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I am submitting herewith a thesis written by Laura Rachelle Pippin entitled "The Effects of Conventional and Convection Oven Baking Treatments on the Texture of Osmotically Processed, Par-fried, Frozen Potato Strips." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

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Associate Vice Chancellor and Dean of The Graduate School

THE EFFECTS OF CONVENTIONAL AND CONVECTION BAKING TREATMENTS ON THE TEXTURE OF OSMOTICALLY PROCESSED, PAR-FRIED, FROZEN POTATO STRIPS

A THESIS
PRESENTED FOR THE
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LAURA RACHELLE PIPPIN
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DEDICATION

This thesis is dedicated to my parents

Mrs. Carolyn Flatt Pippin and Mr. Paul M. Pippin

who have financially supported my career

as a "professional student".

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ABSTRACT

This research was undertaken to study the effects of two baking methods, conventional and convection ovens, on osmotically processed, par-fried, frozen potato strips (OPPFPS). The finished potatoes were evaluated objectively for texture using a TA-XT2 Texture Analyser II and a TA 200 French fry attachment. The OPPFPS also were evaluated by a sensory panel and these results were compared to the objective measurements. The relationship of sensory scores to each other was determined.

Fresh cut potato strips were osmotically processed in a 60° Brix, 43 DE, high-maltose corn syrup solution at 21°C for 2 hr. The osmotic processing produced a 29% loss in moisture and <1% gain in solids, when compared to fresh-cut potato strips. The osmotically processed strips were par-fried in vegetable oil at 190°C for 15 sec and then frozen until needed. OPPFPS were baked at 204°C in a conventional oven for 12 to 21 min or a convection oven for 4 to 9 min.

OPPFPS baked 21 min in a conventional oven contained 47% total solids compared to 38% solids in strips baked 12 min. The OPPFPS baked 9 min in a convection oven contained 44% solids compared to 37% solids in strips baked 4 min. The fat levels in the strips did not change during baking in either oven. OPPFPS contained less fat on a caloric basis (12%) than typically baked, par-fried potato strips (35%) as reported by the USDA (1982).

Average forces (g) required for twenty 1-mm probes to move through 14-mm sections of ten strip samples of OPPFPS were determined. The average forces required to move through a 3.5-mm section of the OPPFPS surrounding the initial maximum force (PK1) were 1566 and 1371 g for strips baked in a conventional oven for 12 and 21 min, respectively. PK1 values were 2140 and 1511 g for strips baked in the convection oven

for 4 and 9 min, respectively. The minimum force (MIN) required to move through the samples was 1022, 636, 1522, and 702 g, for the 12, 21, 4 and 9 min baking treatments, respectively.

Sensory evaluation consisted of panelists scoring their perceptions of an "ideal" baked French fry and then evaluating baked OPPFPS on a scale from "not at all"=1 to "very much so"=6 for six texture, three flavor and overall acceptability attributes. The 21-min and 9-min baked OPPFPS were less crisp (2.9), less firm (3.1) and more soggy (2.9) than panelists perceived an "ideal" baked French fry (4.9, 4.2 and 1.5, respectively). The baked OPPFPS were similar in sweetness (2.4) to an "ideal" French fry (2.4). The 9-min baked OPPFPS were perceived as more oily (3.2) but no more greasy (2.9) than an "ideal" French fry (2.4 and 2.3, respectively).

Significant ($\leq$ 0.05) correlations were found between instrumental PK1 and MIN values and sensory values for "firm" (0.64 and 0.55), "crispy" (-0.54 and -0.49), and "off-flavor" (-0.51 and -0.52). The instrumental PK1 values also were correlated with sensory values for oily (0.42) and soggy (0.41). Panelists' comments indicated that OPPFPS baked for 18 and 21 min in the conventional oven had "burned" flavors. Therefore, these times were too long for baking this type of product at 204°C. OPPFPS baked 9 min in the convection oven were scored most acceptable by the sensory panel. However, only 44% of the panelists found these potato strips from slightly to very much acceptable.

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CHAPTER I

INTRODUCTION

Potato production totaled 19 billion kg in 1991. The value of this production was 2.04 billion dollars. Approximately 54% of the potatoes produced in the United States in 1991 were used as processed products, 49% of which were frozen French fries (USDA, 1992). Potatoes are a staple in the American diet. Dietary goals for Americans recommend that no more than 30% of daily caloric intake come from fat (Anon., 1977). When potatoes are prepared commercially as French fries, they contain over 60% fat by calories, and baked home fries contain 35%. Research by Chen (1993) suggested that osmotic processing of potato strips in some corn syrup solution yields potato strips which contain approximately one-third of the oil content of a typically French fried potato strip. This osmotic processing would reduce the calories contributed by fat in French fried potato strips to less that 30% fat by calories.

French fries which absorb less oil during preparation have three major benefits over traditional fries. The first benefit is that osmotically treated strips contain fewer calories from fat than regular strips. The second and third benefits are related to processing economy. Less energy is required to freeze the concentrated strips than regular fries, because concentrated potato strips contain less water than untreated ones. Since osmotically concentrated strips absorb less oil during the frying process, less cooking oil is needed.

However, drawbacks in producing osmotically concentrated fries exist. The high soluble solids content of treated fries tends to contribute to excessive browning of the fries before they are cooked thoroughly. When osmotically treated fries were evaluated by a 50-

member panel, the fries were rated not as acceptable as the fresh cut, control fries. The researchers attributed this result to the "lack of doneness" and poor texture of the osmotically concentrated fries (Chen, 1993). The potatoes were fried to an acceptable color and not an acceptable texture. Had Chen (1993) used texture as the frying endpoint, the color of the strips would have been much too dark. This study was undertaken to determine if conventional and/or convection baking methods could be employed to produce more desirable, fully cooked osmotically processed, par-fried, frozen potato strips.

Objectives

The first objective of this research was to compare the effects of two baking methods, convection and conventional ovens, on osmotically processed, par-fried, frozen potato strips. The finished potatoes were evaluated objectively for texture using the Texture Analyser and a TA 200 French fry attachment. The second objective was to evaluate baked osmotically processed, par-fried, frozen potato strips using sensory evaluation and to compare these results to the instrumental texture measurements. The relationship of sensory terms to each other also was determined.

CHAPTER II

REVIEW OF LITERATURE

Economic importance of French fries

The United States produced 3.3 billion kg of frozen packed potatoes in 1993. Eighty-six percent of which were packed as French fries. In 1993 the U.S. exported 218,880 metric tons of French fries valued at approximately 154 million dollars (Anon., 1995).

Nutritional composition of potato

The most commonly consumed variety of potato is *Solanum tuberosum* L. Potato tubers (enlarged stolons or underground stems) are approximately 78% moisture, 20% carbohydrates, and 2% protein. By weight, 80% of the carbohydrates found in potatoes are starch. Potato starch consists of amylopectin (75-79%) and amylose (21-25%). Potato protein contains all of the essential amino acids with methionine and cystine being somewhat limited. Potatoes are an excellent source of vitamin C and are good sources of iron and magnesium. They also contain substantial amounts of thiamin, riboflavin, and niacin.

Fat content of par-fries

Institutional par-fries contain about 4% fat, and retail par-fries contain 5-7% fat (USDA, 1982). The difference is due to a longer par-fry time for the retail fries. Home fries tend to contain even higher amounts of fat. Par-fry times are sometimes lengthened in products intended for home use to reduce limpness and increase oily flavor of the fries

(Talburt and Smith, 1987). Huxsoll (1982) reported that par-frying resulted in a 31% net loss in fry weight, with a 6.5% weight gain in oil. Final frying caused a 60% weight loss due to evaporation, a 13% gain in oil weight, and just over a 45% net weight loss. Proximate compositions of selected potato products (USDA, 1982) appear in Table 1.

Factors affecting yields of raw materials

The overall yield of raw French fries tends to fall within the range of 50-75% of the raw potatoes processed (Talburt and Smith, 1987). The type of raw materials used to produce French fries affects the yield. One hundred kg of unpeeled potatoes yield 30-45 kg of finished fries. By choosing the best raw potatoes peeling and cutting losses can be reduced. Peeling and trimming account for 15-40% of processing losses. Removal of slivers and nubbins can account for an additional 10% loss (Talburt and Smith, 1987). When choosing potatoes for fry processing, potatoes should be: smooth-shouldered, shallow-eyed, uniformly sized, defect free, and high specific gravity (Lisinska and Leszczynski, 1989).

Traditional French fry processing steps

Potatoes have to be washed to remove excess dirt, rocks, and trash. Washing can be done by transporting potatoes in water from storage to a peeling area, or it can be accomplished in several types of washers. The outer surface of potatoes is usually removed by conventional lye peeling or abrasive peeling. These two methods reduce losses from peeling. Trimming removes residual skin, green areas, eyes, black spots, rotten spots, and insect injuries. Electronic sorting of whole peeled potatoes allows the defective tubers to be removed. Potatoes are then cut into crinkle-cut or straight-cut strips which are sorted by length. Slivers and nubbins are removed. Blanching in water or steam

Table 1--Proximate composition of 100-g edible portion of potato products

Product	Moisture (g)	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrates (g)
Raw potato[a]	78.96	79	2.07	0.10	17.98
Par-fried potato[b]	65.22	164	2.56	6.46	25.03
Baked par-fried potato[b]	52.90	222	3.46	8.75	33.90
Strips French fried in oil[c]	37.99	315	4.03	16.57	39.56
Ore Ida® Straight Cut[d]	69.05	143	2.38	4.76	23.81
Ore Ida® Crinkle Cut[d]	66.07	167	2.38	4.17	27.38
Kroger Crinkle Cut[d]	69.05	143	2.38	4.76	23.81

[a]Potatoes were peeled (USDA, 1982).
[b]Par-fried in vegetable oil (USDA, 1982).
[c]Strips were par-fried in vegetable oil and prepared in a restaurant by finish frying in vegetable oil (USDA, 1982).
[d]As calculated based on commercial product nutrition labeling, this information is for packaged potato strips prior to baking.

is the next processing step. Blanching has four advantages: (1) more uniform color of the potatoes after frying, (2) reduced fat absorption into the potatoes during frying, (3) reduced frying time, and (4) improved texture of the final product. Dewatering screens are used to remove excess surface moisture resultant from water blanching. Par-frying or oil-blanching for 30-90 sec for institutional fries and 2-4 min for retail fries in 177-190°C oil has been standard industry practice. Par-frying stops any surface enzyme activity remaining after water blanching, and provides the potato-oily flavor associated with French fries. Excess oil on the surface of fries is removed, and the fries are cooled prior to freezing. This decreases the load on the freezer and reduces the chances of fry breakage. Dark, over-fried, or defective fries are removed prior to individually quick freezing, and the fries are then packaged (Talburt and Smith, 1987).

High quality raw materials for French fry manufacture

The most important factor in producing good French fries is the potato variety. Russet Burbank and Netted Gem are generally used in the United States. Other suitable varieties include: Katahdin, Kennebec, Irish Cobbler, Sebago, Russet Rural, Acadia Russet, and Shepody. Bintje is not typically grown in the United States but is popular in European countries. Specific gravity should fall within the range of 1.080 to 1.112. Reducing sugar content should be less than 0.3%, because reducing sugar content affects fry color (Lisinska and Leszczynski, 1989; Talburt and Smith, 1987). Frying oil is also important. Hydrogenated shortenings are good choices for frying because of their high smoke points and resistance to foaming and gum formation (Talburt and Smith, 1987). Careful monitoring of frying oil is necessary to prevent the formation of off-flavors and colors.

