THE EFFECT OF POTASSIUM, MAGNESIUM, CHLORIDE, SULFATE AND NITRATE IONS ON YIELD AND SOME PROCESSING QUALITIES OF POTATOES

by

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A Thesis
Presented to
The Faculty of Graduate Studies and Research
University of Manitoba

In Partial Fulfillment
of the Requirement of the Degree
Master of Science

December, 1965

ACKNOWLEDGMENTS

The writer is indebted to Dr. J. D. Campbell for guidance throughout the course and for constructive criticisms and suggestions in the interpretation of the manuscript.

He wishes to express sincere appreciation to Professor J. Menzies for his interest and assistance in this study. The writer is grateful for technical assistance by Messrs. P. Becker and D. Bruinooge.

He wishes to thank the Provincial Soil Testing Laboratory, Department of Soil Science, University of Manitoba for their help in the soil analyses.

The writer is also indebted to Carnation Foods Company, Ltd., Carberry, Manitoba for their financial support while at the University of Manitoba.

ABSTRACT

Experiments were conducted at Carberry, Manitoba on a Wellwood Loam soil to determine the effect of potassium, magnesium, chloride, sulfate and nitrate ions from four sources of potassium and ammonium sulfate at varying rates on yield and some processing qualities of potatoes. In 1963 and 1964 potassium and chloride ions were used in combination with varying rates of sulfate ions. In 1964 an additional trial was conducted using potassium, magnesium, chloride, sulfate and nitrate ions at varying rates.

The yield of tubers was not influenced by varying the source and rate of potassium.

Differences in specific gravity resulting from treatments were not great, but in one experiment chloride ions in combination with sulfate ions reduced specific gravity of potato tubers below the check. In another experiment chloride ions reduced specific gravity of potato tubers below the check and potassium nitrate.

Source and rate of potassium did not significantly influence percent reducing sugars in the tubers. The effect on color of French fries was only slight. The French fry color in one experiment with potassium chloride gave a lighter colored French fry than potassium sulfate. In another experiment the use of potassium nitrate gave a significantly lighter color of French fries than other treatments but not significantly lighter than the check.

There was no correlation between percent reducing sugars and the visual color rating of French fries but there was a significant correlation when the Hunter Color Difference Meter was used. Highly significant correlations were obtained between visual and Hunter Color Difference Meter rating of French fry color.

Source and rate of potassium did not significantly influence texture or color of boiled tubers. Potassium-magnesium sulfate in one case detrimentally influenced the color of boiled tubers.

The reconditioning ability of tubers was not affected by different rates of potassium, magnesium, chloride, sulfate or nitrate ions. All treatments were unacceptable for processing French fries at 38 - 40°F, but when reconditioned for three weeks at 70°F and 60% relative humidity all treatments were acceptable.

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INTRODUCTION

The establishment of a large potato processing plant at Carberry, Manitoba, has enhanced Manitoba's position in the potato processing industry. Recent data indicate that in 1964, more than one-third of the commercial potatoes grown in Manitoba were processed, while in 1959 only six-percent were utilized for this purpose. In 1964, 3,300 acres of potatoes for processing were grown in the Carberry area. Potato products manufactured at Carberry include frozen French fries and other frozen products, dehydrated diced and sliced potatoes, granules, crystals, potato flour and others. These products are available in all Canadian provices and are exported to other countries. It is expected that new products will be added when a demand arises.

With such a diversity of products and production capacity capable of expansion, it is very important that the raw product be of the highest possible quality for processing. It is essential too, that high yields of potatoes be produced to attract and hold good growers and be competitive with other areas.

The use of mineral fertilizers often results in potato yield increases. However their improper use may result in problems with potato quality. This study was initiated to determine the influence of potassium, magnesium, chloride, sulfate and nitrate ions on potato yield and on the factors affecting the processing qualities of potatoes. The project was conducted in the Carberry area where there are over 100,000 acres ideally suited for potato production.

Processing quality is dependent upon many factors and those considered most important and within the scope of this study were as follows:

(1) Specific gravity which is directly related to the starch content of the potato tuber and to the ratio of raw to finished product was used as one criterion of potato quality.

(2) Percent reducing sugars and fry tests were used as indicators of the non-enzymatic browning reaction which is responsible for unfavourable French fry color. It also affects the quality of potato crystals and granules as well as dehydrated diced and sliced potatoes.

(3) Texture and color of boiled tubers.

LITERATURE REVIEW

YIELD

The Irish potato Solanum tuberosum L. has a high potassium requirement. Potassium is essential for various metabolic activities of the plant, especially the synthesis of simple sugars, and starch and in the translocation of carbohydrates. Because the potato is essentially a starch producing crop its requirements for potassium are high. Should the level of potassium exceed the amount required for optimum yield it can be taken up by the plant in luxury amounts.

Carpenter (9) reported that the total potassium content in one acre of potatoes was about 200 pounds per acre. Approximately fifty percent was found in the tubers and fifty percent in the remaining plant parts. The National Plant Food Institute (4) reported that a 400 bushel crop of potato tubers will contain 150 pounds of potassium as potash (K_2O). This varies with the soil type, season and fertility of the soil.

In general, yield response to potassium has been found to be related to the level of exchangeable potassium in the soil. Tyler, Lorenz and Fullmer (46) showed that where the exchangeable potassium level was less than 100 ppm potato plants were generally deficient and respond to potassium fertilization. Between 100 and 150 ppm yield response was uncertain. Above 150 ppm exchangeable potassium, the response is unlikely and above 200 ppm a yield response in potatoes to potassium fertilizer is highly improbable. Timm (45) stated that where the level of exchangeable potassium in the soil exceeded 250-300 pounds per acre increases in tuber yield were not obtained with the addition of over 66.4 pounds per acre of potassium and in some cases increased addition of potassium reduced yield. Terman (43) also mentioned that the application of high rates of potassium applied in a band at planting may result in slight yield depressions.

