, sensory perception and experience by the panelists. There also may be an increased motivation to answer correctly because panelists tended to be researchers or experienced students.

For CSO, greasiness means increased linearly from 3.4, 3.8, 5.3 to 7.0 for days 6, 7, 9 and 10. This correlates with research that shows as oil ages, oxidation causes breakdown and fat absorption increases (Figures 8,10,12,14). In Extend®, greasiness means went from 4.2, 6.3 to 3.4 and finally with a huge increase at day 10 to 7.0 (Figure 9). This high score could be attributed to oil degradation and increased fat absorption. The low score at day 9 is due to a number of possible variables. In both oils, crispiness went inconsistently up and down, which could correspond to the time the food was fried, or any other variables in preparation such as sitting idle on the serving line. Usually, crispiness increases with a temperature increase, prolonged cooking time, or aging of the oil. In both oils, fried flavor increased with time as would be expected. Interestingly, likeability steadily went down after day 7, which might indicate the quality of the oils was declining (Figure 10,11). Any variations would be most likely attributed to bias or perception of the acceptability of the fried flavor, or as previously mentioned, superior frying practices for the higher value days. Interior tenderness of the fries showed a slight up and down pattern of mean values in both oils, but both oils appeared to be similar in their tenderness. Tenderness relates to freshness of the oil and moistness and softness of the interior of the fry. The inconsistency is probably related to personal perception or the particular french fry tested. Each french fry, although within certain government and manufacturing specifications, can vary in amount of moisture and size to some degree. Also, in both oils, potato flavor means went up and down. Potato flavor is good when the frying oil is fresh and does not impart a strong flavor to the product fried in it. These means should have dropped with respect to the degradation of the oil.

For CSO, day 7 may have been a superior frying day because many of the attributes were rated higher that day and greasiness were rated lower (Figure 10). Concerning Extend® (Figure 11), day 7 was an unusual frying day as shown by lower mean values, with may indicate inconsistent frying practices on that day. (Figure 13) In Extend®, likeability had an opposite reaction than fried flavor with day 7 having the lowest score of 4.0, compared to other days. At day 10, these ratings went back up. Possibly the perception of a very strong fried flavor is negative for likeability since it is related to off flavors and lack of freshness. In general, likeability ratings were similar for all oils. Color indicates old oil if dark and spotty fries are observed. In this case, The color did increase with the age of the oil as would be expected. Color of the FFs showed similar inconsistencies within the oils. For day 7, differences in all attributes and likeability and can not be viewed as a regular fry day for Extend® (Figure 11.).

In summary, bench top evaluations were done to verify results of the surveys done by the inexperienced panelists and to monitor the day to day frying operation. Quality of the food fried in the oils was maintained by the fry cooks over the implemented 10 day fry life and variations were those inherent in a frying operation. Broad conclusions can not be derived from these bench top evaluations. Again, experimental design was limited. This was not a controlled sensory design and therefore the inconsistencies in the ratings can only be used to show trend analysis.

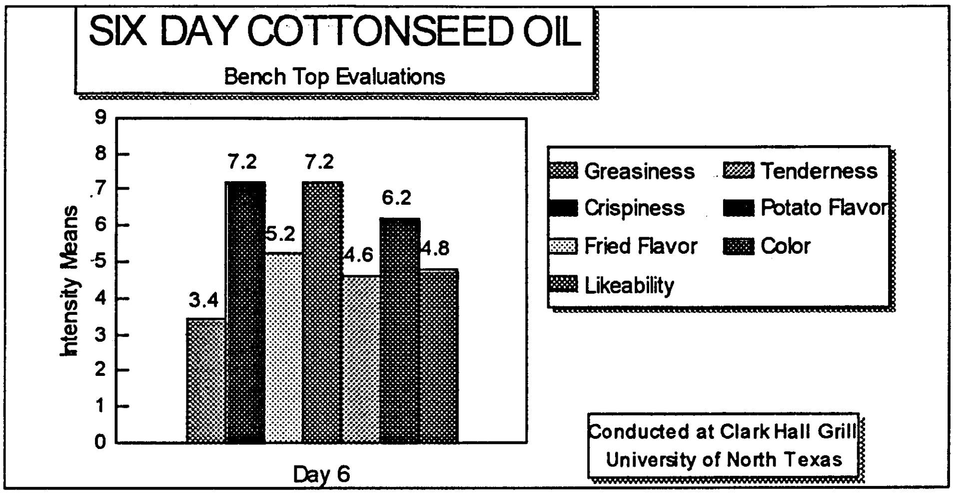

Figure 8. 6 Day Bench Top Evaluations for Cottonseed Oil

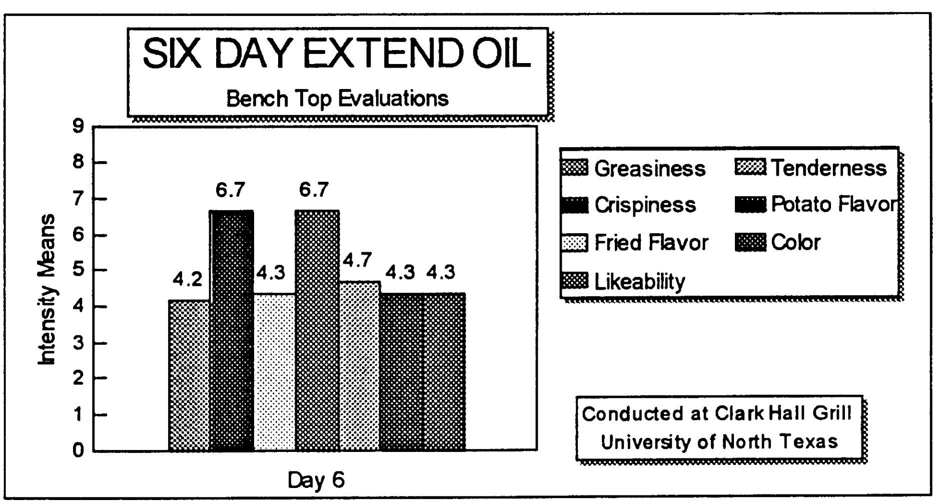

Figure 9. 6 Day Bench Top Evaluations for Extend® Oil

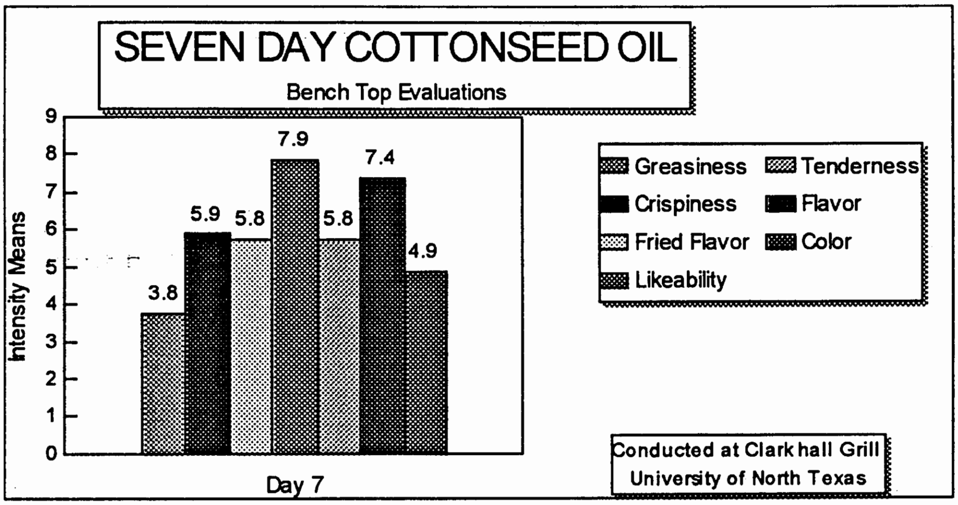

Figure 10 7 Day bench Top Evaluations for Cottonseed Oil

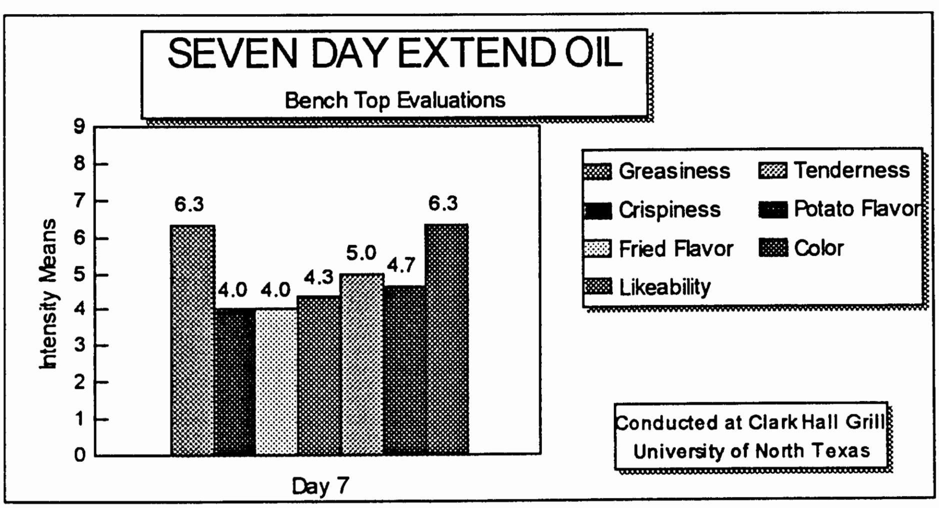

Figure 11. 7 Day Bench Top Evaluations for Extend® Oil

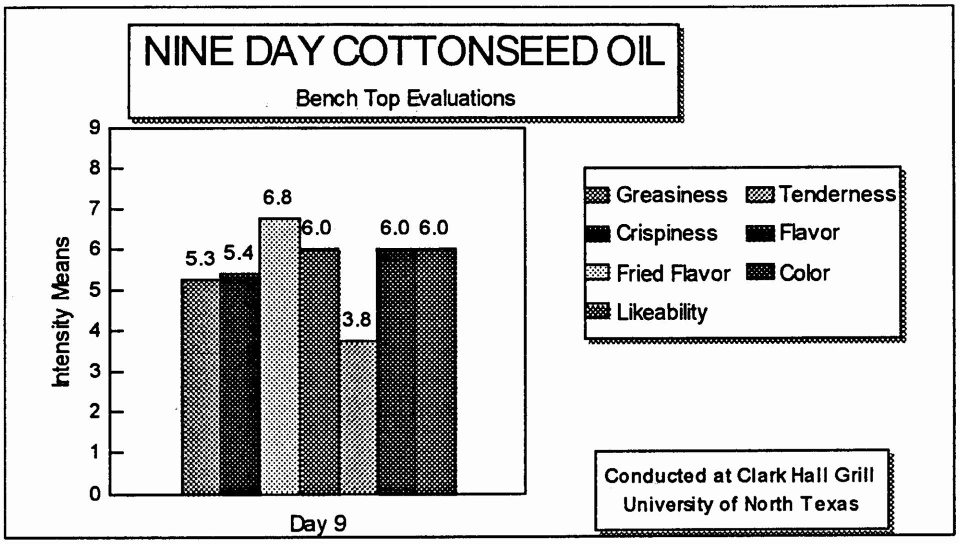

Figure 12 9 Day Bench Top Evaluations for Cottonseed Oil

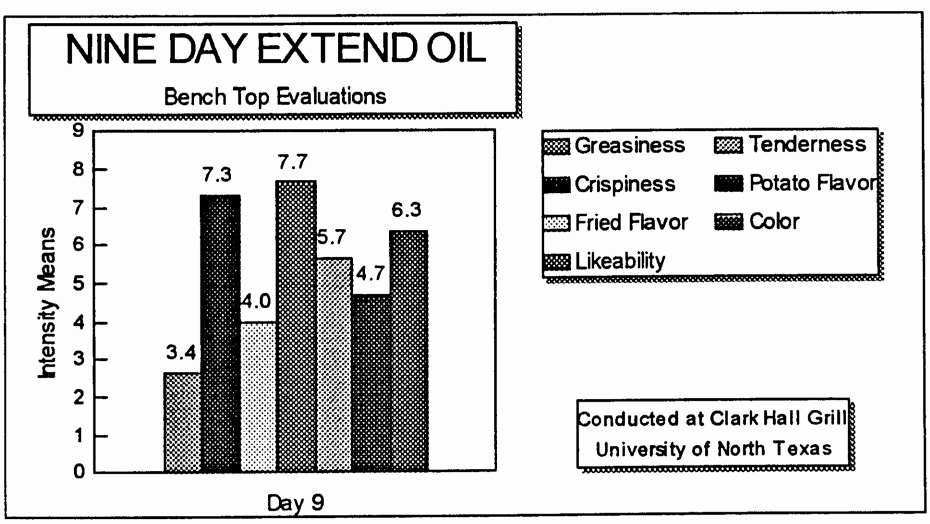

Figure 13. 9 Day Bench Top Evaluations for Extend® Oil

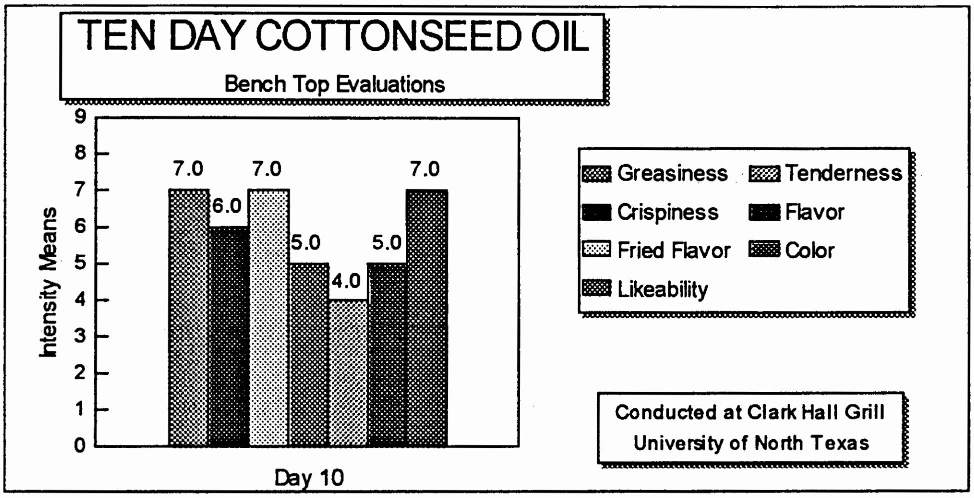

Figure 14. 10 Day Bench Top Evaluations for Cottonseed Oil

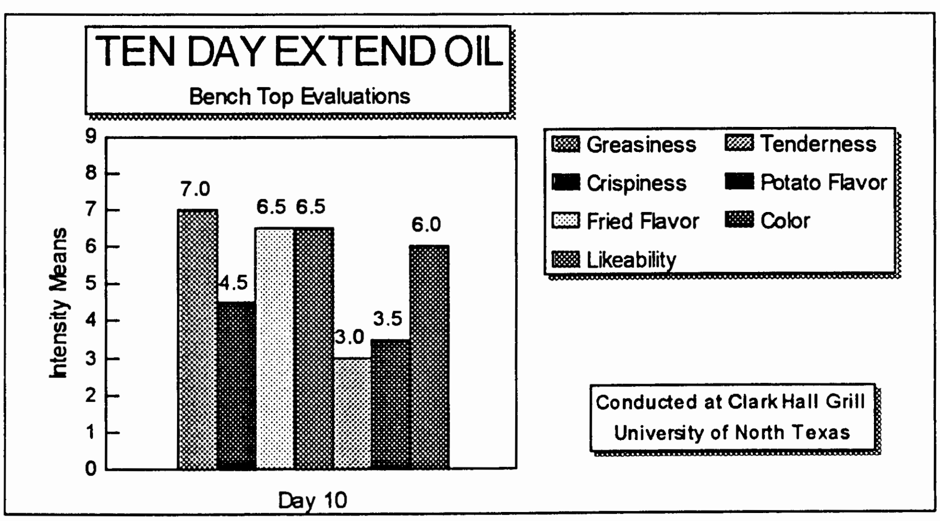

Figure 15. 10 Day Evaluations for Extend® oil

DUO-TRIO CONSUMER TESTING

OVERALL SENSORY RESULTS

Correct responses indicate that the panelists correctly matched the reference to the same sample. No difference was found between the foods fried in both types of oils for likeability, color, greasiness and flavor. (Table 1) Significant difference was determined by using tables (Roessler, 1978).

CORRECT JUDGMENTS

FRESH OILS. Test JSFF97004 was run on 29-OCT-97 using fresh oil samples for both CSO and Extend® oil. Significance was reached at a high degree of confidence of 99.99%, or $p = .001$, and 30 out of 40 correct judgments, or, to a lesser degree at $p = .05$ with 26 out of 40 correct judgments. Actual tally recorded 30 out of 40 choosing correctly.

TEN DAY UNT OILS. Test number JSFF97008 was conducted on 04-DEC-97 using endpoint oils from 02-DEC-97 Extend® oil and 05-NOV-97 CSO (stored at 40°F). Thirty out of 40 panelists made the correct choice in oil. Results showed a high degree of significance for judgments of 30 out of 40 being correct at $p = .001$ with 99.99% confidence. The last endpoint oil test JSFF97006, did not require preference judgments, however, 29 out of 45 panelists chose correctly with a $p = .05$ level of significance.

TEN DAY OILS FROM TWU STUDY The tenth day aging oils at TWU were used in a consumer frying test to correlate them to UNT endpoint oils at about the same fry life. Twenty out of 40 chose correctly.

PREFERENCE

FRESH OILS. CSO showed a higher preference with 23 out of 40 preferring CSO. Seventeen out of 40 preferred Extend® oil. Test JSFF97007, was run on 09-DEC-97 using fresh oils. Twenty-eight out of 40 made correct judgments in delineating between the samples at a high confidence level of 99.99%, p =.001. At p = .05, a lesser degree of significance was attained at 26 out of 40 correct judgments.

TEN DAY ENDPOINT OILS FROM UNT. Sixteen out of 40 panelists preferred CSO and 24 out of 40 preferred Extend® oil at the end of the ten day period. The last endpoint oil test JSFF97006, did not require preference judgments.

TEN DAY OILS FROM TWU STUDY The majority of the 23 out of 40 chose Extend® oil as the preference. Seventeen out of 40 chose CSO. Results showed insignificance for matching reference to sample at any confidence level. Twenty out of 40 chose correctly.

COMMENTS

FRESH OILS were closely matched in test JSFF97007, although CSO was perceived as fresher. Test JSFF97004 showed that FFs fried in CSO had a better fried flavor and were crispier. Extend® oil produced a product that had a slightly bad aftertaste.

TEN DAY ENDPOINT OILS FROM UNT. Test JSFF97008 had comments relating to better flavor for CSO, crispier, more fried flavor (which probably relates to being fried longer due to crispness). Extend® oil had comments signifying that it was less greasy, but had an off or metallic flavor. For test JSFF97009, comments for the oils roughly showed that Extend® oil had a slightly better flavor although it still had a bad aftertaste; either a metallic or an oily aftertaste. CSO had a slightly bad after taste and was perceived as slightly greasy compared to Extend® oil.

TEN DAY OILS FROM TWU STUDY Comments indicated that FFs from the Extend® oil vat were perceived as slightly crispier but had an off flavor.

SUMMARY OF SENSORY TESTS

In summary, there was a high degree of significance in being able to discern the reference from the matching sample in both fresh and ten day oils. Preference results indicate that CSO is perceived more favorably when fresh. Research has shown that CSO imparts a slightly nutty, bland flavor to the fried product, while a PHCO would most likely impart a slightly metallic or fishy undertone, based on its fatty acid profile.