Factors affecting French fry quality

The five main quality factors attributing to French fry quality , as stated by Lisinska and Leszczynski (1989), are: texture, oil content, flavor, color, and total appearance. Talburt and Smith (1987) listed flavor, surface color, fat absorption, form and symmetry, external texture (crispness), and internal texture (mealiness). Texture is generally considered a more important sensory attribute than flavor or color in french fries. In fact, texture frequently defines the overall cooking quality of potatoes (Böhler et al., 1986). Jaswal (1989) suggested that firmness and mealiness are the two most important textural attributes in French fries. The outer portion of good fries should be moderately crisp, show no noticeable separation from the inner portion, and should not be excessively oily. The external texture should be crispy, without being gummy or tough (Talburt and Smith, 1987). The center portion should be completely cooked, tender, and not soggy.

Some studies have reported that dry matter, starch, specific gravity, cell and starch grain size, pectic substances, and non-starchy polysaccharides are factors that affect cooking quality and overall textural characteristics of potatoes. High quality fries usually contain between 20-22% dry matter with 14-16% being starch (Lisinska and Leszczynski, 1989). Low specific gravity potatoes produce droopy, limp fries that shrivel after frying. Talburt and Smith (1987) also noted that fries prepared at home are often soggy, limp, greasy, too dark, or scorched because consumers cannot purchase the high quality potatoes necessary for fry making. Talburt and Smith (1987) also stated that many fries manufactured for institutional use do not produce good home fries. This is probably due to the short par-fry time and high moisture content.

Lisinska and Leszczynski (1989) stated that French fried potato odor and flavor were dependent mainly on the raw potatoes and fat used. Talburt and Smith (1987) as well as Lisinska and Leszczynski (1989) said fries should exhibit a "potato-oily" flavor, and the interior flavor should resemble that of boiled potatoes. French fries should not retain a raw potato flavor. Fry internal and external flavor should not contain bitter, sweet, scorched, and/or caramelized notes. There should be no detection of rancid flavors imparted from the frying oil (Talburt and Smith, 1987).

French fries should be colored a light, golden brown without mottling by brown or black spots. The fries should not have streaks, traces, or grey areas. Color is most affected by the chemical composition of the raw tubers. Of the chemical constituents, reducing sugars are most responsible for fry color. The reducing sugar content should be less than 0.3% for good colored French fries (Lisinska and Leszczynski, 1989). Marquez and Añon (1986) found that reducing sugar content increases when potatoes sprout or if the potatoes are stored at low temperatures (3°C) for more than 6 or 7 days. As reducing sugar content increases, the color quality of fried potatoes decreases. Acceptable color limit ranges for luminosity (L) and chromaticity (a/b) of fried potatoes were given as 51 to 60 for L and chromaticity as -0.20 to 0.35 (Marquez and Añon, 1986).

Osmotic processing

Osmotic dehydration or concentration is a water removal process that consists of placing a food product in a hypertonic solution and allowing the water to diffuse from the food pieces into the surrounding solution. Water and solids move into and out of the solution, but the net water weight lost by the food product is greater than the solute gained. The quantity of moisture removed depends upon several factors. Increasing immersion time, concentration of the solution, solution temperature, and surface area of the food product all increase moisture loss from the product (Ponting et al., 1966). Chen (1993) reported that 43 DE corn syrup as an osmotic solution yielded higher moisture losses from potato strips than did 26 DE corn syrup. As time, concentration, and temperature of the osmotic treatments increased within each DE, moisture loss increased. Moisture was lost at a faster rate during the beginning of osmotic treatment and declined as the solids levels approached osmotic equilibrium. No trends were reported for solids gained. Chen (1993) suggested that an osmotic treatment of 3 hr at 20°C in a 60%, 43 DE corn syrup was preferred for producing potato strips.

Corn syrup

Corn syrup is made from acid or acid-enzyme hydrolyzed corn starch. The depolymerization of corn starch produces smaller and smaller sugar fragments, resulting in dextrose (glucose). A wide variety of syrups are produced depending on the type of hydrolysis and operating conditions used. Acid/heat processed corn syrups wield inconsistent results due to the lack of specificity with which the starch polymers are cleaved. Enzymatic breakdown of starch, although more expensive than acid/heat processes, produces corn syrups containing known constituents based upon the type of enzymes utilized. High maltose corn syrup is produced by a combination of acid/heat processing and enzymatic treatment (Anon, 1996). Dextrose equivalent (DE) is an expression of the depolymerization in corn syrup and is defined by deMan (1990) as "the total amount of reducing sugars expressed as dextrose and is calculated as a percentage of the total dry matter." Maltodextrins have a DE of 3 to 20. Glucose syrup has a DE of 20 or greater. High fructose corn syrup is produced from greater than 95% glucose solutions and contains both glucose and fructose.

Corn syrup solutions are good osmotic agents due to their high solids content. Solutions with high DE levels are more effective because they increase mono- and disaccharide content increasing the osmotic potential. These solutions can function at room temperature; however, some energy may be required to reconcentrate the syrup

(Huxsoll, 1982). They may impart flavor to the product, but the flavor is not as sweet as using a sucrose solution. Corn syrup solutions do not promote the severe color changes that salt solutions do. Corn syrup solutions may be reconcentrated and reused (Bolin et al., 1983).

Types of heat transfer

According to Matz (1972) conduction, convection, and radiation are three energy transfer mechanisms found at work during the baking process. One or more energy transfer mechanisms may occur within each oven type. Convection is the transfer of heat energy to food by the circulation of heated water or air currents. The convection currents are generated in ovens due to the changes in density created upon heating of the water or air. Convection ovens use convection currents which have been generated by the built-in fan to force the heated air onto food surfaces. The increased air flow leads to a more even browning of food surfaces, shorter cooking times, and lower cooking temperatures (Matz, 1988). Conduction is the secondary mode of energy transference in convection ovens. The use of forced convection currents in convection ovens minimizes heat variations throughout the oven chamber (Matz, 1988).

Conduction, as defined by McWilliams (1989), is "the transfer of energy from one molecule to the adjacent molecule in a continuing and progressive fashion so that heat can pass from its source, through a pan, and ultimately throughout the food being cooked." Conduction is the primary mode of energy transfer in conventional ovens. The pan, tray, or tin food container also conducts heat directly to the food surfaces that are in direct contact with the container (Matz, 1988). Radiation and convection also play roles in the conventional oven.

Radiation is a direct method of transferring heat energy, as rays or waves, to food.

Broiling continuously heats food surfaces. When the heat source is off, food is heated by conduction rather than radiation. Radiant energy is subject to shadowing and is responsive to changes in absorptive capacities of the pans, tins, dishes, food products (Matz, 1972). Direct exposure and reflectance effect the amount of browning that occurs during the baking process. For instance, aluminum foil may be used to cover a pie during the early stages of baking to prevent excessive browning of its crust. Darker pans absorb more energy and increase browning where products touch the pans. Cookies placed on shiny pans will have lighter bottoms than cookies placed on darker pans when cooking time and temperatures are held constant.

Texture of cooked potato

Burton (1989) stated that there have been many attempts to correlate raw tuber characteristics with their cooked texture. Knowing this would aid in the prediction of potato cooking behavior. Cooked potato texture results from several contributing factors including: cell size, starch content, the final softness of cell walls, the degree of adhesion remaining between cells, and the extent of cell rupturing. Linking a single factor consistently with cooked potato texture is difficult because of the complexity of interactions among all of the factors. The correlation used most often for prediction of cooked potato texture is the percentage dry matter (or starch) content with mealiness.

Pectins, which comprise over 50% of cell wall materials, provide cell wall strength and cellular adhesion within raw potato tissues. The breakdown of middle lamella pectins during cooking causes cell walls to soften and weaken, and thus the potato softens as it cooks. The resistance of cooked potato to penetrometer or to being cut by a wire, is positively correlated to starch content and mealy texture (Burton, 1989). It was suspected that potatoes which responded this way retained much of their cellular adhesion. Nonaka

(1980) found that the longer the potato tissue was heated, cell adhesion decreased and cell ruptures increased.

Other factors affect cooked potato texture. Even though growing environment (soil type, alkalinity, etc.) influences cooked tuber texture, variety is a better predictor of textural tendency. Customers, depending upon their needs, make purchases based upon variety. The growing season also affects the texture of cooked potatoes. Sloughing increases after hot, dry weather, and potatoes grown during wet seasons are usually more waxy or soapy. Second growth may be responsible for soggy-textured stolon ends of cooked tubers. Storage affects cooked potato texture as well. The cold storage of potatoes at less than 8°C resulted in the evolution of sweet flavors and soggy texture. Potatoes from the same lot which were stored at 8-10°C were pleasantly flavored and had mealy textures. Excessive sprouting results in a hard texture after cooking (Burton, 1989).

Instrumental texture measurement of French fries

DuPont et al. (1992) used three testing instruments to objectively measure French fry textural attributes. The researchers used an instrumented pendulum to measure impact strength; a second pendulum test, based upon the Charpy impact test, to measure impact energy; and an Instron Universal testing machine 3-point bend test to measure elasticity modulus, flexural strength, and deflection to fracture. In the instrumented pendulum tests, a pendulum hammer equipped with an indentor bar was allowed to strike each 5-fry sample. The French fry samples were held against a flexible backplate and were mounted perpendicularly to the indentor bar. Pendulum hammer energy was determined by the drop height. A potentiometer attached to the arm spindle was used to measure penetration depth into sample and rebound height. For the Charpy-based pendulum test, 10-single French fry samples were supported by a L-shaped ledge which contained a central gap.

A J-hammer struck the center of the fry and the swing energy loss was recorded. Corrections for kinetic energy following impact and free swing energy were made to calculate the energy required to break the sample. Low strain rate tests were conducted using an Instron 1122 Universal testing machine. A 3-point bend test was performed using 5-mm radius abutments, an unsupported sample span of 40 mm, and a crosshead speed of 5 mm per min^{-1}. Equations which describe deformation behavior of rectangular beams in pure bending were used as approximations to calculate elasticity modulus, flexural strength, and deflection to fracture. DuPont et al. (1992) concluded that the Charpy pendulum test provided less data, more scatter, and less sensitivity for differentiation between materials. The instrumental pendulum was a simple and compact way to produce enough data to differentiate between mechanical properties. The Instron low strain rate tests indicated similar trends as the instrumental pendulum device. DuPont et al. (1992) also concluded that crispness was the sensory attribute most related to mechanical strength whether measured under low or high strain conditions. Chen (1993) used maximum shear force (N) as measured by an Instron Universal Testing machine as an indicator of relative hardness of the fries. She found that osmotically treated fries were softer in texture than control fries.

CHAPTER III

MATERIALS AND METHODS

Fresh, Idaho-grown, 60 count per 22.7 kg (50 pounds), whole Russet Burbank potatoes were purchased from a local produce market (Neel's Produce, Inc., Knoxville, TN) on an as-needed basis. The potatoes were stored at 20°C and 90% relative humidity to prevent the formation of additional reducing sugars. Car-Gill, Inc. (Memphis, TN) provided 43 DE, high-maltose corn syrup for making the 60° Brix (w/w) corn syrup and tap water solution. The specification sheet for the corn syrup is in Appendix A. A high-maltose corn syrup was selected to yield a finished potato product that would be less sweet and less likely to brown when heated than regular corn syrup.

A sodium chloride and tap water solution having a specific gravity of 1.070 at 21°C was used to evaluate the specific gravity of approximately one-third of each lot of whole, raw potatoes. Only potatoes from tested lots having a minimum specific gravity of 1.070 were mechanically sliced (Hobart Manufacturing Co., Troy, OH) longitudinally into 1.27 x 1.27 cm wide strips. Interior potato strips which had geometrically squared widths and heights were selected and cut into uniform 7-cm lengths. After cutting, the strips were stored in tap water for no longer than 30 min. Surface water was removed from the strips by drying for 4 min in a 21°C impingement oven (Wear-Ever Impinger II, by Lincoln).