Dickens, Harrop and Holmes (11) showed that the total yield of tubers was the same from chloride and sulfate sources of potassium. Potassium chloride however consistently gave a higher yield of large tubers than potassium sulfate. No yield differences due to source of potassium were noted by Rowberry, Sherrell and Johnston (39) except in two out of nine cases where potassium sulfate or potassium sulfate and potassium chloride mixture in a 1:1 ratio increased yields over the potassium chloride treatment. Terman (43) also showed that on the average, potassium chloride and potassium sulfate resulted in the same yields of tubers. In certain experiments, addition of potassium sulfate gave higher yields than potassium chloride, but did not outyield potassium phosphate or potassium nitrate. Berger, Potterton and Hobson (6) found that potassium chloride banded in the row reduced phosphorus uptake which resulted in delayed maturity. This in turn reduced the specific gravity and yield of tubers. They concluded that potassium sulfate is a better source of potassium than is potassium chloride when applied banded in the row with phosphorus and nitrogen fertilizer. They also found that potassium chloride broadcast resulted in a lower concentration of chloride ions in the banded phosphorus fertilizer; with reduced anion competition, phosphorus uptake was increased. They also showed that in many Wisconsin soils, potassium-magnesium sulfate appeared to be the best source of potassium for increasing yields and improving quality.

SPECIFIC GRAVITY

The most important characteristics in the selection of potatoes for processing are (1) a high specific gravity or percent solids, (2) a low reducing sugar content, (3) a good performance in a fry test. Kirkpatrick _et al._, (26) stated that potatoes of high specific gravity produced French fries which were crisper, mealier and less oily than potatoes of low specific gravity. The practicability of separating potatoes into two specific gravity groups in a commercial chip plant was shown by Kunkel, Gregory and Binkley (28). Yield of chips was higher and oil content lower from the tubers which had a high specific gravity.

The yield of dehydrated potato products is directly related to the specific gravity or percent solids of potatoes. According to Cording _et al_., (10) and Kueneman (27) the higher the specific gravity the higher the ratio of raw to finished product. High specific gravity in potato tubers does not ensure that the dehydrated product will have a desirable texture, but tubers with low specific gravity will not make a product of superior texture (40).

Several workers (14,30,31,32,35,41,45) have reported that potassium chloride reduced the specific gravity of potato tubers to a greater extent than did potassium sulfate. Terman (43) showed that specific gravity of tubers from plants fertilized with a combination of nitrate and phosphate sources of potassium were similar to that of tubers from plants fertilized with potassium sulfate. Jung (25) working with potassium chloride, potassium sulfate and potassium nitrate, reported that fertilizer which contained no chlorine promoted starch accumulation in the tubers, while sources containing chlorine lowered the starch content. Favorable effects of potassium nitrate on specific gravity have been recently reported in unpublished work in Connecticut, Florida, Maine and Wisconsin (23).

Latzko (29) considered that chloride compared with sulfate nutrition reduced the production of carbohydrates.

This coupled with a diminished conversion and translocation to the tubers, was held to be directly related to the reduced starch content of potato tubers of chloride treated plants. Dunn and Rost (12) concluded that the chloride ion caused a lower starch content of potatoes fertilized with potassium chloride in contrast to potatoes fertilized with potassium sulfate. They noted the effect of chlorine on the higher water content and drought resistance of tobacco. Terman (43) stated that potassium chloride causes a higher content of water in potato tubers and an accompanying lower content of starch and dry matter. Gausman (16) noted that when the culture solution contained 600 ppm chlorine and the dry matter weight of the tubers tended to decrease. Harrop (19) stated that, although the reduction in specific gravity is not marked, higher rates of potassium sulfate decreased the starch content of tubers. He suggested that the overall starch yield is probably related to the amount of potassium taken up by the potato plant rather than solely to the effect of the chloride ion on the metabolism of the plant.

CHIP COLOR

Hoover and Xander (21) revealed that the only consistent correlation between chipping color and potato compositional factors was in the occurrence and relative concentrations of the reducing sugars, glucose and fructose. Increasing amounts of these compounds resulted in the production of darker colored chips. Hendel (20) reported that non-enzymatic browning in potato granules is approximately proportional to the content of reducing sugars. Kueneman stated (27) that the color of dehydrated diced potatoes, either in the dry form or when reconstituted immediately after processing or after storage, may also be greatly affected by non-enzymatic discoloration. This is evidenced by the development of dark yellow to reddish-brown color in dehydrated diced potatoes. He maintained that dehydrated potatoes should be prepared from raw material that is relatively low in reducing sugar content if the product is to be free from non-enzymatic discoloration when first processed and is to remain reasonably so in storage.

Reconditioning is often necessary before potatoes will make acceptable chips, French fries or dehydrated potatoes. Terman, Goven and Cunningham (44) reported that certain varieties which rated low in specific gravity were satisfactory for French fries when stored at 50°F, but none were suitable when stored at 36° or 40°. Reconditioning at 60° or 70°F for 20 to 28 days lowered the reducing sugar content in all lots of tubers sufficiently for the production of French fries with satisfactory color. Other workers (22,35) also reported that reconditioning lowers reducing sugar concentration. Yamaguchi et al., (47) showed that soil fertility had little apparent effect on color of chips made from tubers stored at 40^{o}F and that storage temperature of tubers appears to be the most important factor in the color of potato chips.

Eastwood and Watts (13) stated that higher levels of applied potassium tended to improve chip color. Although the difference was not significant, potatoes fertilized with potassium chloride tended to give a slightly better chip color than potassium sulfate. Murphy and Goven (34) stated that if chip color is the most important criterion for potatoes used for chipping, the use of potassium chloride as a source of potassium may be desirable. Gausman, Cooper and Struchtemeyer (17) showed that potatoes receiving high amounts of chlorine had less energy-rich sugar compound. This helps to explain why potatoes fertilized with potassium chloride in contrast to potassium sulfate, results in better chip color. Jacob (23) indicated favourable effects of potatoes fertilized with potassium nitrate on chip color in Maine.

MATERIALS AND METHODS

The effect of potassium, magnesium, chloride, sulfate and nitrate ions from four sources of potassium and ammonium sulfate at varying rates on potato yield and quality were studied. In 1963 and 1964 potassium and chloride ions were used in combination with varying rates of sulfate ions. In 1964 an additional trial was conducted using potassium, magnesium, chloride, sulfate and nitrate ions at varying rates.

The Netted Gem variety was used in all experiments because it is used exclusively for processing at the potato processing plant at Carberry. It is a variety of known high quality for French fries and dehydrated potato products and is also the only variety which has all the desirable characteristics required to make the diversity of products that are processed at the Carberry plant.

All experiments were conducted on a Wellwood Loam (14) soil. This soil ranges in texture on the surface from very fine sandy loam to clay loam but is predominantly loam. Soil samples were taken from the plot areas and analysed by the Provincial Soil Testing Laboratory, Department of Soil Science, University of Manitoba, for nitrate nitrogen, available phosphorus and exchangeable potassium. The modified Harper Method (18) was employed to determine the quantity of nitrate nitrogen. The bicarbonate (0.5 $NaHCO_3$) extraction solution, developed by Olsen et al., (35), was used to determine available phosphorus. Exchangeable potassium was extracted with 1.0 N ammonium acetate (NH_4OAc) at pH 7 and determined by flame photometer as outlined by Atkinson *et al*., (5). The Baird Atomic flame photometer was used.

