THE UNIVERSITY OF MANITOBA

A STUDY OF HOT WATER BLANCH SYSTEMS AND THE SIMULATION OF MODEL BLANCH SYSTEMS AND THEIR EFFECT ON THE QUALITY OF POTATO CHIPS

by

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ABSTRACT

A STUDY OF HOT WATER BLANCH SYSTEMS AND THE SIMULATION OF MODEL BLANCH SYSTEMS AND THEIR EFFECT ON THE QUALITY OF POTATO CHIPS

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Blanch water may not always be utilized to its capacity in the potato chip process before it is discharged from the process. Studies were conducted to determine (a) the effect of reused blanch water on the quality of potato chips and (b) the effect of simulated model blanch systems on the quality of potato chips. An attempt was made to establish the effect of specific chemicals in blanch systems on the quality of potato chips. Limited reuse of potato blanch water did not affect potato chip quality. Continued reuse of blanch water resulted in chips of darkened colour and bitter taste, with further use of the water resulting in an unacceptable chip. In the simulated blanch systems colour quality of the chip was affected by the glucose system, flavour and texture were not affected by any of the model systems.

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I. INTRODUCTION

Water and waste management has become a major part of the potato processing industry. The industry must learn to utilize water to get maximum use from a given volume of water and yet not create waste which will be unacceptable.

Potato processors cannot sacrifice quality of product in order to conserve water and hope to keep their product at a competitive level. Potato chips, as well as other potato products have become increasingly popular which is the direct cause for increased production. Popularity of these products is due to their convenience, quality and price. This fact, as well as the rapid population growth, has created a tremendous increase in the production of potato products. This increased production creates a greater requirement for fresh water which in turn puts more stress on the locally available natural water supply

Potato chippers must now start examining the processing systems, raw materials and the equipment used to produce potato chips in order to increase efficiency and maintain quality. Potato growers have improved the quality of chipping potatoes, engineers are supplying more sophisticated equipment and the processor is utilizing his operation to its peak efficiency. The next step is to obtain maximum use out of raw materials. Potatoes no longer need to be peeled for processing thereby increasing yield in the product.

The most recently developed tuber varieties are physiologically suited to processing and give higher quality products. Water management people and food processing engineers must now find ways of utilizing water to a maximum in any given process. Quality parameters must be established for water use in the chip industry and quality tests set up to control water quality for reuse. Before water can be reused in any one system all aspects of the system must be studied and understood so that quality of the product can be maintained. This study was designed to determine the effects of blanch water systems on the quality of potato chips.

II. REVIEW OF LITERATURE

The potato processing system has become very complex and is comprised of many different processing techniques all of which require the use of great quantities of water. The untreated waste water load per day from potato processing plants in the United States of America is equivalent to a population of about 5.5 million people (8). At present 50% of the potatoes consumed in the U. S. A. are in processed form which Smith (26) has suggested will increase to 75% by the year 1980. These facts point out the increased need for water in this industry within ten years.

The present trend in the potato chip industry, according to Brooks (2) is to use more process water than required because it is readily available and relatively inexpensive. Brooks stated that careful use of available water would be of benefit to the processor by reducing the size and therefore the expense of a large treatment facility as well as reducing the total volume of fresh processing water needed for the operation. The potato chip industry to date uses approximately 1 to 2½ gallons of water for every pound of potato processed (19) and quite often this usage could easily be reduced by the reuse or recycling of water in several of the operations. Gallop (7) has pointed out that the potato industry should be capable of recycling its waste waters at the same rate that they are created and that these waste waters therefore should have an input value within one or more of the other processes.

2.1 Potato Chip Processing Methods

Although processing techniques used in the industry are varied, they follow a somewhat similar pattern. The first step consists of peeling, slicing and washing the potato. Becker (1) pointed out that in the future peeling potatoes for chipping will no longer be needed. The tuber will be scrubbed and sliced, increasing the yield in the finished product by 5%. He has also claimed that this will improve flavor, reduce rancidity and most important solve many of the pollution problems associated with the peeling process.

The slice thickness of the potato varies from 1/15" to 1/30" depending upon the physiological condition of the tuber (23). Smith has indicated that the washing step is necessary to remove excess starch and to prevent the potato chip slices from sticking together when fried.

Hot water blanching can be used when tubers contain excessive levels of reducing sugars (ie., more than 0.2%) (3). Brown (3) claimed that blanching temperatures should be between 180° F and 200° F. The present trend is to remove the hot water treatment from the process thereby using only a cold water bath to remove the excess starch. This would greatly decrease the volume as well as the organic content of the water required (8). At the present time it is known that hot water blanching not only increases the organic load in the blanching media (consisting of gelatinized starch and coagulated protein) but also causes an increase in total sugars (34). Gallop (7) pointed out that blanch water acts as a solvent for starches, sugars, proteins, vitamins, chlorophenols and minerals which contribute to the chemical factors affecting the quality of the potato product.

The chips are then dried by sponge rollers to remove excess water. Water remaining on the surface of the tuber slice would overload the frying oil reducing the cooling temperature of the media. The chips should be fried at 375° F. Hot air blasts (3) may be used in place of sponge rollers to dry chip surfaces.

2.2 Factors Affecting Potato Chip Quality

Turnquist (31) has extensively outlined the factors affecting chipping quality in potatoes as have many other researchers. Little information is available at the present time in regards to "how chemical build up in blanch water affects the chipping quality of potatoes."

2.3 Factors Affecting Colour in the Potato Chip

Colour is the primary factor in the quality of potato chips. Many researchers have shown the relationships between reducing sugars and potato chip colour as well as the relationships between environmental factors affecting the reducing sugar content of the tuber (9). Habib and Brown (10) indicated that the colour change is due to chemical reaction in the chips during frying (caramelization and Maillard Reaction). They feel that although high levels of reducing sugars may indicate a dark potato chip, these sugars may be limited in browning by the level of free amino nitrogen available in the slices. Habib and Brown (10) have shown that the basic amino acids, primarily lysine, are more active in the colour reaction than neutral or acidic amino acids. Hoover and Xander (13) agreed that basic amino acids are more active but indicate that histidine and not lysine is significantly involved in the colour reaction. Townsend and Hope (30) concluded that the browning reaction between reducing sugars and amino acids is not really affected by acidic or basic constituents. They also pointed out that low levels of reducing sugars in the potato do not always produce desirable colour. Sucrose, according to Townsend and Hope, reacting with amino acids could form a dark chip depending on the degree of acidity in the frying oil. Smith (25) claimed that sucrose in a potato tuber is important in determining chip colour because of the ability and tendency of sucrose to breakdown into the reactive reducing sugars. Habib and Brown (10) reported the higher the sucrose level the better the colour in the product because the conditions under which the chips are fried do not involve hydrolysis. Yamaguchi et al. (36) claimed that low reducing sugar levels and high sucrose levels in the same tuber does not indicate that the resulting potato chips will be of good colour.

Hoover and Xander (13) stated that phenolic compound levels are significant in chip colour. They also suggested that chlorogenic acid may inhibit the synthesis of starch which could result in chemical compounds which may indirectly be capable of entering the Maillard Reaction.

Henderson (11) suggested that chlorogenic acid is not likely to inhibit the phosphorylase enzyme from converting starch to glucose-1-phosphate in the potato tuber. Therefore the accumulation of reducing sugars in storage by high natural levels of chlorogenic acid would not likely be prevented.

Townsend and Hope (30) suggested that inorganic compounds do little to enhance the colour in chips although phosphates seemed to promote the hydrolysis of sucrose in the tuber.

McConnell and Gerbasi (17) in working with artificial potato juice systems found that iron had an outstanding effect on potato chip colour when added to a solution of glucose and varied amino acids.

Processing techniques can be used to control colour in producing potato chips. Hesen (12) stated that colour could be controlled by varying the thickness of slice, blanching techniques, frying temperatures as well as frying methods. He pointed out that microwave frying would be of benefit in chip colour but the process is too expensive and has the everpresent danger of fire.

2.4 Potato Chip Flavour

Part of the flavour in a potato chip may be associated with the browning reaction which occurs between reducing sugars and amino acids. Smith (24) as well as Self (22) have written that the carbonyls in the potato chip are responsible for the chip flavour. They substantiated this fact by isolating 2,5 dimethylpyrazine from chips indicating flavour enhancement could come from the controlled production of carbonyls in the frying oil. Smith (24) suggested that flavour in the chip may also be associated with the development of melanoidin in pigment. According to Self (22) 30% to 35% of the final total weight of the potato chip is due to the oil absorbed from the frying media. He stated that due to the fat content, chips are vulnerable to fat autoxidation thereby inducing off flavour in the product.

Chang (5) has shown a relationship between methionine and chip flavour. He substantiated this point by frying potato slices in an oil treated with methionine resulting in an improved potato chip flavour.

2.5 Texture of Potato Chips

Matz (16) and Brown (3) stated that potato chips are a result of the dehydration process which occurs simultaneously with the cooking or frying process. Crispness, according to Matz (16) is caused by the crisp network of dehydrated starch and protein. Smith and Davis (27) claimed that the starch cells are gelled, dehydrated and have part of the natural chip water replaced by oil during the frying process.

Potato chips (16) have a critical moisture level of 5%. The moisture content of the chip must be watched closely as the chip will readily pick up moisture between frying and packaging.

Smith (27) found that small amounts of sodium pyrophosphate when added to the frying media resulted in potato chips with increased crispness but with side effects detrimental to quality such as acidic flavour and dark colour.

Blistering of potato chips (27), which affects crispness, is a direct result of cell separation and is caused by the expansion of steam trapped within the slices during the cooking process.

III. METHODS AND MATERIALS

3.1 Introduction

This study was designed to determine the effect of specific blanch water systems on the quality characteristics of the potato chip. Build up of soluble starch, reducing sugars, amino nitrogen, soluble iron and phenols was determined over a series of blanch tests.

Blanch waters were then simulated with various levels of soluble starch, reducing sugars, soluble iron and phenols. The levels of the chemicals used were determined from data obtained from analyzing blanch waters. These simulated waters were then used to blanch potato slices in preparation for frying. The resulting potato chips were then submitted to quality tests. Data was collected for colour, flavour and texture and analyzed to determine the effect of the simulated systems on the quality of potato chips.

Three varieties of Solanum tuberosum L were used in determining the build up of chemicals in the hot water blanch system. The potato varieties used were Kennebec, Superior and Norchip all of which were supplied by the Old Dutch Potato Chip Co. Ltd. upon request.

The final stage of this study was carried out during the fall of 1971 and for this reason the variety used was Kennebec. Kennebec has proven to be an excellent variety for chipping from early storage and it was the variety being used by the Old Dutch Potato

Chip Co. Ltd. at that particular time.

This study was based on the commercial methods of processing and all experiments were carried out as close as possible to commercial conditions.

The data for colour, flavour and textural qualities of the potato chip was analyzed by analysis of variance using the factorial design.

3.2 Laboratory Studies

Laboratory studies were carried out to investigate the build up of chemicals in potato blanch systems and to determine their effect on the quality of potato chips.

3.2.1 Sample Preparation

Blanch waters of three concentrations were prepared by blanching one, two and three lots of potato slices in a given volume of water. A sample was taken after each blanch and analyzed for soluble starch, soluble iron, phenols and reducing sugars.

Simulated blanch systems were prepared using the data from the blanch water analysis. Potato slices were then blanched in these systems, fried and studied for quality.

3.2.1.1 Blanch Water

Potatoes, supplied by Old Dutch Foods Ltd., Winnipeg, Manitoba, Canada, were brought to the laboratory in 22,700 g lots. A random sample of 3,000 g of tuber was selected from the 22,700 g lot, washed, dried and reweighed.

The first of the three samples was blanched in 2 ℓ of tap water at 210° F for three minutes. The slices were then removed and rinsed, the rinse water was used to replenish the volume of the blanch water to the original volume of two litres. The second sample was blanched in the same water as the first sample and the third sample was treated in the same way.

After each sample was blanched, 50 mls of blanch water were taken from the system prior to the addition of rinse water to the blanching media. Ten of the fifty mls were placed in a 100 ml volumetric flask and made to volume. This portion was used for the determination of total reducing sugars, phenols and soluble iron. The remaining portion of the 50 ml sample was used directly in the Starch Test.

3.2.1.2 Blanching and Frying Slices for Chip Quality

Simulated blanch waters were developed with various levels of reducing sugars, soluble starch, phenols and soluble iron. The levels of chemicals in the water were determined by the analysis of the blanch water described in 3.2.2. The chip slices were prepared in the same manner as that described in 3.2.1.1. Five hundred fifty grams of sliced tuber were blanched in 2 ℓ of simulated water at 210° F for three minutes. The slices were then removed from the blanch system and vigorously agitated to remove the excess water. One hundred fifty gram samples were taken from each lot of chips, fried and packaged for testing.

To fry the samples the 150 g sample was placed in a frying basket and fried for three minutes on a model 80-03 "Garland" fryer. The frying media was "Fryene", a commercial vegetable frying fat produced by Swifts of Canada Ltd. The frying temperature was approximately 375° F and kept as uniform as possible. The variation of frying temperature was investigated by Yaciuk (35) and considered not to interfere with the analysis of colour.