Preference was slightly higher for FFs fried in Extend® (PHCO) endpoint oil. This could be attributed to how hot the fries were at the time of sampling, how long the fries had sat before sampling, or other variables including testing error. Using 5 pound fryers is a time consuming, inexact procedure for frying in a scientific setting. However, the situation would reflect in similarities between problems that occur during any normal food service operation that requires cooking on demand, or for continuous replenishing of a buffet line. It is difficult to keep temperatures from fluctuating in the oils and the fries over the entire frying cycle. As fries drop into the oil, oil temperatures decrease. Depending on the recovery time, which is variable, will reflect in a variable product being fried. Peaks and lulls in food service account for much of the variability. Also, participation by sensory panelists is unsteady. There is no way of knowing how many panelists will arrive and at what time, so estimating total fried sample to needs is also inconstant. Sensory measurements are dependent on the preparation of the samples, the physical environment and the quality of training the panel receive (Hui, 1996). Although

1996). Although preference was not significant in ten day frying oils, the oils had an affect on the taste of the FFs as perceived by the panelists.

DUO-TRIO
Results

TEST #		Matched	CSO	Extend	Total
		Preference			
UNT #009	12-Dec-97	27	16	24	40
UNT #008	04-Dec-97	30	18	22	40
TWU#006	11-Nov-97	20	17	23	40
Fresh #004	29-Oct-97	30	23	17	40
Fresh #007	11-Nov-97	28	24	16	40
	Total	135	98	102	200
	Percent	67.50%	49.00%	51.00%	
				2.00% difference	

Table 1. Duo-Trio Test Results Summary

ANALYTICAL TEST RESULTS - Quality of the oils and the foods fried in them

CLARK HALL GRILL, UNT. Objective testing was done using various chemical and instrumental tests to correlate endpoint oil with lab values if possible. Eighteen years of experience was the guiding factor behind the frying operation at UNT. The fry cook had a "feel" for when the cooking of a product was completed and when the oil was at the endpoint. The determinations appeared to be consistent each day, although minor fluctuations between the daily operation did occur. The endpoint of the oil was based on visual color of the oil and the product fried in them, excessive foaming and smoking, sensory bench topping and strong odor development. Daily freshening by adding fresh oil to the vats was done to add back into the vats, oil that was lost to splattering or absorption or other losses. Freshening is a normal procedure done by food service operations in order to extend the use of the oil. It can, up to a point, compensate for loss of oil performance by heat, moisture and chemical reactions (Meyer, 1988). Deep-fat frying oils deteriorate when heated for prolonged periods of time and when exposed to air without heating (Richardson, 1995). Fryers were turned on at 8 AM and turned off at 9 PM. They were covered at night and allowed to cool to minimize degradation. Cooking times of the products were estimated by the experienced cooks. Timers or clocks were not used. Fries were cooked for approximately 3 minutes. Temperature recovery times were less than one minute at 360°F. Two separate vats containing two products, CFSs (Vat A) and FFs (Vat B), accounted for differences in several of the results. Cross contamination did occur between the two vats during the filtering process (which connected both vats), through spattering, or when cooking in the wrong designated vat. Vat A consistently had a darker color due to the breading materials and the fat substrate of the meat and proteins infiltrating the oil. Vat A smoked more quickly. Oil and food poundage were recorded. Visual observations were recorded. Color test kits to determine endpoints of the oil were not used because they were determined not to be a true indicator of quality. The color guide was much darker than oils used in our study and erroneously indicated our oils were fresher than the cooks felt they were at any point. Standards for UNT's food service are extremely high at any stage and this provided for an excellent product. Therefore, the endpoint oils and the foods fried in them remained at high quality throughout the study.

TWU FRY LABORATORY. Temperatures dropped harshly when frozen fries were added to the oil. After several attempts, it was determined that fryers were found to equalize best by raising the temperature to 370°F to account for the 10°F fall. Temperatures recovered within 1 minute and reached on the average 360°F for the duration of the 3 minute frying time to match the UNT study temperatures as best as possible. A timer was used to precisely monitor the pre-determined ideal frying time of $\pm$3 minutes for each 100 grams of FFs ($\pm$3.5 ounces). During the pilot study, the oils were heat stressed at 360°F. for 8 hours per day for a total of 19 days ($\pm$152 total frying hours) until it was determined the food was no longer edible. No fresh oil was added to the fryers. No filtering was done and no filter aids were used, although food particles were skimmed daily to inhibit degradation.

PEROXIDE VALUES

Peroxide tests were performed regularly on the oils at various stages in frying although research has pointed out that peroxide values are not true indicators of oxidation stages in a degrading oil. The PV may not measure the extent of the oxidation (Jones, 1996). Peroxides breakdown readily during storage and heating. Samples were previously frozen so that all PV tests be done at once to insure accuracy in results. Several chemical solutions had to be prepared and needed to be used at the same time for each test to avoid experimental error. As was to be expected, no real trends were shown to verify any particular breakdown stages of the oils. Peroxide values (Figure 16) graphically show inconsistencies in oils during ongoing frying operations. The comparative study at UNT and the side by side comparison at TWU gave inconsistent results regarding peroxide values. PVs were consistently low which would not indicate oxidation was occurring. However, this is not a valid conclusion because under prolonged periods of continuous frying, heating and aeration, hydroperoxide breakdown products are formed but are immediately decomposed (Perkins, 1996). Decomposition is occurring rapidly as shown by the changes in fatty acid profiles. PVs tend to increase as oxidation increases due to degradation of oil during the frying process. Initial and final values were 1.17, 2.7 meq/kg concurrently for UNT Extend® oil. The TWU aged oil values were 1.5 meq/kg initially and finally, 2.7 meq/kg. For UNT CSO, it started out at 1.4 meq/kg and meq/kg. The peroxide values for CSO at TWU went from 1.1 meq/kg to 2.6 meq/kg. The ending values were close in all four oils and all remained low. For quality control purposes, fresh oils have peroxide values < 1 meq/kg. Rancid oils can be as high as 250 meg/kg. Therefore, although the oils had values >1 indicating they were not fresh, the oils in this study did not go beyond the initial breakdown stage as defined by PV values. PV tests are better used for initial oil quality, before degradation beings, and are helpful in predicting stability of the oil. PV tests are also useful when changes are not complex and when you know the history of the oil as in accelerated storage studies. This test was concluded as not being a suitable quality control test for measuring oxidation and for monitoring frying oils.

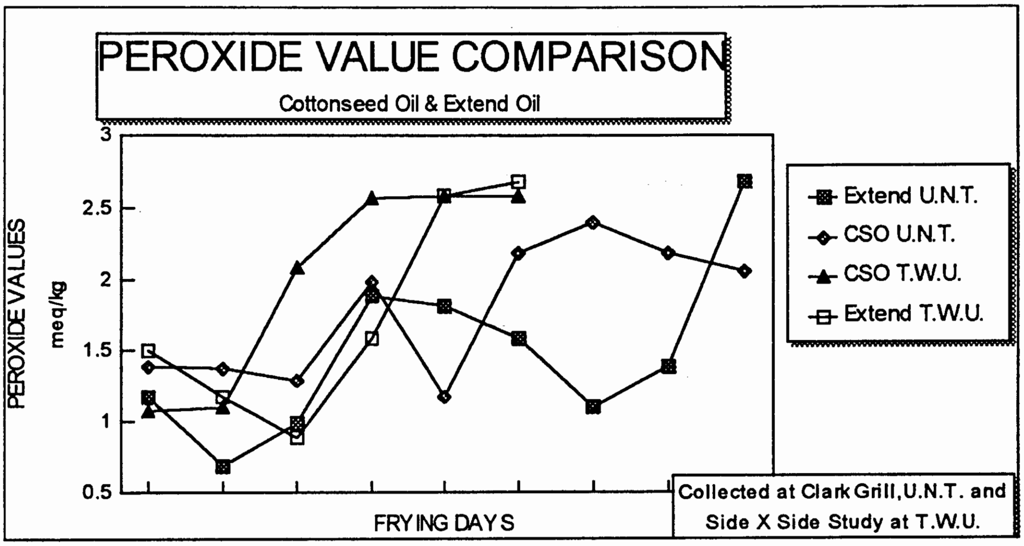

Figure 16. Summary of Peroxide Values

ALKALINE CONTAMINANT MATERIALS (ACM)

A hand held colorimetric quick test was developed for kitchen use to determine levels of ACM in the frying oil quickly. Although not found to be totally accurate, these speedy tests may be all that is needed in some instances (White, 1991). Tests were run at both university frying facilities regularly to see if there use would be of benefit. Generally, in the CSO, ACM values started off at B2 that is considered a high ACM by the test legend. The values for CSO remained steady at B2 and increased to B3 by day 3, remaining there until the oils were discarded at day 10. For the Extend® oil, the beginning value was at B3, and by day 4 changed to a mix of B3 and B4. By day 10, the value was up to B4 that is considered to be very high. ACM values were too close to show any difference, however a trend of increasing ACM as the oil degrades is shown. (Table 2) Very high ACM values are associated with 100-300 PPM of alkaline material. More highly degraded oils would be expected to have higher ACM values. Excessive ACM will cause the oil to degrade more quickly and so their presence is an indicator of breakdown

POLAR CONTAMINANT MATERIALS (PCM)

The hand held PCM test was developed by IUPAC-AOAC-DGF test methods for determination of polar matter, or breakdown products in the oil. During the two frying studies, PCM was monitored. (Table 2) For CSO, frying began at A2, changed to A3 by day 5 and remained there until the oil was discarded. For Extend® oil, PCM values also started at A2, changing at day 4 to A3, and again changing toward the end of the oil life to A4. A3 values correspond to 22% polar materials. A4 values correspond to 25% polar materials. 25% to 27% PCM has been adopted as the point at which oil should be discarded.

In summary, CSO tended to maintain lower PCM values throughout the trials as compared to Extend® oil. It appears that CSO maintains quality longer than Extend® oil if compared using this type of kit. Variations in amount and type of food fried could influence the PCM values although for the most part, frying patterns were consistent throughout the study. Again, these quick tests were developed for the food service worker without any complicated chemicals or testing so are better suited for that purpose.

ACM and PCM Analysis During Frying

CSO	DAY	PCM	ACM
05-Nov-97	0	A2	B2
06-Nov-97	1	A2	B2
07-Nov-97	2	A2	B2
10-Nov-97	3	A2	B3
11-Nov-97	4	A2	B3
12-Nov-97	5	A3	B3
13-Nov-97	6	A3	B3
14-Nov-97	7	A3	B3
17-Nov-97	8	A3	B3
18-Nov-97	9	A3	B3
EXTEND	**DAY**	**PCM**	**ACM**
03-Dec-97	0	A2	B3
04-Dec-97	1	A2	B3
05-Dec-97	2	A2	B3-4
08-Dec-97	3	A2	B3-4
09-Dec-97	4	A3	B3-4
10-Dec-97	5	A3	B3-4
11-Dec-97	6	A3	B3-4
12-Dec-97	7	A3	B3-4
15-Dec-97	8	A3-4	B3-4
16-Dec-97	9	A4	B4

Table 2. Results of the Alkaline Contaminant Material and Polar Contaminant Material Tests

GAS CHROMATOGRAPHY

TRANS FATTY ACIDS (TFAs)

TFAs in fresh CSO were negligible at 0.45%, and increased to 14.8% after 10 days. Fresh Extend® oil initially had a much higher trans value of 23.26% and increased minimally to 27.5% at the 10 day mark. High initial trans in Extend® canola oil can be attributed to the hydrogenation process. Although, CSO had a larger increase in trans, it had still almost half as much trans as the Extend® oil at the end of 10 days. Increases in trans after prolonged frying can more than likely be attributed to the change in the fatty acid profiles that occurs during degradation of oil. It also can be due to the additive effects of the food itself. Fatty acids also exhibit changes in saturation during frying. (Table 3)

TRANS FATTY ACID ISOMERS BY GAS CHROMATOGRAPH RESULTS

SAMPLE (Percent)	COTTONSEED OIL	Extend® HYDROGENATED CANOLA OIL
Fresh Oil	0.45	23.26
Ten Day Oil	14.8	27.5

Table 3. Trans Fatty Acid Summary (shown as percentages)

By Woodson-Tenent Laboratories, Inc. Memphis, Tennessee using Hewlett-Packard 5890 Gas Chromatograph, HP 7673 GC/SFC injector, HP 5890-3396 integrator, Supelco column 2-4023 60 m X 0.25 mm sp 2340, 0.20um fused silica capillary, Smalley Trans series check control, internal standard C13.

FATTY ACID CHANGES

Fatty acid changes were clearly seen in both oils used in the frying studies. Samples were run on the GC until results printed on the computer screen and then printed out on paper. Retention times were compared for the fresh, 3 day and 10 day oil samples of CSO (Figure 17) and Extend® oil. (Figure 18) Three major fatty acids in both oils were determined by comparing these retention times. For both oils, it was determined that (P) palmitic acid (16:0) had an average retention time of 12.26. (O) Oleic acid (18:1) had an average retention time of 16.06, and (L) linoleic acid (18:2) had an average retention time of 17.05. (Table 4)

CSO had an initial fatty acid profile that perfectly matched that of a textbook fatty acid profile. This would verify that the GC used at TWU gave accurate results. (Figure 17, 19) Explanation of these changes corresponds with what would be expected from frying oil degradation. CSO lost palmitic (16:0) saturated fatty acid. The trend for palmitic and oleic for the 0, 3 and 10 day oils increased. However, linoleic decreased to 3% by day 10, which would indicate that the two decreases in 16:0 and 18:2 correspond with the dramatic increase in oleic, a monounsaturated acid. There is so much degradation that is difficult to know why is this happening and why the relative decrease in (16:0).

Extend® oil exhibits a variation in these results. (Table 4) This PHCO maintains its oleic profile, although a slight decrease occurs at day 10. Both oleic (18:1) and linoleic (18:2) polyunsaturated fatty acids decrease gradually over the ten day period. There is an opposite effect on palmitic (16:0) in Extend® oil than there was in CSO. An increase in saturation occurred. Percentages increased from 6% to 11%. (Figure 18)

There could be different geometrical isomers forming, among other things. Also, polymerization and oxidation changes can affect the fatty acid profiles. Oil degrades more quickly with polymerization and oxidation. (Polymerization and oxidized fatty acids cannot be determined by the AOCS Method Ce 1-62 that was used in the TWU labs.) Polymers and trans can be eluted at the same time, further complicating the matter. Possibly the 18:2 are breaking down to form 18:1 trans in CSO since there was such a large increase in trans over the ten day period. 18:2 could be oxidized out of the system, making 18:1 go up. In addition, it is possible that the 18:1 only appear to be high and the trans came out with the 18:1. Co-elution of peaks can confuse matters making it difficult to determine specific fatty acid levels. Also, as seen on the graph, many peaks are muddled together probably relating to trans formation. Select absorption of saturated fatty acids more than the unsaturated fatty acids might also explain this.

We also have to consider that the fat from the food substrate could have additional effects. No definite conclusions can be made from the gas chromatograph results due to the dynamic changes within the system. Extend® oil may be following the path of expected changes. Research has noted that polyunsaturated fatty acid content decreases, creating an increase in saturates during frying, as seen in gas chromatograph results (Varvela, 1988). This is what happened with Extend® oil. Also, TFA did not change as dramatically. Perhaps the hydrogenation process curtails radical change in a hydrogenated oil until well past a 10 day period of frying.

To confirm and justify the fatty acid and trans fatty acid changes, more clear and concise methods, procedures and instrumentation need to be developed and implemented specific to this problem.

