PROCESSING CHARACTERISTICS OF SELECTED POTATO CLONES

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ABSTRACT

PROCESSING CHARACTERISTICS OF SELECTED POTATO CLONES.

By

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Nine selected potato clones, including two Solanum tuberosum - S. stoloniferum species hybrids were processed into potato chips, french fries and flakes. The varieties, Kennebec and Russet Burbank were used as controls.

Data obtained from analysis of the raw material and the products made from each clone was used to reach a conclusion as to whether the clone would have potential as a commercial variety. The hybrid clones were considered seperately because of their unique properties. Clones 1111-2, 706-32 and 706-34 were unacceptable because the products made from them were of dark color, the product yields were low and the texture of the french fries were poor in comparison to the control. Clones 709, 711-8 and 58 were considered marginal. Their yield and total solids content was acceptable but the color and texture characteristics were mixed. One clone, 711-3 was considered to have potential as a commercial variety. The hybrid clones had a high solids content and were generally better in other respects. They have a pronounced yellow flesh due to xanthophyll pigments. In flakes antioxidants must be used to prevent pigment destruction during storage. The fried products have a flavor and texture different from the controls.

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SELECTED POTATO CLONES

By

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INTRODUCTION

Potatoes were first cultivated by the natives of South America more than 2000 years ago. The Spanish explorers first discovered the potato in 1537. Exactly when or how the potato was introduced into Europe is not clear. Its value as a food was not recognized for sometime and it did not become important until the 17th century. The use and importance of the potato as a food, especially for the lower classes then grew rapidly. The potato was returned to the Western Hemisphere in 1719 to Londonderry, New Hampshire by Scottish-Irish immigrants. By the 19th century in the United States, interest in potatoes had grown extensively and plant breeders turned out hundreds of new varieties, only a few of which were successful. (Smith, 1968).

Potato production peaked in the period between World War I and World War II. Per capita consumption declined after the Great Depression until the advances in processing in the mid-1950's stimulated expanded consumption of potatoes. In 1966, 12.2 million tons of potatoes were produced in the U. S., with consumption at about 110 lb per capita. The growth of processing is demonstrated by the fact that in 1956, 14% of all potatoes for food use were processed, while by 1966 41% were processed. (Smith, 1968).

Early plant breeders were interested primarily in developing high yielding varieties with resistance to disease and insects. With the development of processing it was recognized that in addition to these goals, varieties need to be developed for specific processing applications. For example, the level of reducing sugars, which is determined by metabolic activity, is related to potato chip color. It is believed that through genetic selection, control of the enzymes governing the level of reducing sugars and thereby, color, could be attained. (Treadway, 1961).

The purpose of this study was to determine the processing qualities of new selected clones. Potato chips, french fries and potato flakes were made from nine new clones, including two *Solanum tuberosum* - *S. stoloniferum* hybrids, and evaluated to determine their processing suitability.

LITERATURE REVIEW

Until recently, when processing became an important outlet for the potato crop, plant breeders had concentrated on developing new varieties with high yields and resistance to insects or diseases or other characteristics, such as frost resistance and ability to withstand drought. The late blight outbreaks of the mid-19th century in particular, stimulated attempts to breed resistant varieties. (Talburt and Smith, 1967.) It is now recognized that characteristics which are important in processing can also be incorporated in a breeding program.

When studying the processing characteristics of several varieties, Isleib (1962), found that variety *per se*, is not a valid criterion for predicting potato flake quality. It appeared that growing and storage conditions have a definite influence upon the quality of flakes made from the same variety. This means that in evaluating new varieties for their processing characteristics, one must use a standard commercial variety grown and stored in the same manner as the test varieties to remove bias due to the conditions encountered.

There are a number of general attributes of processed potato products which must be considered in evaluating a new variety for its processing suitability. These include color, flavor, texture and product yield. Within these classifications, limits are often established above or below which a product is considered unacceptable.

COLOR. Several factors are related to the color of potato products. In addition to variety and growing conditions, enzymatic and non-enzymatic browning, after cooking darkening greening and natural pigmentation determine the color of processed products.

The most familiar is nonenzymatic browning. This is a reaction between an amino compound and a free carbonyl group which proceeds from the formation of a Schiff's base through Amadori rearrangement and Strecker degradation to compounds which polymerize to form the characteristic brown pigments. (Braverman, 1963). In potatoes the reactants are reducing sugars and free amino acids. Habib and Brown, (1957) found glucose and fructose to be the most generally present reducing sugars. They concluded that low reducing sugars and low basic amino acids are related to light colored chips. Hoover and Xander (1961) found a consistent correlation only between glucose and fructose levels and chip color. Other compounds, including amino acids and minerals gave inconsistent correlations.

Similiar results have been reported by other workers, (Shallenberger 1959; Fitzpatrick, 1965, 1966). The level of reducing sugars and free amino acids depends upon variety and storage conditions. Varieties having low solids tend to accumulate more reducing sugars than varieties of high solids. Low storage temperatures stimulate the accumulation of reducing sugars. Generally this occurs at temperatures below 50°F and increases as the temperature approaches freezing. The level of browning reactants may be reduced by storing the potatoes at high temperatures for several weeks. Maximum reducing sugar ordinarily permissible for potato chip production is 0.2%, fresh weight basis. Similiar limits for french fries and flakes are reported to be 0.4 - 0.6% and 1.0% respectively (Talburt and Smith, 1967).

Injured potato tissue is subject to enzymatic browning which can result in an undesirable discoloration of the finished product. Enzymatic browning results from the reaction of a polyphenol oxidase with a phenolic compound to form red to brown melanin pigments. In potatoes, tyrosine is believed to be the major phenol involved. In normal processing, peeling of the potatoes is the point at which this type of discoloration occurs. The most commonly used preventative treatment is to dip the freshly peeled potatoes in an acidified solution of sodium sulfite or sodium bisulfite at a level of 1000 ppm SO_2. (Talburt and Smith, 1967).

After cooking darkening is another undesirable factor affecting the appearance of processed potatoes. It is generally recognized as being due to the development of a colored complex between ferric ions and an orthodihydric phenol. Chlorogenic acid is usually implicated as the phenol. Many factors are involved in aftercooking darkening, for example, pH, organic acid composition, iron content, orthodiphenol content and the availability of oxygen. This problem can be easily avoided by treating the potatoes with a 2% solution of sodium acid pyrophosphate (fine particle size, fast acting food grade is recommended.) In practice this is done with french fries at the blanching step or with potatoes for flakes at the precooking step. (Smith, 1968).

Greening is a factor of importance to producers and processors of potatoes. It is due to the formation of chlorophyll under the peel, resulting from exposure to light. It is undesirable from the standpoint of appearance and also the bitter flavor which develops coincidentally and is attributed to solanine. Greening is reported to be affected by variety, maturity and age, temperature, intensity and quality of light and duration of exposure. The most effective preventive measure is to avoid exposure to light. (Smith, 1968).

Carotenoids are not normally important to the appearance of commercially produced potatoes in the United States. However, the Solanum tuberosum - S. stoloniferum hybrids used in this study have a pronounced yellow color which affects the appearance of the products made from them, particularly the flakes. Brunstetter and Wiseman, (1947) reported that Katahdin variety contains 3 ppm carotenoid, dry weight. They reported the composition to be lutein, 0.50-0.77 ppm; beta-carotene, 0.30 ppm; aurochrome, 0.11 ppm, and several others unidentified. Pendlington et.al. (1965), reported the carotenoid composition of six British varieties to be similiar, containing beta-carotene, beta-carotene-5,6-monoepoxide, cryptoxanthin -5,6-diepoxide, lutein, cis-violaxanthin, cis-antheraxanthin-5,6-monoepoxide, cis-neoxanthin and an unknown. The physical state of the pigments has been found to affect the color of vegetables after processing. Purcell et.al. (1969) found that in some highly colored vegetables with distinct chromoplasts containing the carotenoid pigments, heating caused them to breakdown and release the pigments into the cell where they joined the lipids to form colored droplets near the cell wall. Heating sufficient to break down the cell resulted in the pigments being dispersed throughout the cellular debris coloring it, with a few droplets remaining intact. Purcell (1962) found that the various carotene and xantophyll pigments of dehydrated sweet potato flakes are neither preferentially spared or oxidized in storage. Processing apparently did not destroy the carotenoids and the use of low temperature storage, nitrogen atmosphere and antioxidants decreased the loss of pigment.

Flavor. The flavor of potatoes is mild and problems with the flavor ordinarily are those of off-flavors. The natural flavor of potatoes arises from the reaction of precursor compounds. Included are amino acids, sugars and pectin. Factors which change these constituents can be expected to change the flavor of the potato products. The major volatile substances of cooked potato include various sulfur compounds, aldehydes, alcohols, ketones and amines. In the deep fat fried products, frying results in the development of different flavor constituents. If these products are stored for some time under unfavorable conditions rancidity will develop. Hexanal is reported to be associated with the development of rancidity in potato chips. Dehydrated potato products have a great tendency to suffer from off-flavor problems. This is due to the low moisture content and large surface area exposed to the air. The principle fatty acids in the lipid fraction of Russet Burbank potatoes is reported to be linoleic, linolenic, stearic and palmitic acids. Oxidation of linoleic and linolenic acids is closely related to the development of off-flavors in the reconstituted product. Hexanal is a major product of autoxidation. It is reported to increase with time in granules stored in oxygen. The addition of BHA and BHT resulted in less hexanal production. (Smith, 1968).

Texture. The texture of potato products, especially french fries and flakes is related to specific gravity, total solids, starch content, and alcohol insoluble solids. High values are associated with mealiness, dryness and sloughing, low values are associated with waxiness and lack of sloughing. Storage temperature and time can affect texture through changes in composition. Texture is important in processing, particularly of flakes since the nature of the process promotes cell breakage, if care is not taken, resulting in an undesirable, pasty product. In addition to gentle mashing and mixing to minimize cell breakage, precooking followed by cooling is used to render the starch less soluble and sodium acid pyrophosphate is also used to insolublize the starch. Microscopic observation has shown that SAPP prevents the starch from spilling out of broken cells. It is believed that the phosphates may increase cross-bonding in the starch rendering it less soluble. (Smith, 1968).

Yield. Product yield is of economic importance to producers and processors. The most important factor governing the yield of chips is the total solids content. Factors which affect total solids will affect the yield. Some of these factors include variety, cultural conditions, maturity and environmental conditions. (Smith, 1968). The yield of french fries and flakes also depends upon dry matter content. Peeling losses vary between varieties and the amount of loss will affect the yield obtained. Other factors which influence yield are variations in moisture and oil content of the product and cull out due to greening, scab, black spot and other physiological disorders.

METHODS AND MATERIALS

Raw Material. The potato samples used in this study were obtained from the Montcalm County Experiment Station Farm through the Department of Crop and Soil Sciences. The samples were brought to the Food Science Department immediately after harvest and placed in 45°F storage. The clones and varieties were harvested during the month of October as they became mature. Additional samples from the same source that were stored at approximately 45°F, were obtained on 18 November, and the first week of December 68 and on 8 January 69. At the time of harvest, yields per acre and the specific gravity of all lots were determined. Specific gravity was determined using the method of Isleib and Thompson (1957).

The numerically designated clones used in this research were 709, 58, 1111-2, 711-3, 711-8, 706-32, 706-34, 321-65, and 322-6. The two commercial varieties used as controls were Russet Burbank and Kennebec. Russet Burbank was the control for french fries and potato flakes and Kennebec was the control for chips. The _Solanum_ _tuberosum_ - _S_. _stoloniferum_ species hybrids used are designated 321-65 and 322-6.