FIELD EXPERIMENTS

Experiment I (1963)

The experimental design was a randomized block with five treatments and six replicates. Rates of application were as follows:

(1) one rate of potassium ions; 24.9 lbs K^+ per acre

(2) two rates of chloride ions; 0 and 22.7 lbs Cl^- per acre

(3) three rates of sulfate ions; 0, 75 and 150 lbs $SO_4^=$ per acre.

The potassium, chloride and sulfate ions were supplied by fertilizer grade potassium chloride (KCl), potassium sulfate (K_2SO_4) and ammonium sulfate ($(NH_4)_2SO_4$). Nitrogen (N) and phosphorus (P) were applied at the rate of 45 lbs N and 60 lbs of phosphate (P_2O_5) per acre to all treatments.

Experiment II (1964)

The experimental design was a Latin square with six treatments. Rates of application were as follows:

(1) two rates of potassium ions; 0 and 24.9 lbs K^+ per acre

(2) two rates of chloride ions; 0 and 22.7 lbs Cl^- per acre

(3) three rates of sulfate ions; 0, 90 and 180 lbs $SO_4^=$ per acre.

The potassium, chloride and sulfate ions were supplied by fertilizer grade potassium chloride, potassium sulfate and ammonium sulfate. Nitrogen and phosphorus were applied at the rate of 60 lbs N and 45 lbs of phosphate (P_2O_5) per acre to all treatments.

Experiment III (1964)

The experimental design was a randomized block with nine treatments and six replicates. Rates of application were as follows:

(1) three rates of potassium ions; 0, 24.9 and 49.8 lbs K^+ per acre

(2) three rates of magnesium ions; 0, 16.5 and 33 lbs Mg^{++} per acre

(3) three rates of chloride ions; 0, 22.7 and 45.4 lbs Cl^- per acre

(4) five rates of sulfate ions; 0, 29.6, 59.2, 95.6 and 191.2 lbs $SO_4^=$ per acre

(5) three rates of nitrate ions; 132.8, 150.3 and 167.8 lbs NO_3^- per acre.

The potassium, magnesium, chloride, sulfate and nitrate ions were supplied by fertilizer grade potassium chloride, potassium sulfate, potassium nitrate (KNO_3) and potassium-magnesium-sulfate ($K_2SO_4 + MgSO_4$). Nitrogen and phosphorus were applied at the rate of 60 lbs N and 45 lbs of phosphate (P_2O_5) per acre.

Nitrogen in Experiments I and II was supplied by fertilizer grade ammonium nitrate and ammonium sulfate. In Experiment III all of the nitrogen was supplied by ammonium nitrate with the exception of two treatments where potassium nitrate supplied part of the nitrogen. Phosphorus in all experiments was supplied by triple superphosphate.

Single row plots were 55 ft. long in 1963 and 40 ft. long in 1964, with rows spaced 40 inches apart and seed pieces spaced 14.6 inches apart within the rows, at a depth of 2 inches. Fertilizer was applied at the same depth as the seed pieces, in bands, 2 inches on both sides of the row, using a V-belt attachment on an assisted feed, single row, commercial planter.

YIELD AND QUALITY EVALUATIONS

(a) Yield of tubers - Yields were calculated by dividing total plot yields by number of plants per plot and multiplying by the appropriate factor to give yields in terms of 100 pound bags per acre. Yields from Experiments I and II are expressed as total and marketable yields. Marketable yields as distinct from total yields were determined by running the total yields through a commercial grader with openings of 1.7/8 inches in the grader chain. Yields from Experiment III are expressed as total yield and yield of tubers four ounces and over.

(b) Specific gravity - Specific gravity was determined by the method outlined by Akeley and Stevenson (1) and Blood and Haddock (8). Sodium chloride solutions ranging in specific gravity from 1.060 to 1.115 at intervals of 0.005 were used. Samples of 30 to 35 tubers chosen at random from each plot were used for the determinations. The modal class as isolated by the specific gravity method was retained for reducing sugars analysis, French fry color and cooking tests.

(c) Yield of dry matter - Yield of dry matter was obtained by multiplying total yield x percent dry matter. Percent dry matter was obtained by converting specific gravity to percent dry matter using the Simplot Conversion Chart, obtained from the J. R. Simplot Co., Caldwell, Idaho.

(d) Reducing sugars - Reducing sugars were determined by the Dinitrophenol method as outlined by Ross (38).

(e) French Fry Color - French fry strips were cut three-eighths by three-eighths inches and fried for two minutes and forty-five seconds in vegetable oil at 350^{o} Farenheit. Two or three potatoes from each plot were used for the test. French fries were evaluated as follows:

(1) French fries from Experiments I and II were evaluated for color by means of Chip Color Photo samples obtained from the "Red Dot" Potato Chip Company of Wisconsin, color was rated from 65 (dark brown) to 90 (golden brown).

(2) French fries from Experiment III were evaluated

for color by means of the Simplot French Fry Color Chart obtained from the J. R. Simplot Co., Caldwell, Idaho, color was rated from 1 (light brown) to 15 (dark brown).

(3) French fries from Experiment III were also evaluated for color by the Hunter Color Difference Meter. Color difference measurements by reflection were made on the Hunter Color Difference Meter, calibrated with a color standard having L (lightness), a (redness) and b (yellowness) readings of 75.2, 13.5 and 8.2 respectively. Total color difference was calculated by Hunterlab total color difference formula (2). The French fries were allowed to cool for five minutes and arranged in the four by four inch optical cell. The readings were taken eight minutes after French fries were removed from the cooking oil.

(f) Reconditioning studies - Reconditioning studies were carried out as follows: random samples of tubers from each plot in Experiment III were removed from cold storage, (38-40^{o}Farenheit), fried and evaluated for color by means of the Simplot French Fry Color Chart. Samples were stored at 70^{o}Farenheit and 60 percent relative humidity for three, four and six weeks and then evaluated for reconditioning by the Simplot French Fry Color Test. Four replicates were used for this experiment.