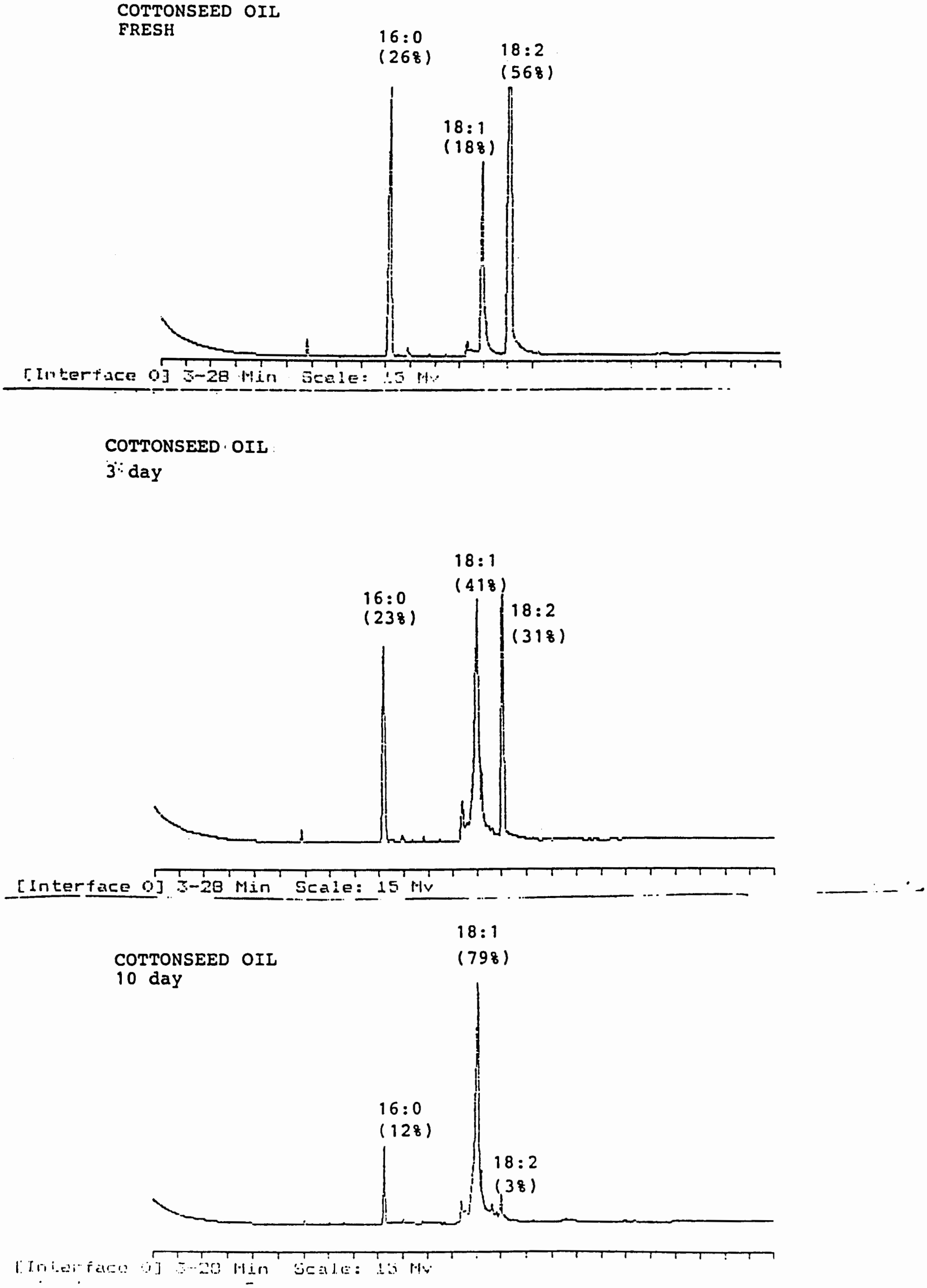

Figure 17. Fatty Acid Changes in CSO

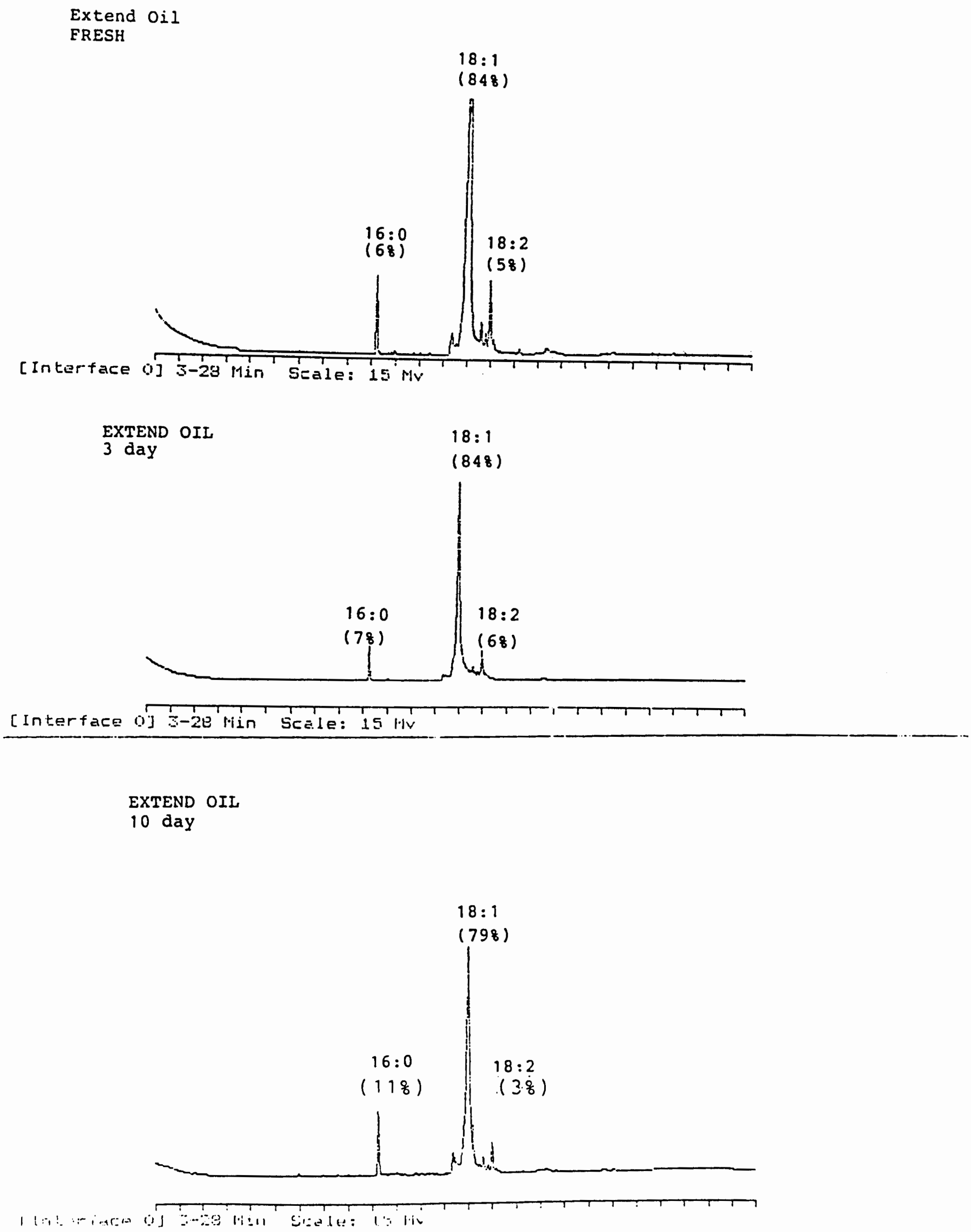

Figure 18. Fatty Acid Changes In Extend

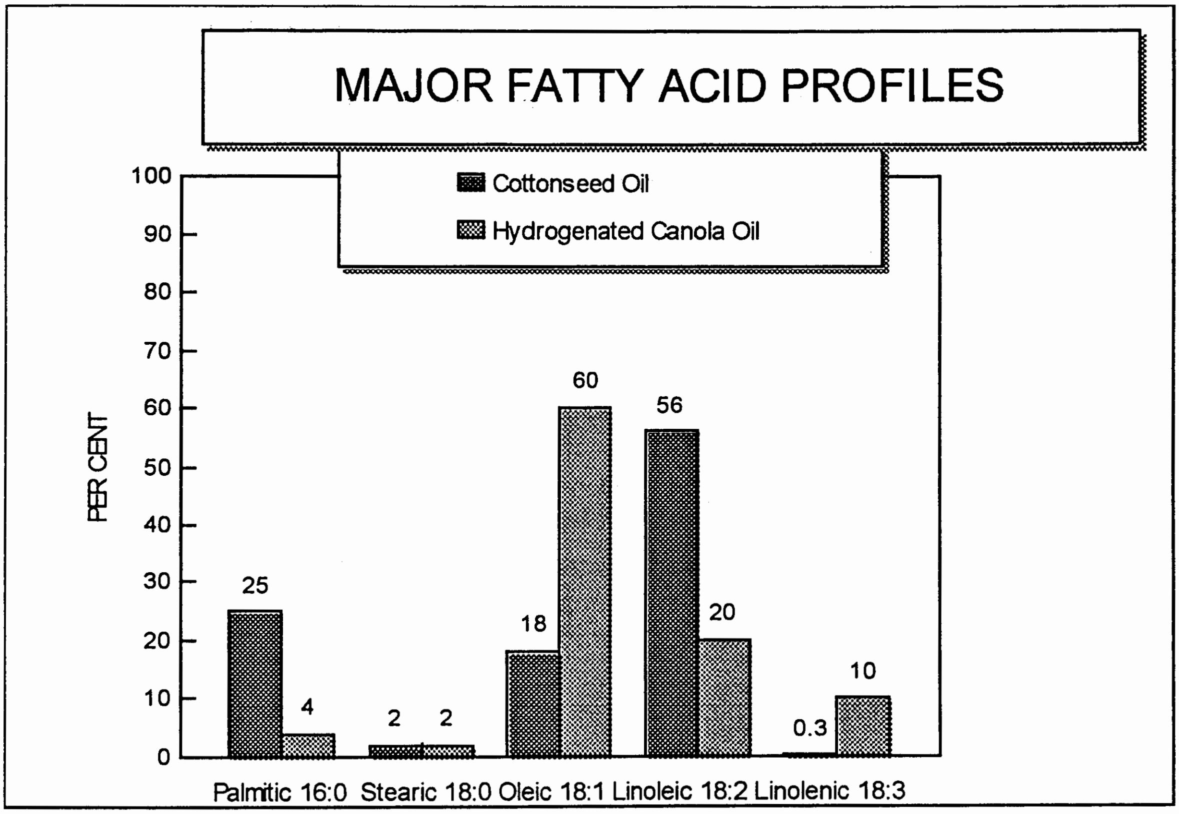

Figure 19. Typical Fatty Acid Profiles

	RETENTION TIMES and PERCENT		
CSO	Palmitic 16:0	Oleic 18:1	Linoleic 18:2
Day 0	12.23 26%	15.97 18%	17.15 56%
Day 3	12.26 23%	16.08 41%	17.14 31%
Day 10	12.29 12%	16.10 79%	17.03 3%
Extend			
Day 0	12.27 6%	16.13 84%	17.02 5%
Day 3	12.25 7%	16.03 84%	16.99 6%
Day 10	12.27 11%	16.09 79%	17.01 3%

Table 4. Percent Fatty Acids as Shown by Retention Times

OIL ABSORPTION AND MOISTURE CONTENT

Since there were several frying runs of Extend® oil and CSO, two runs that lasted 10 days each were chosen (without any unusual variations), to be the official runs for comparison. Several graphs and charts were made for each of the 18 Goldfisch runs and results were consistent with the two official runs. (Figure 20) Raw FFs were analyzed for a baseline resulting in an average of 2.2 g of oil in each pre-fried french fry.

MOISTURE

The raw fries had been pre-fried and analysis showed that on average there was 2.2g oil/100g potatoes. Moisture averaged 50% amongst all fries in both frying oils. Moisture did not appear to change over the course of the ten days for each oil, although it did increase over time (Figure 21).

OIL ABSORPTION

FFs fried in the fresh oils did not show significance at $p = .66$ using a 3D T-Test (BMDP Statistical Software, 1993). For the 10 day test period, CSO had total oil absorption averaging 5.2%. It might be expected that oil absorption should increase with time because greasiness increased. Also, panel comments indicated this trend. However, CSO showed an inconsistent pattern. The graph indicates that CSO had much lower fat absorption than Extend® oil (Figure 20).

Extend® exhibited a total oil absorption trend on days 3-6-9-10 of 9.4%-9.2%-8.9%-12.2%, averaging 9.9%. This shows that fat absorption for Extend® held steady until day 10 when a substantial increase was observed. Except for minor variations during the 10 day period, it appears that Extend® may have a larger influence on oil absorption. Oil content at day 10 of 12.2% was substantially more than CSO at 5.5%.

The TWU side - by - side study also showed a higher oil absorption for Extend®. The difference was minimal, and it appears to be consistent with the UNT results. Percentages of fat were averaged out for all replications at 8.2% total oil absorption for CSO and 9.0% for Extend® over the four days of collection (Figure 22). No significance was found at p =.25.

The average of all (4) runs of the oils collected at UNT at 10 days again showed some discrepancies in oil absorption. (Figure 23) For CSO, oil absorption was 6.5% total oil absorption. Again, Extend® had a larger oil absorption average of 9.4% Differences in oil absorption relate to many factors due to variability inherent in a food service frying operation. There was no significance found at p =.07.

Total oil absorption was calculated to make a two-way justification of percentage oil absorbed to amount of total food fried over each of the two official 10 day runs. (Figure 24) During the CSO run at UNT, 2,017 pounds of food was fried. Oil absorbed averaged over the ten day period equaled 110 pounds. For Extend® oil, 2,001 pounds of food was fried, and an average of 243.3 pounds of total oil was absorbed. This means more than twice as much Extend® oil should have been absorbed than CSO during the same time of 10 days. In addition, all runs were averaged and charted showing roughly the same ratio. (Figure 25) Since the absorption of oil into the CFS was not calculated, nor the actual pounds of oil involved in loss or disappearance taken into consideration, an assumption is made that the effect would be relative in both oils. Also, these food to oil ratios do not include the initial oil that fills up the vats, so this data does not reflect true oil to food ratios as set forth by most facilities.

Differences between the effects of the oils possibly can be attributed to increased polymerization due to the hydrogenation process, and/or differences in increased viscosity over age. The viscosity difference could account for more oil adhering to the fries and therefore being absorbed more at times than others. Variations throughout the study for all tests could have been due to the fat substrate; whether chicken fried steak was fried in the french fry oil vat more than usual, or if cross-over from the filtration process occurred. Variations in how the food was fried have to be considered. Different cooks use different methods of frying. For instance, sometimes the fries were pre-cooked and allowed to cool, then fried later. During cooling, the oil drained over the vat. Drainage procedure is a big factor in oil absorption. It is possible that the fries were not shaken in the same manner each time and more oil may have been absorbed at times. When in a hurry, cooks may not shake the baskets at all, but just pour the fries into a serving pan. Variations in the fries themselves can affect oil absorption. Fries are not uniform in size or shape and will absorb different amounts of oil. In addition, the pre-fried oils could vary between many the manufactured fries and could cause inconsistency in oil content and fatty acid profiles even before frying begin. Although attempts were made to get representative samples for each observation, it is almost impossible to distinguish these differences beforehand without adjusting for randomization when choosing samples. Also, fries on the bottom of the basket may have more oil in them because of oil dripping down onto them.

If the fries were not kept frozen until the actual frying of them, then oil absorption can also be a variable. In a frying operation, fries are taken out of the freezer and are inadvertently allowed to thaw due to consideration of time and of not having to go back and forth to the freezer. Frozen fries absorb less oil. Other effects on fat uptake include: the age of the oil, how long the fries were fried in the oil, how long they sat out uncovered before analyzing, how soon they were put into zip-lock bags, how cool or warm they were when ground before putting into the thimbles, and how accurate the scales used are because there are a multitude of calculations and weighing. It is possible that the longer the fries sat out, the more oil drained away from the fry. Another possibility for variability is how fast the hot fries were put into the zip-lock bags. This may cause more chances for the oil from the food to adhere to the bag. Also, oil can stick to the sides of the food grinder.

Variations in the Goldfisch itself causes numerous problems. For instance, if it is a cool day, the Goldfisch takes longer to complete fat extraction. It is also possible that all the fat was not extracted from the fries by the Goldfisch method. So many things occur in a food service operation that it is hard to get the same frying situation, therefore sample, each day.

In summary, it appears from this data that FFs fried in Extend® oil absorbed more oil consistently during any stage in the frying process, than FFs fried in CSO. However, from all the variables involved in frying and the influence on oil absorption, no significance can be expected nor should be stated without further evidence from a more controlled study. The data collected showed how much oil was used and how much food was fried which suggests that there may be a difference in the oils. Due to the limited scientific involvement at a food service facility, the nature of the fried product and frying variability, more research needs to be done before concluding that the actual absorption trend in this study is significant.

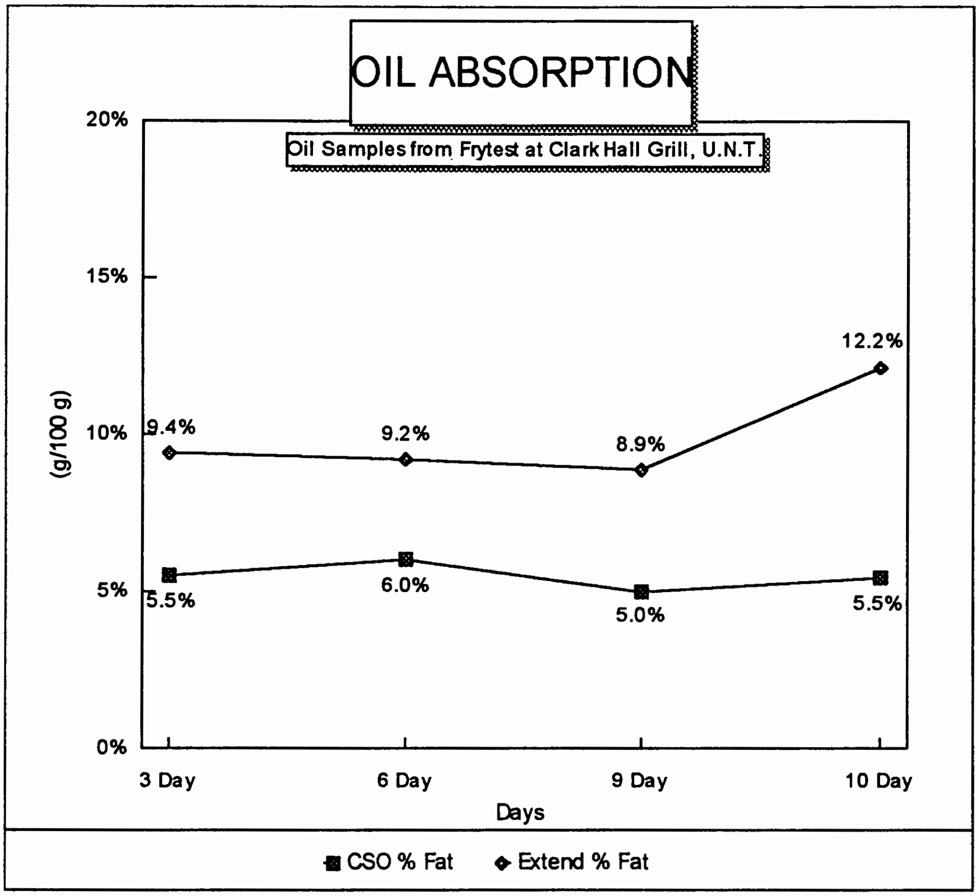

Figure 20. Total Oil Absorbed in UNT French Fries for the Two Official Runs

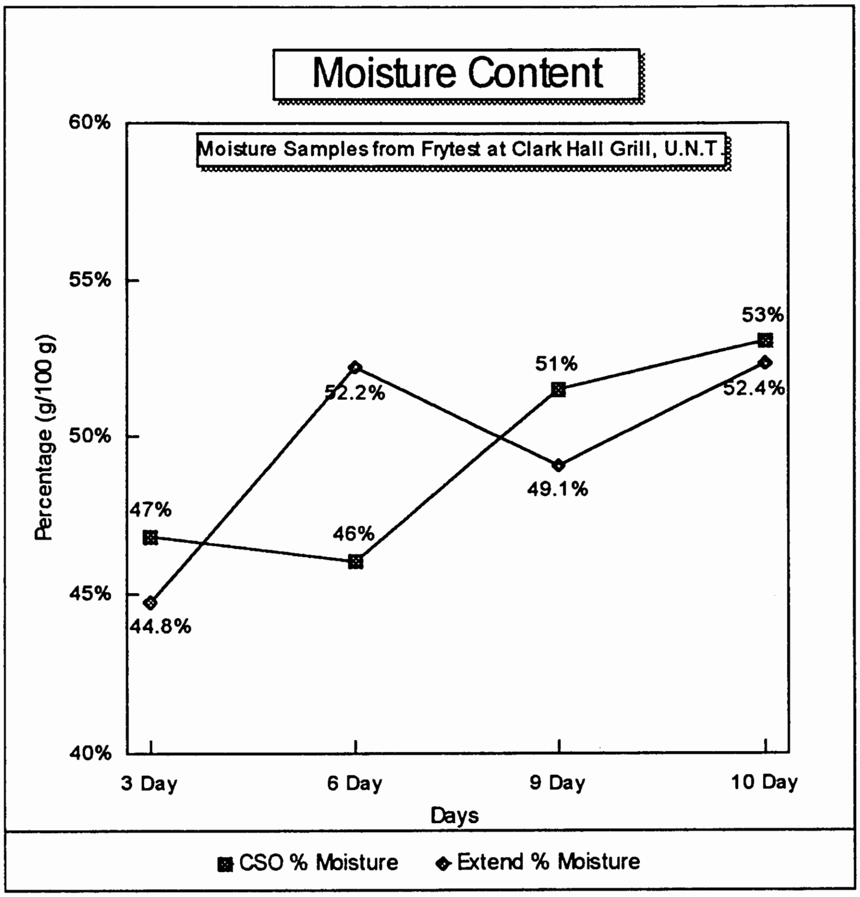

Figure 21. Moisture Content of Fried French Fries from UNT

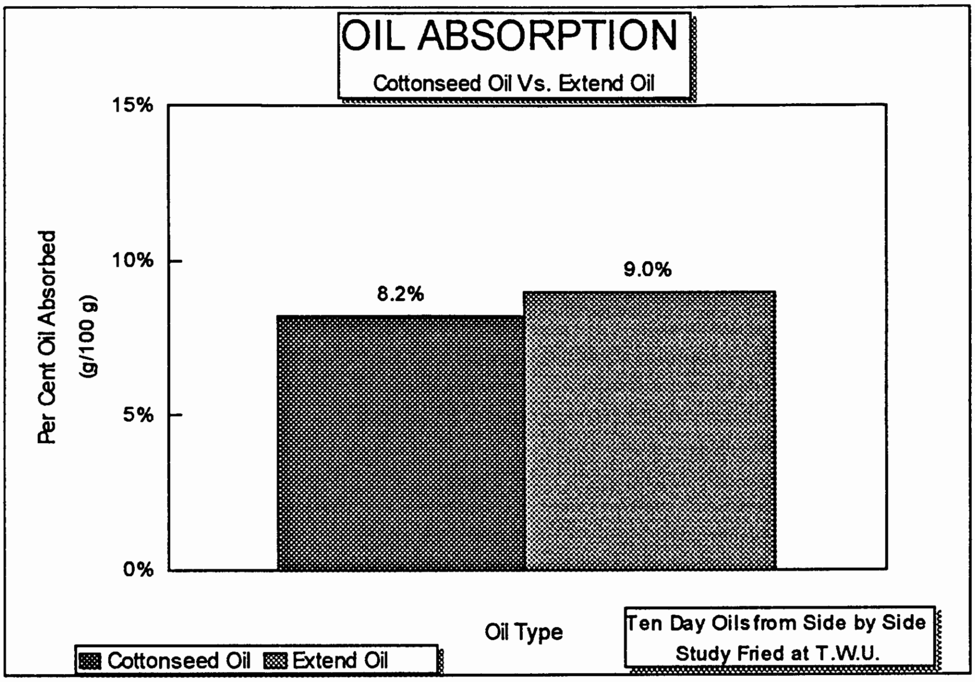

Figure 22. Oil Absorption at 10 days for the Side by Side Study at TWU

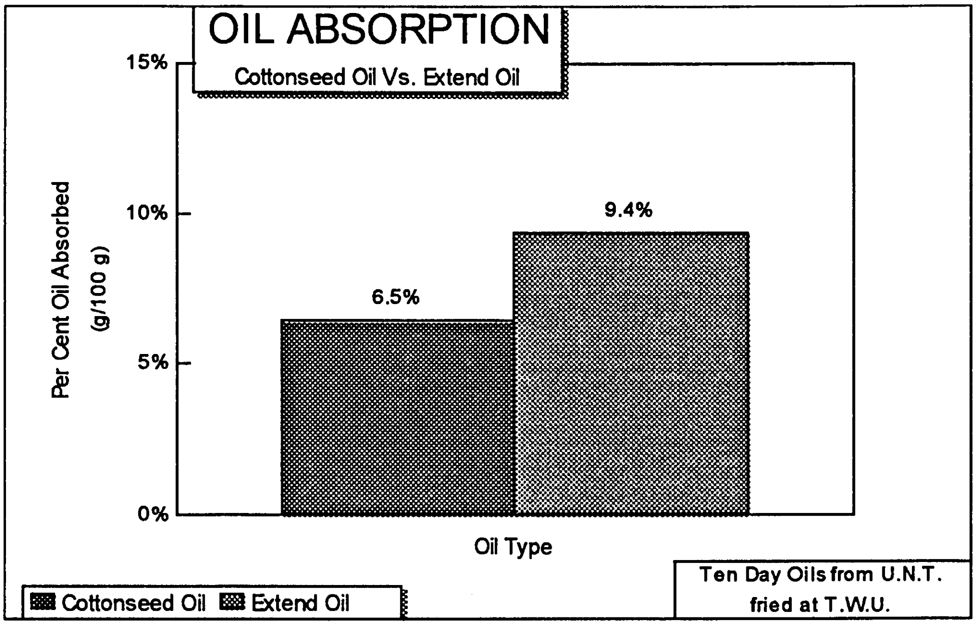

Figure 23. Average Oil Absorption of French Fries fried at TWU using UNT 10 day oils