Storage. The potatoes were stored at 45°F and 70% to 80% relative humidity. The french fries and flakes were produced from potatoes directly from storage. The initial potato chip lots were also produced directly from storage, but since the color was unsatisfactory all subsequent lots were conditioned at 70°F and 80% to 85% relative humidity for 20 days before chipping.

Processing _Procedures_. The procedures used for processing the potatoes are as follows:

Potato Chips:

1.) One to three pound random samples were taken from storage for processing immediately or conditioned for processing.

2.) Potatoes were washed, cut in half and sliced into 1/16 inch slices with a _Slice_ _Chief_ _Senior_ vegetable slicer.

3.) The slices were washed in hot water for 1-2 minutes to remove free starch and thoroughly drained and weighed.

4.) Slices were fried in a General Electric Model HK3 deep fat frier at 375°F. in hydrogenated vegetable oil for 3 to 5 minutes. The finish point was when the slices ceased bubbling.

5.) Slices were drained and cooled on absorbant paper for 3-5 minutes, weighed and transferred to polyethylene bags.

6.) Analysis was begun the day after processing and sensory evaluation was scheduled within a week of processing.

French Fries:

1.) Three to six pound random samples were taken from storage for processing.

2.) Potatoes were washed and preheated in water at 170°F. for two minutes.

3.) They were transferred to a 15% - 20% lye solution at 165°F = 170°F and allowed to soak with constant turning for 4 minutes. The time was occasionally varied ± .5 minutes to account for differences in the peel.

4.) Peel and lye were washed off with a hot water spray, defects were trimmed away and the tubers were held in a 1000 ppm SO_2 solution approximately 1-3 minutes until sliced.

5.) Tubers were sliced into 3/8 inch strips longitudinally, washed, nubbins and slivers removed and weighed.

6.) Samples for reducing sugar and solids determination were removed and the strips were reweighed.

7.) Strips were blanched for five minutes in water at 190°F - 200°F.

8.) The water was drained off thoroughly and the strips were fried for 3½ minutes at 375°F in hydrogenated vegetable oil, drained on absorbant paper and cooled with the aid of a fan for 5-6 minutes.

9.) French fries were transferred to polyethylene bags and stored at -10°F. Sensory evaluations were made after about two months. Analysis on all, samples were made after three to eight months.

Potato Flakes:

1.) A 14 to 84 pound sample was taken randomly from storage for processing.

2.) The condition of the tubers was noted, they were washed, and preheated at 170°F for two minutes in water.

3.) Peeling and trimming was carried out as for the french fries.

4.) Potatoes were sliced into 3/8 inch slices, drained, weighed and returned to the SO_2 solution.

5.) Slices were wasned with running water for 1-2 minutes and precooked for 20 minutes in 165°F water, or for the second and third processing times, in 2% solution of SAPP.

6.) The slices were cooled to 70°F - 80°F in a cold water bath, taken out and allowed to stand for 20 minutes before transferring them to a retort for steaming at 212°F for 30 minutes.

7.) Ricing was done using a Kitchen Aid Model K-5A mixer with the coarse rotary grater attachment. Additives or diluting water were added at this point. Samples were removed for solids analysis before additives were incorporated.

8.) The mash was dried on an Overton Machine Company Model P-36 double drum dryer, 12 inch diameter by 19 1/8 inch length. One drum was used as an applicator roll, the other as a drying roll. Simulation of one to five applicator rolls is possible by a doctor blade control. Conditions normally used were 8 rpm, 4 layers, uncooled applicator roll and 85-90 psi steam pressure.

9.) Production rate in lb/ft^2/hr was obtained and drying characteristics were noted.

10.) The sheets were placed in a polyethylene bag. At the end of processing the sheets were reduced to flakes using a rotary slicer with 3/8 inch spacing between blades.

11.) Analysis was begun within one day of completing processing and sensory evaluation was scheduled within a week. Samples for storage stability were also prepared within a week after processing.

A portion of the flakes produced initially and after three months from Russet Burbank, 321-65 and 322-6 were also placed in No. 2 cans, sealed in air and stored at -10°F and 75°F. Analyses were made after 0, 3 and 6 month storage. The second lot of flakes produced had additives included to determine its effect upon stability of the color. The additive mixture used is listed in Table I.

Table I.
Additive per 10 lb of 20% solids mash.

Ingredient	Amount
Tenox IV (BHA and BHT)*	0.75g
Myverol 18-07 (monoglyceride)*.	1.00g
Skimmilk Solids	2.00g
Sodium Sulfite	0.60g
Sodium Bisulfite.	0.20g

* obtained from Eastman Chemical Company

The level of BHA and BHT (Tenox IV) used in the flakes was 66 ppm wet basis or 310 ppm 6% moisture basis.

Analytical Procedures. The procedures used for analyzing the raw and processed potatoes were as follows.

Reducing Sugars. Raw potato strips obtained during french fry processing were macerated in a Waring blender for 1-2 minutes. The juice (5-10 ml) was transferred to a test tube and the reducing sugar determined using the Dextrocheck method (Ames Company, Division of Miles Laboratories). If there was a delay in analysis the samples were refrigerated at 38°F.

French Fry Preparation. The frozen french fries were prepared for analysis by taking them from -10°F storage and allowing them to thaw for 45 to 60 minutes. The samples were then fried for 0.5 minute in 375°F hydrogenated vegetable oil. The samples were taken hot for analysis. USDA color was determined immediately and texture was tested 2-3 minutes after frying, followed by color and moisture.

Moisture Content. The vacuum oven method was used. (A.O.A.C. Methods of Analysis p. 308). The samples were dried at 70°C and 26-28 inches Hg for 12-14 hours. The moisture of the raw potato was determined by taking samples of raw french fry strips, macerating them in a Waring blender for 1-3 minutes and placing 9-12g of the well mixed sample in previously dried, tared glass petri dish. The samples were dried to constant weight. The moisture content of the potato mash was determined in the same way except blending was unnecessary. Potato chips were broken using a spatula to minimize loss of oil from the surface. Samples of 9-12 g were placed in dried, tared Soxhlet thimbles and dried. French fry samples were macerated for 1-3 minutes in a Waring blender, 9-12 g of well mixed sample was placed in a dried tared Soxhlet thimble and dried.

The moisture content of the potato flakes was determined using a Cenco Infrared Moisture Balance method. All moisture determinations were Made in triplicate.

Oil Content. The oil content of potato chips and french fries was determined by the Soxhlet method (Jacobs, 1958). The dried potato chips and french fries were continuously extracted for 12 hours with petroleum ether (B.P. 30°- 60°C.) at a rate of 3-5 drops per second.

Color. French fry color was determined using the USDA color standards. The finish fried strips were compared to the standards and the color value recorded. The Hunter Color and Color Difference Meter, Model D25L, was used to determine the color of the french fries, chips and flakes. The french fries were laid in a four inch glass sample dish in a manner, and to a depth that minimized light transmission. The samples were presented to the instrument and read through the bottom of the dish. Two readings were taken on each sample at 90° with respect to each other and the values averaged. An enclosure of flat-black poster board was built over the viewing port to eliminate interference from outside light. Potato chip color was determined similarly. The chips were placed in the dish and compressed with a beaker. Sufficient chips were added to minimize light transmission. Potato flakes were placed in the dish to fill it and the dish was gently tapped to settle the flakes. Color standard #2810, L=94.8, a=-0.7, b=2.7, was used for flakes and standard #2814, L=83.0, a=-3.5, b=26.5 was used for french fries and chips.

Bulk Density. The method of Bakker-Arkema, et.al. (1968) was modified to determine the bulk density of potato chips and flakes. A 100g sample of chips was placed in a 2000 ml graduate cylinder. The cylinder was lifted to a height of 2½ inches and dropped 50 times, turning it slightly after each drop. The flake method was similar except a 50g sample was used in a 1000 ml graduate cylinder and it was dropped from a height of 3 inches. Bulk Density was calculated in lb/ft^3 from the packed volume. The determination was made in duplicate for chips and in triplicate for flakes.

French Fry Texture. Texture was characterized by a modified form of the method of Ross and Porter (1966, 1968, 1969). An Instron Universal Testing Instrument, Model TT-BM was used. The shear cell had a single blade with dimensions 1/8 inches wide by 2 9/16 inches long. The operating conditions were the 1 kg to 50 kg load cell used in the 10 kg full scale position, 5 cm/min chart and crosshead speed. French fry strips were placed in the shear cell in one layer seven strips wide. The maximum shear force is reported as the average of three tests. Representative curves are also reported.

Blue Value. Cording's (1959) modification of the method by Mullins (1955) was used. The determination was made in triplicate.

Flake Thickness. A micrometer was used to measure the thickness of the flakes. Six to eight random measurements were taken to arrive at a representative value.

Production Rate. The weight of product from a timed run on the drum dryer was used to calculate drum drying rate in $lb/ft^2/hr$.

Yield. Potato chip yield is reported as:

$$\frac{(\text{Wt. of chips})}{\text{Wt. of slices}} \quad (100)$$

French fry yield as:

$$\frac{(\text{Wt. of french fries})}{(\text{Wt. of raw potatoes})} \quad (100)$$

Potato flake yield as: (6% moisture basis)

$$\frac{(100)\ \ (\%\ \text{Peeling loss})\ \ (\%\ \text{Solids})}{0.94}$$

Sensory Evaluation. Potato chips were evaluated by sensory panels after each processing time. The panel members compared 709, 322-6 and 321-65 to Kennebec and recorded their judgement of the degree of difference in color, flavor and texture. Later panels judged whether the clones were better or worse than the controls. The panels consisted of 18-20 people and were carried out in duplicate. Sensory evaluation of the french fries was done in the same way as for the chips except that care was taken to present the samples hot. Potato flake evaluation was performed similarly. The flakes were made into mashed potatoes by boiling four liters of water with ca 3.4g of table salt. To each 20g of flakes, 80 ml of boiling water was added. The mashed potatoes were stirred until an even consistency was attained. Each panel member was served ca one-half ounce of each sample. The stored flakes were evaluated after three months storage by the method above except that only color and flavor were evaluated and the panel was asked to compare the 75^{o}F sample against the -10^{o}F sample of each clone or variety.

Pigment Extraction. Extractable color was determined by a modification of the method of Wall and Kelly (1943). A 5.00g sample of flakes was weighed out and placed in a blender jar with 140 ml of hexane: 95% ethanol (3:2). The sample was blended in a frothing mixture for five minutes and then quantitatively transferred to a frittered glass funnel with a suction flask and washed alternately, twice each, with hexane and 95% ethanol. The extract was transferred quantitatively to a 500 ml separatory funnel and 100 ml of distilled water was added followed by 50 ml of 5% sodium sulfate solution. The mixture was swirled and allowed to separate. The lower aqueous phase was transferred to a second separatory funnel and extracted three times with 30 ml of hexane. These fractions were transferred to the original hexane fraction. The combined extract was carefully washed with 100 ml of distilled water and transferred to an erlenmeyer flask through 100 mm funnel containing a bed of anhydrous sodium sulfate to remove the remaining water. The dried hexane extract was reduced in a rotary vacuum evaporater and transferred quantitatively to a 10 ml volumetric flask. Extraction of the raw samples were carried out in a similar manner, with the weight adjusted such that the dry matter was equal to that in the corresponding flakes. Maximum absorbance and a scan of the visible absorption spectra were determined on the samples using a Beckman DB spectrophotometer standardized with hexane at 540 nm.

