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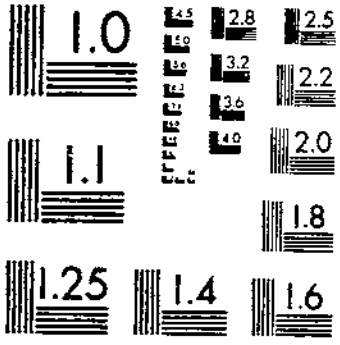
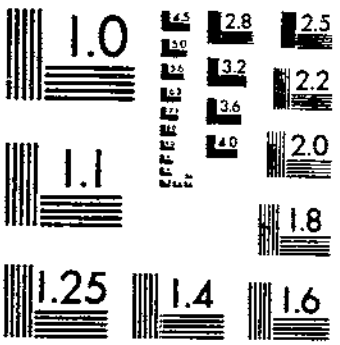


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
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TABLES

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French-Frying Quality of Potatoes as influenced by cooking methods, storage conditions, and specific gravity of tubers [1]

By Mary E. Kirkpatrick, food specialist, Human Nutrition Research Branch, Agricultural Research Service, Peter H. Heinze, Charles C. Craft, physiologists, Biological Sciences Branch, Agricultural Marketing Service, Beatrice M. Mountjoy and Claire E. Falatko, food specialists, Human Nutrition Research Branch, Agricultural Research Service [2]

SUMMARY AND CONCLUSIONS

Investigations were undertaken to obtain information useful in predicting the suitability of potatoes for french frying. Methods of preparation of french fries, specific gravity, storage, and desugaring conditions of raw tubers, and holding conditions and freezer storage of partially fried (parfried) potatoes were studied to determine their effects on palatability characteristics, dry matter, and oil content of french-fried potatoes.

Twenty-five sample lots of potatoes, representing nine varieties of the 1947 crop, were used in nonreplicated preliminary studies. Nine variety-location sample lots from the 1951 and 1952 crops were obtained for a more intensive study. Specific-gravity separations were made, and tubers representing the average specific gravity of each lot were selected for palatability testing and chemical analyses. A judging panel evaluated the french-fried potatoes for color, uniformity-of-browning, lack-of-oiliness, tenderness, crispness, mealiness, and flavor. Shear-force tests were made, and yield data were obtained on the fried potatoes. Chemical analyses were made for dry matter and, on some samples, for reducing-sugar content of the raw tubers and for dry matter and oil content of the french-fried potatoes.

Standardized procedures for the intensive study included quick washing and drying of raw potato strips, since this method produced french fries with higher dry-matter content than either soaking the raw strips 10 minutes or frying with no preliminary washing of strips. For frying, an 8 to 1 ratio by weight of peanut oil to cut potatoes was used. The 2-stage frying method, with temperatures and times closely comparable to those reported in commercial usage, was employed.

Results from the studies on the 1951 and 1952 crops showed that crispness, mealiness, and lack-of-oiliness scores for french-fried potatoes were higher as tubers of higher specific gravity were used. In

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[2] Acknowledgment is made to the following persons for contributions in various phases of the investigations: Linda C. Albright, Elsie F. Dochterman, Benjamin Mazeika, and Albert B. Parks. Acknowledgment is also due the field staff of Biological Sciences Branch, Agricultural Marketing Service, and Horticultural Crops Research Branch, Agricultural Research Service, for assistance in obtaining the potatoes used in this study.

the 1952 crop, improved flavor of the french fries was also correlated with higher specific gravity. In both years tenderness scores were negatively correlated with specific gravity. The percentage of dry matter in the raw and fried samples and yield of french fries tended to increase, whereas oil content of fried samples generally decreased with increase in specific gravity of raw tubers.

Storage of potato tubers for 3 or 5 months at 40° F. caused accumulation of sugar in the raw tubers and excessively brown color and a burned flavor in the french-fried potatoes. In contrast, storage of tubers for 2 months at 55° retarded sugar accumulation and gave french fries with much better color and flavor. Extensive investigations with the 1951 crop showed that color scores for french fries made from potatoes stored at 55° or 60° and flavor scores for french fries from potatoes stored at 50°, 55°, or 60° were significantly higher than from potatoes stored at lower temperatures. French fries made from potatoes stored at 55° were significantly more mealy and had a significantly higher dry-matter content than those from potatoes stored at other temperatures.

Also studied in detail was the effect on french-fried potatoes of desugaring the tubers, which consists of reducing their sugar content by holding them for a period of time at a temperature higher than the storage temperature. When potato tubers stored for 2 months at 55° F. were subsequently held at 70° for 3 weeks, little improvement was obtained in the french fries. Color was the only palatability characteristic affected, and the response was quite variable for the different sample lots. Tubers stored 5 months at 40° and desugared at 70° made french fries slightly more mealy, less oily, and of better color than tubers that were not desugared. Mealiness and crispness scores were slightly higher for 2-week than for 1- or 3-week desugaring periods, but color continued to improve during the third week. Statistically significant differences between 1-, 2-, and 3-week desugaring periods were found only for the color characteristic. Color scores were closely associated with the changes in reducing-sugar content of the raw strips. Variations in reducing-sugar content between tubers within a sample and within different areas of single tubers were found to be associated with the variability in the uniformity of browning of french-fried strips. Differences in varietal responses to desugaring time were shown in the color, mealiness, and flavor scores of french fries. A comparison of desugaring for 2 weeks at temperatures of 70° and 80° following 5 months' storage at 40° indicated significantly higher scores for color and flavor at 80° in some lots of Irish Cobbler potatoes. Other characteristics were not affected to any extent by desugaring temperatures.

Holding of partially fried potatoes at room or refrigerator temperature no longer than 24 hours before the second stage of frying had relatively little effect on the palatability characteristics of the french fries from Chippewa and Kennebec sample lots. In the case of Russet Burbank, small but consistent decreases were noted in the scores for tenderness and flavor. Trends were not consistent for all sample lots, nor were they great enough for significance. Shear-force values were consistently higher for samples that were held than for those cooked without any appreciable time lapse between the two stages of frying. With an increase in holding time, there was an

increase in dry-matter content and a corresponding decrease in yield of the fried product. An apparent increase in oil content for samples held longer periods of time was largely due to decrease in moisture and yield, not to increased absorption of oil.

A comparison of methods of cooking frozen parfried potatoes showed that heating in a preheated 500° F. oven for 10 minutes or heating in a 500° oven 5 minutes followed by 3 minutes in a broiler compared favorably with frying in deep fat, except that there was a slight decrease in tenderness and less uniformity-of-browning. Cooking in a broiler for 5 minutes was the least satisfactory method. No significant differences were found as a result of thawing or not thawing frozen parfried potatoes before cooking by the oven, oven-broiler, or broiler methods.

French-fried potatoes from parfries made at the time the tubers were harvested and held 2 to 9 months in freezer storage were comparable in palatability to freshly prepared french fries. Those made from tubers stored 2 or 4 months at 50° F., then parfried and held in freezer storage 5 to 7 months, were somewhat lower in quality. All frozen samples, whether prepared at harvest or after tuber storage for 2 or 4 months, made french-fried potatoes of satisfactory quality except for mealiness in samples from tubers stored for 4 months.

INTRODUCTION

French frying is said to be the most popular method of cooking potatoes served in restaurants, although for home meals potatoes are more commonly boiled, mashed, or baked. Results of a survey (*36*)[3] on potatoes used in 2 cities, New Orleans and Cincinnati, showed that in terms of pounds of potatoes purchased, french frying was the method of preparation most frequently used. It has been estimated (*8*) that 50 percent of the potatoes served in restaurants are prepared by some method of frying. A survey of household practices in the use of foods (*25*) shows that in Birmingham, Ala., Indianapolis, Ind., and Everett, Wash., french fries were served in 19, 9, and 2 percent, respectively, of the meals that included potatoes.

The relatively infrequent service of home-prepared, french-fried potatoes is probably due more to the difficulties of home preparation than to lack of popularity. Problems presented by the need for special equipment, and the cost, storage, and reuse of the fat, as well as the need for attention to the frying just before serving the meal, discourages the french frying of potatoes in the home.

The use of frozen french-fried potatoes in the home has shown a progressive increase since their advent on the retail market. From 1949 to 1953 the amount of the yearly potato crop processed into frozen french fries increased from 900,000 bushels to 3,500,000 bushels, while the amount of the crop for total food uses during that same period changed very little, from 275,000,000 to 290,000,000 bushels (*26*). Among vegetables processed by freezing, commercially frozen french-fried potatoes rank seventh in quantity of retail sales.[4] In 1953 a total of 60,000,000 pounds of packaged french fries was frozen, of

[3] Italic numbers in parentheses refer to Literature Cited, p. 43.

[4] Personal communication, K. O. Burr, National Association of Frozen Food Packers, Dec. 28, 1954.

which 56,000,000 pounds were put into 9-ounce retail packages and 4,000,000 pounds were packaged in institutional and bulk units.

The growth of this industry has been so rapid that research has not kept pace with production. Information on the french-frying quality of the potatoes on the market is scant. Large restaurants and commercial processors can purchase potatoes of known variety and source, and if they are found satisfactory, buyers can repeat their purchases year after year. The homemaker, however, has little opportunity for selecting the most suitable potatoes to use and consequently may come out with a mediocre product.

Despite the popularity of french-fried potatoes, whether prepared in restaurants or in the home, freshly cooked or frozen, there is unfavorable consumer reaction to unappetizing french-fried potatoes—those that are grease soaked, excessively dark in color, and have a scorched taste. This variation in quality indicates a need for further research.

The purpose of the investigation reported here was to—

(1) find means to predetermine the suitability of potatoes of different variety and location for french frying;
(2) determine the most suitable conditions of storage and desugaring of raw tubers; and
(3) develop procedures adaptable to use with the two-stage frying method in making both fresh and frozen french-fried potatoes.

The findings should aid homemakers, institutional buyers, and processors of frozen french fries to obtain high quality french-fried potatoes throughout the year.

Cooking and palatability tests were made by the Human Nutrition Research Branch of Agricultural Research Service; chemical analyses for moisture and sugar content of raw potatoes, as well as moisture and oil content of finished french fries, by the Biological Sciences Branch of Agricultural Marketing Service. The latter group took responsibility for obtaining and storing the potatoes used in this study.

EXPERIMENTAL PROCEDURES

SELECTION OF POTATOES

In preliminary studies on potatoes from the 1947 crop the following 9 varieties were used: Chippewa, Green Mountain, Irish Cobbler, Katahdin, Russet Burbank, Russet Rural, Sebago, Triumph, and White Rose. Limited studies were continued with 4 varieties from the 1948 crop: Chippewa, Irish Cobbler, Katahdin, and Russet Burbank. Both years each variety was obtained from 2 or 3 locations as described in a previous publication (*23*).

In 1951 and 1952 a more intensive study was undertaken. The 4 varieties of potatoes chosen for the work on the 1951 crop were Chippewa and Green Mountain from Maine, Triumph from North Dakota, and Russet Burbank from Washington. Previous experience with varieties from these areas indicated that they would include potatoes with both high and low specific gravity and with considerable difference in sugar-accumulation characteristics. From the 1952 crop the following varieties of commercial importance for french frying were obtained: Irish Cobbler from Maine and North Dakota, Katahdin from Colorado and Maine, Chippewa and Kennebec from Maine, and Russet Burbank from Washington.

All potatoes were of U. S. No. 1 grade. Nearly all were harvested between mid-September and early November. Data on soil types, fertilizers and insecticides used, and preharvest treatment of vines for the 1952 crop are included in the Appendix (table 21).

STORAGE

Each year after the potatoes were dug they were allowed to cure for a few days, and then 200 to 300 pounds were shipped by rail express to the Plant Industry Station, Beltsville, Md. They were held at 55° F. at the Station for a short time, until they were divided into lots and placed in storage as required for the various tests.

Although it is known that storage temperatures of 50° to 55° F. are conducive to maintaining good tuber quality for french frying, many commercial storage houses use a temperature of 40° or lower in order to minimize sprouting, withering, and decay.

In the preliminary studies in 1947 the potatoes were held at 2 temperatures, 40° and 55° F. After 4 months some of the lots in 40° storage were transferred to 70° and held for varying periods of time up to 8 weeks. French-fried potatoes were made at 2-week intervals during the holding period. Part of the 1948 crop was also stored at 40° for approximately 4 months, then transferred to 70°, and french fried after 2, 4, or 6 weeks.

Samples of each of the variety lots from the 1951 crop were stored at 40°, 45°, 50°, 55°, or 60° F. Some of the lots stored at 40° for 5 months were transferred to 70° and fried after 1, 2, or 3 weeks. The storage temperatures used for the 1952 crop were 40° and 50°. After storage for 4 months, some of the lots in 40° were transferred to 70° or 80° and fried after 2 weeks.

Temperatures in the rooms where the tubers were stored were thermostatically controlled and seldom varied more than 1° from the specified temperatures. The relative humidity was maintained at 85 to 90 percent.

Samples of the Kennebec variety, one of the varieties used in considerable quantity for commercial french fries, were obtained for storage tests of frozen partially fried potatoes. Samples for freezing were taken from tubers shortly after receipt of the harvested lots at Beltsville and from tubers after storage for 2 or 4 months at 50° F. The partially fried potatoes were frozen and stored at 0°. They were removed from frozen storage after various periods up to 9 months, finished with the second-stage fry, and evaluated for quality.

SPECIFIC GRAVITY

Specific gravity of the potatoes was determined by the salt-density method as previously described (*23*). A preliminary sample of approximately 50 tubers was separated before storage to determine the range and the average specific gravity of each lot of potatoes. A few days before the samples from the various storage conditions were used in the cooking tests, specific-gravity separations were made on each lot. The distribution of tubers as shown in table 1 indicates the specific-gravity classes that were available from each of the lots.

TABLE 1.—*Number of tubers in each specific-gravity class*

Variety and location	Total number of tubers	Specific-gravity class														
		1.055	1.060	1.065	1.070	1.075	1.080	1.085	1.090	1.095	1.100	1.105	1.110	1.115	1.120	Over 1.120
1951 crop																
Chippewa: Maine	833	---	46	145	251	201	134	45	8	---	---	---	---	---	---	---
Green Mountain: New York	530	---	6	15	43	95	152	143	55	20	1	---	---	---	---	---
Russet Burbank: Washington	523	---	---	---	---	3	14	39	100	109	133	64	1	---	---	---
Triumph: North Dakota	478	---	8	18	79	122	140	74	30	7	---	---	---	---	---	---
1952 crop																
Chippewa: Maine	614	8	59	106	205	126	18	2	---	---	---	---	---	---	---	---
Irish Cobbler: Maine	720	---	1	5	7	18	73	259	265	91	1	---	---	---	---	---
Irish Cobbler: North Dakota	682	---	---	2	7	10	27	57	178	131	143	77	50	---	---	---
Katahdin: Colorado	676	---	1	2	12	11	33	102	137	183	131	48	16	---	---	---
Katahdin: Maine	506	---	3	7	52	179	160	88	17	---	---	---	---	---	---	---
Kennebec: Maine	1,312	---	2	10	130	348	450	318	72	11	1	---	---	---	---	---
Russet Burbank: Washington	547	---	---	---	---	1	2	4	6	10	50	44	176	192	46	16

In all experiments except those dealing especially with differences due to specific gravity, the samples were chosen from one specific-gravity class representing a high proportion of the lot. The maximum variation between tubers within each individual cooking sample did not exceed 0.005.