The frying media was changed after each sample run to prevent the possible effect of the fat on the colour, taste and texture of the potato chips.

Chips blanched in hot water result in an uptake of approximately 30% to 35% (22). Overuse of the frying media may cause polymerization, rancidity and off colour due to the build up of reducing sugars. To minimize error the fat was changed constantly to ensure good quality product.

After frying the chips were placed on paper towels and blotted to remove excess fat before packaging.

3.2.2 Chemical Methods of Analysis for Blanch Water

The methods of analysis used were basically standard methods of analysis for plant tissue. These methods as such have been adapted for the blanch water with slight modification.

3.2.2.1 Determination of Total Reducing Sugar (21)

This is a standard method for the determination of reducing sugars in plant tissue. Two mls of blanch water were used directly in this method therefore no extracts were carried out on the sample used.

3.2.2.2 Determination of Total Soluble Iron (33)

This is a standard method of analysis in which 25 ml of prepared blanch water was diluted to 5 mls and a 20 ml sample of this diluted blanch water was used for analysis.

3.2.2.3 Determination of Total Phenols

The method used for the determination of total phenols was a modification of the method proposed by Folin and Ciocalteu (6) as used by Yaciuk (35) at the University of Manitoba. A 10 ml aliquot of sample blanch water was used directly in this method of analysis.

3.2.2.4 Starch Determination (28)

This method of Steiner and Guthrie (28) was designed to analyze plant tissue for soluble starch by use of a Polarimeter. This method was adapted for water analysis by placing a 10 ml aliquot of blanch water in a 100 ml pyrex centrifuge tube of known weight, weighed and then analyzed as outlined by Steiner and Guthrie (28).

3.2.3 Colour Measurement of Chips

The colour of each sample was read on a Model D 25 "Hunter-lab" Colour and Colour Difference Meter using a white standard tile with the following values as a reference: $L = 93.8$, $a = -1.1$, $b = +2.3$.

The colour or hue of the chip is given by the "a" and "b" values on the Hunter Colour Difference Meter. The "L" value is a measure of brightness based on an arbitrary scale of zero to one hundred, zero being the darkest or black and one hundred being the brightest or white. Since the most meaningful measurement to the chip industry is the "L" value and the acceptable level is 45 on this scale (32) the "L" value was recorded for analysis.

The chips were broken into small pieces and placed on the "Hunterlab" in glass containers. The L value was then determined with the "a" and "b" values remaining constant.

3.2.4 Texture of the Chip

The texture of the sample chip was determined on the C. W. Brabender/General Foods Textur-o-meter.

The machine was allowed to warm up for one half hour before use. An aluminum dish was used as the sample cup and the large plunger was also used with a clearance set at 3.5 mm. The chart speed was set at a 750 mm chewing speed set on low (12 bites/minute) and the voltage set at 5. The sample was then tested, the sample size was one chip.

3.2.5 Flavour of Chip

Multiple Comparison Method (15)

A taste panel was set up consisting of four judges picked from a group of twenty-one possible judges. The judges were given samples of chips and a reference sample to which each sample was to be compared. Each sample was to be judged as better than, comparable to or inferior to the reference. The samples were tasted without any additives such as salt which could interfere with the comparison of a sample to the reference. The judges were instructed to rinse their mouths after tasting each sample with milk, for comparison to the reference. The judges sampled the chips in an enclosed room, one at a time and were not allowed to discuss their results.

IV. RESULTS AND DISCUSSION

4.1 Introduction

The literature previously cited is based on the chemical composition of potatoes and the variation it may cause on the quality of the potato chip a given tuber may produce. In this study the chemical composition of the blanch water was determined and the effect on the quality of potato chips evaluated.

The object of this experiment was to evaluate the effect of certain chemicals, in the blanch water, on the quality of potato chips. Blanch waters were analyzed for specific chemicals and the build up of these chemicals in the blanch system after one, two and three uses. Once the levels were established blanch waters were simulated using: reagent grade phenol, glucose, ferrous ammonium sulphate and potato starch. Therefore chips were evaluated for quality and the data analysed to show the effect the above chemicals, in a blanch system, would have on the quality of potato chips.

4.2 Method of Analysis

The data collected from the colour and texture studies were analyzed by factorial design analysis of variance. There were four chemical treatments at three levels of use with four replications.

The factorial design analysis of variance was also used on the flavor data. There were four judges, four replications and eleven treatments. The treatments were limited due to the large number of samples.

4.3 Blanch Water

Hot water blanch systems were initially studied to establish levels of reducing sugars, phenols, soluble iron and soluble starch after one, two and three blanches in the same system. Three varieties of chipping potatoes; Kennebec, Norchip and Superior were used for this study. Average levels of the designated chemicals were established after one, two and three blanches (Table I). The hot water blanching trials were repeated twelve times. All chemical analyses were duplicated. Kennebec was used in seven trials, Norchip in four and Superior in one; no differences were observed between varieties. The chemicals studied increased in concentration through this series of blanches with the exception of soluble iron which decreased after the second rinse of the blanch water.

The physical appearance of the blanch water changed noticeably from the first to the third blanch of each trial particularly in the viscosity of the fluid (Figure 1).

It was observed that the water became cloudy and had a slight red-brown tint after one use; the second use of the blanch water intensified the same characteristics, but after the third use the water was very viscous while the colour tint remained the same. At this point the water was no longer usable from a physical standpoint for blanching potato slices. It was felt that the increase in viscosity and cloudiness was due to the gelation of potato starch

TABLE I

Average Composition of Blanch Water

Chemical	Blanch #1	Blanch #2	Blanch #3
Reducing Sugar *	267.89	487.14	606.18
Soluble Iron*	3.79	6.48	3.71
Total Phenol*	3.43	4.97	7.25
Soluble Starch**	0.60	0.80	10.27

*mcg/ml

**% by weight

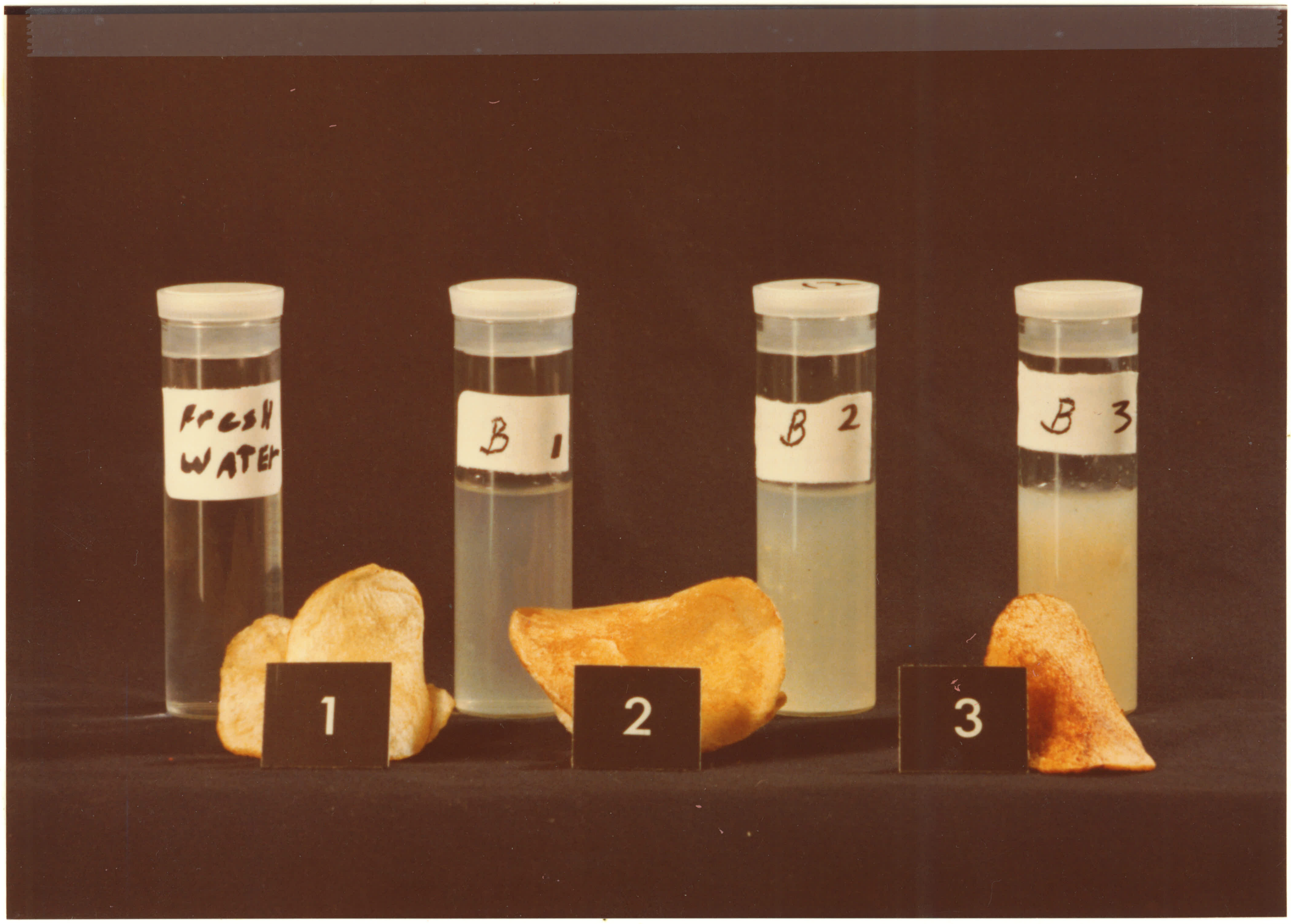


FIGURE 1. Water samples and potato chip samples produced after 0, 1 and 2 blanches.

since the temperature of the blanching medium exceeded the gelation point of potato starch.

The colour of the system was believed to be a result of the oxidation of phenolic compounds, resulting in a rust brown colour. This can be further illustrated by the exposure of a dilute catechol solution to the air for one-half hour which would result in a similar colour.

Blanch water may be treated physically with different techniques such as centrifuging and filtering to remove many of the suspended solids in particular starch and tissue. Cold water blanch systems are much easier to treat physically than are hot water systems as the starch does not gel and the tissue of the potato slice is not as fragile in a cold water system. Centrifuging and filtering in hot water may possibly allow for further use of the blanch media and could possibly be a new area of research as this study only looks at the accumulation of chemicals and the effect on chip quality.

4.4 Chip Quality

Potato slices blanched in fresh water and fried resulted in high quality potato chips but when the blanch water was reused the chips darkened in colour and a slight bitterness was detected in the chips produced from second use blanch water (Figure 1). Chips produced from blanch water used once previously were not inferior in quality to chips produced from fresh water. When the water was used for the third blanch, colour, flavour and texture of the chips were unacceptable. These observations were obtained with a selected group of people (5 persons), using the Arthur D. Little System (15).

It was felt that the colour was affected by the increase of total reducing sugars and amino nitrogen in the blanch system by means of the Maillard Reaction as well as caramelization.

The flavour of the chip was felt to be the result of a combination of factors; (a) increase in caramelization which tends to give a bitter flavour, (b) phenols which will react with free chlorine in tap water to produce chlorophenols, a compound which is readily detected by the palate at very minute concentrations and (c) a build up of alkaloids. The build up of alkaloids could be attributed to two factors. (i) Some potatoes randomly selected appeared to have Solanine build up due to planting too close to the surface. (ii) Tubers used were not peeled and the eyes of the potato tuber are collection points for alkaloids therefore allowing this chemical to remain in the chip slice or else be picked up by the blanching media and eventually being distributed to the surface of following lots of potato slices. Alkaloids were not studied due to the time involved of sample preparation and chemical methods.

The texture was considered to be a problem after the third use of the blanch water. It was suggested that a thin layer of gelatinized starch remained on the potato slice after blanching and rinsing due to the extremely viscous blanch water.

When the chip was fried a crisp network formed due to the starch as suggested by Matz (16). This crisp coating would prevent the uptake of oil to replace the moisture driven from the chip in the dehydration and frying process.

4.5 Effect of the Model System on the Quality of Potato Chips

The levels of chemicals used for the simulated blanch systems were;

Level I is fresh tap water, no chemicals added,

Level II is the lowest level of chemicals found in the blanch systems,

Level III is the highest level of chemicals found in the blanch systems,

as presented in Table II.

4.5.1 Potato Chip Colour

Data for colour (Appendices I & II, Figures 1-16) indicates that glucose when used alone in a water blanch system, significantly affects the colour of potato chips. Neither iron, phenol nor starch showed any significant effect at either level when used alone. There was no significant effect with any combination of the added chemicals in the blanch water on the quality of colour in the potato chip (Appendices I, Figures 1-16).