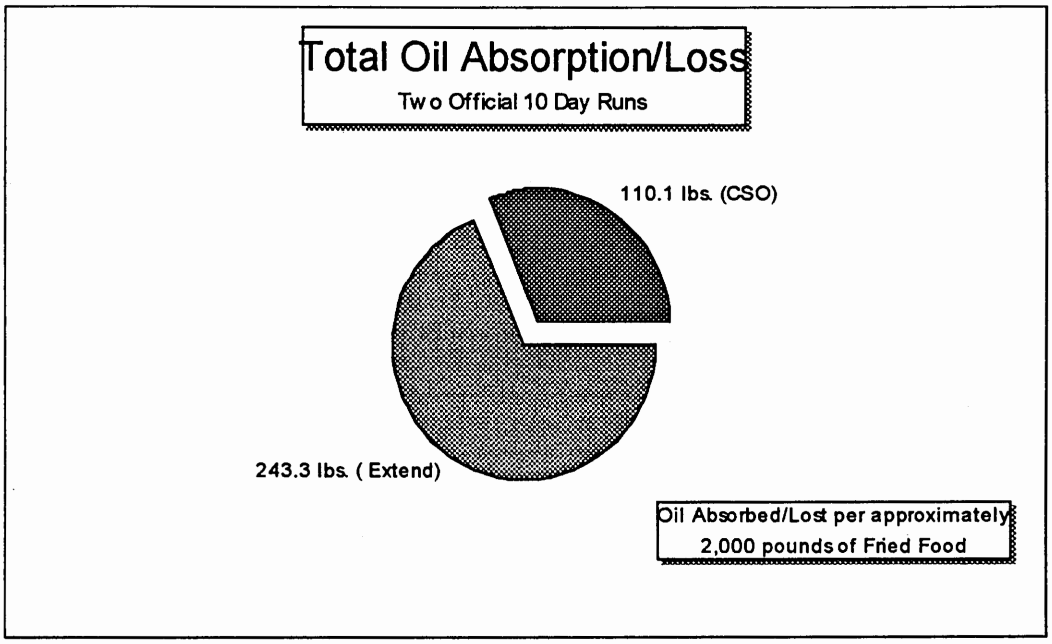

Figure 24. Total Oil Absorption or Loss for the Two Official Runs

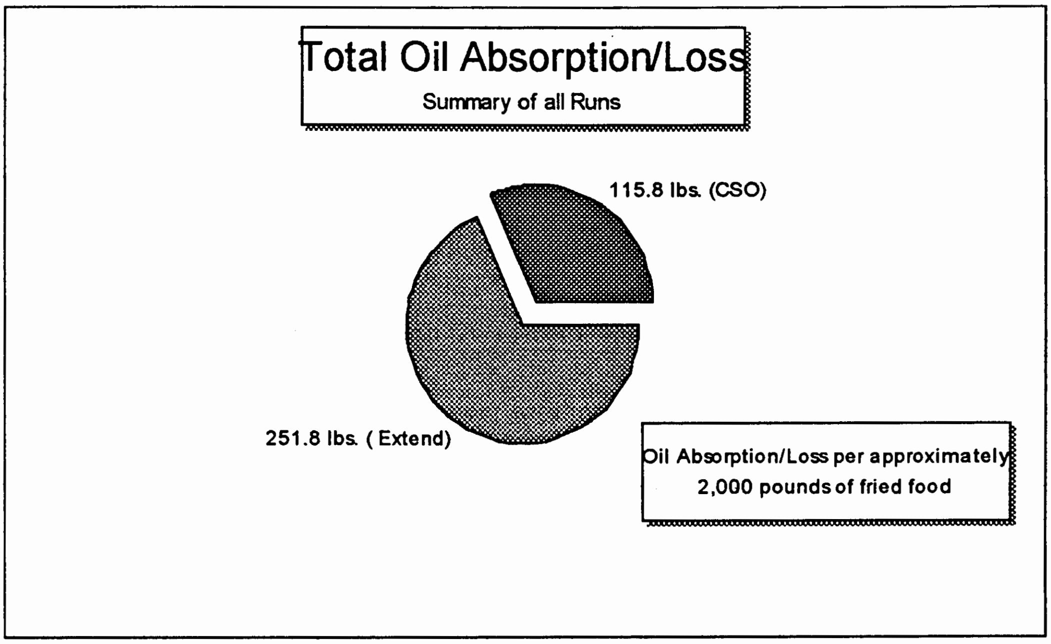

Figure 25. Average Oil Absorption for all Runs Combined

FOOD TO OIL RATIO

ECONOMICS

To a food service operator, cost is an important factor along with supplying a healthy product. One of the most important health concerns today is the type and amounts of nutrients we get from the foods we eat. Deep-fat frying of FFs causes the frying medium, which is the oil, to be absorbed by the food. This relates to losses in oil, and increased cost to the food service director. Extend® oil is a partially hydrogenated oil that has a high cost of processing associated with it due to hydrogenation. As of September 1997, Extend® oil cost $27.54 per 17.5 pound container ($55.08 for 35 pounds). In comparison CSO can be purchased by a commercial food facility for about $14.50 to $17.00 for a 35 pound container. This equates to a higher cost for Extend® of three times the amount for CSO.

The food to oil ratios was determined by adding up all the food fried in one day for the duration of the frying run, and the total pounds of oil used to fry it in. This included the initial 105 pounds of oil added to the empty vats and the oil added daily in the refreshing process. For research purposes, losses due to the sampling of oils for analysis were also considered and subtracted from the oil used. Disappearance or loss of oil could not be verified but was included as oil absorbed.

Figure 26 shows that CSO had lower food to oil ratio of 21.5 for those two particular runs. A summary graph containing all runs of both oils shows the same general affect on food to oil ratios, however, there was less difference between the results.

Extend® oil and CSO had similar ratios of 22.0 and 21.5 respectively. (Figure 27) In Figure 28 (summary graph of all runs), Extend® is also shown to have a slightly higher food to oil ratio. The large amount of oil on day 1 corresponds to the oil added to start the fry run. Day 3 is considered optimum for frying and CSO exhibited a higher level at that day, then continued to drop as did Extend®. At day 5, CSO seemed to drop a little lower than Extend®, however the difference was minimal. Small differences may be expected simply due to the differences in the frying process and the inability to follow the runs in a concise, scientific manner. Cooks merely estimated food cooked daily based on the number of servings per day. Oil was measured as added; however, oil added was a judgmental decision and varied tremendously between runs. The vats were never measured for oil loss during any point in the study. An assumption was made that the cook added just enough oil every day to get the oil to the same level each day. Oil losses cannot be accounted for other than absorption. Also, frying runs varied in the amount of days the oil was allowed to remain in use. These determinations were not scientific. Since all runs were on a trial basis, no time limit was set for any one run. Occasional holidays or special events effected amount of food fried, length of idle time of the oil, and fry life of the oil. Days varied from 6.5 to 12 days. There was no basis for discarding the oil except by individual judgment. Therefore the food to oil ratios cannot be considered as accurate ratios; they simply indicate the amount of oil that is lost during frying a certain amount of food.

Looking at all frying runs, there was not much difference found in the food to oil ratios. Variables make it impossible to derive a firm conclusion. There may be a difference in food to oil between the two oils, but further work needs to be done to establish any such difference.

In general, the higher the food to oil ratio, the more food that can be fried in the same amount of oil. This equates to lower food cost. Both oils have similar food to oil ratios, and both oils should be considered good frying oils. Since CSO holds up during frying just as long, without hydrogenation, it may be considered a good choice based on cost and on nutritional quality since it does not contain trans. The lack of hydrogenation that results in lack of trans fatty acids along with cost, may also make CSO a good choice from a nutritional perspective.

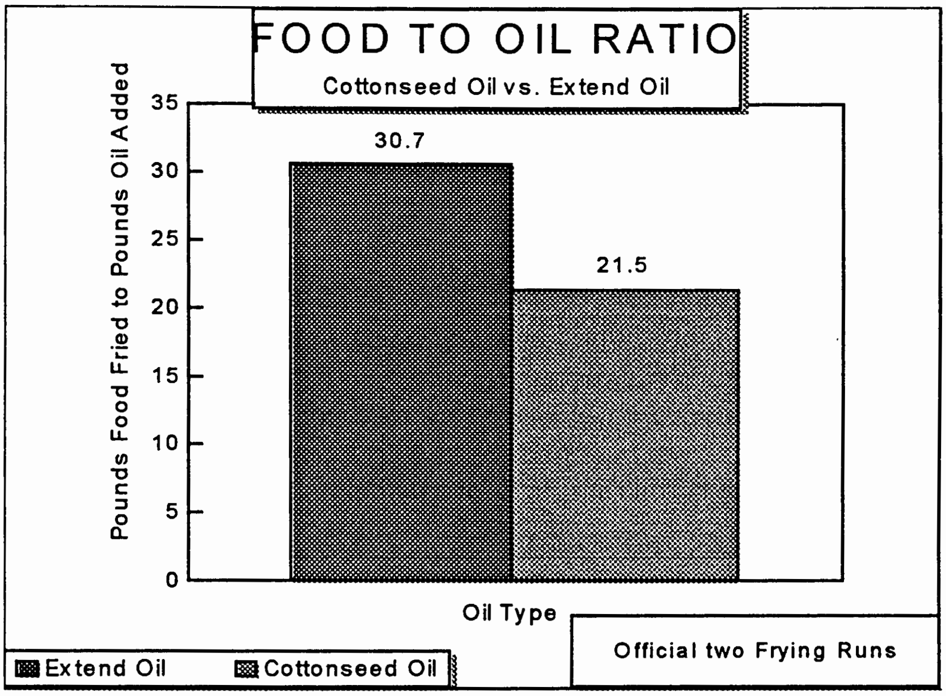

Figure 26. Food to Oil Ratio for the Two Official Frying Runs

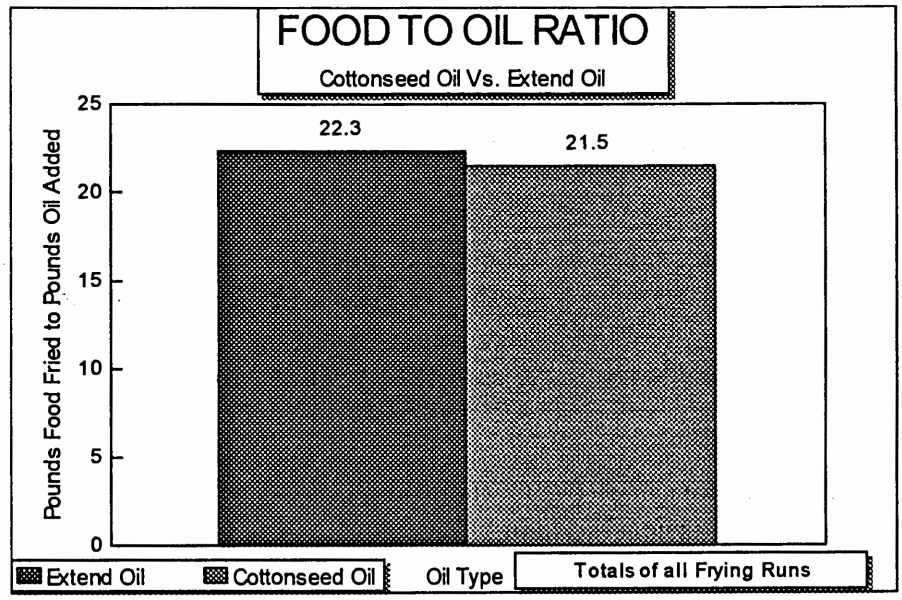

Figure 27. Food to Oil Ratio for all Runs Combined

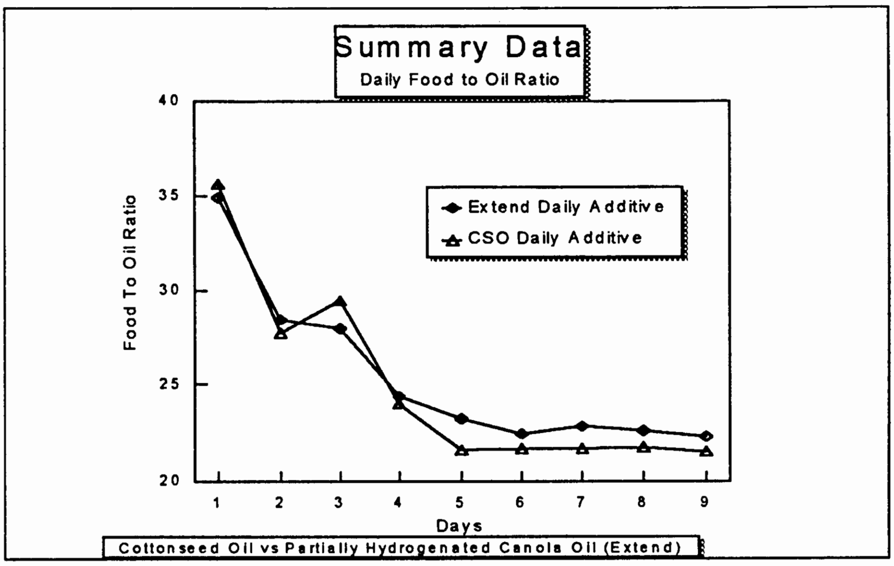

Figure 28. Food to Oil Ratio Summary Data for the Two Official Runs (Day 1 shows larger value due to initial addition of oil)

CHAPTER V

SUMMARY AND CONCLUSIONS

Since deep-fat fried foods continue to be popular in our everyday lives, finding an oil that minimizes the affects of frying on cholesterol and health would be a benefit. We could then increase the variety of the foods we eat, without losing nutrition or quality.

Trans results showed a much larger initial level of trans in Extend® (23.26%) due to hydrogenation then CSO (0.45%).

Extend® showed a higher increase in saturation at the end of the frying process, while CSO had a much improved fatty acid composition. The 18:2 and 16:0 fatty acids decreased while the more stable, healthy monounsaturated oleic acid increased dramatically.

Results for oil absorption were inconsistent. In one set of runs, oil absorption in Extend® was higher specially after 10 days; 12.16%. CSO had only 5.46% oil being absorbed. In another set of frying runs, the results were not as well defined. Extend® showed 13% and CSO showed 10.49% fat absorption. This could be attributed to a number of variations in procedure or products and not to the oils themselves.

Insignificantly less desirable food to fat ratios of (21.5:1) was observed in CSO than Extend®, which calculated at (22.3:1) also signifying that there may be no difference in oil absorption at 10 days. Sensory evaluations, moisture loss, peroxide values, total polar content were not significant after 10 days. There was some indication that CSO had the lead in many areas observed, however not significantly enough to make a statement. Due to the high cost of hydrogenation and several nutritional concerns, CSO would be a good choice for a frying operation based on these results. CSO is a versatile, stable, cost effective, nutritional oil that is accepted well in taste tests and has widespread consumer appeal. Its 26% saturation makes CSO naturally stable without hydrogenation.

Suggested Further Studies

Further studies comparing the effects of prolonged heating and frying using CSO and Extend® oil, other oil types or blends of oils need to be continued to take the oil degradation process to the uppermost end point. During this study, frying was discontinued after approximately ten days, based on quality control standards set by the University of North Texas. In order for accurate conclusions to be made on flavor and nutritional quality, additional time must be devoted to stressing the oils for a longer time in a scientific setting. In addition, more in depth chemical analysis and sensory evaluation may need to be considered to verify the results such as free fatty acid content changes and polymerization. Also, if a food service facility is used for a frying study, care should be given to ensure oil and food used is measured with more accuracy and that there is consistency in determining endpoint of the oils using an objective approach.

REFERENCES

AHA Nutrition Committee. (1982). American Health Association Committee Report: Rationale of Diet-Heart Statement of American Heart Association. Circulation 65: 839A-854A.

Anonymous. (1996a). Fryer oil treatment composition and method. Pamphlet by Miroil. US Patent No. 4: 349,451. Allentown, PA.

Anonymous. (1996b). Better frying is as easy as 1 2 3. Pamphlet by Miroil. US Patent No. 5,200.224 & 5,353.570. Allentown, PA.

ASCN (American Society for Clinical Nutrition). (1996) Special task force paper: Position paper on trans fatty acids. American Journal of Clinical Nutrition. 63: 663-70.

American Oil Chemist Society. (May 1991). Short course: Methods to Access Oil Quality and Stability. Oakbrook, Ill.

Banks, D. (1996). Food service frying. Chapt. in Deep Fat Frying. ed. Perkins, E.G. AOCS Press. Champaign, Ill.

Beare-Rogers, J. (1985). Methods for the Nutritional Assessment of Fats. American Oil Chemists Society.

Beckmann, H. J. (1983). Hydrogenation practices. Journal of The American Oil Chemists Society. 60: 282-290

Blankenship, D.C., & Alford, B.B. (1983). A Monograph: Cottonseed: The New Staff of Life. TWU Press, Denton, TX.

Blumenthal, M.M., Stockler, J.R., Summers, P.J. (1985). Alkaline contaminant materials in used frying oils: A new quick test. Journal of the American Oil Chemists Society. 62: 1373-1374.

Blumenthal, M.M. (1987). Optimum frying: Theory and practice. 2nd ed. Libra Laboratories Press. Piscataway, NJ.

Blumenthal, M.M. (1991). A new look at the chemistry and physics of deep-fat frying. Food Technology. Feb.: 68-71.

BMDP Statistical Software, Inc. (1993) Release 7.1. Los Angeles, CA.

Booth, C Wingett, Koch, S.(8/1994). Trial of New Treatment for Deep Fryers. Food Australia. 46(8)

Bysted, A., Holmer, G. & Lund, P. (1998). Influence of moderate amounts of *trans* fatty acids on the formation of polyunsaturated fatty acids. Journal of American Chemists Society. 75(2): 225-234.

Castelli, W.P. (1987). Dietary fat in nutrition and cardiovascular health.. Procter & Gamble.

Chang, S.S. (1967). Chemistry and technology of deep fat frying. Food Technology. 21, 33-41.

Chang, S.S., Peterson, R.J., Ho, C.T. (1978). Chemical reactions involved in the deep-fat frying of foods. Journal of the American Oil Chemists Society. 55: 718-727.

Charley, H. (1982). Food Science. 2nd ed. Prentice Hall. Englewood Cliffs, NJ.

Davis, J.W. (1992). Aristocrat in Burlap: A history of the potato in Idaho. Idaho Potato Commission.

Deis, R.C. (1997). Fats and oils: Health vs. functionality. Food Product Design. 29-55.

Deis, R.C. (1996). New age fats and oils. Food Product Design. 27-41.

Dijkstra, A.J. (1997). Hydrogenation revisited. Paper based on Stephan S. Chang acceptance lecture. Inform. 8(11): 1151-1152.