ANALYTICAL PROCEDURES

The dry-matter content of the cut raw strips was determined by removing duplicate 50-gram samples from each lot just prior to frying. The samples were dried in a convection-type oven for 20 to 24 hours at 70° F., then drying was continued in a vacuum-type oven at the same temperature until a near constant weight was obtained.

The fried strips were dried by the same procedure as the raw strips, and the dry-matter content as calculated included all materials except moisture. These dried samples were then used for the determination of oil content.

The oil content was determined by a simplified procedure that was compared, in a few preliminary samples, with analysis by a continuous extraction apparatus using ethyl ether as described for meat products (*7*). The simplified procedure was found to give results with a reliability that was considered adequate for these experiments. The samples were covered with toulene and allowed to stand overnight; then the toluene was decanted. This procedure was repeated until the strips had been subjected to three extractions with toluene. A fourth extraction was made with petroleum ether, after which the strips were transferred to a weighed filter paper, washed with petroleum ether, and allowed to stand for a few hours at room temperature before completion of the drying in the ovens at 70° F. The amount of oil extracted was determined by the difference in dried weights before

and after extraction; the oil content is reported on the basis of the freshly fried product before removal of the moisture.

Analyses for reducing and total sugars were made on the tubers or cut raw strips, or both, in the experiments that involved a number of storage temperatures or transference of the potatoes to higher temperatures for desugaring. The picric acid method, as previously described (*24*), was used in several experiments to determine the reducing sugars in each tuber in the frying samples. The small cylindrical sections were removed from the tubers midway between the stem and bud end just before they were cut into strips. The reduced copper method, as described by Heinze and Murneek (*22*), was used for all other sugar analyses.

FRENCH-FRYING METHODS

The two-stage frying method, developed and advocated by commercial research laboratories and also adapted for home use (*5*), was chosen as the basic method for this investigation. Advantages of the two-stage method over the continuous, or one-stage, method are that it shortens the total cooking time, helps maintain oil at proper cooking temperature through more of the cooking process, increases the capacity of the fryers in the second-stage fry, and makes for quick service of the finished product to varying numbers of persons.

Restaurants using the two-stage frying method find an advantage in partially cooking french fries during slack periods in the morning or afternoon before they are needed. At serving time, upon order, partially cooked french fries are quickly finished off by second-stage frying. It has been reported (*1*) that in single-stage frying 77 pounds of potatoes were produced in an hour, but with two-stage frying the capacity of the same fryer to brown in the final stage was 300 pounds per hour.

Details of the method of french frying done in preliminary work (1947 crop) were for the most part the same as previously reported in a study of early-crop potatoes (*24*). Exceptions were that whole potatoes were used rather than halves and that oil temperatures and times for first- and second-stage fry were 195° C. (383° F.) for 2 minutes and 210° C. (410° F.) for 4½ minutes, respectively. Electrical units, each with a heat input of 2,010 watts controlled by a voltage regulator, were the source of heat. Two sheet-iron fry kettles of 4-quart capacity, each containing 1,050 grams of peanut oil, were employed, one for the first-stage fry, the other for the second-stage fry. For a 3 to 1 ratio of oil to potatoes, a 350-gram cooking sample was used.

When work on french frying was resumed in 1951, potatoes were again cut into ⅜-inch strips, the same size as used in the previous study. The two-stage frying method and peanut oil as the frying medium were used, but some modifications in the procedures were made. Larger sheet-iron fry kettles of 8-quart capacity and heavy wire baskets to fit them were obtained, and an 8 to 1 proportion of oil to raw potato was used (2,800 gm. oil to 350 gm. cut raw potato). As in the earlier studies, two identical kettles containing equal weights of oil, one for first-stage frying the other for second-stage frying, were heated on electrical units of identical wattage (2,010 watts)

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and were equipped with mercury thermometers for determining oil temperatures.

The decrease in the amount of oil in the kettle during frying varies with the amount and kind of food fried, the temperature of the oil, and the length of cooking time. To maintain a standard ratio of oil to potato in the 1951 tests, oil was added after each stage of frying to bring the weight to the original 2,800 grams.

The use of an 8 to 1 ratio of oil to cut potato necessitated additional tests to determine satisfactory oil temperatures and periods of cooking time. For first-stage frying an initial temperature of 185° C. (365° F.) and 4 minutes cooking time were chosen; for the second-stage frying, an initial temperature of 199° C. (390° F.) and 1½ minutes cooking time. These temperatures come within the range of frying temperatures recommended by Benes, Carlin, and Logan (*8*).

Based on exploratory tests made in 1951, quick washing of cut potato strips without soaking was incorporated as a pretreatment in subsequent tests herein reported.

A commercial-type electric fry kettle of 15-pound oil capacity with rated wattage of 4,500 watts and automatic temperature control was installed in 1952. With an 8 to 1 proportion of oil to potato the larger capacity provided for 6,810 grams of oil and 851 grams of potato sample.

A bimetal thermometer with a circular dial and a pointer for reading temperatures was used in place of the mercury thermometers previously described. When compared with mercury thermometers the metal thermometer gave a more rapid thermal response.

The change to the automatic fryer in 1952 necessitated further exploratory tests to establish suitable temperature-time combinations for french frying potatoes. After a few preliminary tests with the five 1952 sample lots, the temperatures of 182° C. (360° F.) for first-stage fry and 191° C. (375° F.) for second-stage fry were selected as those most likely to give the best product. From a comparison of 3, 3½, 4, and 4½ minutes for first-stage frying, each combined with 1½ minutes for second-stage frying, the time periods of 4½ and 1½ minutes were established as standard times for all subsequent tests.

In the preliminary tests with the electric fryer, it was observed that the first sample in any one session showed less cooking and higher oil absorption and caused a greater oil temperature drop and lower recovery readings than the succeeding samples. During this first cooking the rise in oil level caused by foaming heated a greater portion of basket and kettle and thus tended to stabilize the oil temperature and performance of the kettle for subsequent samples. Hence, a preliminary sample was cooked and discarded before samples were fried for judging. This procedure was also followed if a lapse of 30 minutes or more occurred between samples.

Preliminary trials indicated that an 8 to 1 ratio of oil to potato could be maintained throughout a series of 4 frying tests by routinely adding 50 grams of oil to the kettle after the preliminary sample and 40 grams after each succeeding parfry sample.

Before the second-stage frying tests were started, the oil was weighed and a sufficient amount added to make the standard weight of 6,810 grams. After each load in the second-stage frying, 15 grams of oil was routinely added to bring the total weight back to approximately 6,810 grams.

PALATABILITY EVALUATION

The criteria used to evaluate quality of french-fried potatoes have varied. East (*18*) reported that in France where deep-fat frying is the accepted method of cooking, potatoes that hold their shape are desirable. In the studies made by Wright and colleagues (*38*) other quality characteristics—color, texture, and flavor—were scored in addition to appearance. Bewell (*9*) reported that potatoes of low dry-matter content were about as good as those of high dry-matter content for deep-fat frying as far as appearance was concerned.

More recently, Alexander and associates (*4, 5*) scored french-fried potatoes for several quality characteristics—oiliness, as well as color, texture, and flavor. Akeley (*2, 3*) in a comparison of eight Maine-grown potato varieties for french-frying quality used only one characteristic, degree of browning, as a basis for recommending varieties suitable for french frying.

A broad conception of the quality characteristics of french fries was shown in the study reported by Benes, Carlin, and Logan (*8*). In setting up standards of quality for french-fried potatoes made for restaurant service they considered flavor, color of surface, correct fat absorption, form and symmetry, crispness, and mealiness as characteristics to be scored. The above standards required that particular attention be given to detecting bitterness, off-flavor, or rancidity in flavor; that perfect color should be light golden brown without mottling or dark streaks; that the form should be regular and pieces fairly uniform in length; that crispness without hardness, leatheriness, or gumminess is desirable; and that the interior should be mealy like a good baked potato, not watery or mushy, and there should be no separation between core and crust. Such standards can be applied equally well to home-prepared french fries. In this study they were used in assigning descriptive terms to numerical points on the rating scale of the judging record.

Before development of the judging record, french fries showing variation in palatability characteristics were prepared from a number of potato samples. They were examined by a group of persons including potato research scientists, food specialists, and representatives from the National Restaurant Association and the United Fresh Fruit and Vegetable Association. From observation and discussion of the qualities of these cooked potatoes, agreement was reached regarding the important characteristics and the levels of quality for each to be included on the judging record.

The palatability characteristics for which french-fried potatoes were scored included color, uniformity-of-browning, lack-of-oiliness, tenderness, crispness, mealiness, and flavor. With the exception of color, all characteristics were judged on a 5 to 1 scale, with 5 representing the highest score and 1 the lowest. For color, a score of 6 was recorded for potatoes that were slightly too light; 5 represented golden color (standard quality) and the scale decreased to 1, very dark (poorest color). Judges were asked to assess the range of color shown in each sample, as well as give a score for uniformity-of-browning. To provide color standards for the judges, potato chips, which show color variations similar to those of french-fried potatoes, were used. Samples of potato chips were selected to represent the scores on the color scale, 6 to 1. In scoring for lack-of-oiliness, the range

of scores was described as very slightly oily (5) to very oily (1). In addition to giving a numerical score for flavor, the judges described the flavors as natural, scorched, burned, bitter, sweet, or other.

As frying of each sample was completed, representative portions for each judge were selected and served on coded plates. No more than five samples were judged in any one session. Samples for each day's judging were selected and prepared at random unless a specific order of sample preparation was required for the statistical treatment of the scores.

The 6 judges comprising the palatability panel had had previous experience in judging potato quality, and 4 had previously judged french-fried potatoes. Before palatability tests on the 1951 potato samples were begun, 2 judging sessions were given for a brief training of the judges. By using potato samples of 3 varieties, each of different specific gravity (1.095, 1.085, or 1.070), and by varying the cooking time, french fries representing at least 3 levels of quality (5, 4, 3, or 5, 4, 2) for all palatability characteristics were obtained.

The first day individual samples representing these scores were given and made known to each judge. The judges studied the product in relation to descriptive terms on the rating scale and discussed the differences among the samples. Open discussion was encouraged so that all judges might understand the basic reasons for assigning certain scores and come to an agreement on standards for each score.

On the second day of training, similar samples were prepared and given to the judges for independent scoring. After scoring was completed, while the panel was present, scores made by all panel members were compared to determine how close to the standard each judge scored and also how closely all the judges agreed on the various scores. A few additional judging sessions were held after 3 months and again at the beginning of the tests in 1952, to review the standards for the palatability panel. Procedures followed were the same as those described above.

SHEAR-FORCE TESTS

One of the instruments used for the objective determination of the tenderness quality of foods is a shearing machine designed by K. F. Warner and L. J. Bratzler. This instrument has been used by several investigators (*10*, *11*, *14*, *21*, *30*) to test the tenderness of meat. Results from these studies showed that tenderness of beef or poultry was negatively correlated with shear-force values. In some studies the relationship was more highly correlated than in others.

JUDGING RECORD FOR FRENCH-FRIED POTATOES

Name_____ Date_____

Palatability characteristics and scoring scale	Rating for sample				
	1	2	3	4	5
Color, exterior:					
6—Slightly light					
5—Golden					
4—Slightly brown					
3—Moderately dark					
2—Dark					
1—Very dark					
Uniformity-of-browning:					
5—Uniformly browned Score					
4—Slightly variable					
3—Moderately variable Range					
2—Variable					
1—Extremely variable					
Lack-of-oiliness:					
5—Naturally oily, very slightly oily					
4—Slightly oily					
3—Moderately oily					
2—Oily					
1—Very oily					
Tenderness:					
5—Tender					
4—Slightly tough					
3—Moderately tough					
2—Tough					
1—Very tough					
Crispness:					
5—Crisp					
4—Slightly limp					
3—Moderately limp					
2—Limp					
1—Very limp					
Mealiness:					
5—Dry, mealy					
4—Slightly moist, moderately mealy					
3—Moderately moist, slightly mealy					
2—Soggy, not mealy					
1—Very soggy, not mealy					
Flavor:					
5—Natural					
4—Slightly off-flavor					
3—Moderately off-flavor					
2—Strongly off-flavor					
1—Very strongly off-flavor					
Check the following flavors when present:					
Natural					
Scorched					
Burned					
Bitter					
Sweet					
Other					

Although no reports were found in the literature that the Warner-Bratzler shearing machine had been used for testing the tenderness of french-fried potatoes, it was used in 1952 to study correlation of shear-force values with palatability scores for tenderness and crispness. An adjustment was made in the machine to make it more suitable for use with french fries. The triangular blade was replaced with a hollow-square blade that accommodated three parallel strips of french-fried potatoes. It was found that three strips, placed side to side and sheared at one time, were adequate to give a reliable poundage reading.

After french-fried potatoes had cooled to room temperature, 15 representative strips, sufficient for 5 replications, were selected from each sample for shearing tests. The pounds of force required to shear through 3 strips was considered the shear-force value. Correlation coefficients between shear-force values and palatability scores of tenderness and crispness were computed.

YIELDS OF FRENCH-FRIED POTATOES FROM SELECTED SAMPLES

Weights of unpared, pared, partially fried, and completely fried potatoes were obtained at different stages of the preparation of french fries for palatability testing. The raw pared potatoes were cut into ⅜-inch strips, rinsed quickly without soaking, and dried with cotton towels. The standard 851-gram frying sample was selected to contain only uniform strips with 4 straight cut sides. Small irregular pieces do not contribute to a uniform sample and overcook quickly, thus causing deterioration of the oil. Yields of partially fried and completely fried samples were calculated as a percentage of the selected raw cut weight. Since only a portion of each pared sample was fried, it was not possible to calculate yields from the original weight of the potatoes as purchased.