The effect that glucose had on the colour of the chip indicates that high reducing sugar levels in a blanching system may affect quality in a similar way in which Habib and Brown (10) indicated that high levels of reducing sugars in the tuber may cause

TABLE II

Levels of Chemicals for Simulated Blanch Water

Chemical	Level #1	Level #2	Level #3
Reducing Sugar*	0	268	606
Soluble Iron*	0	4	6.5
Total Phenol*	0	3.5	7.25
Soluble Starch**	0	0.6	10.25

* mcg/m

** % by weight

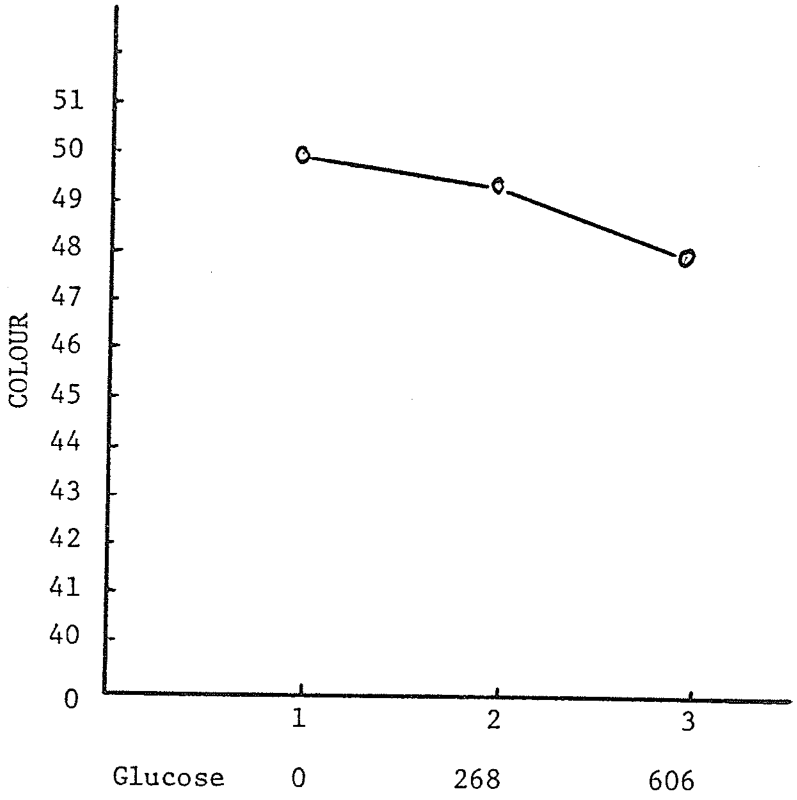


FIGURE 2. Means of Data Showing Effect of Glucose at Levels 1, 2 and 3 on Colour.

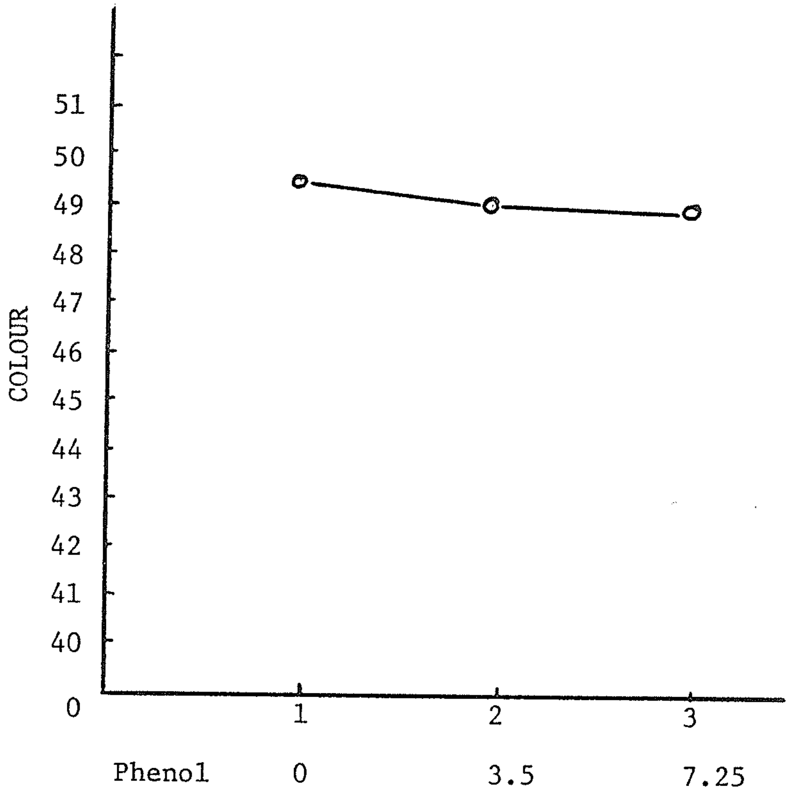


FIGURE 3. Means of Data Showing Effect of Phenol at Levels 1, 2 and 3 on Colour.

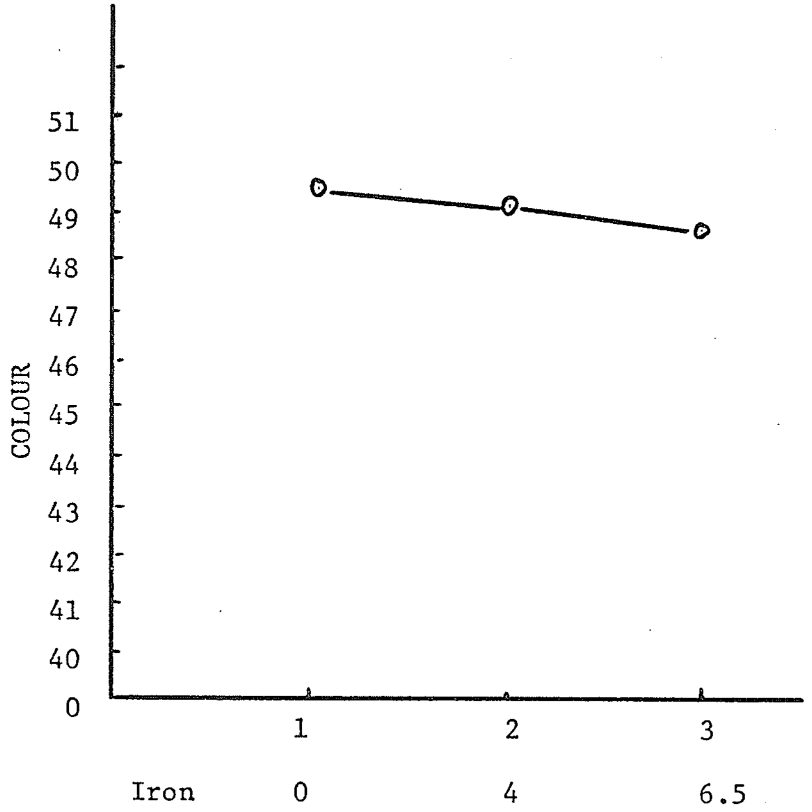


FIGURE 4. Means of Data Showing Effect of Iron at Levels 1, 2 and 3 on Colour.

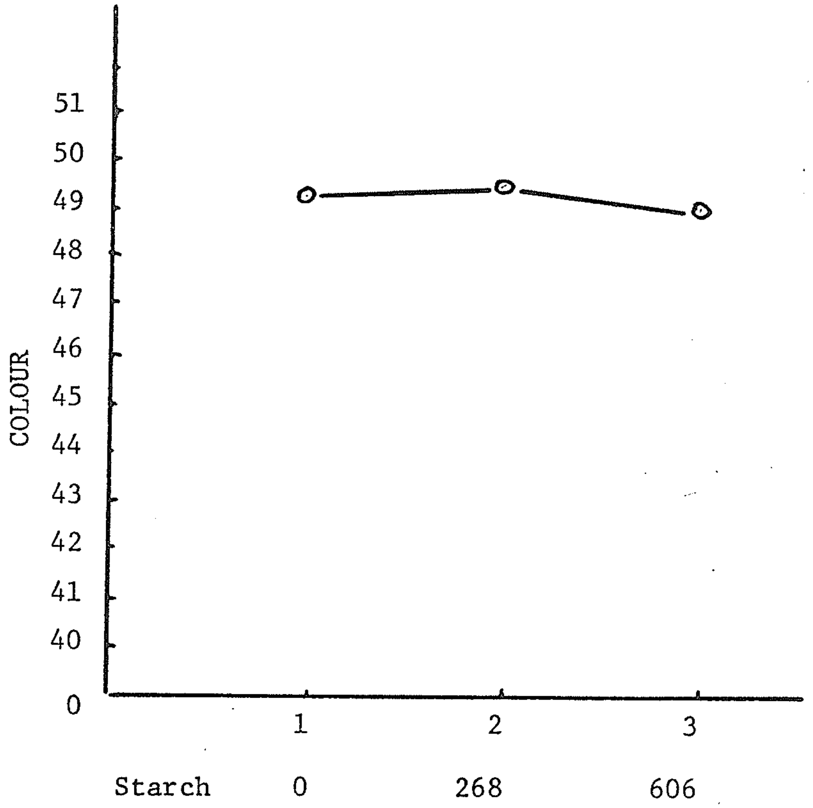


FIGURE 5. Means of Data Showing Effect of Starch at Levels 1, 2 and 3 on Colour.

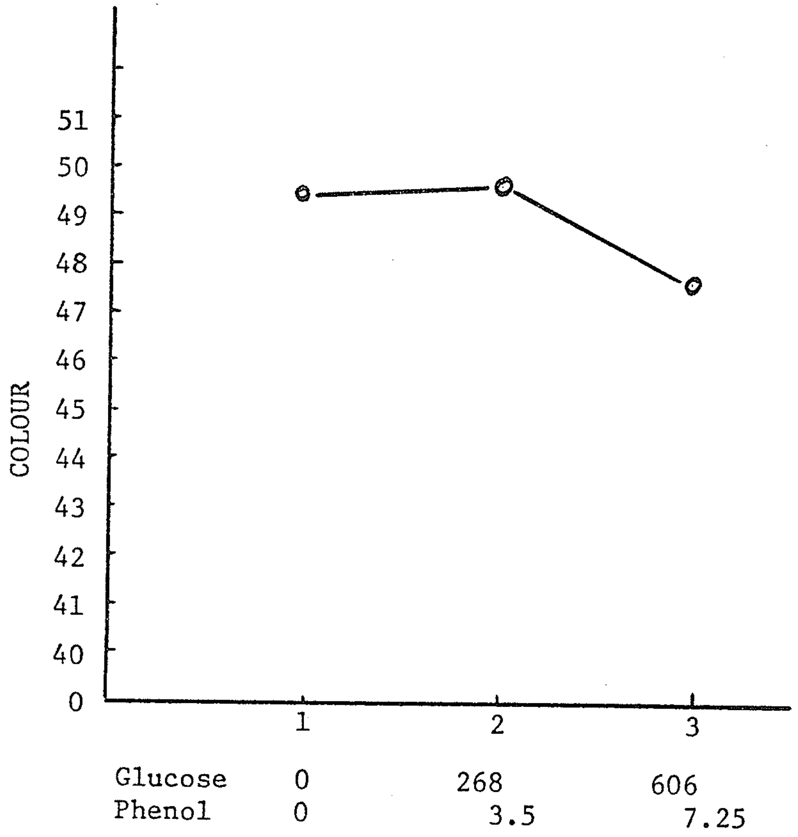


FIGURE 6. Means of Data Showing Effect of Glucose and Phenol at Levels 1, 2 and 3 on Colour.

