THE USE OF DETERGENT FRACTIONATED, EDIBLE BEEF TALLOW IN FOOD SYSTEMS

By

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ABSTRACT

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Edible beef tallow fractionated by detergent (SDS) at controlled temperatures was compared as a deep-fat frying medium with 1) unfractionated tallow, 2) tallow-vegetable oil blends, and 3) a commercial frying oil. Twenty consecutive batches of French fry potatoes were evaluated and oil samples were tested physically and chemically. Results showed a darkening of oil color and progressive increases in viscosity, peroxide value, and refractive indes. No significant difference ($p < 0.05$) in general acceptability of the fries resulted from variation in frying medium, but quality of the fries from all media decreased after 20 fryings.

A comparison was also made between cookies containing vegetable shortening and comparable batches in which edible tallow had been substituted for the shortening. Results obtained with a 450 member panel showed a slight flavor preference for the vegetable shortening cookie, however about 70% of the respondents liked to some degree the cookie prepared with tallow.

To Mom and Bill

with love

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INTRODUCTION

Animal fats (tallow and grease) are the second largest source of fats and oils in the United States (Anon., 1978) and until recently the primary domestic uses of tallow were in the manufacture of candles, soaps and animal feeds. Using improved fractionation procedures, under-utilized, less costly fats and oils are being modified to compete with more expensive fats and oils. The utilization of fractionated, edible beef tallow as a substitute for various food fats and oils has many economic advantages (Taylor et al., 1976).

The United States is the world's largest producer of beef tallow, supplying nearly 5.6 billion pounds annually (Kromer, 1971). Of this total, at least half is exported while only 10% of the total is used domestically for edible products (Taylor et al., 1976; Burnham, 1978). The current abundance of tallow may be attributed to the success of the beef industry, as tallow also is a renewable resource. Considering its current availability, there is a potential for more extensive use of tallow as a food fat. Morris et al. (1956) stated that much of the edible grade tallow was diverted to inedible channels due to the lack of a market in the edible field.

Both the demand and cost for imported oils such as cocoa butter, palm oil, coconut oil and palm kernel oil have been steadily increasing (Taylor et al., 1976). Consequently, fractionated tallow has been considered as an abundant, less expensive substitute for the more costly fats and oils typically used in the food and confectionery industries.

Within the past decade there's been a 20% increase in per capita consumption of food fats in the United States (USDA, 1977). Bartholomew (1980) reported that consumption has reached 58 lb/year within this country. This trend can be attributed to the increase in consumption of oils from vegetable sources, as there's been a steady decline in animal fat consumption (Appendix I). Fractionated fats which are less saturated than their original source may be more competitive with vegetable oils with regard to their nutritional status.

Luddy et al. (1973) reported that tallow could be successfully fractionated with a solvent (acetone) to obtain fractions with quite different physical properties. The USDA's Eastern Regional Research Center obtained three fractions from the solvent fractionation of tallow: a solid, semi-solid, and liquid or oil fraction (Anon., 1977), however disadvantages associated with this method have prompted investigation into alternative methods for the fractionation of tallow. Bussey et al. (1981) recently fractionated tallow using an aqueous fractionation procedure.

The purpose of this study was to compare the olein portions of aqueous (detergent) fractionated tallow, original unfractionated tallow and tallow-vegetable oil blends to a typical commercial frying oil as deep-fat frying media. Additional research was conducted to determine consumer response to cookies prepared with tallow as a replacement for shortening.

REVIEW OF LITERATURE

This review of literature is comprised of three sections. The first two summarize both the utilization and processing of tallow and also the fractionation procedures which have been applied to tallow. Since the major focus of this research was to evaluate fractionated tallow as a deep-fat frying medium, the last portion of this review is devoted to the practice of deep-fat frying.

Tallow

Tallow has been defined as the solid fat deposits of animals; its pure form is white and odorless. It is used to make soap, candles and butter substitutes (Burnham, 1978). When considering the current applications of tallow and tallow fractions, this definition appears outdated.

Tallow Production

The volume output of tallow ranks second only to soybean oil (Kromer, 1971). Although government figures estimated nearly 6 billion pounds of tallow are produced annually, the National Renderers Association indicated a figure closure to 8.1 billion pounds per year (Kromer, 1971). Bartholomew (1980) attributed the increase in the annual production of tallow to two elements: 1) government support programs to the beef industry and 2) the expansion of beef cattle feeding in this country. A major problem associated with increased production has been finding markets for the increasing surplus of tallow above domestic requirements. Exports have absorbed much of the excess and represented nearly one-half of the total output in 1971 (Kromer, 1971). However, larger production of foreign-produced oils has recently provided competition for U.S. tallow exports (Anon., 1976).

Edible vs. Inedible Tallow

Not all tallow is considered food grade. Kromer (1965) differentiated between inedible and edible tallow relating the difference to standards set by the USDA. He stated that "by law, the raw fat available for edible rendering must come from federally inspected cattle and be handled and processed under government regulations." Rendering plants must be operated under the same inspection and processing standards set by the USDA as for the processing of table meats (Burnham, 1978). Although total tallow production is up 63% (Bartholomew, 1980) only a small portion of this amount is comprised of edible tallow (Burnham, 1978; Kromer, 1965). There is the potential however, that if demand for edible tallow increased, as much as 70% of tallow production could be handled to meet edible classification standards (Anon., 1977).

Rendering

The rendering process differs very little for inedible and edible tallow. Kromer (1971) described the rendering process as that utilized to obtain tallow and other by-products (primarily meat meal) from the fat, skin, meat, bones and offal of an animal. The main objective is to separate any residual moisture in the raw material from the fat and solids (Burnham, 1978). The primary difference in the rendering of edible vs. inedible tallow is the use of lower and higher temperatures, respectively (Burnham, 1978).

Utilization of Tallow

Inedible tallow. Traditionally tallow was used as a major component in candles, however with time and technological advancements, tallow has been used in soaps, as a source of glycerine, fatty acids, and in other industrial products (Burnham, 1978). The major domestic use of tallow has been in animal feeds (Kromer, 1971; Anon., 1978); as much as 40% is utilized for this purpose (Anon., 1976). Twenty-five percent of this country's tallow production is used to produce fatty acids for industrial purposes (Anon., 1976; Anon., 1978). Even though the change to petro-based detergents reduced the demand for tallow in soap production, the third largest domestic use for tallow is in soaps (Anon., 1978).

Edible tallow.[1] One of the earliest applications of tallow was as an ingredient in shortenings (Morris *et al.*, 1956; Kromer, 1965).

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[1]For the remainder of this review of literature, edible tallow will be referred to as simply "tallow" unless otherwise specified.

Morris et al. (1956) studied beef tallow in shortening preparations in an attempt to optimize the plastic range of a tallow shortening. Tallow has also been used for frying by restaurants because of its desirable flavor (Baeuerlen et al., 1968).

An increased consumer awareness with regard to nutrition could have negative implications for beef tallow consumption as evidenced by decreased consumption of fats from animal sources (USDA, 1977) (Appendix I). A recent study which was sponsored by the American Soybean Association revealed that most consumers were aware that animal fats are higher in saturated fats while vegetable oils are associated with polyunsaturates (Andres, 1980). Tauber (1980) reported that nutrition and the avoidance of fat, cholesterol, sugar, etc. ranked third in level of concern for consumers.

"There is little doubt that the production of edible beef tallow would increase substantially if a more profitable market for the product could be anticipated (Luddy et al., 1973)." Fractionation can yield a product comprised of over 65% unsaturates (Luddy et al., 1973; Bussy et al., 1981) thus there is a potential for increased tallow utilization as a result of fractionation (Anon., 1977).

Fat Fractionation Technology

In order to separate the saturated fatty acids from the unsaturated fatty acids in a fat, low temperature crystallization was employed (Schwitzer, 1959). This method involved chilling the fat with subsequent pressing to squeeze out the unsaturates. Later in time, fractional crystallization was used primarily for the isolation of pure individual glycerides (Riemenschneider et al., 1946; Swern, 1964). More recently, Luddy et al. (1973) employed a solvent fractionation technique to obtain liquid, solid and semisolid components with many potential uses. Although tallows contain too high a percentage of solids to be used effectively as shortening agents (Hoerr, 1960), excess solids can be partially removed by fractional crystallization. Bussey et al. (1981) summarized the advantages and disadvantages of the three established methods of fractionation: dry fractionation, solvent fractionation and detergent (aqueous) fractionation.

Dry Fractionation

As described by Haraldsson (1974), dry fractionation is "the crystallization of the oil (normally after refining) followed by straight separation of the fractions by means of filtration or pressing." Riemenschneider et al. (1946) investigated the use of low temperature fractionation as a step in determining glyceride compositions of fats and oils. Another application of low temperature, dry fractionation was in the separation of butterfat into fractions, each with unique melting points (Baker, 1970). Baker (1970) suggested that the liquid butterfat fraction had potential as a deep-fat frying medium and the hard butterfat fraction as an ingredient in the manufacture of chocolate. Although dry fractionation is the simplest and longest established method, filtering can become difficult at low temperatures or when small crystals are formed (Bussey et al., 1981).

Solvent Fractionation

Solvent fractionation has an advantage over dry fractionation in that is is a more efficient means of separation (Bussey et al., 1981). Luddy et al. (1973, 1977) demonstrated that tallow could be successfully fractionated by acetone crystallization. Three distinct portions were obtained: A solid with applications as a hardening agent in margarines and shortenings; a semi-solid with characteristics comparable to cocoa butter; and a liquid oil with applications as an all-purpose cooking oil. Holsinger et al. (1978) successfully substituted the oil fraction from solvent fractionated beef tallow for soybean oil in a whey-soy drink mix. The primary disadvantages of solvent fractionation are the need for flame-proof equipment, the high cost of solvents and the difficulty of removing trace solvent residues (Bussey et al., 1981).

Detergent (Aqueous) Fractionation

The third method of fractionation is aqueous fractionation, developed by Haraldsson (1974) for use with palm oil. The basic principle of detergent fractionation involves the dispersion of a partly crystallized oil in water which contains a surfactive agent. By means of centrifugation to separate the oil and water phases, fatty acid crystals can be separated from the oil (Bussey et al., 1981; Haroldsson, 1974). Bussey et al. (1981) investigated ways to optimize the detergent fractionation process in their work with beef tallow. Detergent fractionation of tallow yielded many fractions including an oil, a hard white solid and a softer yellow solid.

The application of detergent fractionated tallow as a shortening agent in baked products has been recently studied. Hoojat and Zabik (1979) found that the substitution of tallow fractions for shortening produced acceptable sugar snap cookies. Bundy _et al_. (1981) used tallow fractions in white layer cakes and indicated that acceptable cakes could be produced if additional emulsifiers were added to the batters.

Deep-Fat Frying

Foods prepared by deep-fat frying play major roles in our diets and are products of a multi-billion dollar industry. Often associated with the fast-food segment of the food service industry, foods such as doughnuts, potato chips, French fried foods, chicken and seafood often rely on deep-fat frying as a method of cookery. Fats utilized as deep-fat frying media serve dual roles: functioning as a means for heat transfer and contributing to the nutrition and flavor of fried products (Bates, 1952).

Baeuerlen _et al_. (1968) enumerated the characteristics of an optimum frying fat: 1) a light or fairly light color; 2) a surface free from foam and smoke; 3) a clean, clear appearance free of burnt particles; and 4) flavor, or blandness, which enhances the eating quality of the fried food. Thompson _et al_. (1967) demonstrated that the degree of deterioration of a fat was dependent on how it had been used. Twenty one sets of fat or oil samples were collected from commercial deep-frying operations. One sample in the set was fresh, unused oil; the other was the same batch of oil after it was used and ready to be discarded. Samples were obtained from restaurants, hospitals, food manufactureres and armed services. Results were based on comparative iodine values, peroxide values, free fatty acid analysis, viscosity and gas chromatography. Investigators found that some food processors adequately maintained their frying oils while others abused and damaged theirs.

Robertson (1967) reviewed the changes which occurred in foods during deep-fat frying. The amount of fat absorbed in a food is dependent on: 1) length of cooking; 2) total surface area of the fat; 3) the smoke point of the fat; and 4) the composition and nature of the food (Lowe, 1955). Bates (1952) also related fat absorption to viscosity of the frying fat, frying temperature used, and formulation of the product being fried.

Changes in Frying Fats

The major changes which affect the quality of a frying fat are: hydrolysis, polymerization, oxidation and discoloration. As a result of an increased interest in changes which occur to a fat in deep-fat frying, numerous studies were reported during the 1950's.

Hydrolysis. In 1932, Porter et al. reported that the deterioration of a fat was mainly due to hydrolysis which yielded glycerol and acids. Later, Carlin et al. (1954), Baeuerlen et al. (1968), and Roth and Rock (1972) acknowledged that hydrolysis (Figure 1) was the major chemical reaction affecting a fat however it was of secondary importance to that of oxidation.

Roth and Rock (1972) classified three conditions in the frying process: storage, standby, and frying (Table 1). They associated hydrolysis with the "frying period" when the fat was exposed to air,

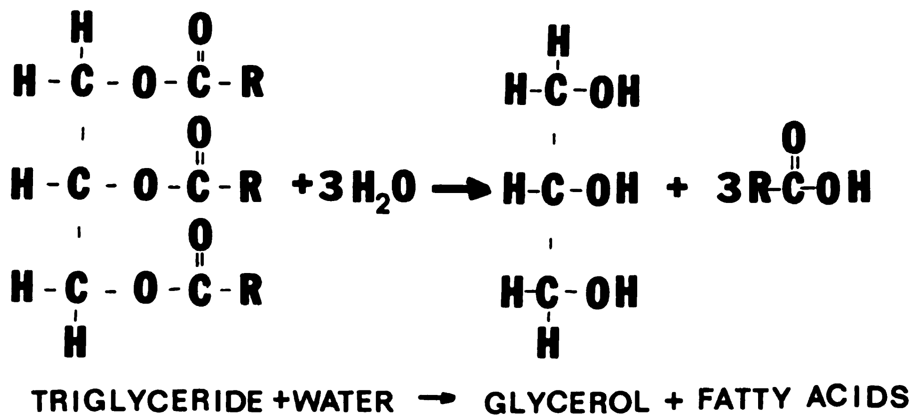

Figure 1. Chemical reaction of fat hydrolysis.

water vapor, and the food being fried. Fatty acids are the main products of fat hydrolysis.

Smoke point. In 1940, Lowe et al. reported that the free fatty acid content of a frying fat was inversely proportional to the smoke point. Vail and Hilton (1943) later studied the smoke points of 27 fats and oils and they too found an inverse relationship to the smoke point and the percentage of free fatty acids. Monoglycerides were shown to lower the smoke point of continuous processed lard, however fat absorption was unaffected by monoglyceride presence (Bennion and Hanning, 1956). Lowe et al. (1958) determined the smoke points of some commercially available fats which contained emulsifiers. Factors which reduced smoke points were: increased fatty acid content, increased fat surface area exposed to air, and accumulated bits of food.

Oxidation. During the process of deep-fat frying the oil is continuously or repeatedly used at elevated temperatures in the presence of oxygen (Thompson, 1967). Perkins (1967) discussed the chemical

Table 1. Type of reactions during the frying process (Roth and Rock, 1972).

PERIOD	REACTIONS	REACTIVE RATE	PRODUCTS
a) Storage	1. Autoxidation	Slow	Hydroperoxides
			Carbonyls
b) Standby	1. Autoxidation	Fast	Carbonyls
	2. Isomerization	Fast	Long and short chain acids
	3. Pyrolysis	Slow	Esters
	4. Polymerization	Slow	Alcohols
			Glycols
			Trans isomers
			Hydrogen
			Carbon dioxide
			Carbon monoxide
			Water
			Ethers
			Epoxides
			Branched chain fatty acids
c) Frying	1. Same as standby		Same as standby
	2. Hydrolysis	Fast	Fatty acids
			Mono- and diglycerides
			Glycerine

reactions which occur during the autoxidation of a frying fat or oil (Figure 2). During the induction period no detectable reactions occur; however, soon after the peroxide content rises rapidly to a maximum, it declines as the percentage of oxygen in the oil gradually increases. As polymerization increases so does viscosity. Volatile compounds (aldehydes, ketones, acids, alcohols and hydrocarbons) are formed during degradation. Perkins and Van Akkeren (1965) studied intermittent heating and cooling cycles of cottonseed oil and found increased deterioration as a result. They attributed the results to an increased build-up of peroxides and carbonyls which were destroyed by subsequent heating. These compounds could then propagate the formation of additional free radicals. Catalytic agents such as copper, cobalt and iron can increase the rate of oxidative reactions in a fat (Tilgner, 1978).

Antioxidants. Antioxidants extend the shelf life of a fat by reacting with free radicals formed during the initiation and propagation stages of oxidation. One of the greatest challenges to the effective use of antioxidants is in deep-fat frying because of the relatively high temperatures involved and the large quantities of moisture usually driven off (Sherwin, 1972). Butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) are steam distillable and propyl gallate decomposes at high temperatures (Sherwin, 1972). Magoffin and Bentz (1949) reported three ways that an antioxidant is removed from a frying oil: by steam distillation, by absorption into the fried product, and by its consumption in its role as an antioxidant. After 5,000 pounds of potatoes were fried in a vegetable shortening, the amount of antioxidant in the fat decreased from .026 to .004% (Magoffin and Bentz, 1949).

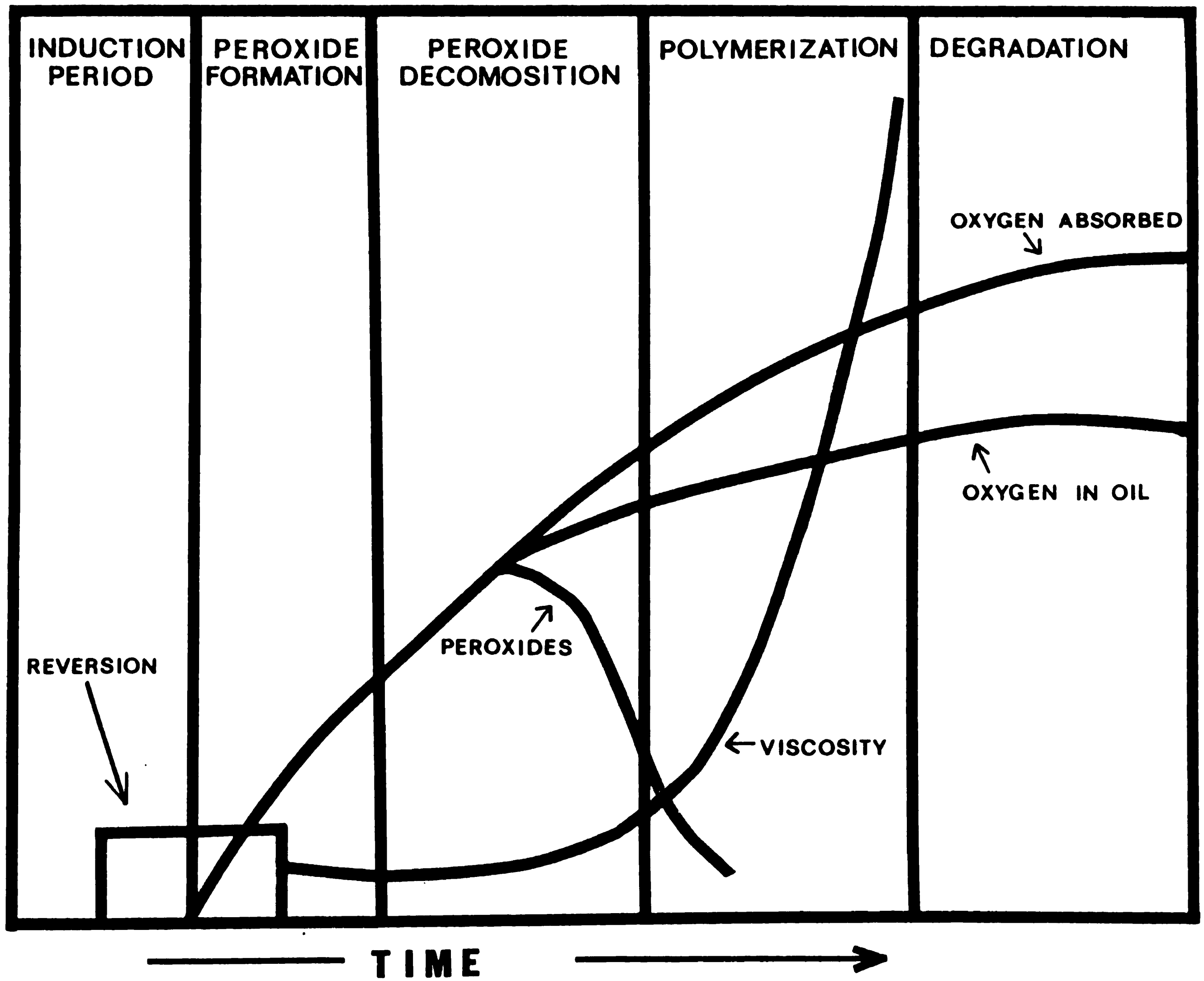

Figure 2. The stages of oxidation of a fat (Perkins, 1967).

Sair and Hall (1951) discussed the addition of antioxidant-salt products after the frying process and their success in increasing the storage life of potato chips and other deep fried food products. With certain types of nuts, antioxidants are combined with the dressing oil used for glazing purposes.

Nutritive Considerations of Heated Oils

The possibility of a health danger due to the mishandling of frying oils is a topic of current interest. Rice et al. (1960) reviewed studies indicating that the conditions needed for the nutritional damage of fat were much more severe than were possible in home or commercial cooking operations. Melnick (1957) has emphasized the fact that conditions observed in the laboratory resulting from thermally damaged fat are extreme and therefore irrelevant to commercial operations. Johnson et al. (1957) however, have reported enlarged livers in rats fed diets containing corn oil which has been thermally oxidized by bubbling air through oil held at 180°C for 24 hours. Chang et al. (1978) used infrared and mass spectrometry to identify 220 volatile decomposition products produced during deep-fat frying, many of which had known toxic properties.

The Care of Frying Fat

The method of care of a frying fat is an important factor in determining its frying life. Rust and Harrison (1960) studied the effect of four methods of care on the length of frying life and deteriorations in the fat. They found that filtering and refrigeration of the fat and cleaning of the fryer between frying periods prolonged the frying life. Jacobson (1967) suggested using the lowest possible temperature commensurate with product quality in the frying of foods as a means of maintaining fat quality. Freeman (1969) reported that an oil "kept busy with food will last longer than one standing idle at frying temperatures." He attributed this to the steam which is liberated from the fried food, acting as a "blanket" to protect the oil from oxygen.

Both Fritsch *et al*. (1979) and Graziano (1979) investigated the use of changes in dielectric constant of oils as a measure of oil deterioration. This type of test provides a quick, on-site way for determining the degree of degradation in a frying fat without depending on physical changes alone.

EXPERIMENTAL PROCEDURE

This research was initiated to determine whether detergent fractionated edible beef tallow is suitable for use in various food systems. The olein fraction of tallow obtained by detergent fractionation and tallow-vegetable oil blends were investigated as media for deep-fat frying. Additional research was conducted to determine consumer accepability of chocolate chip cookies prepared with tallow as a replacement for shortening. These cookies were sampled by 449 people in Port Huron, Michigan and information was obtained regarding the acceptability of the cookies as well as some demographic information about the participants.

Deep-Fat Frying Study

Materials

Edible tallow obtained from the A.W. Stadler Company in Cleveland, Ohio was fractionated using the detergent fractionation procedure described by Bussey et al. (1981). Softened tallow was mixed with 0.6% sodium dodecyl sulfate (SDS) (by weight of tallow) and allowed to crystallize for 18 hours at 45°C. A 5% aqueous solution (based on the volume of water) of electrolyte (sodium sulfate) was added and dispersed for one hour. Centrifugation at 2700 rpm for 15 minutes at room temperature followed immediately and the olein portion was retained for deep-frying. Subsequent fractions at 40°C, 35°C, and 25°C were obtained by decreasing the temperature and centrifuging as already described. Figure 3 summarizes the fractionation procedure.

For use as deep-fat frying media the following fats were used: four olein fractions (25°C, 35°C, 40°C and 45°C fractionation temperatures); 50% blends of unfractionated tallow with soybean oil (T-SBO) and with corn oil (T-CO); original, unfractionated tallow (OT); and a partially hydrogenated soybean commercial frying oil (CFO) ("Newe-Frye", Humko Products, Kraft Inc., Memphis, TN.). The commercial frying oil was used as a standard for comparison purposes and was purchased from Michigan State University Food Stores. The vegetable oils used in the tallow blends were obtained from a local food retailer. BHA was added to all tallow fractions, tallow-vegetable oil blends and original tallow so that all variables contained the legal allowable limit of antioxidant which is 0.02% BHA based on weight of fat. Product specifications for the commercial frying oil indicated TBHQ had been added to preserve freshness. Commercially frozen straight-cut, extra fancy "shoestring" style French fry potatoes were obtained from Michigan State University Food Stores.