The strips were then submerged in 21°C, 60°Brix osmotic solution in a ratio of 1:5 (w/w) potato to syrup for 2 hr. Preliminary study using a 60°Brix sucrose solution yielded fries which were discolored before par-frying could be accomplished. Immersion times of strips in the 60° Brix , high maltose corn syrup solution revealed that durations longer than 2 hr adversely affected the potato strip texture. Strips treated longer than 2 hr were limp and browned excessively when par-fried. Ten-fry samples of raw, non-osmotically-processed potato strips were weighed, and then were reweighed after osmotic processing. The average weight of 10 raw, non-processed strips was 121 g and 18.8 g solid content. Average weight after osmotic processing decreased to 87 g and the solids content increased to 27.2 g. The strips osmotically processed 2 hr lost approximately 29% moisture with less than 1% solids gained. After processing, the strips were drained in a stainless steel, slotted basket so the syrup could be reclaimed. The strips were then rinsed for approximately 1 min in a 21°C agitated tap water bath to remove the clinging solution from the strips' surfaces. Surface moisture was again removed by placing the strips in a 21°C impingement oven for 4 min. The strips were then par-fried in 15.87 kg of frying shortening (FRYMAX, Proctor and Gamble, Cincinnati, OH) at 190°C for 15 sec in a shallow deep fryer (Model No. 8050, Gold Metal Products, Co., Cincinnati, OH). Par-fry times longer than 15 sec caused an undesirable degree of browning of the potato strips. After par-frying the strips were blotted with paper towels to remove most of the surface oil. The osmotically processed, par-fried potato strips weighed 69.2% of the raw potato strips. The strips were then placed one by one on screens so that no strip touched any other strip. The strips were then frozen and placed in freezer bags and held frozen at -20°C until needed. The strips were mixed so that an equal number of strips from each production run were cooked for any trial.

Pilot testing in the conventional (Kenmore Electric Range, Sears, Chicago, IL) and convection (Blodgett Oven Company) ovens determined a range of four times for each oven necessary to produce varying degrees of doneness (partially cooked to overcooked as indicated by visible browning) in the osmotically processed, par-fried, frozen strips. The oven temperature for both ovens was set at 204°C (400°F). The manufacturers' recommended bake times for traditional potato strips baked in the conventional oven ranged from 18-21 min. Pilot testing indicated that bake times longer than 21 min in the conventional oven and times longer than 9 min in the convection oven produced baked strips which were excessively brown. The baking treatment times in the conventional oven were 12, 15, 18, and 21 min. The treatment times in the convection oven were 4, 5.7, 7.3, and 9 min. Bake times were shorter in the convection oven because this oven inherently bakes more rapidly than the conventional oven. Strips were baked on Echo's Baker's Secret® non-stick cookie baking sheets in the conventional oven. Round, 20.32-cm or 8-inch diameter, Echo's Baker's Secret® non-stick coated pans were used to bake strips in the convection oven. Cake pans were chosen to prevent the convection currents from blowing strips together. Preliminary tests indicated the internal temperature of the potato strips was not affected by the use of pans rather than baking sheets.

The conventional oven cavity measured 40.64 cm wide by 57.15 cm high by 41.91 cm deep. In the conventional oven, the racks were placed 13.97 cm and 25.4 cm from the top of the oven cavity. The convection oven cavity measured 38.74 cm wide by 50.8 cm high by 53.34 cm deep. The oven racks were placed 24.13 cm and 35.56 cm from the oven cavity's top.

Physical and chemical measurements

Concentration of corn syrup solids in the osmotic solution was measured by an Abbe refractometer (Model CM5501, Bausch & Lomb Optical Co., Rochester, NY). The proximate components of the ash and protein were not determined for any raw, osmotically processed, par-fried or finished products because experimental treatments should not have changed these values. Moisture contents of raw potato strips; osmotically processed potato strips; osmotically processed, par-fried potato strips, and baked osmotically processed, par-fried potato strips were determined using the AOAC vacuum oven method

14.003 (AOAC, 1984). Two-gram, ground potato samples were weighed and dried in the vacuum oven at 70°C, 175 mm Hg for 24 hr. The solids content was obtained by difference. Crude fat analysis was determined by using a modified, AACC method for the determination of total fat content in flour 30-25 (AACC, 1983). Dried samples (2 g) were secured in Whatman No. 2, 15-cm filter paper and extracted for 8 hr with petroleum ether in a Soxhlet apparatus. The cylindrical solvent reservoir contained 2500 mL before spilling over into the boiling flask. Fill time for the reservoir was approximately 80 min. The solvent was allowed to spill 5 times. After solvent evaporation, samples were dried in a 100°C oven to a constant weight. Crude fat was calculated by difference.

Instrumental texture measurements

Instrumental texture measurements [force (g) by time (sec)] were measured using the TA-XT2 Texture Analyser II (Texture Technologies, Corp., Scarsdale, NY) and a TA 200 French fry attachment. Exact parameter settings for the Texture Analyser II can be found in Appendix B. Ten baked strips, which had been held under the heat lamp (60°C) for approximately 10 min, were placed on the sample holder perpendicular to the stainless steel probes. The TA 200 French fry attachment consisted of two pieces: a 10-fry sample holder which mounted to the Texture Analyser's base and a plastic plate which housed 20 stainless steel, 1-mm diameter probes which screwed into the Texture Analyser's arm. The cylindrical probes, 2 per strip, punctured all of the strips simultaneously without going through the side of the strips that had been in direct contact with the baking pans.

The average force to penetrate the top half of each 10-fry sample (AVG1), the minimum force required to penetrate the core or middle of the fries (MID), and the average force required pass through the bottom half of the fries (AVG2) were calculated. Peak 1 (PK1) was the averaged value of the force required to pass through the 10-fry samples during the 2.5 sec to 6.0 sec portion of the 14 sec test. Peak 2 (PK2) comprised the average force value to pass through each 10-fry sample during 9 to 12.5 sec period of each test. Preliminary texture measurements of maximum force values generated from each curve and the area under each half of the curve were measured and statistically analyzed; however, the analyses revealed that the AVG1, MIN, AVG2, PK1, and PK2 values revealed more significant differences among the treatments.

Sensory analysis

Baked, osmotically processed strips were evaluated by sensory panelists consisting of students, faculty, and staff of the University of Tennessee at Knoxville. Panelists were asked to answer demographic questions, to describe their perceptions of the "ideal" baked French fry, and to evaluate individually 4 samples during each sensory session. Panelists evaluated samples which were illuminated by cool, white fluorescent lighting in isolated sensory booths in the sensory laboratory of the Food Science and Technology Department. Strips were held a minimum of 10 min under a 60°C heat lamp and a maximum of 25 min before being served one at a time to panelists. The 10-min holding time was used to allow the fries to cool so panelists would not get burned by the baked strips. Each panelist received 2 pieces of different strips for each 3-digit, randomly coded sample. The 4 samples were served in a balanced order to prevent positional bias. Score sheets were based on a 6-point, modified consumer texture profile scale as described by Szçzesniak et al. (1975), Swanson and Penfield (1988), and Brochetti and Penfield (1989). Panelists were asked to check the box that applied to each trait for each sample. "Not at all" and "Very much so" were the anchoring terms on both the "ideal" ballot and the sample score cards (Appendix C). Demographic data was collected from the panelists (Appendix C). A simple formula was used to disqualify unsuitable panelists who did not correctly use the scorecards. The polar texture terms "good" and "bad" were selected to gage correct use of the scorecards. For instance, a example of an improper panelist response occurred when the panelists scored a single sample as both "not at all" good and bad. If the good attribute score less the bad attribute score equaled 0.0 or a negative number, the panelists' scores were removed from the data set.

Statistical analysis

Experimental design was a randomized, complete block in which four bake times with three replications were randomized across six days of sensory evaluation (Appendix D). Independent variables include: two oven types, four different cooking times for each oven, and three replicates of each time. The three replicates were placed on the upper and lower baking locations at least once. Dependent variables included: moisture and fat contents of baked, osmotically processed, par-fried, frozen potato strips; the baked potato strips' objective surface and core textures as determined using the Texture Analyzer II; and product characteristic scores and overall acceptability as determined by the sensory panel.

The potato strips baked in each oven were analyzed separately to determine the affects of baking within each oven. Moisture and fat data were analyzed by PROC GLM (SAS, 1989). Sensory evaluation scores including ideal scores and instrumental texture measurements were analyzed by PROC MIXED (SAS/Stat®, 1996). Correlations among the instrumental measurements (AVG1, MIN, AVG2, PK1, and PK2) and each of the sensory evaluation characteristics were determined by PROC CORR (SAS, 1989) (Appendix E). PROC CORR (SAS, 1989) was also used to determine if relationships existed among the sensory attributes. For all statistical procedures, p-values less than 0.05 were considered significantly different.

CHAPTER IV

RESULTS AND DISCUSSION

Proximate analysis

Analysis of variance of the total solids and wet basis, fat contents of baked, osmotically processed, par-fried potato strips (Table 2) indicated that position in the oven did not significantly ($p>0.05$) affect the total solids or fat contents in either the convection or conventional oven. However, the time of baking did significantly affect ($p<0.05$) total solids contents of potato strips baked in the conventional oven as well as total solids and fat contents of convection-oven-baked potato strips.

Total solids and fat (wet basis) mean separations ($p>0.05$) sorted by oven for osmotically processed, par-fried, baked potato strips are shown in Table 3. The solids contents of the osmotically processed, par-fried potato strips baked in the two ovens had similar ranges. The solids contents of potato strips baked in the conventional oven ranged from 36.6 to 44.4 g per 100 g of potato strips, and the convection-oven-baked potato strips ranged from 37.5 to 47.0 g per 100 g potato strips. This indicated that baking time could be manipulated to affect similar solids contents of potatoes in both ovens.

The total solids content per 100 g of the potato strips increased during baking in both ovens. In the conventional oven, the 21-min baked potatoes had a higher solids content, 47.0 g per 100 g, than the 12-min conventional-oven-baked potatoes, 37.5 g per 100 g. Fat contents for conventional oven treatments ranged from 2.7 g to 2.0 g, but there were no significant differences detected. In the convection oven, the potatoes baked for 9 min had significantly more solids, 44.4 g per 100 g, than the other convection oven treatments. Potato strips which baked for 4 min contained only 36.6 g solids per 100 g

Table 2--Analysis of variance[a] of total solids and fat (wet basis) contents of osmotically processed, par-fried, frozen potato strips after having been baked in a conventional or convection oven

Source	df	Mean square	Pr > F
Solids			
Conventional oven			
Time	3	0.0052584	0.0045
Position	1	0.0014727	0.1189
Error	7	0.0004666	
Convection oven			
Time	3	0.0032238	0.0001
Position	1	0.0003256	0.1052
Error	7	0.0000941	
Fat (wet basis)			
Conventional oven			
Time	3	0.0000215	0.2750
Position	1	0.0000125	0.3681
Error	7	0.0000135	
Convection oven			
Time	3	0.0000290	0.0391
Position	1	0.0000125	0.1912
Error	7	0.0000060	

[a]Used PROC GLM (SAS, 1989), with $p < 0.05$.