Erickson, D.R., List, G.R. (1994). Storage, handling, and stability of edible fats and oils. Chpt. in Bailey's Industrial Oil and Fat Products. 3(4): 273-304. ed. T. Applewhite, John Wiley & Sons.

Erickson, D.R., Frey, N. (1994). Property-Enhanced Oil. Food Technology. Nov.:63-68.

Escher, F. (1997). Potato chip oil fat uptake during frying. Seminar presented at Frito Lay, Dallas, TX. July 30.

Firestone, D., Stier, R.F., & Blumenthal, M.M. (1991). Regulation of Frying fats and oils. Food Technology. Feb.: 90-95.

Food and Agriculture Organization Paper 57. Fats and oils in human nutrition: Report of a joint expert consultation of the World Health Organization and the Food and Agriculture Organization. Unpub. 4611 Assembly Drive, Lanham, MD 20706.

Freeland-Graves, J.H. & Peckman, G.C. (1996). Foundations of Food Preparation. Prentice- Hall, Inc. Englewood Cliffs.

Friedman, B. Fritsch, C.W. (1981) Measurements of frying fat deterioration: A brief review. Journal of the American Oil Chemists Society. 58: 272-274.

Gamble, M.H., Rice, P., & Selman, J.D. (1987). Relationship between oil uptake and moisture loss during frying of potato slices from C.V. and U.K. tubers. International Journal of Food Science and Technology. 22: 233-41.

Giese, J. (1996). Fats, oils and fat replacers. Food Technology. Nov. (50): 78-83.

Grob, J. (1990). Fryer Design and Maintenance: Institutional fryers. Short Course on Deep Fat Frying of Foods: Science Practice. University of California at Davis. May. 1990.

Guillaumin, R. (1988). Kinetics of fat penetration in food. In frying of food: Principles, changes and new approaches. pp. 82-89. Ellis Horwood Ltd. Chichester.

Hammond, E. G. (1988). Trends in fats and oils consumption and the potential effects of new technology. Food Technology. Jan: 117-120.

Haumann, B.F. (1996). The goal: tastier and healthier fried foods. Inform. 7: 320-334.

Hermann, P. (Fall 1993). Fats: telling the good from the bad. Health News & Review. 2: 14

Hui, Y.H. (1996). Canola Oil; Chpt. in Bailey's Industrial Oil and Fat Products. Ch. 1: pp 1-95. John Wiley & Sons, Inc.

Hussain, S.S., & Morton, I.D. (1974). Absorption of food of frying oil. International Congres of Food Science and Technology. 1: 322-334.

International Food Information Council Foundation. (1993). IFIC Review: Sorting out the facts about fat. Http://ificinfo.health.org/review/ir-fat.html. Wash., D.C.

Johnson, B.A. (July 1997). The world according to french fries. Restaurants and Institutions. 35-48.

Jones, L.A., King, C.C. (1996) Chpt. in Bailey's Industrial Oil and Fat Products. Ch. 4: pp 159--240. John Wiley & Sons, Inc.

Jonnalagadda, S.S., Mustad, V.A., Yu, S., Etherton, T.D., Kris-Etherton, P. M. (1996). Effects of individual fatty acids on chronic diseases. Nutrition Today. May/June, 32(3): 90-106.

Kelly, T. (1997). Seminar: Deep-fat frying. Nutrition & Food Sciences, Texas Woman's University, Denton. Texas.

King, C.C., & Camire, E.E. (1989) Cottonseed oil as a frying medium. Journal of the American Oil Chemists Society. 66: 192-195.

Kulp, K., & Loewe, R. (1996). Batters and Breading in Food Processing. American Association of Cereal Chemists, Inc. St. Paul, MN.

Kuntz, L.A. (1995) Building better fried foods. Food Product Design. 129-146.

Lawless, H.T., & Classen, M.R. (1993). Application of the central dogma in sensory evaluation. Food Technology. 43: 139-146.

Levine, L. (1990a). Understanding frying operations. Cereal Food World. 35: 272-274.

Levine, L. (1990b). Understanding frying operations, part II. Cereal Food World. 35: 514.

Lichtenstein, A.H. (1995). Trans fatty acids and hydrogenated fat: what do we know? Nutrition Today. 30: 102-107.

Lowe, R., Nelson, P.M., Buchanan, J.H. The physical and chemical characteristics of lards and other fats in relation to their culinary value. III. For Frying Purposes. Iowa Agriculture Experimental Station Restaurant Bulletin. 279.

Lulai, E.C. (1986). Potato Specific Gravity. American Potato Journal. Aug.: 28-29.

Lulai, E.C., & Orr, P.H. (1979). Influence of potato specific gravity on yield and oil content of chips. American Potato Journal. 56: 380-390.

Lyderson, A.L. (1983). Mass Transfer in Engineering Practice. John Wiley & Sons. New York, NY.

Makinson, J. H. Greenfield, H., Wong, M.L. Y Wills, R.B. (1987). Fat uptake during deep fat frying of coated and uncoated foods. Journal of Food Composition Analysis. 1: 93-101.

May, W.A., Peterson, R.J., Chang, S.S. (1978). Synthesis of some unsaturated lactones and their relationship to deep-fat fried flavor. Food Science. 43: 1248-1252.

McDonald, R. E., & Mossoba, M.M. (1997). New Techniques and Applications in Lipid Analysis. AOCS Press. Illinois.

McMahon, K.E. (1995) Consumer Nutrition and Safety Trends. Nutrition Today. 30: 152-156.

Meilgaard, M., Civille, G.V. & Carr, B. (1991). Sensory Evaluation Techniques. CRC Press, Inc. Boca Raton.

Melton, S.L., Trigiano, M.P., & Yang, R.(1993). Potato chips fried in canola and/or cottonseed oil maintain high quality. Journal of Food Science. 58(5): 1079-1083.

Meyer, W. H. (1988). Food Fats and Oil. Institute of Shortening and Edible Oil, Inc. New York.

Moreira, R. G., Palau, J.E., Sun, X. Deep-fat frying of tortilla chips: An engineering approach. Food Technology. 49: 146-150.

Moskowitz, H. (1988). Applied Sensory Analysis of Foods. Vol. 1. CRC Press, Inc. Boca Raton, FL

Nawar, W.W. (1985) Lipids. Chpt. 4. in Food Chemistry. ed. O.R. Fennema. Marcel Dekker, Inc. NY.

Naylor, D., McGowen, E., Phengvath, P. Handel, A.P. (1992) Adsorbent_Treatment of Frying Oil Using Intermittent and Continuous Methods. University of Pennsylvania, Nutrition & Food Sciences. May.

Miroil. Pamphlet: New Frying Technology. Miroil, Division of Process Systems, Inc. Allentown, PA.

O'Neil, C. (July 1997). Lighten up french fries. Restaurants and Institutions. 151-4.

Orthoefer, F.T., Gurkins, S, Liu, K. (1996). Dynamics of frying. Chpt. in Deep Fat Frying: Chemistry, Nutrition, and Practical Applications. AOCS Press. Champaign, IL.

Perkins, E.G. (1967). Formation of non-volatile decomposition products in heated fats and oils. Food Technology. 21: 125-129.

Perkins, E.G., Visek, W. J. (1983). AOCS Monograph: Dietary Fats and Health. American Oil Chemists Society, Champaign, IL. Ch. 4: 21-51.

Perkins, E.G. (1996). Chpt. in Deep Fat Frying. ed. Perkins, E. G. Aocs Press. Ch. 3.p 44.

Pinthus, E.J. Weinberg, P., & Saguy, I.S. (1993). Criterion for oil uptake during deep fat frying. Journal of Food Science. 58: 204-222.

Richardson, I., Finley, J. (1985). Chemical Changes in Food During Processing. Avi Publishers, Westport,CT.

Robertson, C.J. (1967) The practice of deep fat frying. Food Technology. 21:34-26.

Roessler, E.B., Panghorn, R.M., Sidel, J.L., Stone, H. (1978). Expanded statistical tables for estimating significance in paired-preference, paired-difference, duo-trio and triangle tests. Journal of Food Science. 43: 940-941.

Sebidio, JL, Bonpunt, A, Grandgirard, A, Prevost, J. (1990). Deep fat frying of frozen pre-fried french fries: Influence of the amount of linolenic acid in the frying medium. Journal of Agricultural Food Chemistry. 38: 1862-1867.

Smith, L.M., Clifford, A. J., Creveling, R.K., Hamblin, C.L. (1985). Lipid content and fatty acid profiles of various deep-fat fried foods. Journal of the American Oil Chemists Society. 62 (6): 996-999.

Stauffer, C.E. (1996). Fats and Oils. Eagan Press, St. Paul, MN.

Steir, R.F., Blumenthal, M.M. (1990). Heat transfer in frying. Baking Snack System. 12: 15-19.

Stevenson, S. G., Slaubaugh M.R. (1984). Chemistry for Today: General, Organic and Biochemistry. 2nd ed. West Publishing Co. St. Paul, MN.

Talley, L.J., Rappole, C.L., & Burns, E.E. (1990). A Comparison of Commercial Frying Oils. University of Houston and Texas A & M University.

Takeoka, G.R., Full, G.H., & Dao, L.T. (1997). Effect of heating on the characteristics and chemical composition of selected frying oils and fats. Journal of Agriculture Food Chemistry. 45(8): 3244-3249.

Saguy, I. S., & Pinthus, E.J. (1995). Oil uptake during deep fat frying: Factors and mechanism. Food Technology. 50: 142-152.

Sebedio, J-L., Bonpunt, A, Grandgirard, & Prevost, J. (1990). Deep fat frying of frozen prefried french fries: Influence of the amount of linolenic acid in the frying medium. Journal of Agriculture Food Chemistry. 38: 1862-67.

Singh, R.P. (1995). Heat and mass transfer in foods during deep fat frying. Food Technology. 50: 34-137.

Smith, L.M., Clifford, A.J., Creveling, R.K., & Hamblin, C.L. (1985). Lipid content and fatty acid profiles of various deep-fat fried foods. Journal of the American Chemists Society. 62: 996-998.

Stauffer, C.E. (1996). Fats & Oils. Eagan Press. St. Paul, MN.

Steir, R.F., & Blumenthal, M.M. (1990) Heat transfer in frying. Baking Snack System. 12: 15-19.

Stone, H., McDermott, B.J., & Sidel, J.L. (1991). The importance of sensory analysis for the evaluation of quality. Food Technology. 45: 88-95.

Talburt, W.F., Smith, O. (1975). Potato Processing. Avi Publishing. Westport, CT.

Van Twisk, P.V., & Du Plessis, L.M. (1997a). Industrial frying oil - Basic Aspects. Palm Oil Technical Bulletin. Kuala Lumpur, Malaysia. Jan-Mar.

Van Twisk, P.V., & Du Plessis, L.M. (1997b). Industrial frying oil - Practical Aspects. Palm Oil Technical Bulletin. Kuala Lumpur, Malaysia. Mar-May.

Varvela, G. (1988). Current facts about the frying of food. Chpt. in Frying of food - Principles, Changes, New Approaches. pp. 8-119. VCHP Publishers, NY, N.Y.

Varvela, G., Ruiz-Roso, B. (1992). Some effects of deep fat frying on fat intake. Nutrition Reviews. 50(9): 256-262.

Warner, K., & Mounts, T.L. (1993). Frying stability of soybean and canola oil with modified fatty acid compositions. Journal of the American Oil Chemists Society. 70(10): 983-988.

Watkins, B. (1998). Trans fatty acids: A health paradox? Food Technology. 52(3): 120.

Weiss,T. J. (1983). Food Oils and Their Uses. 2nd ed. Avi Publishing. Westport, CT.

Woodruff, S., Blunt, K. (1919). Change in fats absorbed by fried foods. Journal of Home Economics. Oct.: 440-452.

Williams, A.W., Gray, C.E. (1918). Fat absorption in frying donuts. University of Illinois Bulletin. No. 47.

Weil, A. (1992). Margarine vs. Butter. Natural Health. March-April (12).

White, P. J. (1991). Methods for measuring changes in deep-fat frying oils. Food Technology. Feb.: 75-80.

Wilsey Foods (1997). Pamphlet by Deep Fat Frying Quality Management. City of Industry, CA.

Woolfe, J.A. (1987). Potato in the Human Diet. pp. 34-55, 122-189. Cambridge University Press, Great Britain.

APPENDIX A.

Duo-Trio Difference Test Ballot

Test No.: __________ Panelist No.: __________

DUO-TRIO DIFFERENCE TEST

Product:

Instructions: Proceed when you are ready. (Quietly so as not to distract others.)

1.) Take a bite of cracker and a sip of water to rinse your mouth.
2.) Taste the reference R first, then taste the coded pair of samples.
3.) Circle the number of the sample which is THE SAME as the reference R.

R __________ __________

4.) Why is R and the sample you chose the same?

____

____

THANK YOU VERY MUCH!!

DUO-TRIO Difference Test

APPENDIX B

Duo-Trio Difference Test With Preference Ballot

Test No.: J5FF97008 Panelist No.: ___________

DUO-TRIO DIFFERENCE TEST

Product:

Instructions: Proceed when you are ready. (Quietly so as not to distract others.)

1.) Take a bite of cracker and a sip of water to rinse your mouth.
2.) Taste the reference R first, then taste the coded pair of samples.
3.) Circle the number of the sample which is THE SAME as the reference R.

R ___________ ___________

4) Taste the samples again, Then circle the one you prefer.

___________ ___________

5) Describe the reasons why you preferred the one you chose.

APPENDIX C.

Respondent Screening Sheet

RESPONDENT SCREENING SHEET PANELIST No. _______
TEST No. JSFE97009

THESE FRENCH FRIES ARE DEEP-FAT FRIED IN 100% PURE VEGETABLE OILS

QUESTIONS:	YES	NO
Do you like FRENCH FRIES?	______	______
Would you be willing to taste FRENCH FRIES?	______	______

If you answered "NO", please STOP HERE and infrom the screener that you prefer NOT to participate in the current test.

Please check the appropriate lines which pertain to you:

SEX: Male	_______	AGE: under 18	_____	30-44	_____
Female	_______	18-29	_____	45-65	_____
		over 65	_____		

APPENDIX D.

Oil Evaluation Ballot

EVALUATION OF UNT FRENCH FRY OIL (VAT B)

DAY / DATE: ______________________ **OIL TYPE: CSO / EXTEND**

1) OIL AGE (DAYS IN VAT)

0	1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16	17
18	19	20	21	22	23	24	25	26

2) OIL AGE (DAYS IN USE): ____________

3) SMOKING

1	2	3	4	5
None	Light	Moderate	Substantial	Heavy

4) SERVINGS FFAM: ____________ SERVINGS FFPM: ____________________

5) POUNDS FF: ________________ POUNDS FF TO DATE: _________________

6) OIL ADDED: ________________ OIL ADDED TO DATE: _________________

7) OIL REMOVED: ______________ OIL REMOVED TO DATE: ______________

8) FOOD TO OIL RATIO: _________________

9) ALKALINITY: __________________

10) POLAR CONTENT: ______________

11) FILTERING TIMES TODAY: AM: ___________ PM: _____________
TIMES FILTERED TO DATE: ___________

12) FILTER CHANGE TIME: ________________
TIMES FILTER CHANGED TO DATE: _________________

Oil Evaluation Ballot

APPENDIX E.

Four Attribute Likeability Ballot

Test No. UNTFF97001 PRODUCT: FRENCH FRIES Panelist No. ________

Instructions: **Before you eat anything on your plate**, please taste several French Fries **WITHOUT salt, ketchup, gravy or other condiment**. Please taste enough French Fries to form an opinion of the intensity of the attribute and **CIRCLE** the number which best expresses that opinion. Return the test and pencil for your prize.

Please taste several French Fries WITHOUT CONDIMENTS, then **CIRCLE** the number which best expresses your opinion of the **INTENSITY** of the attribute.

1) GREASINESS

1	2	3	4	5	6	7	8	9
Not Greasy				Somewhat Greasy				Very Greasy

2) CRUST CRISPINESS

1	2	3	4	5	6	7	8	9
Very Soggy				Slightly Soggy / Slightly Crispy				Very Crispy

3) FRIED FLAVOR

1	2	3	4	5	6	7	8	9
Flavorless				Moderate Flavor				Very Strong Flavor

4) OVERALL LIKEABILITY

1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike				Like Extremely

THANK YOU FOR YOUR ASSISTANCE WITH OUR RESEARCH!!!!

Four Attribute Likeability Ballot

APPENDIX F.

Six Attribute 2-Sample Likeability Ballot

Test No. KSFF97001 PRODUCT: FRENCH FRIES Panelist No. ________

INSTRUCTIONS: Please evaluate one sample at a time, working from TOP to BOTTOM. Proceed when you are ready. (Quietly, so as not to distract others.) Second sample is evaluated on BACK page.

FOR EACH SAMPLE: Take a bite of cracker and a sip of water to rinse your mouth. Please taste the appropriate sample, then **CIRCLE** the number which best expresses your opinion of that sample for the following attributes.

SAMPLE ________

1) GREASINESS

1	2	3	4	5	6	7	8	9
Not Greasy				Somewhat Greasy				Very Greasy

2) CRISPINESS

1	2	3	4	5	6	7	8	9
Very Soggy				Slightly Soggy / Slightly Crispy				Very Crispy

3) TENDERNESS

1	2	3	4	5	6	7	8	9
Very Smooth				Slightly Smooth / Slightly Rough				Very Rough

4) MOISTNESS

1	2	3	4	5	6	7	8	9
Very Dry				Somewhat Moist				Very Moist

5) FRIED FLAVOR

1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither Like Nor Dislike				Like Extremely

6) OVERALL LIKEABILITY

1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither Like Nor Dislike				Like Extremely

<u>Six Attribute 2-Sample Likeability Ballot</u>

SAMPLE ________

1) GREASINESS

1	2	3	4	5	6	7	8	9
Not Greasy				Somewhat Greasy				Very Greasy

2) CRISPINESS

1	2	3	4	5	6	7	8	9
Very Soggy				Slightly Soggy / Slightly Crispy				Very Crispy

3) TENDERNESS

1	2	3	4	5	6	7	8	9
Very Smooth				Slightly Smooth / Slightly Rough				Very Rough

4) MOISTNESS

1	2	3	4	5	6	7	8	9
Very Dry				Somewhat Moist				Very Moist

5) FRIED FLAVOR

1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither Like Nor Dislike				Like Extremely

6) OVERALL LIKEABILITY

1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither Like Nor Dislike				Like Extremely

CIRCLE WHICH SAMPLE YOU PREFER AND COMMENT WHY? ________ ________

____

____

____

APPENDIX G.

Sensory Evaluation Laboratory Notice

ATTENTION

SENSORY TESTING
THIS WEEK!

WEDNESDAY OCT. 29

THURSDAY OCT. 30
10 TO 5 PM or CLOSE

FRENCH FRIES

FREE PRIZES!

Please come and get a FREE snack and drink!

Human Development Bldg. Room GOO8
(Basement)

APPENDIX H.

Duo-Trio Master Sheet

Duo-Trio Master Sheet

TWO SAMPLE MASTER SHEET

DAY/ DATE: ____________________ PRODUCT: FRENCH FRIES TEST #: __________
TIME START: ________ TIME END: ________ LIGHT: RED/WHITE SERVED: 1st / 2nd

Product # 1. ____________________ Product # 2: ____________________
Oil Type/ Age: ____________________ Oil Type/ Age: ____________________

Panel	Product # 1	Product # 2	Reference		Panel	Product # 1	Product # 2	Reference	
1	B____	A____	R	CSO	31	A____	B____	R	CSO
2	B____	A____	R		32	B____	A____	R	
3	B____	A____	R		33	B____	A____	R	
4	A____	B____	R		34	A____	B____	R	
5	A____	B____	R		35	A____	B____	R	
6	B____	A____	R	Extend	36	A____	B____	R	Extend
7	A____	B____	R		37	B____	A____	R	
8	B____	A____	R		38	B____	A____	R	
9	B____	A____	R		39	A____	B____	R	
10	B____	A____	R		40	B____	A____	R	
11	A____	B____	R	CSO	41	A____	B____	R	CSO
12	B____	A____	R		42	B____	A____	R	
13	A____	B____	R		43	A____	B____	R	
14	A____	B____	R		44	A____	B____	R	
15	A____	B____	R		45	B____	A____	R	
16	B____	A____	R	Extend	46	B____	A____	R	Extend
17	A____	B____	R		47	B____	A____	R	
18	B____	A____	R		48	A____	B____	R	
19	A____	B____	R		49	B____	A____	R	
20	B____	A____	R		50	B____	A____	R	
21	A____	B____	R	CSO	51	A____	B____	R	CSO
22	A____	B____	R		52	A____	B____	R	
23	B____	A____	R		53	B____	A____	R	
24	B____	A____	R		54	A____	B____	R	
25	A____	B____	R		55	B____	A____	R	
26	A____	B____	R	Extend	56	A____	B____	R	Extend
27	B____	A____	R		57	A____	B____	R	
28	B____	A____	R		58	B____	A____	R	
29	A____	B____	R		59	A____	B____	R	
30	A____	B____	R		60	B____	A____	R	

DEMOGRAPHICS:	FEMALE	MALE
18 - 29		
30 - 44		
45 - 65		
> 65		

N = ________

APPENDIX I.