Deep-Fat Frying

Four Sears (model #34-6425) deep-fat fryers with aluminum interiors and a 1.4 liter capacity were used for the deep-fat frying of French fries. Each variable and its replicate were randomly distributed among

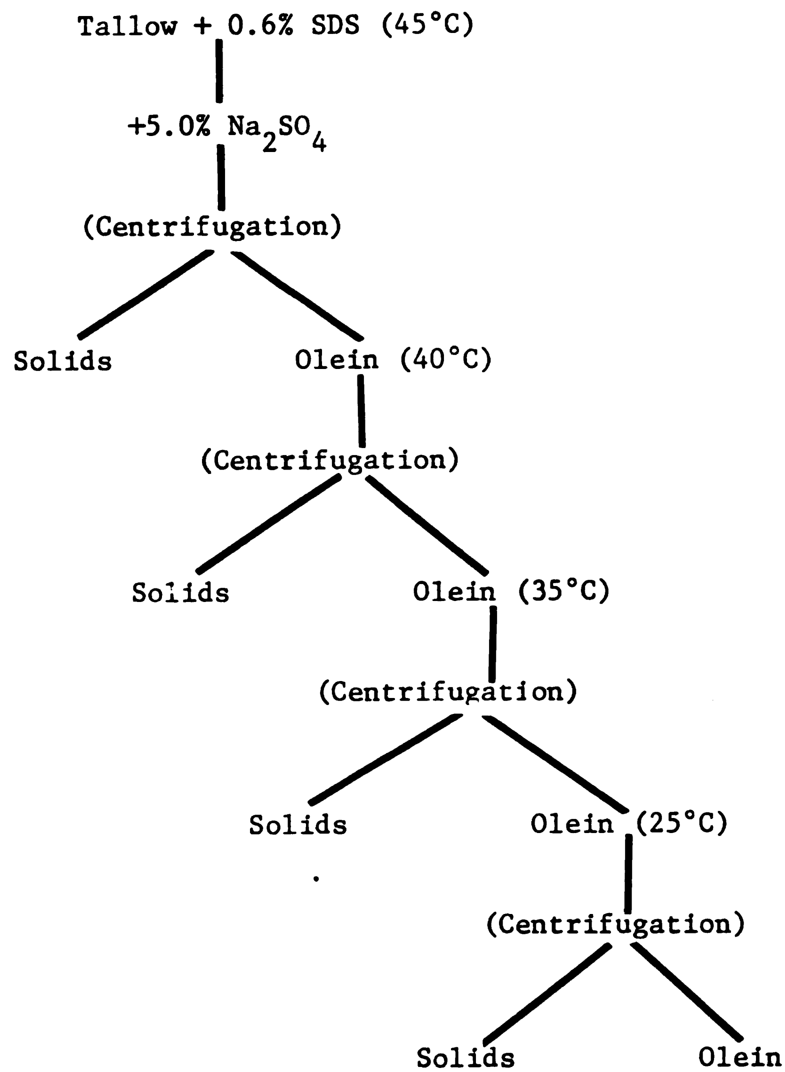

Figure 3. Detergent (SDS) fractionation of edible beef tallow.

four groups and then were arranged so as to avoid using the same fryer for both a variable and its replicate. For each group of variables, the entire deep-frying portion of the experiment was completed before progressing to the next group of variables. The distribution of the variables among fryers is found in Table 2.

Table 2. Distribution of eight variables and their replicates[1] among four fryers.

Group Number	Fryer Number 1	2	3	4
1	CFO	35°C	T-SBO	T-CO
2	$T\text{-}CO_2$	25°C	40°C	$T\text{-}SBO_2$
3	45°C	CFO_2	OT	OT_2
4	$25°C_2$	$45°C_2$	$35°C_2$	$40°C_2$

[1]Replicates are denoted by a subscript

Initially, 1323 g of oil were preheated to 185^{o}C (approximately 15 minutes) and loads of the frozen French fries weighing 150 g were fried for seven minutes at this initial temperature. At the end of the frying period, fries were drained on a double thickness of paper toweling and either presented to a panel for sensory scoring or packaged and held at -23^{o}C until needed for further analyses. Seventy ml of oil were retained from each fryer for oil analyses after each of 20 consecutive fryings. In order to evaluate the oils under the most severe conditions of use, the quantity of oil was never restored to the original volume of 1323 g after any of the fryings. After every fifth frying, oils were filtered through a double thickness of cheesecloth and throughout the experiment both the oils and fryers were stored at 4°C overnight. Approximately four fryings were completed each day.

Oil Analyses

Color. Before the first frying and after every frying thereafter, the color of the oil was measured using a model D-25 Hunter color difference meter with an inverted head. A yellow tile (L=78.4, a_L=-1.9, b_L=+25.0) was used to standardize the instrument. Approximately 70 ml of warm oil were placed in a optical glass cylinder cup (7.4 x 1.9 cm), and covered with an inverted, white-lined can to provide a standard optical background before taking a reading. After the first reading was taken, the sample was rotated 90°, a second reading obtained, and the average value reported.

Viscosity. Oil viscosities were determined prior to the initial frying and after each consecutive frying. A Nametre model 7.006 Direct Readout Viscometer was used in conjunction with an Exacal 100 controlled temperature circulating water bath at 50°C $\pm$ .01°C. Approximately 40 ml of warm oil obtained from each fryer were placed in glass beakers (3.5 cm x 7.7 cm) and the beakers were then lowered into the circulating water bath. Samples were allowed to temper for 15 minutes before lowering the viscometer head into the sample. Once the head was immersed in the oil, the sample was allowed to equilibrate an additional 15 minutes before a reading was taken.

After color and viscosity were determined for each sample, enough oil for determining refractive index, peroxide value and GLC analysis was retained and stored at -23°C in culture tubes with screw-on tops.

Refractive index. After frying was completed for all variables and their replicates, refractive indices were determined on the stored, frozen oil samples. Indices were determined for the unused oils and after each consecutive frying. A Bausch and Laumb, Abbe-3L refractometer equipped with a 40° ± .01°C circulating water bath was used. Samples were allowed to equilibrate on the prism of the refractometer for one minute before readings were taken. The values reported were the average of two readings.

Peroxide value. Oil samples obtained after the first, fourth, sixth, ninth, eleventh, fourteenth, sixteenth, eighteenth, and twentieth fryings as well as unused oil samples were used for determining peroxide values. AOAC Method 28.023 (AOAC, 1975) was used and the procedure was repeated for each sample, reported values being an average value.

Fatty acid analysis. Oil samples obtained from the unused oil and after the first, sixth, eleventh, sixteenth and twentieth fryings were analyzed for their fatty acid profiles. Fatty acid methyl esters were prepared for GLC analysis using the boron trifluoride-methanol procedure described by Morrison and Smith (1964). The methyl esters were analyzed with a 5830A Hewlett Packard gas chromatograph equipped with a flame ionizing detector. A glass column, 6 ft. x 1/4 in. inside diameter, packed with 15% diethylene glycol succinate (DEGS) on 80/100 Chromosorb was used. The column was operated isothermally at 190°C with a nitrogen flow rate of 30 ml/min. The temperature of the injector and detector was maintained at 210°C and 350°C respectively. Fatty acid percentages were calculated for C_{14}, C_{16}, $C_{16:1}$, C_{18}, $C_{18:1}$, $C_{18:2}$, and $C_{18:3}$ fatty acids using a 18850A Hewlett Packard microprocessing integrater.

French Fry Analyses

French fries from the first, sixth, eleventh, sixteenth, and twentieth fryings were used for both physical/chemical and sensory analyses. Immediately after frying, French fries were drained and a portion was presented to panelists for sensory evaluation. The remaining fries were used for both color and texture measurements, after which fries were ground in a Waring blender until homogeneous, packaged in individual polyethylene bags with whirl closures and held at -23°C until needed for further analyses. On the fryings when no analyses were performed, fries were packaged, without grinding, in polyethylene bags with zip tops and stored at -23°C.

Color. Color readings for the fries prepared in the eight oils were obtained using the same equipment and procedure described for determination of oil color. The instrument was again standardized to a yellow tile.

Texture. An Allo-Kramer shear press equipped with a TR-3 recorder was used to evaluate texture of the French fries. A 100 pound transducer and range of 10 were used, with a single blade cell to measure the force required to shear a single fry. A randomly selected French fry was placed perpendicular to the blade and the value reported was an average of three separate fries.

Moisture content. Five gram samples of thawed, ground French fries were accurately weighed to the nearest 0.0001 g and dried at 90°C overnight under a vacuum of 27 inches of Hg in a Hotpack vacuum oven, model 633 (AOAC Method 14.003). The samples were cooled in a desiccator before being reweighed. The percentage moisture in the cooked French fries was calculated according to the formula:

$$\% \text{ moisture} = \frac{\text{original sample wt (g)} - \text{dried sample wt (g)}}{\text{original sample wt (g)}} \text{ X } 100$$

Duplicate measurements were made on each frying and the average was reported as the percent moisture.

Fat content. Fat was extracted from duplicate 8 g samples, accurately weighed to the nearest 0.0001 g, of thawed, ground fries using the chloroform-methanol method of extraction described by Bligh and Dyer (1959). The majority of the chloroform was evaporated from the chloroform-lipid extract by means of a stream of nitrogen while samples were held in a 35°C water bath. The remaining traces of chloroform were removed by placing flasks containing the samples in a Hotpack vacuum oven (model 633) set at 40°C, with a vacuum of 27 in of Hg, overnight.

Percentage fat was determined using the following equation:

$$\% \text{ fat} = \frac{\text{wt of extracted lipid (g)}}{\text{original sample wt (g)}} \text{ X } 100$$

Fat content was expressed as a percentage of total solids. Conversions were made by the formula:

$$\% \text{ fat (solids basis)} = \frac{\% \text{ fat (wet basis)}}{(100 - \% \text{ moisture of sample}) \text{ X } .01}$$

Approximately 15 drops of lipid obtained from the extraction were retained in 10 ml glass vials with plastic tops and stored at -23°C until needed for GLC analysis. The remaining lipid extract was used in the determination of peroxide value of the extracted fat.

Peroxide value. AOAC Method 28.023 (AOAC, 1975) was used for determining peroxide values of the fat extracted from the French fry samples. Duplicate determinations were made and the average was reported as peroxide value.

Fatty acid analysis. The same method of sample preparation and GLC analyses as described for oil samples was used in the determination of fatty acid profiles for the fat extracted from French fries. The conditions used previously (temperature and flow rates) were also used for the fat samples extracted from the fries.

Sensory evaluation. After the first, sixth, eleventh, sixteenth, and twentieth fryings taste panels were conducted using a trained, 10-member panel. Fries were presented to the panelists while hot and were unsalted so that any off-flavors would not be masked by the salt. For each variable, small paper packages similar to those used by fast-food outlets for French fries were labeled with a random number specific for that variable. Three fries fried in each of the oils were packaged into bags and the bags were placed in pre-heated, covered institutional-type serving trays. A reference sample from a local fast-food restaurant was included with the samples as a color reference. The fries were then presented to taste panelists in individual booths lit with fluorescent lights simulating daylight. Characteristics evaluated were: texture, greasiness, off-flavors (rancidity), color and overall acceptability using a linear, 100 mm scale (see Appendices for scorecard).

Analyses of data

Data were analyzed for variance using the STAT package with the Michigan State University CDC CYBER 170, Model 750 computer. When significant differences were found between the two extreme means, Duncan's Multiple Range Test (Duncan, 1957) was used to pinpoint differences among means.

Consumer Acceptability Study

One thousand chocolate chip cookies, five hundred made with vegetable shortening and five hundred with tallow, were prepared for subjective evaluation by consumers in Port Huron, Michigan.

Materials

Common lots of granulated sugar, flour and miniature chocolate baking chips were obtained from Michigan State University Food Stores. Common lots of brown sugar, eggs, vanilla, salt and baking soda were purchased from a local food retailer. Half of the cookies were prepared with a hydrogenated vegetable shortening containing mono- and diglycerides (Crisco®) obtained from Michigan State University Food Stores, while the other half of the cookies were prepared with edible tallow as the shortening agent. Tallow was obtained from the A.W. Stadler Co., Cleveland, Ohio.

Cookie Preparation

The same formulation was used for both the cookies prepared with vegetable shortening (control) and the cookies prepared with tallow with the type of fat being the only difference (Table 3). The method of preparation and baking time was identical for both variables.

Preparation began with the creaming of the fat, granulated sugar and brown sugar for three minutes at medium speed (90 rpm) using the paddle attachment in a Kitchen Aid mixer, model K5-A. The bowl was scraped down after one minute of mixing. The egg and vanilla were added to the

Table 3. Formulation for chocolate chip cookies.

Ingredient	Control Cookie	Tallow Cookie
Vegetable shortening, g	170.0	
Tallow, g		170.0
Granulated sugar, g	114.0	114.0
Brown sugar, g	114.0	114.0
Whole egg, g	96.0	96.0
Vanilla, ml	5.0	5.0
Flour, g	284.0	284.0
Salt, g	6.0	6.0
Baking soda, g	3.7	3.7
Chocolate chips, g	250.0	250.0

creamed mixture and were mixed for two minutes at medium speed. The dry ingredients (flour, salt and baking soda) were sifted once, added to the previous mixture and mixed for one minute at low speed (60 rpm). The bowl was scraped down after 30 seconds of mixing. The chocolate chips were then added and mixed for 30 seconds at medium speed. The dough was shaped into balls weighing approximately 15 g and placed on stainless steel baking sheets, 17 x 10 x 1/8 inches (42.50 x 25 x 0.31 cm). Baking sheets were lightly greased with vegetable shortening, approximately one gram per sheet. Before baking, the dough balls were flattened slightly with the bottom of a beaker which had been lightly floured. The cookies were baked for 12 minutes at 375^{o}F (190^{o}C) in a 12 1-lb loaf size National Reel Type Test Baking Oven. The cookies were removed from the baking sheets after baking, cooled on wire racks and packaged in individual, transparent polyethylene bags with whirl closures. The bags were labeled with either a "#" representing the control cookie or a "%" representing the tallow cookie. All cookies were stored at -23°C until evaluated. (Total storage time was less than 3 weeks.)

Cookie Evaluation

As part of a taste-panel exhibit representing the Agricultural Economics Consumer Marketing Information Program, cookies were evaluated by 208 adults and 241 children at the "Fun and Facts Fair" in Port Huron, Michigan in April, 1980. Two separate questionnaires were used: one for children under 16 and another for 16 years and older (see Appendices for sample questionnaires). The children were asked to evaluate both cookies, state their preference and their frequency of eating cookies. A space for comments was provided. The adults were also asked to evaluate both cookies, state their preference and the reason for preference, and their willingness to buy a similar type of cookie. Also asked were: frequency of eating and buying cookies, type of cookies most frequently purchased, and ages of household members who would like this type of cookie. Demographic information obtained from only the adults included: sex and age of respondent, number living in household, age of children under 18 living at home and total family income for 1979 before taxes. Both the questionnaires for children and adults used a hedonic scale for evaluating the cookies; the childrens' having a 5-point facial hedonic scale and the adults' having a 7-point descriptive hedonic scale. Throughout the taste panel the order of tasting was alternated to eliminate the possibility of bias, with half the participants receiving the tallow cookie first and half receiving the control cookie first.

Analyses of Data

Chi square (Snedecor and Cochran, 1967) was used to analyze data obtained from the consumer taste panel. From the childrens' survey, cross tabulations were done for preference vs. opinion of each cookie and for frequency of eating cookies vs. opinion of each cookie and preference. From the adults' survey, cross tabulations were done for demographic data and preference vs. opinion of each cookie, preference, willingness to buy, and frequency of eating and buying cookies. Cross tabulations were also done for willingness to buy vs. frequency of eating and buying cookies.

RESULTS AND DISCUSSION

This study was designed to determine the feasibility of using detergent fractionated beef tallow as well as unfractionated tallow blended with vegetable oils, as deep-fat frying media for French fry potatoes. Objective and subjective data were examined to determine the effect of fractionation on the functionality of tallow, tallow fractions, and tallow blends. In addition, chocolate chip cookies prepared with tallow as a substitute for shortening were presented to consumers for sensory evaluation.

Frying Oils

Tallow, tallow fractions and tallow blends were studied as deep-fat frying media partially because of the increased use of deep frying in restaurants and fast-food outlets. Also it was desired that these oils be studied under the stressful conditions which are inherent to this type of cookery. The common practice of adding fresh oil to maintain a constant volume in the cooker wasn't followed so as to allow the maximum rate and extent of oil destruction.

Color

Means and standard deviations for Hunter color values are presented in Table 4 and the analyses of variance for these data are summarized in Table 5. Duncan's Multiple Range Test revealed the two tallow-vegetable oil blends were significantly darker then the original tallow (OT) or tallow fractions ($p < 0.05$). Additionally they were found to be significantly more yellow (larger b_L values) than the OT or 40°C tallow fraction ($p < 0.05$). This is probably a result of carotene pigments present in the vegetable oils.

Freeman (1969) suggested that it was the tocopherols and other components of an oil which produced colored components upon oxidation which increased the general color of the oil. Figures 4a-6b illustrate the changes in oil color over the period of 20 fryings. As expected, all oils became darker and more yellow after each successive frying which contributed to the high standard deviations for oil averages. Lowe et al. (1940) attributed the darkening of frying oils to two factors: breaking down of the fat and the accumulation of small food particles. Jacobson (1967) correlated color changes of a fat to an increase in free fatty acid content. Since free fatty acids discolor readily, they alter the color of a fat as their concentrations increase (Bates, 1952).

The development of yellows (increased b_L values) occurred in all oils over a period of fryings and was also reported by Bennion and Hanning (1956) in their study of lard decomposition during the frying of French fries. Although L and b_L values changed noticable over the frying period, a_L values (greenness) remained somewhat constant; all oils exhibiting a slight green tinge (Figures 6a and 6b).

Table 4. Means and standard deviations[1] for color values of original tallow, tallow fractions, tallow blends and a commercial fry oil.

Type of Oil	Hunter Color Values		
	L^2	$a_L{}^3$	$b_L{}^4$
Original Tallow	41.6 ± 0.6[d]	-4.7 ± 0.3[a]	+11.9 ± 1.5[a]
Tallow Fractions:			
25°C	41.4 ± 1.0[bc]	-4.8 ± 0.5[abc]	+12.5 ± 2.3[c]
35°C	41.7 ± 1.6[a]	-4.9 ± 0.5[cd]	+12.4 ± 2.3[c]
40°C	41.4 ± 0.6[b]	-4.8 ± 0.6[ab]	+12.1 ± 2.1[ab]
45°C	41.4 ± 0.9[b]	-4.8 ± 0.3[abcd]	+12.4 ± 1.9[bc]
Tallow Blends:			
w/Soybean Oil	40.9 ± 0.8[d]	-4.9 ± 0.5[bcd]	+14.0 ± 1.9[e]
w/Corn Oil	40.4 ± 0.7[e]	-4.9 ± 0.4[d]	+16.1 ± 1.4[f]
Commercial Frying Oil	41.2 ± 0.7[c]	-5.0 ± 0.4[d]	+13.3 ± 1.9[d]

[1]Mean and standard deviation of the mean based on duplicate determinations after each of 20 fryings.

[2]Lightness (100 = white, 0 = black)

[3]Greenness

[4]Yellowness

[abc]Column means with the same superscript are not significantly different at $p < 0.05$ (Duncan, 1957).

Table 5. Analyses of variance of color values of original tallow, tallow fractions, tallow blends and a commercial frying oil.

		Mean Squares		
Source	df	L	a_L	b_L
Total	335			
Variable	7	7.89**	0.50**	83.57**
Fry Sequence	20	9.49**	1.19**	47.73**
Interaction	140	0.61**	0.17	1.55**
Within	168	0.12	0.13	0.37

**Significant at the 1% level of probability.

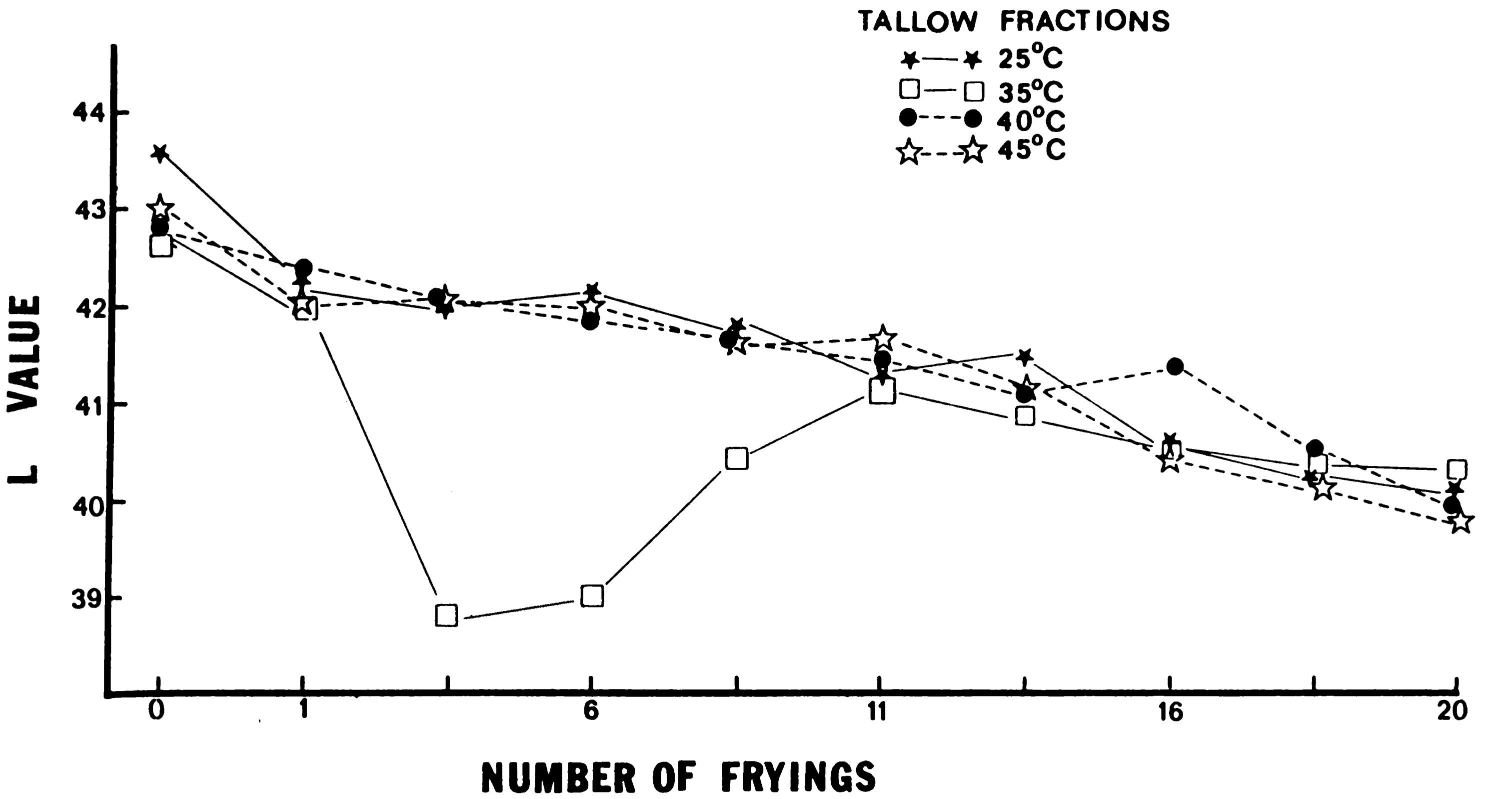

Figure 4a. Change in color (lightness) of tallow fractions over 20 successive fryings.