Table 3--Mean and standard error data[a] for total solids and fat contents of baked, osmotically processed, par-fried potato strips for four conventional and four convection oven treatments which were sorted by oven

Time (min)	Solids mean ± Std error[b] per 100 g edible portion	Fat mean ± Std error[b] per 100 g edible portion
Conventional Oven		
12.0	37.52c ± 1.08	1.99a ± 0.23
15.0	41.06bc ± 2.37	2.33a ± 0.47
18.0	44.79ab ± 2.92	2.29a ± 0.45
21.0	47.03a ± 2.90	2.65a ± 0.24
Convection Oven		
4.0	36.57c ± 1.35	1.93a ± 0.19
5.7	39.63b ± 1.54	2.05a ± 0.36
7.3	41.24b ± 0.21	2.57a ± 0.03
9.0	44.44a ± 0.82	2.46a ± 0.33

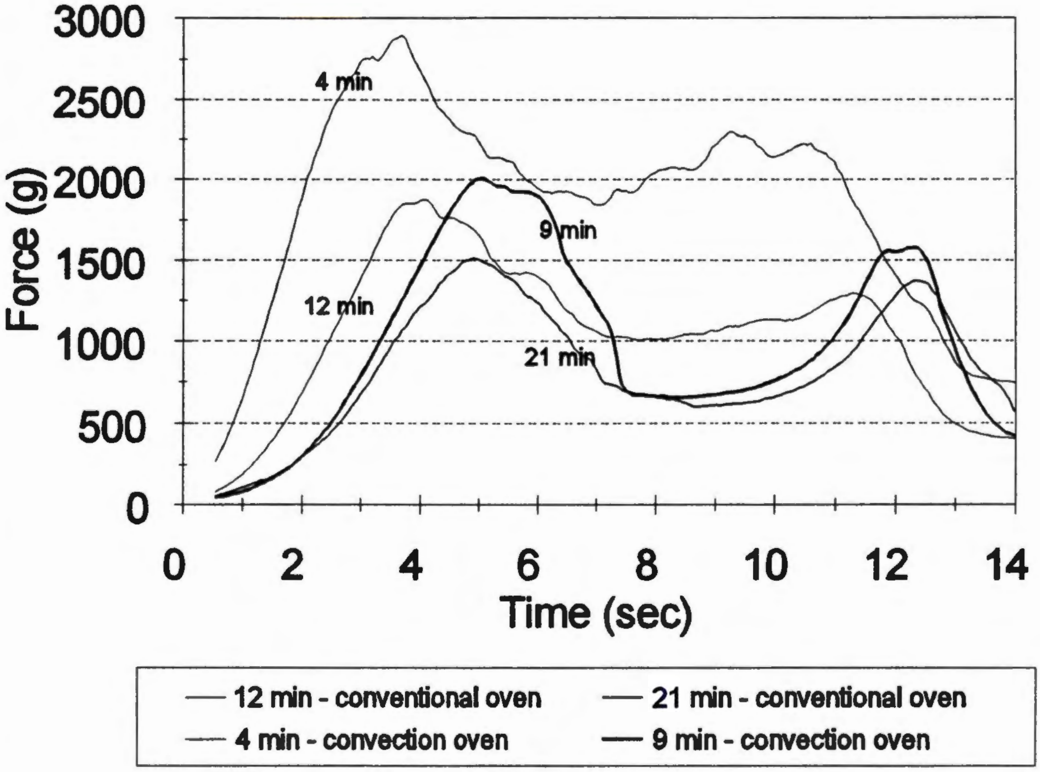
[a]df = 7 for solids and fat data; 3 replications per mean; $p < 0.05$.
[b]Means in the same column within the same oven treatment followed by the same letter are not significantly different.

which was significantly lower than any of the other convection oven treatments. The increase in total solids per 100 g of potato strips with increasing bake times was expected due to the evaporation of moisture from the potato strips during the baking process. Among the convection treatments, fat levels ranged between 2.5 g per 100 g potatoes baked 9 min to 1.9 g per 100 g in the potatoes baked 4 min. The mean separation by Student-Newman-Kuels (SAS, 1989) found no significant differences among the means at a 0.05 probability level even though the analysis of variance had a probability of 0.039.

The USDA (1982) (Table 1, p 5) reported baked, par-fried potato strips contain a solids content of 47.1 g per 100 g of potato. The potato strips baked in the conventional oven for 21 min during this study were very close to this reported value. This indicates the potatoes were baked to a finished product similar to potatoes prepared by accepted baking procedures. However, baked, par-fried potato strips were reported to contain 8.75 g of fat per 100 g edible portion (USDA, 1982). This amount constitutes 35% calories from fat. The baked, osmotically processed, par-fried potato strips from this study ranged from 2.0 to 2.7 g fat per 100 g edible portion in the conventional oven and from 1.9 g per 100 g to 2.6 g per 100 g edible portion in the convection oven. Therefore, osmotically processed, par-fried potato strips ranged from 10-12% calories from fat in the conventional oven and from 11-13% in the convection oven. This reduction in fat would aid in meeting the dietary goal which recommends that no more than 30% of total daily calories come from fat (Anon., 1977).

Instrumental texture measurements

Examples of the force by time curves of the twenty probes moving through ten osmotically processed, par-fried potato strips baked for the minimum and maximum times in each oven are shown in Figure 1. The portions of the curves used to determine the



AVG1 = average force over 0.5 to 7 sec period
PK1 = average force over 2.5 to 6 sec period
MIN = minimum force between the two peak areas
AVG2 = average force over 7 to 14 sec period
PK2 = average fore over 9 to 12.5 sec period

Fig. 1-Typical TA-TX2 Texture Analyser II curves generated from ten osmotically processed, par-fried, potato strips baked for 12 or 21 min in a conventional oven or 4 or 9 min in a convection oven

instrumental texture measurements, AVG1, MIN, AVG2, PK1, and PK2, also are shown. Day did not significantly affect the separations of the force measurements; therefore, treatments were not separated by day. The time by position interaction significantly affected all of the instrumental values in both ovens; therefore, the data were analyzed for the eight time-location combinations in each oven. The Least-squares means (LSmeans) of baked, osmotically processed, par-fried potato strips for the AVG1, MIN, AVG2, PK1, and PK2 data are shown in Table 4.

The LSmean values of AVG1 and AVG2 force (g) texture measurements were lower than corresponding values for PK1 and PK2 force measurements. This was anticipated since PK1 and PK2 values were averages of narrower time ranges on each side of the maximum forces as the probes entered or exited the ten potato-strip samples.

The LSmeans separations for AVG1 and PK1 were similar, as were PK2 and AVG2 LSmeans for potato strips baked in the conventional oven. The potato strips baked for 15 min in the lower position had the largest LSmean values for all five instrumental texture measurements. It was noted during the baking procedures that the potato strips being baked for this combination (15-min, lower rack) were placed in the oven consistently when the heating element was starting to reheat the oven cavity. The oven temperature was set at 204°C but the temperature in the oven ranged from 193 to 204°C during the heating cycle. Since the temperature was at approximately 193°C when baking the 15-min-lower potatoes it would be expected that the effect on the texture of the potato strips would not be as great. This would account for the higher texture values measured instrumentally.

The AVG1 value for potato strips baked for 18 min on the lower rack had the lowest LSmean but the AVG2, PK1 and PK2 LSmeans were not significantly different among the 18-min or 21-min treatments. The LSmeans for the 12-min baked potato strips were not significantly different from the LSmeans for 21-min baked strips for the AVG1, AVG2, PK1,

Table 4—Conventional and Convection oven g force LSmeans[a] and standard error data for the time by position interaction of baked, osmotically processed, par-fried potato strips as determined by the Texture Analyser II

	Conventional oven treatments Cook time (min) and oven position (upper = U or lower = L)							
	12 U	12 L	15 U	15 L	18 U	18 L	21 U	21 L
AVG1[b]	1171bcd ± 88	1209bc ± 72	1231b ± 72	1587a ± 103	1172bcd ± 70	922e ± 87	1053d ± 74	1033cd ± 86
MID[c]	983b ± 109	1062b ± 87	966b ± 87	1456a ± 121	728c ± 84	574c ± 106	641c ± 88	630c ± 107
AVG2[d]	1007bd ± 81	1025bc ± 67	904de ± 67	1403a ± 95	869de ± 65	798e ± 80	890de ± 69	861ce ± 79
PK1[e]	1553bde ± 122	1579bd ± 101	1646b ± 101	1963a ± 132	1596bc ± 97	1240e ± 126	1394cde ± 104	1347de ± 122
PK2[f]	1180bd ± 116	1181bc ± 97	1078bcd ± 97	1598a ± 126	1069bcd ± 93	864de ± 121	981de ± 100	925ce ± 116

	Convection oven treatments							
	4 U	4 L	5.7 U	5.7 L	7.3 U	7.3 L	9 U	9 L
AVG1[b]	1806a ± 206	1416ab ± 147	1224b ± 208	1204b ± 146	1068b ± 146	1212b ± 206	1082b ± 145	1111b ± 205
MID[c]	1887a ± 340	1157ab ± 241	1003ab ± 341	904b ± 240	775b ± 240	824b ± 340	725b ± 240	679b ± 339
AVG2[d]	1852a ± 258	1162b ± 183	1020b ± 259	958b ± 182	884b ± 183	907b ± 258	879b ± 182	837b ± 257
PK1[e]	1875b ± 99	2405a ± 129	1677bcde ± 137	1627cd ± 94	1422ef ± 96	1718bcd ± 129	1438df ± 92	1584cde ± 113
PK2[f]	2137a ± 102	1327b ± 77	1200bc ± 111	1134c ± 72	1036c ± 74	111bc ± 102	1061c ± 71	1063c ± 89

[a]LSmeans within a row having the same letter were not significantly different ($p < 0.05$) and df = 45.
[b]Mean average force required to penetrate the the top half of a 10-French fry sample.
[c]Mean minimum force required to pass through the core sections of a 10-French fry sample.
[d]Mean average force required to penetrate the bottom half of a 10-French fry sample.
[e]Mean average force required to pass through a 10-French fry sample for the 2.5 to 6.0 sec time range of each measurement.
[f]Mean average force required to pass through a 10-French fry sample for the 9.0 to 12.5 sec time range of each measurement.

or PK2 measurements. However, MIN LSmeans for the 18-min and 21-min potato strips baked in the conventional oven were significantly lower than 12-min and 15-min-upper potato strips. This decrease in force required to pass through the middle section of the potato strips was expected because the structural components of potatoes soften as they bake.

In the convection oven the differences among the LSmeans for the force required to penetrate the potato strips and pass through portions of the potato were clearer. The AVG1, AVG2 and MIN LSmeans for the 4-min-upper and the PK1 and PK2 LSmeans for 4-min baked potato strips were significantly greater forces than the LSmeans from the 9-min baked potato strips. This decrease in force was expected for potato strips baked in the convection oven just as it was in the conventional oven.

The forces required for the probes to pass through the potato strips were similar between the two ovens. The AVG1 and AVG2 LSmeans ranged from 798 to 1209 g in the conventional oven and from 837 to 1852 g in the convection oven. The MIN LSmeans ranged from 1062 to 574 g and from 1887 to 679 g in the conventional and convection ovens, respectively. These values indicated that potato strips can be baked in either oven to reduce the force necessary for the probes to move through the potato strips.

Sensory evaluation

Sensory panels were conducted on six different days. Out of 189 respondents 62% were female (Appendix, F). The largest number of panelists, 36.5%, fell into the 30-39 age group. The 20-29 age group followed with 33.3%. Nearly 58% of the panelists reported eating French fries several times per month, and another 30% stated that they consumed French fries several times per week. Almost 44% of respondents said that they liked French fries "very much", and another 28% reported "extremely" liking French fries.

Approximately 22% of panelists liked French fries "moderately".