Thin Layer Chromatography. After the spectra were determined, the 10 ml extract was evaporated under nitrogen to 3-4 ml. Approximately 30-50 ul was applied to an Eastman precoated silica gel thin layer sheet. The sheets were previously activated at 110°C for six minutes. The solvent system used was Skellysolve B: Acetone: Methanol (89:10:1) and the sheets were developed to 10 cm from the origin. The visualizing agent was 2', 7' -dichlorofluorescein, 0.2% in 95% ethanol.

RESULTS AND DISCUSSION

Raw Material. The specific gravities of the clones ranged from 1.070 to 1.109 (Table II) and there was a 92% correlation between specific gravity and solids. The yields per acre ranged from 201.0 to 421.6 hundred weight. Based on the yield per acre ranged from 44.5 to 87.0 hundred weight.

Table II.
Specific Gravity and Yield of Potatoes

Sample	Specific Gravity	Yield CWT[1]/acre	Yield CWT[1] solids/acre
Russet Burbank	1.089	NA[2]	NA[2]
Kennebec	1.075	421.6	82.2
321-65	1.109	286.6	81.0
322-6	1.095	201.0	44.5
711-3	1.080	388.1	84.5
58	1.079	317.0	66.5
709	1.075	415.1	79.5
711-8	1.075	397.5	87.0
706-34	1.075	391.3	73.0
706-32	1.074	381.5	71.0
1111-2	1.070	309.2	51.5

1 = Hundred weight, 2 = Not Available.

Total Solids. The solids content varied from 16.7% for 1111-2 to 28.3% for 321-65 (Table III.), the differences were significant at the 1% level. No significant changes occurred in the solids content with time from November to March.

Table III
Total Solids Content

Sample	Nov.	Dec.	Mar.	$\bar{X}$	*
		% Solids			
321-65	28.3	26.0	26.5	26.9	
322-6	22.1	24.1	22.9	23.0	
Russet Burbank	24.1	23.2	21.3	22.9	
711-3	21.8	22.1	21.7	21.9	
711-8	21.9	21.2	18.7	20.6	
Kennebec	19.5	18.8	22.1	20.1	
706-34	18.6	19.2	20.6	19.5	
709	19.0	19.5	19.9	19.5	
58	21.0	18.5	18.3	19.5	
706-32	18.6	17.3	16.6	19.3	
1111-2	16.7	16.8	17.4	17.0	

* Differences at 5% level, Duncan's Multiple Range Test.

Reducing Sugars. Significance at the 5% level was found between clones and varieties. Reducing sugars varied from 0.05% to 1.0% in 321-65 and 1111-2 respectively (Table IV). No difference with time in storage was observed.

Table IV
Reducing Sugars

Sample	Nov.	Dec.	Mar.	$\bar{X}$	*
		% Reducing Sugar			
321-65	0.05	0.2	0.05	0.1	
322-6	0.4	0.05	0.1	0.2	
Russet Burbank	0.1	0.4	0.2	0.2	
Kennebec	0.2	0.4	0.2	0.3	
711-3	0.2	0.4	0.4	0.3	
58	0.2	0.6	0.4	0.4	
709	0.6	0.2	0.8	0.5	
706-32	0.4	0.6	0.6	0.5	
706-34	0.6	0.4	0.6	0.5	
711-8	0.4	0.6	0.6	0.5	
1111-2	0.4	1.0	0.6	0.7	

* Differences at 5% level, Duncan's Multiple Range Test.

Physiological Condition. On 3 January, 321-65 and 706-32 were just beginning to sprout, and the tubers of all of the lots were in good condition. Two months later all of the potatoes were sprouting and the tubers of many were flacid. Difficulty in maintaining the humidity high enough was responsible in part for desiccation which occured.

Potato Chips. Yield varied from 23.1 to 32.8 lb/100 lb (Table V). Significant differences were found between clones (1% level). The hybrids had a higher yield than the other clones. A significant correlation coefficient of r= 0.73 (1% level) between yield and total solids content was also found.

Table V
Potato Chip Yield

Sample	Nov.	Dec.	Mar.	$\bar{X}$	*
	Yield (lb/100 lb)				
321-65	32.8	32.2	30.5	31.8	
322-6	30.3	31.9	29.7	30.6	
Kennebec	27.9	30.1	28.0	28.7	
711-8	27.5	27.6	30.6	28.6	
711-3	26.6	28.4	26.4	27.1	
706-34	25.0	27.5	27.8	26.8	
58	25.8	26.6	27.8	26.7	
709	27.9	27.1	24.0	26.3	
706-32	23.1	26.2	26.3	25.2	
1111-2	24.0	24.5	23.6	24.0	

* Differences 5% level, Duncan's Multiple Range Test.

Moisture. There were no differences in moisture content between clones or times of processing when careful control of the chipping conditions were maintained. Higher moisture levels will occur when the frier is overloaded as occurred at the March processing time (Table VI). Moisture varied from 1.3% to 2.5% in November and December and from 1.8 to 4.2% in March.

Table VI.
Potato Chip Moisture

Sample	Nov.	Dec.	Mar.
	% Moisture*		
Kennebec	2.0	2.0	3.9
321-65	2.2	2.0	2.3
322-6	2.5	2.3	1.8
709	2.1	1.8	3.2
1111-2	1.9	1.8	3.5
706-32	2.2	1.7	3.5
706-34	1.3	1.6	3.4
711-3	2.2	2.3	4.2
711-8	2.1	2.0	3.2
58	1.6	1.8	3.3

* Difference between times (5% level).

Oil Content. Oil absorption varied from 50.8% to 28.2% (Table VII). Differences were significant between clones, but not between processing times. Oil absorption was found to be inversely related to total solids (r = -0.78, 1% level).

Table VII
Potato Chip Oil Absorption

Sample	Nov.	Dec.	Mar.	*	$\bar{X}$
	% Oil				
706-32	42.0	43.2	50.8		45.3
709	42.0	45.0	43.4		43.5
1111-2	41.4	44.4	44.2		43.3
706-34	39.6	40.3	42.7		40.9
Kennebec	40.8	37.6	42.4		40.3
58	40.4	38.6	39.3		39.4
711-8	35.7	39.0	38.3		37.7
711-3	33.7	37.6	38.9		36.7
322-6	33.5	35.8	33.1		34.1
321-65	32.3	34.9	28.2		31.8

* Differences at 5% level, Duncan's Multiple Range Test.

Bulk Density. Significant differences in bulk density between clones was observed (Table VIII). The bulk density varied from 3.8 lb/ft^3 to 7.3 lb/ft^3. Considerable variation occured in the bulk density values which could be related to variations in the size of the potato chips. Missing values (Kennebec, March bulk density and 322-6, December peeling loss) were calculated according to the method of Guenther (1964, p.77).

Color. Potato chips with high L values and low a/b ratio are considered most desirable. The chips processed in November without conditioning were found to be visually unacceptable. This is shown in the significantly lower L values and higher a/b ratios, compared to those processed in December and March which were conditioned. There were also significant differences between clones. Clones 709, 58, 706-32, 706-34 and 1111-2 did not respond well to conditioning and did not produce satisfactorily light chips. High solids clones had better color than the low solids clones (Tables IX and X).

Table VIII
Potato Chip Bulk Density

Sample	Nov.	Dec.	Mar.	*	$\bar{X}$
	Bulk Density, lb/ft^3				
321-65					
321-65	7.2	5.3	7.3		6.6
322-6	5.9	4.8	7.2		6.0
Kennebec	5.9	5.3	(5.7)+		5.6
709	6.1	4.3	5.7		5.4
711-3	6.2	5.2	4.4		5.3
706-34	5.5	4.4	4.3		4.7
58	4.9	4.5	4.3		4.6
711-8	3.8	5.2	4.6		4.5
706-32	4.3	4.5	3.9		4.2
1111-2	3.8	4.0	3.9		3.9

\+ dummy value
* Differences at 5% level, Duncan's Multiple Range Test.

Table IX
Potato Chip Hunter L Values

Sample	Nov.	Dec.	Mar.	*	$\bar{X}$
	Hunter L Value				
321-65	53.2	62.3	60.4		58.6
322-6	40.4	62.8	55.5		52.9
Kennebec	42.0	56.3	55.5		51.3
711-3	46.2	55.6	50.6		50.8
711-8	37.4	56.5	45.2		46.4
709	43.8	41.4	45.6		43.6
58	39.0	41.6	47.8		42.8
706-32	37.7	37.2	46.6		40.5
706-34	32.0	40.7	40.7		37.8
1111-2	36.2	36.4	36.0		36.2

* Differences at 5% level, Duncan's Multiple Range Test.

Table X
Potato Chip Hunter a/b Ratio

Sample	Nov.	Dec.	Mar.	X	*
	Hunter a/b ratio				
1111-2	0.56	0.51	0.46	0.51	
706-34	0.63	0.46	0.38	0.49	
58	0.54	0.48	0.31	0.44	
706-32	0.51	0.52	0.29	0.44	
709	0.42	0.43	0.33	0.39	
711-8	0.57	0.19	0.32	0.36	
711-3	0.42	0.19	0.25	0.29	
Kennebec	0.46	0.18	0.17	0.27	
322-6	0.51	0.02	0.13	0.22	
321-65	0.23	0.02	0.03	0.09	

* Differences at 5% level, Duncan's Multiple Range Test.

Sensory Evaluation. Potato chips made in November were found to be different from Kennebec in color and flavor. In addition, 321-65 and 322-6 were different from 709 in color and 321-65 was different from 709 in flavor. Texture was found to be different between Kennebec and 322-6 and 321-65. The differences between 709 and the other clones is due to greater nonenzymatic browning. The panel at the second processing time found all of the clones to be different from Kennebec in color, flavor and texture. For color and flavor, the third panel found Kennebec, 321-65 and 322-6 different from 709 which was judged less acceptable. No texture differences were observed.

<u>French</u> <u>Fries</u>. Yield, peeling loss and moisture content were not different for either times or clones. Yield varied

from 33.1 lb to 52.4 lb/100 lb (Table XI). Peeling loss was found to range from 15.3% to 34.2% (Table XII). Table XIII shows the moisture content of the french fries which varied from 42.6% to 56.9%.

Table XI.
French Fry Yield

Sample	Nov.	Dec.	Mar.
	Yield (lb/100 lb)		
321-65	52.4	48.8	47.9
Russet Burbank	48.4	45.8	41.7
711-8	45.6	45.0	46.1
711-3	44.4	42.3	49.5
322-6	45.2	41.7	44.1
58	44.5	40.0	47.1
706-34	33.2	47.8	47.1
709	36.9	43.5	47.7
706-32	33.1	44.3	46.6
1111-2	33.4	39.2	46.8

Table XII.
French Fry Peeling Loss

Sample	Nov.	Dec.	Mar.
	% Peeling Loss		
Russet Burbank	21.5	24.3	23.8
321-65	18.2	24.0	22.1
322-6	18.1	23.0	22.8
709	20.2	20.8	20.4
711-3	20.3	23.2	18.3
711-8	17.1	25.9	19.6
58	21.1	25.3	19.2
706-32	34.2	20.6	20.7
706-34	33.0	18.0	15.3
1111-2	20.0	25.5	18.0

Table XIII
French Fry Moisture Content

Sample	Nov.	Dec.	Mar.
	% Moisture		
Russet Burbank	50.3	49.9	47.0
321-65	43.9	42.6	44.9
322-6	48.9	45.0	44.4
711-3	49.6	47.8	50.9
711-8	54.4	51.8	52.9
58	52.2	53.2	56.7
709	56.7	51.4	56.9
706-32	52.4	54.9	55.4
706-34	53.2	53.7	56.4
1111-2	56.3	53.3	55.3

Table XIV
French Fry Oil Absorption

Sample	Nov.	Dec.	Mar.	X	*
	% Oil (Dry Basis)				
706-32	29.5	31.3	30.8	30.5	
1111-2	29.0	31.7	29.6	30.1	
706-34	29.4	28.9	31.2	29.8	
709	27.6	26.9	28.3	27.6	
58	28.6	26.2	27.5	27.4	
711-8	26.8	27.5	26.5	26.9	
711-3	21.1	23.1	25.0	23.1	
Russet Burbank	21.4	23.5	22.7	22.5	
322-6	21.7	19.1	21.8	20.9	
321-65	21.2	19.1	20.8	20.4	

* Difference at 5% level, Duncan's Multiple Range Test.