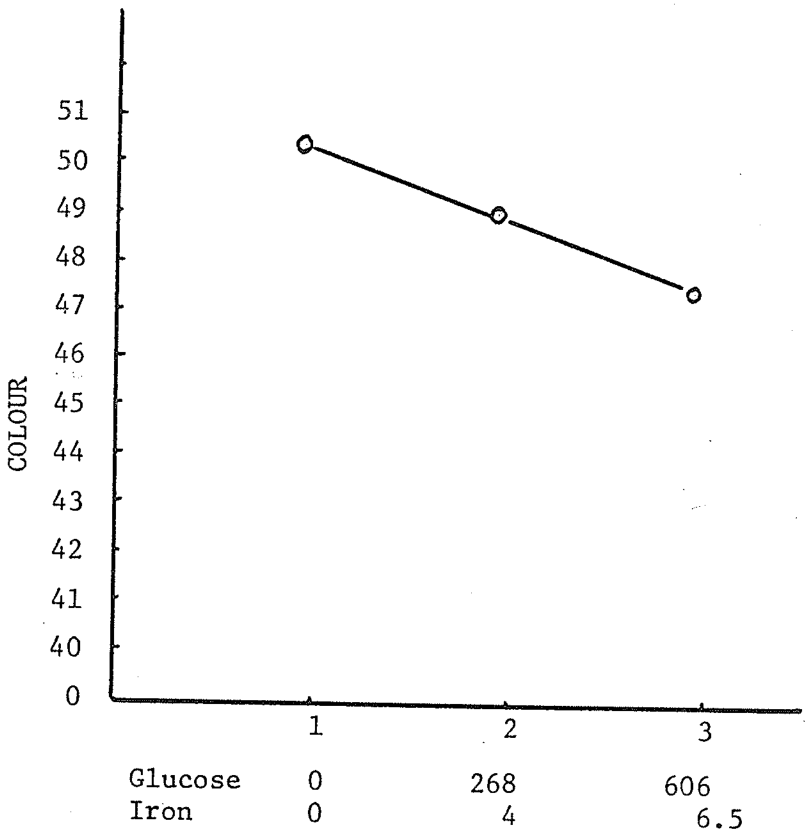
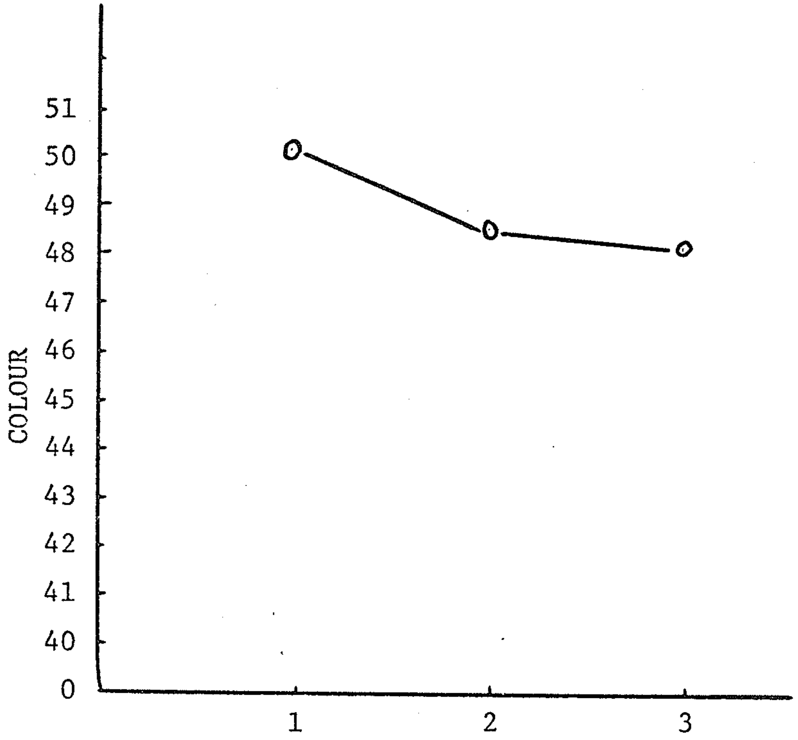
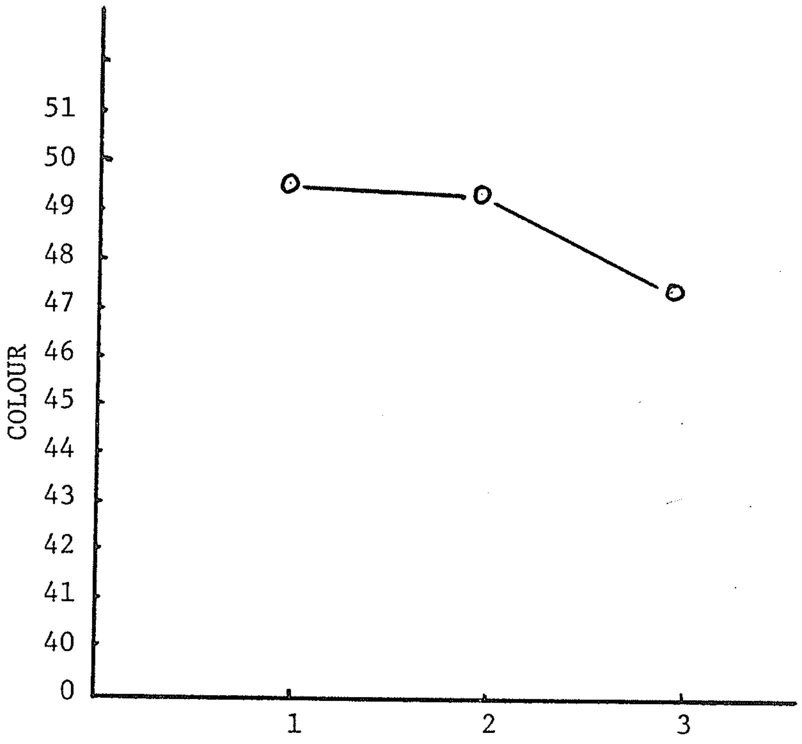


FIGURE 7. Means of Data Showing Effect of Glucose and Phenol at Levels 1, 2 and 3 on Colour.



Phenol	0	3.5	7.25
Iron	0	4	6.5

FIGURE 8. Means of Data Showing Effect of Phenol and Iron at Levels 1, 2 and 3 on Colour.



Glucose	0	268	606
Starch	0	0.6	10.25

FIGURE 9. Means of Data Showing Effect of Glucose and Starch at Levels 1, 2 and 3 on Colour.

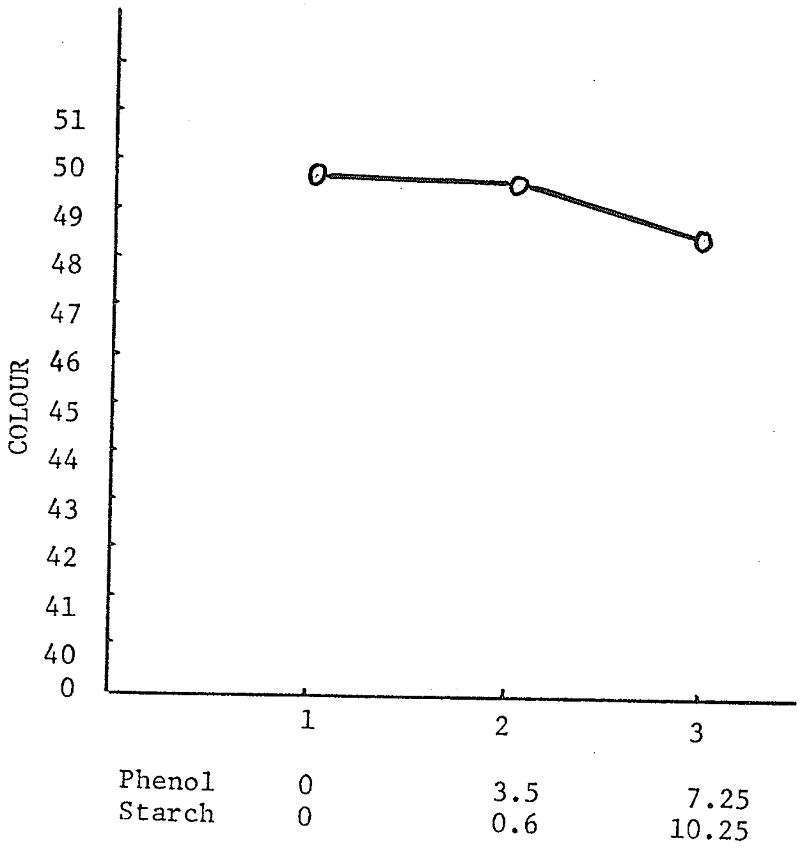


FIGURE 10. Means of Data Showing Effect of Phenol and Starch at Levels 1, 2, and 3 on Colour.

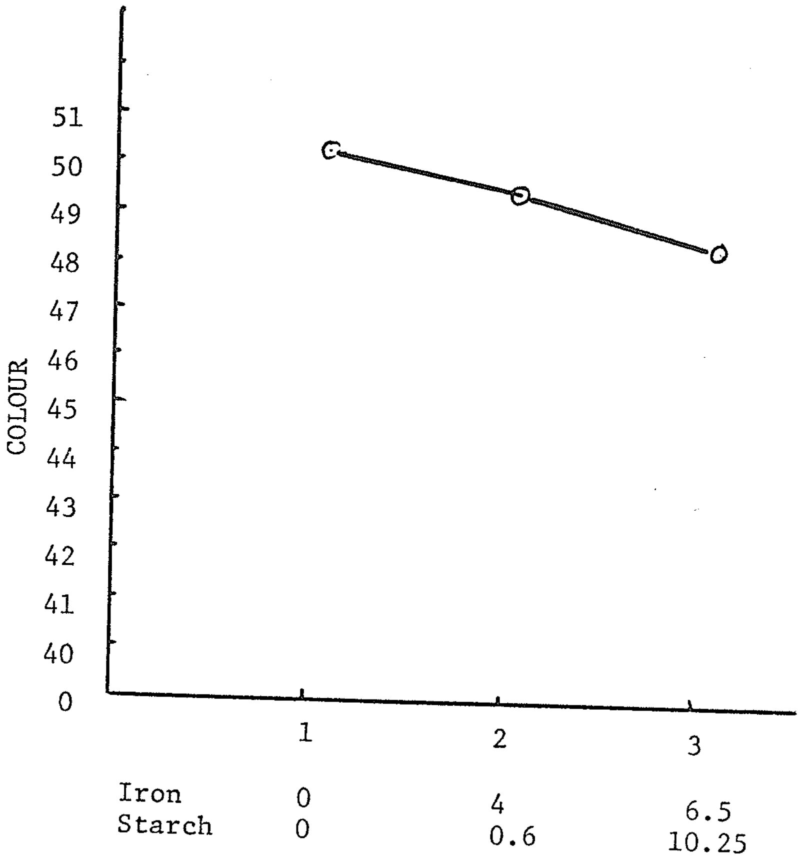
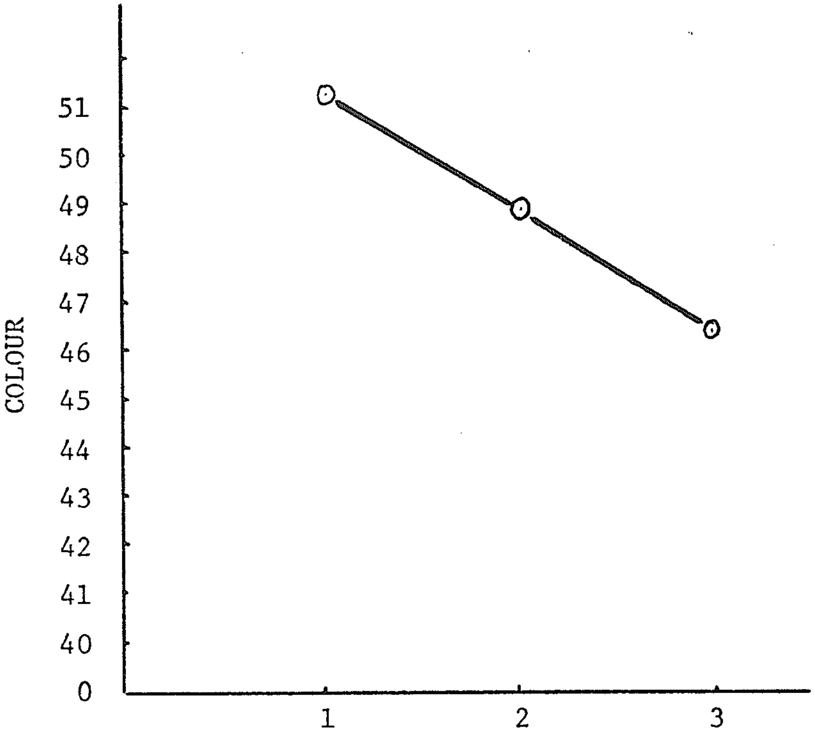
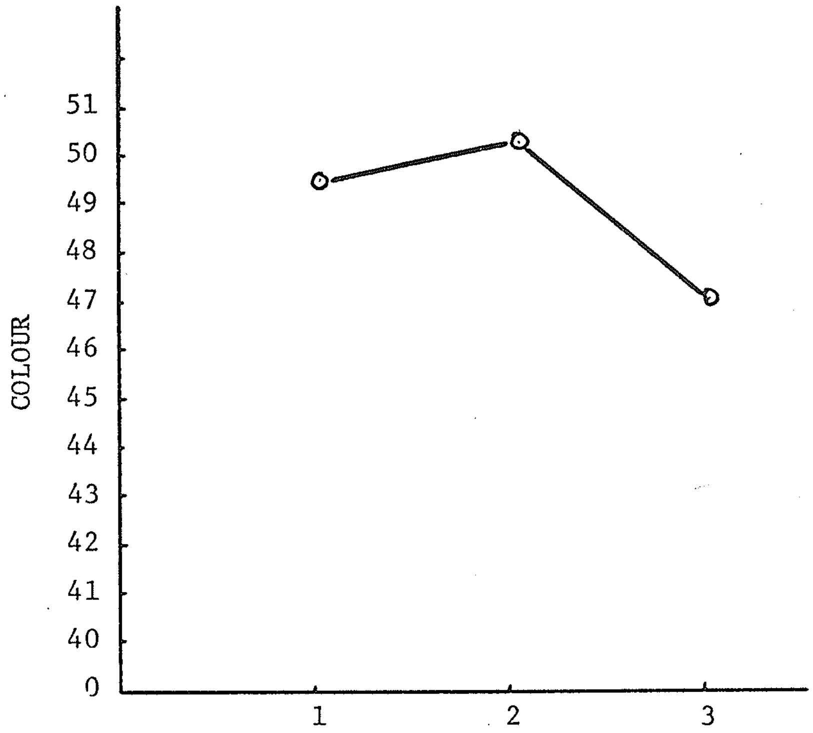


FIGURE 11. Means of Data Showing Effect of Iron and Starch at Levels 1, 2 and 3 on Colour.