(g) Boiling tests - Boiling tests were performed by placing two hand peeled potatoes from each sample specific gravity modal class into boiling water until cooked. The cooked samples were evaluated by several judges for texture and color. Texture was rated from 0 to 40 as follows:

(1) 0 very soggy
(2) 15 soggy
(3) 25 slightly mealy
(4) 35 mealy
(5) 40 very mealy

Color was rated from 0 to 30 as follows:

(1) 0 poor
(2) 10 fair
(3) 20 good
(4) 30 excellent

The mean values of the judges were used in the analysis of variance.

The analyses and the interpretation of the results are based on the methods described by Steel and Torrie (42) in "Principles and Procedures of Statistics".

RESULTS AND DISCUSSION

EXPERIMENT I (1963)

The effect of chloride and sulfate ions at different rates alone and in combination from two sources of potassium and ammonium sulfate on total and marketable yield of potato tubers is shown in Table I. The treatments had no significant effect at the 5 percent level on total or marketable yield.

TABLE I. The effect of chloride and sulfate ions at different rates on total and marketable yield of potato tubers.

Treatment	Rate of Application (lb/ac)			Yield (cwt/ac)	
	K	Cl	SO_4	Total	Marketable
KCl	24.9	22.7		231.7	206.6
KCL+$(NH_4)_2SO$	24.9	22.7	75	233.6	204.4
KCl+$(NH_4)_2SO$	24.9	22.7	150	245.0	211.2
$K_2SO_4+(NH_4)_2SO_4$	24.9		75	236.9	207.5
$K_2SO_4+(NH_4)_2SO_4$	24.9		150	229.1	200.2
				n.s.	n.s.

A factorial experiment (33) at the same location with three rates of nitrogen, phosphate and potash (0, 30 and 60 pounds per acre) was conducted simultaneously with Experiment I. Potassium chloride was the source of potassium used in the experiment. The effect of different rates of potassium on yield of marketable tubers is shown in Table 2. The differences due to added potassium from potassium chloride were not significant at the 5 per cent level.

TABLE 2. The effect of different rates of potassium on yield of marketable tubers

Levels of Potassium (lb/ac)	Marketable Yield (cwt/ac)
0.0	182.3
24.9	187.5
49.8	192.0
	n.s.

Soil test data shown in Table 3 were taken from the 1963 experimental area which included Experiment I and the factorial experiment mentioned above.

TABLE 3. Results of soil test for Nitrogen, Phosphorus and Potassium

Location and Soil Type	NO_3-N to 2 ft. (lb/ac)	NO_3-N to 4 ft. (lb/ac)	Avail. P (lb/ac)	Exch. K (lb/ac)
Carberry				
Wellwood Loam	49	74	24	502

According to the Provincial Soil Testing Laboratory, Department of Soil Science, University of Manitoba (24) the amount of exchangeable potassium (502 pounds per acre) would be considered high for cereal grains and potatoes. The lack of yield response to the addition of potassium is therefore not surprising.

Chloride and sulfate ions at different rates had no significant effect on specific gravity or yield of dry matter. This is shown by the data in Table 4.

TABLE 4. The effect of chloride and sulfate ions at different rates on specific gravity and yield of dry matter of potato tubers.

Treatment	Rate of Application (lb/ac)			Specific Gravity	Yield of Dry Matter (cwt/ac)
	K	Cl	SO_4		
KCL	24.9	22.7		1.0966	54.30
KCL+$(NH_4)_2SO_4$	24.9	22.7	75	1.0971	56.32
KCL+$(NH_4)_2SO_4$	24.9	22.7	150	1.0972	57.03
K_2SO_4+$(NH_4)_2SO_4$	24.9		75	1.0994	59.03
K_2SO_4+$(NH_4)_2SO_4$	24.9		150	1.0996	59.86
				n.s.	n.s.

Neither chloride nor sulfate ions at different rates had any significant effect on texture or color of boiled tubers as is shown by the data in Table 5.

The effect of chloride and sulfate ions at different rates alone and in combination from two sources of potassium and ammonium sulfate on French fry color is shown by the data in Table 6. The chloride ions gave a significantly (0.05) lighter color of French fries than the sulfate ions in two out of three cases. Different rates of sulfate ions appeared to have no effect on color of French fries.

TABLE 5. The effect of chloride and sulfate ions at different rates on texture and color of boiled potato tubers.

Treatment	Rate of Application (lb/ac) K	Cl	SO_4	Texture*	Color*
KCl	24.9	22.7		30.90	21.82
$KCl+(NH_4)_2SO_4$	24.9	22.7	75	31.90	21.92
$KCl+(NH_4)_2SO_4$	24.9	22.7	160	31.93	20.60
$K_2SO_4+(NH_4)_2SO_4$	24.9		75	30.87	21.55
$K_2SO_4+(NH_4)_2SO_4$	24.9		150	33.17	21.83
				n.s.	n.s.

*Higher numbers represent a more mealy texture and a better color

TABLE 6. The effect of chloride and sulfate ions at different rates on color of French fries.

Treatment	Rate of Application (lb/ac) K	Cl	SO_4	French fry color*	
KCl	24.7	22.7		82.33	a**
$KCl+(NH_4)_2SO_4$	24.7	22.7	150	82.67	a
$KCl+(NH_4)_2SO_4$	24.7	22.7	75	79.33	ab
$K_2SO_4+(NH_4)_2SO_4$	24.7		150	78.33	b
$K_2SO_4+(NH_4)_2SO_4$	24.7		75	77.67	b

* Higher numbers represent a lighter color.
** Data not identified by the same letter (a,b) are significantly different at the 5% level (Duncan's Multiple Range Test)

EXPERIMENT II (1964)

Neither potassium, chloride nor sulfate ions at different rates had any significant effect on total or marketable yield of potato tubers, as is indicated by the data shown in Table 7.

TABLE 7. The effect of potassium, chloride and sulfate ions at different rates on total and marketable yield of potato tubers.

Treatment	Rate of Application (lb/ac) K	Cl	SO_4	Yield (cwt/ac) Total	Marketable
KCl	24.9	22.7		196.3	176.4
$KCl+(NH_4)_2SO_4$	24.9	22.7	180	202.7	180.8
$KCl+(NH_4)_2SO_4$	24.9	22.7	90	198.4	176.4
$K_2SO_4+(NH_4)_2SO_4$	24.9		180	187.9	163.6
$K_2SO_4+(NH_4)_2SO_4$	24.9		90	174.9	152.1
Check	0.0			191.5	163.7
				n.s.	n.s.

Soil test data from Experiments II and III plot area are shown in Table 8. As in Experiment I, the Provincial Soil Testing Laboratory, Department of Soil Science, University of Manitoba (24) would consider the amount of exchangeable potassium (468 pounds per acre) high for cereal grains and potatoes. The lack of yield response to the addition of potassium is therefore not surprising.