STATISTICAL DESIGN AND TREATMENT OF DATA

The various experiments were set up according to conventional statistical designs; therefore, a detailed discussion is not given. Analysis of variance was applied to the palatability scores obtained from the studies on the 1951 and 1952 crops. The method of analysis was varied in accordance with the specific designs proposed for the different tests. The data for each test consisted of either 2 or 3 replicate sets of scores from 5 or 6 judges.

The statistical analyses were made by variety-location rather than by variety, even though the same variety was frequently represented by several locations. Thus, each lot of potatoes was treated as a distinct sample, and no evaluation of a variety as such was attempted except for the varietal response to desugaring.

Simple correlation and regression or covariance analyses were used to study relationships between specific gravity, shear force, and compositional factors and various palatability characteristics of the french fries.

The mean scores in the tests involving cooking time, storage, and desugaring of the 1951 sample lots and specific gravity, storage of frozen parfries, and the method of final cooking of frozen parfries of the 1952 sample lots were differentiated by statistical procedures developed by Tukey (*35*) or Duncan (*17*). To simplify the discus-

sion of relative significance, the means were usually partitioned into three distinguishable groups and in the tables are designated as being either significantly higher or lower than the other related means.

RESULTS AND DISCUSSION

STANDARDIZATION OF METHOD

Washing or Soaking Pretreatments

It is common practice to soak cut potato strips in cold water before french frying them. Soaking is considered beneficial in preventing discoloration of raw potato strips between cutting and frying, in making raw strips from shriveled tubers more crisp, and in preventing strips from sticking together, and the soaking period provides a convenient interval between the preparation and frying of the strips. In the preliminary study of 1947, a 10-minute soaking of cut potato strips was arbitrarily selected as part of the standard procedure. Other workers (5) have reported 15 minutes as an adequate soaking time.

In 1951, to determine the effect of treatment on the final product a comparison was made of french fries from raw cut potato strips that were (1) unwashed, (2) washed quickly, and (3) soaked 10 minutes. All samples were blotted dry and wrapped in towels until fried. Potatoes of Chippewa and Russet Burbank varieties having specific gravities of 1.070 and 1.100, respectively, selected as representative of low and high dry-matter content, were used for two replications of each test. Dry matter of raw and french-fried strips, oil content of the french-fried product, and yield were determined.

Quick washing of cut strips resulted in higher dry-matter content in french-fried potatoes than other treatments of both sample lots (table 2). In the raw potato strips the dry-matter content of unwashed samples was higher in both specific-gravity lots than in samples washed quickly or soaked 10 minutes, although differences were slight in potatoes of low specific gravity. The results indicate no consistent relationship between method of treatment and oil content or yield of fried product. Since quick washing without soaking gave a higher percentage of dry matter in the final product with both sample lots, it was the method selected for pretreatment of cut potato strips in all future tests.

TABLE 2.—*Influence of treatment of selected raw cut potatoes on dry matter, oil content, and yield of french fries*

Variety and location	Raw potatoes			French-fried potatoes		
	Specific gravity	Treatment [1]	Dry matter	Dry matter	Oil content	Yield [2]
			Percent	*Percent*	*Percent*	*Percent*
Chippewa: Maine	1.070	Unwashed	17.6	44.0	10.7	51.9
	1.070	Washed quickly	17.4	45.8	12.2	51.0
	1.070	Soaked 10 min.	17.4	43.2	10.5	53.0
Russet Burbank: Washington	1.100	Unwashed	25.9	55.6	10.9	54.6
	1.100	Washed quickly	25.6	55.7	11.4	54.1
	1.100	Soaked 10 min.	24.6	55.7	11.7	54.3

[1] Each treatment had 2 replications.
[2] Based on raw cut weight of selected strips.

Cooking Temperatures and Times

With the 3 to 1 ratio of oil to potato used in the preliminary study in 1947 a rapid drop in the temperature of the oil, from 195° C. (385° F.) to approximately 132° C. (270° F.), occurred at the beginning of the 2-minute first-stage frying period, followed by a small but consistent recovery. During the 4½-minute second-stage fry there was a drop in oil temperature from 210° C. (410° F.) to approximately 182° C. (360° F.) and a recovery of 7° to 15° C. (12° to 27° F.). Although these temperatures and the total cooking time were adequate to fry the potatoes to doneness, the finished product was less mealy and more oily than desirable. A high initial temperature helped to compensate for the drop in temperature, but, even so, with the 3 to 1 ratio of oil to potato and a 2-minute time for the first-stage fry the drop in temperature indicated an overload on the frying kettle.

This preliminary study did not allow replication of cooking and palatability tests, but showed trends which indicated that a longer time for first-stage fry and a shorter time for second-stage fry with a higher ratio of oil to potato would lessen the drop in oil temperature and thus give a higher quality product.

In 1951 the higher ratio of oil to potato (8 to 1) and longer first-stage frying time allowed a somewhat lower initial temperature and brought about better recovery of oil temperature before frying was completed. A higher initial temperature and a lower moisture content of parfried potatoes in the second-stage fry resulted in more rapid recovery of oil temperature than in the first-stage fry. Quick recovery in oil temperatures permits continued rapid cooking without undue absorption of oil by the potatoes and is associated with a high-quality product.

Six time combinations—4½, 2; 4½, 1½; 4, 2; 4, 1½; 3½, 2½; and 3½, 2 minutes for the first- and second-stage frying, respectively—were employed with the 4 sample lots of potatoes used that year. With an initial oil temperature of 185° C. (365° F.) for the first-stage fry, the temperature of the oil dropped to an average low of 151° C. (304° F.) within a period of 2 minutes. This drop in temperature is similar to that reported by Benes, Carlin, and Logan (*8*), which was from an initial temperature of 370° F. to a low of 320° for an 8 to 1 load for approximately the same frying time. Lowest temperatures recorded in the 1951 study (151° C., 304° F.) were well above the 265° to 280° F. temperatures occurring during a 5-minute period with a 4 to 1 load reported by Benes, Carlin, and Logan as not making a satisfactory product. In the second-stage fry the oil temperature dropped from an initial temperature of 199° C. (390° F.) to an average low of 190° C. (374° F.) within 1 minute. Although the specific gravities of the 4 sample lots varied from 1.075 to 1.095, there appeared to be no effect on drop or recovery of oil temperature due to this variation.

French-fried potatoes were scored for palatability by 4 laboratory staff members. Although no single time period combination was best for all characteristics, a comparison of the scores indicated that in color, uniformity-of-browning, tenderness, and flavor potato strips cooked 4 minutes in the first-stage fry and 1½ minutes in the second-stage fry were as good as or better than those cooked for other time

period combinations. No definite trends were established for lack-of-oiliness, crispness, and mealiness.

From results of moisture analyses and weights of the 24 cooking samples it appeared that dry-matter content and yield of french fries were related to total cooking time, that is, the longest cooking time gave highest dry matter and lowest yield.

In 1952, 5 sample lots were selected to establish cooking time periods with the counter-type electric fry kettle. These lots represented 5 specific-gravity classes, 1.065, 1.075, 1.090, 1.105, and 1.110. A few exploratory tests indicated that the automatic temperature control prevented the extreme drop in temperature previously experienced with top-of-range fryers and speeded initial heating as well as recovery of oil temperature during the frying process. Therefore, lower temperatures were needed than those used with top-of-range fry kettles. An initial temperature of 182° C. (360° F.) for the first-stage fry was then used with varying time periods of 3, 3½, 4, and 4½ minutes. The initial temperature of 190° C. (375° F.) for the second-stage fry was used with only one time period, 1½ minutes.

The drop in oil temperature during the first-stage fry from an initial temperature of 182° C. (360° F.) to an average of 156° C. (313° F.) was less than occurred the previous year when top-of-range fry kettles were used. The maximum drop occurred within 1 minute and the temperature returned to 171° C. (341° F.) by the end of the first-stage fry. During the second-stage fry, the oil temperature dropped from 190° C. (375° F.) to an average of 181° C. (358° F.) in 25 seconds and recovered to 184° C. (364° F.) by the end of the 1½-minute cooking time.

Statistical analysis of palatability panel judgments (table 3) indicated that differences due to parfry time were small in relation to variety-location differences. With various sample lots the effect of a specific cooking time on some of the palatability factors was not clear cut. In some cases a shorter first-stage fry gave higher scores than a longer one, although differences were slight and significant in only a few instances. Scores for lack-of-oiliness and mealiness were in general as high with the longer first-stage fry, and in some cases higher than a short first-stage fry; the dry-matter content of the french fries also was higher. However, yield of french fries decreased with increased cooking.

In consideration of all factors concerned, a 4½-minute time for first-stage frying was selected for use in most of the subsequent tests. While it is recognized that in common practice it may not be desirable to use a constant time for the first-stage frying because of the variability in response of different lots of potatoes, it was considered necessary in these studies to maintain a standard frying procedure.

RELATIONSHIP OF SPECIFIC GRAVITY TO PALATABILITY

Specific gravity of raw potatoes has been recognized for a number of years as a measure of certain qualities in potatoes, but little has appeared in the literature concerning the relationship of specific gravity to the palatability characteristics of french-fried potatoes. In the studies reported, a difference of opinion is noted. Grieg and

TABLE 3.—*Influence of cooking time on the quality of french-fried potatoes, 1952 crop*

Variety and location	Raw potatoes		Cooking time		French-fried potatoes										
					Mean palatability scores [1]							Shear force	Dry matter	Oil content	Yield [3]
	Specific gravity	Dry matter	First-stage fry	Second-stage fry	Color [2]	Uniformity-of-browning	Lack-of-oiliness	Tenderness	Crispness	Mealiness	Flavor				
		Percent	*Minutes*	*Minutes*								*Pounds*	*Percent*	*Percent*	*Percent*
Chippewa: Maine	1.065	16.2	3½	1½	4.5	4.5	2.9	4.9	2.6	2.1	4.1	1.7	45.0	13.0	51.2
		17.0	4	1½	4.1	4.1	2.6	4.9	2.3	1.6	3.6	1.4	46.8	12.8	50.1
		16.7	4½	1½	3.6	3.2	2.6	4.9	2.0	1.9	3.6	2.1	48.9	13.8	47.0
Irish Cobbler: North Dakota	1.105	24.7	3	1½	4.5	4.1	4.3	4.0	4.4	4.2	4.7	4.0	56.3	11.9	55.7
		24.7	3½	1½	4.2	4.0	4.5	3.9	4.3	3.9	4.8	5.1	57.2	11.4	54.2
		26.0	4	1½	3.8	4.0	4.5	3.6	4.4	4.1	4.6	5.3	60.2	11.9	51.7
Katahdin: Colorado	1.090	22.5	3	1½	4.2	3.9	4.0	4.6	4.1	3.4	4.7	2.5	52.8	11.4	54.2
		22.6	3½	1½	4.6	4.4	4.1	4.4	3.8	3.5	4.9	2.7	53.4	12.2	54.1
		22.4	4	1½	4.6	4.4	4.3	4.3	4.1	3.6	4.9	3.6	56.8	12.6	51.5
		22.9	4½	1½	4.1	4.0	4.2	3.9	3.9	3.5	4.1	3.4	58.1	12.6	49.4
Kennebec: Maine	1.075	20.4	3½	1½	5.1	4.7	3.9	4.8	4.0	3.3	4.7	2.6	50.2	12.8	51.5
		20.7	4	1½	4.6	3.8	4.1	4.2	3.7	3.1	4.4	3.4	52.4	13.4	48.8
		20.1	4½	1½	4.9	4.7	4.5	4.5	4.1	3.5	4.9	3.6	52.8	13.0	47.7
Russet Burbank: Washington	1.110	26.4	3	1½	4.0	3.3	4.6	3.7	4.7	4.5	4.6	4.6	58.3	11.1	56.6
		26.4	3½	1½	3.7	3.1	4.6	3.6	4.6	4.5	4.5	5.3	58.7	12.2	54.8
		25.8	4	1½	3.6	3.1	4.4	3.6	4.4	4.5	4.3	5.0	61.6	12.4	52.6

[1] Mean of 10 values (2 replicates by 5 judges). 5 represents the optimum score and 1 the poorest.
[2] Color was scored on a 6-point scale on which 6 represented too light a color and 5 optimum.
[3] Based on raw cut weight of selected strips.

Smith (*20*) made a study to determine consumer reaction to potatoes classified according to specific gravity as "bakers," "boilers," and "fryers." They designated those tubers with a low specific gravity of 1.070 or less as fryers. Cobb (*12*) reported that potatoes with a specific gravity below 1.075 will cook up soggy and are best for frying or salads. On the other hand, Alexander and coworkers (*4*) reported the desirability of selecting mealy rather than nonmealy potatoes for french frying since they found, in Katahdin potatoes, that the mealier potatoes gave better quality french fries. Gould (*19*) and Terman (*31*) stated that potatoes of high specific gravity gave larger yields of french fries with lower oil content. Other investigators (*37*) have shown the same relationship to be true for chips.

In 1951, 15 samples of potatoes, ranging in specific gravity from 1.060 to 1.105, were selected from 4 varieties with 3 to 5 samples of different specific gravities from each variety. The mean scores for the palatability characteristics and the accompanying compositional data are given in table 4.

For all varieties except Triumph from North Dakota, scores for lack-of-oiliness, crispness, and mealiness show a gradual increase as specific gravity increased. Analysis of variance and covariance analysis indicated that the influence of specific gravity on these factors is significant. Color, uniformity-of-browning, tenderness, and flavor did not appear to have a linear relationship with specific gravity. An increase in the dry-matter content of the raw strips and of the completely fried strips, a decrease in oil content of two varieties, and a slight increase in yield were all found to accompany the increase in scores for crispness and mealiness.

The relationship of lack-of-oiliness, crispness, and mealiness to specific gravity is shown more clearly in table 5, where the coefficients of regression represent the change in the mean scores for these 3 palatability factors for each 0.01 change in specific gravity. A number of statistically significant coefficients were obtained for the various individual variety samples, even though they represent relatively short ranges in specific gravity. The coefficients for the averages of all varieties were highly significant for all 3 palatability characteristics. A test of the variety means adjusted to a common specific gravity indicated that the differences between varieties in scores for crispness were caused by differences in specific gravity. Although adjusted means for lack-of-oiliness and mealiness were still significantly different, specific gravity did not explain the differences obtained between varieties for these characteristics.