Oil Content. Differences in oil content at the 1% level. were found between clones. Oil absorption ranged from 31.7% to 19.1% (Table XIV). The correlation between solids and oil content was r = -0.85, 1% significance. Storage time did not affect the absorption of oil.

Texture. Instron Universal Testing Instrument maximum shear force values differed between samples at the 1% level. They varied from 3.0 kg to 7.3 kg and were significantly higher for the higher solids clones. In addition to maximum force, the shape of the curve is also related to the textural characteristics. Figure I illustrates the differences in the curves of two clones of different texture. Clone 322-6 (November) is representative of a desirable, mealy textured french fry. It has a pronounced crust burst peak followed by relaxation and a long crust shear peak. Clone 706-32 (November), results in a soggy french fry which is evident from the lack of a crust burst and a lower crust shear peak. Representative curves from the rest of the clones are found in the appendix A.

Table XV.
French Fry Maximum Shear Force

Sample	Nov.	Dec.	Mar.	$\bar{X}$	*
	Maximum Force (Kg)				
322-6	4.8	5.9	7.3	6.0	
321-65	5.9	5.2	5.2	5.4	
Russet Burbank	5.2	4.5	5.6	5.1	
58	4.8	3.8	3.9	4.2	
706-32	4.5	3.8	3.6	4.0	
711-3	4.0	3.8	4.1	3.9	
711-8	4.4	3.6	3.3	3.8	
1111-2	3.4	4.0	3.4	3.6	
706-34	3.2	3.2	3.7	3.4	
709	3.0	3.9	3.0	3.3	

* Differences at 5% level, Duncan's Multiple Range Test.

Color. A significance at the 1% level between times and clones was found for both the USDA color standards and Hunter color values. USDA color varied from 0 to 4 and was darker for 1111-2, 706-32 and 706-34 (Table XVI). Increased storage time gave lighter colored french fries. Hunter L values gave the same general results (Table XVII). This was a good verification of the subjective method as a quality control tool. Hunter b values, a measure of yellowness, are significantly greater for the hybrid clones due to their naturally greater pigmentation (Table XVIII).

Figure I.

Instron Shear Force Curves

of 706-32 and 322-6

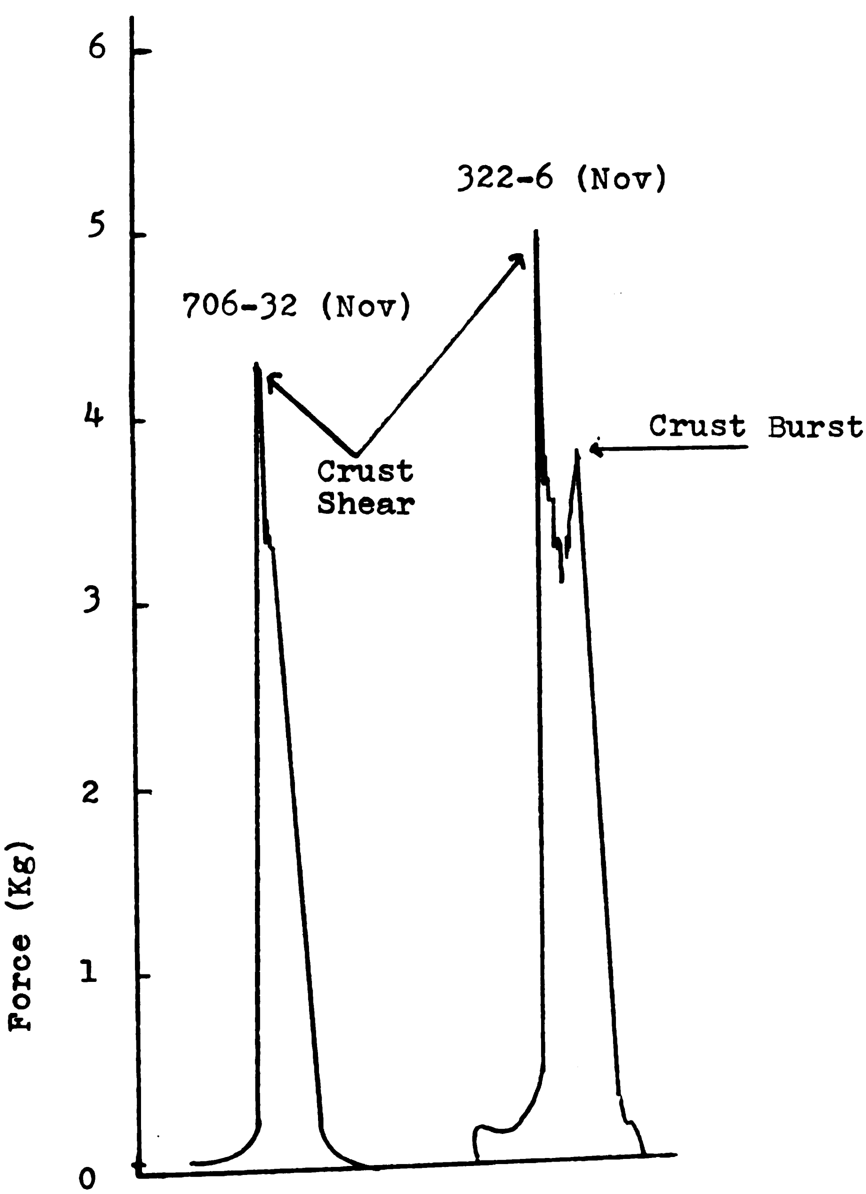


Table XVI
USDA French Fry Color

Sample	Nov.	Dec.	Mar.	$\bar{X}$	*
	USDA Color Values				
1111-2	3	4	2	3.0	
706-32	3	4	2	3.0	
706-34	3	4	2	3.0	
709	2	2	1	1.7	
711-3	2	2	1	1.7	
711-8	2	2	1	1.7	
58	1	3	0	1.3	
322-6	2	1	1	1.3	
321-65	1	1	1	1.3	
Russet Burbank	1	1	0	0.7	

* Differences at 5% level, Duncan's Multiple Range Test.

Table XVII
French Fry Hunter L Values

Samples	Nov.	Dec.	Mar.	$\bar{X}$	*
	Hunter L Values				
321-65	52.2	54.6	54.4	53.7	
Russet Burbank	40.2	49.6	55.8	51.9	
322-6	47.2	54.4	53.6	51.7	
711-3	47.7	46.2	52.2	48.2	
58	42.4	40.8	51.1	44.8	
709	41.0	44.0	48.6	44.5	
711-8	44.9	39.6	47.8	44.1	
706-32	40.2	31.2	44.4	38.6	
706-34	40.4	31.2	43.5	38.4	
1111-2	37.2	31.6	43.4	37.4	

* Difference at 5% level, Duncan's Multiple Range Test.

Table XVIII
French Fry Hunter b Values

Sample	Nov.	Dec.	Mar.	$\bar{X}$	*
	Hunter b Values				
321-65	24.8	25.0	24.3	24.7	
322-6	22.1	25.1	24.5	23.9	
Russet Burbank	20.7	19.6	21.8	20.7	
711-3	21.0	20.7	19.4	20.4	
709	17.8	18.4	19.7	18.6	
711-8	19.2	17.4	18.3	18.3	
58	18.1	17.8	18.5	18.1	
706-32	17.2	12.8	18.0	16.0	
706-34	17.5	12.6	17.4	15.8	
1111-2	15.3	12.1	17.9	15.1	

* Differences at 5% level, Duncan's Multiple Range Test.

Sensory Evaluation. The first lot of french fries were found to be different from Russet Burbank in color, flavor and texture. Differences were not significant in the last two panels for any of the attributes. This is believed to be due to the panels being divided as to whether the clones were better or worse than the reference.

Potato Flakes. Peeling loss and flake thickness was not different between clones or times. Peeling loss ranged from 12.6% to 26.4% (Table XIX) and flake thickness varied from 0.004 inch to 0.008 inch (Table XX).

Yield. Differences between clones at the 5% level were found. The high solids potatoes tended to have the higher yield. Yield varied from 13.0 lb to 23.2 lb/100 lb. (Table XXI). The correlation between solids and yield was r= 0.97, 1% level.

Table XIX
Potato Flake Peeling Loss

Sample	Dec.	Mar.	Apr.
	% Peeling Loss		
Russet Burbank	21.3	22.7	19.7
709	12.6	24.7	18.0
1111-2	23.8	18.6	-
706-32	26.4	21.7	-
711-3	21.1	20.9	-
711-8	24.8	20.6	-
58	24.6	19.6	-
322-6	(19.4)	19.9	23.7
321-65	21.5	25.3	24.9

Table XX
Potato Flake Thickness

Sample	Dec.	Mar.	Apr.
	Flake Thickness (1/1000 in.)		
Russet Burbank	7	6	7
709	5	4	5
1111-2	5	5	-
706-32	5	5	-
706-34	6	5	-
711-3	6	7	-
711-8	5	6	-
58	5	7	-
322-6	6	6	6
321-65	5	8	7

Table XXI
Potato Flake Yield

Sample	Dec.	Mar.	$\bar{X}$	*	Apr.
	Flake Yield (lb/100 lb)				
321-65	21.6	21.5	21.6		23.2
322-6	19.1	21.3	20.2		21.0
Russet Burbank	19.4	18.8	19.1		19.6
711-3	17.4	19.6	18.5		-
706-34	15.6	17.4	16.5		-
711-8	15.6	17.8	16.4		-
58	14.8	17.7	16.2		-
709	18.1	14.1	16.1		17.5
1111-2	13.5	16.0	14.8		-
706-32	13.0	15.2	14.1		-

* Difference at 5% level, Duncan's Multiple Range Test.

Table XXII.
Potato Mash Solids Content

Samples	Dec.	Mar.	$\bar{X}$	*	Apr.
	% Mash Solids				
321-65	26.2	26.8	26.5		29.3
322-6	23.2	24.7	24.0		26.2
Russet Burbank	23.0	22.6	22.8		23.3
711-3	21.2	23.8	22.5		-
711-8	19.9	20.8	20.4		-
58	18.8	21.1	20.0		-
706-34	18.5	20.5	19.5		-
709	19.9	18.0	19.0		20.5
1111-2	17.0	18.9	18.0		-
706-32	17.0	18.7	17.8		-

* Differences at 5% level, Duncan's Multiple Range Test.

All of the yields are converted to a 6% moisture basis for comparison purposes.

Mash Solids Content. Solids content was different between times and clones. Increases in solids with time occured. Clone 321-65 was significantly higher than all of the others, while 322-6, Russet Burbank and 711-3 followed in solids content (Table XXII).