TABLE 8. Results of soil test for nitrogen, phosphorus and potassium, 1964.

Location and Soil Type	NO_3N to 2 ft. (lb/ac)	NO_3N to 4 ft. (lb/ac)	Avail. P. (lb/ac)	Exch. K (lb/ac)
Carberry Wellwood Loam	21	29	23.2	468

The result of potassium, chloride and sulfate ions at different rates alone and in combination from two sources of potassium and ammonium sulfate on specific gravity and yield of dry matter is shown by the data in Table 9.

TABLE 9. The result of potassium, chloride and sulfate ions at different rates on specific gravity and yield of dry matter of potato tubers.

Treatment	Rate of Application (lb/ac) K	Cl	SO_4	Specific Gravity	Yield of Dry Matter (cwt/ac)
Check	0.0			1.0831 a*	41.38
$K_2SO_4+(NH_4)_2SO_4$	24.9		180.0	1.0816 a b	40.04
KCl	24.9	22.7		1.0811 a b	41.66
$K_2SO_4+(NH_4)_2SO_4$	24.9		90.0	1.0810 a b	37.00
$KCl+(NH_4)_2SO_4$	24.9	22.7	90.0	1.0801 b	41.63
$KCl+(NH_4)_2SO_4$	24.9	22.7	180.0	1.0799 b	42.52
					n.s.

* Data not identified by the same letter (a,b) are significantly different at the 5% level.

The tubers from the check had significantly higher specific gravities than those from the treatments having both chloride and sulfate ions. The differences however are not large being a reduction of only 0.64 percent in terms of total solids content from the highest to the lowest specific gravity. The treatments resulted in no differences in the yield of dry matter of the tubers.

The application of potassium, chloride, and sulfate ions at different rates alone and in combination from two sources of potassium and ammonium sulfate did not significantly influence the texture and color of boiled tubers, as shown by the data in Table 10. Harrop (18) stated that to determine differences in texture by panel assessment the differences in dry matter must be in the order of one percent. Converting specific gravity to dry matter the differences in Experiment II would be less than one percent and thus it is not surprising that no differences in texture were noted.

Application of potassium, chloride and sulfate ions at different rates did not influence the color of French fries as is shown by the data of Table 11.

EXPERIMENT III (1964)

The effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions from four sources of potassium on total yield and yield of tubers four ounces and

TABLE 10. The effect of potassium, chloride and sulfate ions at different rates on texture and color of boiled tubers.

Treatment	Rate of Application (lb/ac) K	Cl	SO_4	Texture*	Color*
Check 4	0.0			31.01	18.05
KCl	24.9	22.7		20.01	18.21
$KCl+(NH_4)_2SO_4$	24.9	22.7	90	30.83	18.10
$KCl+(NH_4)_2SO_4$	24.9	22.7	180	30.63	17.60
$K_2SO_4+(NH_4)_2SO_4$	24.9		90	30.33	17.38
$K_2SO_4+(NH_4)_2SO_4$	24.9		180	30.63 n.s.	17.45 n.s.

* Higher numbers represent a more mealy texture and better color.

TABLE 11. The effect of potassium, chloride and sulfate ions at different rates on color of French fries.

Treatment	Rate of Application (lb/ac) K	Cl	SO_4	French Fry Color*
Check	0.0	0.0	0	82.50
KCl	24.9	22.7	0	82.50
$K_2SO_4+(NH_4)_2SO_4$	24.9	0.0	180	81.67
$KCl+(NH_4)_2SO_4$	24.9	22.7	90	80.83
$KCl+(NH_4)_2SO_4$	24.9	22.7	180	80.83
$K_2SO_4+(NH_4)_2SO_4$	24.9	0.0	90	77.50 n.s.

* Higher numbers represent a lighter color.

over is shown by the data in Table 12. Statistical analysis of the data indicated that the treatments had no significant effect on total yield or yield of tubers four ounces and over.

In no case was the yield significantly increased by the addition of potassium. This is not surprising since soil test data shown in Tables 3 and 8 indicate that the soil was high in exchangeable potassium.

The effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions from four sources of potassium on specific gravity and yield of dry matter of potato tubers is shown by the data in Table 13.

The tubers from the check treatment gave a significantly (0.05) higher specific gravity than the mean of the specific gravities of the tubers from all the sources and rates of potassium combined (Appendix 10). The application of potassium nitrate resulted in tubers with a significantly higher specific gravity than those from plots receiving potassium-magnesium sulfate and potassium chloride. Tubers from the potassium chloride, potassium-magnesium sulfate and potassium sulfate plots did not differ significantly from one another. Different rates of potassium had no significant effect on specific gravity of potato tubers (Appendix 10).

The reduction in specific gravity of potato tubers by different sources of potassium appears to be due to the

TABLE 12. The effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on total yield and yield of potato tubers four ounces and over

Treatment	Rate of Application (lb/ac)					Yield (cwt/ac)	
	K	Mg	Cl	SO_4	NO_3	Total	Four ounces and over
KCl	49.0	-	45.4		132.8	199.1	138.0
Check	0.0	-			132.8	195.1	136.3
K_2SO_4+$MgSO_4$	49.8	33.0		191.2	132.8	194.7	132.5
KNO_3	49.8	-			167.8	191.1	130.0
KCl	24.9	-	22.7		132.8	188.8	132.5
K_2SO_4+$MgSO_4$	24.9	16.5		95.6	132.8	185.4	127.9
KNO_3	24.9	-			156.3	183.3	131.3
K_2SO_4	49.8	-		59.2	132.8	178.1	121.5
K_2SO_4	24.9	-		29.6	132.8	180.8	125.8
						n.s.	n.s.

TABLE 13. The effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on specific gravity and yield of dry matter of potato tubers.

Treatment	Rate of Application (lb/ac) K	Mg	Cl	SO_4	NO_3	Specific Gravity		Yield of Dry Matter (cwt/ac)
Check	0.0				132.8		1.0828 mean	41.15
KNO_3	24.9				150.3	1.0816	1.0821 a*	39.13
KNO_3	49.8				167.8	1.0825		41.08
K_2SO_4	24.9			29.6	132.8	1.0813	1.0814 ab	38.43
K_2SO_4	49.8			59.2	132.8	1.0814		37.92
K_2SO_4+$MgSO_4$	24.9	16.5		95.6	132.8	1.0804	1.0803 b	39.07
K_2SO_4+$MgSO_4$	49.8	33.0		191.2	132.8	1.0801		40.80
KCl	24.9		22.7		132.8	1.0804	1.0797 b	39.56
KCl	49.8		45.4		132.8	1.0790		41.42 n.s.