For each of the six days of sensory evaluation, panelists provided scores for their perception of the "ideal" baked French fry and then scored four samples individually. Sensory evaluation score cards appear in Appendix C. The time by position interaction significantly affected sensory attribute values in both ovens; therefore, the data were analyzed for the eight time-location combinations in each oven. Judges when nested within day of sampling did not significantly affect the LSmean separations so it was not included for this analysis. For ease of discussion, attributes are divided into the categories of texture, flavor, tactile, and overall acceptability. Table 5 contains the LSmeans and standard errors for the textural attributes of both the convection and conventional ovens as well as the panelists' perceptions of the "ideal" baked potato strip. Panelists expected the ideal baked potato strip to be crispy (4.9) and firm (4.2) but not at all soggy.

In the conventional oven, significant differences among LSmeans were detected by the panelists for the oily, crispy, and soggy attributes. The panelists rated the potato strips baked 12 min, upper rack with a LSmean of 4.0, and this rating was significantly more oily than all other conventional oven treatments. The 21-min, 18-min-lower, and 15-min-lower baked potato strips were perceived to be like the ideal in terms of "oily". These baked potato strips also were not different from the 15-min-upper and 18-min-upper potato strips. The oily attribute of the potato strips had a statistically significant positive relationship with soggy attribute (Appendix E). As oiliness increased, so did sogginess. No significant differences in proximate analysis of fat in potato strips baked in the conventional oven (Table 3, p 21) were detected, but the panelists scored differences in the oily attribute of the potato strips. The oil may penetrate the potato more as water is lost and the structure of the potato is modified by cooking.

The potato strips baked for 18 and 21 min on the lower racks had LSmeans for crisp

Table 5--Least-squares means and standard errors of baked, osmotically processed, par-fried, potato strip textural attributes rated using sensory evaluation via consumer profiling[a]

Oven[d]	Time(min)	Pos.	Attribute[bc] Oily	Crispy	Soggy	Firm	Mealy
CNL	12.0	U	4.0a ± 0.27	1.4e ± 0.33	3.8a ± 0.31	3.4a ± 0.26	3.3a ± 0.34
		L	3.3b ± 0.20	1.9de ± 0.25	3.1ac ± 0.23	3.2a ± 0.18	3.3a ± 0.24
	15.0	U	3.0bd ± 0.20	2.0de ± 0.25	3.3ab ± 0.23	2.9a ± 0.19	3.1a ± 0.25
		L	2.5dx ± 0.28	2.6cd ± 0.33	2.6c ± 0.32	3.4a ± 0.27	3.1ax ± 0.35
	18.0	U	3.1bc ± 0.20	2.2d ± 0.24	2.5bc ± 0.33	3.2a ± 0.19	3.0ax ± 0.24
		L	2.5cdx ± 0.28	3.9a ± 0.33	2.5c ± 0.33	3.4a ± 0.28	3.2ax ± 0.35
	21.0	U	2.7cdx ± 0.20	2.9bc ± 0.25	3.1ac ± 0.23	3.0a ± 0.19	2.8ax ± 0.25
		L	2.6cdx ± 0.27	3.2ab ± 0.32	2.6c ± 0.30	3.1a ± 0.25	3.1ax ± 0.33
	IDEAL		2.4x ± 0.07	4.9 ± 0.07	1.5 ± 0.07	4.2x ± 0.08	2.5x ± 0.11
CVT	4.0	U	3.8a ± 0.39	1.7cd ± 0.23	3.5a ± 0.35	4.3ax ± 0.33	3.1a ± 0.29
		L	3.5ab ± 0.27	1.5d ± 0.15	3.1a ± 0.24	4.2abx ± 0.23	2.7ax ± 0.20
	5.7	U	2.8abx ± 0.38	2.1bc ± 0.22	3.1a ± 0.33	3.5bcx ± 0.32	3.2a ± 0.27
		L	3.1abx ± 0.27	1.9cd ± 0.16	3.0a ± 0.24	3.3c ± 0.23	3.1a ± 0.20
	7.3	U	2.8bx ± 0.26	2.0c ± 0.15	2.9a ± 0.23	3.2c ± 0.22	3.2a ± 0.19
		L	2.8abx ± 0.38	2.1bc ± 0.21	3.2a ± 0.33	3.3c ± 0.31	2.9ax ± 0.27
	9	U	2.9abx ± 0.27	2.6ab ± 0.15	2.8a ± 0.24	3.1c ± 0.23	2.9ax ± 0.20
		L	3.4ab ± 0.37	3.0a ± 0.20	2.9a ± 0.31	3.2c ± 0.30	3.2a ± 0.26

[a]30 panelists per replication with 3 replications across 16 oven treatments.
[b]6-point attribute intensity scales where 1=not at all and 6=very much so.
[c]Values within the same column within the same oven having different letters (a-e) are different ($p < 0.05$).
[d]CVT=convection oven, CNL=conventional oven, U=upper rack, L=lower rack.
[e]Values within the same column within the same oven followed an "x" are not different ($p > 0.05$) from the corresponding ideal.

of 3.9 and 3.2, respectively, and were not scored significantly different from each other. Also, the 21-min-lower LSmeans were not significantly different from the 21-min-upper LSmeans. Panelists scored these three treatments as significantly more crispy than the other conventional oven treatments. They may have been scored more crispy by the panelists because they contained less water than the potato strips baked for shorter amounts of time. In general, as baking times increased crispiness increased and sogginess scores decreased. All strips baked in the conventional oven were perceived as less crispy and more soggy than the ideal. Correlation data reinforced this negative relationship between crispy and soggy attributes.

No significant differences in firm or mealy attributes of potato strips baked in the conventional oven were noted by the panelists. All strips were significantly less firm than the ideal. It was likely that panelists did not understand the term mealy and tended to rate all treatments similarly. "Mealy" is considered a positive attribute in baked potato strips (Jaswal, 1989; Talburt and Smith, 1987) but based upon the panelists' low score of the ideal baked potato strip for the mealiness attribute, mealiness was identified by panelists as an undesirable trait. Panelists did not perceive any relationships among mealy and crispy or overall acceptability (Appendix E) which also indicated that panelists did not understand the mealy term. Conversations with panelists after they had evaluated the strips indicated that some of the panelists equated mealy with grainy instead of the texture of cooked baked potato. A better explanation of the meaning of mealy was necessary for this panel to recognize mealiness as being a desirable quality for baked French fries.

The strips baked 4 min in the convection oven were perceived significantly more oily than the ideal but so was the 9-min-lower baked potato strips. This indicates that in the convection oven, the baking time did not significantly affect perceived oiliness.

The potato strips baked in the lower position for 9 min had a LSmean score of 3.0

and were rated significantly more crisp by the panel than all other convection-oven-baked potato strips with the exception of the potato strips baked in the upper position for 9 min. Crispiness was expected to increase as the solids content increased which occurs at the increased baking times. It also was noted that the crispy ratings were still on the lower end of the crispy scale; and as expected, all strips baked in the convection oven were perceived as less crispy than the ideal. It was noted that the crispy attribute had a negative relationship with soggy and positive relationships with firm, good, and overall acceptability (Appendix E). This possibly accounted for some of the panelists' low scores for overall acceptability of the potato strips.

In the convection oven, firmness decreased as baking times became longer. Potato tissues soften as they cook, and the panelists detected this phenomena. Panelists scored the potato strips baked 4 min on the upper rack as significantly more firm than all of the other convection oven baked strips except the potato strips baked 4 min on the lower rack. Apparently, 4 min heating in the convection oven was not sufficient time to cause cellular breakdown and a softer potato texture as stated by Nonaka (1980) and Burton (1989). Panelists commented on these potato strips as being "not done" and "undercooked". Panelists scored the 4-min and 5.7-min- upper baked potato strips similar as the ideal. Higher instrumental core (MID) LSmeans of osmotically processed, par-fried, potato strips baked for the shorter baking times also verify this. DuPont et al. (1992) stated that crispiness was the sensory attribute most related to mechanical strength of potato strips; however, in this study firmness was a better indicator. Firmness had the highest positive relationship with the instrumental texture measurements for all sensory attributes with correlations of 0.55 to 0.64 (Appendix E).

No significant differences in potato strips baked at the four times in the convection oven were detected by the panelists for the soggy and mealy texture attributes. All strips were more soggy than the ideal.

Table 6 contains the flavor, tactile, and overall acceptability LSmeans and standard error data as well as the panelists' perceptions of the ideal baked potato strip. When scoring their perceptions of the ideal baked potato strip, panelists expected baked strips to not have a sweet flavor (2.4), off flavor (1.3), or be greasy to the touch (2.3). Fries were expected to have a very typical flavor (4.9). Overall acceptability was scored for the ideal baked potato strips by the panelists.

No significant differences were detected by panelists for any of the sweet flavor LSmeans of the conventional-oven-baked potato strips. All of the strips baked in the conventional oven were not significantly different in sweet flavor when compared to the ideal.

The potato strips baked in the conventional oven off-flavor LSmeans ranged from 2.4 to 3.3 and were significantly larger than the respective ideal mean, but no obvious trends were evident. It was also noted that sweet flavor was not significantly related to typical flavor or off-flavor. No trends were evident for the LSmeans for the typical flavor attribute, and no conventional oven baked potato strips were perceived as similar to the typical flavor ideal. This was probably due to the "raw" and "under cooked" comments on the 12-min strips and the "burned" comments for the strips baked 21 min.

Panelists scored the strips baked 12 min as significantly greasier to the touch than strips baked for 21 min. All strips were perceived as being greasier to the touch than the ideal. The frying oil may have remained on the 12-min strips' surfaces causing this perception. The oil may have cooked more deeply into the strips which were baked for the 21-min. It was not due to a difference in oil contents (Table 3).

As far as overall acceptability, panelists deemed the 12-min-upper baked potato strips significantly less acceptable than the 15-min-lower and 18-min-upper baked potato

Table 6--Least-squares means and standard errors of baked, osmotically processed, potato strip attributes rated using sensory evaluation via consumer profiling[a]

			Attribute[bc]				
Oven[d]	Time(min)	Pos.	Sweet Flavor	Off-Flavor	Typical Flavor	Greasy (tactile)	Overall Acceptability
CNL	12.0	U	2.3ax ± 0.24	3.3a ± 0.29	2.6b ± 0.26	3.9a ± 0.24	2.0b ± 0.36
		L	2.4ax ± 0.17	2.8ab ± 0.21	2.9ab ± 0.19	3.7ab ± 0.18	2.6ab ± 0.26
	15.0	U	2.4ax ± 0.18	2.5b ± 0.21	3.2a ± 0.19	3.4abc ± 0.18	2.9ab ± 0.26
		L	2.4ax ± 0.25	2.4b ± 0.30	3.4a ± 0.27	2.6dex ± 0.25	3.0a ± 0.37
	18.0	U	2.4ax ± 0.17	2.7ab ± 0.21	3.0ab ± 0.19	3.2bd ± 0.18	3.0a ± 0.26
		L	2.4ax ± 0.26	2.8ab ± 0.31	2.9ab ± 0.28	3.0cde ± 0.26	3.0ab ± 0.37
	21.0	U	2.5ax ± 0.17	3.0ab ± 0.21	3.1ab ± 0.19	2.7e ± 0.18	2.7ab ± 0.26
		L	2.4ax ± 0.23	3.2a ± 0.27	2.8ab ± 0.25	2.8de ± 0.23	2.7ab ± 0.35
	IDEAL		2.4x ± 0.09	1.3 ± 0.06	4.9 ± 0.09	2.3x ± 0.07	NM[e]
CVT	4.0	U	2.4ax ± 0.36	2.7a ± 0.33	2.8ab ± 0.25	3.8ab ± 0.41	2.0c ± 0.25
		L	2.4ax ± 0.25	3.2a ± 0.22	2.5b ± 0.17	3.8a ± 0.28	1.9c ± 0.17
	5.7	U	2.9ax ± 0.35	2.7a ± 0.31	3.1a ± 0.24	2.9abx ± 0.40	2.8ab ± 0.24
		L	2.2ax ± 0.25	2.9a ± 0.23	3.0a ± 0.18	3.2ab ± 0.29	2.7b ± 0.18
	7.3	U	2.5ax ± 0.24	2.7a ± 0.22	3.2a ± 0.17	3.1ab ± 0.28	3.0ab ± 0.16
		L	2.5ax ± 0.35	2.8a ± 0.31	3.4a ± 0.24	3.0abx ± 0.40	3.2ab ± 0.24
	9.0	U	2.1ax ± 0.25	2.9a ± 0.22	3.4a ± 0.17	2.9bx ± 0.28	3.1ab ± 0.17
		L	2.4ax ± 0.34	2.7a ± 0.29	3.1a ± 0.23	2.9abx ± 0.38	3.3a ± 0.22