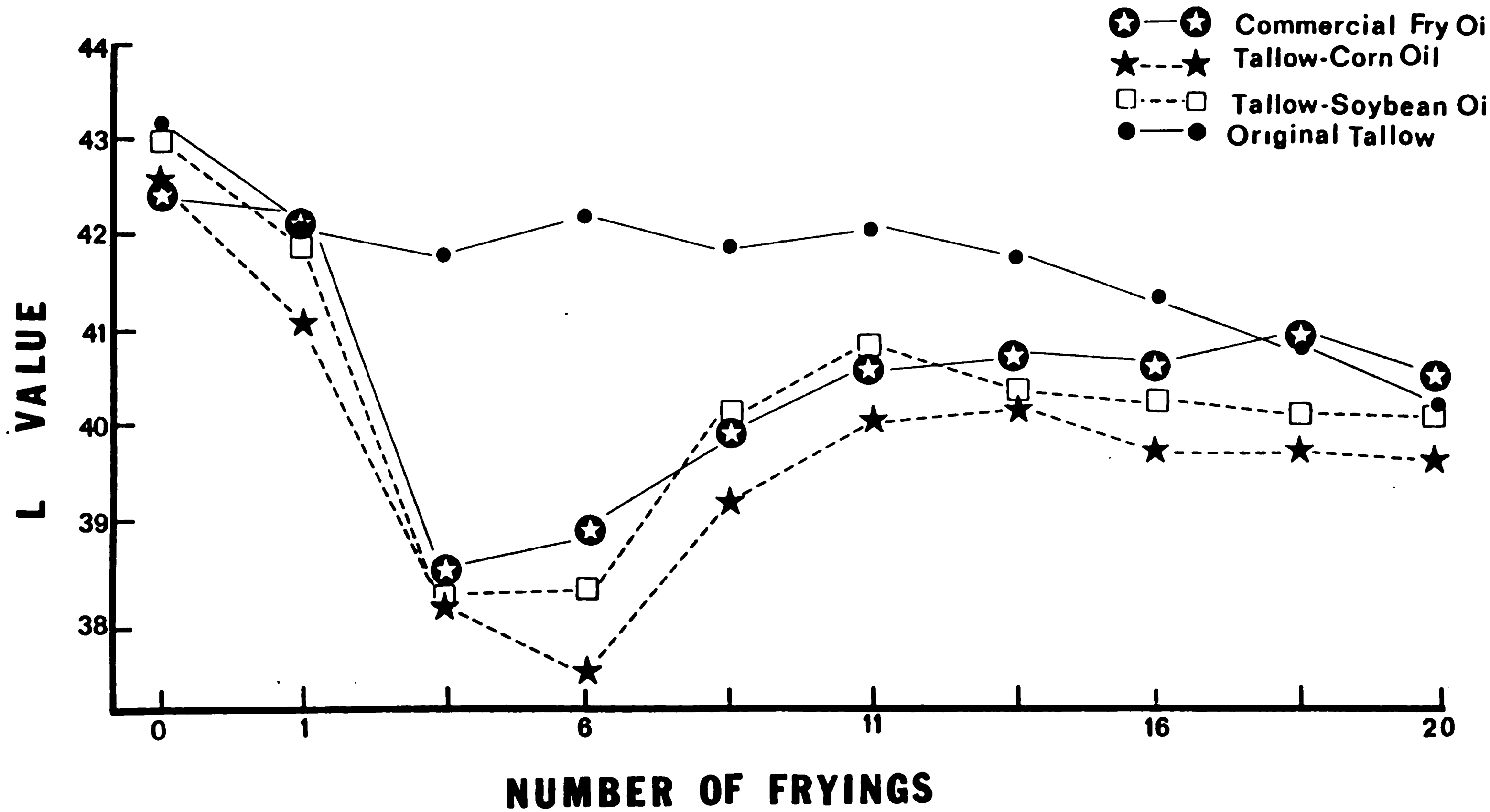

Figure 4b. Change in color (lightness) of original tallow, tallow blends and a commercial frying oil after 20 successive fryings.

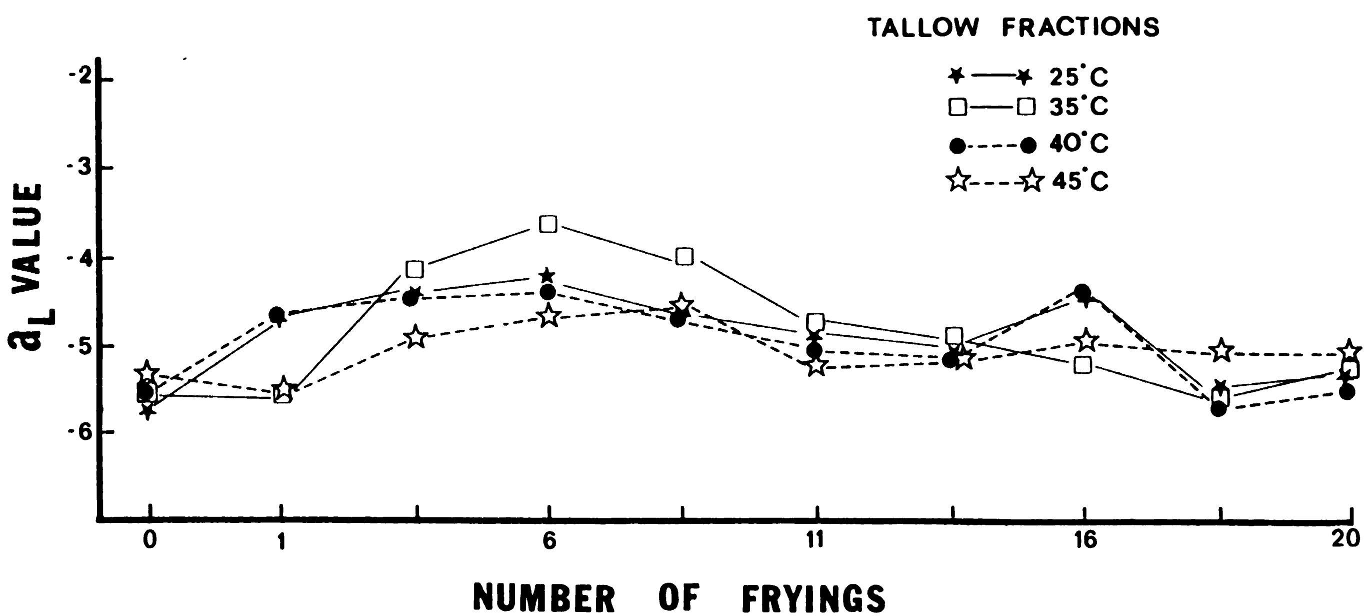

Figure 5a. Change in greenness (Hunter a_L value) of tallow fractions used for deep frying over a period of 20 fryings.

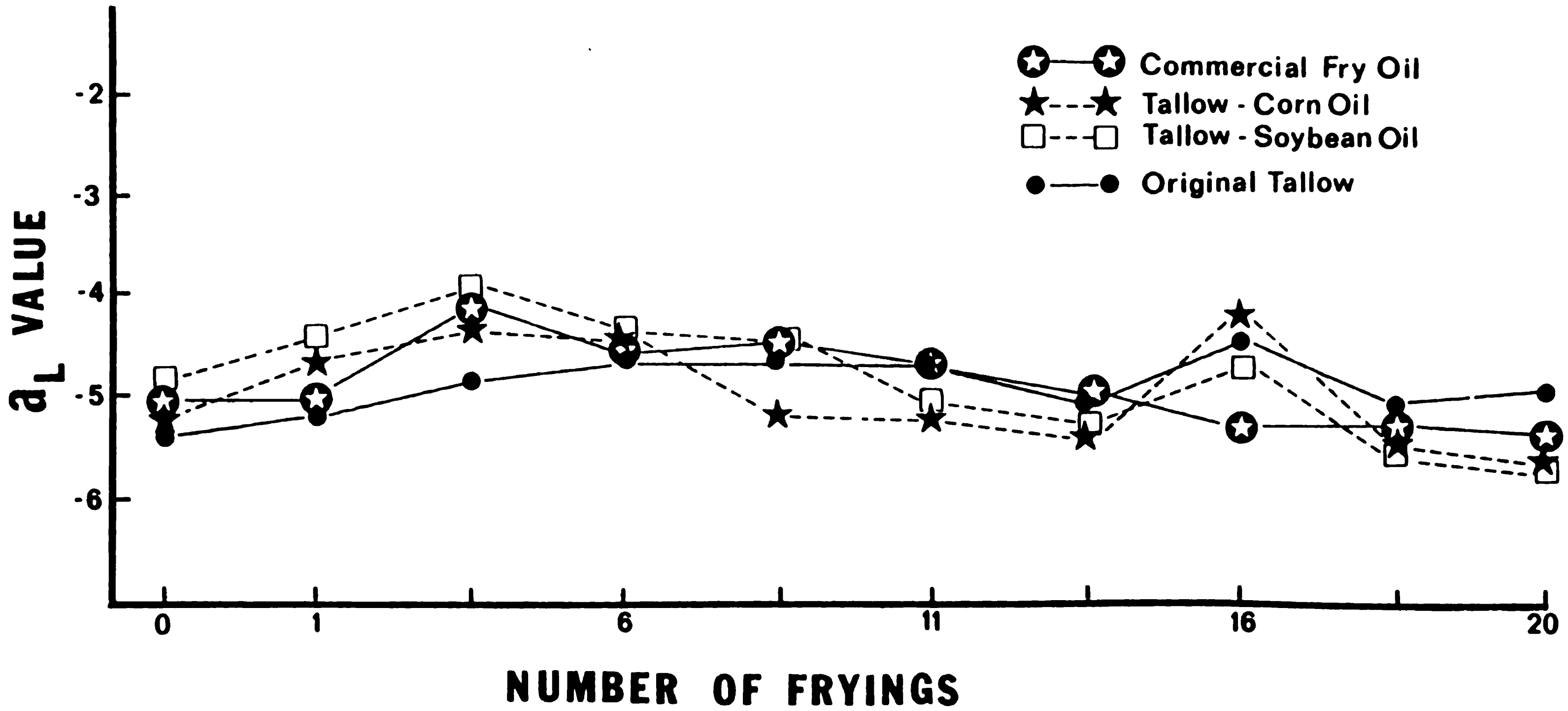

Figure 5b. Change in greenness (Hunter a_L value) of original tallow, tallow blends, and a commercial frying oil used for deep frying over a period of 20 fryings.

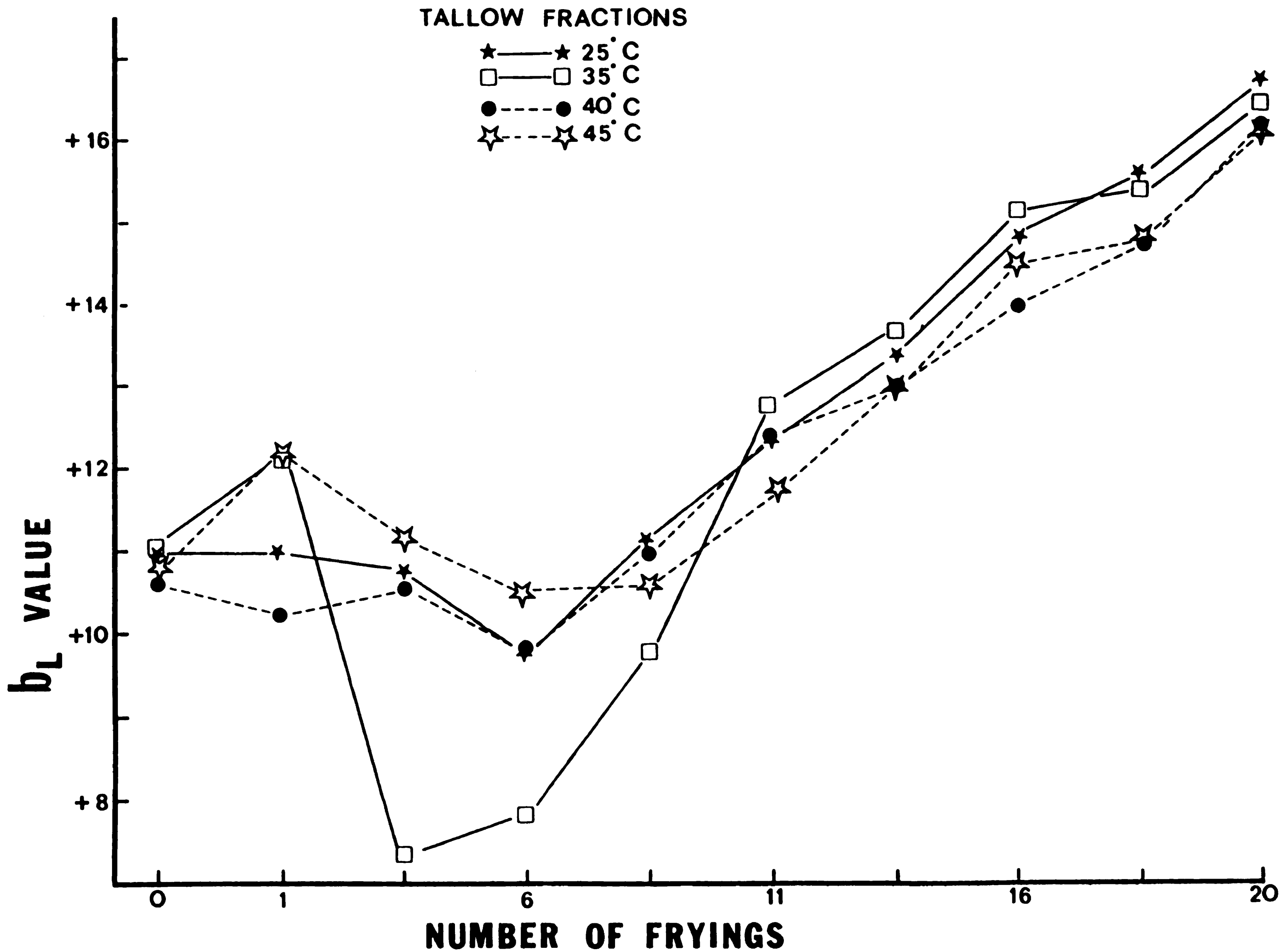

Figure 6a. Change in yellowness (Hunter b_L value) of tallow fractions used for deep frying over a period of 20 fryings.

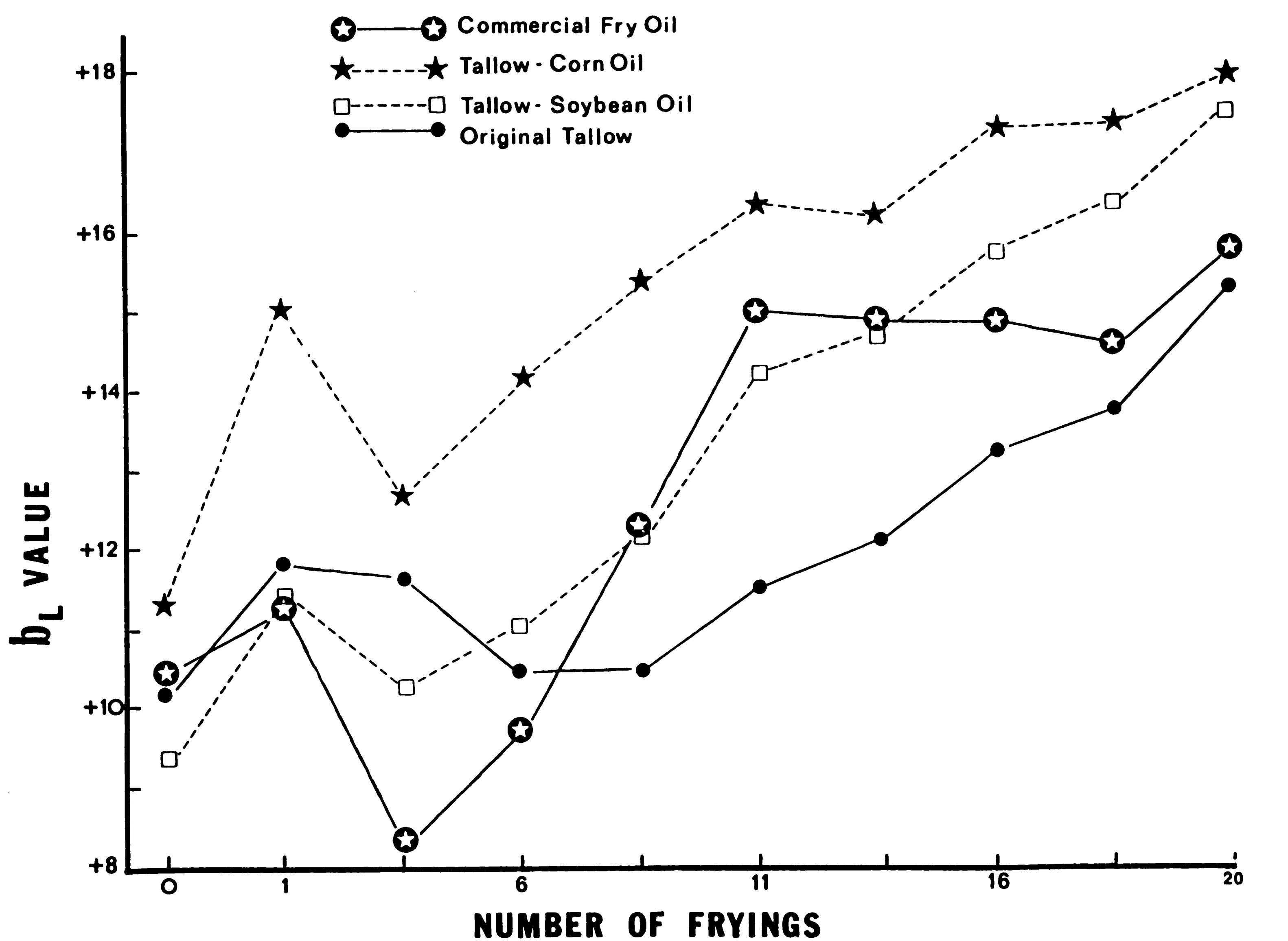

Figure 6b. Change in yellowness (Hunter b_L value) of original tallow, tallow blends, and a commercial frying oil used for deep frying over a period of 20 fryings.

Viscosity and Refractive Index

Means and standard deviations of the means for oil viscosities and refractive indices are presented in Table 6. The analyses of variance for these data are given in Tables 7 and 8. Mean viscosities for the oils ranged from 27.3 centipoise x g/cm^3 for tallow-corn oil (T-CO) to 45.5 centipoise x g/cm^3 for the commercial frying oil (CFO) (Table 12). Figure 7 shows the viscosity of the oil samples over the course of 20 fryings. Although product specifications for the CFO indicated that it was a clear liquid above 35°C, the CFO was not included in this figure or in the analysis of variance because polymorphic crystal structure at 50°C made an accurate viscosity reading impossible.

Polyunsaturated fatty acids tend to polymerize when fats or oils are submitted to strong heat treatment (Grob et al., 1980). As polymerization occurs, viscosity increases (Perkins, 1967). The increase in viscosity for all oil samples in this present study has been attributed to fatty acid polymerization. Carlin et al. (1954) also reported that increased viscosity was evidence of thermal decomposition of frying fats.

Refractive indices were largest for the tallow fractions which Bussey et al. (1981) reported as having the least saturated fatty acid profiles. This was also confirmed by subsequent GLC analyses for all of the oil samples (Table 11). Increased refractive indices are indicative of thermal decomposition and polymer formation of a fat or oil (Carlin et al., 1954). Figure 8 shows the increase in refractive indices which occurred over 20 frying periods for each of the variables. Lowe et al. (1940) found that refractive indices of lard and other fats not only increased with continued use, but also as frying temperatures

Table 6 . Means and standard deviations[1] for viscosities and refractive indices of original tallow, tallow fractions, tallow blends and a commercial frying oil[2].

Type of Oil	Viscosity (Centipoise x g/cm^3)	Refractive Index
Original Tallow	29.7 ± 2.1^{bcd}	$1.4588 \pm .0004^{a}$
Tallow Fractions:		
25°C	29.0 ± 1.8^{b}	$1.4593 \pm .0003^{c}$
35°C	30.5 ± 3.4^{d}	$1.4591 \pm .0006^{b}$
40°C	29.1 ± 1.7^{b}	$1.4590 \pm .0004^{b}$
45°C	30.1 ± 2.0^{cd}	$1.4588 \pm .0004^{a}$
Tallow Blends:		
w/Soybean Oil	29.3 ± 3.6^{bc}	$1.4524 \pm .0005^{d}$
w/Corn Oil	27.3 ± 2.9^{a}	$1.4639 \pm .0004^{e}$
Commercial Frying Oil	45.5 ± 18.5	$1.4653 \pm .0003^{f}$

[1]Mean and standard deviation of the mean based on duplicate determinations after each of 20 fryings.

[2]The commercial frying oil was omitted from the analysis of variance for viscosity due to extreme standard deviation.

[abc]Column means with the same superscript are not significantly different at $p < 0.05$ (Duncan, 1957).

Table 7. Analysis of variance of viscosities of original tallow, tallow fractions and tallow blends[1].

Source	df	Mean Squares
Total	293	
Variable	6	42.66**
Fry Sequence	20	63.66**
Interaction	120	2.19
Within	147	2.83

[1]The commercial frying oil was omitted from the analysis of variance due to extreme standard deviation.

**Significant at the 1% level of probability.

Table 8. Analysis of variance of refractive indices of original tallow, tallow fractions, tallow blends and a commercial frying oil.

Source	df	Mean Squares
Total	335	
Variable	7	.0003**
Fry Sequence	20	.0000**
Interaction	140	.0000
Within	168	.0000

**Significant at the 1% level of probability.

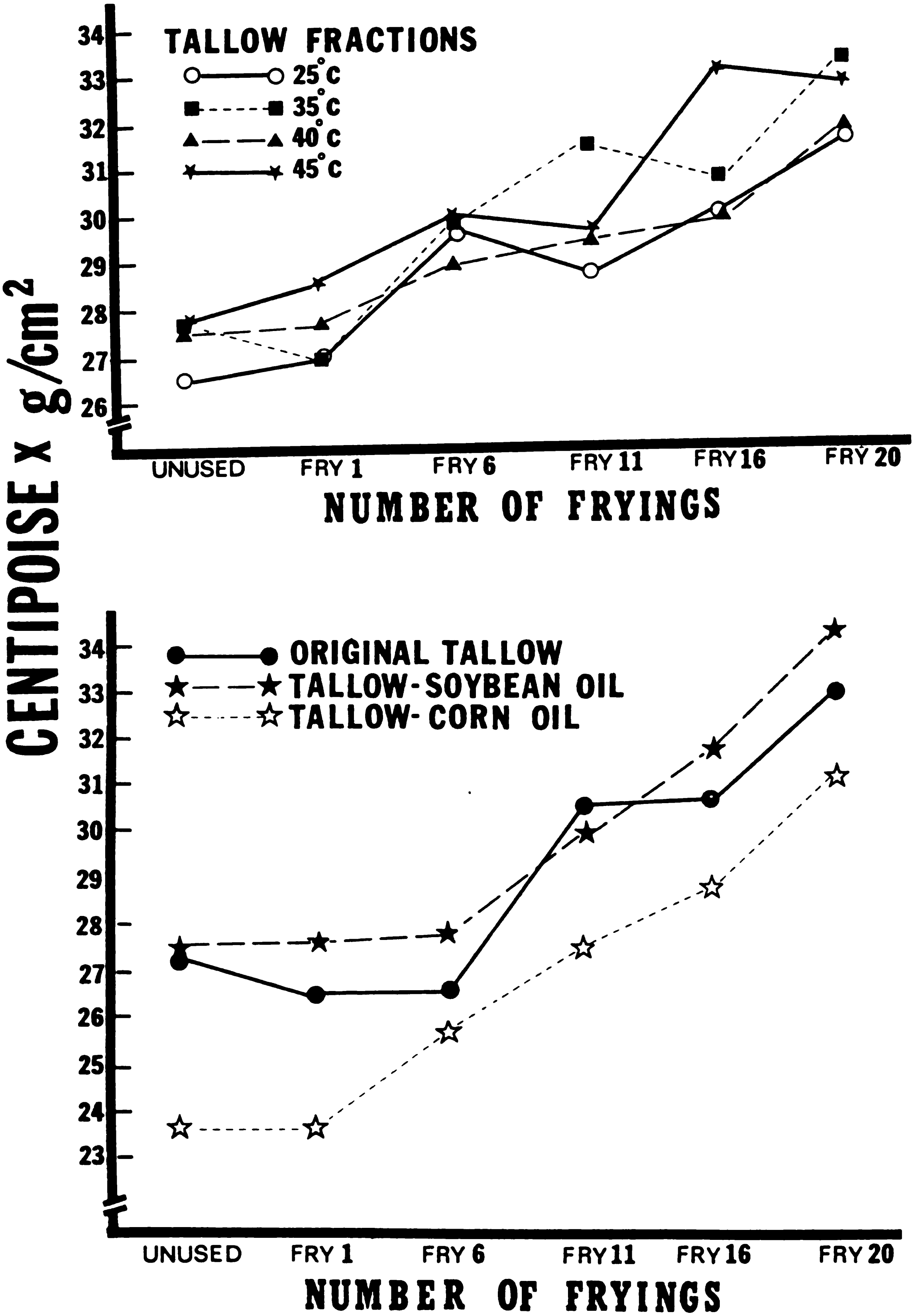

Figure 7. Change in viscosity of original tallow, tallow fractions, tallow blends, and a commercial frying oil over a period of 20 consecutive fryings.