In 1952, carefully replicated samples were prepared from each of 6 variety-location lots at 3 or 4 selected specific-gravity levels. In contrast to the results of the preceding year, all palatability characteristics were found to be affected by the specific gravity of the potatoes. The mean palatability scores are given in table 6. Except for tenderness, all scores tended to increase with an increase in specific gravity. A comparison of scores for a single palatability characteristic within a given specific-gravity level showed a slightly higher number of significant differences between variety-location lots than expected by chance alone. The differences occurred most frequently for mealiness and flavor. The data for these characteristics indicate that the dif-

TABLE 4.—*Influence of specific gravity of raw tubers on quality of french-fried potatoes, 1951 crop*

Variety and location	Raw potatoes		Cooking time		French-fried potatoes									
					Mean palatability scores [1]							Dry matter	Oil content	Yield [3]
	Specific gravity	Dry matter	First-stage fry	Second-stage fry	Color [2]	Uniformity-of-browning	Lack-of-oiliness	Tenderness	Crispness	Mealiness	Flavor			
		Percent	*Minutes*	*Minutes*								*Percent*	*Percent*	*Percent*
Chippewa: Maine	[4] 1.060	16.2	4	1½	3.8	3.6	3.2	5.0	2.8	2.8	4.6	49.2	14.1	44.4
	[4] 1.065	16.7	4	1½	3.4	4.4	2.8	4.6	2.4	2.6	4.2	49.6	14.1	42.7
	[4] 1.070	18.8	4	1½	3.5	3.8	3.5	4.2	3.0	2.5	3.8	53.0	14.2	45.9
	1.080	20.8	4	1½	4.0	3.8	3.8	4.6	3.7	3.2	4.5	55.2	13.3	46.4
	[4] 1.085	22.6	4	1½	3.3	3.8	4.0	4.0	3.8	3.3	4.2	56.4	13.0	47.6
Green Mountain: New York	1.075	18.9	4	1½	4.3	4.0	3.4	4.4	3.1	2.9	4.2	51.8	13.1	46.6
	1.085	19.9	4	1½	4.6	3.4	3.8	4.1	3.6	3.3	4.5	54.5	12.2	47.4
	1.090	21.6	4	1½	4.8	4.2	3.8	4.2	3.8	3.5	4.0	56.3	12.3	48.0
Russet Burbank: Washington	1.085	21.1	4	1½	4.8	3.8	4.1	4.3	4.0	3.9	4.7	56.0	12.0	48.1
	1.090	22.3	4	1½	4.9	3.9	4.3	4.2	4.0	4.3	4.5	58.4	12.5	48.4
	1.100	25.5	4	1½	4.9	4.1	4.6	3.9	4.6	4.8	4.9	62.7	12.1	48.2
	1.105	25.1	4	1½	4.8	4.1	4.8	3.7	4.7	4.7	4.9	62.7	12.2	49.3
Triumph: North Dakota	1.070	19.5	4	1½	3.4	3.7	3.4	4.4	3.3	2.8	4.1	52.3	13.7	46.9
	1.080	20.9	4	1½	3.1	4.0	3.5	3.9	3.2	2.8	3.6	56.5	14.3	47.8
	1.085	22.9	4	1½	3.2	4.0	3.4	4.2	3.3	2.7	3.9	56.1	13.6	47.8

[1] Mean of 10 values (2 replicates by 5 judges). 5 represents the optimum score and 1 the poorest.
[2] Color was scored on a 6-point scale on which 6 represented too light a color and 5 optimum.
[3] Based on raw cut weight of selected strips.
[4] Not replicated.

ferences were not varietal in nature, since they were not repeated at successive specific-gravity levels. For example, at the specific gravity of 1.090 the mealiness score was significantly lower for Katahdins from Colorado than for either of the Irish Cobbler samples, but at the specific gravity of 1.095 the score was higher for the Katahdins than for the Irish Cobblers.

TABLE 5.—*Mean palatability scores and regression coefficients*[1] *relating palatability of french fries with specific gravity in 4 varieties of potatoes, 1951 crop*

Variety and location	Specific-gravity range	Lack-of-oiliness		Crispness		Mealiness	
		Mean score	Regression coefficient[2]	Mean score	Regression coefficient[2]	Mean score	Regression coefficient[2]
Chippewa: Maine	1.060–1.085	3.56	+0.38**	3.24	+0.55*	2.93	+0.28
Green Mountain: New York	1.075–1.090	3.64	+.28	3.50	+.50*	3.25	+.40
Russet Burbank: Washington	1.085–1.105	4.45	+.35**	4.34	+.42*	4.43	+.42
Triumph: North Dakota	1.070–1.085	3.45	+.01	3.28	−.02	2.72	−.05
Average	1.060–1.105	3.83	+.29**	3.65	+.41**	3.42	+.30**

[1] Indicates change in mean palatability score for a 0.01 increase in specific gravity.
[2] * Significant at the 5-percent level; ** significant at the 1-percent level.

The relationship of specific gravity to the various palatability characteristics of french-fried potatoes as shown by regression and correlation coefficients is given in table 7. Color, tenderness, and uniformity-of-browning gave the lowest correlation coefficients, but all cofficients were statistically significant. Similarly, all regression coefficients were significant. Except for color and uniformity-of-browning, the above coefficients were based on all the data pooled for the 6 variety-locations. Those for color and uniformity-of-browning were based only on the variation within variety-location. For color and uniformity-of-browning, the regression fitted to the means of variety-location lots indicated no linear relationship with specific gravity. Although specific gravity linearly influenced the color and uniformity-of-browning within a variety lot, the lack of a linear between-mean regression implies that for these 2 characteristics some factor other than specific gravity differentiated one variety-location lot from another. Variation between lots in reducing sugar content was one of the factors causing a difference in varietal response in color and uniformity-of-browning. All other characteristics were linearly related to specific gravity, and the relationship was apparently unaffected by other factors which may differentiate one variety from another.

The linear relationship of lack-of-oiliness, tenderness, crispness, mealiness, and flavor with specific gravity is illustrated in figure 1. The regression lines are based on coefficients obtained from all 6 variety-location lots and do not represent any particular lot. Mealiness and crispness are influenced to a great extent and lack-of-oiliness and flavor to a somewhat lesser extent by specific gravity. Scores for all 4 characteristics increased with higher specific-gravity values of the raw tubers. Scores for tenderness, on the other hand, showed a slight

TABLE 6.—*Mean palatability scores [1] of french-fried potatoes for 6 variety-locations at selected specific-gravity levels, 1952 crop*

Palatability characteristics	Variety and location	Palatability score when specific gravity is—								Test difference [2]
		1.060	1.070	1.075	1.085	1.090	1.095	1.100	1.110	1.115	
Color [3]	Chippewa: Maine	3.7	[4]3.0	3.7							1.1
	Katahdin: Maine		5.0	4.6	4.8						
	Katahdin: Colorado				4.0	4.2	4.9	4.8			
	Irish Cobbler: Maine				4.0	4.3	4.3				
	Irish Cobbler: North Dakota					3.7	[4]3.3	4.1	4.7		
	Russet Burbank: Washington							4.2	4.3	4.7	
	Average	3.7	4.0	4.2	4.3	4.1	4.2	4.4	4.5	4.7	
Uniformity-of-browning	Chippewa: Maine	3.4	3.1	4.2							1.7
	Katahdin: Maine		4.3	4.8	4.8						
	Katahdin: Colorado				3.2	3.9	4.5	4.5			
	Irish Cobbler: Maine				4.5	4.2	4.5				
	Irish Cobbler: North Dakota					3.6	3.5	4.0	4.6		
	Russet Burbank: Washington							2.9	3.9	4.0	
	Average	3.4	3.7	4.5	4.2	3.9	4.2	3.8	4.2	4.0	
Lack-of-oiliness	Chippewa: Maine	2.4	3.0	3.1							1.0
	Katahdin: Maine		3.4	3.5	4.0						
	Katahdin: Colorado				3.9	3.7	3.9	4.2			
	Irish Cobbler: Maine				3.7	4.0	3.9				
	Irish Cobbler: North Dakota					4.2	3.9	4.1	4.5		
	Russet Burbank: Washington							4.4	4.7	4.5	
	Average	2.4	3.2	3.3	3.9	4.0	3.9	4.2	4.6	4.5	
Tenderness	Chippewa: Maine	4.7	5.0	4.3							.5
	Katahdin: Maine		4.6	4.7	4.3						
	Katahdin: Colorado				4.3	4.2	4.4	3.9			
	Irish Cobbler: Maine				4.2	[4]3.6	4.2				
	Irish Cobbler: North Dakota					3.9	4.0	3.7	3.8		
	Russet Burbank: Washington							4.0	4.2	3.7	
	Average	4.7	4.8	4.5	4.3	3.9	4.2	3.9	4.0	3.7	

Crispness	Chippewa: Maine	1.9	1.8	2.2						
	Katahdin: Maine		2.4	3.0	3.1					
	Katahdin: Colorado				3.4	3.2	3.7	4.3		
	Irish Cobbler: Maine				3.1	3.5	3.9			
	Irish Cobbler: North Dakota					3.5	3.6	4.1	4.4	
	Russet Burbank: Washington							4.1	4.5	4.5
	Average	1.9	2.1	2.6	3.2	3.4	3.7	4.2	4.4	4.5
Mealiness	Chippewa: Maine	1.5	1.9	[4] 1.8						
	Katahdin: Maine		1.9	2.4	2.8					
	Katahdin: Colorado				2.8	[4] 2.4	3.3	3.9		
	Irish Cobbler: Maine				3.0	3.4	3.1			
	Irish Cobbler: North Dakota					3.5	[4] 2.6	3.9	4.0	
	Russet Burbank: Washington							3.7	4.3	4.3
	Average	1.5	1.9	2.1	2.9	3.1	3.0	3.8	4.2	4.3
Flavor	Chippewa: Maine	3.0	[4] 3.3	3.8						
	Katahdin: Maine		4.3	3.8	4.2					
	Katahdin: Colorado				4.0	4.6	4.8	4.8		
	Irish Cobbler: Maine				4.3	[4] 3.8	4.8			
	Irish Cobbler: North Dakota					4.3	[4] 3.9	4.8	5.0	
	Russet Burbank: Washington							4.4	4.8	4.8
	Average	3.0	3.8	3.8	4.2	4.2	4.5	4.7	4.9	4.8

Crispness	.9
Mealiness	.6
Flavor	.6

[1] Adjusted for session differences. Mean of 10 values (2 replicates by 5 judges). 5 represents the optimum score; 1 the poorest.
[2] Any 2 variety-location means having a difference as large as or larger than the test differences are significantly different at the 5-percent level.
[3] Color was scored on a 6-point scale on which 6 represented too light a color and 5 optimum.
[4] Significantly lower at the 5-percent level than at least one other variety-location mean score within the same specific gravity as measured by test difference.

TABLE 7.—*Regression*[1] *and correlation coefficients relating palatability of french-fried potatoes with specific gravity, 1952 crop*

Palatability characteristics	Regression coefficients[1]	Correlation coefficients[2]
Color	+0.35*	+0.61*
Uniformity-of-browning	+.54**	+.79**
Lack-of-oiliness	+.36**	+.92**
Tenderness	−.20**	−.77**
Crispness	+.54**	+.96**
Mealiness	+.64**	+.93**
Flavor	+.32**	+.83**

[1] Indicates change in mean palatability score for a 0.01 increase in specific gravity.
[2] * Significant at the 5-percent level; ** significant at the 1-percent level.

but significant decrease as specific gravity increased. Although the shear-force values do not show any very definite trends, a significant correlation coefficient of −0.47 with tenderness was obtained. This coefficient indicates that only 22 percent of the variance in tenderness scores of these lots is explained by the variance in shear-force values.

Within each variety lot, the percentage of dry matter in the raw samples increased with increasing specific gravity (table 8). Dry matter and yield of french fries tended to increase with higher specific gravity, although cooking time was also a factor. Oil content was generally lower in the higher specific-gravity lots.

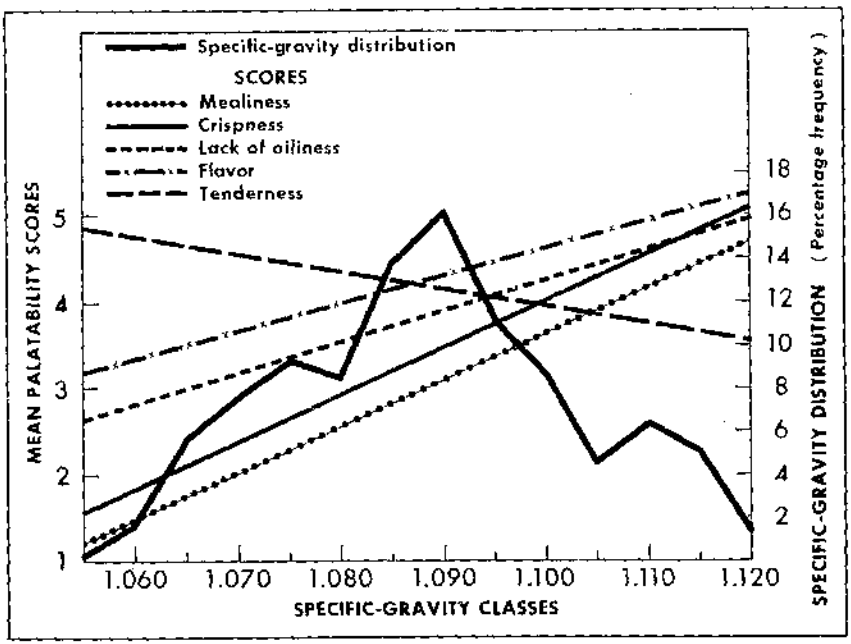

FIGURE 1.—Specific gravity distribution of potatoes from six variety-locations, 1952 crop, and regression lines of mean scores for various characteristics on specific gravity.

TABLE 8.—*Influence of specific gravity of raw tubers on dry matter, cooking time, oil content, shear force, and yield of french-fried potatoes, 1952 crop*

Variety and location	Raw potatoes		Cooking time		French-fried potatoes			
	Specific gravity	Dry matter	First-stage fry	Second-stage fry	Dry matter	Oil content	Shear force	Yield [1]
		Percent	*Minutes*	*Minutes*	*Percent*	*Percent*	*Pounds*	*Percent*
Chippewa: Maine	1.060	16.1	4½	1½	46.3	13.6	2.2	46.8
	1.070	17.8	4½	1½	50.6	13.9	2.1	47.9
	1.075	18.5	4½	1½	49.8	13.3	2.0	50.8
Irish Cobbler: Maine	1.085	22.1	4	1½	54.4	12.0	3.7	50.6
	1.090	22.7	4	1½	56.2	12.1	3.4	50.3
	1.095	24.8	3½	1½	56.2	11.8	3.5	52.2
Irish Cobbler: North Dakota	1.090	22.3	4	1½	55.1	12.7	3.8	50.9
	1.095	24.1	3½	1½	54.5	12.1	4.3	52.3
	1.100	23.9	3½	1½	55.7	11.8	4.1	52.4
	1.110	27.0	3	1½	56.8	11.4	3.4	55.7
Katahdin: Colorado	1.085	22.4	4	1½	54.2	12.4	3.5	51.0
	1.090	21.5	4	1½	52.3	11.8	3.0	52.2
	1.095	24.4	3½	1½	54.4	11.6	3.2	54.2
	1.100	24.7	3½	1½	54.2	11.8	3.3	53.1
Katahdin: Maine	1.070	20.2	4½	1½	52.6	13.8	2.7	40.1
	1.075	20.8	4½	1½	54.0	13.0	3.4	48.4
	1.085	22.1	4	1½	54.1	12.6	2.6	50.5
Russet Burbank: Washington	1.100	20.2	3½	1½	56.6	12.1	4.4	55.7
	1.110	27.2	3	1½	57.4	11.2	5.1	56.2
	1.115	28.6	3	1½	58.1	10.6	4.8	56.9

[1] Based on raw cut weight of selected strips.