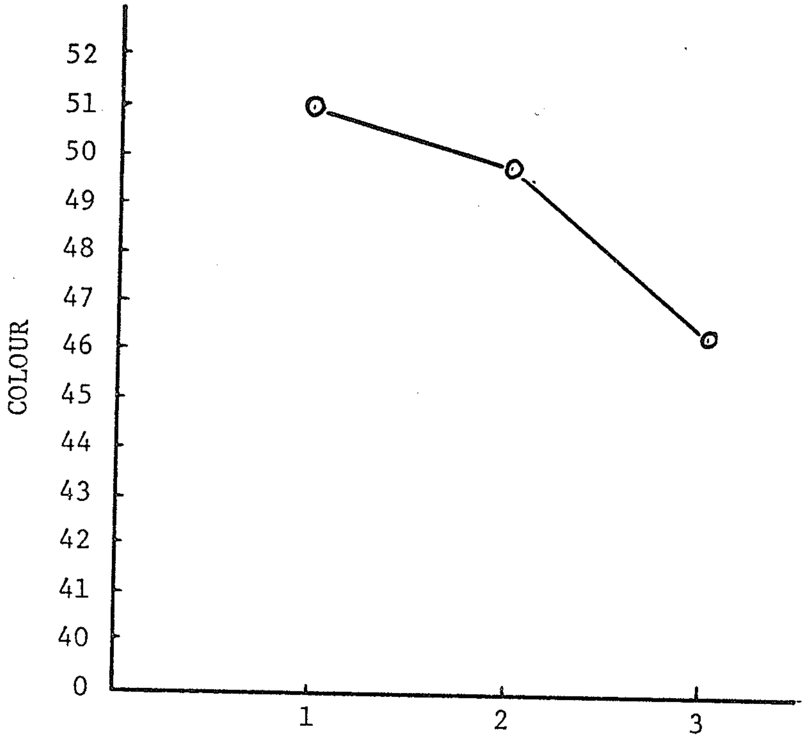
Glucose	0	268	606
Phenol	0	3.5	7.25
Iron	0	4	6.5

FIGURE 12. Means of Data Showing Effect of Glucose, Phenol and Iron at 1, 2 and 3 levels on Colour.



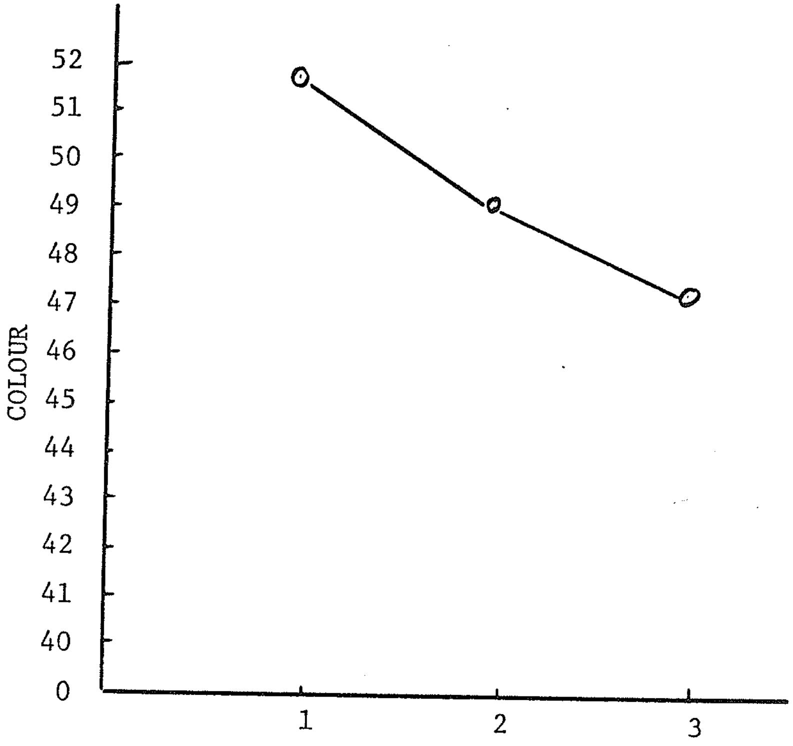
Glucose	0	268	606
Phenol	0	3.5	7.25
Starch	0	0.6	10.25

FIGURE 13. Means of Data Showing Effect of Glucose, Phenol and Starch at Levels 1, 2 and 3 on Colour.



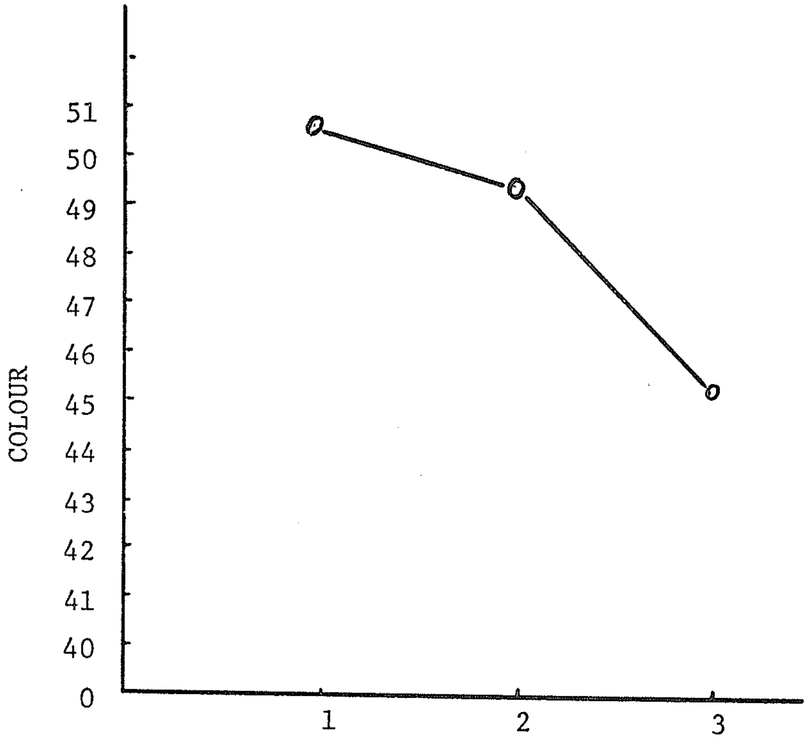
Glucose	0	268	606
Iron	0	4	6.5
Starch	0	0.6	10.25

FIGURE 14. Means of Data Showing the Effect of Glucose, Iron and Starch at Levels 1, 2 and 3 on Colour.



Phenol	0	3.5	7.25
Iron	0	4	6.5
Starch	0	0.6	10.25

FIGURE 15. Means of Data Showing the Effect of Phenol, Iron and Starch at Levels 1, 2 and 3 on Colour.



Glucose	0	268	606
Phenol	0	3.5	7.25
Iron	0	4	6.5
Starch	0	0.6	10.25

FIGURE 16. Means of Data Showing Effect of Glucose, Phenol, Iron and Starch at Levels 1, 2 and 3 on Colour.

a dark potato chip. The colour of the chip although not acceptable when processed in the model system, was not extremely dark in appearance. It is suggested by the author that the colour did not darken more as there were no amino acids added to the blanch system and as stated by Habib and Brown (10), the sugars may be limited in browning by the level of amino nitrogen available in the system.

It is felt that some type of chemical interaction between glucose and the other chemicals in the model system prevent the glucose from entering into the Maillard Reaction during the frying process. The effect on colour by phenols and inorganic compounds (11, 13, 30) is mainly by metabolism in the tuber, the ultimate effect being to increase the reducing sugars in that system. As indicated by the model system, these compounds would not likely affect the colour of the chip when they are present in the blanching medium.

4.5.2 Potato Chip Texture

Analysis of variance data indicated that the simulated chemical systems used for blanching had no significant effect on the textural quality of the potato chips at either 5% or 1% levels (Appendices III & IV, Figures 17-31). This indicates that it is not likely that any of the chemicals used alone or in any possible combination with each other in a model system would affect the textural quality of potato chips.

Matz (16) stated that crispness is due to a network of dehydrated starch and protein in the potato chip as a result of

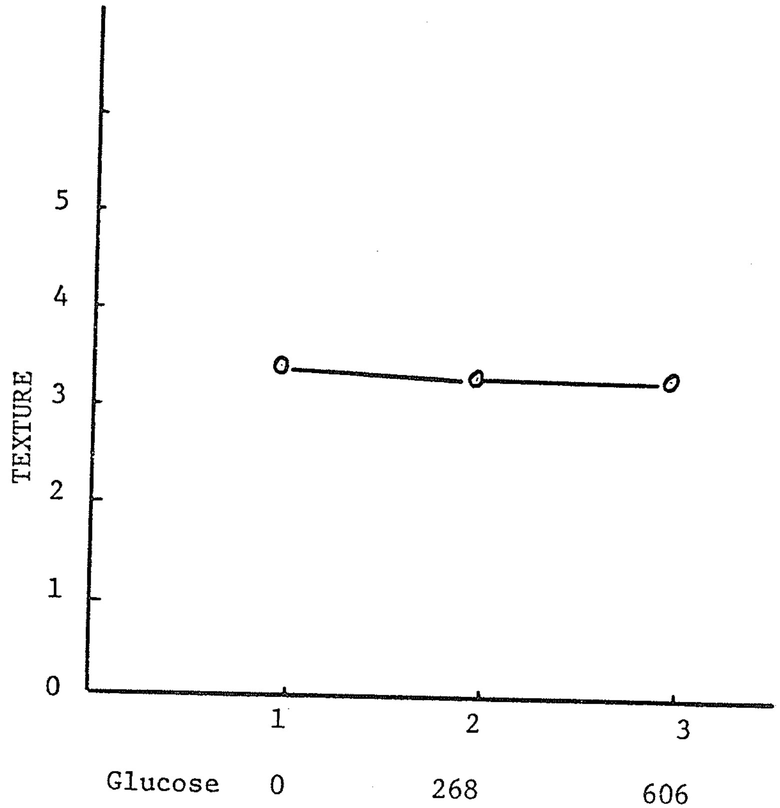


FIGURE 17. Means of Data Showing Effect of Glucose at Levels 1, 2 and 3 on Texture.

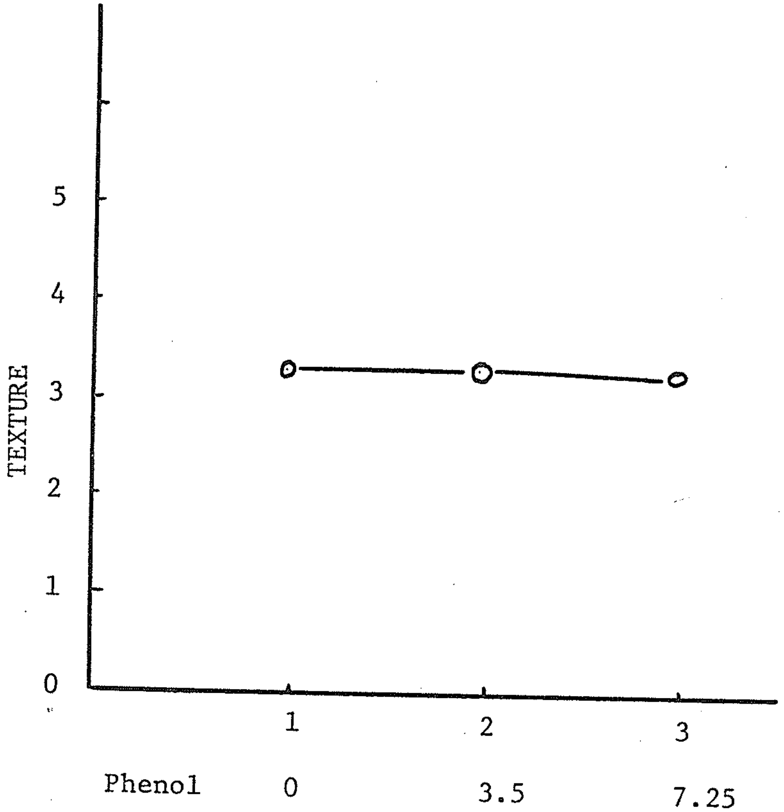


FIGURE 18. Means of Data Showing Effect of Phenol at Levels 1, 2 and 3 on Texture.

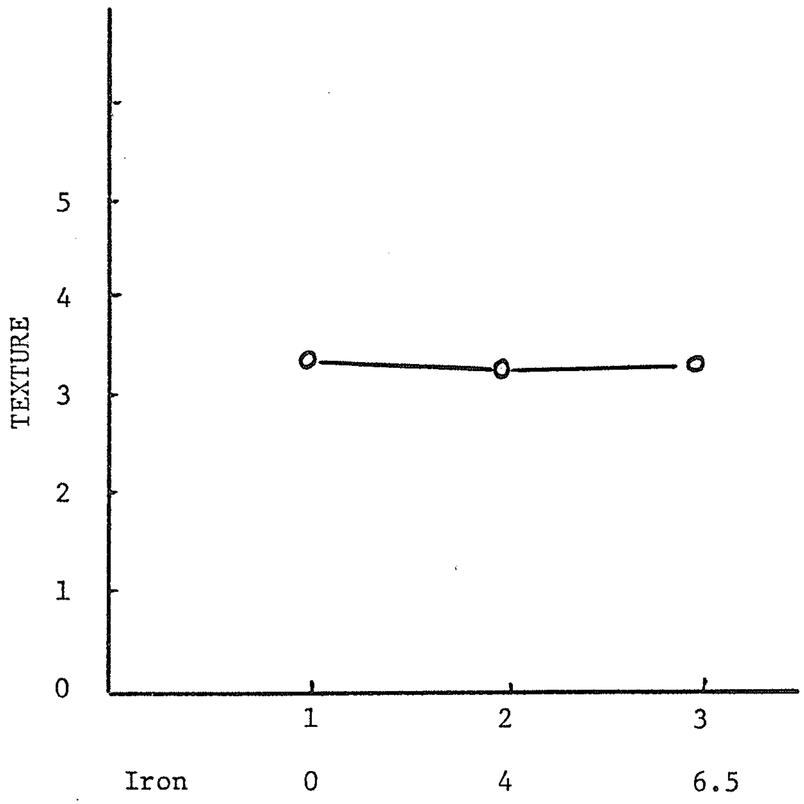


FIGURE 19. Means of Data Showing Effect of Iron at Levels 1, 2 and 3 on Texture.