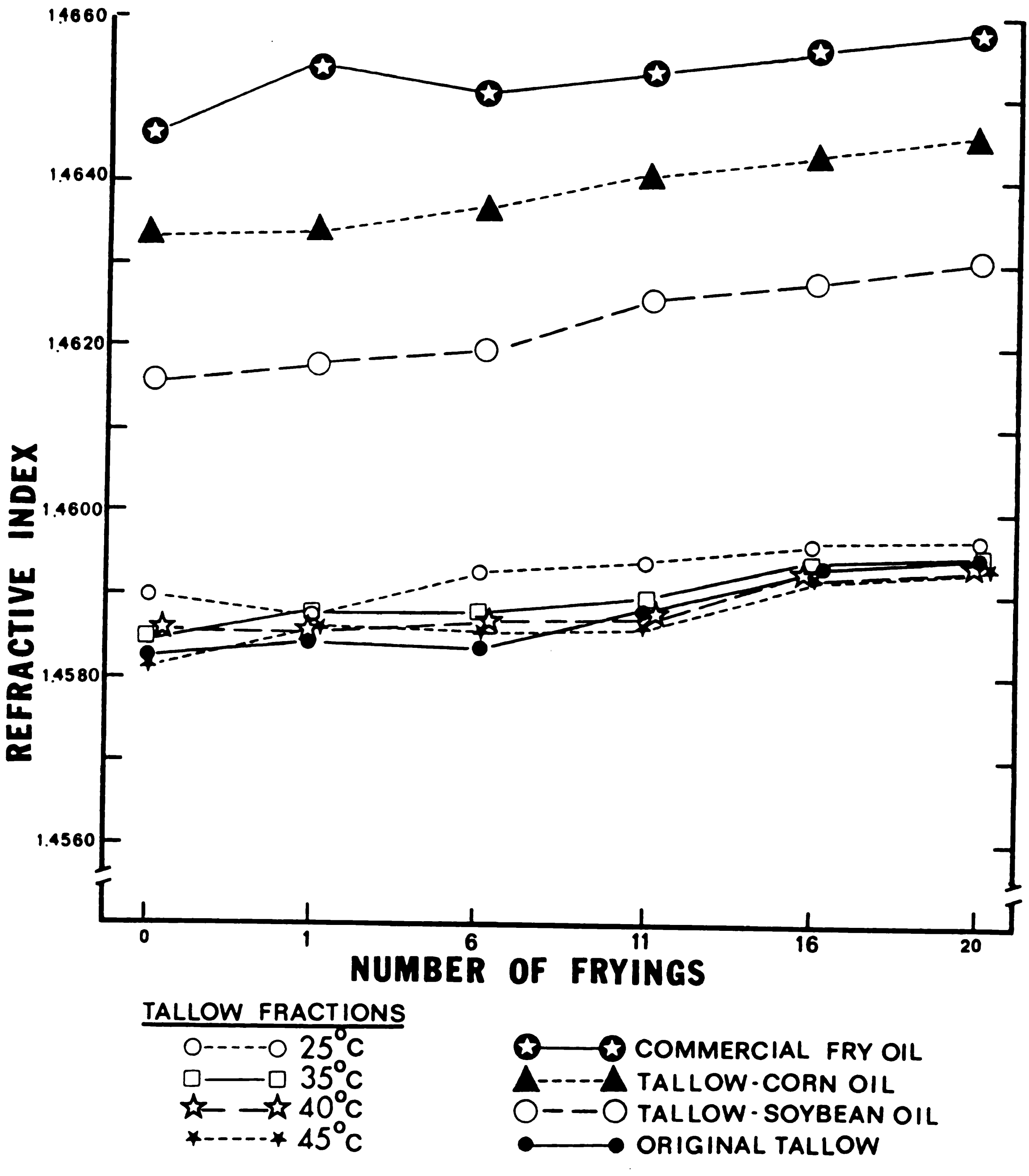

Figure 8. Change in refractive indices of original tallow, tallow fractions, tallow blends, and a commercial frying oil over a period of 20 successive fryings.

were progressively increased. Since the total heating time of each oil sample was approximately 10 hours in the present study, one wouldn't expect drastic formation of polymeric acids. However since oils were heated and cooled intermittently the amount of breakdown which occurred may have exceeded that which was expected (Perkins and VanAkkeren, 1965).

Peroxide Values

Means and standard deviations of the means for peroxide values appear in Table 9. Analysis of variance for these data appear in Table 10. Peroxide values for the OT, T-CO, and T-SBO were significantly higher ($p < 0.05$) than the tallow fractions or the CFO, indicative of a greater extent of oxidation. Figures 9a and 9b represent the change in peroxide values over a period of 20 fryings for each of the oils. Values increased steadily for all oils until reaching a peak after the sixth frying; thereafter the peroxide values fluctuated extensively. Bennion and Hanning (1955) also reported peroxide values with large variations for oils used to deep-fry potatoes.

As peroxides and hydroperoxides are initially formed in autoxidation, the peroxide value of an oil increases. However as these products decompose to form volatile ketones, aldehydes, acids and alcohols, peroxide values decrease. Chang et al. (1952) reported peroxide values for lard decreased to negligible values after only 40 minutes of heating. They attributed this to the decomposition of peroxides as quickly as they were formed. Perkins and Van Akkeren (1965) suggested that it was the intermittent heating, cooling and heating cycles which encouraged peroxide formation and subsequent destruction by heating. Since fryers for this study were heated only long enough to fry a

Table 9. Means and standard deviations[1] for peroxide values of original tallow, tallow fractions, tallow blends and a commercial frying oil.

Type of Oil	Peroxide Value (meq/1000g)
Original Tallow	11.3 ± 6.2^{bcd}
Tallow Fractions:	
25°C	7.9 ± 4.3^{ab}
35°C	9.6 ± 4.9^{abc}
40°C	7.2 ± 4.1^{a}
45°C	9.8 ± 4.6^{bc}
Tallow Blends:	
w/Soybean Oil	11.4 ± 4.9^{bcd}
w/Corn Oil	12.6 ± 7.1^{cd}
Commercial Frying Oil	8.1 ± 4.4^{ab}

[1]Mean and standard deviation of the mean based on duplicate determinations after each of 20 fryings.

[abc]Column means with the same superscript are not significantly different at $p < 0.05$ (Duncan, 1957).

Table 10. Analysis of variance of peroxide values of original tallow, tallow fractions, tallow blends and a commercial frying oil.

Source	df	Mean Squares
Total	159	
Variable	7	72.24**
Fry Sequence	9	277.08**
Interaction	63	14.25**
Within	80	7.93

**Significant at the 1% level of probability.

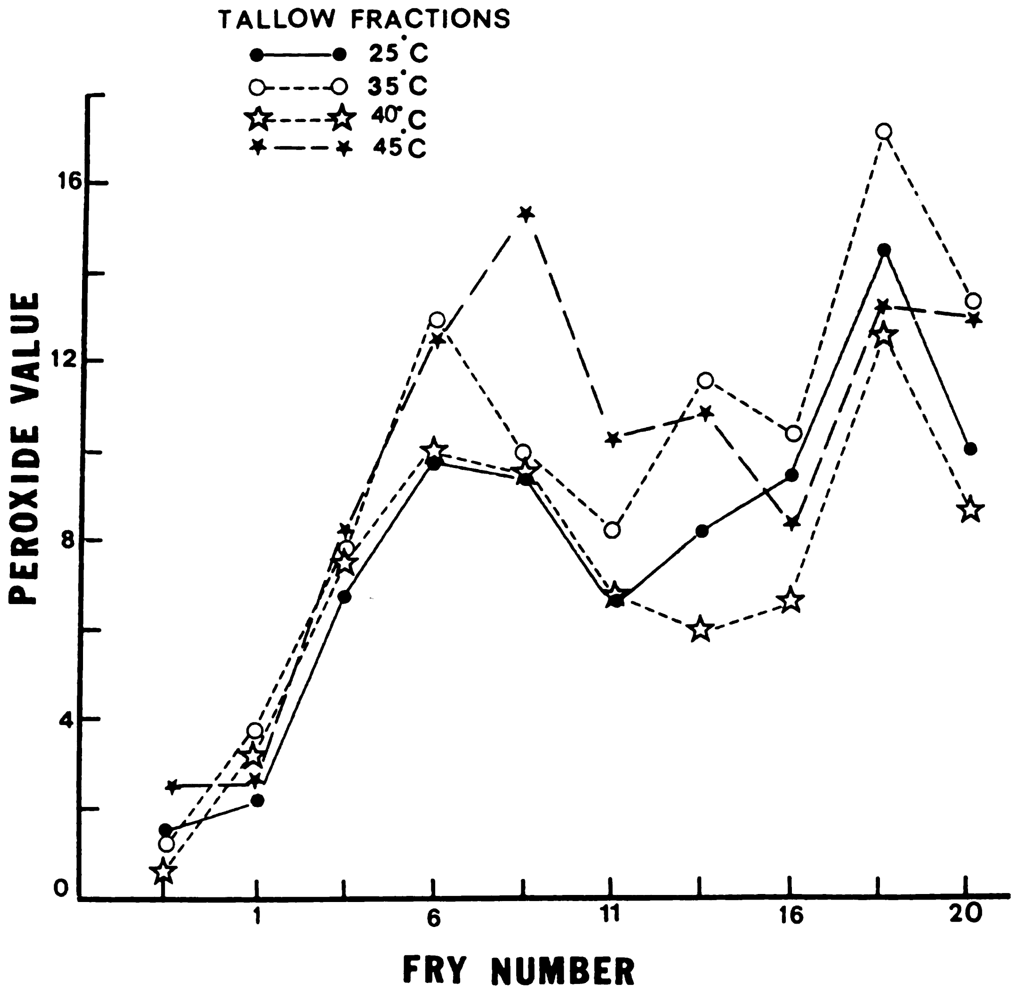

Figure 9a. Change in peroxide values of tallow fractions over a period of 20 successive fryings.

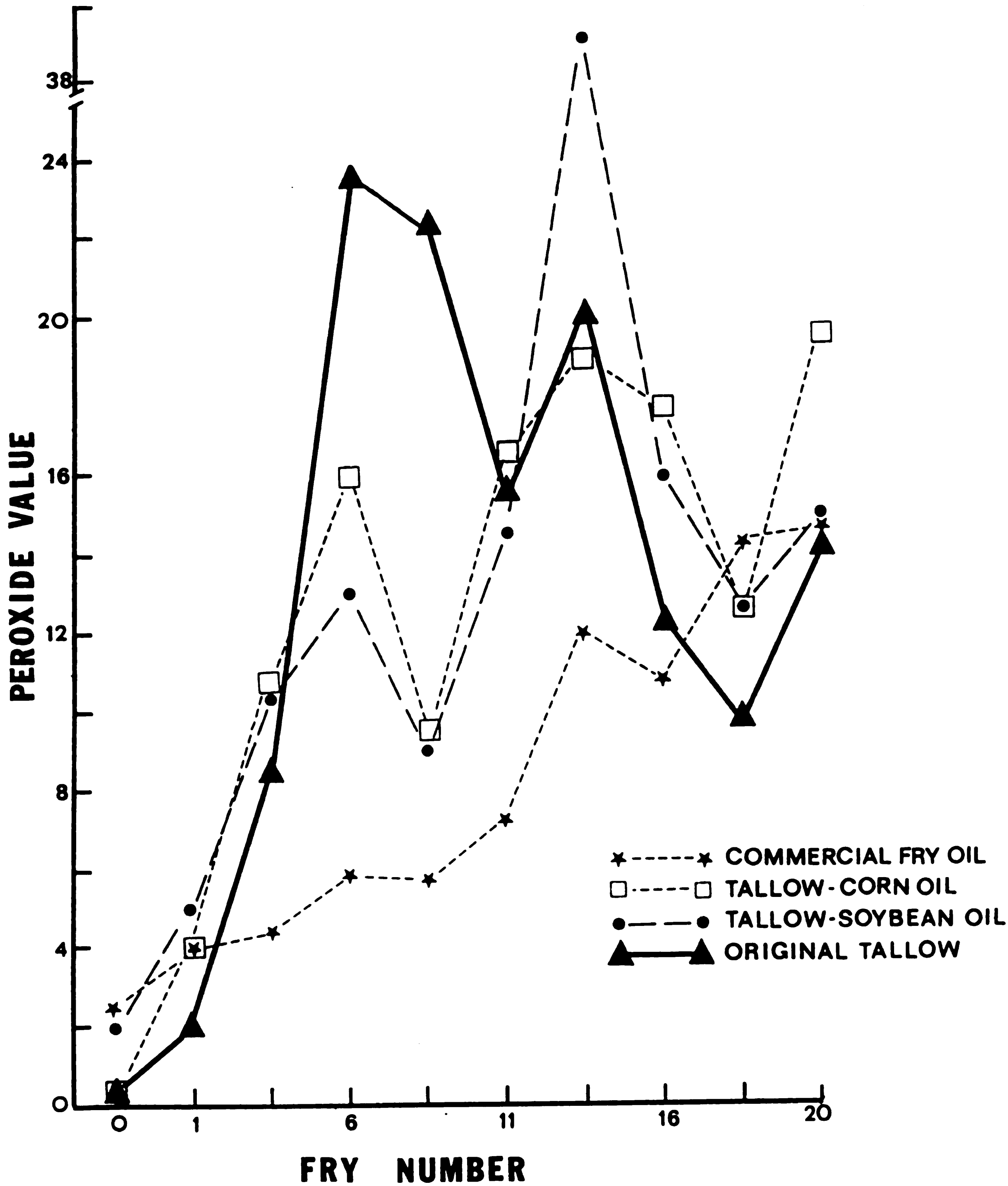

Figure 9b. Change in peroxide values of original tallow, tallow blends, and a commercial frying oil used for deep frying over a period of 20 fryings.

single batch of fries before being allowed to cool, intermittent heating may have contrituted to the variation in peroxide values.

Beef tallow contains only negligable tocopherols to provide natural antioxidant properties; 0.001% compared to soybean oil with 0.168% (Schwitzer, 1956). Although the legal limit of antioxidant (0.02% BHA) was added to all oil systems, peroxide values generally doubled after only one frying. Roth and Rock (1972) discussed the lack of antioxidant effectiveness during deep-fat frying. An extreme rate of hydroperoxide formation and decomposition occurs during heating and storage of the oil followed by rapid decomposition into free radicals. The reaction rate is such that antioxidants present in levels allowable in food cannot inhibit the large number of free radicals present. Carlin et al. (1954) suggested that unless constantly replenished, antioxidants may be quickily lost at frying temperatures. BHA is steam distillable thus easily lost as moisture is driven off in deep frying (Sherwin, 1972). It has been postulated, therefore, that the antioxidant present in each of the experimental oils was ineffective in inhibiting peroxide formation.

Fatty Acid Determination by Gas Chromatography

Relative percentages of fatty acids as determined by gas chromatographic (GC) analyses of methyl esters of all frying oils are presented in Table 11. A sample chromatogram is found in the Appendices. As the temperature at which tallow was fractionated decreased, the percentage of saturated fatty acids present in olein fractions tended to decrease. Linoleic acid was present in only trace amounts for both original and fractionated tallow samples.

Table 11. Mean relative percentage of fatty acids present in frying oils over a period of 20 successive fryings.[1]

Frying Oils	Percent Fatty Acids						
	C_{14}	C_{16}	$C_{16:1}$	C_{18}	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Original Tallow	3.50	27.49	3.45	17.45	48.12	tr.	---
25°C	3.46	25.38	5.37	13.58	51.44	tr.	---
35°C	3.99	27.32	3.86	14.62	49.51	tr.	---
40°C	3.73	25.85	5.51	13.86	51.02	tr.	---
45°C	3.43	26.18	4.47	16.20	49.69	tr.	---
Tallow-Soybean Oil	1.85	20.11	1.31	10.31	46.68	18.75	0.42
Tallow-Corn Oil	1.74	20.28	1.90	9.42	36.33	30.31	tr.
Commercial Frying Oil	0.07	12.99	--	6.49	47.06	32.36	0.90

[1]Data based on 2 replications.

Perkins (1967) explained that many popular frying fats are based on beef tallow because of the lower percentages of linoleic acid present, thus reducing the potential for oxidation.

Table 12 summarizes the change in fatty acid content of each oil over the course of 20 fryings. There were slight losses of linoleic acid for the T-SBO, T-CO, and CFO. Chang et al, (1952) and Kilgore (1964) also reported losses of linoleic acid in vegetable oil after heating. Grob (1980) analyzed, by gas chromatography, tallow based frying oils before and after heat treatment and reported an increased proportion of saturated peaks at the cost of unsaturated peaks after heating.

Results from fatty acid determination in this study were somewhat erratic and were attributed to both small variations within samples and to the condition of the column. It is recommended for future studies that the column be repacked after approximately every 20 samples rather than 45 samples to maintain peak separation efficiency.

Table 12. Change in fatty acid composition of frying oils over a period of 20 fryings[1].

Frying Oils	Percent Fatty Acids						
	C_{14}	C_{16}	$C_{16:1}$	C_{18}	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Original Tallow							
Unused	3.70	29.16	4.56	17.83	44.75	tr.	--
Fry 1	3.71	27.81	3.53	17.20	47.77	tr.	--
Fry 6	3.51	26.90	4.69	17.19	47.72	tr.	--
Fry 11	3.55	27.51	2.56	17.72	48.66	tr.	--
Fry 16	3.25	26.58	3.02	17.23	49.93	tr.	--
Fry 20	3.29	26.98	2.35	17.50	49.88	tr.	--
25°C Fraction							
Unused	3.37	24.53	6.04	12.81	51.67	tr.	--
Fry 1	3.47	24.43	6.01	13.34	52.68	tr.	--
Fry 6	3.42	24.88	5.87	13.53	52.31	tr.	--
Fry 11	3.20	24.07	6.95	13.39	51.15	tr.	--
Fry 16	3.54	26.72	3.95	14.37	49.63	tr.	--
Fry 20	3.75	27.64	3.38	14.03	51.21	tr.	--
35°C Fraction							
Unused	4.34	29.90	3.26	14.23	48.28	tr.	--
Fry 1	3.69	25.80	5.62	14.50	50.35	tr.	--
Fry 6	3.74	26.51	3.23	15.08	50.09	tr.	--
Fry 11	3.91	26.47	3.30	14.80	50.18	tr.	--
Fry 16	4.09	26.98	4.43	14.38	48.60	tr.	--
Fry 20	4.15	28.25	3.33	14.74	49.54	tr.	--
40°C Fraction							
Unused	3.46	22.65	8.09	11.28	54.39	tr.	--
Fry 1	3.79	25.54	6.13	13.51	50.95	tr.	--
Fry 6	3.82	27.37	4.55	14.70	49.47	tr.	--
Fry 11	3.68	26.21	4.43	14.44	51.21	tr.	--
Fry 16	3.69	26.60	5.55	14.02	50.30	tr.	--
Fry 20	3.95	26.75	4.29	15.22	49.79	tr.	--
45°C Fraction							
Unused	3.51	25.94	5.61	15.24	49.57	tr.	--
Fry 1	3.56	25.97	5.49	15.97	48.92	tr.	--
Fry 6	3.32	26.94	2.74	17.06	49.95	tr.	--
Fry 11	3.36	26.01	5.27	16.35	49.02	tr.	--
Fry 16	3.50	26.59	2.69	16.41	50.82	tr.	--
Fry 20	3.33	25.62	5.04	16.16	49.84	tr.	--
Tallow-Soy Oil							
Unused	2.03	21.39	2.06	11.00	45.61	17.49	0.43
Fry 1	1.81	18.89	1.67	9.50	46.60	21.18	0.36
Fry 6	1.83	20.16	1.79	10.54	46.34	18.85	0.50
Fry 11	1.82	19.75	1.89	10.13	46.64	19.33	0.50
Fry 16	1.81	20.17	1.91	9.76	47.25	18.86	0.25
Fry 20	1.81	20.28	2.11	10.91	47.61	16.81	0.48
Tallow-Corn Oil							
Unused	1.79	21.15	2.14	9.80	35.29	29.83	tr.
Fry 1	1.70	19.44	2.14	9.40	34.89	32.32	tr.
Fry 6	1.72	19.61	1.62	9.09	36.00	31.95	tr.
Fry 11	1.78	20.34	1.45	9.24	36.34	30.86	tr.
Fry 16	1.71	20.47	2.60	9.54	36.97	28.71	tr.
Fry 20	1.74	20.68	1.46	9.44	38.50	28.17	tr.
Commercial Oil							
Unused	0.04	12.53	--	6.24	45.06	34.89	1.23
Fry 1	0.03	11.97	--	6.52	45.28	34.54	1.66
Fry 6	0.05	13.72	--	6.01	46.71	32.70	0.81
Fry 11	0.10	12.19	--	6.51	46.53	32.97	1.70
Fry 16	0.10	13.77	--	6.26	48.28	30.01	tr.
Fry 20	0.07	13.77	--	7.37	50.49	28.17	tr.

French Fries

French fry potatoes were chosen for deep-fat frying because of their inherent blandness which would therefore allow any flavor differences imparted by the oils to be recognized more easily. Means and standard deviations as well as analyses of variance for sensory and objective evaluations accompany this discussion.

Sensory Evaluation

Means and standard deviations of the means for sensory characteristics are presented in Table 13 and a summary of the analyses of variance for these qualities is presented in Table 14. Color and general acceptability were not significantly ($p < 0.05$) affected by the type of frying oil. French fries fried in the OT were slightly more crisp and less greasy than those fried in the tallow fractions separated at 25°C, 35°C, or 40°C. Fries prepared in the T-CO blend had the least presence of off flavors, however all fries were scored equal to or better than the fries prepared in the CFO.

All fries became progressively lighter after the first frying and were more greasy, less crisp by fry eleven. These changes in sensory scores were also reflected in high standard deviations for oil averages. Changes in sensory scores for color and texture of French fries after every fifth frying are presented in Appendices VII and VIII. Results obtained by sensory analyses for these two parameters paralleled those obtained by objective analyses and will therefore be discussed with objective data.

Figure 10 illustrates the changes in off-flavors after every fifth

Table 13. Means and standard deviations[1] for sensory characteristics of French fries prepared in tallow, tallow fractions, tallow blends or a commercial frying oil.

Type of Oil	Sensory Characteristics				
	Color[2]	Texture[3]	Greasiness[4]	Flavor[5]	General Acceptability[6]
Original Tallow	39.0 ± 11.5^{a}	57.5 ± 10.3^{b}	40.4 ± 15.2^{a}	36.5 ± 10.4^{ab}	52.0 ± 6.7^{a}
Tallow Fractions:					
25°C	31.2 ± 9.3^{a}	39.1 ± 8.6^{b}	55.8 ± 8.3^{b}	34.9 ± 7.8^{ab}	47.6 ± 7.9^{a}
35°C	31.9 ± 10.1^{a}	41.6 ± 14.0^{b}	53.8 ± 14.6^{b}	38.5 ± 8.8^{abc}	48.9 ± 8.9^{a}
40°C	32.3 ± 15.3^{a}	42.4 ± 12.2^{b}	51.8 ± 11.1^{b}	35.9 ± 9.2^{ab}	48.7 ± 8.6^{a}
45°C	38.9 ± 11.8^{a}	49.4 ± 8.1^{ab}	47.1 ± 9.8^{ab}	38.2 ± 7.6^{abc}	48.7 ± 9.3^{a}
Tallow Blends:					
w/soybean oil	28.4 ± 13.4^{a}	47.4 ± 11.8^{ab}	46.6 ± 10.2^{ab}	45.8 ± 14.2^{bc}	42.6 ± 12.9^{a}
w/corn oil	26.2 ± 10.9^{a}	44.6 ± 12.2^{a}	49.5 ± 8.9^{ab}	29.4 ± 12.4^{a}	54.5 ± 11.4^{a}
Commercial oil	35.8 ± 11.4^{a}	50.2 ± 11.3^{ab}	48.3 ± 11.3^{ab}	48.6 ± 17.0^{c}	42.1 ± 15.9^{a}

[1] Mean and standard deviation of the mean based on evaluation of French fries from fry 1, 6, 11, 16, & 20.

[2] Scale of 0 (very light) to 100 (very dark).

[3] Scale of 0 (limp) to 100 (very crisp).

[4] Scale of 0 (no greasiness) to 100 (very greasy).

[5] Scale of 0 (no off-flavor) to 100 (extreme off-flavor).

[6] Scale of 0 (unacceptable) to 100 (acceptable).

[abc] Column means with the same superscript are not significantly different at $p < 0.05$ (Duncan, 1957).

Table 14. Analyses of variance of French fries prepared in original tallow, tallow fractions, tallow blends or a commercial frying oil.