Sensory Testing Instructions

SENSORY - TASTE TESTING

The following are a few suggestions to make TASTE TESTING an enjoyable experience for you, and less time consuming.

◆◆

First, sign your name on the sign-in sheet located in room HDB G009. When there are (2) sign-in sheets you may do BOTH of the tests one after the other. Please sign both sign-in sheets!

After signing in, proceed to the testing booths, choose an empty booth. If all Booths are full, please wait quietly in the hall forming a line if necessary. We will get you in a booth as soon as possible.

◆◆

Once inside the testing booth, turn on the green light, **then you will receive a tray. When you have received your tray, turn off the** green light. ***Read your ballot carefully and follow the instructions.*** **When you are through with your taste test, turn on your** red light.

Wait in the booth until your tray has been picked up, then turn off your *red light* ***before you leave the booth.***

◆◆

When you leave the booth, come to the other side of the lab to room G008, and you may be further instructed on the finality of your ballot or test. You will receive a "prize" as a thank you for doing the taste test.

Sensory Testing Instructions

APPENDIX J.

Food to Oil Worksheets

EXTEND OIL
Food to Oil Ratio
Eight frying days

DATE FRIED	French Fries Pounds	Chicken Fried Steak Pounds	Oil Added Next A.M. Pounds	Oil Taken Pounds	Cumulative Food to Oil Ratio
09-Oct-97	182.63	60.00	0.00	0.00	0.00
10-Oct-97	131.25	37.00	7.00	0.00	24.04
13-Oct-97	225.94	86.50	14.00	0.00	22.32
14-Oct-97	182.81	82.50	14.00	0.00	18.95
15-Oct-97	164.06	63.00	12.25	0.00	18.54
16-Oct-97	178.13	93.50	7.00	0.00	38.80
17-Oct-97	140.63	44.00	14.00	0.00	13.19
20-Oct-97	167.81	74.00	14.00	0.00	17.27
TOTALS	**1,373.26**	**540.50**	**82.25**	**0.00**	**23.27**
Total Pounds	**1,913.76**		**82.25**		
Food:Fat Ratio	**23.27 :1**				

Food to Oil Ratio Worksheets

EXTEND OIL
Food to Oil Ratio
Nine frying days

DATE FRIED	French Fries Pounds	Chicken Fried Steak Pounds	Oil Added Next A.M. Pounds	Oil Taken Pounds	Cumulative Food to Oil Ratio
03-Dec-97	178.13	34.00	7.00	(0.75)	33.94
04-Dec-97	168.75	60.50	7.00	(0.75)	36.68
05-Dec-97	192.19	34.50	7.00	(0.75)	36.27
08-Dec-97	206.25	77.00	12.25	(0.63)	24.37
09-Dec-97	178.13	56.50	14.00	(0.63)	17.54
10-Dec-97	168.75	30.50	3.50	(0.75)	72.45
11-Dec-97	168.75	56.25	3.50	(0.75)	81.82
12-Dec-97	168.75	31.25	10.50	(0.75)	20.51
15-Dec-97	150.00	40.75	6.96	(0.75)	30.72
TOTALS	**1,579.70**	**421.25**	**71.71**	**(6.50)**	**30.68**
Total Pounds	**2,000.95**		**65.21**		
Food:Fat Ratio	**30.68 :1**				
	150	40.75	49	-0.75	
	30.68				

COTTONSEED OIL
Food to Oil Ratio
Nine frying days

DATE FRIED	French Fries Pounds	Chicken Fried Steak Pounds	Oil Added Next A.M. Pounds	Oil Taken Pounds	Cumulative Food to Oil Ratio
22-Oct-97	210.94	67.25	5.25	0.00	52.99
23-Oct-97	182.81	57.50	12.25	0.00	19.62
24-Oct-97	182.81	30.25	8.75	0.00	24.35
27-Oct-97	234.38	67.25	17.50	0.00	17.24
28-Oct-97	196.88	57.00	17.50	0.00	14.51
29-Oct-97	251.06	56.75	14.00	0.00	21.99
30-Oct-97	186.56	65.50	8.75	0.00	28.81
31-Oct-97	112.50	26.50	8.75	0.00	15.89
03-Nov-97	187.50	52.50	10.50	0.00	22.86
TOTALS	**1,745.44**	**480.50**	**103.25**	**0.00**	**21.56**
Total Pounds	**2,225.94**		**103.25**		
Food:Fat Ratio	**21.56 :1**				

COTTONSEED OIL
Food to Oil Ratio
Nine frying days

DATE FRIED	French Fries Pounds	Chicken Fried Steak Pounds	Oil Added Next A.M. Pounds	Oil Taken Pounds	Cumulative Food to Oil Ratio
05-Nov-97	168.75	47.00	9.63	(1.00)	25.00
06-Nov-97	168.75	60.00	9.63	(1.00)	26.51
07-Nov-97	140.63	38.75	3.50	(1.00)	71.75
10-Nov-97	178.13	43.75	15.75	(1.00)	15.04
11-Nov-97	168.75	45.50	14.00	(1.00)	16.48
12-Nov-97	234.38	60.00	14.00	(0.50)	21.81
13-Nov-97	168.56	60.00	14.00	(1.00)	17.58
14-Nov-97	168.75	34.00	7.00	(0.50)	31.19
17-Nov-97	178.13	53.00	14.00	(0.50)	17.12
TOTALS	**1,574.83**	**442.00**	**101.51**	**(7.50)**	**21.45**
Total Pounds	**2,016.83**		**94.01**		
Food:Fat Ratio	**21.45 :1**				

EXTEND OIL
Food to Oil Ratio
Twelve frying days

DATE FRIED	French Fries Pounds	Chicken Fried Steak Pounds	Oil Added Next A.M. Pounds	Oil Taken Pounds	Cumulative Food to Oil Ratio	MEAN
08-Sep-97	140.63	25.50	14.00	0.00	11.87	1
09-Sep-97	140.63	70.50	10.50	0.00	20.11	2
10-Sep-97	140.63	75.00	8.75	0.00	24.64	3
11-Sep-97	305.25	94.50	28.00	0.00	14.28	4
12-Sep-97	140.63	25.50	14.00	0.00	11.87	5
15-Sep-97	145.31	76.25	17.50	0.00	12.66	6
16-Sep-97	196.88	80.00	17.50	0.00	15.82	7
17-Sep-97	168.75	54.50	15.75	0.00	14.17	8
18-Sep-97	225.00	78.50	17.50	0.00	17.34	9
19-Sep-97	131.25	50.00	7.00	0.00	25.89	10
22-Sep-97	201.56	66.00	19.25	0.00	13.90	11
23-Sep-97	271.88	84.25	14.00	0.00	25.44	12
TOTALS	**2,208.40**	**780.50**	**183.75**	**0.00**	**16.27**	17.33
Total Pounds	**2,988.90**		**183.75**			
Food:Fat Ratio	**16.27 :1**					

EXTEND OIL
Food to Oil Ratio
Eight frying days

DATE FRIED	French Fries Pounds	Chicken Fried Steak Pounds	Oil Added Next A.M. Pounds	Oil Taken Pounds	Cumulative Food to Oil Ratio
25-Sep-97	201.56	63.00	7.00	0.00	37.79
29-Sep-97	201.56	75.00	10.50	0.00	26.34
30-Sep-97	222.75	70.00	10.50	0.00	27.88
01-Oct-97	206.25	55.00	10.50	0.00	24.88
02-Oct-97	210.00	63.50	14.00	0.00	19.54
03-Oct-97	112.50	26.25	0.00	0.00	ERR
06-Oct-97	210.94	90.00	10.50	0.00	28.66
07-Oct-97	145.31	51.00	2.45	0.00	80.13
TOTALS	**1,510.87**	**493.75**	**65.45**	**0.00**	**30.63**
Total Pounds	**2,004.62**		**65.45**		
Food:Fat Ratio	**30.63 :1**				
	0.1875				
	1075	3225			
	201.5625	201.5625			
	1075				
	3				
	3225				
	201.5625				

APPENDIX K.

Oil Absorption Worksheets

A **UNCOOKED FRIES 2nd Run**

22-Jan-98

	Raw Fries 1	2	3	4	5	6
A. Beaker	63.8348	65.9312	58.7614	65.4505	65.0421	66.4330
After	63.9922	66.0241	58.8183	65.5397	65.1234	66.5155
B. Extracted Fat	0.1574	0.0929	0.0569	0.0892	0.0813	0.0825
C. (1)Thimble	13.9222	13.1101	12.9025	13.1697	13.1710	13.5493
(2)Thimble plus Sample Before	18.1098	18.1696	16.8370	18.0700	17.8182	18.5446
(3)Thimble plus Sample After	15.1425	14.5739	14.0446	14.6222	14.5482	15.0497
D. Sample (C 1 -C2)	4.1876	5.0595	3.9345	4.9003	4.6472	4.9953
E. Moisture (C2 -C3)	2.9673	3.5957	2.7924	3.4478	3.2700	3.4949
F. Percent Fat Content (B/D)	3.76%	1.84%	1.45%	1.82%	1.75%	1.65%
G. Moisture Percent (E /D)	70.86%	71.07%	70.97%	70.36%	70.36%	69.96%
H. **Average of Fat**	**2.02%**					
Average of Moisture	**70.58%**					

UNCOOKED FRIES

07-Nov-97

	Raw Fries 1	2	3
A. Beaker	63.4376	63.8470	64.8651
After	63.5184	63.9606	64.9259
B. Extracted Fat	0.0808	0.1136	0.0608
C. (1)Thimble	14.1869	13.1110	12.9605
(2)Thimble plus Sample Before	18.1173	16.7000	16.1812
(3)Thimble plus Sample After	16.1048	15.0184	14.4420
D. Sample (C 1 -C2)	3.9304	3.5890	3.2207
E. Moisture (C2 -C3)	2.0125	1.6816	1.7392
F. Percent Fat Content (B/D)	2.06%	3.17%	1.89%
G. Moisture Percent (E /D)	51.20%	46.85%	54.00%
H. **Average of Fat**	**2.38%**		
Average of Moisture	**50.59%**		

Oil Absorption Worksheets

B **Day 3 French Fries Fried in Cottonseed Oil @ University of North Texas**

07-Nov-97

	******* ******* Fried	Fries *******	*******
	1	2	3
A. Beaker	63.2840	64.3064	64.5075
After	63.5486	64.6515	64.8476
B. Extracted Fat	0.2646	0.3451	0.3401
C. (1)Thimble	13.0659	12.9677	13.5568
(2)Thimble plus Sample Before	17.4406	17.1616	17.2763
(3)Thimble plus Sample After	15.6386	15.2083	15.2744
D. Sample (C 1 -C2)	4.3747	4.1939	3.7195
E. Moisture (C2 -C3)	1.8020	1.9533	2.0019
F. Percent Fat Content (B/D)	6.05%	8.23%	9.14%
G. Moisture Percent (E /D)	41.19%	46.57%	53.82%
H. Average of Fat	7.73%		
Average of Moisture	46.85%		

C Day 4 French Fries Fried In Cottonseed Oil @ University of North Texas
10-Nov-97

	1	2	3	4	5	6
A. Beaker	64.7368	64.0441	64.0095	65.0023	64.3979	65.0566
After	64.9213	64.2423	64.2701	65.2624	64.7038	65.3971
B. Extracted Fat	0.1845	0.1982	0.2606	0.2601	0.3059	0.3405
C. (1)Thimble	20.7143	14.3035	12.9954	13.7379	13.6853	14.4445
(2)Thimble plus Sample Before	24.7386	18.9225	17.1584	17.5108	17.7522	18.2873
(3)Thimble plus Sample After	22.8927	15.7034	14.3150	15.6740	15.7784	16.4128
D. Sample (C 1 -C2)	4.0243	4.6190	4.1630	3.7729	4.0669	3.8428
E. Moisture (C2 -C3)	1.8459	3.2191	2.8434	1.8368	1.9738	1.8745
F. Percent Fat Content (B/D)	4.58%	4.29%	6.26%	6.89%	7.52%	8.86%
G. Moisture Percent (E /D)	45.87%	69.69%	68.30%	48.68%	48.53%	48.78%
H. **Average of Fat**	**6.33%**					
Average of Moisture	**55.51%**					

D **Day 6 French Fries Fried in Cottonseed Oil @ University of North Texas**

12-Nov-97

	1	2	3	4	5	6
A. Beaker	63.4394	63.8494	64.8678	63.2861	59.9254	0.0000
After	63.7032	64.1645	65.2473	63.5257	60.1641	
B. Extracted Fat	0.2638	0.3151	0.3795	0.2396	0.2387	0.0000
C. (1)Thimble	13.9893	14.3015	12.9989	13.8136	13.9481	
(2)Thimble plus Sample Before	17.7125	17.7055	16.6105	17.1428	17.3231	
(3)Thimble plus Sample After	15.9840	16.1367	14.9510	15.6054	15.7857	
D. Sample (C 1 -C2)	3.7232	3.4040	3.6116	3.3292	3.3750	0.0000
E. Moisture (C2 -C3)	1.7285	1.5688	1.6595	1.5374	1.5374	0.0000
F. Percent Fat Content (B/D)	7.09%	9.26%	10.51%	7.20%	7.07%	0.00%
G. Moisture Percent (E /D)	46.43%	46.09%	45.95%	46.18%	45.55%	0.00%
H. **Average of Fat**	**8.24%**					
Average of Moisture	**46.04%**					

E **Day 9 French Fries Fried in Cottonseed Oil @ University of North Texas**

17-Nov-97

	1	2	3	4	5	6
A. Beaker	64.2075	65.0231	64.3068	64.0418	64.7336	64.9995
After	64.4712	65.3576	64.5311	64.3402	65.0841	65.2290
B. Extracted Fat	0.2637	0.3345	0.2243	0.2984	0.3505	0.2295
C. (1)Thimble	14.1463	13.1017	13.0963	13.3279	14.0516	13.5492
(2)Thimble plus Sample Before	17.3621	17.3221	16.8037	16.9531	18.8544	17.5001
(3)Thimble plus Sample After	15.7522	15.2539	14.9895	15.1662	15.9683	15.5586
D. Sample (C 1 -C2)	3.2158	4.2204	3.7074	3.6252	4.8028	3.9509
E. Moisture (C2 -C3)	1.6099	2.0682	1.8142	1.7869	2.8861	1.9415
F. Percent Fat Content (B/D)	8.20%	7.93%	6.05%	8.23%	7.30%	5.81%
G. Moisture Percent (E /D)	50.06%	49.00%	48.93%	49.29%	60.09%	49.14%
H. **Average of Fat**	**7.23%**					
Average of Moisture	**51.47%**					

F <u>Day 10 French Fries Fried In Cottonseed Oil @ University of North Texas</u>

18-Nov-97

	1	2	3	4	5	6
A. Beaker	63.4345	63.8452	64.8656	63.2836	59.9245	64.5940
After	63.7696	64.2490	65.0756	63.4791	60.1283	64.9908
B. Extracted Fat	0.3351	0.4038	0.2100	0.1955	0.2038	0.3968
C. (1)Thimble	14.4161	14.3664	13.0239	13.9376	13.1972	14.4672
(2)Thimble plus Sample Before	18.4586	18.0178	16.5554	17.3489	16.7116	19.0844
(3)Thimble plus Sample After	16.2398	16.0874	14.7123	15.5434	14.8443	16.6757
D. Sample (C 1 -C2)	4.0425	3.6514	3.5315	3.4113	3.5144	4.6172
E. Moisture (C2 -C3)	2.2188	1.9304	1.8431	1.8055	1.8673	2.4087
F. Percent Fat Content (B/D)	8.29%	11.06%	5.95%	5.73%	5.80%	8.59%
G. Moisture Percent (E /D)	54.89%	52.87%	52.19%	52.93%	53.13%	52.17%
H. **Average of Fat**	**7.66%**					
Average of Moisture	**53.03%**					

G **Day 3 French Fries Fried in Extend @ University of North Texas**

21-Nov-97

First ARM Extend

	1	2	3	4	5	6
A. Beaker	64.0055	65.0510	64.3022	64.0390	64.7313	64.9977
After	64.3811	65.3799	64.5662	64.2983	65.0093	65.4039
B. Extracted Fat	0.3756	0.3289	0.2640	0.2593	0.2780	0.4062
C. (1)Thimble	14.1592	14.2186	13.0791	13.8735	13.2153	14.4437
(2)Thimble plus Sample Before	17.7240	17.9079	16.7916	17.3779	17.7569	18.1678
(3)Thimble plus Sample After	16.0339	16.1190	15.0511	15.6990	15.6014	16.3947
D. Sample (C 1 -C2)	3.5648	3.6893	3.7125	3.5044	4.5416	3.7241
E. Moisture (C2 -C3)	1.6901	1.7889	1.7405	1.6789	2.1555	1.7731
F. Percent Fat Content (B/D)	10.54%	8.91%	7.11%	7.40%	6.12%	10.91%
G. Moisture Percent (E /D)	47.41%	48.49%	46.88%	47.91%	47.46%	47.61%
H. **Average of Fat**	**8.41%**					
Average of Moisture	**47.62%**					

H Day 4 French Fries Fried in Extend @ University of North Texas

24-Nov-97

	1	2	3	4	5	6
A. Beaker	63.4336	63.8445	64.8653	63.2808	59.9254	64.5049
After	63.8475	64.4149	65.2687	63.4604	60.1829	64.9580
B. Extracted Fat	0.4139	0.5704	0.4034	0.1796	0.2575	0.4531
C. (1)Thimble	13.9491	13.2737	13.1054	13.3633	13.2543	13.7207
(2)Thimble plus Sample Before	17.7466	17.7651	17.4495	16.7832	17.4331	17.9777
(3)Thimble plus Sample After	15.9448	15.5443	15.3404	15.1312	15.4275	15.9399
D. Sample (C 1 -C2)	3.7975	4.4914	4.3441	3.4199	4.1788	4.2570
E. Moisture (C2 -C3)	1.8018	2.2208	2.1091	1.6520	2.0056	2.0378
F. Percent Fat Content (B/D)	10.90%	12.70%	9.29%	5.25%	6.16%	10.64%
G. Moisture Percent (E /D)	47.45%	49.45%	48.55%	48.31%	47.99%	47.87%
H. Average of Fat	9.30%					
Average of Moisture	48.30%					

I **Day 5 French Fries Fried In Extend @ University of North Texas**
25-Nov-97

	1	2	3	4	5	6
A. Beaker	66.8188	60.1147	58.7630	65.9904	64.1431	64.5926
After	67.2903	60.4214	59.1965	66.3794	64.6888	65.1097
B. Extracted Fat	0.4715	0.3067	0.4335	0.3890	0.5457	0.5171
C. (1)Thimble	14.1504	14.2230	13.1240	13.8727	13.9257	14.4291
(2)Thimble plus Sample Before	18.4486	17.4303	17.5520	18.4283	18.2537	18.2738
(3)Thimble plus Sample After	16.3288	15.8474	15.4015	16.1946	16.9060	16.3893
D. Sample (C 1 -C2)	4.2982	3.2073	4.4280	4.5556	4.3280	3.8447
E. Moisture (C2 -C3)	2.1198	1.5829	2.1505	2.2337	1.3477	1.8845
F. Percent Fat Content (B/D)	10.97%	9.56%	9.79%	8.54%	12.61%	13.45%
G. Moisture Percent (E /D)	49.32%	49.35%	48.57%	49.03%	31.14%	49.02%
H. **Average of Fat**	**10.80%**					
Average of Moisture	**45.90%**					