* Data not identified by the same letter (a,b) are significantly different at the 5% level.

associated ion and was greatest with the chloride ion. This is indicated by the data in Table 9, where the chloride ions in combination with the sulfate ions reduced specific gravity below the check, but sulfate or chloride ions alone did not. This is also shown in Table 13 where potassium nitrate has a higher specific gravity of potato tubers than potassium chloride and potassium magnesium sulfate. Rader, White and Whittaker (37) showed that the salt index from potassium chloride and potassium-magnesium sulfate is higher than that of potassium nitrate and potassium sulfate. It could be that the higher salt index caused a reduction in specific gravity of potato tubers.

The effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions from four sources of potassium on color and texture of boiled tubers is shown by the data in Table 14.

The treatments did not significantly influence the texture of boiled tubers, but the application of potassium chloride and potassium sulfate had a significantly better color of boiled tubers than the potassium-magnesium sulfate treatment. Thus it would appear that the magnesium ions in conjunction with the additional sulfate ions were adversely affecting the color of boiled tubers.

The effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions from four sources of potassium on percent reducing sugars and French fry color

TABLE 14. The effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on texture and color of boiled tubers.

Treatment	Rate of Application (lb/ac)					Texture*	Color*	
	K	Mg	Cl	SO_4	NO_3			Mean
Check	0.0				132.8	29.75	19.25	
KCl	24.9		22.7		132.8	32.58	19.62	19.35 a**
KCl	49.8		45.4		132.8	31.43	19.08	
K_2SO_4	24.9			29.6	132.8	31.57	18.50	18.63 a
K_2SO_4	49.8			59.2	132.8	30.95	18.75	
KNO_3	24.9				150.3	30.62	17.82	17.65 ab
KNO_3	49.8				167.8	30.52	17.48	
K_2SO_4 + $MgSO_4$	24.9	16.5		95.6	132.8	30.72	16.60	16.83 b
K_2SO_4 + $MgSO_4$	49.8	33.0		191.2	132.8	30.25 n.s.	17.05	

* Higher numbers represent a more mealy texture and a better color.

** Data not identified by the same letter (a,b) are significantly different at the 5% level.

potato tubers is shown by the data in Table 15. As indicated by the data in the table neither percent reducing sugars nor French fry color of potato tubers was significantly influenced by the treatments.

The analysis of covariance involving percent reducing sugars and color of French fries gave correlation values of 0.035 for the error component and 0.530 for the treatment component. These values are not statistically significant at the 5 percent level indicating that for this experiment there was no association between these measurements. However, the treatment having the lowest percent reducing sugars gave the lightest color of French fries and the treatment having the highest percent reducing sugars gave the darkest color of French fries. Differences between treatments in percent reducing sugars and in color of French fries were small. This is probably one of the reasons why a poor correlation was attained. Also, French fry color evaluation was done several weeks after the determination of percent reducing sugars and it is possible that slight changes in percent reducing sugar occurred during that period accounting for the lack of a significant correlation.

Analysis of covariance was calculated involving reading obtained from the Hunter Color Difference Meter and visual rating of color of French fries and percent reducing sugars. The correlation values are presented in Table 16.

TABLE 15. The effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on percent reducing sugars and French fry color of potato tubers.

Treatment	Rate of Application (lb/ac)					Percent Reducing Sugars	French* fry Color
	K^+	Mg^{++}	Cl	SO_4	NO_3		
Check	0.0				132.8	0.598	5.00
KCl	24.9		22.7		132.8	0.596	5.00
KCl	49.8		45.4		132.8	0.634	5.83
K_2SO_4	24.9			29.6	132.8	0.610	5.17
K_2SO_4	49.8			59.2	132.8	0.603	5.17
KNO_3	24.9				150.3	0.554	4.83
KNO_3	49.8				167.8	0.562	5.33
$K_2SO_4Mg\ SO_4$	24.9	16.5		95.6	132.8	0.609	5.17
$K_2SO_4MgSO_4$	49.8	33.0		191.2	132.8	0.575 n.s.	5.33 n.s.

* Lower numbers represent a lighter color.

TABLE 16. Correlation between Hunter Color difference meter values and visual rating of color of French fries and percent reducing sugars.

Comparison	Replicates	Treatment	Error	Total
Visual rating vs. "L" reading	0.93**	0.57	0.62**	0.64**
Visual rating vs. "a" reading	0.85*	0.51	0.37*	0.46*
Visual rating vs. "b" reading	0.55	0.45	0.45**	0.43**
Visual rating vs. total color difference	0.87*	0.49	0.62**	0.61**
% Reducing sugars vs. "L" reading	0.64	0.69*	0.09	0.28*
% Reducing sugars vs. "a" reading	0.49	0.58	0.14	0.28*
% Reducing sugars vs. "b" reading	0.73	0.63	0.12	0.09
% Reducing sugars vs. total color difference	0.64	0.64	0.06	0.26

* 5 percent level of significance

** 1 percent level of significance

Significant correlation values were obtained for error and total components in all comparisons of visual rating of color of French fries with objective evaluations of L, a and b reading and total color difference. Significant correlation values between L readings and percent reducing sugars were obtained for total component and treatment component, and for total component between a reading and percent reducing sugars. Hunterlab evaluations were done at the same time as visual ratings. Correlation between percent reducing sugars and the Hunterlab rating indicate that objective ratings are more accurate than visual rating.

Analysis of variance were run on all objective color rating data of French fries. Significant differences were obtained for L readings and total color difference but not for a and b reading. The effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions from four sources of potassium on objective color rating of French fries by L reading and total color difference is shown by the data of Table 17.

The order of potassium sources was the same for the two ratings namely potassium nitrate gave the lightest color of French fries followed by potassium-magnesium sulfate, potassium chloride and potassium sulfate. None of the potassium sources gave a lighter color French fry than the check.

The application of potassium nitrate resulted in a significantly lighter color of French fries as indicated by

TABLE 17. The effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on objective rating of color of French fries by L readings and total color difference.