		Mean Squares				
Source	df	Color	Texture	Greasiness	Flavor	General Acceptability
Total	79					
Variable	7	216.34	348.23*	230.45*	371.49**	176.77
Fry Sequence	4	859.40**	507.99**	823.53**	307.63	495.09**
Interaction	28	79.48	74.38	80.51	116.60	99.49
Within	40	110.53	123.79	96.11	119.94	82.61

**Significant at the 1% level of probability

*Significant at the 5% level of probability

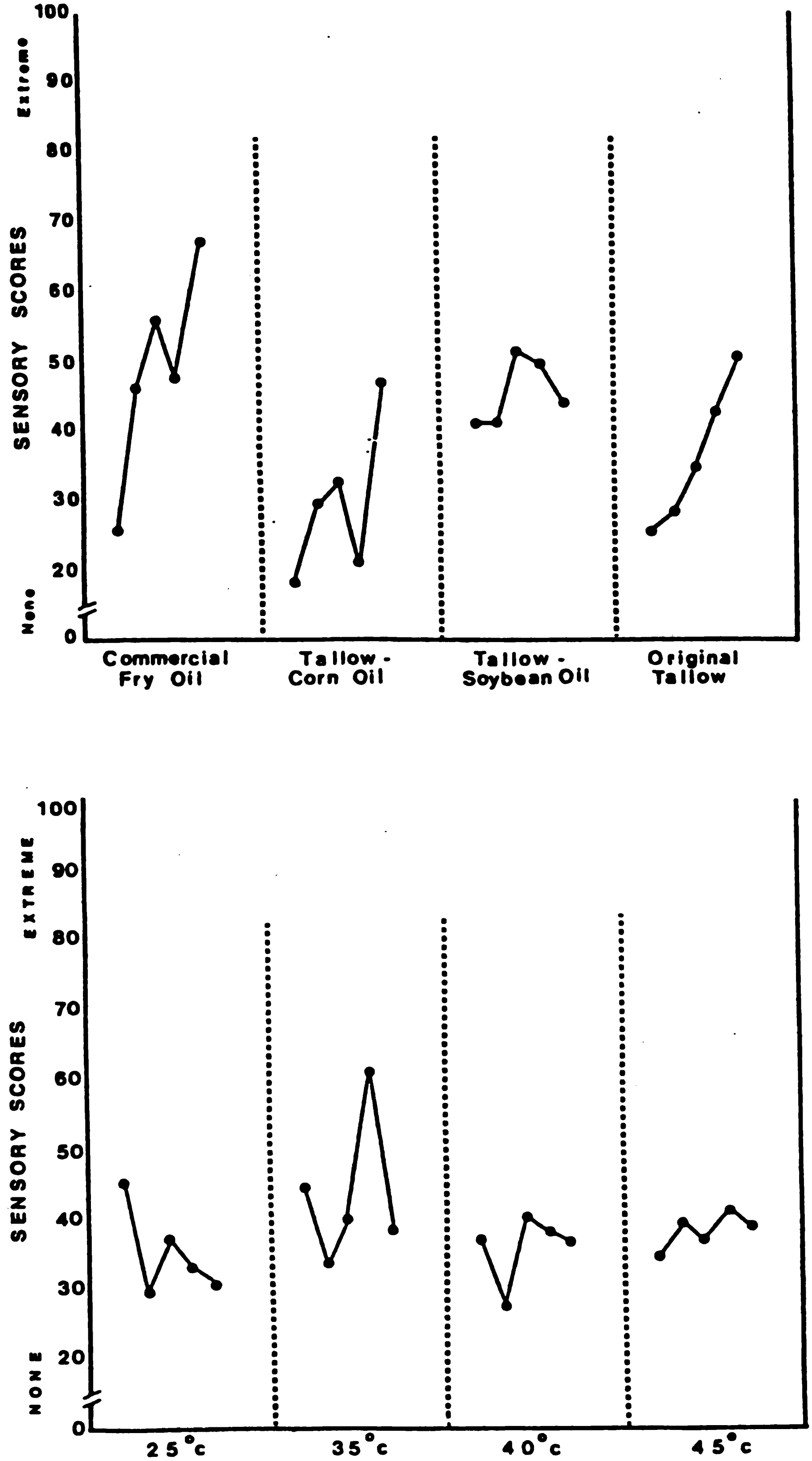

Figure 10. Presence of off-flavors in French fries fried in original tallow, tallow fractions, tallow blends and a commercial frying oil after every fifth successive frying.

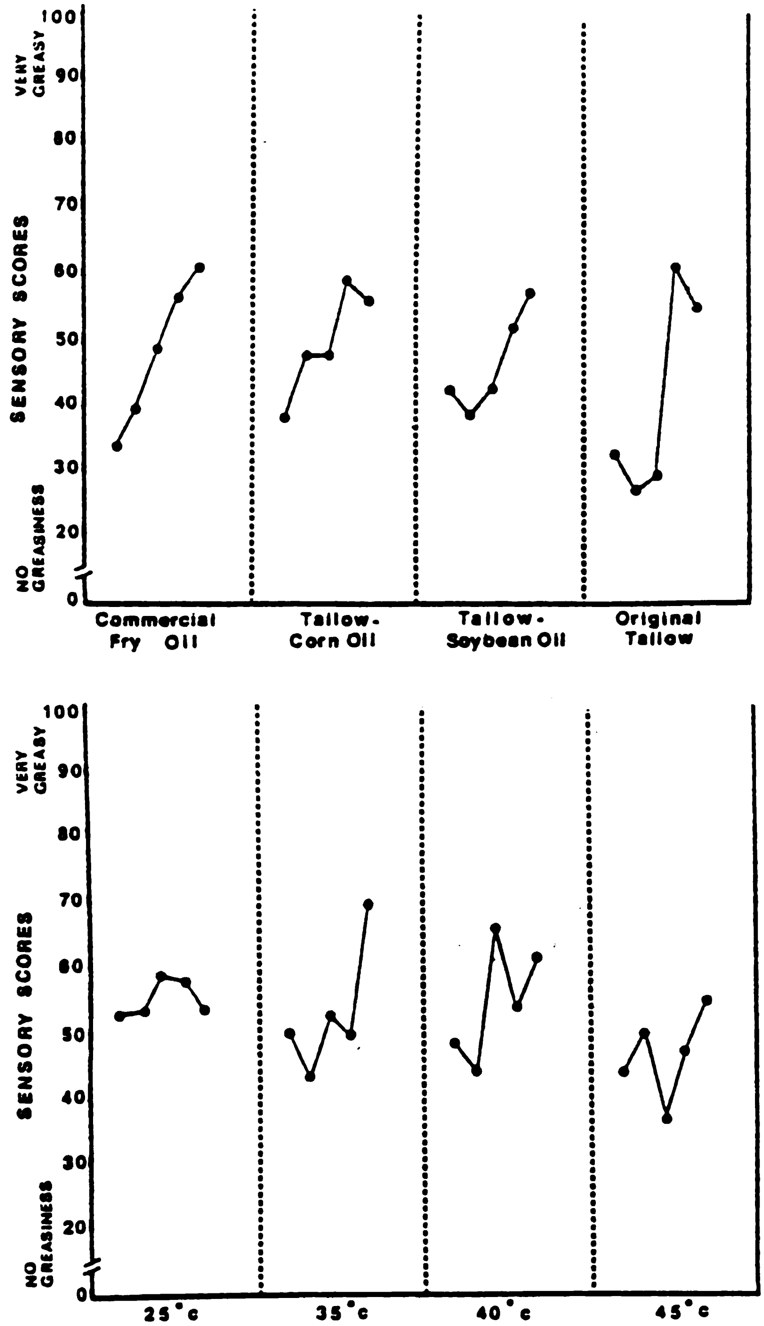

Figure 11. Greasiness of French fries fried in original tallow, tallow fractions, tallow blends and a commercial frying oil after every fifth successive frying.

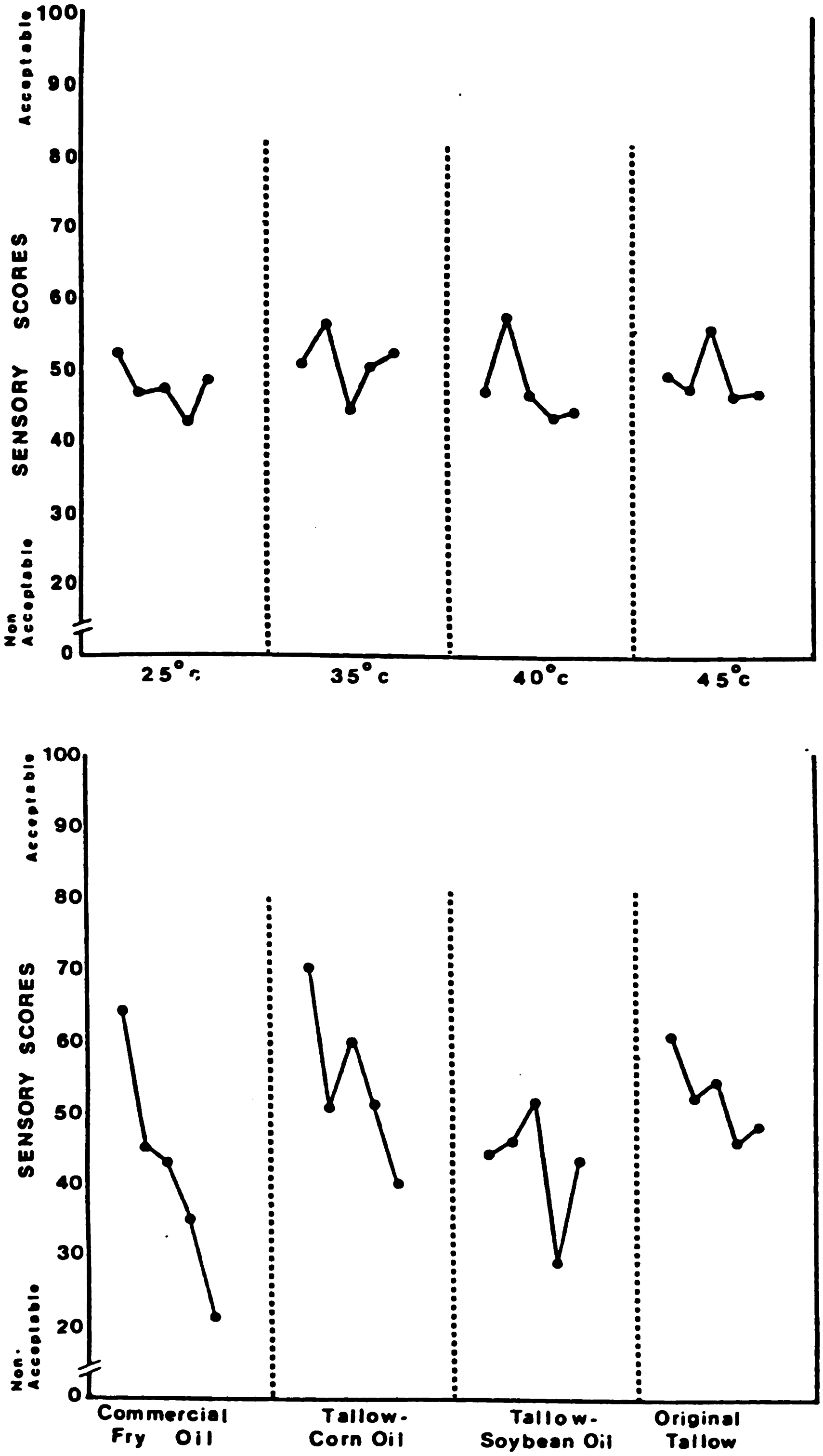

Figure 12. Overall acceptability of French fries fried in original tallow, tallow fractions, tallow blends and a commercial frying oil after every fifth successive frying.

frying from the first through the twentieth frying. There were no significant changes ($p < 0.05$) in flavor of fries over the 20 fryings but it is interesting to note that for the 25°C, 35°C and 40°C tallow fractions, off-flavors decreased after the first frying and increased again after the sixth frying. Rust and Harrison (1960) reported that a taste panel preferred potatoes cooked in fat that had been used a short time to those cooked in fresh fat. It is possible that the moisture present in the French fries naturally steam deodorized the oils as the fries were frying. Melnick *et al*. (1958) found that the volatilization of water from potato chips during frying essentially steam deodorized and refined the frying oil throughout its use. Other researchers have also reported the protective effect of steam and its ability to distill decomposition products from a frying oil (Perkins and Van Akkeren, 1965; Fuller *et al*., 1971).

Changes in greasiness and general acceptability over the period of 20 fryings are presented in Figures 11 and 12, respectively. Fries became significantly ($p < 0.05$) more greasy after the eleventh frying however general acceptability was not affected significantly ($p < 0.05$) until the sixteenth frying. It has been reported in the literature (Anon., 1977) that consumers preferred snack foods fried in the olein ("beef oil") portion of solvent fractionated tallow to those fried in vegetable oils.

Objective Evaluation of French Fries

Color. Means and standard deviations of the means for Hunter color values appear in Table 15. Analyses of variance of these data

Table 15. Means and standard deviations[1] for color values of French fries prepared in original tallow, tallow fractions, tallow blends and a commercial frying oil.

Type of Oil	Hunter Color Values		
	L^2	$a_L{}^3$	$b_L{}^4$
Original Tallow	55.5 ± 2.6^a	$+0.6 \pm 2.2^a$	19.9 ± 0.8^a
Tallow Fractions:			
25°C	55.8 ± 1.4^a	$+0.8 \pm 1.5^a$	20.6 ± 0.9^a
35°C	54.9 ± 2.9^a	-0.2 ± 1.8^a	20.3 ± 1.5^a
40°C	57.8 ± 4.0^a	$+0.2 \pm 2.7^a$	20.4 ± 1.1^a
45°C	55.6 ± 1.8^a	-0.1 ± 1.3^a	20.5 ± 0.7^a
Tallow Blends:			
w/Soybean Oil	54.9 ± 2.2^a	$+0.8 \pm 1.8^a$	19.8 ± 0.8^a
w/Corn Oil	54.8 ± 3.0^a	$+0.6 \pm 2.3^a$	19.9 ± 1.0^a
Commercial Frying Oil	53.5 ± 3.7^a	$+0.5 \pm 2.5^a$	19.3 ± 0.6^a

[1]Mean and standard deviation of the mean based on duplicate measurements of French fries from fry 1, 6, 11, 16 and 20.

[2]Lightness (100 = white, 0 = black).

[3]-a = greenness, +a = redness.

[4]yellowness

[abc]column means with the same superscript are not significantly different at $p < 0.05$ (Duncan, 1957).

Table 16. Analyses of variance of color values of French fries prepared in original tallow, tallow fractions, tallow blends and a commercial frying oil.

Source	df	Mean Squares		
		L	a_L	b_L
Total	79			
Variable	7	5.59	1.36	1.83
Fry Sequence	4	55.06**	31.71**	0.37
Interaction	28	5.74	2.81	0.74
Within	40	4.73	2.54	1.09

**Significant at the 1% level of probability.

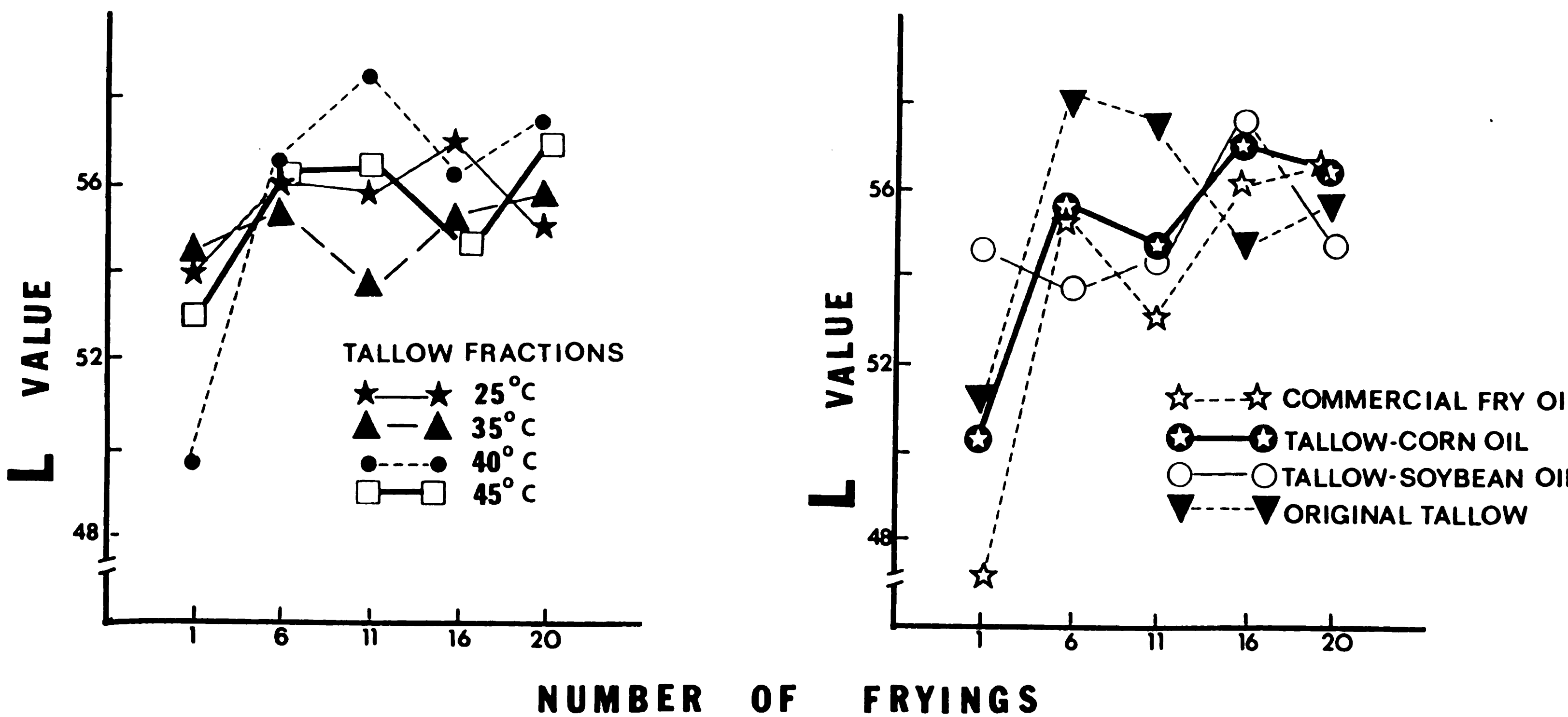

Figure 13. Change in lightness (Hunter L value) of fries fried in tallow fractions, original tallow, tallow blends and a commercial frying oil over 20 frying periods.

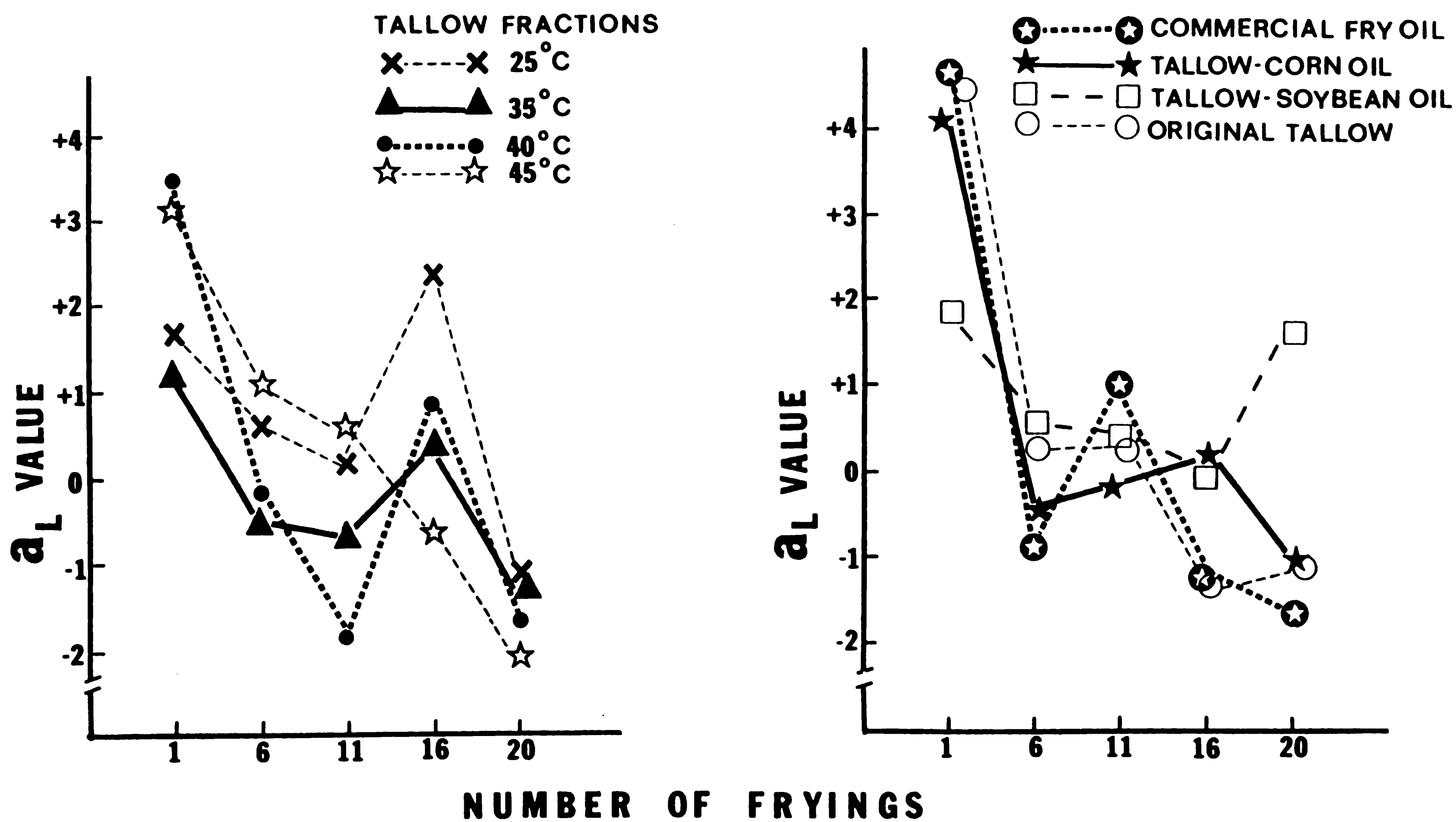

Figure 14. Change in redness/greenness (Hunter a_L value) of fries fried in tallow fractions, original tallow, tallow blends and a commercial frying oil over 20 frying periods.

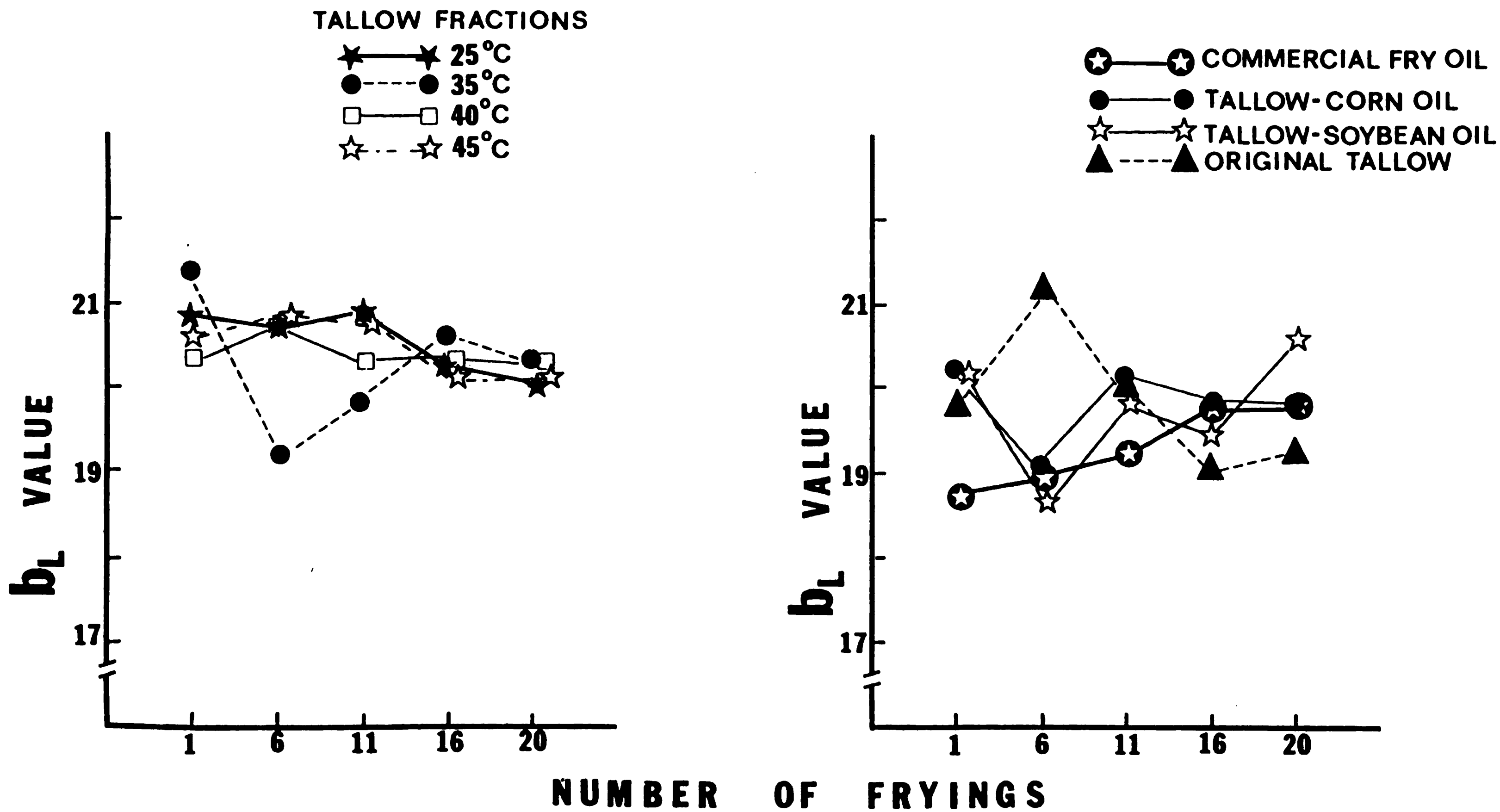

Figure 15. Change in yellowness (Hunter b_L value) of fries fried in tallow fractions, original tallow, tallow blends and a commercial frying oil over 20 frying periods.

shown in Table 16 indicate no significant differences ($p < 0.05$) in color of the fries prepared in any of the oils. Differences in color were detected, however, over the course of 20 fryings. Figures 13-15 illustrate the change in Hunter color values of French fries over the period of 20 fryings. Fries were darkest and most red ($p < 0.05$) after the first frying, however the color of the fries from the sixth through the twentieth frying did not differ significantly. There were no significant ($p < 0.05$) changes in yellowness of fries fried in any of the oils over 20 successive fryings, but fries fried in all oils became lighter. Rust and Harrison (1960) also found that French fried potatoes didn't brown after approximately 19 frying periods. A possible cause for the fries becoming lighter with successive fryings was the ratio of French fry weight to oil weight. As the quantity of oil in the fryers decreased (due to fat absorption by the potatoes and removal of oil for analyses) and the weight of frozen French fry load remained constant, the cold fries had a greater effect on the initial drop of the 185°C frying temperature with each successive frying. This would have resulted in a longer frying time required in order to reach the same degree of doneness. Robertson (1967) reported that the degree of color development depends on the time and temperature of frying; the type of fat used has little effect. When temperatures are too low, Maillard browning of fried products will not occur.