J **Day 6 French Fries Fried In Extend @ University of North Texas**

26-Nov-97
01-Dec-97

Last day before holiday and first day back from holiday treated as day 6 each	1	2	3	4	5	6
A. Beaker	64.0029	65.0457	64.2980	64.0347	64.7270	64.9938
After	64.4749	65.2429	65.0074	64.4592	64.9221	65.4518
B. Extracted Fat	0.4720	0.1972	0.7094	0.4245	0.1951	0.4580
C. (1)Thimble	13.9404	13.1680	13.0573	13.3950	13.3877	13.6818
(2)Thimble plus Sample Before	17.8652	16.6778	17.6143	17.4989	17.6545	17.6516
(3)Thimble plus Sample After	16.0123	15.0012	15.5039	15.2426	15.3310	15.5173
D. Sample (C 1 -C2)	3.9248	3.5098	4.5570	4.1039	4.2668	3.9698
E. Moisture (C2 -C3)	1.8529	1.6766	2.1104	2.2563	2.3235	2.1343
F. Percent Fat Content (B/D)	12.03%	5.62%	15.57%	10.34%	4.57%	11.54%
G. Moisture Percent (E /D)	47.21%	47.77%	46.31%	54.98%	54.46%	53.76%
H. **Average of Fat**	**11.50%**			**8.73%**		
Average of Moisture	**47.03%**			**54.41%**		

K **Day 7 French Fries Fried in Extend @ University of North Texas**

02-Dec-97

Three days of holiday idle time
Second day back from holiday
and day before oil change

	1	2	3	4	5	6
A. Beaker	65.9368	59.7499	59.4486	65.4557		
After	66.4387	60.3443	60.0160	65.9070		
B. Extracted Fat	0.5019	0.5944	0.5674	0.4513	0.0000	0.0000
C. (1)Thimble	22.3074	20.5168	16.8515	23.1467		
(2)Thimble plus Sample-Before	26.3479	24.7392	20.3944	27.7306		
(3)Thimble plus Sample After	24.3179	22.5689	18.5744	25.4300		
D. Sample (C 1 -C2)	4.0405	4.2224	3.5429	4.5839	0.0000	0.0000
E. Moisture (C2 -C3)	2.0300	2.1703	1.8200	2.3006	0.0000	0.0000
F. Percent Fat Content (B/D)	12.42%	14.08%	16.02%	9.85%	0.00%	0.00%
G. Moisture Percent (E /D)	50.24%	51.40%	51.37%	50.19%	0.00%	0.00%
H. **Average of Fat**	**12.90%**					
Average of Moisture	**50.77%**					

L **Day 3 French Fries Fried In Extend @ University of North Texas**

05-Dec-97

Second ARM Extend

	1	2	3	4	5	6
A. Beaker	63.8374	59.9229	58.7633	63.2764	64.8564	64.1998
After	64.3446	60.6806	58.9569	63.7340	65.2428	64.6936
B. Extracted Fat	0.5072	0.7577	0.1936	0.4576	0.3864	0.4938
C. (1)Thimble	13.9439	13.2977	12.9032	13.2825	13.4730	13.5810
(2)Thimble plus Sample Before	17.7384	17.4542	16.0247	16.7798	17.4383	17.4442
(3)Thimble plus Sample After	16.0272	15.5759	14.6400	15.2015	15.6868	15.7173
D. Sample (C 1 -C2)	3.7945	4.1565	3.1215	3.4973	3.9653	3.8632
E. Moisture (C2 -C3)	1.7112	1.8783	1.3847	1.5783	1.7515	1.7269
F. Percent Fat Content (B/D)	13.37%	18.23%	6.20%	13.08%	9.74%	12.78%
G. Moisture Percent (E /D)	45.10%	45.19%	44.36%	45.13%	44.17%	44.70%
H. **Average of Fat**	**12.48%**					
Average of Moisture	**44.78%**					

M **Day 6 French Fries Fried In Extend @ University of North Texas**

10-Dec-97

	1	2	3	4	5	6
A. Beaker	66.8097	65.9321	58.7619	65.9888	65.0420	64.4973
After	67.2934	66.3668	59.3238	66.4819	65.5304	64.9209
B. Extracted Fat	0.4837	0.4347	0.5619	0.4931	0.4884	0.4236
C. (1)Thimble	13.2934	13.0867	13.0372	13.2376	13.4424	13.7191
(2)Thimble plus Sample Before	18.2335	17.3382	17.2662	17.6738	16.6249	18.0191
(3)Thimble plus Sample After	15.9469	15.1133	15.0612	15.2970	14.9393	15.5689
D. Sample (C 1 -C2)	4.9401	4.2515	4.2290	4.4362	3.1825	4.3000
E. Moisture (C2 -C3)	2.2866	2.2249	2.2050	2.3768	1.6856	2.4502
F. Percent Fat Content (B/D)	9.79%	10.22%	13.29%	11.12%	15.35%	9.85%
G. Moisture Percent (E /D)	46.29%	52.33%	52.14%	53.58%	52.96%	56.98%
H. **Average of Fat**	**11.39%**					
Average of Moisture	**52.21%**					

N **Day 8 French Fries Fried In Extend @ University of North Texas**
12-Dec-97

	1	2	3	4	5	6
A. Beaker	63.8338		59.4447	65.4504	64.8515	64.1924
After	64.4006		59.9764	65.8695	65.1852	64.3802
B. Extracted Fat	0.5668	0.0000	0.5317	0.4191	0.3337	0.1878
C. (1)Thimble	14.2019		13.1720	23.2032	20.9087	14.4903
(2)Thimble plus Sample Before	18.0274		16.4153	26.2490	24.0899	17.2980
(3)Thimble plus Sample After	16.2205		14.7878	24.7998	22.5918	15.9821
D. Sample (C 1 -C2)	3.8255	0.0000	3.2433	3.0458	3.1812	2.8077
E. Moisture (C2 -C3)	1.8069	0.0000	1.6275	1.4492	1.4981	1.3159
F. Percent Fat Content (B/D)	14.82%	0.00%	16.39%	13.76%	10.49%	6.69%
G. Moisture Percent (E /D)	47.23%	0.00%	50.18%	47.58%	47.09%	46.87%
H. **Average of Fat**	**12.66%**					
Average of Moisture	**47.80%**					

O **Day 9 French Fries Fried In Extend @ University of North Texas**
15-Dec-97

	1	2	3	4	5	6
A. Beaker	64.7208	65.9307	58.7605	63.2717	65.0393	66.4303
After	65.1061	66.3769	59.0613	63.5483	65.3178	66.9470
B. Extracted Fat	0.3853	0.4462	0.3008	0.2766	0.2785	0.5167
C. (1)Thimble	13.9257	13.1180	12.8841	13.1758	13.2466	13.6363
(2)Thimble plus Sample Before	16.8623	16.6063	16.5245	16.2969	16.7015	16.9049
(3)Thimble plus Sample After	15.4106	14.8896	14.7507	14.7572	14.9966	15.3122
D. Sample (C 1 -C2)	2.9366	3.4883	3.6404	3.1211	3.4549	3.2686
E. Moisture (C2 -C3)	1.4517	1.7167	1.7738	1.5397	1.7049	1.5927
F. Percent Fat Content (B/D)	13.12%	12.79%	8.26%	8.86%	8.06%	15.81%
G. Moisture Percent (E /D)	49.43%	49.21%	48.73%	49.33%	49.35%	48.73%
H. **Average of Fat**	**11.07%**					
Average of Moisture	**49.12%**					

P **Day 10 French Fries Fried In Extend @ University of North Texas**

16-Dec-97

	1	2	3	4	5	6
A. Beaker	59.9210	59.7445	64.9850	65.9874	64.3828	64.4954
After	60.3479	60.2603	65.4649	66.4472	64.8341	65.0661
B. Extracted Fat	0.4269	0.5158	0.4799	0.4598	0.4513	0.5707
C. (1)Thimble	22.7352	20.6653	16.7215	14.0370	14.0261	23.9199
(2)Thimble plus Sample Before	25.4793	23.4922	19.8036	18.1326	17.8829	27.5381
(3)Thimble plus Sample After	24.0277	21.9984	18.1980	15.9978	15.8530	25.6663
D. Sample (C 1 -C2)	2.7441	2.8269	3.0821	4.0956	3.8568	3.6182
E. Moisture (C2 -C3)	1.4516	1.4938	1.6056	2.1348	2.0299	1.8718
F. Percent Fat Content (B/D)	15.56%	18.25%	15.57%	11.23%	11.70%	15.77%
G. Moisture Percent (E /D)	52.90%	52.84%	52.09%	52.12%	52.63%	51.73%
H. **Average of Fat**	**14.36%**					
Average of Moisture	**52.35%**					

A **Day 10 French Fries Fried In Cottonseed Oil & Extend @ Texas Womans University**
11-Nov-97

Side by side comparison at TWU

	CSO			EXTEND		
	4	5	6	1	2	3
A. Beaker	58.7679	64.2465	60.1186	66.8136	67.1655	65.8919
After	59.0843	64.5881	60.6527	67.1854	67.6253	66.3797
B. Extracted Fat	0.3164	0.3416	0.5341	0.3718	0.4598	0.4878
C. (1)Thimble	13.1897	13.1556	13.5527	14.2632	13.1295	13.0169
(2)Thimble plus Sample Before	16.6687	16.5926	18.1484	17.7795	16.8543	17.3037
(3)Thimble plus Sample After	15.0109	14.9455	15.9840	16.0100	14.9976	15.1786
D. Sample (C 1 -C2)	3.4790	3.4370	4.5957	3.5163	3.7248	4.2868
E. Moisture (C2 -C3)	1.6578	1.6471	2.1644	1.7695	1.8567	2.1251
F. Percent Fat Content (B/D)	9.09%	9.94%	11.62%	10.57%	12.34%	11.38%
G. Moisture Percent (E /D)	47.65%	47.92%	47.10%	50.32%	49.85%	49.57%
H. **Average of Fat**	**10.36%**			**11.17%**		
Average of Moisture	**47.51%**			**48.49%**		

B **Day 10 French Fries Fried in Cottonseed Oil & Extend @ T.W.University**

19-Nov-97

	*********** CSO ***********			*********** EXTEND ***********		
Endpoint oils collected from UNT	from 11-19-97			from 9-26-97		
Fried at TWU	1	2	3	4	5	6
A. Beaker	65.9960	64.1432	60.1145	66.8020	67.1634	58.7625
After	66.2829	64.6127	60.6491	67.2748	67.5912	59.2739
B. Extracted Fat	0.2869	0.4695	0.5346	0.4728	0.4278	0.5114
C. (1)Thimble	13.3093	14.0317	13.7339	14.0560	13.2003	13.0972
(2)Thimble plus Sample Before	16.0181	18.9450	17.3780	17.6599	16.0436	16.3546
(3)Thimble plus Sample After	14.7534	16.1565	15.7345	15.8884	14.6850	14.8361
D. Sample (C 1 -C2)	2.7088	4.9133	3.6441	3.6039	2.8433	3.2574
E. Moisture (C2 -C3)	1.2647	2.7885	1.6435	1.7715	1.3586	1.5185
F. Percent Fat Content (B/D)	10.59%	9.56%	14.67%	13.12%	15.05%	15.70%
G. Moisture Percent (E /D)	46.69%	56.75%	45.10%	49.16%	47.78%	46.62%
H. **Average of Fat**	**11.46%**			**14.55%**		
Average of Moisture	**50.56%**			**47.90%**		

C Day 10 French Fries Fried in CSO &Extend @ T.W.University

12-Nov-97

Endpoint oil collected from UNT Fried at TWU	CSO from 11-19-97			EXTEND from 12-2-97		
	1	2	3	4	5	6
A. Beaker	66.8134	60.1175	63.4258	65.9932	64.1460	64.5934
After	67.1960	60.5912	63.5855	66.4831	64.8082	65.2558
B. Extracted Fat	0.3826	0.4737	0.1597	0.4899	0.6622	0.6624
C. (1)Thimble	14.1626	14.2017	12.9873	13.7781	13.8241	14.4322
(2)Thimble plus Sample Before	18.2017	18.3516	16.3644	17.8010	18.1597	19.0663
(3)Thimble plus Sample After	16.1087	16.2000	14.6168	15.9660	16.2047	16.9794
D. Sample (C 1 -C2)	4.0391	4.1499	3.3771	4.0229	4.3356	4.6341
E. Moisture (C2 -C3)	2.0930	2.1516	1.7476	1.8350	1.9550	2.0869
F. Percent Fat Content (B/D)	9.47%	11.41%	4.73%	12.18%	15.27%	14.29%
G. Moisture Percent (E /D)	51.82%	51.85%	51.75%	45.61%	45.09%	45.03%
H. **Average of Fat**	**8.78%**			**13.97%**		
Average of Moisture	**51.81%**			**45.23%**		

D **Day 0 French Fries Fried In CSO & Extend @ T.W. University**

09-Dec-97

FRESH OIL FRIED AT TWU Side by Side Comparison		**CSO** fresh			**EXTEND** fresh	
	1	2	3	4	5	6
A. Beaker	64.7233	60.1148	64.9894	64.0314	64.5863	66.4331
After	65.0666	60.4258	65.2321	64.2692	64.8895	66.7615
B. Extracted Fat	0.3433	0.3110	0.2427	0.2378	0.3032	0.3284
C. (1)Thimble	22.3072	20.4696	16.6668	13.8744	13.7730	23.6830
(2)Thimble plus Sample Before	27.0786	24.4124	19.6913	17.4141	17.6557	26.9777
(3)Thimble plus Sample After	25.2747	22.8361	18.5138	16.0787	16.1952	25.7160
D. Sample (C 1 -C2)	4.7714	3.9428	3.0245	3.5397	3.8827	3.2947
E. Moisture (C2 -C3)	1.8039	1.5763	1.1775	1.3354	1.4605	1.2617
F. Percent Fat Content (B/D)	7.19%	7.89%	8.02%	6.72%	7.81%	9.97%
G. Moisture Percent (E /D)	37.81%	39.98%	38.93%	37.73%	37.62%	38.29%
H. **Average of Fat**	**7.87%**			**8.11%**		
Average of Moisture	**38.37%**			**37.86%**		

E **Day 10 French Fries Fried In CSO &Extend @ T.W. University**

17-Dec-97

Endpoint oil collected from UNT
Fried at TWU

	CSO from 11-19-97			EXTEND from 12-16-97		
	1	2	3	4	5	6
A. Beaker	66.8080	63.9969	60.1107	64.0277	67.6142	64.1408
After	67.4449	64.4988	60.5494	64.7021	68.3262	64.6697
B. Extracted Fat	0.6369	0.5019	0.4387	0.6744	0.7120	0.5289
C. (1)Thimble	14.1435	14.2912	13.0050	23.1402	20.8784	14.5599
(2)Thimble plus Sample Before	18.5094	17.2247	16.5443	26.9131	24.5581	18.5454
(3)Thimble plus Sample After	16.3179	15.8261	14.8460	25.2500	22.9959	16.8784
D. Sample (C 1 -C2)	4.3659	2.9335	3.5393	3.7729	3.6797	3.9855
E. Moisture (C2 -C3)	2.1915	1.3986	1.6983	1.6631	1.5622	1.6670
F. Percent Fat Content (B/D)	14.59%	17.11%	12.40%	17.87%	19.35%	13.27%
G. Moisture Percent (E /D)	50.20%	47.68%	47.98%	44.08%	42.45%	41.83%
H. **Average of Fat**	**14.55%**			**16.74%**		
Average of Moisture	**48.79%**			**42.77%**		

E **Day 10 French Fries Fried in CSO &Extend @ T.W. University**

17-Dec-97

Endpoint oil collected from UNT
Fried at TWU

	CSO from 11-19-97			EXTEND from 12-16-97		
	1	2	3	4	5	6
A. Beaker	323.1086	312.6189	308.7590	327.6679	330.6754	319.8217
After	325.0747	314.7166	310.6688	329.9146	333.2404	322.3406
B. Extracted Fat	1.9661	2.0977	1.9098	2.2467	2.5650	2.5189
C. (1)Thimble	77.1123	76.1498	69.9457	79.1119	74.8053	78.7892
(2)Thimble plus Sample Befo	96.4765	95.5263	88.1264	97.5676	93.2714	98.2477
(3)Thimble plus Sample After	87.4656	85.9642	79.6951	89.1931	85.0784	89.5885
D. Sample (C 1 -C2)	19.3642	19.3765	18.1807	18.4557	18.4661	19.4585
E. Moisture (C2 -C3)	9.0109	9.5621	8.4313	8.3745	8.1930	8.6592
F. Percent Fat Content (B/D)	10.15%	10.83%	10.50%	12.17%	13.89%	12.94%
G Moisture Percent (E /D)	46.53%	49.35%	46.38%	45.38%	44.37%	44.50%
H. **Average of Fat**	**10.49%**			**13.00%**		
Average of Moisture	**47.44%**			**44.74%**		

F **Day 10 French Fries Fried in CSO &Extend @ T.W. University**

ALL RUNS COMBINED

worksheet a-b-c-e

FRIED IN OILS AT

TWU & UNT

	CSO			EXTEND		
	1	2	3	4	5	6
A. Beaker	258.3853	252.5041	243.7696	263.6365	266.0891	253.3886
After	260.0081	254.2908	245.4367	265.6454	268.3509	255.5791
B. Extracted Fat	1.6228	1.7867	1.6671	2.0089	2.2618	2.1905
C. (1)Thimble	54.8051	55.6802	53.2789	65.2375	61.0323	55.1062
(2)Thimble plus Sample Befo	69.3979	71.1139	68.4351	80.1535	75.6157	71.2700
(3)Thimble plus Sample After	62.1909	63.1281	61.1813	73.1144	68.8832	63.8725
D. Sample (C 1 -C2)	14.5928	15.4337	15.1562	14.9160	14.5834	16.1638
E. Moisture (C2 -C3)	7.2070	7.9858	7.2538	7.0391	6.7325	7.3975
F. Percent Fat Content (B/D)	11.12%	11.58%	11.00%	13.47%	15.51%	13.55%
G Moisture Percent (E /D)	49.39%	51.74%	47.86%	47.19%	46.17%	45.77%
H. **Average of Fat**	**11.24%**	**9.04%**	less 2.2%	**14.15%**	**11.95%**	less 2.2%
Average of Moisture	**49.68%**			**46.36%**		

Day 10 French Fries Fried in CSO &Extend @ T.W. University

ALL RUNS COMBINED

		CSO			EXTEND		
	Endpoint oil collected from UNT Fried at TWU						
		1	2	3	4	5	6
A.	Beaker	522.7260	500.8765	492.4100	524.4908	529.5990	507.3184
	After	525.9985	504.4193	495.4528	528.3746	533.9660	511.5400
B.	Extracted Fat	3.2725	3.5428	3.0428	3.8838	4.3670	4.2216
C.	(1)Thimble	118.7277	118.6744	109.6719	130.0862	122.7081	120.8785
	(2)Thimble plus Sample Bef	149.2057	150.0476	138.4131	159.9416	152.0328	152.2140
	(3)Thimble plus Sample Aft	134.6456	134.1468	124.8924	146.2975	138.9640	138.2824
D.	Sample (C 1 -C2)	30.4780	31.3732	28.7412	29.8554	29.3247	31.3355
E.	Moisture (C2 -C3)	14.5601	15.9008	13.5207	13.6441	13.0688	13.9316
F.	Percent Fat Content (B/D)	10.74%	11.29%	10.59%	13.01%	14.89%	13.47%
G.	Moisture Percent (E /D)	47.77%	50.68%	47.04%	45.70%	44.57%	44.46%
H.	**Average of Fat**	**10.88%**	**8.68%**	less 2.2%	**13.78%**	**11.58%**	less 2.2%
	Average of Moisture	**48.55%**			**44.90%**		

APPENDIX L.