Treatment	Rate of Application (lb/ac)					L color ratings of French fries*		Color of French fries by total color difference**	
	K^+	Mg^{++}	Cl	SO_4	NO_3		mean		mean
Check	0.0				132.8	52.3		3.92	
KNO_3	24.9				150.3	52.1	52.1 a***	4.28	4.09 a***
KNO_3	49.8				167.8	52.0		3.90	
$K_2SO_4M_9SO_4$	24.8	16.5		95.6	132.8	51.8	51.6 ab	4.07	4.57 ab
$K_2SO_4M_9SO_4$	49.8	33.0		191.2	132.8	51.3		5.07	
K_2SO_4	24.9			29.6	132.8	49.2	50.7 b	7.02	6.02 bc
K_2SO_4	49.8			59.2	132.8	52.2		5.01	
KCl	24.9		22.7		132.8	50.6	49.9 b	5.90	6.47 c
KCl	49.8		45.4		132.8	49.2		7.03	

* Higher numbers represent a lighter color.
** Lower numbers represent a lighter color
*** data not identified by the same letter (a,b) are significantly different at the 5% level.

the L readings and total color difference than the potassium sulfate and potassium chloride treatments. Although the potassium-magnesium sulfate treatment gave a significantly lighter color of French fries by total color difference than potassium chloride, this difference was not detected by the L readings. Application of different rates of potassium had no effect on color of French fries as determined by L readings and total color difference.

Since ammonium nitrogen can be rapidly oxidized by soil organisms to nitrate nitrogen it would seem that the absence of chloride and sulfate ions and not the presence of the additional amount of nitrate ions had a beneficial effect on color of French fries. The magnesium ions in combination with sulfate ions did not differ significantly from the potassium nitrate treatment. Since sulfate ions gave a darker color of French fries it may be that the magnesium ions offset some of the detrimental effects of the sulfate ions.

RECONDITIONING EXPERIMENT

The effect of treatments on color of French fries from tubers held at 38° to 40°F and then reconditioned for three, four and six weeks (Table 18) on color of French fries was not significant.

TABLE 18. The effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on color of French fries from tubers held at 38-40°F and after reconditioning potatoes for three, four and six weeks.

Treatment	Rate of Application (lb/ac)					French Fry Color* at 38-40°F after reconditioning			
	K	Mg	Cl	SO_4	NO_3	38-40°F	3 wks.	4 wks.	6 wks.
Check	0.0				132.8	12.25	6.00	5.75	6.00
KCl	24.9		22.7		132.8	12.50	6.50	5.25	5.25
KCl	49.8		45.5		132.8	12.50	6.25	6.00	6.00
K_2SO_4	24.9			29.6	132.8	12.50	7.00	5.00	5.25
K_2SO_4	49.8			59.2	132.8	11.75	6.75	6.00	4.75
KNO_3	24.9				150.3	11.25	6.50	4.50	5.50
KNO_3	49.8				167.8	11.75	6.75	6.50	6.25
$K_2SO_4MgSO_4$	24.9	16.5		95.6	132.8	12.00	5.50	5.00	5.00
$K_2SO_4MgSO_4$	49.8	33.0		191.2	132.8	12.25	6.25	5.25	4.50
						n.s.	n.s.	n.s.	n.s.
					Means		6.39	5.47	5.39

* Lower numbers represent a lighter color of French fry.

To be acceptable for processing, French fry samples should have a rating of 9 or less, with only a small percentage in the 10 to 12 range. All samples taken out of storage at 38-40°F. were unacceptable for making French fries until they had gone through a three week period of reconditioning. Only a small decrease in lightness of color of French fries was noted from the three to four week period of reconditioning. After four weeks of reconditioning little or no change in color of French fries appeared to take place.

The effect of different treatments of potassium sources on color of French fries becomes of lesser importance when compared with the effect of temperature. This is evidenced by the small differences in color between fertilizer treatments as compared to the large differences in color of french fries between tubers held at 38-40 degrees F. and tubers reconditioned at 70 degrees F. for three weeks.

SUMMARY AND CONCLUSIONS

No significant yield response to the addition of potassium fertilizer was obtained in any experiment. This is not surprising as in both years the fields tested had high exchangeable potassium. It would appear that the use of potassium fertilizers for increasing yields of potatoes on a Wellwood Loam soil testing high in exchangeable potassium is not justified.

The reduction of specific gravity of potato tubers from different sources of potassium appeared to be due to the associated ions and was greatest with the chloride. The addition of potassium nitrate resulted in the least reduction in specific gravity of any source of potassium but was not superior to the check. Although certain treatments reduced specific gravity slightly in no case did this result in tubers unsuitable for processing of French fries nor were yields of dry matter influenced by any potassium source.

Although the tubers were analysed for percent reducing sugars in Experiment III significant differences were not detected. However, potassium nitrate appeared to give the lowest percent reducing sugars. Association between visual color rating of French fries and percent reducing sugars was poor. The small differences between treatments in visual color rating and percent reducing sugars and the several weeks interval between the two evaluations may have caused the poor association. However, close association was obtained with visual rating of French fries and Hunter Color Difference Meter rating of color of French fries. Some association was also obtained with percent reducing sugars and L and a reading of color of French fries by Hunter Color Difference Meter.

Visual color ratings of French fries was not consistently affected by different ions and usually no real differences were detected, except in Experiment I where the chloride ions appeared to give a lighter color of French fries than sulfate ions. Objective ratings by L reading and total color difference reading of color of French fries in Experiment III showed potassium nitrate to be superior to potassium sulfate and potassium chloride but not superior to potassium magnesium sulfate. However, the treatment with no potassium gave the best color of French fries when measured by L rating and total color difference.

Texture and color of boiled tubers was not affected by different rates of potassium, magnesium, chloride, sulfate as nitrate ions except in Experiment III where magnesium and additional sulfate ions appeared to give a poorer color of boiled tubers.

No difference in reconditioning ability due to potassium source were noted. When potato tubers were processed into French fries directly from 38-40^{o}F storage all treatments gave an unacceptable product. Tubers from all treatments were acceptable for processing of French fries after three weeks of reconditioning at 70°F. and 60% relative humidity. Very little change in color of French fries occurred after longer periods of reconditioning. The reconditioning experiment also indicated the tremendous influence of storage temperature of potato tubers on color of French fries as compared with the small difference due to treatment effects.

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APPENDIX I. Analysis of variance for the effect of chloride and sulfate ions at different rates on total and marketable yield of potato tubers.

Source of Variance	D.F.	Total Yield M.S.	Marketable Yield M.S.
Replicates	5	1,168.33	1382.88*
Treatments	4	225.73	98.30
Error	20	435.20	481.65
Total	29		
C.V.		8.87%	10.66%

* 5.00 percent level of significance

APPENDIX 2. Analysis of variance for the effect of chloride and sulfate ions at different rates on specific gravity and yield of dry matter of potato tubers.