Bulk Density, Production Rate, Flake Moisture and Blue Value. Differences were observed in all of these attributes with processing times. This is attributed to the use of additives at the second processing stage. All of the characteristics were generally improved. In March all of the clones were treated with sodium acid pyrophosphate and only Russet Burbank, 709, 321-65 and 322-6 were treated with all of the additives. Since no differences between clones occured, the changes were logically attributed to the use of SAPP. Bulk density was found to increase with time, and varied from 6.5 lb/ft^3 to 9.2 lb/ft^3 (Table XXIII). Table XXIV shows the production rates obtained. They varied from 1.2 to 4.5 $lb/ft^2/hr$.

Table XXIII
Potato Flake Bulk Density

Samples	Dec.	Mar.	Apr.
Bulk Density, lb/ft^3			
Russet Burbank	9.2	8.4	8.8
709	6.7	8.7	8.8
1111-2	6.7	7.6	-
706-32	6.5	7.9	-
706-34	7.1	8.1	-
711-3	6.5	7.0	-
711-8	6.7	7.1	-
58	6.6	7.6	-
322-6	7.6	7.3	7.7
321-65	7.8	8.3	8.4

Table XXIV
Potato Flake Production Rate

Samples	Dec.	Mar.	Apr.
Production Rate lb/ft^2/hr.			
Russet Burbank	2.8	3.5	2.5
709	1.8	1.6	2.2
1111-2	1.4	2.0	-
706-32	1.4	1.2	-
706-34	1.7	2.1	-
711-3	1.9	4.5	-
711-8	1.4	2.2	-
58	1.7	4.5	-
322-6	2.6	2.3	2.4
321-65	2.4	4.0	2.7

Flake moisture varied from 2.8% to 8.1% and tended to be higher in the March samples (Table XXV). SAPP resulted in a very large reduction in Blue Value in all cases (Table XXVI). Blue value varied from 110 to 270 in the untreated samples and from 44 to 112 in the treated samples.

Table XXV
Potato Flake Moisture Content

Sample	Dec.	Mar.	Apr.
	% Moisture		
Russet Burbank	6.6	7.7	8.5
709	3.2	4.4	4.4
1111-2	5.0	5.9	-
706-32	3.4	3.4	-
706-34	2.8	3.4	-
711-3	3.6	4.5	-
711-8	2.9	6.1	-
58	2.8	8.1	-
322-6	3.7	5.3	5.6
321-65	3.6	5.6	6.8

Table XXVI
Potato Flake Blue Value

Sample	Dec.	Mar.	Apr.
	Blue Value		
Russet Burbank	152	85	44
709	162	85	54
1111-2	152	80	-
706-32	270	112	-
706-34	245	97	-
711-3	110	97	-
711-8	178	95	-
58	158	85	-
322-6	170	80	60
321-65	205	104	44

Color. Hunter L and b values were different for clones and L value was also different for times. The range in L value was from 75.7 to 84.7, while b value varied from 14.0 to 24.8. Color was generally better for the second processing time and with Russet Burbank, 321-65, 709 and 322-6. It was noted that color improved with time for both french fries and flakes. This must be due to some compositional change in the potatoes other than reducing sugar content which could not be related to color with time. The differences in b value are due to the yellow pigments in the hybrid clones and nonenzymatic browning which was evident in some of the clones (Table XXVIII).

Table XXVII
Potato Flake Hunter L Values

Sample	Dec.	Mar.	$\bar{X}$	*	Apr.
	Hunter L Values				
Russet Burbank	82.7	84.7	83.7		83.4
321-65	80.9	83.0	82.0		81.8
709	81.7	80.7	81.2		83.2
322-6	79.7	82.0	80.8		80.1
711-3	79.7	80.7	80.2		-
711-8	78.2	82.0	80.1		-
58	78.8	81.0	79.7		-
1111-2	78.0	78.6	78.3		-
706-34	76.3	79.4	77.8		-
706-32	75.7	75.9	75.8		-

* Differences at 5% level, Duncan's Multiple Range Test.

Table XXVIII
Potato Flake Hunter b Values

Sample	Dec.	Mar.	$\bar{X}$	*	Apr.
		Hunter b Value			
322-6	24.8	24.3	24.6		24.0
321-65	22.6	24.5	23.6		24.0
706-34	22.6	20.6	21.6		-
706-32	21.3	20.8	21.0		-
1111-2	21.4	20.5	21.0		-
711-8	20.4	18.8	19.6		-
711-3	20.2	18.1	19.2		-
58	19.8	17.6	18.7		-
709	18.0	19.3	18.6		17.3
Russet Burbank	14.0	15.8	14.9		16.2

* Differences at 5% level, Duncan's Multiple Range Test.

Sensory Evaluation. The clones were judged to be different in color from Russet Burbank. The difference in 709 was not due to natural pigmentation, and was not evident from the Hunter color values. Differences in flavor between 709, and 322-6 and Russet Burbank were also detected. Texture was different only for 709. Further sensory evaluation to determine preferences was not conducted because of problems with the flavor of the flakes containing additives.

Potato Flake Stability. Flakes with no additive showed no significant differences in Hunter L or b values between the 0 and three and six month -10°F and 75°F lots. However, the changes were visually apparent for the hybrid clones at 75°F. It is believed that the small amount of data was probably the reason no statistical significance was obtained. The flakes with antioxidant did not show any differences (Tables XXIX and XXX).

Table XXIX.
Stability of Hunter L and b Values in
Flakes Without Antioxidant

	Hunter L and b Values									
	0 mo.		3 mo.				6 mo.			
			-10°F		75°F		-10°F		75°F	
Sample	L	b	L	b	L	b	L	b	L	b
Russet Burbank	88.7	14.0	82.8	14.3	82.5	13.0	12.8	14.2	82.4	13.1
322-6	79.7	24.8	79.7	20.0	80.6	14.3	80.8	19.0	80.2	14.3
321-65	80.9	22.6	81.4	21.8	81.4	14.0	81.2	21.4	81.2	13.0

Table XXX.
Stability of Hunter L and b Values in
Flakes With Antioxidant

	Hunter L and b Values					
	0 mo.		3 mo.			
			-10°F		75°F	
Sample	L	b	L	b	L	b
Russet Burbank	84.7	15.8	83.6	15.8	83.3	15.5
322-6	82.0	24.3	81.2	23.8	80.9	22.4
321-65	83.0	24.5	82.5	24.6	81.0	22.6

Pigment Extract. The absorbance values reported in Tables XXXI and XXXII are the absorbance maximas of the visible absorption spectrum of the pigment extract. The maximas occured at 440 nm$\pm$ 5 nm. The maximas varied between the flake samples depending upon clone or variety and the storage condition of the flakes. The peaks were quite distinct for the extract from raw potatoes and freshly made flakes. With storage the peaks broadened, and became less clearly defined. Absorbance decreased with storage time and was generally greater at -10^{o}F than at 75^{o}F. The loss of pigment was significant for the flakes stored without antioxidant at 75^{o}F, low temperature and antioxidant was found to be effective in retarding color loss. Typical absorbance curves, represented by 322-6, are shown in Figure II. Absorbance curves of the rest of the pigment extracts are found in the Appendix.

The extraction procedure as originally applied to the flakes was found to be inadequate for removing all of the pigment. A corrective modification involved adding back enough water to the flakes to make a thick mash. This was applied only to the flakes with additive (Table XXXII) to avoid invalidating the results obtained from the other flakes (Table XXXI). This makes comparison between the additive and non-additive flakes possible only on a relative basis.

Thin layer chromatography was found to be unsatisfactory for characterizing changes in the pigments during storage. The reasons for this were the instability of the pigments and the failure of the sheets used to adequately resolve the compounds present.

Figure II

Title: Visible Spectra of Pigment Extracts from 322-6 (Without Antioxidant).

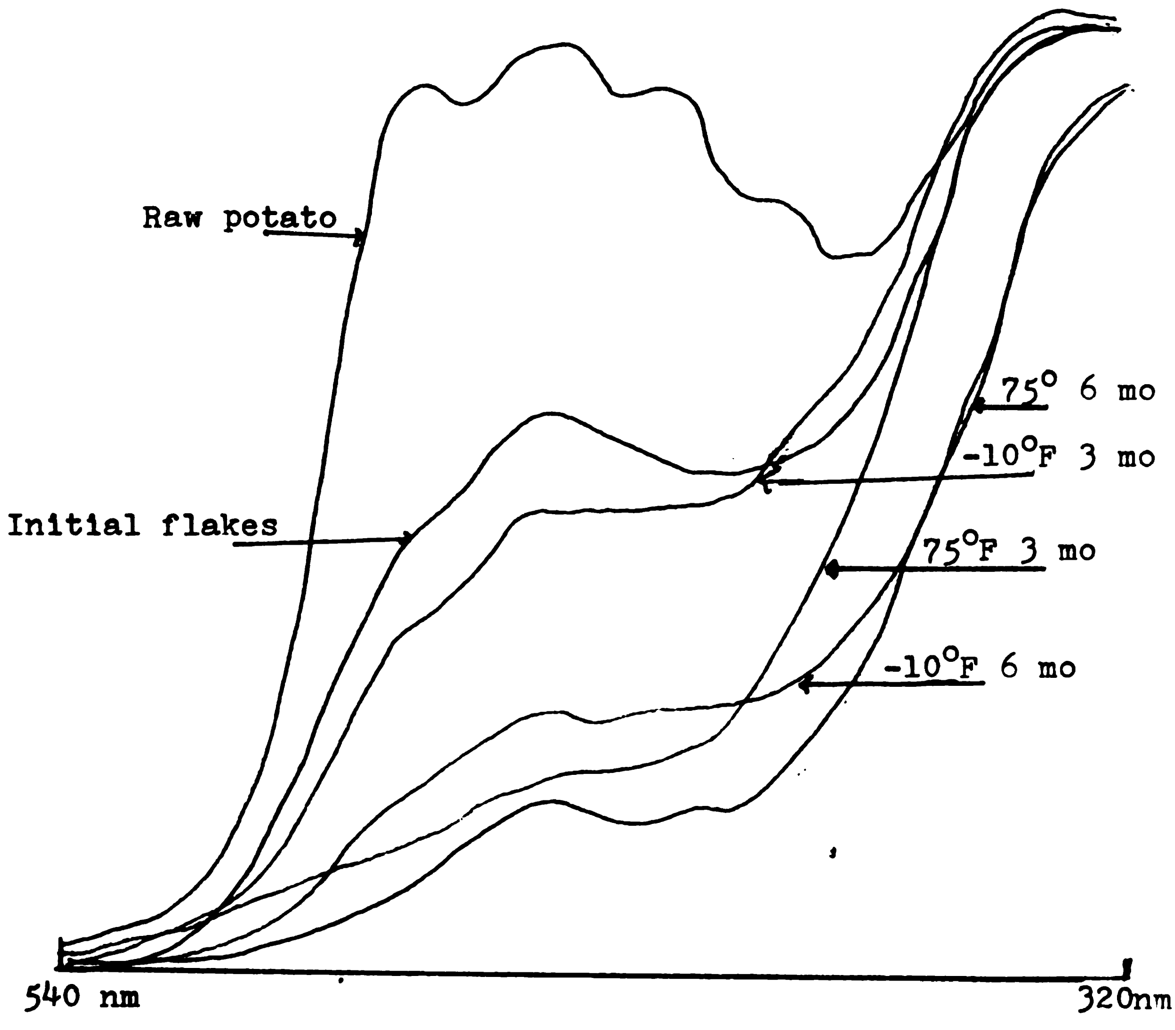


Table XXXI
Maximum Absorbance of Pigment Extract from Flakes Without Antioxidant

Sample	Absorbance 0 mo.	3 mo. -10°F.	3 mo. 75°F.	6 mo. -10°F	6 mo. 75°F
Russet Burbank	0.14	0.12	0.12	0.08	0.06
322-6	0.36	0.28	0.10	0.14	0.08
321-65	0.27	0.27	0.12	0.25	0.06

Table XXXII
Maximum Absorbance of Pigment Extract from Flakes With Antioxidant

Sample	Absorbance 0 mo.	3 mo. -10°F	3 mo. 75°F
Russet Burbank	0.24	0.16	0.14
322-6	0.81	0.76	0.62
321-65	0.68	0.60	0.46

Sensory Evaluation. Russet Burbank was not different between -10°F and 75°F for color or flavor. Clones 321-65 and 322-6 were found to be different in color between the two temperatures. A slight decrease in flavor acceptance was found for 322-6 after storage at 75°F.

SUMMARY AND CONCLUSIONS

In reaching conclusions regarding the processing quality of the clones studied in this project it is important to consider that the samples were obtained from one source and that the production of one year was used. It is most important, therefore to relate to the commercial varieties used as controls in making judgements.

The most important characteristics of the potatoes and their products to be considered in reaching conclusions as to whether they will be successful varieties are yield per acre and yield of product, color, and texture.

In coming to some conclusions as to the potential of the clones, they are divided into those which are unacceptable, those which are marginal and those which are acceptable.

The unacceptable clones included 1111-2, 706-32, and 706-34. They were judged unacceptable because the products made from them were of dark color, the texture of the french fries was not as good as the control, and the product yields were lower.

The marginal clones were 709, 711-8, and 58. They were higher in solids and yield and varied in their color and texture characteristics. Because the response was mixed it is possible that they would respond well in other seasons or growing conditions.

711-3 was considered to have potential as a conventional variety. It had slightly higher solids and yields than the marginal clones and had consistently better color. It is reccommended that this clone be given greater consideration in future studies.

The hybrid clones are considered separately because of their unique properties. Of all the tests run on the potato products, 321-65 and 322-6 usually gave the best results. They had higher yields, lighter color, better texture, less oil, greater bulk density and lower reducing sugars. They are not lacking disadvantages however. They have a characteristic yellow flesh due to a high level of xanthophyll pigments. In the flakes this color is very evident and is unstable unless additives are used to preserve it. The color may also be unacceptable to consumers. It is concluded that three choices exist for dealing with this problem. One is to preserve the color and influence consumers to consider it desirable, the second is to develop a means of bleaching the pigment and the third is to eliminate the pigment to selective breeding. Other factors are important in these clones. The flavor of 322-6 was found to be different by the taste panels and it was found to be slightly undesirable in the stored flakes. The texture of chips is different from other varieties. Whether this is good or bad is not known but the taste panels did detect it. The french fries were also different, having a dryer texture which could be undesirable if it is too dry. This is not a problem in flakes because the moisture in the mashed potatoes made from them can be adjusted to a desirable level.

LITERATURE CITED

1. Association of Official Agricultural Chemists, 1965, Official Methods of Analysis; Tenth, Ed., Washington, D. C.

2. Bakker-Arkema, F. W., 1968, et. al., Production of Instant Legume Powders., Michigan State University, Ag. Expt. Station Mimeo.

3. Borenstein, B. and R. H. Bunnell, 1966, Carotenoids: Properties, Occurance and Utilization of Foods in Advances in Food Research. Vol. 15. Academic Pres. New York.

4. Braverman, J. B. S., Introduction to the Biochemistry of Foods, Elsevier Publishing Co., New York., 1963

5. Brunstetter, B. C. and H. B. Wiseman, 1947, Carotenoid Pigments in Tubers of Katahdin Variety of Irish Potato. Plant Physiology.

6. Chawan, T. B., Effect of Storage Temperature and Atmosphere on the Chipping Quality of Potatoes. M. S. Thesis, Dept. of Food Science., Michigan State University, 1965.

7. Copley, M. J. & Van Arsdel, W. B., 1964 Food Dehydration, Vol. II, AVI Pub. Co. Westport, Conn.

8. Cording, J. et. al., Potato Flakes: A New Form of Dehydrated Mashed Potatoes. I. Pilot Plant Process Using Double Drum Dryer. ARS - 73-2 EUR.DD. USDA., 1954.

9. Cording, J. et. al., Potato Flakes: A New Form of Dehydrated Mashed Potatoes., 1955, II Some Factors Influencing Texture. ARS - 73 - 9 USDA, E. U. R. D. D., 1955.

10. Cording, J. et. al., Advances in the Dehydration of Mashed Potatoes by the Flake Process. Food Technology, 11(4):236, 1957

11. Cording, S., 1959, Estimation of Soluble Starch in Potato Flakes as indicated by Iodine Color of the Water Extract.

12. Drazga, F. H. and R. R. Eskew, Observations on Drum Drying Mashed Potatoes, Food Technology: 16(12): 103, 1962.

13. Drazga, F. H., R. K. Eskew & F. B. Talley, 1964, Storage Properties of Potato Flakelets., Fooa Technology 18:1201.

14. Drazga, F. H., R. K. Eskew & F. B. Talley, Storage Properties of Potato Flakelets., Food Technology 18:1201, 1964.

15. Drazga, F. H., R. K. Eskew & F. B. Talley, 1964, Storage Properties of Potato Flakelets., Food Technology 18:1201.

16. Eskew, R. K. & F. H. Drazga, 1962, Potato Flakelets - A New Dense Product from Flakes. Food Technology 16(4):99.

17. Feustel, I. C. et. al., 1963, Processing of Frozen French Fried Potatoes and Other Frozen Potato Products. W. U. R. D. D., U. S. D. A. ARS - 74-8.

18. Fitzpatrick, T. J., E. A. Talley, and W. L. Porter, 1965, Preliminary Studies on the Fate of Sugars and Amino Acids in Chips Made from Fresh and Stored Potatoes. J. Agr. and Food Chem. 13:10, 1965.

19. Fitzpatrick, T. J., E. A. Talley, and W. L. Porter, 1965, Preliminary Studies on the Fate of Sugars and Amino Acids in Chips Made from Fresh and Stored Potatoes. J. Agr. and Food Chem. 13:10.

20. Freed, M. Ed., 1966, Methods of Vitamin Assay. Interscience. John Wiley & Sons., New York.

21. Gould, Wilbur A., Potato Chip Processing and Collection of Data. Mimeo. Dept. of Horticulture., The Ohio State University, Columbus, Ohio.

22. Guenther, W. C., Analysis of Variance, Prentice-Hall, Inc. Englewood Cliffs, N. J., 1964.

23. Habib, A. T. and Brown, H. D., 1956, Factors Influencing the Color of Potato Chips. Food Technology, 10:332

24. Habib, A. T. and H. D. Brown, 1957, Role of Reducing Sugars and Amino Acids in the Browning of Potato Chips. Food Technology 11 (2):85.

25. Hoover, Edward F. and Xander, Paul A., Potato Composition and Chipping Quality. Am. Pot. J. 38:163, 1961.

26. Hoover, E. F. and Xander, P. A., Influence of Specific Compositional Factors of Potatoes on Chipping Color. Am. Pot. J. 40:17, 1963.

27. Isleib, D.R. and N. R. Thompson, 1957, Potato Handling Equipment for Use in Experimental Work. Am. Potato J. 34:70.

28. Isleib, D. R., 1962, Dehydrated Mashed Potatoes Made from Different Varieties and Sources. Am. Pot. J. 39:149.

29. Jacobs, M. B., 1958, The Chemical Analysis of Foods and Food Products, D. Van Nostrand Company, Inc. Princeton, New Jersey.

30. Kintner, Judith A. and Elizabeth Tweed, 1967, Potato Processing for Dehydration. Food Technology.

31. Li, Jerome C. R., 1964, Statistical Inference I. Edwards Brothers Inc., Ann Arbor, Michigan.

32. Little, T. M., F. J. 1966, Hills, Experimental Methods for Extension Workers, Agricultural Extension Service. University of California, Davis.

33. Mullins, W. R. et. al., Estimation of Free Starch in Potato Grannules and its Relation to Consistency of Reconstituted Product. Food Technology 9 (8):393, 1955.

34. Pendlington, S., Dupont, M. S. and F. J. Trussell, The Carotenoid Pigments of Solanum tuberosum, Biochem. J. 94:25 p., 1965.

35. Purcell, A. E., 1962, Carotenoids of Goldrush Sweet Potato Flakes, Food Technology 16(1):99.

36. Purcell, A. E., W. M. Walter, Jr. and W. T. Thompkins, 1969, Relationship of Vegetable Color to the Physical State of the Carotenes., J. Agr. and Food Chem. 17:41.

37. Reeve, R. M. et.al., 1968, Deterioration of Frozen Pan-Fried Potatoes Upon Holding After Thawing, I. Objective Color Measurement and Fat Absorption. Food Technology 22:205.

38. Reeve, R. M. et. al., 1968, Deterioration of Frozen Pan-Fried Potatoes Upon Holding After Thawing, 2. Composition, Histology and Objective Measurements of Texture. Food Tech. 22:208.

39. Ross, L. R. and W. L. Porter, Preliminary Studies on Application of Objective Tests to Texture of French Fried Potatoes. Am. Pot. J. 43:177, 1966

40. Ross, L. R. and W. L. Porter, Interpretation of Multiple Peak Shear force curves obtained with French Fried Potatoes. Am. Potato J. 45:461, 1968.

41. Ross, L. R. and W. L. Porter, Objective Measurements of French Fried Potatoe quality. Laboratory Techniques for Research use. Am. Potato J. 46:192, 1969.

42. Self, R. "Potato Flavor" (Ch. 16) in Symposium on Food Chemistry and Physiology of Flavors, Ed. by Schultz, Day and Libbey. AVI. Pub. Co., Westport, Conn.

43. Shallenberger, R. S., O. Smith and R. H. Treadway, 1959, Role of the Sugars in the Browning Reaction in Potato Chips. J. of Ag. and Food Chem. 7:274,

44. Smith, O., Potatoes: Production, Storing, Processing, Westport, Conn., AVI Publishing Co., 1968.

45. Smith, O. and C. O. Davis, Potato Quality XIII. Preventing After-Cooling Discoloration in Oil Blanched French Fries. Am. Pot. J. 39:45., 1962.

46. Smith, O. and C. O. Davis, Potato Quality XIV Preventing Graying in Dehydrated Potato Products. Am. Pot. J. 39:135, 1962.

47. Smith, O. & C. O. Davis., 1963, Potato Quality XV. Improving Texture and Measuring Textural changes in Potato Flakes. Am. Pot. J. 40:67, 1963.

48. Talburt, W. F. & Smith, O., 1967, Potato Processing, 2nd Ed. AVI Pub. Co., Westport, Conn., 1967.

49. Treadway, R. M., 1961, Work Session on "Developing Potatoes For Processing." Am. Potato J. 38:414.

50. U. S. D. A., 1967, "United States Standards for Grades of Frozen French Fried Potatoes." 1967 Fruit and Vegetable Division, C & MS. U. S. D. A., W. D. C., 1967.

51. Wall, M. E. and E. G. Kelly, Determination of Pure Carotene in Plant Material, Ind. Eng. Chem. Anal. Ed. 15:18, 1943.

52. Zaehringer, Mary V. et. al., Specific Gravity and Composition of Potatoes for various Processing and Cooking Purposes, Potato Handbook:, 1967.

APPENDIX A

INSTRON SHEAR FORCE CURVES OF FRENCH FRIES

Figure III

Title: Instron Shear Force Curves of French Fries.