Texture. An Allo-Kramer shear press equipped with a single blade cell was utilized to determine the texture or crispness of French fries. Means and standard deviations of the means are given in Table 17. Analysis of variance for those means are presented in Table 18. Fries fried in the 25°C, 35°C, and 40°C fractions were less crisp than those

Table 17. Means and standard deviations[1] for texture (crispness) of French fries prepared in original tallow, tallow fractions, tallow blends, and a commercial frying oil.

Type of Oil	Shear (lb/cm^2)
Original Tallow	4.5 ± 0.9^{ab}
Tallow Fractions:	
25°C	3.7 ± 0.9^{a}
35°C	3.7 ± 1.1^{a}
40°C	3.8 ± 1.4^{a}
45°C	4.1 ± 1.3^{ab}
Tallow Blends:	
w/Soybean Oil	5.0 ± 0.8^{b}
w/Corn Oil	4.3 ± 1.0^{ab}
Commercial Frying Oil	5.0 ± 1.1^{b}

[1]Mean and standard deviation of the mean based on duplicate measurements of French fries from fry 1, 6, 11, 16, and 20.

[abc]Column means with the same superscript are not significantly different at $p < 0.05$ (Duncan, 1957).

Table 18. Analysis of variance of texture (crispness) of French fries prepared in original tallow, tallow blends and a commercial frying oil.

Source	df	Mean Squares
Total	79	
Variable	7	3.00*
Fry Sequence	4	3.36*
Interaction	28	1.00
Within	40	1.06

*Significant at the 5% level of probability

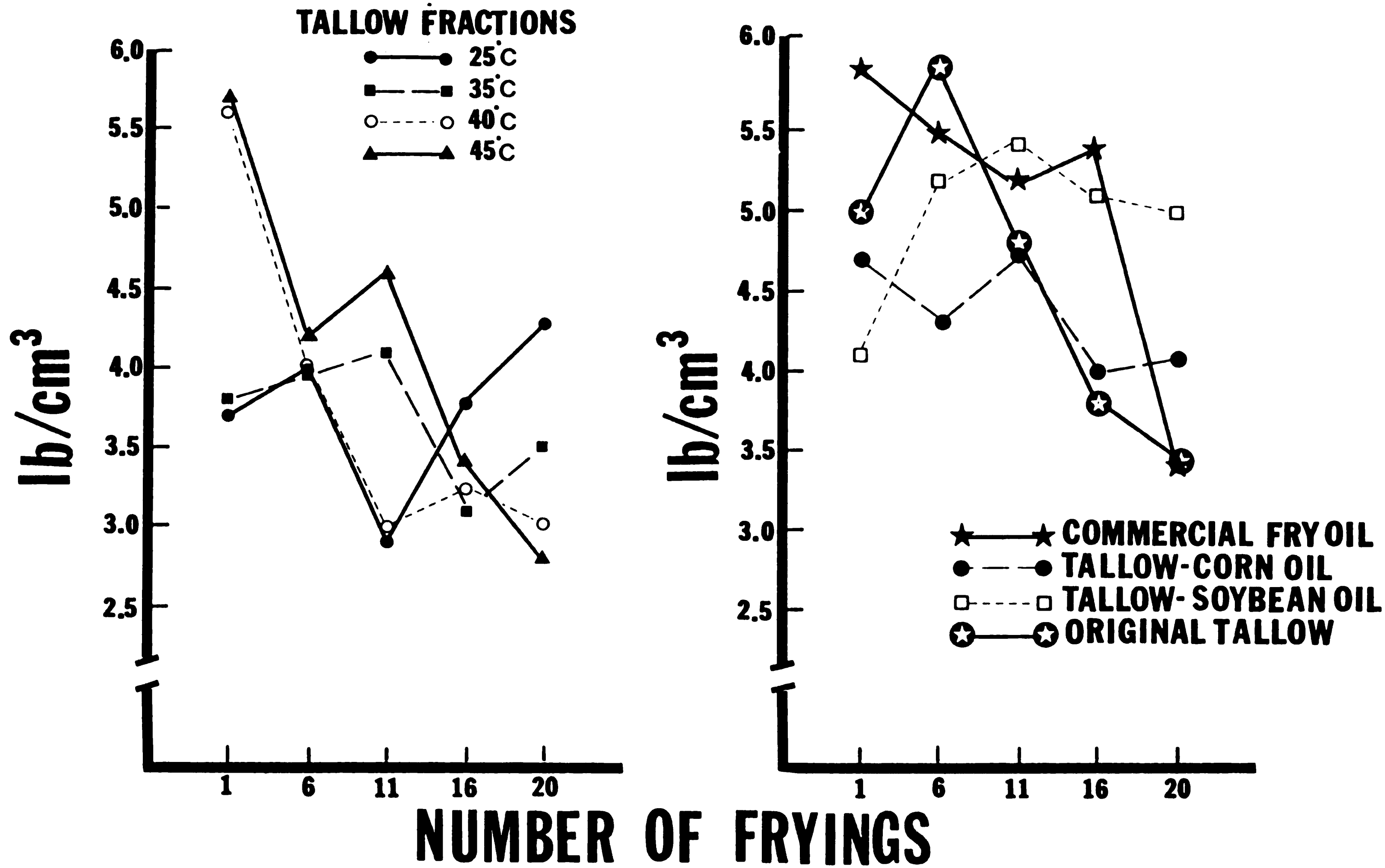

Figure 16. Change in crispness of French fries prepared in original tallow, tallow fractions, tallow blends and a commercial frying oil over a period of 20 consecutive fryings.

fried in the T-SBO or the CFO. French fried potatoes also became significantly less crisp ($p < 0.05$) after the eleventh frying (Figure 16) as evidenced by a decrease in pounds force required to shear through a single fry. A possible explanation for decreased crispness is the decreased oil to French fry ratio mentioned previously. As oil quantities decreased toward the final fryings, frozen fries cooled the oil to the point where fries temporarily "sat" in the oil and were essentially undercooked (less crisp) at the end of the constant 7 minute frying time.

Chemical Analyses

French fries fried in all oils were analyzed for moisture and fat; in addition peroxide values were determined for the extracted fat. Means and standard deviations of the means are presented in Table 19. Analyses of variance of the data are presented in Table 20.

No significant differences were found in moisture contents among the French fries fried in any of the oils. Moisture content did generally increase over the 20 fry periods with significant ($p < 0.05$) differences after fry 16 (Table 21). It is postulated that as the oil temperatures dropped with the addition of frozen fries, less dehydration of the fries occurred. Consequently more moisture was retained in the French fry.

Fat was extracted from French fries and the percentage fat was calculated on a solids basis. The fries prepared in both the T-CO and CFO contained significantly ($p < 0.05$) less fat than those prepared in the other oils while fries prepared in the 25°C tallow fraction had

Table 19. Means and standard deviations[1] of chemical analyses of French fries prepared in original tallow, tallow fractions, tallow blends and a commercial frying oil.

Type of Oil	Percent Moisture	Percent Fat (Solids Basis)	Peroxide Value (meq/1000g)
Original Tallow	32.0 ± 3.4^{a}	30.7 ± 1.2^{bc}	5.5 ± 2.2^{a}
Tallow Fractions:			
25°C	34.3 ± 4.7^{a}	34.6 ± 4.3^{d}	5.9 ± 1.6^{a}
35°C	35.4 ± 2.7^{a}	31.8 ± 3.9^{c}	5.5 ± 2.2^{a}
40°C	35.5 ± 5.0^{a}	31.6 ± 3.1^{a}	5.6 ± 1.7^{a}
45°C	31.3 ± 2.9^{a}	31.7 ± 3.6^{c}	6.0 ± 3.0^{a}
Tallow Blends:			
w/Soybean Oil	35.3 ± 5.1^{a}	28.9 ± 2.5^{b}	8.7 ± 3.0^{b}
w/Corn Oil	35.1 ± 5.6^{a}	19.8 ± 4.2^{a}	9.6 ± 3.1^{b}
Commercial Frying Oil	33.7 ± 4.4^{a}	19.7 ± 3.0^{a}	5.8 ± 2.8^{a}

[1]Mean and standard deviation of the mean based on duplicate readings of French fries from fry 1, 6, 11, 16, and 20.

[abc]Column means with the same superscript are not significantly different at $p < 0.05$ (Duncan, 1957).

Table 20. Analyses of variance of chemical analyses of French fries prepared in original tallow, tallow fractions, tallow blends and a commercial frying oil.

		Mean Squares		
Source	df	Moisture	Fat	Peroxide Value
Total	79			
Variable	7	26.79	324.07**	26.16**
Fry Sequence	4	94.73**	73.54**	35.97**
Replication	1	1.07	22.36	15.19
Interaction	28	11.20	6.75	4.91
Within	39	17.01	7.76	4.03

**Significant at the 1% level of probability.

Table 21. Percent moisture and fat[1] of French fries prepared in original tallow, tallow fractions, tallow blends and a commercial frying oil after 1, 6, 11, 16, and 20 fryings.

	Fry 1		Fry 6		Fry 11		Fry 16		Fry 20	
Type of Oil	% Moisture	% Fat[2]	% Moisture	% Fat	% Moisture	% Fat	% Moisture	% Fat	% Moisture	% Fat
Original Tallow	32.50	31.15	29.89	30.19	27.20	30.55	35.35	31.03	25.03	30.73
Tallow Fractions:										
25°C	32.01	35.46	32.56	38.69	30.38	36.28	37.52	32.28	39.11	30.56
35°C	34.35	36.43	36.75	31.59	34.46	32.66	35.25	26.16	36.27	32.10
40°C	30.42	32.46	32.70	33.35	34.10	34.50	39.24	26.75	41.26	31.02
45°C	31.56	33.10	31.39	32.93	27.63	31.23	31.18	30.05	34.66	31.12
Tallow Blends:										
w/Soybean Oil	29.68	30.92	35.00	29.18	34.35	29.32	42.26	25.93	35.13	28.96
w/Corn Oil	32.89	23.61	35.64	21.03	34.28	23.43	33.09	15.04	39.75	16.00
Commercial Frying Oil	32.93	22.26	34.80	20.36	30.78	20.31	35.11	15.80	35.69	19.62

[1] Based on duplicate determinations.

[2] Percent fat is expressed on a solids basis.

the highest fat content (significant at $p < 0.05$) (see Appendix IX). Bates (1952) reported no significant differences in fat absorption resulting from the use of various fats ranging from hard fat flakes through shortening to salad oils.

Fries from the first, sixth, and eleventh frying contained significantly ($p < 0.05$) more fat than those from the sixteenth and twentieth frying and those fried during the sixteenth frying were found to have the lowest fat content ($p < 0.05$). Table 21 gives the mean fat contents of fries fried in each oil over a period of 20 fryings. These results were unexpected since fat content was expected to increase as breakdown products were formed in the oils. Perhaps with the slower rate of cooking which occurred toward later fryings, greater starch gelatinization within the potato took place thereby causing a barrier to fat absorption.

Peroxide value determinations were made on the fat extracted from the fries. The peroxide values of the French fries prepared in the tallow blends were significantly higher ($p < 0.05$) than the other oils, indicative of greater oxidative products present in the tallow blends. The high percentage of unsaturated fatty acids present in the soy and corn oil may have contributed to the increased oxidation of these samples. A figure representing these results appears in the Appendices. Subsequent fatty acid analysis of the extracted oils revealed a higher linoleic acid content in these blends than was present in either the tallow fractions or original tallow.

Results from fatty acid determinations by gas chromatography of extracted oils are located in Tables 22 and 23. Fatty acid profiles from the oil extracts generally followed the same trend as did the

Table 22. Mean relative percentages of fatty acids present in fat extracted from French fries over a period of 20 successive fryings[1].

Frying Oils	Percent Fatty Acids						
	C_{14}	C_{16}	$C_{16:1}$	C_{18}	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Original Tallow	2.92	25.34	3.69	20.35	45.63	1.83	tr.
25°C	3.35	25.09	6.40	12.98	48.61	3.60	tr.
35°C	3.57	25.83	5.93	13.43	51.23	tr.	--
40°C	3.38	24.91	4.18	16.61	47.55	3.37	tr.
45°C	3.52	26.17	3.76	18.75	43.78	4.02	tr.
Tallow-Soybean Oil	1.74	19.71	2.60	9.24	47.78	18.76	0.46
Tallow Corn Oil	1.81	20.71	2.63	8.07	36.61	30.17	tr.
Commercial Frying Oil	0.13	11.59	0.22	7.90	46.21	31.14	2.80

[1]Data based on 2 replications.

Table 23. Change in fatty acid composition of fat extracted from French fries over a period of 20 fryings.

Frying Oils	Percent Fatty Acids						
	C_{14}	C_{16}	$C_{16:1}$	C_{18}	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Original Tallow							
Fry 1	3.19	26.35	3.94	21.12	42.91	1.25	tr.
Fry 6	3.05	25.44	3.74	20.39	25.38	2.10	tr.
Fry 11	2.89	26.10	4.15	19.95	45.30	1.62	tr.
Fry 16	2.86	25.14	3.39	20.05	46.11	2.45	tr.
Fry 20	2.63	23.67	3.32	20.24	48.44	1.71	tr.
25°C Fraction							
Fry 1	3.35	23.84	7.47	12.64	48.55	4.15	tr.
Fry 6	3.44	25.67	5.51	12.94	48.98	3.46	tr.
Fry 11	3.32	24.76	7.14	12.88	48.42	3.49	tr.
Fry 16	3.31	24.79	6.91	12.69	48.05	4.28	tr.
Fry 20	3.31	26.41	4.97	13.76	49.06	2.61	tr.
35°C Fraction							
Fry 1	3.81	26.58	5.96	12.52	51.13	tr.	—
Fry 6	3.56	24.87	6.22	13.70	50.15	tr.	—
Fry 11	3.55	25.69	5.97	14.00	50.80	tr.	—
Fry 16	3.43	25.31	5.87	13.39	52.00	tr.	—
Fry 20	3.52	26.71	5.65	13.54	50.50	tr.	—
40°C Fraction							
Fry 1	3.52	25.13	4.10	16.86	46.82	3.57	tr.
Fry 6	3.61	25.64	4.39	17.01	56.83	2.52	tr.
Fry 11	3.59	25.35	4.24	17.28	46.30	3.24	tr.
Fry 16	3.21	24.03	3.94	15.85	48.39	4.59	tr.
Fry 20	2.96	24.41	4.23	16.05	49.41	2.95	tr.
45°C Fraction							
Fry 1	3.53	25.31	3.72	17.79	42.28	7.37	tr.
Fry 6	3.52	26.22	4.10	18.99	44.61	2.56	tr.
Fry 11	3.65	26.23	3.50	19.03	43.54	4.06	tr.
Fry 16	3.47	25.58	3.77	18.43	45.30	3.45	tr.
Fry 20	3.41	27.53	3.70	19.52	43.18	2.66	tr.
Tallow-Soy Oil							
Fry 1	1.88	19.85	2.40	8.89	45.67	20.81	0.51
Fry 6	1.64	18.94	3.01	9.38	47.11	19.44	0.49
Fry 11	1.81	19.91	2.22	9.43	49.14	17.22	0.54
Fry 16	1.63	18.99	2.30	9.39	49.21	18.06	0.42
Fry 20	1.76	20.88	3.05	9.09	47.74	18.30	0.36
Tallow-Corn Oil							
Fry 1	1.93	21.51	1.81	7.99	34.88	31.89	tr.
Fry 6	1.80	20.39	2.60	7.74	35.60	31.88	tr.
Fry 11	1.81	20.10	3.71	7.95	35.97	30.47	tr.
Fry 16	1.66	20.07	2.68	8.22	38.17	29.19	tr.
Fry 20	1.83	21.49	2.38	8.42	38.45	27.43	tr.
Commercial Oil							
Fry 1	0.11	10.94	0.16	6.92	44.16	34.59	3.12
Fry 6	0.15	11.44	0.13	7.70	46.50	31.53	2.55
Fry 11	0.12	11.39	0.28	8.41	45.23	32.24	2.33
Fry 16	0.14	11.74	0.12	7.92	47.44	29.44	3.21
Fry 20	0.15	12.46	0.41	8.56	47.71	47.91	2.79

frying oils however due to the greater column sensitivity, the presence of linoleic acid was detected for the tallow fractions whereas it was only detected in trace amounts in the frying oils. Kilgore (1964) reported that the fatty acid content of fat extracted from potatoes was the same as the fat used to fry them. It was reported however that after 10 hours of frying, the fat extracted from the potatoes had a lower linoleic acid content than the frying fats. This was also found to be generally true for the tallow-vegetable oil blends in this study, since the total elapsed heating time after 20 fryings was approximately 10 hours.

Consumer Acceptability of Chocolate Chip Cookies

Chocolate chip cookies were chosen for the consumer acceptability study with the thought that any off-flavors contributed by the tallow might be masked by the chocolate. Hoojat and Zabik (1979) found that tallow could be successfully incorporated into a control sugar-snap cookie with minimal differences from a sugar-snap cookie prepared with vegetable shortening. As part of an exhibit representing Michigan State University's Extension Consumer Marketing Program in Port Huron, Michigan, a consumer acceptability panel was conducted to determine acceptability and preference for a cookie made with tallow and one made with a vegetable shortening agent.

A breakdown of demographic characteristics of the adult participants appears in the Appendices. A total of 241 children (ages 16 and below) also responded (total N=449), however no demographic information was obtained from them.

Tables 24, 25 and 26 summarize the adults' opinion of both chocolate chip cookies, the childrens' opinion of both cookies and the cookie preference, respectively. All respondents tended to like, to some degree, vs. dislike both the cookie made with tallow and the control cookie. Although a greater percentage of total respondents preferred the control cookie to that prepared with tallow, approximately one-third of the children responding indicated that they liked both cookies equally, while 17% of the adults said they preferred neither one nor the other.

Table 24. Adult respondents' opinion of chocolate chip cookies prepared with tallow and vegetable shortening[1].

	Percent Response	
Degree of Liking	Control Cookie	Tallow Cookie
Like very much	36	24
Like moderately	38	36
Like slightly	17	19
Neither like nor dislike	3	5
Dislike slightly	2	10
Dislike moderately	0	2
Dislike very much	2	4

[1]Data based on 208 responses.

Table 25. Child respondents' opinion of chocolate chip cookies prepared with tallow and vegetable shortening[1].

	Percent Response	
Degree of Liking	Control Cookie	Tallow Cookie
Like very much	48	35
Like moderately	37	31
Neither like nor dislike	9	20
Dislike moderately	4	9
Dislike very much	2	5

[1]Data based on 241 responses.

Table 26. Percent of total respondents' preference for chocolate chip cookies prepared with tallow or vegetable shortening.

Respondents	Prefer Control	Prefer Tallow	Prefer Both Equally	Prefer Neither Cookie
Adult[1]	57%	26%	*	17%
Children[2]	44%	23%	31%	2%

[1]Data based on 208 respondents.

[2]Data based on 241 respondents.

*Not present on adult questionnaires as a response.

Chi-square analyses were conducted and are reported in Tables 27-30. A significant interaction ($p < 0.01$) was found between preference and degree of liking for each cookie for both adult and children respondents. As expected, a greater percentage of respondents, both adults and children, preferring the control cookie said they liked it to some degree vs. disliking it. This same trend held true for respondents preferring the tallow cookie. It is interesting to note that for the adults who liked both cookies equally, a greater percentage rated both the control and tallow cookie as "liked very much" than those who preferred either the control or the tallow cookie.

The adults who preferred the control cookie listed flavor and texture as the major reasons for their preference. Some participants detected an off-flavor in the tallow cookie which left an aftertaste and therefore preferred the control cookie. The presence of higher, less sharp melting point fatty acids may contribute to the aftertaste by lingering in one's mouth longer than would a lower, sharper melting point fat. Baeuerlen et al. (1968), in their discussion of the selection of a frying fat, reported tallow has a higher melting point than lard and therefore does not impart a good mouthfeel. Of the children who stated a reason for preferring the control cookie, approximately 15% mentioned the off-flavor or aftertaste of the tallow cookie. Adults preferring the tallow cookie also listed flavor and texture as their primary reasons for preference. Apparently the flavor of the tallow, while objectionable to some, was also preferred by some of the participants. Morris et al. (1956) attributed the limited use of tallow in shortenings to its tendency to develop reverted flavors. Baeuerlen et al. (1968) however, have reported that tallow has

Table 27. Chi-square[1] cross tabulation results[2] for cookie preference vs. opinion of control cookie -- Adult questionnaire[3].

Cookie Preference	Opinion of Control Cookie -- Frequency of Response (and %)				
	Like Very Much	Like Moderately	Like Slightly	Neither Like nor Dislike or Dislike	Total
Control	50 (42.2%)	50 (42.2%)	14 (11.9%)	4 (3.4%)	118 (56.7%)
Tallow	11 (20.0%)	14 (25.5%)	18 (32.7%)	12 (21.8%)	55 (26.4%)
Both Equal	16 (45.7%)	14 (40.0%)	4 (11.4%)	1 (2.9%)	35 (16.8%)
Total	77 (37.0%)	78 (37.0%)	36 (17.3%)	17 (8.2%)	208 (100.0%)

[1]Snedecor and Cochran, 1967.

[2]Significant at $p < 0.01$.

[3]N=208

Table 28. Chi-square[1] cross tabulation results[2] for cookie preference vs. opinion of control cookie -- Childrens' questionnaire.

Cookie Preference	Opinion of Control Cookie -- Frequency of Response (and %)				
	Like	Neither Like nor Dislike	Dislike Slightly or Moderately	Dislike Very Much	Total
Control	57 (54.8%)	40 (38.5%)	5 (4.8%)	2 (1.0%)	104 (45.0%)
Tallow	6 (11.1%)	27 (50.0%)	11 (20.4%)	10 (18.5%)	54 (23.4%)
Both Equal	50 (68.5%)	18 (24.7%)	3 (4.1%)	2 (2.7%)	73 (31.6%)
Total	113 (48.9%)	85 (36.8%)	19 (8.2%)	14 (61.%)	231 (100.0%)[3]

[1]Snedecor and Cochran, 1967.

[2]Significant at $p < 0.01$.

[3]N=241; 10 respondents left question of preference unanswered.

Table 29. Chi-square[1] cross tabulation results[2] for cookie preference vs. opinion of tallow cookie -- Adult questionnaire[3].

	Opinion of Tallow Cookie -- Frequency of Response (and %)				
Preference	Like Very Much	Like Moderately	Like Slightly	Neither Like nor Dislike or Dislike	Total
Control	5 (4.2%)	41 (34.7%)	30 (25.4%)	42 (35.6%)	118 (56.7%)
Tallow	26 (47.3%)	21 (38.2%)	8 (14.5%)	0 (0.0%)	55 (26.4%)
Both Equal	18 (51.4%)	14 (40.0%)	2 (5.7%)	1 (2.9%)	35 (16.8%)
Total	49 (23.6%)	76 (36.5%)	40 (19.2%)	43 (20.7%)	208 (100.0%)

[1]Snedecor and Cochran, 1967.

[2]Significant at $p < 0.01$.

[3]N=208.

Table 30. Chi-square[1] cross tabulation results[2] for cookie preference vs. opinion of tallow cookie -- Childrens' questionnaire.

Cookie Preference	Opinion of Tallow Cookie -- Frequency of Response (and %)				
	Like	Neither Like nor Dislike	Dislike Slightly or Moderately	Dislike Very Much	Total
Control	10 (9.6%)	29 (27.9%)	38 (36.5%)	27 (26.0%)	104 (45.0%)
Tallow	35 (64.8%)	15 (27.8%)	4 (7.4%)	0 (0.0%)	54 (23.4%)
Both Equal	40 (54.8%)	27 (37.0%)	3 (4.1%)	3 (4.1%)	73 (31.6%)
Total	85 (36.8%)	71 (30.7%)	45 (19.5%)	30 (13.0%)	231 (100.0%)[3]

[1]Snedecor and Cochran, 1967.

[2]Significant at $p < 0.01$.

[3]N=241. 10 respondents left question of preference unanswered.

superior resistance to oxidation.

The texture of the tallow cookie was slightly crunchier than the control cookie which was found to be a characteristic undesirable to some but equally desirable to others. The control cookie was prepared with a vegetable shortening containing mono- and diglycerides and the tallow cookie had no added emulsifier. It was probably due to this fact that the control cookie was slightly softer. Morris et al. (1956) discussed the advantage of using tallow-vegetable oil blends as shortening agents in order to increase the plastic range and facilitate the manufacture of more uniform products.

Table 31 shows Chi-square cross tabulation results for adult cookie preference vs. frequency of buying cookies. A significant ($p < 0.05$) interaction was found between adult preference and frequency of buying cookies. A greater percentage of those people preferring the control cookie tended to only buy cookies monthly or less, than did those either preferring the tallow cookie or having no preference. Respondents with no preference tended to buy cookies bi-weekly or more.

Remaining data obtained from the adult questionnaires tended to confirm expectations. There was a significant ($p < 0.01$) interaction between willingness to buy vs. frequency of buying cookies. Adult respondents were asked whether they would be willing to purchase this type of cookie if it were available for $1.19 per 13 oz. package which was the average retail price of similar cookies at the time of this study. As might be expected, the people who purchased cookies weekly, biweekly or even monthly were more willing to buy than those who purchased cookies less than once a month. Those who purchased less

Table 31. Chi-square[1] cross tabulation results[2] for adult cookie preference vs. frequency of buying cookies[3].

Cookie Preference	Frequency of Buying Cookies -- Frequency of Response (and %)				
	Weekly	Bi-weekly	Monthly	Less Than Monthly	Total
Control	15 (12.7%)	25 (21.2%)	28 (23.7%)	50 (42.4%)	118 (56.7%)
Tallow	9 (16.4%)	18 (32.7%)	8 (14.5%)	20 (36.4%)	55 (26.4%)
Both Equal	10 (28.6%)	13 (37.1%)	3 (8.6%)	9 (25.7%)	35 (16.8%)
Total	34 (16.3%)	56 (26.9%)	79 (38.0%)	79 (38.0%)	208 (100.0%)

[1] Snedecor and Cochran, 1967.

[2] Significant at $p < 0.05$.

[3] N=208.

frequently tended to think the suggested price was too high. Since they purchased cookies infrequently, this may have been their opinion of the price of all cookies.

Results relating stage of the family life cycle to cookie buying frequency were typical of what was expected: a higher percentage of weekly cookie buyers had children under 13 years old living at home while the least heavy cookie purchasers (less than monthly) had no children at home. This was attributed to children being the heaviest cookie eaters. Age of the respondent and stage of the family life cycle were related to preference for the control or cookie made with tallow only at the 10% level of probability.

Significant at the $p < 0.10$ level, were age of adult respondent vs. preference and stage of the family life cycle vs. preference. Respondents who preferred the control cookie tended to be 25-44 years old, those who preferred the tallow cookie tended to be over 45 years old, and those with no preference tended to be under 25 years old. Respondents who preferred the control cookie were generally those with either no children or only children 12 years old and younger. Those who preferred the tallow cookie tended to have teen-age children between the ages of 13 and 17, while those with no preference between cookies tended to have both children less than 13 years old and teen-agers living at home.

SUMMARY AND CONCLUSIONS

Four different olein fractions were obtained by detergent (SDS) fractionation of tallow and the purpose of this study was to determine the acceptability of these fractions plus two tallow-vegetable oil blends as deep-fat frying media. Consumer response to cookies prepared using tallow as a replacement for shortening was also determined.

The olein fractions obtained by detergent fractionation of four tallow samples at controlled temperatures (25°C, 35°C, 40°C, and 45°C) were compared to original, unfractionated tallow (OT). Additionally, a 50% tallow-corn oil (T-CO) and a 50% tallow-soybean oil (T-SBO) blend were also compared. A commercial frying oil (CFO) was used as a standard for comparison. Commercially frozen French fry potatoes were fried in each of the eight oils over a period of 20 fryings and both the oils and the fries prepared in the oils were analyzed throughout the study. Objective analyses of the oil consisted of: color determination, viscosity, refractive index, peroxide value, and fatty acid determination by gas chromatography. French fries were evaluated for texture; color; moisture; fat content; peroxide value and fatty acid determination of the extracted fat; and by a trained sensory panel.

Objective measurements of oil quality indicated that all oils became darker and more yellow over the period of frying. Mean color values showed the two tallow-vegetable oil blends to be significantly darker than the other variables. Viscosity, refractive indices, and peroxide values increased for all oils over 20 frying periods, indicative of oil breakdown. The T-CO was significantly less viscous than other oils. The CFO underwent polymorphic crystal changes at the temperature used for determining viscosity and therefore accurate readings were not obtained for this sample. Refractive indices corresponded well with fatty acid profiles obtained by GLC analyses. Values were largest for the oils with the least saturated fatty acid profiles. Peroxide values were significantly higher for the OT, T-SBO, and T-CO than the tallow fractions or the CFO, indicating a greater degree of oxidation in these oils.

There were no significant differences in color or moisture of the French fries fried in any of the oils. Shear press results indicated that all fries became less crisp over the 20 frying periods. Fries prepared in the T-CO and CFO contained significantly less fat than did those prepared in the other oils; fries prepared in the 25°C fraction had the highest percentage of fat (expressed on a solids basis). Peroxide values of the fat extracted from the fries prepared in the tallow blends were significantly higher than the other oils.

Organoleptic evaluation of the fries prepared in all variables indicated that color and general acceptability were not significantly affected by the type of frying oil. Fries fried in the OT were slightly more crisp and less greasy than those fried in the tallow fractions separated at 25°C, 35°C or 40°C. All fries were scored equal to, or better than those fried in the CFO. In general, all French fries became lighter, less crisp, and more greasy over the course of 20 fryings. Off-flavors decreased after the first frying and increased again after the sixth which was attributed to a natural steam deodorization effect as moisture from the fries bubbled through the hot oil.

The intention of this study was to evaluate the performance of tallow fractions and tallow blends under stressful conditions, thus fat was not replenished during the course of the experiment. The functional life of an oil used in deep-fat frying may be dependent on the turnover rate, or the rate of addition of fresh oil to the used oil (Perkins and Van Akkeren, 1965). Since there was no turnover of fat over the period of 20 fryings, it may be expected that simulation of commercial frying practices would improve results currently obtained for tallow fractions and tallow blends.

Results have indicated that fractionated beef tallow held up as well physically as a commercial frying oil and in addition the flavor rated more favorably with taste panel members. The T-CO blend showed very good potential as a deep-fat frying medium. Both the oil and fries prepared in it were rated higher than the other variables for all tests performed except peroxide value, in which case values for the T-CO blend were quite high. This was somewhat of a dichotomy since as peroxide values increased, flavor scores were expected to decrease, however taste panelists preferred fries fried in the T-CO.

In the second portion of this research a consumer acceptability study was conducted in April, 1980 to test chocolate chip cookies prepared with tallow for preference as compared to cookies prepared with a commercial shortening. Cookies were evaluated by a total of 449 participants (208 adults and 241 children) using separate questionnaires for the adults and children. All respondents were asked to evaluate both cookies, state their preference, and state their frequency of eating cookies. Additionally, the adults were asked about their cookie-buying practices and for certain demographic information.

Although chocolate chip cookies prepared with tallow weren't scored as favorably as the control cookie made with vegetable shortening, tallow appeared to be an acceptable shortening agent in chocolate chip cookies. A greater percentage of children, and a slightly smaller percentage of adults, than preferred the control, had no preference for either cookie. Adults preferring the control cookie tended to list flavor and texture as the major reasons for their preference. The tallow contributed a slight off-flavor and aftertaste to the cookies. This was attributed to the higher melting point fatty acids present in tallow which lingered in the mouth. The texture of the tallow cookie was slightly harder believed to be a result of no emulsifiers present in this cookie.

Chi-square cross tabulation results indicated a greater percentage of those people preferring the control cookie tended to only buy cookies monthly or less, than did those who preferred the tallow cookie or those who had no preference. There was a significant interaction between willingness to buy vs. frequency of buying cookies. Those respondents who purchased cookies frequently were more willing to pay $1.19 for a 13-ounce package (the current price for a comparable type cookie).

Remaining cross tabulations tended to substantiate that which was expected. The largest number of cookie purchasers had children under 13 years old living at home while those who purchased cookies less than monthly had no children at home. Although not significant, families with the largest income tended to purchase cookies more frequently, however there was no relationship between income and cookie preference.

Tallow appeared to be an acceptable shortening agent in chocolate chip cookies. Although a slightly higher preference for an all vegetable shortening cookie was indicated, 79% of the adults and 66% of the children liked the cookie made with edible tallow.

PROPOSALS FOR FURTHER RESEARCH

1. Since adding back fresh fat to fryers in order to facilitate adequate fat turnover is the prevalent commercial practice, fractionated tallow and tallow blends should be evaluated as deep fat-frying media by simulating commercial practices.

2. The effect of frying a batter system on the quality of fractionated tallow and tallow blends as frying media should be investigated.

3. Since the consumer acceptance of fractionated tallow as a food fat depends upon its nutritive value, nutrition studies need to be conducted. Such investigations should include cholesterol studies and toxicity of thermally damaged tallow and tallow fractions.

4. Although consumer acceptability of cookies made with tallow as a shortening agent was good, this study should be repeated using tallow fractions to determine their acceptance in a flavored cookie.

5. While consumers reacted favorably to the cookie prepared with tallow, the current interest in cholesterol and unsaturated fats may pose marketing problems for this type of product. A

a consumer attitude survey may be useful in determining ways to position this type of product in the marketplace.

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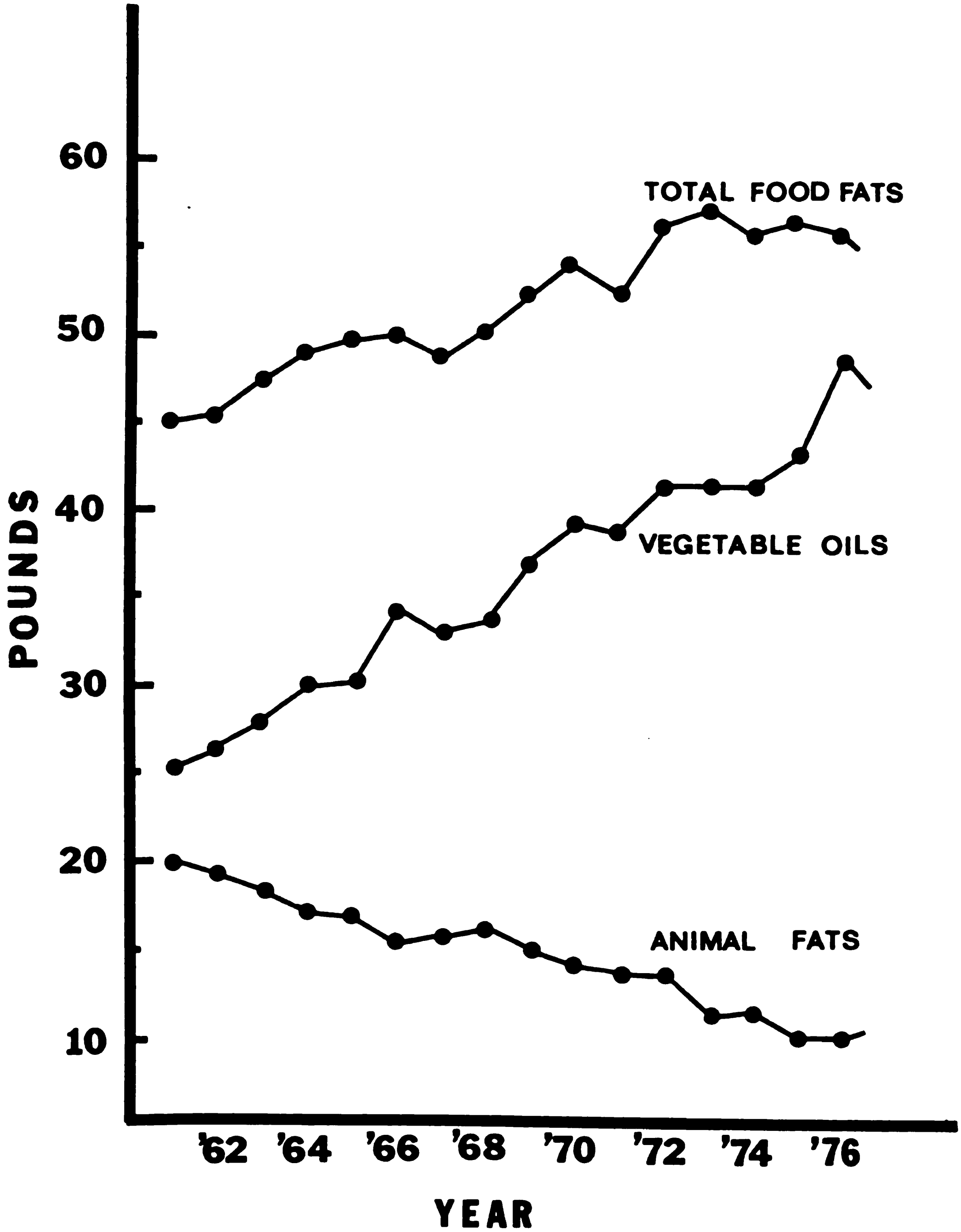
A P P E N D I C E S

APPENDIX I

U.S. PER CAPITA CONSUMPTION OF TOTAL FOOD FATS, VEGETABLE OILS AND ANIMAL FATS 1960 - 77 (USDA, 1977)



APPENDIX II

FRENCH FRY SCORECARD

Sample No. _______
Name ____________

Instructions:

1. Please check to make sure that the sample number on this sheet matches that on the sample being evaluated.
2. The reference French fry is NOT meant for tasting and is to be used as an aid in scoring COLOR only.
3. Place an "X" along the horizontal where your perception of each attribute is best represented.

TEXTURE: Limp |——————|——————| Very Crisp

GREASINESS No Greasiness |——————|——————| Very Greasy

OFF-FLAVORS: (Rancidity) None |——————|——————| Extreme

DESCRIBE THE FLAVOR: ____________________

COLOR: Lighter |——————|——————| Darker

---

4. Rate the overall acceptability and include any comments:

OVERALL ACCEPTABILITY Unacceptable |——————|——————| Acceptable

COMMENTS: ____

____

THANKS!

APPENDIX IIIa

COOKIE QUESTIONNAIRE FOR ADULTS

Number ____________ (1)

COOKIES - TASTE TEST

MICHIGAN STATE UNIVERSITY

Directions: Typewriter symbols (# and %) are used to identify both samples you will be tasting. Please taste one sample and record your judgement before going on to the other samples.

Cookies should be tasted one bite at a time.

1. Please taste the sample marked %. Now indicate below which statement best describes your opinion. Check one.

☐1	☐2	☐3	☐4	☐5	☐6	☐7	6
Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	

2. Next taste the sample marked #. Again, please indicate below the statement that best describes your opinion. Check one.

☐1	☐2	☐3	☐4	☐5	☐6	☐7	7
Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	

3. Which sample did you prefer? Check one.

☐1	☐2	☐3	8
Sample #	Sample %	Liked both # and % equally	

Reason for preference ________________________________

4. If this type of cookie were available for $1.19 per 13 oz. package, would you buy it?

☐5	☐4	☐3	☐2	☐1	9
Yes, would definitely buy it	Yes, would probably buy it	Not sure, maybe sometime	Probably wouldn't buy it	Definitely wouldn't buy it	

5. How often do you or anyone else in your household eat cookies? Check one.

☐1	☐2	☐3	☐4	☐5	☐6	10
Everyday	3-4 times a week	Once or twice a week	Once or twice a month	Less than once a month	Never	

6. How often do you buy cookies? Check one.

☐1	☐2	☐3	☐4	☐5	11
Weekly	Every 2 weeks	Monthly	Less than monthly	Never buy, or only bake my own (Go to question 7)	

   a. If you do buy cookies, what type or types of cookies do you buy most often? Check those that apply.

☐1	☐2	☐3	☐4	☐5	☐6	12
Packaged, ready-to-eat	Refrigerator slice & bake	Frozen, ready to bake	Cookie mix	Packaged as from a bakery	Other (Explain) ____________	

APPENDIX IIIa (cont'd)

7. Check the age groups of the people in your household who would like this type of cookie. Check all the age groups that apply. 13

☐1	☐2	☐3	☐4	☐5	☐6
Children 12 years & under	Children 13-17 years	Men 18 years & older	Women 18 years and older	Nobody in the household would like them	Nobody eats cookies

---

NOW WOULD YOU PLEASE ANSWER SOME QUESTIONS ABOUT YOURSELF AND YOUR FAMILY?

8. Please indicate your sex. Female ☐1 Male ☐2 14

9. What is your age as of your last birthday? Please check one. 15

☐1	☐2	☐3	☐4	☐5
Under 18 years	18-24 years	25-44 years	45-64 years	65 and over

10. How many persons are currently living in your household (include yourself)?

______________________________ 16

11. Check the age groups of the children under 18 living at home. Check one. 18

☐1	☐2	☐3	☐4
No children, or none under 18 years	All children under 13 years	All children between 13 & 17 years	Some in both groups (under 13 and between 13 & 17)

12. Into which of the following groups would your 1979 total family income fall (before taxes were deducted)? Check only one. 19

☐1	☐2	☐3	☐4
Under $10,000	$10,000 - $19,999	$20,000 - $29,999	$30,000 and over

COMMENTS____

____

THANK YOU

APPENDIX IIIb

COOKIE QUESTIONNAIRE FOR CHILDREN

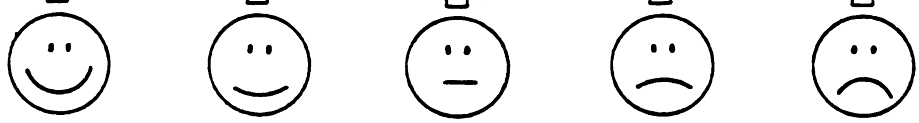
Number ________________ (1)

COOKIES - TASTE TEST

MICHIGAN STATE UNIVERSITY

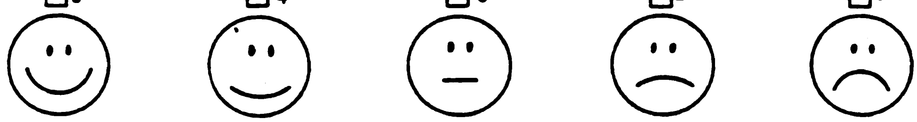
1. Please taste the cookie marked . Check the box over the face which best describes how you like this cookie. <u>Check one</u>.

☐ 5 ☐ 4 ☐ 3 ☐ 2 ☐ 1 6



2. Now, please taste the cookie marked , and again check the box over the face that best describes how you like this cookie. <u>Check one</u>.

☐ 5 ☐ 4 ☐ 3 ☐ 2 ☐ 1 7



3. Check which of these cookies you liked well enough to ask your mom or dad to buy. <u>Check one</u>.

☐ 1	☐ 2	☐ 3	☐ 4	8
Sample	Sample	Both and	Neither nor	

4. How often do you eat cookies?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	9
Everyday	A couple of times a week	Once or twice a month	Less than one time a month	Never	

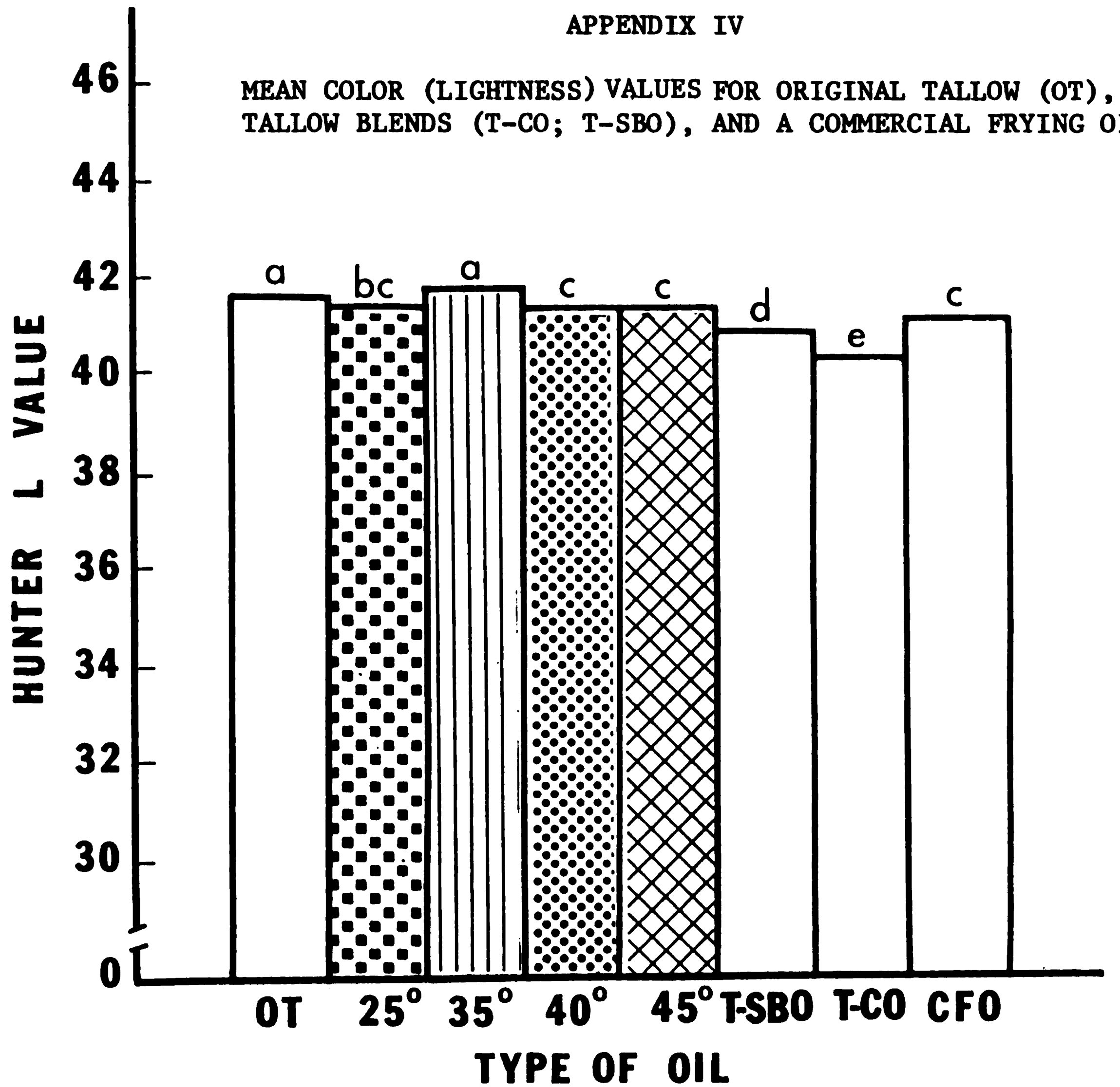
COMMENTS ____

____

THANK YOU

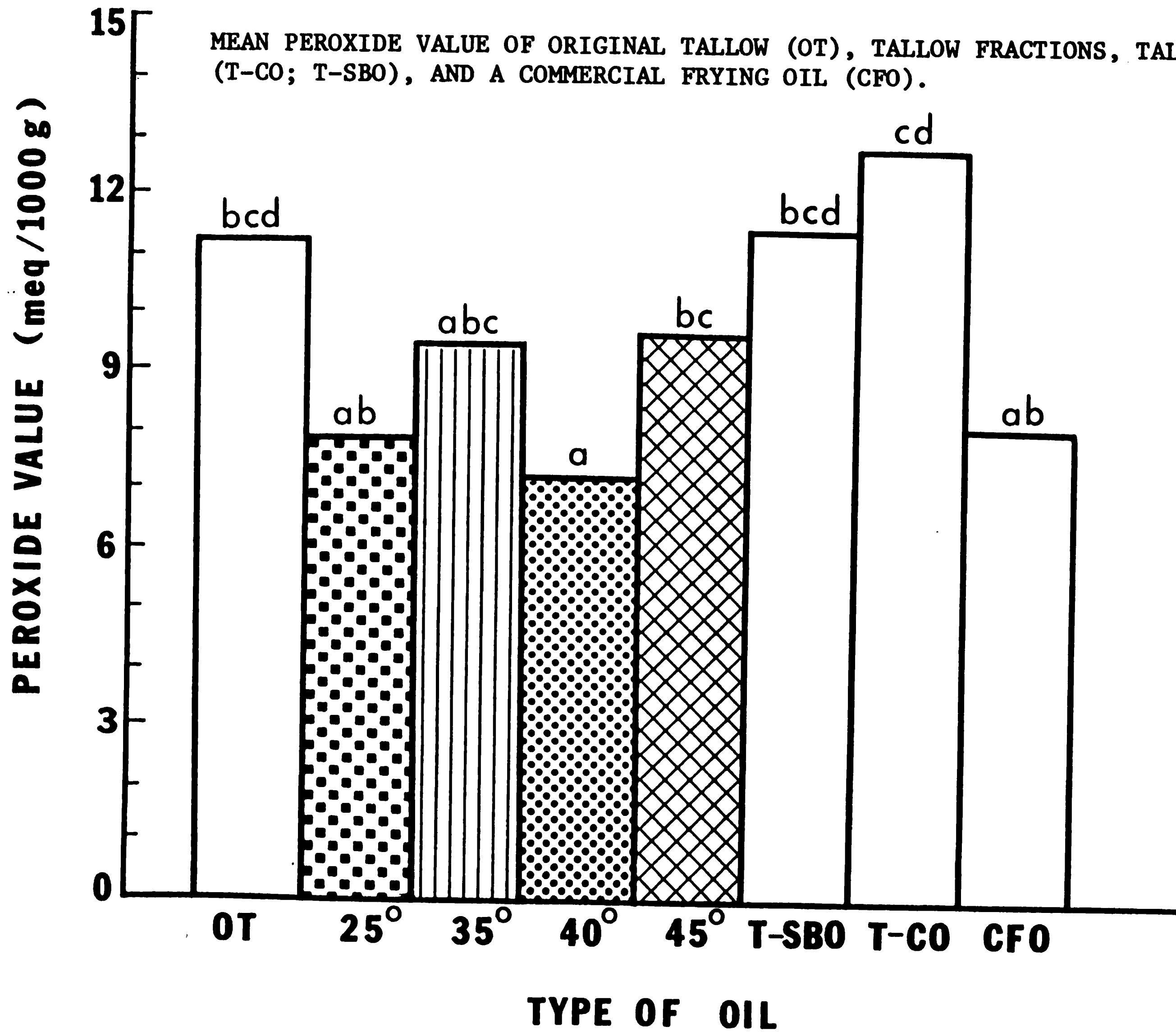
APPENDIX IV

MEAN COLOR (LIGHTNESS) VALUES FOR ORIGINAL TALLOW (OT), TALLOW FRACTIONS, TALLOW BLENDS (T-CO; T-SBO), AND A COMMERCIAL FRYING OIL (CFO)



APPENDIX V

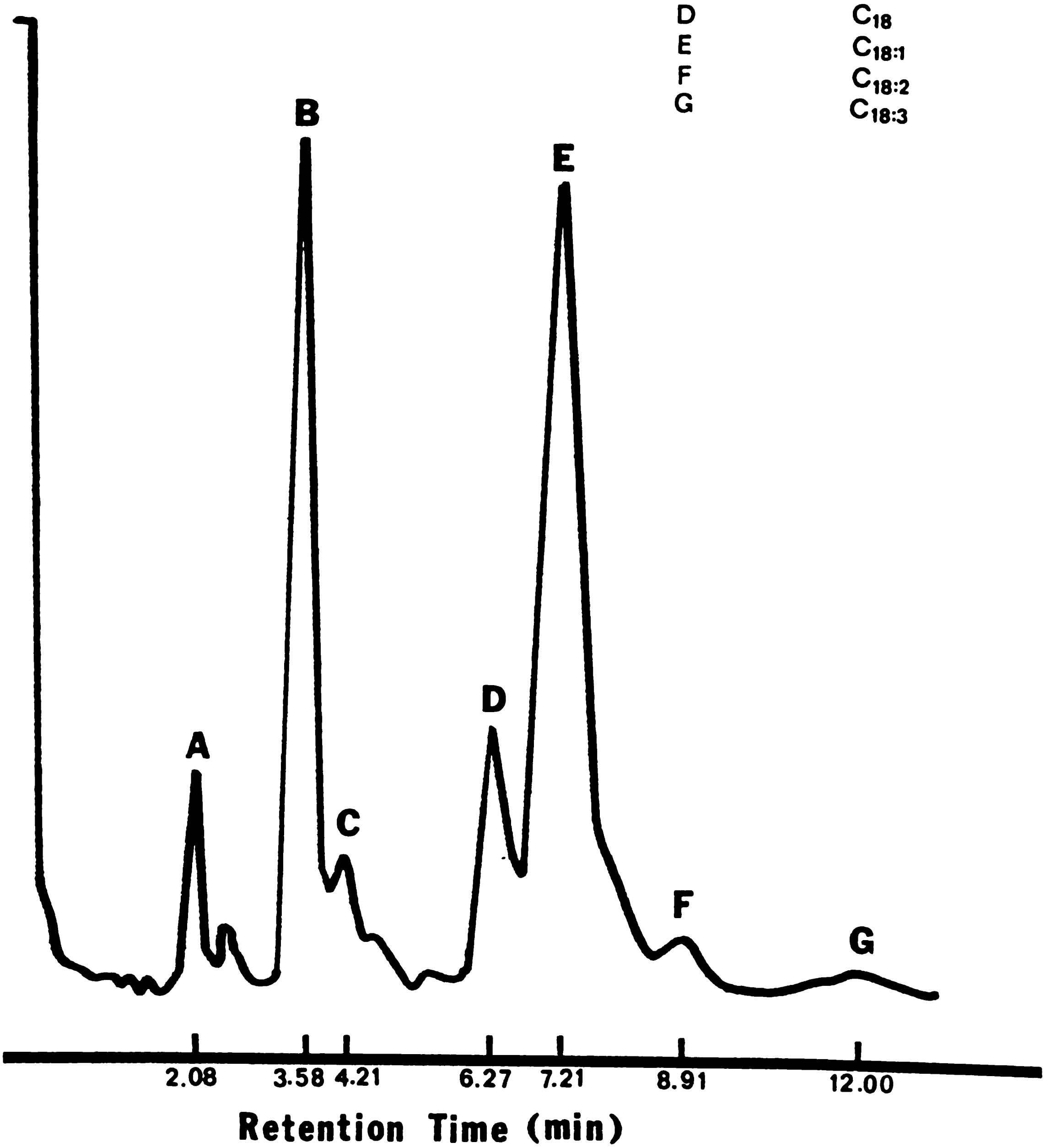
MEAN PEROXIDE VALUE OF ORIGINAL TALLOW (OT), TALLOW FRACTIONS, TALLOW BLENDS (T-CO; T-SBO), AND A COMMERCIAL FRYING OIL (CFO).



APPENDIX VI

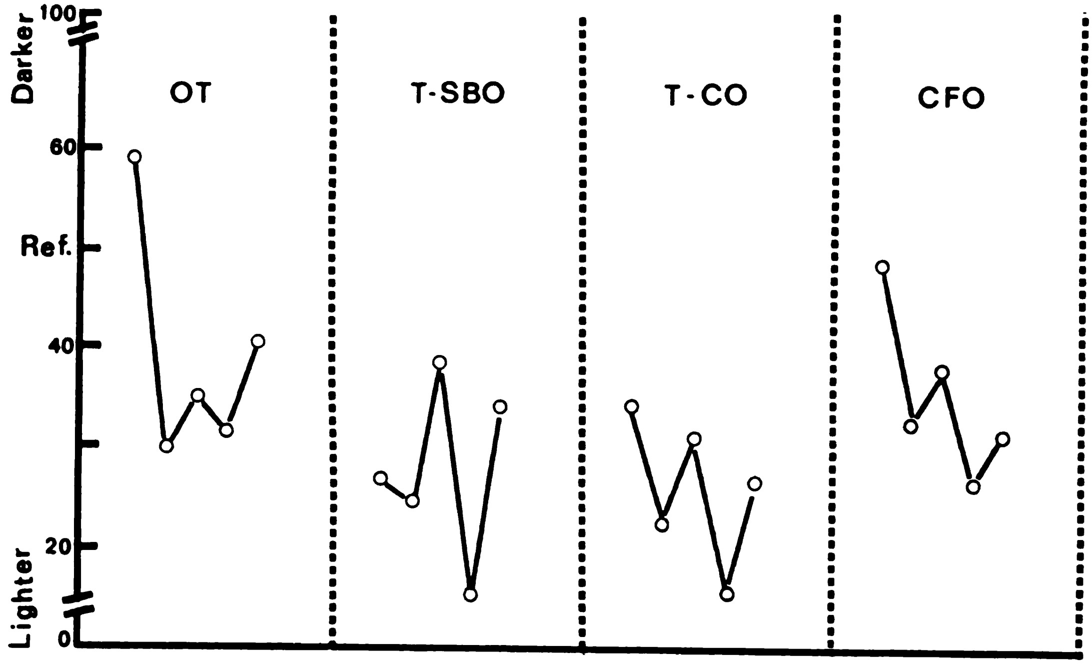
CHROMATOGRAM USED FOR DETERMINING FATTY ACID PROFILES BY GAS CHROMATOGRAPHY

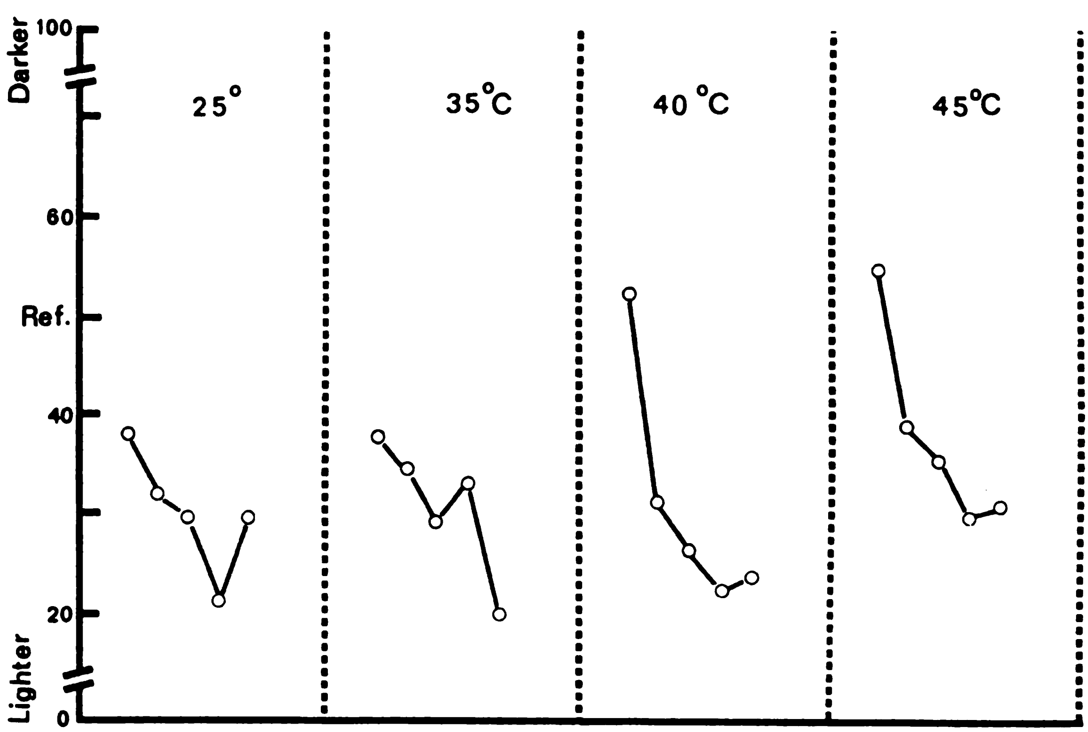
PEAK	FATTY ACID
A	C_{14}
B	C_{16}
C	$C_{16:1}$
D	C_{18}
E	$C_{18:1}$
F	$C_{18:2}$
G	$C_{18:3}$



APPENDIX VII

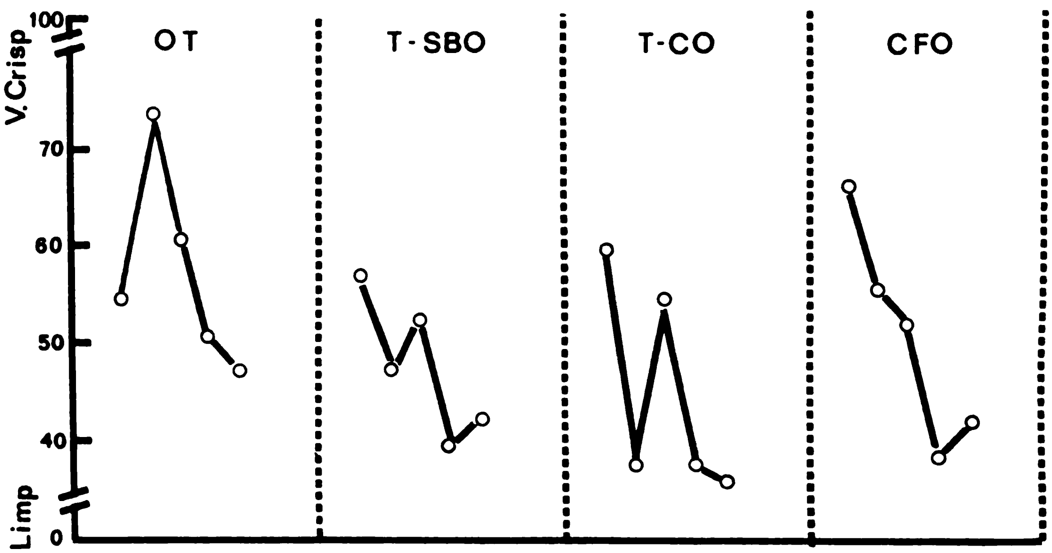
ORGANOLEPTIC COLOR OF FRENCH FRIES PREPARED IN ORIGINAL TALLOW (OT), TALLOW FRACTIONS, TALLOW BLENDS (T-CO; T-SBO), AND A COMMERCIAL FRYING OIL AFTER EVERY FIFTH SUCCESSIVE FRYING

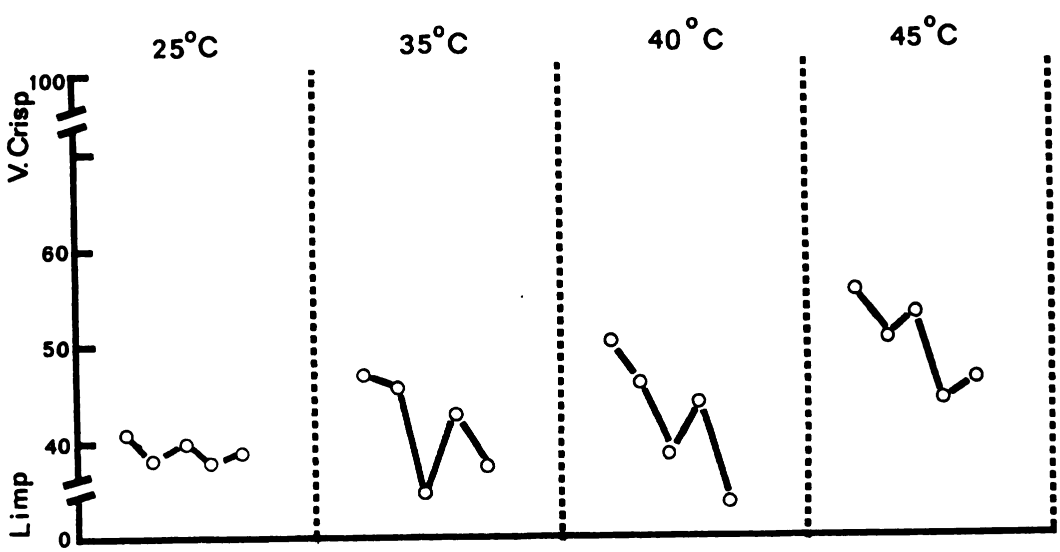




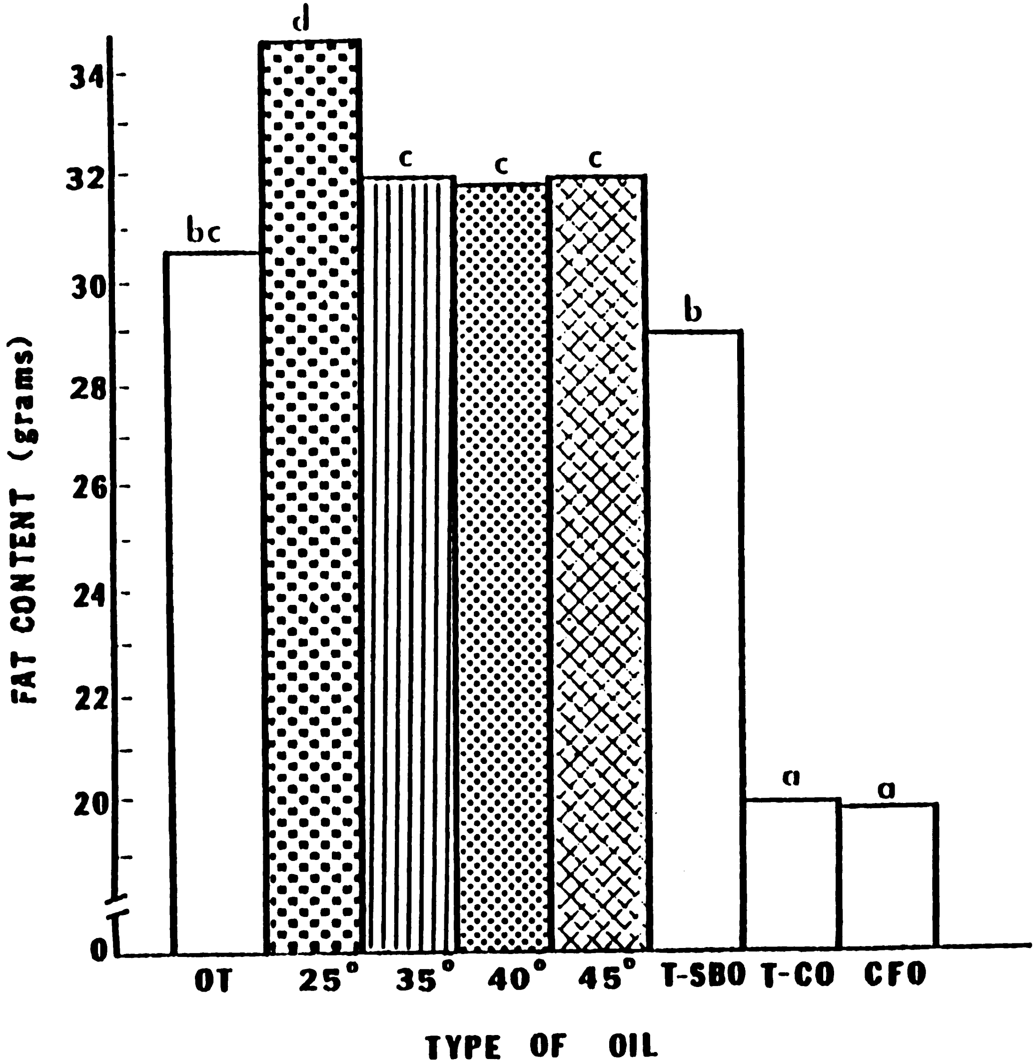
APPENDIX VIII

ORGANOLEPTIC TEXTURE OF FRENCH FRIES PREPARED IN ORIGINAL TALLOW (OT), TALLOW FRACTIONS, TALLOW BLENDS (T-SBO; T-CO), AND A COMMERCIAL FRYING OIL AFTER EVERY FIFTH SUCCESSIVE FRYING



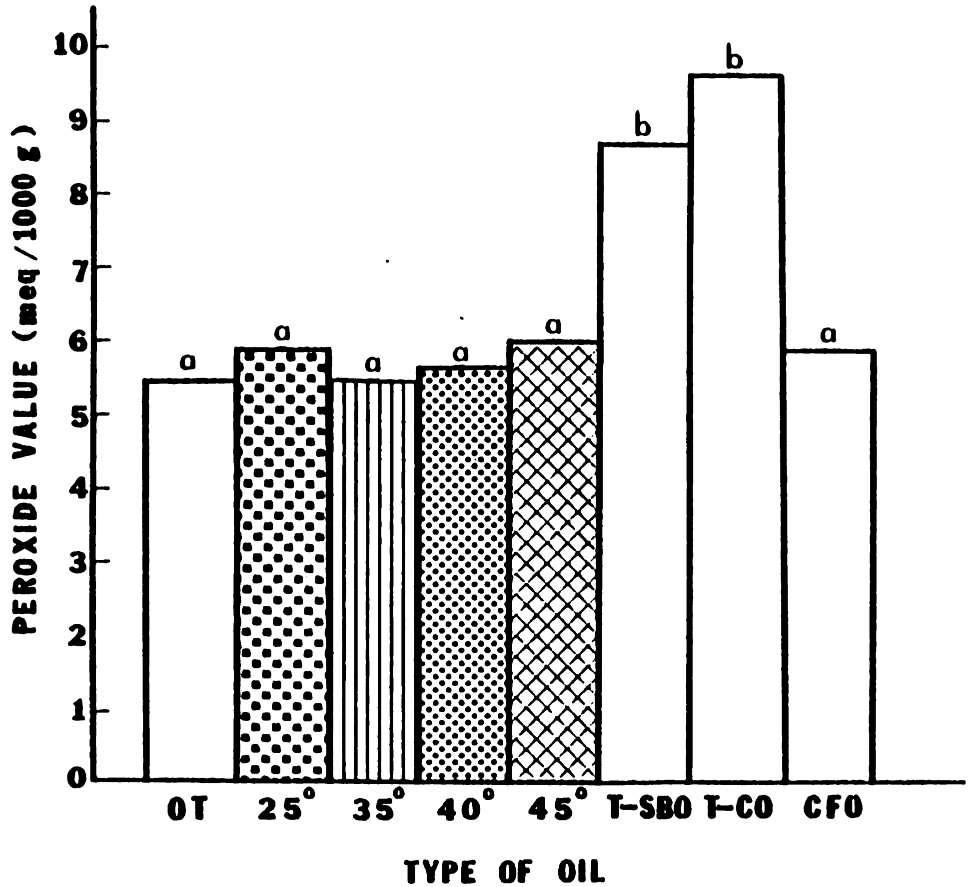


APPENDIX IX MEAN FAT CONTENT (SOLIDS BASIS) OF FRENCH FRIES PREPARED IN ORIGINAL TALLOW (OT), TALLOW FRACTIONS, TALLOW BLENDS (T-SBO; T-CO), AND A COMMERCIAL FRYING OIL (CFO)



APPENDIX X

MEAN PEROXIDE VALUES OF FAT EXTRACTED FROM FRENCH FRIES PREPARED IN ORIGINAL TALLOW (OT), TALLOW FRACTIONS, TALLOW BLENDS (T-SBO; T-CO), AND A COMMERCIAL FRYING OIL (CFO)



APPENDIX XI

DEMOGRAPHIC CHARACTERISTICS OF ADULTS RESPONDING TO CONSUMER PANEL FOR CHOCOLATE CHIP COOKIES PREPARED WITH AND WITHOUT TALLOW (N=208)

Sex of Respondent	%
Male	21
Female	79
	100%

Age of Respondent	%
Under 18	18
18 - 24 yrs.	11
25 - 44 yrs.	40
45 - 64 yrs.	25
65 and older	6
	100%

Size of Household	%
1 - 2 members	29
3 - 4 members	44
5 or more members	27
	100%

Stage of Family Life Cycle	%
Adults only	35
Adults w/children only under 13 yrs. old	23
Adults w/children only between 13-17 yrs. old	25
Adults w/children both under 13 yrs. old and between 13-17 yrs. old	17
	100%

1979 Total Taxable Family Income	%
Under $10,000	12
$10,000 - $19,999	26
$20,000 - $29,999	26
$30,000 and over	23
No response	13
	100%