[a]30 panelists per replication with 3 replications across 16 oven treatments.
[b]6-point attribute intensity scales where 1=not at all and 6=very much so.
[c]Values within the same column within the same oven having different letters (a-e) are different ($p<0.05$).
[d]CVT=convection oven, CNL=conventional oven, U=Upper rack, L=lower rack.
[e]NM=not measured.
[f]Values within the same column within the same oven followed by an "x" are not different ($p > 0.05$) from the corresponding ideal.

strips. The ideal overall acceptability was not measured because it was assumed that the ideal baked potato strip would be highly acceptable to all panelists. The strips baked 21 min were rated as acceptable by only 34% of the panelists (Appendix G). All other conventional oven treatments were rated acceptable by even fewer panelists. The 12 and 21-min strips were scored bad more frequently than were the 15 and 18-min strips. Half of all panelists thought the strips baked for 12 min were bad. This was most likely due to the lack of doneness noted by panelists.

In the convection oven, significant differences for sweet flavor and off-flavor attribute LSmeans were not detected by panelists; however, panelists perceived all strips baked in the convection oven as having significantly more off-flavor and similar sweet flavor as the respective ideals. This indicated the panelists thought the samples had more off-flavor than was desirable. Sweet flavor was as the panelists had expected.

With the exception of the 4-min-lower baking treatment, all potato strips baked in the convection oven were scored as having significantly less typical flavor than all other strips with the exception of the 4-min-upper treatment. Panelists also rated all the strips baked in the convection oven as having less typical flavor than the ideal. Perhaps the panelists noticed a raw starch flavor since many panelists remarked that the two 4-min bakes were "raw", "undercooked", or "not done".

The only differences denoted by the panelists for the greasy (tactile) attribute of baked, potato strips were between the 4-min, lower and the 9-min, upper treatments. Panelists perceived no differences among the greasiness of the 9-min baked strips and the respective ideal. This indicated that the panelists thought the samples baked 4 min were greasier to the touch than was expected. Again, greasy was positively related to oily and soggy.

Forty-four percent (Appendix G) of panelists rated strips baked 9 min on the acceptable portion of the score card, and this was a highest acceptability percentage for all oven treatments. However, the 9-min baked strips were rated good by only 48% of the panelists. These strips were scored as bad by 38% of panelists. Conversely, the 4-min baked strips were scored acceptable by only 12% of the panelists, and they were scored not acceptable by 64% of the panelists. Only 20% scored the 4-min strips acceptable. The 4-min baked potato strips were scored by panelists as less acceptable than all other convection oven treatments. This may have been due to the fact that potatoes baked for a shorter times were not considered done by the panelists. Overall acceptability was positively related with good, firm, crispy and typical attributes and negatively related to soggy and off-flavor attributes.

There were significant ($p< 0.05$) positive and negative relationships (Appendix E) among average instrumental texture measurements of osmotically processed, par-fried potato strips baked in both ovens and averaged sensory attribute scores of the same. Positive relationships ($p < 0.05$) were found among all force (g per sec) measurements and the firm and bad sensory attributes. As force (g per sec) required to penetrate the baked strips decreased, sensory panelists rated potatoes as less "firm" and less "bad". The force (g per sec) measurements were negatively correlated with crispy, with the exception of the AVG 2 values. As objective force (g per sec) values increased, the potato strips were deemed by panelists as being less crispy. Perceived off-flavor increased as instrumental force (g) measurements increased which may be related to a "burned" flavor which was an indication of longer cook times. There was a negative relationship between "good" texture and the instrumental values of approximately -0.5 but no relationship (-0.03 to 0.03) with "overall acceptability" and instrumental values.

CHAPTER V

SUMMARY AND CONCLUSIONS

Osmotically processed potato strips were prepared by slicing fresh Russet Burbank potatoes and soaking the 1.27 cm x 1.27 cm x 7 cm strips in a 60° Brix corn syrup solution for 2 hr. After rinsing and drying, osmotically treated strips were par-fried in 190°C vegetable shortening for 15 sec. Fries were baked in the convection and conventional ovens at 204°C. The four bake times for the convection oven were 4, 5.7, 7.3, and 9 min. Bake times for the conventional oven were 12, 15, 18, and 21 min. Two oven positions, upper and lower, were used in each oven. Each time by position combination was replicated three times over six days. Strips were analyzed for moisture and fat. Ten-potato strip samples were analyzed objectively using the TA-XT2 Texture Analyser II and the TA 200 fry attachment. Sensory analyses were performed on all treatments.

Statistical analysis of total solids and wet basis fat data of osmotically processed, par-fried, potato strips showed that solids and fat contents weren't affected by oven position ($p < 0.05$) for either oven. In both the convection and conventional ovens, solids of potato strips increased as baking times increased. Fat contents did not differ in conventional oven treatments, and after mean separation no differences were detected ($p < 0.05$) in the convection oven. All strips contain less fat than commercially-fried strips and non-osmotically processed, baked par-fries. All treatments contained less than 2.75% fat. Commercially produced par-fries contain 4-7% fat. On a caloric basis, osmotically processed, baked potato strips contained approximately 12% calories from fat, and this amount is much less than the 35% calories from fat of par-fried, baked, potato strips and the 47% calories from fat in potato strips French fried in oil (USDA, 1982).

In the convection oven, instrumental MIN mean values showed that as bake times increased the force required to move through the samples decreased. This trend did not occur in the conventional oven due to the high LSmean for potatoes baked 15 min on the lower rack. These potatoes were possibly underbaked due to the temperature cycling in the conventional oven.

The sensory evaluation required panelists to score their perceptions of the "ideal" baked French fry, and then to score four samples individually. Nine-minute baked strips were significantly crisper than all other strips baked in the convection oven. The 4-min baked strips were firmer than all other convection-baked strips. This also was indicated by higher core (MIN) LSmeans in the instrumental texture measurements (Table 3). Panelists did not detect any significant differences in soggy and mealy attributes for potato strips baked in the conventional oven. When compared to the LSmeans for potato strips, panelists rated the convection and conventional baked strips as oiler, soggier, and more mealy than each corresponding ideal mean. As expected, all convection and conventional baked, osmotically processed, potato strips were less crispy than the panelists' ideal. All convection and conventional baked strips were less firm than the ideal with the exception of the 4-min baked strips.

All potato strips baked in the conventional and convection ovens were scored lower than the ideal for the typical flavor attribute and were scored higher for off-flavor and greasy to the touch than the ideal. Overall acceptability LSmeans of baked, osmotically processed, baked potato strips increased as baking times grew longer. There were no significant differences detected among conventional or convection oven baked potato strips for sweet flavor. Therefore, osmotically processing potato strips in a 60%, 43 DE high-maltose corn syrup solution for 2-hr produced strips that were not perceived as sweeter than the ideal.

The PK1 instrumental values had the largest number of significant correlations with sensory attributes, and MIN values had several similar correlations. Significant correlations between instrumental PK1 and MIN values and sensory values were for "firm" with a correlation of 0.64 and 0.55, respectively; "crispy" , -0.54 and -0.49, respectively; and "off-flavor", -0.51 and -0.52, respectively. The instrumental PK1 values also were correlated with sensory values for oily, 0.42, and soggy, 0.41.

Osmotically processed, par-fried potato strips baked for shorter times were perceived less acceptable than potatoes baked for longer times in both ovens. In the conventional oven, baking potato strips for 18 and 21 min resulted in finished potato strips which were reported as having a "burned" flavor. Therefore, these times are too long for baking this type of product at the 204°C. The potato strips baked 9 min in the convection oven were found acceptable by 44% of the panelists. This was the highest percentage of panelists that found the potato strips acceptable for any oven treatment. The 4-min baked strips were scored acceptable by only 27% of panelists. The osmotically processed, par-fried baked potato strips needed to be more crispy and less soggy to match what panelists perceived as an "ideal" baked French fry. Therefore, manufacturing "ideal" baked potato strips would require increased baking times that produce potato strips which contain an acceptable flavor.

This research produced osmotically processed, par-fried, baked potato strips which were baked to a moisture content similar to a commercially baked product and contained less fat than commercially produced, non-osmotically processed, baked potato strips. However, sensory evaluation indicated that none of the oven treatments produced potato strips that equaled the panelists' perceptions of the "ideal" baked potato strip. An optimum arrangement of bake time, oven temperature, and oven used was not reached. Perhaps lowering the oven temperature from 204°C to 191°C with increased baking times would decrease the browning of the baked osmotically processed, par-fried strips while yielding an acceptable texture and flavor.

Valuable information could be learned from baking commercially-produced potato strips. Instrumental testing would determine the force (g force per sec) required to move through the surface and core of thoroughly cooked potato strips that have been baked according to the manufacturer's directions. This could be compared to sensory panelists' evaluations of the commercial standard. By using a commercially produced, non-osmotically processed, baked potato strip as a test sample, researchers would know if any baked potato strip would meet with consumer's expectations of the "ideal" baked potato strip. This would allow for selection of sensory terms that were most useful for evaluating this type of potato product.

REFERENCES

References

AACC. 1983. *Approved Methods of the American Association of Cereal Chemists*, 8th ed. Am. Assoc. Cereal Chemists, St. Paul, MN.

Anonymous. 1977. The U.S. Senate, Select Committee on Nutrition and Human Needs. *Dietary Goals for the United States*, 2nd ed. The U.S. Government Printing Office, Washington, DC.

Anonymous. 1995. *The Almanac of the Canning, Freezing, Preserving Industries*, 78th ed. Edward E. Judge and Sons, Inc. Westminster, MD.

Anonymous. 1996. Corn Syrup Certificate of Analysis for Clearsweet® 43% High Maltose Corn Syrup. Cargill Foods, Memphis, TN.

AOAC. 1984. *Official Methods of Analysis*, 14th ed. Assoc. Official Analytical Chemists, Washington, D.C.

Böhler, G, Escher, F., and Solms, J. 1986. Evaluation of cooking quality of potatoes using sensory and instrumental methods. 1. Sensory evaluation. Lebensm.-Wiss. u-Technol. 19: 338-343.

Bolin, G.R., Huxsoll, C.C., Jackson, R., and Ng, K.C. 1983. Effect of osmotic agents and concentration on fruit quality. J. Food Sci. 48: 202-204.

Brochetti, D. and Penfield, M.P. 1989. Sensory characteristics of bakery products containing distillers' dried grain from corn, barley, and rye. J. Food. Quality 12: 413-426.

Burton, W.G. 1989. *The Potato.* 3rd ed., John Wiley and Sons, Inc., New York.

Chen, Y. 1993. Osmotic Concentration of Potato in Corn Syrup Solutions Prior to Freezing. M.S. thesis, Univ. of Tennessee, Knoxville.

deMan, J.M. 1990. *Principles of Food Chemistry*, 2nd ed. Van Nostrand Reinhold Company, Inc., New York.

DuPont, M.S., Kirby, A.R., and Smith, A.C. 1992. Instrumental and sensory tests of texture of cooked frozen French fries. Intl. J. Food Sci. Technol. 27: 285- 295.

Huxsoll, C.C. 1982. Reducing the refrigeration load by partial concentration of foods prior to freezing. Food Technol. 36: 98-102.

Jaswal, A.S. 1989. Texture of French fried potato: chemical composition of non-starch polysaccharides. Am. Potato J. 66: 835-841.

Lisinska, G. and Leszczynski, W. 1989. *Potato Science and Technology*, Elsevier Applied Science. London, UK.

Matz, S.A. 1972. Ovens and Associated Equipment. Ch. 21. *In Baking and* Engineering Technology, 2nd ed. The AVI Publishing Company, Inc., Westport, CT.

Matz, S.A. 1988. Ovens and Baking. Ch. 9. In *Equipment for Bakers*. Pan-Tech International, Inc., McAllen, TX.

Marquez, G. and Añon, M.C. 1986. Influence of reducing sugars and amino acids in the color development of fried potatoes. J. Food Sci. 51: 157-160.

McWilliams, M. 1989. *Foods: Experimental Perspectives.* Macmillan Publishing Company., New York.

Nonaka, M. 1980. The textural quality of cooked potatoes. I. The relationship of cooking time to the separation and rupture of potato cells. Am. Potato J. 57: 141-149.

Ponting, J.D., Waters, G.G., Forrey, R.R., Jackson, R., and Stantley, W.L. 1966. Osmotic dehydration of fruits. Food Technol. 20: 125-128.

SAS. 1989. SAS® Language and Procedures, Version 6. SAS Institute, Inc., Cary, NC.

SAS/Stat®. 1996. Software: Changes and Enhancements through Release 6.11. SAS Institute, Inc., Cary, NC.

Swanson, R.B. and Penfield, M.P. 1988. Barley flour level and salt level selection for a whole-grain bread formula. J. Food Sci. 53: 896-901.

Szçzesniak, A.S., Loew, B.J., and Skinner, E.Z. Consumer texture profile technique. J. Food Sci. 1253-1257.

Talburt, W.F. and Smith, O. 1987. *Potato Processing*. 4th ed. Van Nostrand Reinhold Company, Inc., New York.

USDA. 1992. Potatoes and Sweet Potatoes. 1990-91. Production, Disposition, Value, Stocks and Utilization. Crop Reporting Board, Statistical Reporting Source, USDA, Washington, DC. 20250. Pot 6(9-92), page 17.

USDA. 1982. *Composition of Foods: Vegetables and Vegetable Products Handbook 8-11.* U.S. Dept. of Agriculture, Washington, DC.

APPENDICES

APPENDIX A

CORN SYRUP SPECIFICATION SHEET

CARGILL FOODS

Corn Milling

Product Information

Clearsweet® 43%
High Maltose Corn Syrup

Cargill's Clearsweet® 43% HM is a specially prepared acid-enzyme type corn syrup which contains maltose as its major carbohydrate constituent. This high maltose syrup improves flavor, body, and texture at high sucrose replacement levels while imparting resistance to color formation, to moisture absorption and to crystallization in finished products such as hard candies. It produces finished products which have exceptional stability, clarity, and brilliance.

REPRESENTATIVE CHEMICAL AND PHYSICAL DATA

Essential Properties		**Characteristics**	
Dextrose Equivalent (DE)	45	Appearance	Clear Liquid
Baume, Comm (140°/60°+1)	43	Taste	Sweet, Bland
Refractive Index (45°C)	1.4937	Odor	Characteristic
Total Solids (%)	80.9		
Moisture (%)	19.1		
Sulfated Ash (%)	0.4		
Nitrogen (%)	0.006		
pH (1:1)	4.9		
Sulfur Dioxide (PPM)	40 Max.		
Calories/100g	316		

Weight/Volume Factors		**Viscosity**	**(Centipoise)**
Specific Gravity (100°/60°F)	1.4199	80°F	54,000
Pounds/Gallon (100°F)	11.84	90°F	22,000
Pounds/Gallon (DSB)	9.58	100°F	11,500
		110°F	6,500
Chromatographic Analysis		120°F	4,200
(% Dry Basis)		130°F	2,500
Dextrose	9	140°F	1,600
Maltose	43		
Maltotriose	18		
Higher Saccharides	30		

CA-203

NORTH AMERICAN CORN MILLING DIVISION SWEETENER SALES LOCATIONS

Box 1467	Box 1400A	Box 13368	Port of Stockton Rd 13
Cedar Rapids, IA 52406	Dayton, OH 45413	Memphis, TN 38113	Stockton, CA 95201
319-399-2138	513-237-1272	901-775-5805	209-942-4171
319-399-2103 (fax)	513-237-1238 (fax)	901-775-5872 (fax)	209-942-2671 (fax)

CARGILL, INC. - MEMPHIS, TN

CORN SYRUP CERTIFICATE OF ANALYSIS

LOAD ORDER #	:	1
DATE SHIPPED	:	06/14/96
PRODUCT	:	43HM
LOT #	:	4850-7
D.E.	:	
BAUME'	:	43.05
DRY SOLIDS	:	80.98
pH	:	4.98
COLOR	:	94
HEATED COLOR	:	
SO2	:	25.0
% DEXTROSE	:	9.1
% MALTOSE	:	44.5
% TRIOSE	:	
% HIGH SACC	:	

COMMENTS :

APPROVED : Nick Brown JSN

NICK BROWN
LABORATORY SERVICES MANAGER

CC:

FAX #

APPENDIX B

TEXTURE PARAMETERS

Operating procedures for the TA-XT2 Texture Analyser II

Mode	: Measure Force in Compression
Option	: Return to Start
Force Units	: Grams
Distance Format	: mm
Pre-Test Speed	: 10.0
Test Speed	: 1.0
Post-Test Speed	: 10.0
Distance	: 15.0
Trigger Type	: Auto
Trigger Force	: 20

APPENDIX C

SENSORY EVALUATION SCORE CARDS

IDEAL OVEN BAKED FROZEN FRENCH FRY BALLOT

Panelist Number________

Listed below are characteristics commonly used to describe French fry texture, flavor, and quality. For each characteristic, please place a check in one box that best describes your perceptions of an "ideal" baked French fry.

TEXTURE (how French fries feel in your mouth)

	NOT AT ALL					VERY MUCH SO
Oily/Greasy	☐	☐	☐	☐	☐	☐
Good	☐	☐	☐	☐	☐	☐
Mealy	☐	☐	☐	☐	☐	☐
Soggy	☐	☐	☐	☐	☐	☐
Bad	☐	☐	☐	☐	☐	☐
Firm	☐	☐	☐	☐	☐	☐
Crispy	☐	☐	☐	☐	☐	☐

FLAVOR (How product tastes throughout chewing and swallowing)

Sweet	☐	☐	☐	☐	☐	☐
Typical	☐	☐	☐	☐	☐	☐
Off-flavor	☐	☐	☐	☐	☐	☐

TEXTURE (How the product feels to the touch)

Oily/Greasy	☐	☐	☐	☐	☐	☐

BAKED FRENCH FRY SCORE SHEET

Panelist Number________ Sample Number________

Please taste the baked French fry sample. For each characteristic below, place a check in the box that best describes each characteristic.

TEXTURE (how French fries feel in your mouth)

	NOT AT ALL					VERY MUCH SO
Oily/Greasy	☐	☐	☐	☐	☐	☐
Good	☐	☐	☐	☐	☐	☐
Mealy	☐	☐	☐	☐	☐	☐
Soggy	☐	☐	☐	☐	☐	☐
Bad	☐	☐	☐	☐	☐	☐
Firm	☐	☐	☐	☐	☐	☐
Crispy	☐	☐	☐	☐	☐	☐

FLAVOR (How product tastes throughout chewing and swallowing)

Sweet	☐	☐	☐	☐	☐	☐
Typical	☐	☐	☐	☐	☐	☐
Off-flavor	☐	☐	☐	☐	☐	☐

TEXTURE (How the product feels to the touch)

Oily/Greasy	☐	☐	☐	☐	☐	☐

ACCEPTABILITY (Overall rating of product)

Acceptability	☐	☐	☐	☐	☐	☐

DEMOGRAPHIC DATA

Panelist number _______

Please answer the following questions by placing check mark in the appropriate locations.

Gender: _____Male _____Female

Age:

Less than 20_____
20-29_____
30-39_____
40-49_____
50-59_____
60-69_____
69 and over_____

How often do you eat French fries?

Every day_____
Several times a week_____
Several times a month_____
Several times a year_____
Never_____

In general, how well do you like French fries?

_____Like extremely
_____Like very much
_____Like moderately
_____Like slightly
_____Dislike slightly
_____Dislike moderately
_____Dislike very much
_____Dislike extremely

APPENDIX D

SCHEDULE OF TREATMENTS BY DAY

Schedule of treatments by day

Day	Treatments (oven/time/position)			
1	CVT 7.2 L[a]	CVT 7.2 U	CNL 12 L[b]	CNL 18 U
2	CVT 5.4 L	CVT 9.0 U	CNL 21 U	CNL 15 L
3	CVT 9.0 U	CVT 4.0 L	CNL 18 U	CNL 15 L
4	CVT 5.4 L	CVT 4.0 U	CNL 21 L	CNL 12 U
5	CVT 5.4 U	CVT 4.0 L	CNL 15 U	CNL 18 L
6	CVT 9.0 L	CVT 7.2 U	CNL 21 L	CNL 12 U

[a]CVT = convection oven
[b]CNL = conventional oven

APPENDIX E

PROC CORRELATION DATA

Correlations among instrumental and sensory attributes

	MIN Instr	AVG 1 Instr	AVG 2 Instr	PK 1 Instr	PK 2 Instr
Oily	0.3999[a] 0.0528[b]	0.3547 0.0890	0.3304 0.1148	0.4212 0.0404	0.4037 0.0504
Crispy	-0.4939 0.0142	-0.4693 0.0207	-0.3496 0.0940	-0.5355 0.0070	-0.4412 0.0309
Soggy	0.3715 0.0739	0.3702 0.0749	0.3085 0.1425	0.4055 0.0493	0.3469 0.0968
Firm	0.5486 0.0055	0.5815 0.0029	0.5878 0.0025	0.6376 0.0008	0.6233 0.0011
Mealy	0.1047 0.6263	-0.1006 0.6398	0.0289 0.8935	-0.1536 0.4737	-0.0071 0.9735
Sweet Flavor	0.0587 0.7853	-0.0267 0.9014	0.0172 0.9366	-0.0354 -0.8693	-0.0263 0.9026
Off Flavor	-0.5227 0.0088	-0.4971 0.0135	-0.5351 0.0071	-0.5060 0.0116	-0.5186 0.0094
Typical Flavor	0.3187 0.1290	0.2525 0.2339	0.2102 0.3243	0.3179 0.1301	0.2763 0.1911
Greasy (tactile)	-0.2674 0.2064	-0.2281 0.2836	-0.2666 0.2079	-0.2517 0.2354	-0.2373 0.2641
Overall Accept-ability	-0.0060 0.9777	-0.0358 0.8682	0.0388 0.8573	-0.0193 0.9285	-0.0020 0.9923
Good	-0.5002 0.0128	-0.5130 0.0104	-0.5103 0.0108	-0.5405 0.0064	-0.5136 0.0102
Bad	0.4733 0.0195	0.4381 0.0323	0.4873 0.0157	0.4681 0.0210	0.4863 0.0160