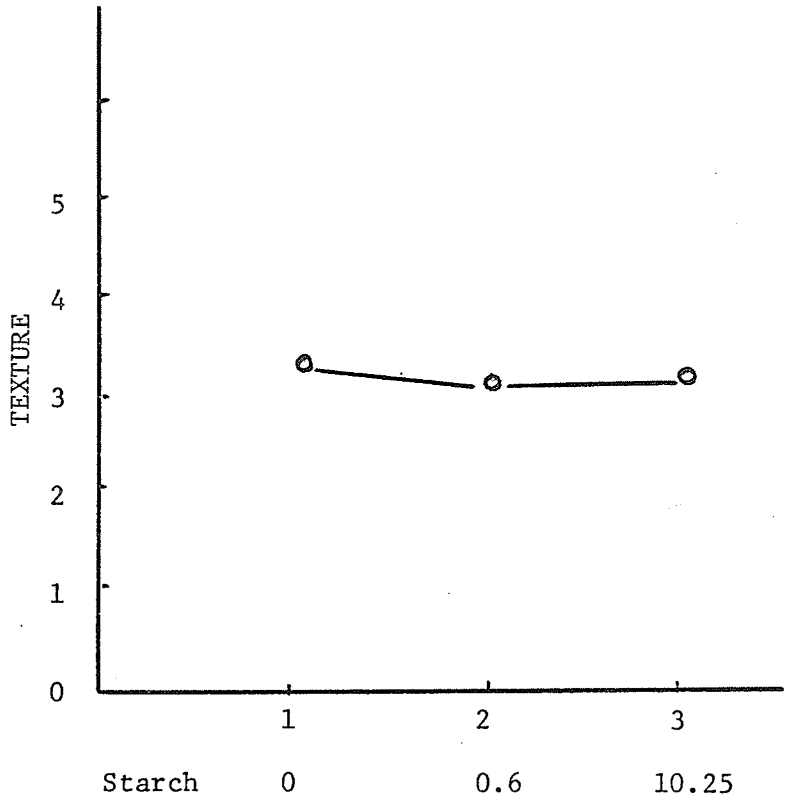


FIGURE 20. Means of Data Showing Effect of Starch at Levels 1, 2 and 3 on Texture.

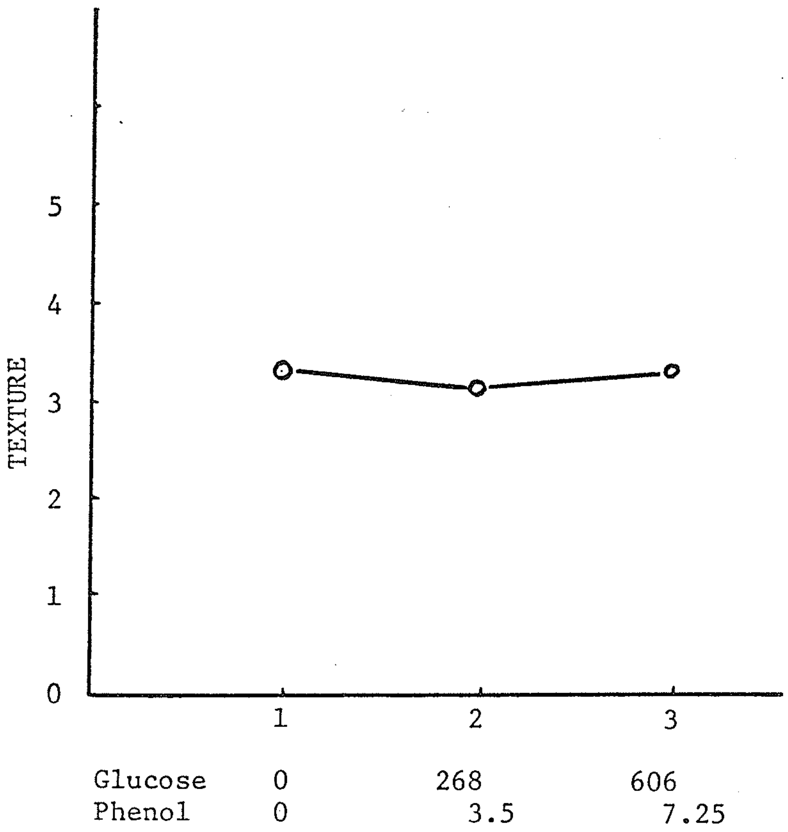


FIGURE 21. Means of Data Showing Effect of Glucose and Phenol at Levels 1, 2 and 3 on Texture.

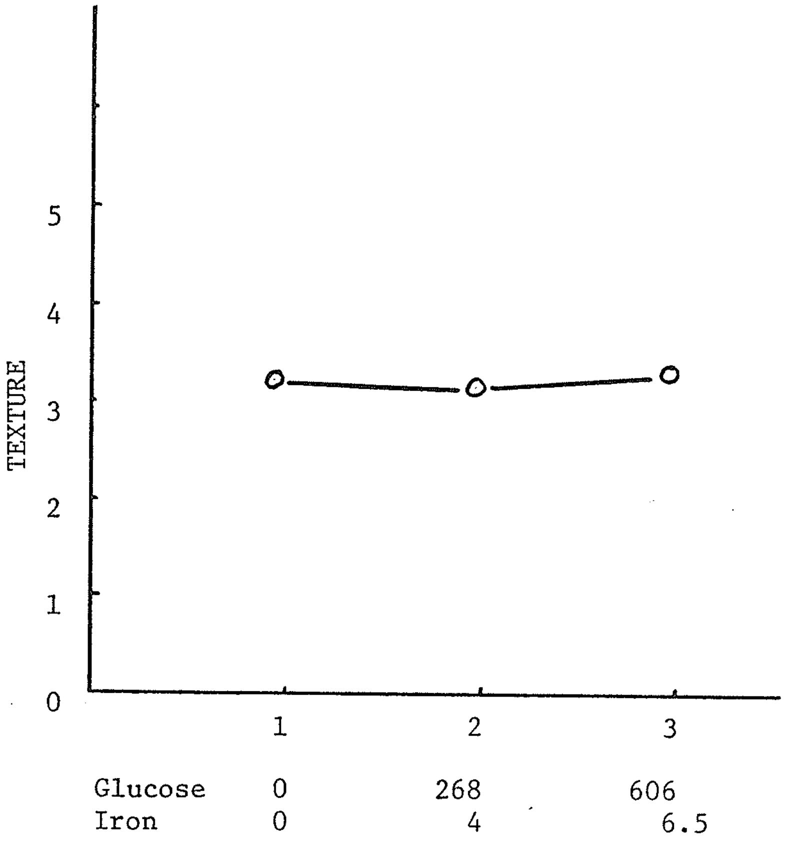
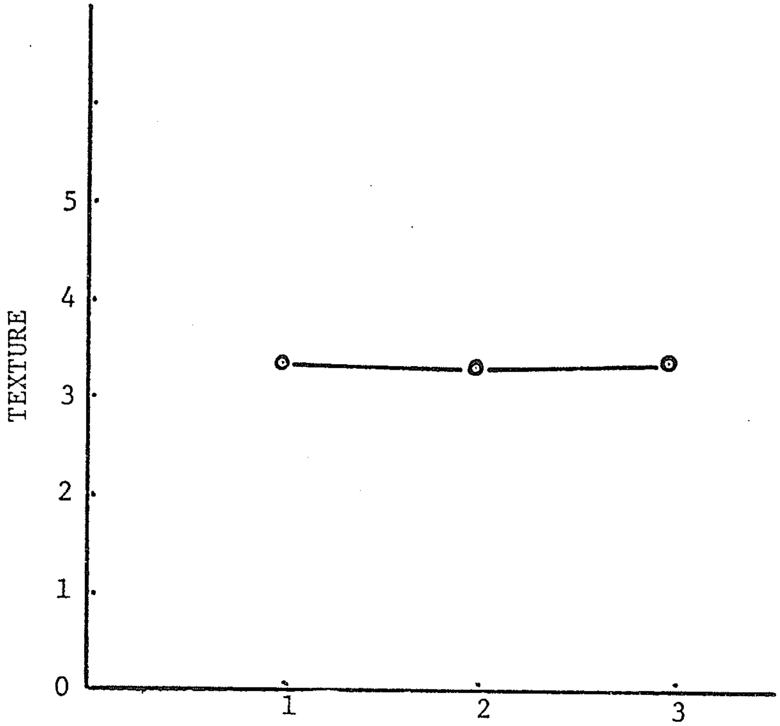
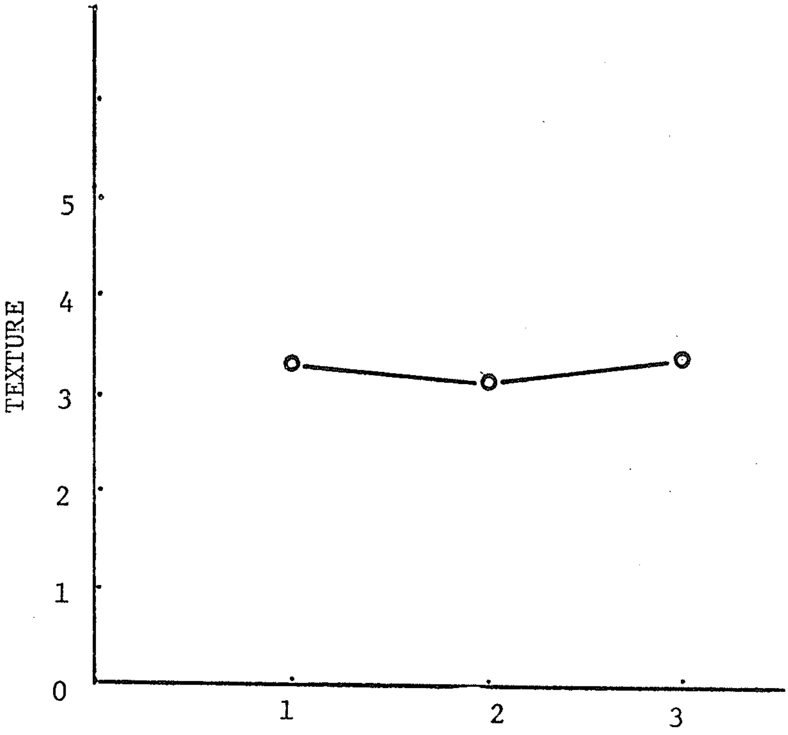


FIGURE 22. Means of Data Showing Effect of Glucose and Iron at Levels 1, 2 and 3 on Texture.



Phenol	0	3.5	7.25
Iron	0	4	6.5

FIGURE 23. Means of Data Showing Effect of Phenol and Iron at Level 1, 2 and 3 on Texture.



Glucose	0	268	606
Starch	0	0.6	10.25

FIGURE 24. Means of Data Showing Effect of Glucose and Starch at Level 1, 2 and 3 on Texture.

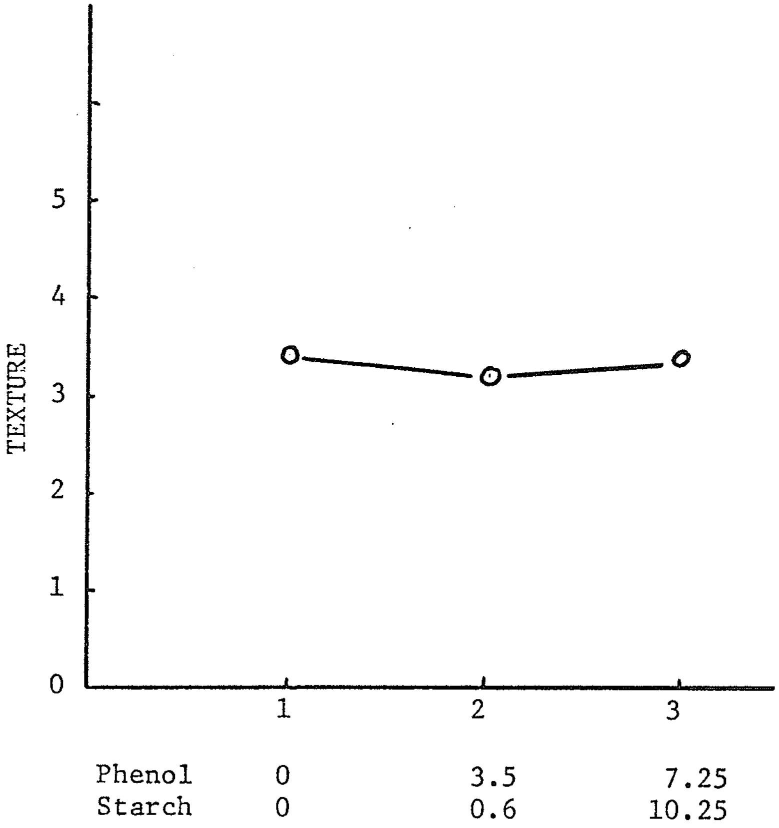


FIGURE 25. Means of Data Showing Effect of Phenol and Starch at Levels 1, 2 and 3 on Texture.