EFFECT OF STORAGE OF TUBERS ON PALATABILITY

Wright and coworkers (*38*) reported on the quality of french-fried potatoes made from Irish Cobbler, Green Mountain, Russet Burbank, and Katahdin potatoes of the 1931 crop grown at Arlington Farm, Rosslyn, Va., and stored under different conditions. French fries of golden-yellow color, tender texture, very desirable flavor, and very good general quality were obtained from tubers stored at 50° or 60° F., whereas tubers of the same varieties stored at 40°, 36°, or 32° gave french fries of increasingly dark color, oily texture, burned sweet flavor, and undesirable general quality. Chemical analyses of raw tubers made at the same time showed an increase in reducing sugar with a corresponding decrease in storage temperature.

In 1930 Sweetman (*28*) found that potato chips made from potatoes of Green Mountain, Bliss Triumph, and Irish Cobbler varieties stored 2 weeks or more in commercial cold storage (32° to 37° F.) were very much darker than those made from tubers of the same lot when used at the beginning of the study or when held in storage at 40° to 55°. Wright and Whiteman (*39*) reported in 1948 that potato chips made from both Green Mountain and Triumph tubers stored 2 months at 55° were unsalable and that tubers of these same varieties after 3 months' storage at 40° could not be satisfactorily desugared at 70°.

In 1950 Terman, Goven, and Cunningham (*31*) reported that Maine potatoes of Green Mountain, Mohawk, Kennebec, Katahdin, and Teton varieties when stored at 36° or 40° F. for 3 months were high in sugar and made french-fried potatoes too dark in color to be satisfactory. At 50° storage, Kennebec variety was generally satisfactory when held as long as 5 months, whereas 4 months proved unsatisfactory for Katahdin and Teton, and 3 months was too long for Green Mountain and Mohawk.

Results from a recent study conducted by Heinze and coworkers (*23*) showed that soon after harvest Green Mountain potatoes from two Maine locations, as well as from one in New York, contained considerable sugar. Sugar was also high in tubers stored 3 months at 55° F. and increased greatly in tubers in 40° storage for 3 and 6 months.

Palatability tests, previously unreported from the same study, were made on french-fried potatoes prepared from 24 sample lots of the 1947 crop after the tubers had been stored at 55° F. for approximately 1 or 2 months and at 40° for approximately 3 or 5 months.

Since palatability tests were unreplicated, the resulting data were not statistically analyzed, but the following trends were observed. Storage at 55° F. for 1 or 2 months retarded accumulation of sugars in the tubers of some sample lots to the extent that french fries made from them without desugaring had good color and flavor. Potatoes stored for 2 months at 55°, however, gave french fries somewhat better in color and less oily than those from 1-month storage. No appreciable difference was noted in other quality characteristics. Storage of tubers at 40° for 3 or 5 months caused excessive browning and burned flavor in french fries, although the Russet Burbank samples were medium brown in contrast to the dark brown obtained with other varieties. Whether the potatoes were stored for 3 or 5 months at 40° made little difference in the color of the french fries. None of the sample lots used without desugaring after either storage period produced french fries of acceptable color or flavor.

Potatoes from the 1951 crop were stored for various time periods at 4 different temperatures. Upon removal from storage the tubers were examined for firmness, shriveling, and amount of sprouting (table 9). After 16 weeks' storage at 45° and 50° F. tubers of all varieties were firm, but at temperatures of 55° and 60° some softening

TABLE 9.—*Effect of time and temperature of storage on condition of raw tubers, sprouting, and yield of pared potatoes, 1951 crop*

Variety and location	Storage		Condition of tubers	Sprouts	Yield of pared potatoes [1]
	Time	Temperature			
	Weeks	*° F.*		*Percent*	*Percent*
Chippewa: Maine	16	45	Firm	0	81.5
	16	50	....do	0	79.6
	16	55	Medium firm	3.8	81.2
	16	60	Very shriveled	7.1	76.1
	20	45	Slightly shriveled	1.2	77.8
	20	50	....do	1.9	80.7
Green Mountain: New York	16	45	Firm	0	80.7
	16	50	....do	0	83.0
	16	55	....do	2.1	78.0
	16	60	Shriveled	4.8	77.1
	20	45	Firm	.3	81.1
	20	50	Slightly shriveled	2.5	79.5
Russet Burbank: Washington	16	45	Firm	0	85.2
	16	50	....do	0	84.9
	16	55	....do	1.0	78.1
	16	60	....do	2.1	83.2
	20	45	....do	0	83.4
	20	50	....do	.3	85.3
Triumph: North Dakota	16	45	Firm	0	76.1
	16	50	....do	2.3	76.1
	16	55	Very shriveled	5.0	73.4
	16	60	....do	7.2	66.7
	20	45	Slightly shriveled	3.3	76.4
	20	50	....do	3.9	73.4

[1] Based on unpared weight upon removal from storage. Potatoes were pared by hand.

and shriveling were noted in Chippewa, Green Mountain, and Triumph varieties. After 20 weeks' storage Russet Burbank potatoes remained firm at all temperatures, whereas Green Mountain potatoes were firm after storage at 45° but shriveled in storage at 50°. Potatoes of both Chippewa and Triumph varieties shriveled somewhat when stored at either 45° or 50°.

Losses from sprouting were greatest at 60° F. and were greater in Chippewa and Triumph than in the other varieties. Sprouting was negligible in the lots stored at 45° and 50° for 16 weeks, but after 20 weeks some sprouting occurred in all lots except Russet Burbank. In general, yield of hand-pared potatoes showed an inverse relationship to percentage of sprouting. Russet Burbank in most cases gave the least sprouting and the highest yield of pared potatoes.

Palatability scores for french-fried potatoes for all characteristics except tenderness were significantly higher for Russet Burbank potatoes than for the sample lots of Chippewa, Green Mountain, or Triumph stored at 45° and 50° F. for 12, 18, or 21 weeks as well as at 55° and 60° for 12 or 18 weeks (table 10). The quality of tenderness was judged as "resistance to bite." Chippewa potatoes had the highest score for tenderness, although not significantly higher than the other sample lots. Chippewa also had the lowest dry-matter content. Highest values for dry matter of raw tubers as well as of the finished product were obtained from Russet Burbank potatoes. This sample lot also gave french fries of lowest oil content and highest yield.

French fries made from Russet Burbank potatoes that were stored 21 weeks showed no significant deterioration in palatability when compared with those from tubers stored 12 weeks. On the other hand, french fries from Chippewa, Green Mountain, and Triumph lots tended to have lower scores when tubers were stored for periods longer than 12 weeks. Those made from Chippewa and Triumph lots had significantly poorer color and flavor from the 18-week storage than from either the 12- or 21-week storage samples. Green Mountain and Russet Burbank samples each showed this trend less frequently. This variation is not explained by reducing-sugar content in the tubers after 18 weeks of storage. The results of chemical analyses (table 10) show that the raw tubers stored 18 weeks tended to have less reducing sugar than tubers stored 12 or 21 weeks. Apparently other factors not investigated here had an influence on changes in reducing-sugar content, as well as on changes in color and flavor of the french fries.

Data from all sample lots combined show that storage temperature had a significant effect at the 5-percent level on the color, mealiness, and flavor scores of french fries (table 11). Color scores were significantly better for french fries made from potatoes stored at 55° or 60° F. than from those stored at 45° or 50°. The score for mealiness was significantly better at 55° than at any of the other temperatures. This is in keeping with the observed lower moisture content in french fries for those lots stored at 55°. There was no significant difference between flavor scores of french fries made from potatoes stored at 50°, 55°, and 60°, but all were significantly better in flavor than those made from potatoes stored at 45°. A statistical analysis of color, mealiness, and flavor scores from 4 storage temperatures for 12- and 18-week periods only indicates the same storage effects as were shown when

TABLE 10.—*Influence of storage of raw tubers on quality of french-fried potatoes, 1951 crop*

Variety and location	Raw potatoes: Storage: Temperature	Raw potatoes: Storage: Time	Raw potatoes: Specific gravity	Raw potatoes: Dry matter	Raw potatoes: Reducing sugar	French-fried potatoes: Mean palatability scores [1]: Color [2]	Uniformity-of-browning	Lack-of-oiliness	Tenderness	Crispness	Mealiness	Flavor	French-fried potatoes: Dry matter	Oil content	Yield [3]
	° *F.*	*Weeks*		*Percent*	*Percent*								*Percent*	*Percent*	*Percent*
Chippewa: Maine	45	12	1.069	17.2	0.47	3.2	4.4	2.9	4.7	2.9	2.3	3.8	52.4	14.3	45.4
		18	1.068	17.0	.36	2.7	4.5		4.7	2.2	1.7	2.8	50.2	14.5	45.4
		21	1.072	17.4	.38	3.3	4.3		4.7	3.1	2.3	2.5	53.0	14.0	45.7
	50	12	1.070	17.6	.37	3.7	3.8	2.7	4.5	2.9	2.5	3.9	52.1	14.8	45.2
		18	1.068	16.7	.29	3.2	3.7		4.6	2.7	1.9	3.3	52.3	14.7	44.9
		21	1.073	17.7	.34	3.8	4.1		4.8	2.7	1.8	4.0	52.7	15.0	45.8
	55	12	1.072	18.5	.33	4.2	3.9	3.1	4.3	3.1	2.9	4.0	53.3	14.0	45.6
		[4] 18	1.077	18.7	.19	4.0	3.8		4.2	3.3	2.5	4.0	53.4	13.7	46.7
	60	12	1.070	17.9	.32	4.1	3.5	2.8	4.6	2.7	2.3	4.1	51.1	13.8	45.8
		[4] 18	1.071	17.8	.23	3.9	3.7		4.6	2.3	1.8	3.5	51.5	13.9	46.3
Green Mountain: New York	45	12	1.082	19.6	.51	2.3	2.6	3.2	3.9	2.8	2.3	2.7	54.4	14.3	45.9
		18	1.080	18.4	.39	2.0	3.1		4.3	2.1	1.8	2.4	55.6	14.2	46.1
		21	1.082	19.2	.46	2.4	2.9		4.2	2.9	2.4	2.3	55.4	14.1	45.4
	50	12	1.080	19.8	.28	3.9	3.4	3.7	3.9	3.5	3.1	4.0	53.9	14.0	46.6
		18	1.079	18.6	.28	3.1	3.3		4.3	2.7	2.3	3.2	55.0	13.6	45.9
		21	1.082	18.5	.35	2.6	1.7		4.5	2.5	1.8	2.5	53.6	13.8	46.2
	55	12	1.082	20.4	.20	4.6	3.2	3.3	4.1	3.5	2.9	4.3	56.7	13.8	46.5
		18	1.083	19.6	.21	3.8	2.7		4.3	2.5	2.5	3.7	54.4	12.6	47.0
	60	12	1.083	19.8	.16	4.7	3.5	3.5	4.5	3.3	3.1	4.6	56.4	14.2	46.9
		18	1.083	20.5	.15	3.7	2.7		4.1	2.4	2.0	3.5	56.1	13.8	47.0
Russet Burbank: Washington	45	12	1.097	24.6	.15	5.0	3.8	4.5	3.9	4.5	4.4	4.5	61.4	12.4	48.8
		18	1.101	25.0	.12	4.4	4.1		4.5	4.9	4.6	4.5	63.4	13.2	48.7
		21	1.097	23.9	.33	4.8	4.1		4.0	4.7	4.5	4.8	60.4	12.8	48.2
	50	12	1.098	23.8	.11	5.4	4.3	4.7	4.0	4.7	4.6	4.7	61.0	12.2	48.6
		18	1.100	24.6	.10	4.9	4.1		4.5	4.9	4.8	4.9	61.8	13.1	48.7
		21	1.100	24.3	.16	4.7	4.1		4.1	5.0	4.7	4.7	63.3	12.9	48.4
	55	12	1.097	24.9	.09	5.4	4.3	5.0	4.1	4.7	4.7	4.7	61.6	12.1	48.7
		18	1.098	23.9	.05	4.9	3.9		4.1	4.9	4.9	4.9	61.8	12.2	49.0
	60	12	1.095	24.0	.15	5.3	3.9	4.6	4.4	4.5	4.5	4.8	61.3	12.4	48.1
		18	1.097	24.7	.04	5.3	4.7		4.3	4.9	4.7	4.6	62.0	12.1	49.2
Triumph: North Dakota	45	12	1.073	19.1	.53	2.3	3.7	3.1	4.3	2.9	2.5	3.0	54.4	14.4	46.4
		18	1.074	19.1	.54	1.8	4.4		4.3	2.5	1.7	2.1	54.8	14.4	46.3
		21	1.081	18.9	.51	2.2	4.0		4.3	2.5	2.1	2.8	54.5	14.0	47.0
	50	12	1.075	19.3	.43	2.9	4.1	3.2	4.3	2.9	2.3	3.5	53.9	13.9	46.7
		18	1.073	18.6	.39	2.3	3.9		4.2	2.1	1.4	2.5	54.3	14.7	46.6
		21	1.080	20.3	.50	2.7	3.5		4.1	2.7	2.1	2.9	55.4	13.3	47.3
	55	12	1.072	19.6	.31	3.8	3.7	3.3	4.4	2.9	2.5	3.8	54.7	14.0	46.4
		18	1.078	21.5	.27	3.5	3.4		3.9	3.1	2.3	3.4	56.7	13.5	47.9
	60	12	1.075	19.4	.37	3.5	3.7	2.9	4.5	2.7	2.3	3.7	52.6	14.0	48.6
		18	1.077	21.0	.28	3.3	2.8		4.1	2.9	1.9	2.9	54.6	14.0	47.4

[1] Mean of 15 values (3 replicates by 5 judges). 5 represents the optimum score and 1 the poorest.
[2] Color was scored on a 6-point scale on which 6 represented too light a color and 5 optimum.
[3] Based on raw cut weight of selected strips.
[4] Mean of 10 values (2 replicates by 5 judges).

scores for 21 weeks' storage were included in the analyses. These results are in agreement with a brief report made by Richardson and Douglass in 1929 (*27*) that Netted Gem (Russet Burbank) potatoes had less moisture and were mealier and of better color and flavor when stored at 53° to 60° than at 40°.