[a]correlation values; where n = 24 and $p \leq 0.05$
[b]r-values

Correlation Analysis of Sensory Factors

	OILY	MEALY	SOGGY	FIRM	CRISPY	SWEET	TYP	OFF	GREASY	ACCEPT
MEALY	0.09672 0.0116									
SOGGY	0.36850 0.0001	0.23619 0.0001								
FIRM	-0.05658 0.1402	-0.09109 0.0178	-0.28703 0.0001							
CRISPY	-0.11985 0.0017	-0.03081 0.4238	-0.27800 0.0001	0.29979 0.0001						
SWEET	0.13791 0.0003	0.05744 0.1346	0.03506 0.3599	0.05319 0.1656	0.14122 0.0002					
TYP	-0.06084 0.1135	-0.00436 0.9101	-0.05809 0.1308	0.18427 0.0001	0.25048 0.0001	-0.03753 0.3292				
OFF	0.11009 0.0039	0.12673 0.0009	0.18420 0.0001	-0.07167 0.0616	-0.15828 0.0001	-0.01703 0.6567	-0.34282 0.0001			
GREASY	0.64345 0.0001	0.07085 0.0648	0.29723 0.0001	-0.00941 0.8063	-0.12008 0.0017	0.18971 0.0001	-0.08190 0.0330	0.14293 0.0002		
ACCEPT	-0.16029 0.0001	-0.05540 0.1523	-0.24607 0.0001	0.21895 0.0001	0.42409 0.0001	0.09467 0.0140	0.60256 0.0001	-0.31314 0.0001	-0.14753 0.0001	
GOOD	-0.18539 0.0001	0.01743 0.6505	-0.23174 0.0001	0.17656 0.0001	0.43269 0.0001	0.10978 0.0041	0.54937 0.0001	-0.33248 0.0001	-0.17662 0.0001	0.71675 0.0001

APPENDIX F

DEMOGRAPHIC SENSORY DATA

DEMOGRAPHIC DATA

Gender	Frequency	Percent
Male	72	38.1
Female	117	61.9
Age		
<20	12	6.3
20-29	63	33.3
30-39	69	36.5
40-49	23	12.2
50-59	15	7.9
60-69	7	3.7
Consumption Frequency		
several times/year	24	12.7
several times/month	109	57.7
several times/week	56	29.6
How well liked		
like extremely	53	28.0
like very much	83	43.9
like moderately	41	21.7
like slightly	8	4.2
dislike moderately	1	0.5
dislike very much	2	1.1
dislike extremely	1	0.5

APPENDIX G

SENSORY EVALUATION FREQUENCY DATA

Sensory Term	Bake Time (min)	Number of each sensory numerical scores 1[a]	2	3	4	5	6	AVG	%1-3	%4-6
Oily	Ideal	27	82	60	17	5	1	2.4	88.0%	12.0%
	4	5	21	23	17	19	11	3.6	51.0%	49.0%
	5.7	9	30	26	16	10	4	3.0	68.4%	31.6%
	7.3	14	32	24	13	6	6	2.8	73.7%	26.3%
	9	10	34	19	20	8	4	2.9	66.3%	33.7%
	12	4	25	22	16	18	10	3.5	53.7%	46.3%
	15	10	36	21	17	9	4	2.9	69.1%	30.9%
	18	12	36	18	18	10	3	2.9	68.0%	32.0%
	21	9	45	23	14	6	0	2.6	79.4%	20.6%
Crispy		1	2	3	4	5	6			
	Ideal	1	5	15	33	91	27	4.8	10.9%	89.1%
	4	56	27	6	1	4	1	1.7	93.7%	6.3%
	5.7	37	31	16	5	4	0	2.0	90.3%	9.7%
	7.3	36	31	20	6	2	0	2.0	91.6%	8.4%
	9	20	25	20	19	10	3	2.8	67.0%	33.0%
	12	54	27	5	5	4	0	1.7	90.5%	9.5%
	15	31	32	19	9	3	2	2.2	85.2%	14.6%
	18	27	25	12	18	10	3	2.7	67.4%	32.6%
	21	14	28	14	19	15	6	3.1	58.3%	41.7%
Soggy		1	2	3	4	5	6			
	Ideal	115	56	11	6	0	2	1.6	95.8%	4.2%
	4	19	21	17	11	16	9	3.1	61.3%	38.7%
	5.7	17	28	16	16	11	5	2.9	65.6%	34.4%
	7.3	20	16	23	19	9	8	3.1	62.1%	37.9%
	9	23	29	14	12	13	3	2.7	70.2%	29.8%
	12	16	20	15	14	22	7	3.3	54.3%	45.7%
	15	19	23	21	15	8	8	2.9	67.0%	33.0%
	18	16	27	20	16	12	2	2.9	67.7%	32.3%
	21	17	36	12	15	9	5	2.8	69.1%	30.9%
Firm		1	2	3	4	5	6			
	Ideal	0	12	41	60	61	18	4.2	27.6%	72.4%
	4	8	11	10	16	26	25	4.2	30.2%	69.8%
	5.7	11	15	19	28	13	7	3.4	48.4%	51.6%
	7.3	11	20	20	26	15	3	3.2	53.7%	46.3%
	9	11	22	22	20	17	4	3.2	57.3%	42.7%
	12	17	21	14	18	18	7	3.2	54.7%	45.3%
	15	11	24	22	22	16	2	3.1	58.8%	41.2%
	18	11	21	22	23	18	1	3.2	56.3%	43.8%
	21	10	27	18	24	16	1	3.1	57.3%	42.7%

[a]1 = "not at all" and 6 = "very much so"

Sensory Term	Bake Time (min)	Number of each sensory numerical scores						AVG	%1-3	%4-6
Mealy		1[a]	2	3	4	5	6			
	Ideal	68	37	40	28	9	9	2.5	75.9%	24.1%
	4	20	25	21	16	10	4	2.8	68.8%	31.3%
	5.7	12	22	24	24	11	2	3.1	61.1%	38.9%
	7.3	19	17	21	18	17	3	3.1	60.0%	40.0%
	9	18	20	27	15	11	5	3.0	67.7%	32.3%
	12	12	13	29	19	16	5	3.3	57.4%	42.6%
	15	15	22	21	22	13	4	3.1	59.8%	40.2%
	18	16	24	21	19	13	4	3.0	62.9%	37.1%
	21	16	19	32	19	6	3	2.9	70.5%	29.5%
Sweet		1	2	3	4	5	6			
Flavor	Ideal	44	78	42	13	11	0	2.3	87.2%	12.8%
	4	31	30	16	12	3	3	2.3	81.1%	18.9%
	5.7	24	31	23	12	4	1	2.4	82.1%	17.9%
	7.3	26	31	19	13	2	2	2.4	81.7%	18.3%
	9	35	30	17	10	4	0	2.1	85.4%	14.6%
	12	28	27	23	14	2	0	2.3	83.0%	17.0%
	15	24	32	25	11	4	0	2.4	84.4%	15.6%
	18	30	33	16	7	9	2	2.4	81.4%	18.6%
	21	30	26	21	13	5	2	2.4	79.4%	20.6%
Off-flavor		1	2	3	4	5	6			
	Ideal	135	37	12	3	1	1	1.4	97.4%	2.6%
	4	22	23	16	10	15	10	3.0	63.5%	36.5%
	5.7	27	24	15	16	8	5	2.7	69.5%	30.5%
	7.3	32	20	11	14	7	9	2.7	67.7%	32.3%
	9	28	26	12	13	13	5	2.7	68.0%	32.0%
	12	24	22	11	17	14	7	3.0	60.0%	40.0%
	15	30	24	21	7	11	2	2.5	78.9%	21.1%
	18	28	24	16	11	9	7	2.7	71.6%	28.4%
	21	12	31	25	9	12	8	3.0	70.1%	29.9%
Typical		1	2	3	4	5	6			
Flavor	Ideal	0	5	34	27	49	74	4.8	20.6%	79.4%
	4	21	28	24	10	6	5	2.6	77.7%	22.3%
	5.7	8	21	35	16	11	3	3.1	68.1%	31.9%
	7.3	6	21	28	26	10	3	3.2	58.5%	41.5%
	9	8	22	29	13	19	4	3.3	62.1%	37.9%
	12	16	28	24	15	9	2	2.8	72.3%	27.7%
	15	7	24	26	20	11	8	3.3	59.4%	40.6%
	18	12	26	27	16	10	5	3.0	67.7%	32.3%
	21	12	20	30	21	11	3	3.1	63.9%	36.1%

[a]1 = "not at all" and 6 = "very much so"

Sensory Term	Bake Time (min)	1[a]	2	3	4	5	6	AVG	%1-3	%4-6
		Number of each sensory numerical scores								
Greasy Touch	Ideal	34	83	56	11	6	1	2.3	90.6%	9.4%
	4	7	17	22	18	18	14	3.7	47.9%	52.1%
	5.7	10	25	26	15	13	6	3.1	64.2%	35.8%
	7.3	11	26	28	11	12	7	3.1	68.4%	31.6%
	9	16	30	20	16	7	7	2.9	68.8%	31.3%
	12	5	17	19	24	19	11	3.7	43.2%	56.8%
	15	8	29	21	22	10	6	3.2	60.4%	39.6%
	18	11	33	18	17	15	3	3.0	63.9%	36.1%
	21	15	32	24	18	6	2	2.7	73.2%	26.8%
Acceptable		1	2	3	4	5	6			
	Ideal	0	0	0	0	0	0			
	4	40	30	15	7	3	1	2.0	88.5%	11.5%
	5.7	15	29	23	16	9	0	2.7	72.8%	27.2%
	7.3	9	30	20	22	9	6	3.1	61.5%	38.5%
	9	16	17	20	23	17	1	3.1	56.4%	43.6%
	12	27	27	18	16	6	0	2.4	76.6%	23.4%
	15	11	32	20	14	16	2	3.0	66.3%	33.7%
	18	13	31	19	17	14	3	3.0	64.9%	35.1%
	21	19	22	21	25	4	3	2.8	66.0%	34.0%
Good		1	2	3	4	5	6			
	Ideal	3	1	19	9	42	117	5.3	12.0%	88.0%
	4	38	24	15	10	7	2	2.3	80.2%	19.8%
	5.7	14	16	27	23	12	3	3.1	60.0%	40.0%
	7.3	8	23	24	23	13	4	3.2	57.9%	42.1%
	9	11	20	19	28	15	3	3.3	52.1%	47.9%
	12	24	25	19	16	8	3	2.7	71.6%	28.4%
	15	7	22	25	25	13	5	3.3	55.7%	44.3%
	18	5	29	20	19	17	5	3.3	56.8%	43.2%
	21	12	21	32	15	13	4	3.1	67.0%	33.0%
Bad		1	2	3	4	5	6			
	Ideal	151	26	9	2	1	3	1.4	96.9%	3.1%
	4	10	10	15	14	23	24	4.1	36.5%	63.5%
	5.7	8	20	25	20	15	5	3.3	57.0%	43.0%
	7.3	19	20	21	16	10	6	3.0	65.2%	34.8%
	9	11	31	21	10	16	6	3.1	66.3%	33.7%
	12	11	19	17	12	23	13	3.6	49.5%	50.5%
	15	14	28	24	11	16	3	3.0	68.8%	31.3%
	18	18	25	16	11	21	5	3.1	61.5%	38.5%
	21	11	30	17	18	12	9	3.2	59.8%	40.2%

[a]1 = "not at all" and 6 = "very much so"

VITA

Laura Rachelle Pippin was born in Chattanooga, Tennessee on June 17, 1968. She graduated from Cookeville High School in 1986. She attended Tennessee Technological University where she received a Bachelor of Science in Home Economics in May of 1992. She received a Master of Science degree in Food Science and Technology in May 1997. She is a member of Institute of Food Technologists.