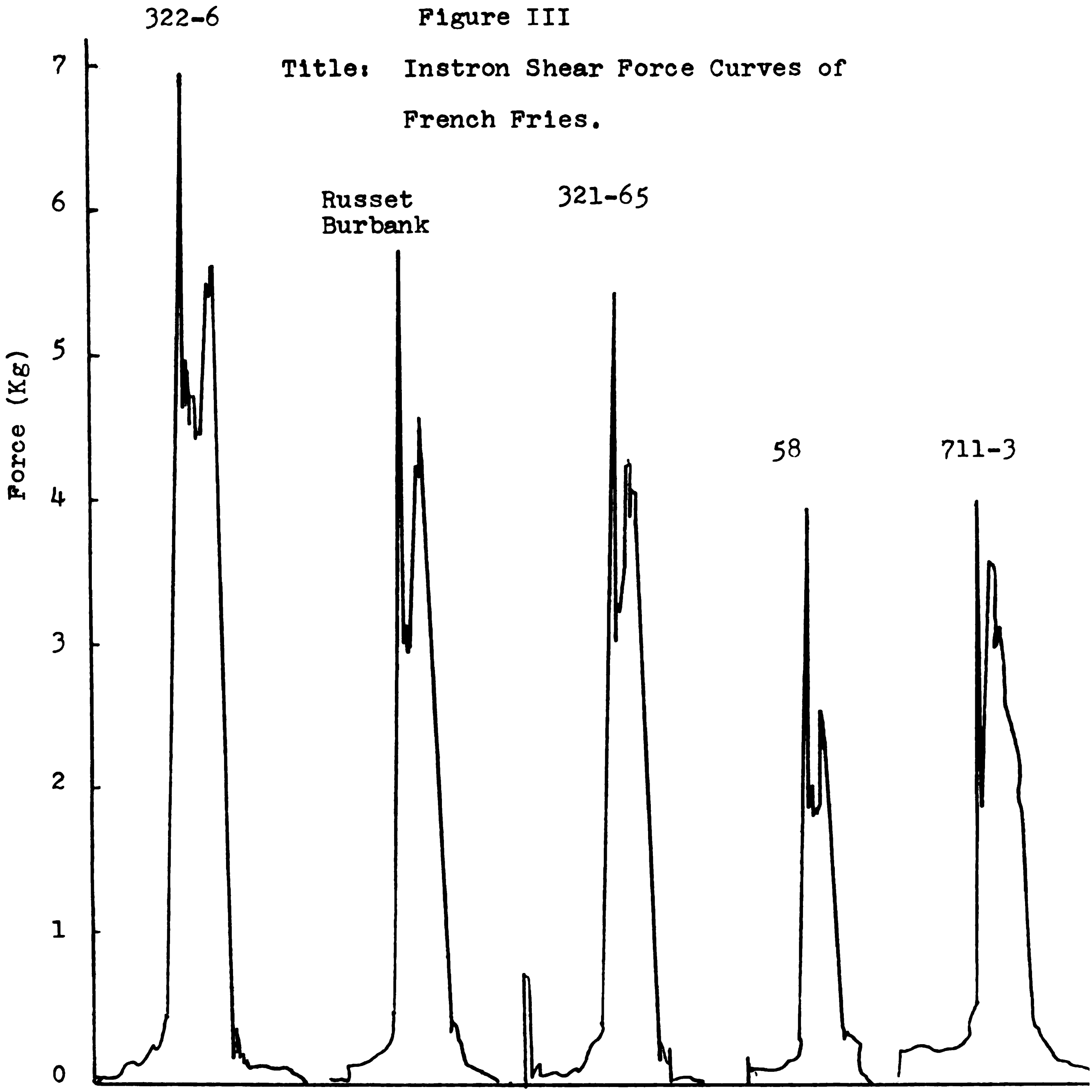
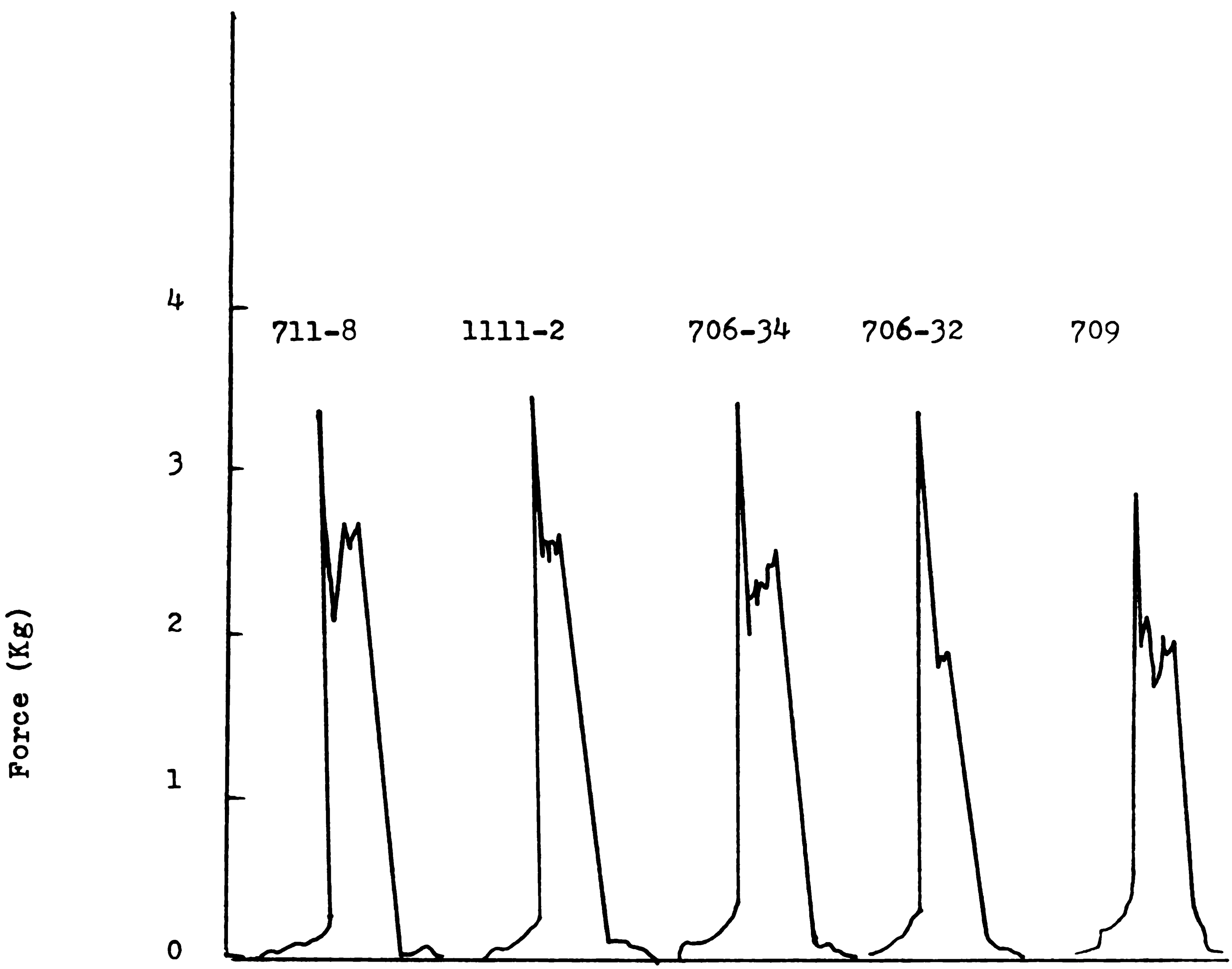


Figure IV

Title: Instron Shear Force Curves of French Fries.



APPENDIX B

VISIBLE SPECTRA OF PIGMENT EXTRACTS

Figure V

Title: Visible Spectra of Pigment Extracts From Russet Burbank (Without Antioxidant).

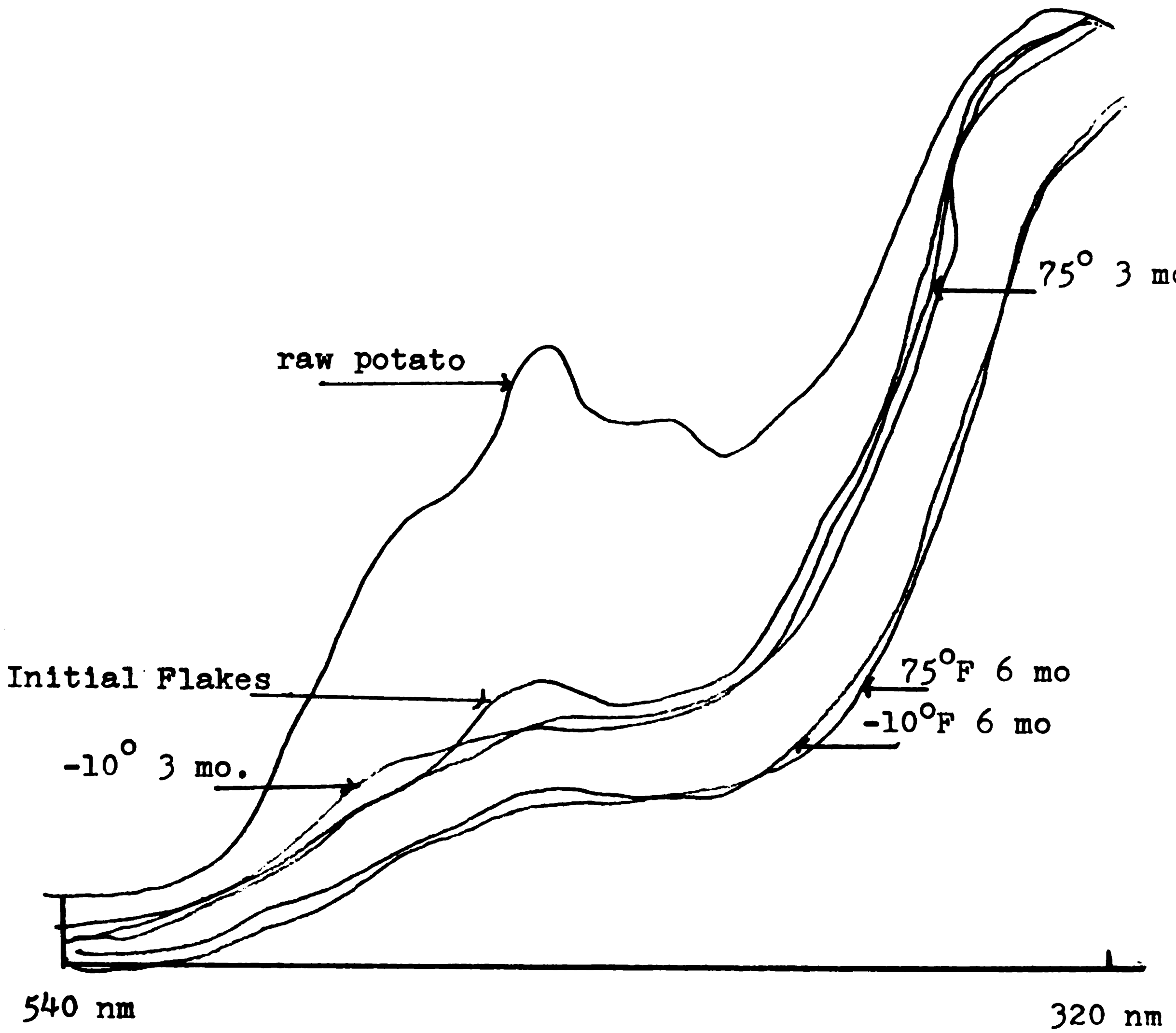


Figure VI

Title: Visible Spectre of Pigment Extracts from Russet Burbank (With Antioxidant)