Storage conditions of time and temperature did not significantly affect scores for uniformity-of-browning, lack-of-oiliness, tenderness, and crispness.

TABLE 11.—*Mean palatability scores*[1] *of french-fried potatoes for each storage temperature, all varieties and storage periods combined, 1951 crop*

Storage temperature	Storage time	Color	Uniformity-of-browning	Lack-of-oiliness[2]	Tenderness	Crispness	Mealiness	Flavor
	Weeks							
45° F.	12, 18, 21	[3] 3.0	3.8	3.5	4.3	3.2	2.7	[3] 3.3
50° F.	12, 18, 21	3.6	3.7	3.6	4.3	3.3	2.8	3.7
55° F.	12, 18	[4] 4.3	3.6	3.7	4.2	3.5	[4] 3.2	4.1
60° F.	12, 18	[4] 4.2	3.6	3.5	4.4	3.2	2.8	4.0
45° F.	12, 18	[3] 3.0	3.8	3.5	4.3	3.1	2.7	[3] 3.2
50° F.	12, 18	3.7	3.8	3.6	4.3	3.3	2.8	3.8

[1] 5 represents the optimum score and 1 the poorest.
[2] Lack-of-oiliness was judged only at the 12-week storage period.
[3] Significantly lower than the other scores at the 5-percent level.
[4] Significantly higher than the other scores at the 5-percent level.

EFFECT OF DESUGARING OF TUBERS ON PALATABILITY

A number of investigators (*6*, *28*, *32*, *34*, *38*, *41*) have shown that potatoes stored at a temperature of 40° F. or lower during the winter months accumulate sugars in the tubers with a parallel decrease in starch.

It has also been found (*6*, *29*) that removing potatoes from 40° F. storage to 70° caused the sugar content to decrease rapidly by retransformation to starch and by loss in respiration. A decrease in sugar content of tubers brought about color improvement in finished potato chips. This practice of removing potato tubers from low temperature storage to a higher temperature for a period of time before they are to be used is commonly referred to as desugaring.

Comparatively few reports on desugaring of potatoes for french frying have appeared in the literature, although many studies on desugaring potatoes for chipping have been reported. From the standpoint of color in the finished product many of the results obtained with potato chips also apply to french-fried potatoes.

Wright and associates (*38*) compared the effect of desugaring for 6 weeks at 70° F. on potatoes that had been held for 41 days at temperatures of 32°, 36°, and 40°. Sugar content of the tubers held at temperatures as low as 32° and 36°, when transferred to 70° for 6 weeks, did not decrease to that in comparable lots stored at 40° and desugared at 70°.

Thiessen (*32*) found that Bliss Triumph potatoes when stored in a potato cellar with a temperature of 38° to 42° F. contained too much sugar to produce good potato chips at any time during the winter months. The long desugaring required by this variety, 35 to 45 days, was not considered feasible. On the other hand Thiessen found that Irish Cobblers accumulated less sugar than the Triumphs, and after

desugaring 30 to 40 days at 50° to 60° the Irish Cobbler produced potato chips of good color and texture.

Reducing sugar has been reported to be more responsible than sucrose for overbrowning in potato chips (*33*, *40*). The amount of reducing sugar in the tubers, hence the influence on browning during the frying of chips, was found to be influenced by many factors: The variety of potato, place where grown, maturity when dug, temperature of storage, time held in storage, and temperature and time of desugaring (*4*, *8*, *16*, *32*, *40*). Much variation was found in the response of potatoes to desugaring conditions.

In preliminary studies in the USDA laboratories, potatoes (1947 crop) that had been stored at 55° F. for 2 months were desugared at 70° for 3 weeks. Palatability scores for french-fried potatoes showed that color was the only characteristic affected by desugaring. All sample lots except Green Mountain, Triumph, and White Rose gave french fries lighter in color than the standard, whereas french fries from these 3 lots were no different in color from those made from lots stored continuously at 55°. Judging from these results little benefit was derived from desugaring potatoes previously stored at 55°.

Potatoes stored at 40° F. for 5 months were desugared at 70° for 2, 4, 6, or 8 weeks. After 2 weeks at the higher temperature the potatoes produced french fries that were slightly more mealy, less oily, and of markedly better color than those from potatoes not desugared. Longer periods at 70°—4, 6, or 8 weeks—did not contribute to further improvement in any of the palatability characteristics except color, which continued to become somewhat lighter at each successive period.

Studies of 40° F. storage were continued on the 1948 crop with samples from 11 lots of potatoes representing 4 varieties each from several locations. Potatoes were stored at 40° for 4 months and desugared at 70° for 2, 4, or 6 weeks. An estimation of the reducing-sugar content of each of the 6 or 8 tubers in each sample was made by the picric acid method. Replicated samples from the 11 lots were french fried after each of the 3 periods. Of the 66 french-fried samples evaluated for color, 17 were considered by the judges as too dark to be acceptable, and 21 of the remaining 49 were scored as variable in color. For the tubers in the variable samples, the average range between the highest and lowest reducing-sugar values was 0.12 percent. For the remaining 28 samples that were not checked as variable the range was 0.08 percent.

It became apparent in these early experiments that a considerable variation in reducing-sugar content between tubers within a sample was frequently responsible for a lack of uniformity-in-browning. In further studies it was observed that an appreciable gradient in reducing-sugar content may exist within the tuber, the stem end usually containing more sugar than the remaining portions. This variation was frequently associated with a dark color on one end of the fried strips.

Potatoes from the 1951 sample lots stored at 40° F. for 5 months were desugared at 70° for 1, 2, or 3 weeks. French-fried potatoes made from tubers when they were taken out of 40° storage and also after each week at the higher temperature were scored for palatability. Analysis of variance of the mean scores showed that desugaring time

significantly affected the color, uniformity-of-browning, crispness, mealiness, and flavor.

Samples of all 4 varieties were given the lowest score for color when taken from 40° F. storage with no desugaring (table 12). With each week's increase in holding time there was progressive improvement in color except in the third week for Green Mountain and Triumph varieties. These 2 varieties showed no further color improvement after 2 weeks. The differences in the response of the varieties to desugaring at 70° appeared in the statistical analysis as a significant interaction of variety with time. Chemical analyses showed that the tubers were highest in reducing sugar when sampled from 40° storage and that holding at 70° caused a progressive decrease in reducing sugar for the 3 weeks. Analyses for total sugar content showed a similar trend.

French fries made from Chippewa, Green Mountain, and Triumph potatoes scored higher in uniformity-of-browning before tubers were desugared than after desugaring, probably because they were browner and hence appeared to be more uniform. As desugaring progressed and overall color improved, a more mottled, less uniform appearance was evident, probably owing to the changes of sugar content in different areas of the tuber. The uniformity of color in french fries made from Russet Burbank potatoes did not appear to be affected by time of desugaring.

Scores for crispness and mealiness of french fries made from Chippewa potatoes desugared 1, 2, or 3 weeks at 70° F. were significantly better than scores for potatoes not desugared. For the Green Mountain samples 2 weeks gave significantly crisper french fries than the other desugaring periods. Desugaring had no significant effect on crispness and mealiness of french fries from Russet Burbank and Triumph varieties or on mealiness of the Green Mountain variety, although slightly higher scores were obtained with the 2-week desugaring period.

Desugaring of tubers brought about some improvement in flavor scores of french fries in all 4 varieties. For Green Mountain and Triumph varieties, flavor scores were too low to be satisfactory, even though those from Triumph improved significantly with 2 weeks' desugaring. Reducing-sugar values for Green Mountain and Triumph before desugaring were 1.15 and 1.23 percent and remained high, 0.79 and 0.77 percent, respectively, after 3 weeks' desugaring. Flavor scores for the Chippewa samples ranged from 2.0 with no desugaring to 3.4 after 3 weeks' desugaring. These changes were accompanied by an appreciable drop from 1.11 to 0.48 percent in reducing-sugar content. Less change was noted in french fries from Russet Burbank; for this sample lot the flavor score increased in 3 weeks from 3.7 to 4.3. Reducing sugar in these same potatoes decreased from 0.52 to 0.17 percent. Scores for flavor at each testing period were higher for french fries from Russet Burbank than for those made from the other varieties.

As shown in table 12, the raw tubers of Russet Burbank variety had the highest dry-matter content. French fries made from this variety also had the highest dry-matter content, the lowest oil content, and the highest scores for mealiness and crispness as well as the greatest yield.

TABLE 12.—*Influence of time of desugaring raw tubers at 70° F. on quality of french-fried potatoes, 1951 crop*

Variety and location	Raw potatoes					French-fried potatoes								
				Sugar		Mean palatability scores [1]								
	Desugaring time	Specific gravity	Dry matter	Reducing	Total	Color [2]	Uniformity of browning	Tenderness	Crispness	Mealiness	Flavor	Dry matter	Oil content	Yield [3]
	Weeks		*Percent*	*Percent*	*Percent*							*Percent*	*Percent*	*Percent*
Chippewa: Maine	0	1.072	17.3	1.11	1.37	[4] 1.7	4.8	4.5	[4] 1.8	[4] 1.2	2.0	53.6	15.1	44.5
	1	1.072	17.5	.84	.98	2.5	4.4	4.3	2.5	1.9	2.8	54.4	14.1	45.4
	2	1.073	18.2	.58	.74	3.1	3.7	4.4	2.7	1.9	2.9	53.9	14.3	44.9
	3	1.073	18.0	.48	.80	3.5	3.9	4.6	2.7	2.1	3.4	53.6	14.2	45.2
Green Mountain: New York	0	1.082	17.9	1.15	1.98	1.2	[5] 3.2	4.3	1.4	1.1	1.3	54.8	15.0	45.7
	1	1.083	18.4	.96	1.54	1.6	[5] 2.9	4.6	1.3	1.1	1.5	55.0	14.3	46.3
	2	1.083	19.3	.82	1.43	2.1	2.1	4.2	[5] 2.0	1.5	1.8	54.5	14.0	46.1
	3	1.081	18.8	.79	1.45	2.1	2.0	4.3	1.7	1.3	1.8	53.0	14.2	46.4
Russet Burbank: Washington	0	1.097	23.1	.52	.77	2.9	3.4	4.0	4.3	3.8	3.7	62.5	13.9	47.5
	1	1.099	23.9	.24	.46	3.7	3.4	4.1	4.5	3.9	4.1	63.3	13.5	47.5
	2	1.098	23.7	.21	.47	4.1	3.4	4.1	4.8	4.2	4.1	62.6	13.3	47.9
	3	1.097	24.6	.17	.50	4.3	3.5	4.2	4.3	3.8	4.3	62.7	13.4	47.4
Triumph: North Dakota	0	1.075	19.6	1.23	1.89	[4] 1.3	3.7	4.2	1.8	1.2	1.1	57.5	15.4	45.7
	1	1.075	19.8	1.09	1.68	[4] 1.5	4.3	4.2	2.0	1.3	1.4	56.5	15.1	45.6
	2	1.078	19.3	.78	1.34	[5] 2.2	3.9	4.3	2.1	1.5	[5] 2.2	55.7	15.1	46.1
	3	1.077	19.0	.77	1.29	2.1	[4] 3.2	4.2	1.9	1.4	1.5	55.7	15.0	45.7

[1] Mean of 15 values (3 replicates by 5 judges). 5 represents the optimum score and 1 the poorest.
[2] Color was scored on a 6-point scale on which 6 represented too light a color and 5 optimum.
[3] Based on raw cut weight of selected strips.
[4] Significantly lower than other means within a variety at the 5-percent level.
[5] Significantly higher than other means within a variety at the 5-percent level.

This is in agreement with results of Whiteman and Wright (*37*) who, in work on potato chips, found that with Russet Burbank and two other varieties an increase in specific gravity usually gave an increase in yield and a decrease in oil content of the chips.

With increase in desugaring time Chippewa, Green Mountain, and Russet Burbank varieties decreased in reducing-sugar and increa ed in dry-matter content. This relationship was not shown in the Triumph variety. High oil content, up to 15 percent in french fries, appeared to parallel high reducing sugar in the raw samples stored at 40° F. and not desugared. Russet Burbank potatoes, which had the lowest reducing-sugar content, also had the lowest oil content (13 percent) after french frying.

To determine the influence of variety, palatability scores for desugaring periods of 0, 1, 2, and 3 weeks were combined (table 13). For color, crispness, mealiness, and flavor of french fries, Russet Burbank was scored significantly higher than Chippewa, which in turn was scored significantly higher than Green Mountain and Triumph. In uniformity-of-browning, Green Mountain scored significantly lower at the 5-percent level than the other three varieties. No significant differences in tenderness were found among varieties.

TABLE 13.—*Mean palatability scores*[1] *of french-fried potatoes for each variety, desugaring at 70° F. for periods of 0, 1, 2, and 3 weeks combined, 1951 crop*

Variety and location	Color	Uniformity-of-browning	Tenderness	Crispness	Mealiness	Flavor
Chippewa: Maine	2.7	4.2	4.5	2.4	1.8	2.8
Green Mountain: New York	[2] 1.7	[2] 2.6	4.4	[2] 1.6	[2] 1.3	[2] 1.6
Russet Burbank: Washington	[3] 3.8	3.4	4.1	[3] 4.4	[3] 3.9	[3] 4.1
Triumph: North Dakota	[2] 1.8	3.8	4.2	[2] 2.0	[2] 1.4	[2] 1.6

[1] 5 represents the optimum score and 1 the poorest.
[2] Significantly lower than other means at the 5-percent level.
[3] Significantly higher than other means at the 5-percent level.

Scores from all varieties combined show effects of 40° F. storage of tubers with no desugaring as compared with desugaring for 1, 2, or 3 weeks (table 14). Color of french fries was significantly better after 2 weeks' desugaring of raw tubers, but there was no further significant improvement after 3 weeks' desugaring time. Mealiness and flavor scores were significantly better for french fries made from desugared tubers than from tubers not desugared, although no statistical difference between 1, 2, or 3 weeks' time was indicated. Tenderness appeared to be unaffected by desugaring of the tubers. For uniformity-of-browning and crispness, an interaction of variety with desugaring time was found in the statistical analysis which indicated that variety appeared to have more influence on these characteristics than desugaring time.