BMDP Statistical Printouts

BMDP Statistical Software, Inc. | BMDP Statistical Software
12121 Wilshire Blvd, Suite 300 | Cork Technology Park, Model Farm Rd
Los Angeles, CA 90025 USA | Cork, Ireland
Phone (310) 207-8800 | Phone +353 21 542722
Fax (310) 207-8844 | Fax +353 21 542822

```
Release: 7.1     (AXP/OpenVMS)          DATE:     1-JUN-98       AT 11:21:56
 Manual: BMDP Manual Volumes 1, 2, and 3.
 Digest: BMDP User's Digest.
Updates: State NEWS. in the PRINT paragraph for summary of new features.

PROGRAM INSTRUCTIONS

/PROBLEM        TITLE IS 'class 2 sample ttest equal freq'.
/input          Var = 2.
                Format is FREE.
                File = 'ju.dta'.
/Variable       Names are Group,Days.
                Grouping is Group.
/Group          Codes(1) are 1,2.
                Names(1) are CSO,EXTEND.
/Twogroup       Group = Group.
                Variable = Days.
/End

PROBLEM TITLE IS
class 2 sample ttest equal freq

NUMBER OF VARIABLES TO READ . . . . . . . . . .         2
NUMBER OF VARIABLES ADDED BY TRANSFORMATIONS. .         0
TOTAL NUMBER OF VARIABLES . . . . . . . . . . .         2
CASE FREQUENCY VARIABLE . . . . . . . . . . . .
CASE WEIGHT VARIABLE. . . . . . . . . . . . . .
CASE LABELING VARIABLES . . . . . . . . . . . .
NUMBER OF CASES TO READ . . . . . . . . . . . . TO END
MISSING VALUES CHECKED BEFORE OR AFTER TRANS. . NEITHER
BLANKS IN THE DATA ARE TREATED AS   . . . . . . MISSING
INPUT FILE. . .ju.dta
REWIND INPUT UNIT PRIOR TO READING. . DATA. . .     YES
NUMBER OF INTEGER WORDS OF MEMORY FOR STORAGE .   19998

VARIABLES TO BE USED
    1 Group        2 Days

DATA FORMAT:  FREE

THE LONGEST RECORD MAY HAVE UP TO   80 CHARACTERS.
```

PAGE 2 3D class 2 sample ttest equal freq

CASE NO.	1 Group	2 Days
1	CSO	9.09
2	CSO	9.94
3	CSO	11.62
4	EXTEND	10.57
5	EXTEND	12.34
6	EXTEND	11.38

NUMBER OF CASES READ. 6

VARIABLE NO.	NAME	STATED VALUES FOR MINIMUM	MAXIMUM	MISSING	CODE	GROUP INDEX	CATEGORY NAME	INTERVALS .GT.	.LE.
1	Group				1.000	1	CSO		
					2.000	2	EXTEND		

GROUPING VARIABLE. . . Group

CATEGORY	FREQUENCY
CSO	3
EXTEND	3

DESCRIPTIVE STATISTICS OF DATA

VARIABLE TOTAL STANDARD ST.ERR COEFF S M A L L E S T L A
R G E S T
NO. NAME FREQ. MEAN DEV. OF MEAN OF VAR VALUE Z-SCR CASE VALUE
Z-SCR CASE RANGE

```
   2 Days          6  10.823  1.1911  .48627  .11005  9.0900 -1.46     1  12.340
 1.27     5  3.2500

TEST TITLE IS
class 2 sample ttest equal freq


VARIABLES TO BE ANALYZED. . . . . . . . Days
USE COMPLETE CASES ONLY?. . . . . . . .      NO
PRINT GROUP CORRELATION MATRICES? . . .      NO
COMPUTE HOTELLINGS T SQUARE?. . . . . .      NO
COMPUTE ROBUST STATISTICS?. . . . . . .      NO
COMPUTE NONPARAMETRIC STATISTICS? . . .      NO
GROUPING VARIABLE . . . . . . . . . . .       1 Group

NUMBER OF CASES READ. . . . . . . . . . . . . . .       6

GROUPS USED IN COMPUTATIONS-  CSO       EXTEND
```

```
PAGE    3  3D class 2 sample ttest equal freq


Days       VARIABLE NUMBER   2
*****************************
GROUP   1 CSO                   2 EXTEND                     CSO         EXTEND
     TEST STATISTICS   P-VALUE  DF
                                                  ------------------------------
   --------------------------------
                                                  MEAN        10.2167     11.4300
   LEVENE F FOR

    VARIABILITY    0.56 0.4953 1,    4
                                                  STD DEV      1.2875      0.8861
                                                  S.E.M.       0.7433      0.5116
   POOLED     T      -1.34 0.2499      4
                                                  SAMPLE SIZE       3           3
   SEPARATE   T      -1.34 0.2583    3.5
H    H         H                   X     X     X  MAXIMUM     11.6200     12.3400
M--------------------M  M--------------------M  MINIMUM      9.0900     10.5700
I  AN H=     1 CASES   A  I  AN X=     1 CASES  A  Z MAX        1.09        1.03
N    (N=     3)        X  N    (N=     3)       X  Z MIN       -0.88       -0.97
```

CASE (MAX)	3	5
CASE (MIN)	1	4

```
NUMBER OF INTEGER WORDS USED IN PRECEDING SUBPROBLEM     721
CPU TIME USED      0.090 SECONDS
```

```
PAGE    1  3D

BMDP3D - T-TESTS

Copyright 1977, 1979, 1981, 1982, 1983, 1985, 1987, 1988, 1990, 1993
                 by BMDP Statistical Software, Inc.

       BMDP Statistical Software, Inc.| BMDP Statistical Software
       12121 Wilshire Blvd, Suite 300 | Cork Technology Park, Model Farm Rd
       Los Angeles, CA 90025 USA      | Cork, Ireland
          Phone (310) 207-8800        |    Phone +353 21 542722
          Fax   (310) 207-8844        |    Fax   +353 21 542822

Release: 7.1     (AXP/OpenVMS)         DATE:    29-MAY-98       AT 11:11:24
 Manual: BMDP Manual Volumes 1, 2, and 3.
 Digest: BMDP User's Digest.
Updates: State NEWS. in the PRINT paragraph for summary of new features.

PROGRAM INSTRUCTIONS

/PROBLEM        TITLE IS 'class 2 sample ttest equal freq'.
/input          Var = 2.
                Format is FREE.
                File = 'tt.dta'.
/Variable       Names are Group,Days.
                Grouping is Group.
/Group          Codes(1) are 1,2.
                Names(1) are CSO,EXTEND.
/Twogroup       Group = Group.
                Variable = Days.
/End

PROBLEM TITLE IS
class 2 sample ttest equal freq

NUMBER OF VARIABLES TO READ . . . . . . . . . . .        2
NUMBER OF VARIABLES ADDED BY TRANSFORMATIONS. .          0
TOTAL NUMBER OF VARIABLES . . . . . . . . . . .          2
CASE FREQUENCY VARIABLE . . . . . . . . . . . . .
CASE WEIGHT VARIABLE. . . . . . . . . . . . . . .
CASE LABELING VARIABLES . . . . . . . . . . . . .
NUMBER OF CASES TO READ . . . . . . . . . . . . . TO END
MISSING VALUES CHECKED BEFORE OR AFTER TRANS. . NEITHER
BLANKS IN THE DATA ARE TREATED AS   . . . . . . MISSING
INPUT FILE. . .tt.dta
REWIND INPUT UNIT PRIOR TO READING. . DATA. . .     YES
NUMBER OF INTEGER WORDS OF MEMORY FOR STORAGE .   19998

VARIABLES TO BE USED
     1 Group       2 Days

DATA FORMAT:  FREE

THE LONGEST RECORD MAY HAVE UP TO   80 CHARACTERS.
```

PAGE 2 3D class 2 sample ttest equal freq

CASE NO.	1 Group	2 Days
1	CSO	11.46
2	CSO	8.78
3	CSO	10.49
4	CSO	14.55
5	EXTEND	14.55
6	EXTEND	13.97
7	EXTEND	13.00
8	EXTEND	16.74

NUMBER OF CASES READ. 8

VARIABLE NO.	NAME	STATED VALUES FOR MINIMUM	MAXIMUM	MISSING	CODE	GROUP INDEX	CATEGORY NAME	INTERVALS .GT.	.LE.
1	Group				1.000	1	CSO		
					2.000	2	EXTEND		

GROUPING VARIABLE. . . Group

CATEGORY	FREQUENCY
CSO	4
EXTEND	4

DESCRIPTIVE STATISTICS OF DATA

```
 VARIABLE    TOTAL          STANDARD  ST.ERR    COEFF     S M A L L E S T     L A
R G E S T
 NO. NAME     FREQ.  MEAN     DEV.    OF MEAN  OF VAR  VALUE  Z-SCR  CASE  VALUE
Z-SCR  CASE  RANGE

   2 Days         8  12.943  2.5687  .90817  .19847  8.7800 -1.62     2  16.740
 1.48     8  7.9600
```

TEST TITLE IS
class 2 sample ttest equal freq

```
VARIABLES TO BE ANALYZED. . . . . . . . . Days
USE COMPLETE CASES ONLY?. . . . . . . .       NO
PRINT GROUP CORRELATION MATRICES? . . .       NO
COMPUTE HOTELLINGS T SQUARE?. . . . . .       NO
COMPUTE ROBUST STATISTICS?. . . . . . .       NO
COMPUTE NONPARAMETRIC STATISTICS? . . .       NO
GROUPING VARIABLE . . . . . . . . . . .        1 Group

NUMBER OF CASES READ. . . . . . . . . . . . . . .      8

GROUPS USED IN COMPUTATIONS-  CSO       EXTEND
```

PAGE 3 3D class 2 sample ttest equal freq

```
Days      VARIABLE NUMBER   2
*****************************
GROUP   1 CSO                  2 EXTEND                      CSO         EXTEND
      TEST STATISTICS   P-VALUE  DF
                                                 ------------------------------
    -------------------------------
                                                 MEAN        11.3200     14.5650
    LEVENE F FOR

     VARIABILITY    0.47 0.5169 1,    6
                                                 STD DEV      2.4216      1.5847
                                                 S.E.M.       1.2108      0.7924
    POOLED      T    -2.24 0.0661    6
                                                 SAMPLE SIZE       4           4
    SEPARATE    T    -2.24 0.0732    5.2
 H   H H       H                     X  XX    X  MAXIMUM     14.5500     16.7400
```

```
M-------------------M M-------------------M MINIMUM      8.7800      13.0000
I  AN H=    1 CASES  A  I  AN X=    1 CASES  A  Z MAX        1.33        1.37
N    (N=    4)       X  N    (N=    4)       X  Z MIN       -1.05       -0.99
                                                CASE (MAX)      4           8
                                                CASE (MIN)      2           7

NUMBER OF INTEGER WORDS USED IN PRECEDING SUBPROBLEM     727
CPU TIME USED      0.060 SECONDS
```

FRESH OIL ABSORPTION

BMDP3D - T-TESTS

BMDP Statistical Software, Inc. | BMDP Statistical Software
12121 Wilshire Blvd, Suite 300 | Cork Technology Park, Model Farm Rd
Los Angeles, CA 90025 USA | Cork, Ireland
Phone (310) 207-8800 | Phone +353 21 542722
Fax (310) 207-8844 | Fax +353 21 542822

```
Release: 7.1     (AXP/OpenVMS)         DATE:     1-JUN-98       AT 11:15:30
 Manual: BMDP Manual Volumes 1, 2, and 3.
 Digest: BMDP User's Digest.
Updates: State NEWS. in the PRINT paragraph for summary of new features.

PROGRAM INSTRUCTIONS

/PROBLEM        TITLE IS 'class 2 sample ttest equal freq'.
/input          Var = 2.
                Format is FREE.
                File = 'ju.dta'.
/Variable       Names are Group,Days.
                Grouping is Group.
/Group          Codes(1) are 1,2.
                Names(1) are CSO,EXTEND.
/Twogroup       Group = Group.
                Variable = Days.
/End

PROBLEM TITLE IS
class 2 sample ttest equal freq

NUMBER OF VARIABLES TO READ . . . . . . . . . . .       2
NUMBER OF VARIABLES ADDED BY TRANSFORMATIONS. .         0
TOTAL NUMBER OF VARIABLES . . . . . . . . . . . .       2
CASE FREQUENCY VARIABLE . . . . . . . . . . . . .
CASE WEIGHT VARIABLE. . . . . . . . . . . . . . .
CASE LABELING VARIABLES . . . . . . . . . . . . .
NUMBER OF CASES TO READ . . . . . . . . . . . . . TO END
MISSING VALUES CHECKED BEFORE OR AFTER TRANS. . NEITHER
BLANKS IN THE DATA ARE TREATED AS    . . . . . . . MISSING
INPUT FILE. . .ju.dta
REWIND INPUT UNIT PRIOR TO READING. . DATA. . .     YES
NUMBER OF INTEGER WORDS OF MEMORY FOR STORAGE .   19998

VARIABLES TO BE USED
     1 Group       2 Days

DATA FORMAT:  FREE

THE LONGEST RECORD MAY HAVE UP TO   80 CHARACTERS.
```

PAGE 2 3D class 2 sample ttest equal freq

CASE NO.	1 Group	2 Days
1	CSO	7.19
2	CSO	7.89
3	CSO	8.02
4	EXTEND	6.72
5	EXTEND	7.81
6	EXTEND	9.97

NUMBER OF CASES READ. 6

VARIABLE NO.	NAME	STATED VALUES FOR MINIMUM	MAXIMUM	MISSING	CODE	GROUP INDEX	CATEGORY NAME	INTERVALS .GT.	.LE.
1	Group				1.000	1	CSO		
					2.000	2	EXTEND		

GROUPING VARIABLE. . . Group

CATEGORY	FREQUENCY
CSO	3
EXTEND	3

DESCRIPTIVE STATISTICS OF DATA

VARIABLE TOTAL STANDARD ST.ERR COEFF S M A L L E S T L A R G E S T
NO. NAME FREQ. MEAN DEV. OF MEAN OF VAR VALUE Z-SCR CASE VALUE Z-SCR CASE RANGE

```
  2 Days         6  7.9333  1.1133  .45451  .14033  6.7200 -1.09     4  9.9700
 1.83     6  3.2500

TEST TITLE IS
class 2 sample ttest equal freq


VARIABLES TO BE ANALYZED. . . . . . . . Days
USE COMPLETE CASES ONLY?. . . . . . . .      NO
PRINT GROUP CORRELATION MATRICES? . . .      NO
COMPUTE HOTELLINGS T SQUARE?. . . . . .      NO
COMPUTE ROBUST STATISTICS?. . . . . . .      NO
COMPUTE NONPARAMETRIC STATISTICS? . . .      NO
GROUPING VARIABLE . . . . . . . . . . .       1 Group

NUMBER OF CASES READ. . . . . . . . . . . . . . .      6

GROUPS USED IN COMPUTATIONS-  CSO      EXTEND
```

```
PAGE   3  3D class 2 sample ttest equal freq


Days      VARIABLE NUMBER   2
*****************************
GROUP    1 CSO                  2 EXTEND                  CSO        EXTEND
      TEST STATISTICS   P-VALUE  DF
                                                   ------------------------------
    --------------------------------
                                                   MEAN        7.7000      8.1667
    LEVENE F FOR

     VARIABILITY    3.76 0.1247 1,    4
                                                   STD DEV     0.4464      1.6541
                                                   S.E.M.      0.2577      0.9550

    POOLED     T    -0.47 0.6617     4
                                                   SAMPLE SIZE      3           3

    SEPARATE   T    -0.47 0.6783    2.3
  H    HH                   X     X          X     MAXIMUM     8.0200      9.9700
M--------------------M  M--------------------M     MINIMUM     7.1900      6.7200
I  AN H=    1 CASES   A  I  AN X=    1 CASES  A    Z MAX       0.72        1.09
```

```
N    (N=    3)       X  N    (N=    3)       X  Z MIN        -1.14        -0.87
                                                CASE (MAX)       3            6
                                                CASE (MIN)       1            4

NUMBER OF INTEGER WORDS USED IN PRECEDING SUBPROBLEM     721
CPU TIME USED      0.130 SECONDS
```

Appendix M.

Trans Fatty Acid Results

Woodson-Tenent Laboratories, Inc.

345 ADAMS AVE
P O BOX 2135
MEMPHIS TN 38101
(901) 521-4500

W-T SAMPLE NO.: M97-742042
SAMPLE OF: COTTONSEED OIL
SAMPLE ID: SAMPLE A
PO NUMBER: P0098728
CUST #: 01780500

W-T REPORTING DATE: 1/07/98
ENTRY DATE: 12/23/97

TEXAS WOMAN'S UNIVERSITY
ATTN JULIA OR DR KING
1200 FRAME ST
DENTON TX 76204

REPORT OF ANALYSIS

TEST	RESULT	UNITS
TOTAL TRANS FATTY ACID ISOMERS - GC	0.45	%

RESPECTFULLY SUBMITTED,
WOODSON-TENENT LABORATORIES, INC.

J A WILLIAMS
BRANCH MANAGER

Woodson-Tenent Laboratories, Inc.

345 ADAMS AVE
P O BOX 2135
MEMPHIS TN 38101
(901)521-4500

W-T SAMPLE NO.: M98-802337
SAMPLE OF: COTTONSEED OIL - 10 DAY
SAMPLE ID: A
PO NUMBER: P0099872
CUST #: 01780500

W-T REPORTING DATE: 1/30/98
ENTRY DATE: 1/26/98

TEXAS WOMAN'S UNIVERSITY
ATTN JULIA OR DR KING
1200 FRAME ST
DENTON TX 76204

R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS
TOTAL TRANS FATTY ACID ISOMERS - GC	14.8	%

RESPECTFULLY SUBMITTED,
WOODSON-TENENT LABORATORIES, INC.

J A WILLIAMS
BRANCH MANAGER

Analytical and Consulting Chemists Since 1933

"RESULTS ARE ON AN AS-RECEIVED BASIS UNLESS OTHERWISE SPECIFIED."

Woodson-Tenent Laboratories, Inc.

345 ADAMS AVE
P O BOX 2135
MEMPHIS TN 38101
(901)521-4500

W-T SAMPLE NO.: M98-802338 W-T REPORTING DATE: 1/30/98
SAMPLE OF: EXTEND-PARTIALLY HYDROG. CANOLA OIL 10 DAY ENTRY DATE: 1/26/98
SAMPLE ID: B
PO NUMBER: P0099872
CUST #: 01780500

TEXAS WOMAN'S UNIVERSITY
ATTN JULIA OR DR KING
1200 FRAME ST
DENTON TX 76204

R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS
TOTAL TRANS FATTY ACID ISOMERS - GC	27.5	%

RESPECTFULLY SUBMITTED,
WOODSON-TENENT LABORATORIES, INC.

J A WILLIAMS
BRANCH MANAGER

Analytical and Consulting Chemists Since 1933

"RESULTS ARE ON AN AS-RECEIVED BASIS UNLESS OTHERWISE SPECIFIED."

Woodson-Tenent Laboratories, Inc.

345 ADAMS AVE
P O BOX 2135
MEMPHIS TN 38101
(901)521-4500

W-T SAMPLE NO.: M97-742043 W-T REPORTING DATE: 1/07/98
SAMPLE OF: EXTEND-PARTIALLY HYDROGENATED CANOLA OIL ENTRY DATE: 12/23/97
SAMPLE ID: SAMPLE B
PO NUMBER: P0098728
CUST #: 01780500

TEXAS WOMAN'S UNIVERSITY
ATTN JULIA OR DR KING
1200 FRAME ST
DENTON TX 76204

R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS
TOTAL TRANS FATTY ACID ISOMERS - GC	23.26	%

RESPECTFULLY SUBMITTED,
WOODSON-TENENT LABORATORIES, INC.

J A WILLIAMS
BRANCH MANAGER

Analytical and Consulting Chemists Since 1933

"RESULTS ARE ON AN AS-RECEIVED BASIS UNLESS OTHERWISE SPECIFIED."