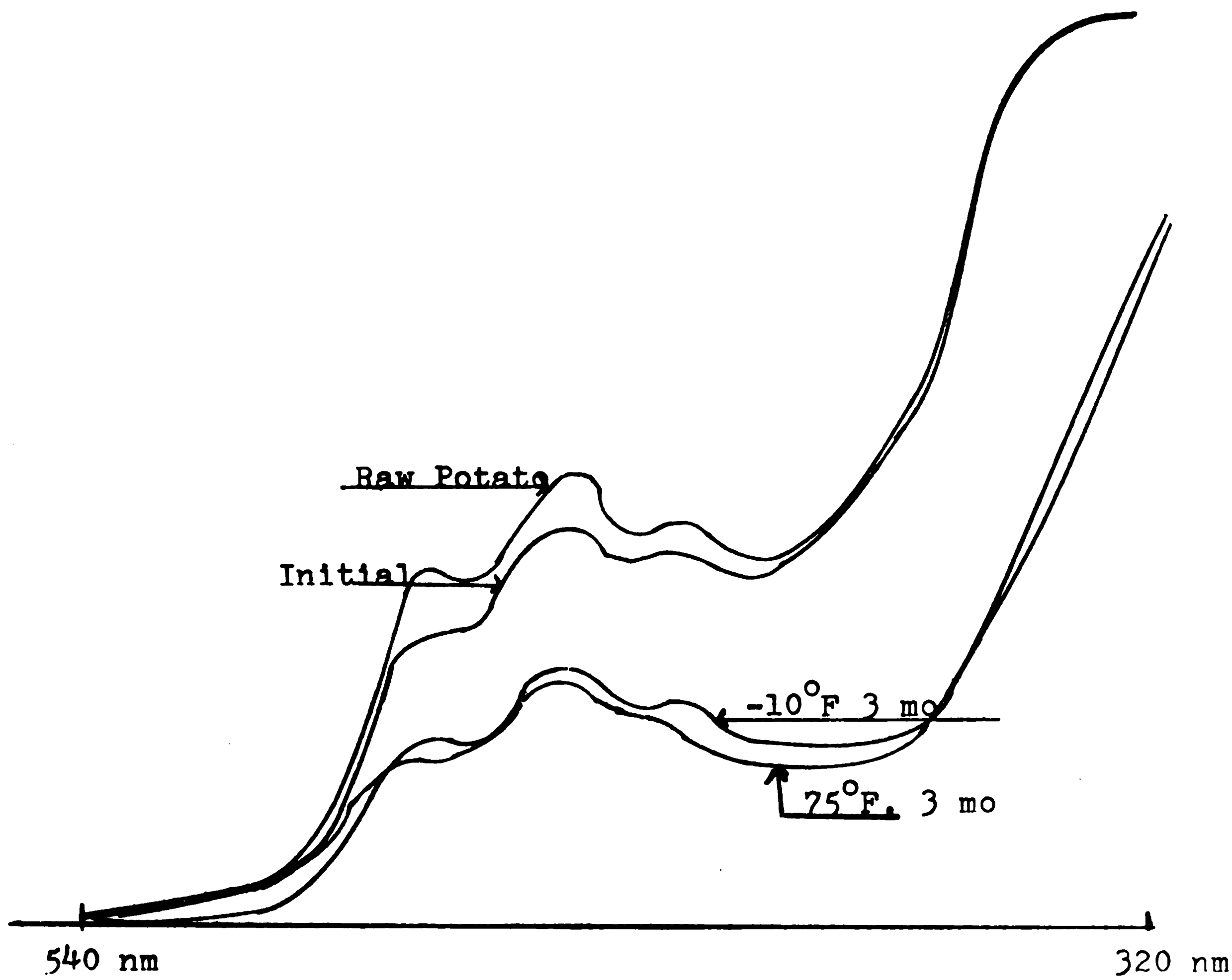


Figure VII

Title: Visible Spectra of Pigment Extracts from 322-6 (With Antioxidant).

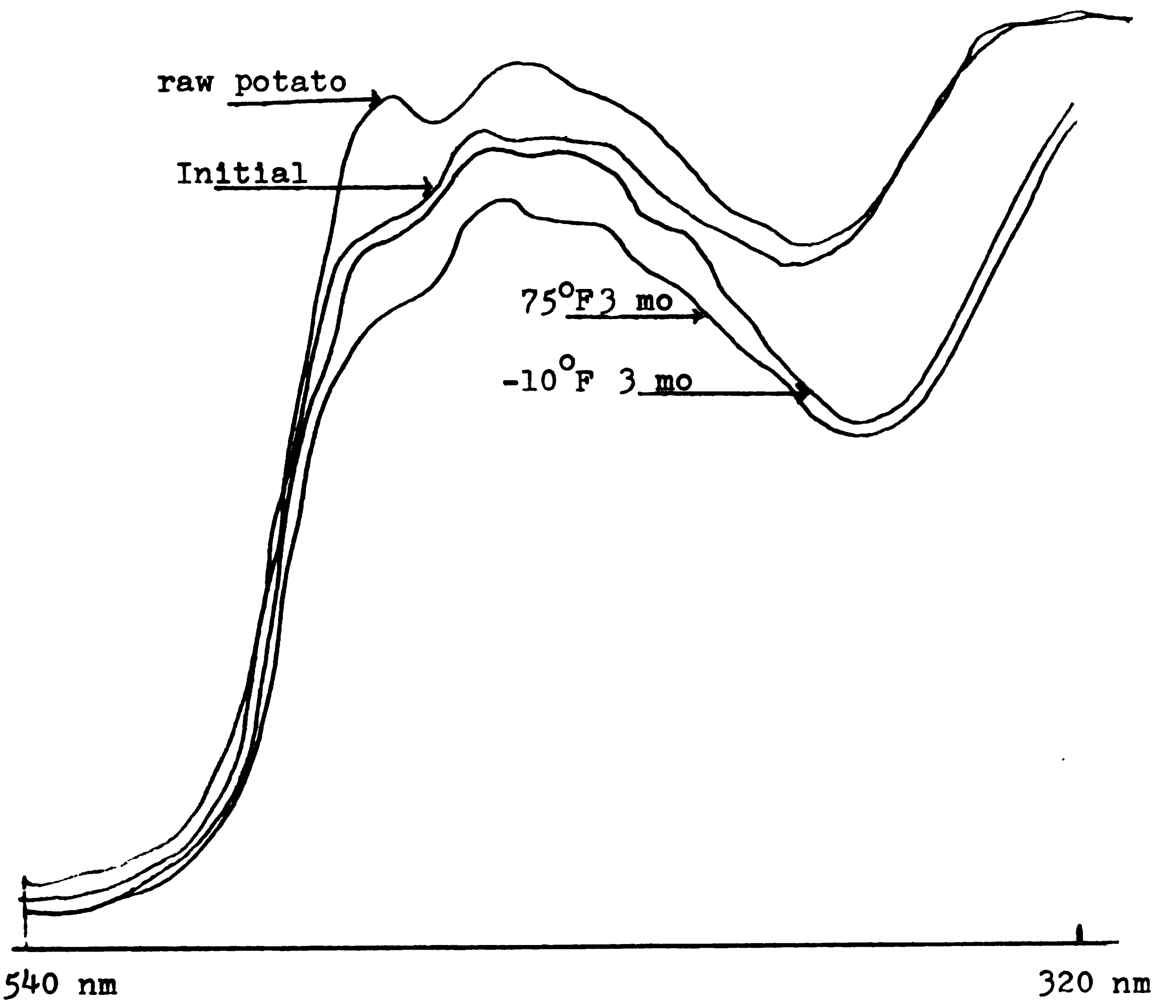


Figure VIII

Title: Visible Spectra of Pigment Extracts from 321-65 (Without Antioxidant).

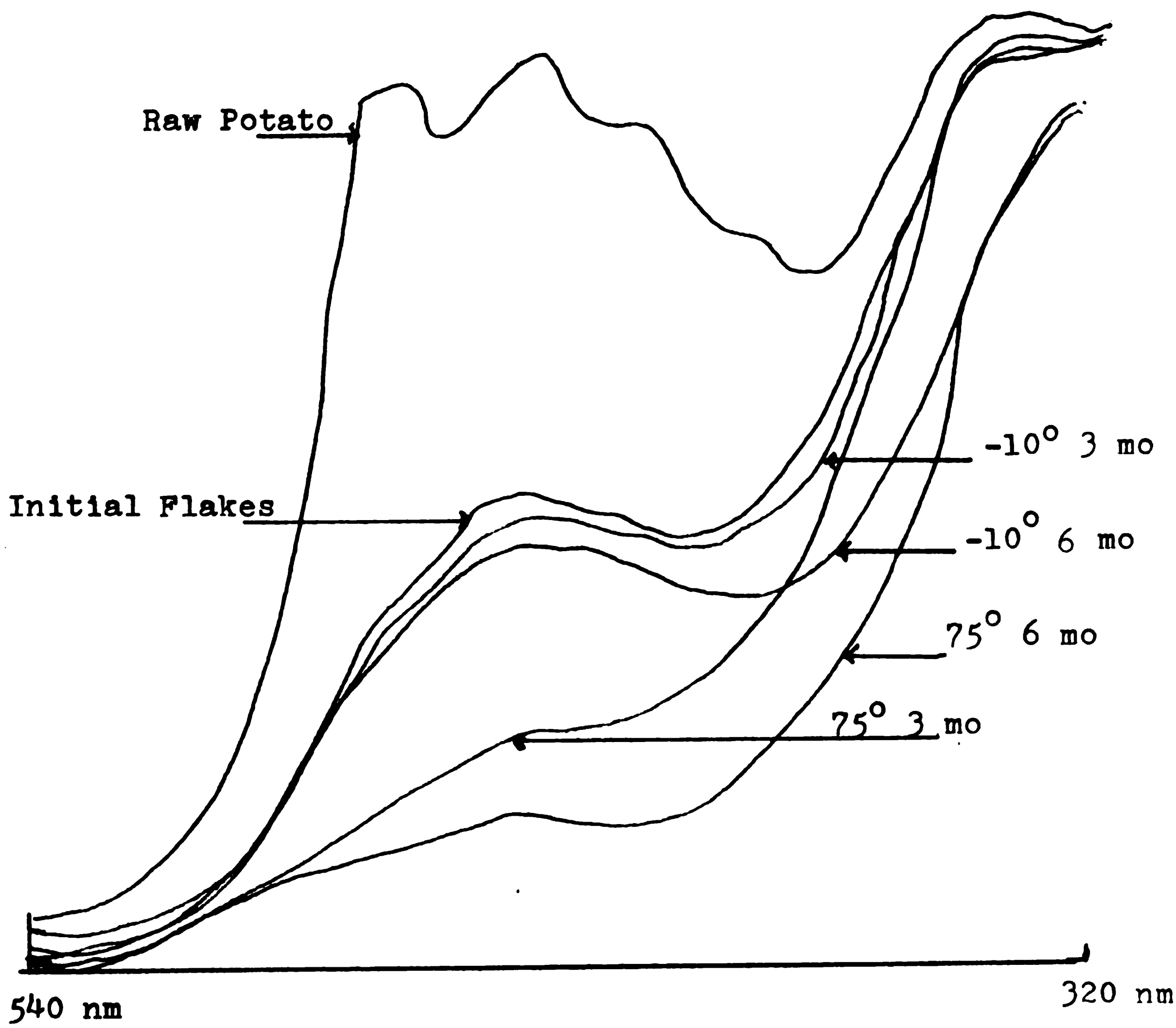


Figure IX

Title: Visible Spectra of Pigment Extracts from 321-65 (with Antioxidant).