Source of Variance	D.F.	Specific Gravity M.S.	Yield of Dry Matter M.S.
Replicates	5	16.31	77.07*
Treatments	4	11.75	29.33
Error	20	6.51	25.19
Total	29		
C.V.		2.60%	8.76%

* 5.00 percent level of significance

APPENDIX 3. Analysis of variance for the effect of chloride and sulfate ions at different rates on texture and color of boiled potato tubers.

Source of Variance	D.F.	Texture M.S.	Color M.S.
Replicants	5	15.01	8.56
Treatments	4	5.35	1.78
Error	20	18.21	4.63
Total	29		
C.V.		13.45%	10.03%

APPENDIX 4. Analysis of variance for the effect of chloride and sulfate ions at different rates on color of French fries.

Source of Variance	D.F.	M.S.
Replicates	5	25.48
Treatments	4	35.70*
Error	20	9.99
Total	29	
C.V.		3.95%

* 5.00 percent level of significance.

APPENDIX 5. Analysis of variance for the effect of potassium, chloride and sulfate ions at different rates on total and marketable yield of potato tubers.

Source of Variance	D.F.	Total Yield M.S.	Marketable Yield M.S.
Rows	5	1,579.41**	1,101.10
Columns	5	1,131.96*	1,286.32*
Treatments	5	590.78	666.23
Error	20	371.81	325.43
Total	35		
C.V.		10.05%	10.72%

* 5.00 percent level of significance
** 1.00 " " " "

APPENDIX 6. Analysis of variance for the result of potassium, chloride and sulfate ions at different rates on specific gravity and yield of dry matter of potato tubers.

Source of Variance	D.F.	Specific Gravity M.S.	Yield of Dry Matter M.S.
Rows	5	73,434.03	60.78*
Columns	5	86,184.03*	65.46*
Treatments	5	82,184.69*	23.57
Error	20	28,319.44	16.48
Total	35		
C.V.		2.07%	9.98%

* 5.00 percent level of significance.

APPENDIX 7. Analysis of variance for the effect of potassium, chloride and sulfate ions at different rates on texture and color of boiled tubers.

Source of Variance	D.F.	Texture M.S.	Color M.S.
Rows	5	3.58	.49
Columns	5	3.46*	16.84**
Treatments	5	.64	.94
Error	20	1.08	.52
Total	35		
C.V.		3.40%	4.01%

* 5.00 percent level of significance
** 1.00 " " " "

APPENDIX 8. The analysis of variance for the effect of potassium, chloride and sulfate at different rates on color of French fries.

Source of Variance	D.F.	M.S.
Rows	5	92.16**
Columns	5	43.36*
Treatments	5	20.69
Error	20	11.68
Total	35	
C.V.		4.22%

* 5.00 percent level of significance
** 1.00 " " " "

APPENDIX 9. Analysis of variance for the effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on total yield and yield of potato tubers four ounces and over.

Source of Variance	D.F.	Total Yield M.S.	Yield of tubers four ounces and over M.S.
Replicates	5	355.74	457.33
Treatments	8	309.08	180.92
Check vs. Rest	1	361.59	218.92
Source	3	424.08	319.17
Rate	1	490.56	15.06
Source x Rate	3	116.07	85.41
Error	40	250.99	217.51
Total	53		
C.V.		6.31%	11.29%

APPENDIX 10. Analysis of variance for the effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on specific gravity and yield of dry matter of potato tubers.

Source of Variance	D.F.	Specific Gravity M.S.	Yield of Dry Matter M.S.
Replicates	5	2557.40**	12.85
Treatments	8	831.55*	12.75
Check vs. Rest	1	1804.84*	32.44
Source	3	1358.75*	12.69
Rate	1	42.20	19.01
Source x Rate	3	242.50	4.17
Error	40	361.49	12.86
Total	53		
C.V.		2.37%	8.99%

* 5.00 percent level of significance
** 1.00 " " " "

APPENDIX 11. Analysis of variance for the effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on texture and color of boiled tubers.

Source of Variance	D.F.	Texture M.S.	Color M.S.
Replicates	5	8.29*	.48
Treatments	8	3.70	6.61
Check vs. Rest	1	9.07	6.90
Source	3	5.34	14.66*
Rate	1	3.41	.06
Source x Rate	3	.37	.64
Error	40	2.56	3.90
Total	53		
C.V.		5.18%	10.86%

* 5.00 percent level of significance

APPENDIX 12. Analysis of variance for the effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on percent reducing sugars and French fry color of potato tubers.

Source of Variance	D.F.	Percent Reducing Sugars M.S.	French fry color M.S.
Replicates	5	7,337.94	1.44
Treatments	8	3,893.37	.49
Check vs. Rest	1	3,559.26	.28
Source	3	7,594.51	.24
Rate	1	26.11	1.69
Source x Rate	3	1,593.60	.41
Error	40	3,839.94	.94
Total	53		
C.V.		10.5%	18.65%

APPENDIX 13. Analysis of variance for the effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on rating of color of French fries by L readings and total color differences.

Source of Variance	D.F.	L Reading M.S.	Total Color Difference M.S.
Replicates	5	7.02	8.01
Treatments	8	8.45	9.44*
Check vs. Rest	1	9.81	9.79
Source	3	13.00*	15.49*
Rate	1	.00	.06
Source x Rate	3	6.27	6.43
Error	40	4.25	4.14
Total	53		
C.V.		4.03%	39.57%

* 5.00 percent level of significance

APPENDIX 14. Analysis of variance for the effect of different rates of potassium, magnesium, chloride, sulfate and nitrate ions on color of French fries from potato tubers held at 38-40°F. and after reconditioning potatoes for three, four and six weeks.

Source of Variance	D.F.	French Fry Color at 38-40°F M.S.	after reconditioning 3 wks M.S.	4 wks M.S.	6 wks M.S. *
Replicates	5	6.28**	1.30	.41	1.21
Treatments	8	.75	.83	1.45	1.59
Check vs. Rest	1	0.08	.04	.04	2.84
Source	3	1.38	1.08	1.42	1.86
Rate	1	.00	1.13	2.00	.03
Source x Rate	3	.59	.75	1.76	1.42
Error	40	.76	.67	1.16	.94
Total	53				
C.V.		7.20%	12.83%	20.00%	17.73%

* 5.00 percent level of significance
** 1.00 " " " "