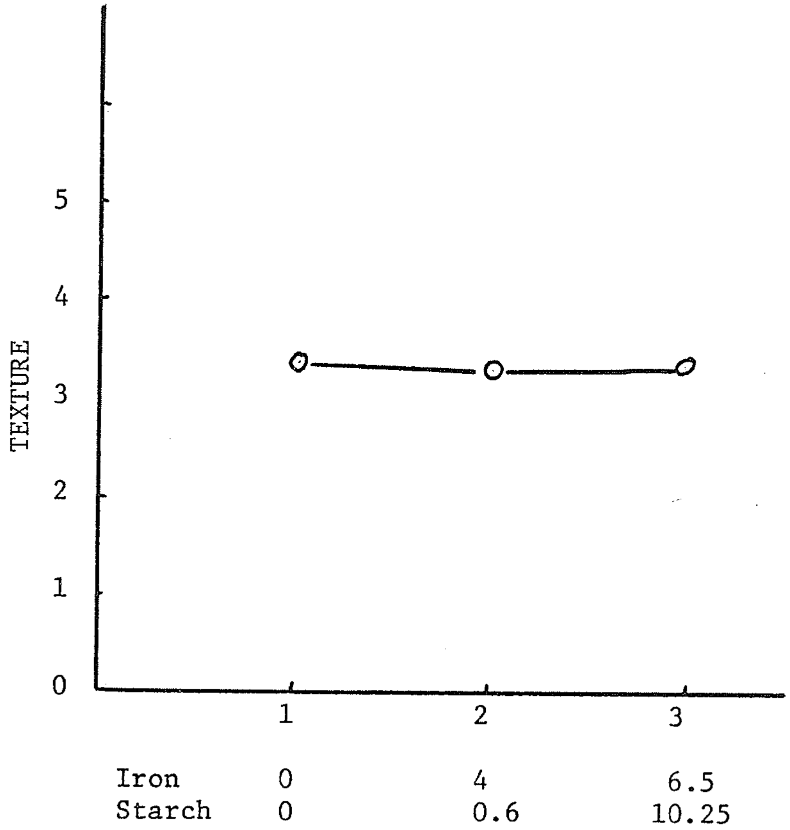
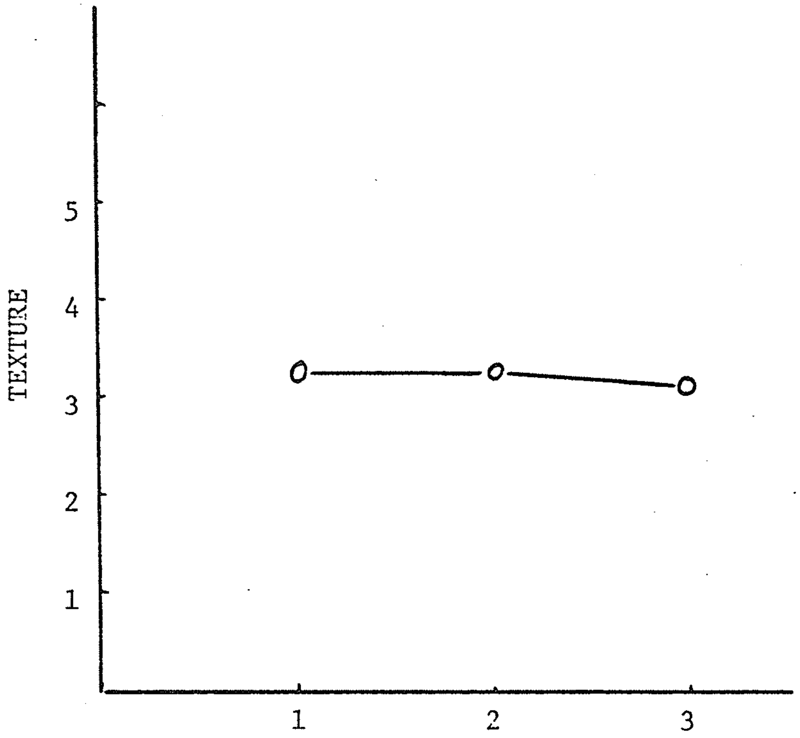
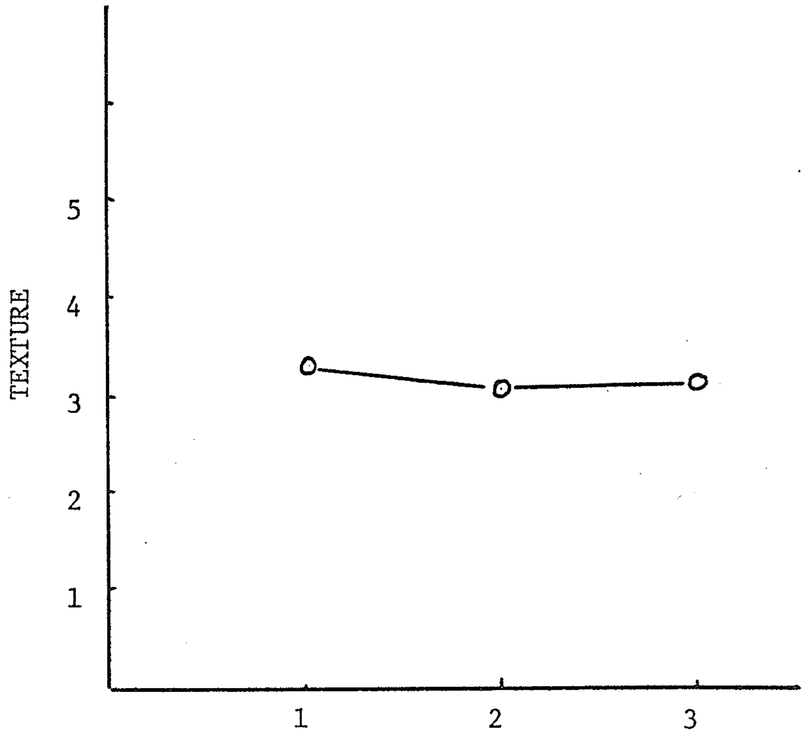


FIGURE 26. Means of Data Showing Effect of Iron and Starch at Levels 1, 2 and 3 on Texture.



Glucose	0	268	606
Phenol	0	3.5	7.25
Iron	0	4	6.5

FIGURE 27. Means of Data Showing Effect of Glucose, Phenol and Iron at Levels 1, 2, 3 on Texture.



Glucose	0	268	606
Phenol	0	3.5	7.25
Starch	0	0.6	10.25

FIGURE 28. Means of Data Showing Effect of Glucose, Phenol and Starch at Levels 1, 2, 3 on Texture.

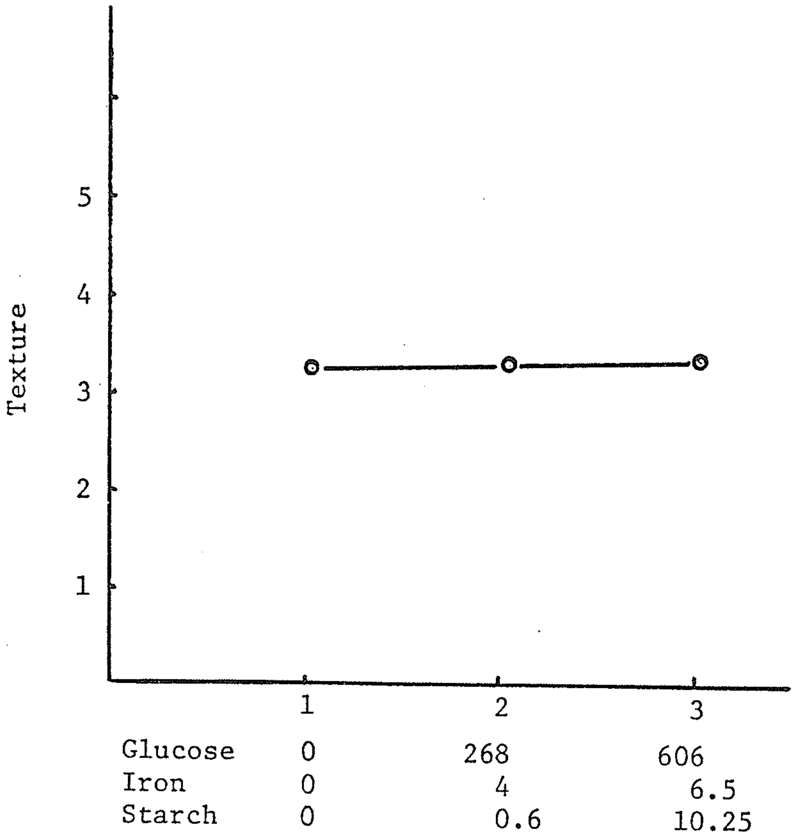


FIGURE 29. Means of Data Showing Effect of Glucose, Iron and Starch at Levels 1, 2, 3 on Texture.

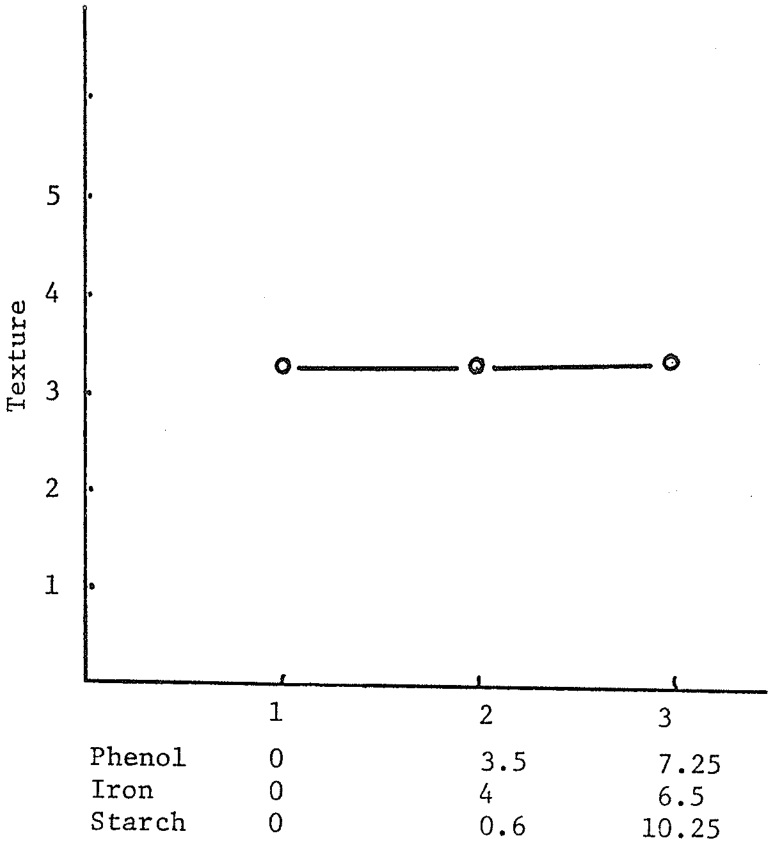
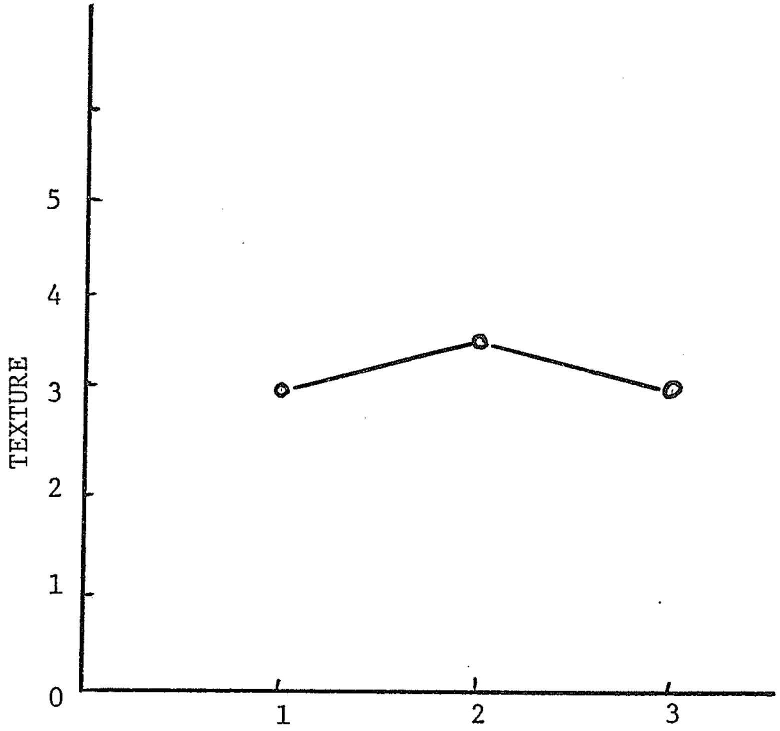


FIGURE 30. Means of Data Showing Effect of Phenol, Iron and Starch at Levels 1, 2, 3 on Texture.