Although 70° F. has been the desugaring temperature most commonly used, some investigators (*4, 8, 15*) have held potatoes at temperatures higher than 70°. In the study reported here, for the 1951 crop the greatest improvement in palatability of french fries was brought about within the first 2 weeks of the desugaring period at 70°. In continuing tests on the 1952 crop, therefore, the time selected

TABLE 14.—*Mean palatability scores*[1] *of french-fried potatoes at each desugaring period, all varieties combined, 1951 crop*

Desugaring time (weeks)	Color	Uniformity-of-browning	Tenderness	Crispness	Mealiness	Flavor
0	[2] 1.8	3.8	4.3	2.3	[2] 1.8	[2] 2.0
1	2.3	3.7	4.3	2.6	2.1	2.5
2	[3] 2.9	3.3	4.2	2.9	2.3	2.8
3	[3] 3.0	3.2	4.3	2.7	2.2	2.7

[1] 5 represents the optimum score, and 1 the poorest.
[2] Significantly lower than other means at the 5-percent level.
[3] Significantly higher than other means at the 5-percent level.

for desugaring was 2 weeks, and temperatures of both 70° and 80° were used.

As shown in table 15, no significant differences were found between 70° and 80° F. desugaring temperatures for uniformity-of-browning, lack-of-oiliness, tenderness, crispness, and mealiness in french fries. For color, results from the 80° desugaring temperature were as good as or better than those from the 70° temperature. The same was true for flavor except in one instance, that of Katahdins from Maine. Differences in color and flavor were significant at the 5-percent level for Irish Cobbler potatoes from Maine. Desugaring Irish Cobblers from North Dakota at 80° gave significantly better color to french fries than desugaring at 70°. The 80° temperature also gave better flavor, but the difference was not great enough for significance. As shown with the 1951 crop, color and flavor scores were inversely related to values for reducing sugar. No significant differences between desugaring temperatures of 70° and 80° were indicated for dry-matter content of raw tubers or fried product, oil content, shear force, and yield of french fries.

Since prolonged storage at relatively high temperatures increases shriveling, sprouting, softening, and eventual decay of the tubers and hence decreases pared yields, the most desirable desugaring conditions (temperature and time) therefore, are those that give maximum value in decreasing sugar content of the raw tubers with a minimum of shriveling and sprouting.

HOLDING CONDITIONS FOR PARTIALLY FRIED POTATOES

Although the holding of partially fried potatoes between the first- and second-stage frying has become an accepted restaurant practice, little or no published information is available regarding the best holding conditions. The possible temperature variations to which partially fried potatoes might be subjected when held in other than freezer storage are from approximately 40° F. (4.5° C.) in a refrigerator up to 90° F. (32° C.) in a kitchen. The time might vary from ½ hour to 24 hours. The tests reported here were conducted to determine the holding conditions of time and temperature that would produce the best quality french fries.

Partially fried potatoes made from Chippewa potatoes from Maine and Russet Burbank potatoes from Washington (1951 crop) were held after first-stage frying for 4 or 6 hours at room temperature

TABLE 15.—*Influence of temperature of desugaring raw tubers for 2 weeks on quality of french-fried potatoes, 1952 crop*

Variety and location	Raw potatoes					French-fried potatoes										
	Desugaring temperature	Specific gravity	Dry matter	Sugar		Mean palatability scores [1]							Shear force	Dry matter	Oil content	Yield [3]
				Reducing	Total	Color [2]	Uniformity-of-browning	Lack-of-oiliness	Tenderness	Crispness	Mealiness	Flavor				
	°F.		*Percent*	*Percent*	*Percent*								*Pounds*	*Percent*	*Percent*	*Percent*
Chippewa: Maine	70	1.070	17.6	0.28	0.39	2.8	2.9	2.8	4.9	2.0	1.4	2.4	2.4	49.3	14.1	48.3
	80	1.070	17.2	.21	.38	3.4	3.1	2.6	4.8	2.2	1.6	2.8	2.7	50.2	14.2	48.8
Irish Cobbler: Maine	70	1.090	22.5	.22	.39	2.8	3.3	4.1	4.1	3.6	3.0	2.8	3.9	58.0	13.3	49.0
	80	1.090	22.3	.12	.28	[4] 4.1	3.8	3.8	4.4	3.7	2.9	[4] 3.7	4.4	57.2	13.1	49.0
Irish Cobbler: North Dakota	70	1.090	21.4	.37	.47	2.4	2.9	3.9	3.7	3.8	3.0	2.4	4.8	50.2	13.0	49.3
	80	1.090	21.3	.22	.40	[4] 3.2	3.1	3.7	3.8	3.6	3.1	3.0	4.8	55.9	12.9	49.5
Katahdin: Colorado	70	1.095	23.4	.10	.19	4.5	4.3	4.1	4.1	3.9	3.4	4.0	4.0	58.0	13.1	50.3
	80	1.095	23.3	.08	.22	4.7	4.5	4.0	4.4	3.7	3.5	4.4	3.5	58.6	13.8	50.9
Katahdin: Maine	70	1.080	20.0	.13	.24	3.9	3.4	3.4	4.6	3.0	2.4	3.2	3.5	53.4	13.5	49.3
	80	1.080	20.7	.11	.29	4.1	3.2	3.2	4.7	2.8	2.3	3.1	3.3	53.6	13.1	49.2
Russet Burbank: Washington	70	1.115	27.1	.11	.27	4.7	4.4	4.8	3.5	4.7	4.9	4.8	6.2	63.2	12.6	51.8
	80	1.115	26.4	.07	.28	4.7	4.0	4.6	3.7	4.9	5.0	5.0	6.0	63.8	13.0	51.7

[1] Mean of 15 values (3 replicates by 5 judges). 5 represents the optimum score and 1 the poorest.
[2] Color was scored on a 6-point scale on which 6 represented too light a color and 5 optimum.
[3] Based on raw cut weight of selected strips.
[4] Significantly higher at the 5-percent level than the score for the other desugaring temperature.

(72° F.) or for 18 hours at refrigerator temperature (40° F.). These samples were fried off and compared with french fries made with only a momentary time lapse between first- and second-stage frying. Between fryings, partially fried potatoes were held in shallow open containers.

Since the Chippewa and Russet Burbank potatoes differed in specific gravity and dry-matter content, it is not surprising that the french fries from these two variety lots showed significant differences in color, lack-of-oiliness, crispness, mealiness, and flavor, as indicated by analysis of variance of palatability scores.

Holding the partially fried potatoes, under the conditions studied, had relatively little effect on the palatability characteristics of the french fries (table 16). The few observed effects were most noticeable in the Russet Burbank potatoes, where small but consistent decreases in the scores for tenderness and flavor with increased holding time were noted. Although some other differences in scores occurred, trends were not consistent or were not great enough for significance. The holding conditions were well controlled, so many factors that frequently influence palatability scores were largely eliminated. The holding conditions studied caused an increase in dry-matter content of the french fries and a concomitant decrease in yield.

In 1952 potatoes of another variety, Kennebec, were used to obtain further information on this problem. Samples were parfried and held in uncovered dishes at room temperature, approximately 80° F., for ½, 2, or 4 hours; in uncovered dishes in a walk-in refrigerator at approximately 40° for 4 or 24 hours; and packaged in a polyethylene bag and held also in the walk-in refrigerator for 24 hours. For use as a standard control, other samples were fried with no time lapse between first- and second-stage frying.

Analysis of variance revealed no significant differences in palatability factors for samples held under different conditions of temperature and time and judged in series 1 and 2 (table 17). For samples tested in series 3, however, the freshly fried sample (not held after parfrying) was significantly more tender than the samples that were held unpackaged for either 4 or 24 hours or for 24 hours in a polyethylene bag. This finding is confirmed by shear-force values obtained from samples of the three series. Potatoes fried with no holding of the parfries before second-stage frying gave shear-force values consistently lower than those obtained for samples held ½, 2, 4, or 24 hours. In series 1, where holding time was increased from zero to ½, 2, or 4 hours, the values for shear force showed a parallel increase with time.

From the results obtained in the 2 years, 1951 and 1952, tenderness was the one palatability characteristic most affected by the length of time the parfries were held. With an increase in holding time there was also an increase in dry-matter content of the fried product and a corresponding decrease in yield. The samples held for longer periods of time yielded french fries with higher oil content. The apparent increase in oil content, however, is largely explained by the decrease in moisture content and yield of those samples and does not indicate increased absorption of oil.

TABLE 16.—*Influence of holding parfried potatoes before second-stage frying on the quality of french fries, 1951 crop*

Variety and location	Raw potatoes		Parfried potatoes		French-fried potatoes									
					Mean palatability scores [1]							Dry matter	Oil content	Yield [3]
	Specific gravity	Dry matter	Holding temperature	Holding time	Color [2]	Uniformity-of-browning	Lack-of-oiliness	Tenderness	Crispness	Mealiness	Flavor			
		Percent	*°F.*	*Hours*								*Percent*	*Percent*	*Percent*
Chippewa: Maine	1.072	18.6		0	4.0	3.8	3.6	4.2	3.5	2.8	4.2	49.7	12.1	48.4
	1.074	18.1	72	4	3.5	3.2	3.5	3.9	3.5	3.1	4.0	58.4	14.3	40.3
	1.074	19.1	72	6	3.5	3.1	3.9	3.7	3.7	3.2	4.1	58.4	14.3	42.1
	1.076	18.5	40	18	3.8	4.0	3.6	4.2	3.6	3.2	4.2	59.3	14.7	42.0
Russet Burbank: Washington	1.095	22.6		0	4.6	3.9	4.9	4.3	4.4	4.7	5.0	58.4	12.0	50.6
	1.095	23.9	72	4	4.5	4.4	4.9	4.0	4.4	4.4	4.9	67.3	13.8	43.6
	1.095	23.3	72	6	4.5	4.1	4.9	3.7	4.9	4.9	4.7	70.1	14.6	42.9
	1.095	25.5	40	18	4.4	3.8	4.7	3.5	4.4	4.4	4.5	68.5	14.8	43.6

[1] Mean of 10 values (2 replicates by 5 judges). 5 represents the optimum score and 1 the poorest.
[2] Color was scored on a 6-point scale on which 6 represented too light a color and 5 optimum.
[3] Based on raw cut weight of selected strips.

TABLE 17.—*Influence of holding parfried potatoes before second-stage frying on the quality of french fries, 1952 crop*

Judging series	Raw potatoes		Parfried potatoes, holding conditions			French-fried potatoes									
						Mean palatability scores [1]							Shear force	Dry matter	Oil content	Yield [3]
	Specific gravity	Dry matter	Temperature	Time	Container	Color [2]	Uniformity-of-browning	Lack-of-oiliness	Tenderness	Crispness	Mealiness	Flavor				
		Percent	*°F.*	*Hours*									*Pounds*	*Percent*	*Percent*	*Percent*
1	1.082	21.9		0	Open shallow	4.9	4.0	4.4	4.2	4.1	3.5	4.9	3.9	55.6	13.0	49.9
	1.085	22.3	80	½	do	4.7	4.3	4.3	4.3	4.1	3.6	4.8	4.1	57.6	13.1	49.1
	1.082	22.0	80	2	do	4.7	4.0	4.2	4.0	4.1	3.6	4.8	4.6	57.4	13.0	47.6
	1.082	20.9	80	4	do	4.8	4.6	4.1	4.0	4.1	3.3	4.6	4.9	59.8	13.7	45.2
2	1.082	21.4		0	do	5.0	4.6	4.3	4.4	4.0	3.8	5.0	3.6	53.7	12.1	49.8
	1.082	21.8	80	4	do	4.8	4.4	4.2	4.5	3.6	3.3	4.9	5.2	60.1	13.6	45.5
	1.083	21.1	40	4	do	5.0	4.8	4.4	4.7	4.0	3.9	5.0	5.3	58.1	13.3	47.1
	1.082	21.6	40	24	do	4.8	4.4	4.2	4.0	3.7	3.5	4.8	5.2	62.1	14.2	43.2
3	1.082	21.2		0	do	4.9	4.4	4.0	4.7	3.3	3.1	5.0	3.6	53.1	12.6	49.2
	1.083	21.2	40	4	do	4.3	4.2	3.9	4.0	3.8	2.8	4.3	4.4	58.8	13.6	46.2
	1.082	21.4	40	24	do	4.2	4.2	4.1	3.9	3.3	2.7	4.7	4.9	61.6	14.5	44.2
	1.083	21.4	40	24	Polyethylene bag	4.7	4.6	3.9	4.3	3.6	2.7	4.6	4.2	60.6	15.3	45.9

[1] Mean of 15 values (3 replicates by 5 judges). 5 represents the optimum score and 1 the poorest.
[2] Color was scored on a 6-point scale on which 6 represented too light a color and 5 optimum.
[3] Based on raw cut weight of selected strips.

FROZEN FRENCH-FRIED POTATOES

Second-stage Cooking of Frozen Partially Fried Potatoes

French-fried potatoes that have been completely cooked before freezing are often overbrowned when heated for serving. Preliminary investigations in this study showed that a better frozen product was obtained when french fries were only partially fried before freezing and the cooking completed when they were prepared for serving. The same procedure of freezing a partially fried product has been tried out by some processing plants and is now being used to some extent. At the present time, most of the output of frozen partially fried potatoes is being packaged in bulk or institutional-size units.

To complete the cooking of frozen partially fried potatoes, the usual procedure in restaurants or institutions would probably be frying in deep fat. In the home, however, use of this procedure would have disadvantages. A more desirable method is one that is simpler and requires no special equipment, yet gives a product comparable to that obtained by deep-fat frying.

To find such a simplified method, 3 procedures for second-stage cooking were investigated: (1) oven, 500° F., 10 minutes; (2) broiler, 500°, 5 minutes, and (3) oven, 500°, 5 minutes plus broiler, 500°, 3 minutes. Samples from the same parfry lot were prepared for comparison of these methods and also for cooking by the standard method, in deep fat at 375° for 1½ minutes. The sample for deep-fat frying was always thawed to room temperature to prevent the extreme drop in temperature of the fat that would result if frozen parfries were fried off without preliminary thawing. Other frozen parfried samples were cooked by the 3 procedures both without thawing and after thawing for 4 hours at room temperature, 72°. A control sample, deep-fat-fried without freezing, was included for comparison.

Four replications of the unfrozen controls and 2 replications of each of the other 7 treatments were used to obtain a 3x3 simple lattice design for statistical analysis of the palatability scores.

Mean palatability scores for french fries prepared by the different methods of second-stage cooking are given in table 18. The data show that for all palatability factors except tenderness and uniformity-of-browning, heating in a preheated 500° F. oven for 10 minutes or heating in a 500° oven for 5 minutes followed by 3 minutes in a broiler compared favorably with the control method of frying in deep fat. Cooking in a broiler at 500° for 5 minutes was less satisfactory than the other methods.

All color scores were high, 4.4 or above, indicating that good color was obtained from all methods. Statistical analysis showed that no method was significantly better than another. The mean scores for uniformity-of-browning (4.6) for the unfrozen control samples fried off in deep fat were significantly higher than most of the scores for the other samples. Oven and oven-broiler methods gave the lowest scores for tenderness; with one exception the scores were significantly lower than those for the deep-fat-fried samples. Most tender were the samples cooked off in deep fat. Crispness, mealiness, and flavor were significantly poorer for samples cooked in the broiler than by

TABLE 18.—*Influence of different second-stage cooking methods for frozen parfried potatoes on the quality of french fries, 1952 crop*

Second-stage cooking method	Condition of parfried potatoes before cooking	French-fried potatoes									
		Mean palatability scores [1]							Shear force	Dry matter	Oil content
		Color [2]	Uniformity-of-browning	Lack-of-oiliness	Tenderness	Crispness	Mealiness	Flavor			
									Pounds	*Percent*	*Percent*
Standard deep fat	Unfrozen	4.6	4.6	4.0	4.4	3.8	2.6	4.4	4.0	55.2	13.8
Standard deep fat	Frozen, thawed	4.6	4.1	4.2	4.6	3.7	2.9	4.8	3.9	55.7	16.1
Oven-broiler (500° F., 5+3 minutes)	Frozen	4.5	3.3	4.7	3.7	4.0	3.1	4.2	4.2	55.4	9.9
Oven-broiler (500° F., 5+3 minutes)	Frozen, thawed	4.5	3.5	4.3	3.0	3.8	2.9	4.4	6.2	57.9	9.8
Oven (500° F., 10 minutes)	Frozen	4.4	3.5	4.5	3.4	3.7	3.4	4.3	5.7	57.0	9.9
Oven (500° F., 10 minutes)	Frozen, thawed	4.6	3.5	4.7	3.0	4.2	3.4	4.1	7.7	59.7	10.7
Broiler (500° F., 5 minutes)	Frozen	4.7	4.2	4.1	3.9	3.1	2.1	3.2	2.1	48.8	8.8
Broiler (500° F., 5 minutes)	Frozen, thawed	5.2	3.6	4.3	4.2	2.7	2.3	3.7	4.3	51.2	9.1
Test difference [3]		.9	.8	.7	1.0	.9	.9	.8			

[1] Mean of 10 values (2 replicates by 5 judges) except for unfrozen sample which was a mean of 20 values (4 replicates by 5 judges). 5 represents the optimum score and 1 the poorest.

[2] Color was scored on a 6-point scale on which 6 represented too light a color and 5 optimum.

[3] Any 2 means having a difference as large as or larger than the test difference are significantly different at the 5-percent level.

any other method. Differences among the other methods were not great enough for significance.

The unfrozen control samples were judged to be significantly more oily than several lots of french fries cooked by simplified methods, a result that was to be expected, since the controls were subjected to additional oil absorption in the second stage of cooking. Chemical analysis also showed that the simplified methods for second-stage cooking produced french fries with an oil content (8.8 to 10.7 percent) that was considerably lower than the oil content (16.1) of the french fries prepared by the conventional method of frying in deep fat.

Inspection of the means indicated a relationship between tenderness and oiliness, although the correlation coefficient, −0.48, was not high enough for significance. There was no correlation of mealiness with crispness, or of color with uniformity-of-browning.

No statistical differences were caused by thawing or not thawing the frozen parfried potatoes before cooking by the oven, oven-broiler, or broiler methods. Since deep-fat-fried samples were always thawed before second-stage frying, they were not included in the comparison.

Storage of Tubers and of Partially Fried Potatoes

The processing of large quantities of potatoes as frozen french fries has created a heavy demand for raw stock suitable for making a high-quality product. The known variation in potatoes caused by variety, production area, and cultural conditions has made problems for the processing industry. Furthermore, if processing plants operate on a 12-month basis the effect of storage on the raw potatoes must be considered.

Since storage of potatoes brings about changes that are reflected in their cooking quality, it follows that the quality of the frozen french-fried product will depend to some extent on the length of time the tubers are stored before the parfries are prepared for freezing.

The time that parfries are held in freezer storage is another factor that might be expected to affect quality of french fries. Dawson and associates (*13*) have reported that home-frozen french fries stored at 0° F. maintained good quality for 2 months, but after 2 months changes in flavor and texture made them less acceptable. Comparable data on commercially frozen french-fried potatoes are lacking.

To obtain more information on the effect of storage of tubers and of frozen parfries on quality of french-fried potatoes, a study was made with Kennebec potatoes, a variety commonly used for french frying. The potatoes were from the 1952 crop grown in Maine and had an average specific gravity of 1.080 to 1.085.

The combination plan used for storage of tubers and partially fried potatoes is shown below.

Tubers stored at 50° F. before first-stage fry (months)	*Parfried potatoes stored at 0° F. before second-stage fry*				
	Months	*Months*	*Months*	*Months*	*Months*
0 (harvest)	0	2	4	6	9
2	0	2	4	7	
4		0	2	5	

Shortly after harvest, potatoes were french-fried and judged for palatability. Subsamples from the same parfry lot were cooled,

carefully packaged in suitable boxes for freezing, and stored at 0° F. for 2, 4, 6, or 9 months. After each storage period, samples were given second-stage frying and judged for palatability.

Other tubers from the same lot were stored under controlled conditions at 50° F. for 2 or 4 months. Partially fried potatoes made from tubers stored at 50° for 2 months were given the second-stage fry and judged immediately or frozen as parfries and held in freezer storage for 2, 4, or 7 months. Partially fried potatoes made from tubers stored at 50° for 4 months were fried off and judged immediately or frozen as parfries and held in freezer storage for 2 or 5 months before judging.

The data are shown in table 19, together with the test differences required for significance at the 5-percent level, as determined by analysis of variance. Some of the mean scores for color, crispness, and mealiness were significantly different from one or more other means. Except for one color score, the effects of storage of frozen parfries were not great enough to produce significant differences between frozen samples that were prepared simultaneously but stored for different periods of time.

Covariance analysis was applied to data for french fries prepared from tubers previously stored for 0, 2, or 4 months, and regression coefficients were computed that showed the change in mean scores for each month the parfries were held in freezer storage. A negative regression of color on storage time was obtained. An average regression coefficient of −0.10 for all lots indicated that mean color scores decreased approximately 0.1 for each month of freezer storage. No other palatability characteristics were significantly affected, although very slight trends toward lower quality ratings with increased freezer storage time were noted.

Shear-force values for french fries increased with the time the parfries were in freezer storage and gave a significant correlation coefficient of +0.55 with crispness. The correlation is of a low order, and no corresponding change in the crispness scores is apparent. A nonsignificant correlation coefficient of −0.39 with tenderness indicated only a slight tendency for the tenderness scores to decrease with increased shear-force values.

In all of the freshly fried samples dry matter and oil content were lower and yield was higher than in french fries prepared from the frozen parfries. Changes of frozen samples with time in storage were negligible.

The storage of the tubers before preparation of the partially fried potatoes had a considerable influence on the palatability ratings of the french fries. Regression coefficients of color, lack-of-oiliness, crispness, and mealiness on time of tuber storage were all significantly different from the corresponding coefficients of those characteristics on time of storage of the frozen parfries. Color scores increased as the storage time of the tubers was prolonged, whereas increased time in storage of the frozen parfries caused a decrease in color scores. Scores for lack-of-oiliness, crispness, and mealiness decreased more rapidly in french fries from the tuber-stored samples than in those from the frozen partially fried samples.

Holding tubers in storage at 50° F. for various periods of time before preparing the partially fried potatoes for freezing influenced

TABLE 19.—*Influence of length of storage of raw tubers and frozen parfries on quality of french-fried potatoes, 1952 crop*

Tuber storage, 50° F.	Raw potatoes, dry matter	Parfried potatoes		French-fried potatoes										
				Mean palatability scores [1]							Shear force	Dry matter	Oil content	Yield [3]
		Condition	Storage time	Color [2]	Uniformity-of-browning	Lack-of-oiliness	Tenderness	Crispness	Mealiness	Flavor				
	Percent										*Pounds*	*Percent*	*Percent*	*Percent*
0 months (harvest)	21.4	Fresh	Unstored	5.0	4.3	4.4	4.3	4.1	3.6	4.9	3.7	53.9	11.8	49.9
	22.2	Frozen	2 months	5.0	4.5	4.4	4.7	4.4	3.9	5.0	3.8	59.3	15.1	47.7
	20.9	do	4 months	5.0	4.5	3.9	4.5	4.1	3.2	4.8	4.6	60.4	15.8	46.6
	21.4	do	6 months	4.3	3.9	4.0	3.8	3.8	3.3	4.4	5.1	61.1	15.8	45.5
	21.2	do	9 months	4.7	4.7	4.2	4.4	4.0	3.5	4.8	5.1	60.0	17.1	46.7
2 months	20.7	Fresh	Unstored	5.2	4.6	3.9	4.3	3.5	3.0	4.7	3.5	53.8	13.3	49.5
	20.3	Frozen	2 months	5.3	4.7	3.9	4.7	4.1	3.4	4.6	4.7	60.2	17.3	46.8
	20.6	do	4 months	4.7	4.3	4.0	4.4	3.7	3.5	4.7	4.6	61.0	16.6	45.9
	20.3	do	7 months	3.9	3.8	3.9	4.2	3.5	3.0	4.3	5.2	61.8	18.0	45.7
4 months	20.8	Fresh	Unstored	5.6	4.7	3.7	4.4	3.5	2.7	4.3	4.0	53.0	12.2	50.6
	20.3	Frozen	2 months	5.2	4.4	3.6	4.7	3.2	2.7	4.4	3.5	58.6	17.5	47.9
	20.1	do	5 months	5.2	4.5	3.5	4.6	3.1	2.5	4.5	4.8	60.6	19.0	47.1
Test difference [4]				.9	1.1	1.0	1.0	.8	.8	.8				

[1] Mean of 15 values (3 replicates by 5 judges). 5 represents the optimum score and 1 the poorest.
[2] Color was scored on a 6-point scale on which 6 represented too light a color and 5 optimum.
[3] Based on raw cut weight of selected strips.
[4] Any 2 means having a difference as large as or larger than the test difference are significantly different at the 5-percent level.

the final product as shown in table 20. The palatability scores have been adjusted by regression to give comparative values for samples frozen from tubers at harvest and stored for 5 months, frozen and held for 3 months after the tubers were stored for 2 months, and frozen and held for 1 month after the tubers were stored for 4 months.

Samples from tubers stored 4 months gave a mean adjusted score of 5.5 for color, which was significantly higher than the scores for the samples frozen at harvest or after 2 months of tuber storage. However, the latter samples with scores of 4.7 and 4.8 were of a more desirable golden-brown color and closer to the optimum score of 5 than the lighter colored french fries from the tubers stored 4 months. Scores above 5 indicated that the samples were too light in color to have the most desirable appearance. The frozen french fries prepared from the tubers at harvest received significantly higher scores for lack-of-oiliness, crispness, and mealiness than the samples prepared from the tubers stored 4 months. Flavor scores also tended to decrease with increased storage time of the tubers, but the differences failed to approach statistical significance at the 5-percent level. In most instances the scores for the samples prepared for freezing after 2 months of tuber storage were intermediate between those for samples prepared at harvest and after 4 months of tuber storage.

TABLE 20.—*Mean palatability scores adjusted by regression to values for frozen french-fried potatoes judged 5 months after harvest, 1952 crop*

Tuber storage at 50° F.	Parfry storage at 0° F.	Color	Uniformity of browning	Lack-of-oiliness	Tenderness	Crispness	Mealiness	Flavor
0 months (harvest)	5 months	4.7	4.4	4.2	4.3	4.0	3.5	4.7
2 months	3 months	4.8	4.3	3.9	4.5	3.7	3.2	4.6
4 months	1 month	5.5	4.5	3.6	4.6	3.3	2.6	4.4
Test difference [1]		.5	.3	.3	.4	.4	.5	.4

[1] Any 2 means having a difference as large as or larger than the test difference are significantly different at the 5-percent level.

The data presented here for one variety, Kennebec from Maine (specific gravity 1.080 to 1.085), indicate that the best french-fried potatoes were obtained when the samples parfried shortly after harvest of the tubers were fried off immediately or frozen, stored at 0° F., and given the second-stage fry anytime up to 9 months after harvest. A slight decrease in color scores with increased time in frozen storage appeared to be due more to a dullness of the color than to increased browning. This decrease in color rating was offset by higher scores for lack-of-oiliness, crispness, mealiness, and to some extent flavor in the samples prepared at harvest. However, all frozen samples, whether prepared at harvest or after the tubers had been stored at 50° for 2 or 4 months, made satisfactory french-fried potatoes, with the possible exception of the samples from the tubers stored for 4 months, which scored low in mealiness. Potatoes of higher specific gravity would be expected to give more mealy french-fried potatoes.

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APPENDIX

TABLE 21.—*Information on the factors of production of the various lots of potatoes, 1952 crop*

Variety and location	Planting date	Harvesting date	Soil type	Fertilizer (N-P_2O_5-K_2O)	Previous crop	Irrigation	Insecticides and fungicides	Vine killer
Chippewa: Maine	May 17	Sept. 17	Sandy loam	8-12-12+1 percent Mg.; 2,000 lb. per acre.	Clover	None	Parathion and Dithane	Frost Sept. 7.
Irish Cobbler: Maine	May 15	Oct. 8	do	do	Potatoes	do	do	Do.
Irish Cobbler: North Dakota.	May 10	Sept. 28	Fargo silty clay loam.	4-24-12; 300 lb. per acre	Barley	do	DDT	Early blight.
Katahdin: Colorado	May 26	Oct. 3	Gravelly loam	None	Alfalfa	7 applications	DDT and Dithane	Mechanical.
Katahdin: Maine	May 14	Sept. 29	Sandy loam	8-16-16+1 percent Mg.; 1,400 lb. per acre.	Potatoes	None	DDT, parathion, and tribasic copper.	Frost Sept. 7.
Kennebec: Maine	do	Sept. 28	do	do	do	do	do	Do.
Russet Burbank: Washington.	May 29	Sept. 30	Light loam over pea gravel.	17-16-5; 600 lb. per acre	Sagebrush	Rill	DDT with fertilizer	Rotobeater.

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