Glucose	0	268	606
Phenol	0	3.5	7.25
Iron	0	4	6.5
Starch	0	0.6	10.25

FIGURE 31. Means of Data Showing Effect of Glucose, Phenol, Iron and Starch at Levels 1, 2 and 3 on Texture.

frying. As neither protein nor amino acids were added to the model system it is possible that perhaps, protein and amino acids may be limiting factors in blanch water on the textural quality of the potato chip.

It was found in a study by McConnell and Gerbasi (17) that a combination of glucose, amino nitrogen and iron salt in solution and applied to filter paper discs (asbestos and cellulose) and fried caused the disc to become very brittle and dark. This may also indicate that amino acids may play a part in the textural quality of potato chips. The iron did not appear to have any effect on the quality of the chips produced in this study using the model blanch system.

4.5.3 Potato Chip Flavour

A multiple comparison difference analysis test (Appendices VII) was conducted to determine what effect the simulated model system would have on the flavour of potato chips. The analysis of variance data indicated that no significant differences occurred at either the 5% or 1% levels for treatments. The results showed that the judges disagreed in their assessment of product flavour but the interaction between judges and treatments was not significant, indicating that product flavours did not vary significantly (Appendices V & VI).

A flavour problem was expected due to the levels of phenol in the blanch water. It was expected that the phenol would react with the free chlorine forming a bitter substance, chlorophenol, to which the palate is extremely sensitive. This does not seem to have occurred as extreme bitter flavour was not reported by any of the judges. Flavour in chip can be developed to some extent by the browning reaction which occurs during frying. It was expected that a flavour problem would have occurred in the chips blanched in glucose as these chips were not acceptable for colour. A bitter flavour can usually be detected in chips which are dark in colour but this association did not appear in this study.

Self (22) and Chang (5) stated that the fat in the frying medium affects the flavour of the product. Flavour contamination by the fat was prevented by minimal use of the fat and other good manufacturing practices to prevent quality deterioration in the "fryene".

V. CONCLUSIONS WITH SUGGESTIONS FOR FURTHER STUDIES

Chemical build up occurs in blanch waters at approximately the same levels whether Kennebec, Norchip or Superior varieties are used. Glucose, soluble starch and phenolic compounds increase as the frequency of water usage increases. Soluble iron decreases in concentration when the blanch water is reused more than twice. The fluid will become highly viscous due to the gelatinization of potato starch. The water is unusable after a third blanch due to the increase in viscosity.

Blanch water cannot be reused more than once, without some type of physio-chemical treatment, without affecting at least one of the quality factors of a potato chip (Figures 1 and 32). However two lots of 550 g of tubers were blanched in the same 2 ℓ of water with no detectable quality defects in the product, outside of a slight darkening in colour (Figure 1).

Potato chip colour is affected by the presence of glucose in the model blanch medium. Soluble starch, soluble iron and phenol in the model system do not affect colour quality in a potato chip, nor will they affect texture. Although the judges disagreed in their assessment of the product flavour it was proven that all the samples were acceptable in flavour therefore unaffected by the forementioned chemicals.

Although reusing blanch water may affect the quality of chips regardless of potato variety, this study indicates that soluble iron, soluble starch and phenols will not alter the potato chip quality to any significant extent. Reducing sugars in blanch water will affect the quality of potato chip colour as illustrated by the study using model systems but will not affect flavour or texture.

The author recommends further study in this research project. Factors which should be considered are:

(1) removal of gelatinized starch from blanch water by physical methods,

(2) effect of amino nitrogen in the model system on the colour, flavour and texture of the potato chip,

(3) effect of alkaloids in the model system on the colour, flavour and texture of the potato chip,

(4) the correlation of C.O.D. and pH on the blanch system on the quality of the potato chip.

VI. INDUSTRIAL APPLICATION

Problems in water pollution are rapidly decreasing the availability of water to the food industry. The potato chip industry is particularly guilty of wasting water. A potato chip plant in Manitoba, Canada, estimates that their usage is one litre of water for every 300 g of tuber processed.

As this thesis has shown a ratio of 550 g tuber to one litre of water may be used in a hot water blanch system with no adverse effect on quality, therefore it is likely that many chipping plants could decrease their water usage. As many plants are now converting to cold water blanch systems the water should be able to handle an even greater load of potato tubers.

Recycling in a cold water blanch system could easily be established in comparison to recycling hot blanch water. The concentration of potato matter would not build up as fast in cold water and the cold water is not as likely to leak out as high a concentration of chemicals as the hot water system. The most obvious advantage is that colloidal starch would be removed without difficulty in the cold water blanch. Phenolics and amino acids may be removed by resin columns and activated carbon and the reducing sugars may be kept at a safe level through dilution with fresh water.

In a hot water system the gelation of starch causes many problems in cleaning and recycling the water. This problem as well as others are presently under study at the Food Science Department, University of Manitoba under the direction of Dr. R. A. Gallop.

Although the trend in the chipping industry is towards low reducing sugar potato varieties and cold water blanch systems the French Fry Industry must continue to use a hot water blanch system. The authors conducted a brief study on the effects of recycling blanch water on the quality of French Fries. The affect on colour and flavour were found to correspond with the results in the first section of this thesis. The effect on colour can be observed in Figure 32.

FIGURE 32. Water samples and potato french fry samples produced after 0, 1, 2 and 3 blanches and 1 primary purification treatment.

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APPENDIX I

Analysis of Variance

Color of Potato Chips

Analysis of Variance

Colour of Potato Chips

Source	Degrees of Freedom	Sum of Squares	Mean Square	Calculated F	Tabulated F(.05)*	Tabulated F(.01)**
Glu	2	253.81	126.91	9.29	3.04	4.71
Phe	2	36.31	18.16	1.33	3.04	4.71
Glu Phe	4	116.31	29.08	2.13	2.41	3.41
Iro	2	43.56	21.78	1.59	3.04	4.71
Glu Iro	4	14.69	3.67	0.27	2.41	3.41
Phe Iro	4	47.25	11.81	0.87	2.41	3.41
Glu Phe Iro	8	40.81	5.10	0.37	1.98	2.60
Sta	2	23.75	11.88	0.87	3.04	4.71
Glu Sta	4	19.81	4.95	0.36	2.41	3.41
Phe Sta	4	19.19	4.80	0.35	2.41	3.41
Glu Phe Sta	8	62.44	7.81	0.57	1.98	2.60
Iro Sta	4	89.31	22.33	1.63	2.41	3.41
Glu Iro Sta	8	33.75	4.22	0.31	1.98	2.60
Phe Iro Sta	8	101.44	12.68	0.93	1.98	2.60
Glu Phe Iro Sta	16	115.81	7.24	0.53	1.69	2.09
Error	240	3279.06	13.66			
TOTAL	323	5081.13				

* 5% level of significance.
** 1% level of significance.

APPENDIX II

Mean Colour Reading of Data Plotted

Mean Colour Reading of Data Plotted

Treatment	Level*	Mean
Glucose	1	50.24
	2	49.62
	3	48.17
Phenol	1	49.75
	2	49.14
	3	49.13
Iron	1	49.78
	2	49.27
	3	48.98
Starch	1	49.37
	2	49.59
	3	49.06

* See Table II.

Mean Colour Reading of Data Plotted

Treatment	Level*	Mean
Glu phe	11	49.80
	22	49.83
	33	47.84
Glu iron	11	50.89
	22	49.27
	33	47.72
Phe iron	11	50.49
	22	48.70
	33	48.54
Glu starch	11	49.89
	22	49.69
	33	47.52
Phen sta	11	49.89
	22	49.91
	33	48.88
Iron sta	11	50.45
	22	49.46
	33	48.19

* See Table II.

Mean Colour Reading of Data Plotted

Treatment	Level*	Mean
Glu Phe Iron	111	51.04
	222	48.77
	333	46.38
Glu Phe Sta	111	49.51
	222	50.31
	333	47.17
Glu Iron Sta	111	51.23
	222	49.85
	333	46.58
Phe Iron Sta	111	51.85
	222	49.04
	333	47.29
Glu Phe Iron Sta	1111	50.90
	2222	49.52
	3333	45.32

* See Table II.

APPENDIX III

Analysis of Variance

Texture of Potato Chips

Analysis of Variance

Texture of Potato Chips

Source	Degree of Freedom	Sum of Squares	Mean Square	Calculated F	Tabulated F(.05)*	Tabulated F(.01)**
Glu	2	0.92	0.46	2.24	3.04	4.71
Phe	2	0.24	0.12	0.60	3.04	4.71
Glu Phe	4	0.97	0.24	1.18	2.41	3.41
Iro	2	0.13	0.06	0.31	3.04	4.71
Glu Iro	4	0.51	0.13	0.63	2.41	3.41
Phe Iro	4	0.69	0.17	0.84	2.41	3.41
Glu Phe Iro	8	1.92	0.24	1.17	1.98	2.60
Sta	2	0.66	0.33	1.60	3.04	4.71
Glu Sta	4	0.35	0.09	0.42	2.41	3.41
Phe Sta	4	1.52	0.38	1.85	2.41	3.41
Glu Phe Sta	8	1.45	0.18	0.88	1.98	2.60
Iro Sta	4	1.01	0.25	1.23	2.41	3.41
Glu Iro Sta	8	2.05	0.26	1.25	1.98	2.60
Phe Iro Sta	8	2.97	0.37	1.81	1.98	2.60
Glu Phe Iro Sta	16	4.67	0.29	1.42	1.69	2.09
Error	240	49.18	0.21			
TOTAL	323	77.45				

* 5% level of significance.
** 1% level of significance.

APPENDIX IV

Mean Texture Reading of Data Plotted

Mean Texture Reading of Data Plotted

Treatment	Level*	Mean
Glucose	1	3.39
	2	3.31
	3	3.44
Phenol	1	3.35
	2	3.41
	3	3.39
Iron	1	3.37
	2	3.37
	3	3.40
Starch	1	3.42
	2	3.32
	3	3.40

* See Table II.

Mean Texture Reading of Data Plotted

Treatment	Level*	Mean
Glu phe	11	3.39
	22	3.23
	33	3.38
Glu Iron	11	3.35
	22	3.28
	33	3.39
Phe Iron	11	3.33
	22	3.37
	33	3.48
Glu Sta	11	3.38
	22	3.20
	33	3.44
Phe Sta	11	3.44
	22	3.32
	33	3.48
Iro Sta	11	3.45
	22	3.41
	33	3.48

*See Table II.

Mean Texture Reading of Data Plotted

Treatment	Level*	Mean
Glu Phe Iro	111	3.31
	222	3.33
	333	3.24
Glu Phe Sta	111	3.39
	222	3.27
	333	3.31
Glu Iro Sta	111	3.30
	222	3.34
	333	3.45
Phe Iro Sta	111	3.32
	222	3.32
	333	3.79
Glu Phe Iro Sta	1111	3.18
	2222	3.60
	3333	3.20

*See Table II.

APPENDIX V

Analysis of Variance

Flavour of Chip

Analysis of Variance

Flavour of Potato Chips

Source	Degree of Freedom	Sum of Squares	Mean Square	Calculated F	Tabulated F(.05)*	Tabulated F(.01)**
Judges	3	34.11	11.37	5.37	2.68	3.94
Treatments	10	7.78	0.78	0.37	1.90	2.47
Judges & Treatments	30	47.76	1.59	0.75	1.55	1.85
Error	129	273.29	2.12			
TOTAL	175	382.16				

* 5% level of significance
** 1% level of significance

APPENDIX VI

Means of Flavour Data

Means of Flavour Data

Treatment	Level*	Mean
Glu Phe Iro Sta	1111	5.00
	1112	5.13
	1113	4.81
	1121	4.81
	1131	5.06
	1211	4.88
	1311	4.81
	2111	5.31
	3111	4.88
	2222	4.50
	3333	4.69

*See Table II.

APPENDIX VII

Questionnaire

Multiple Comparison

Difference Analysis

MULTIPLE COMPARISON

DIFFERENCE ANALYSIS

NAME ______________________________ DATE ____________________

QUESTIONNAIRE:

You are receiving samples of potato chips to compare for flavor. You have been given a reference sample, marked R, to which you are to compare each sample. Test each sample; show whether it is better than, comparable to, or inferior to the reference. Then mark the amount of difference that exists.

Sample Number								
Better than R								
Equal to R								
Inferior to R								

AMOUNT OF DIFFERENCE:

None								
Slight								
Moderate								
Much								
Extreme								

COMMENTS:

Any comments you may have about the flavor of the samples may be made here: