STUDIES ON CONDITIONING OF POTATOES FOR POTATO CHIPS MAKING

Thesis for the Degree of M. S.

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Takao Miyamoto

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OF POTATOES FOR POTATO CHIPS MAKING

By

TAKAO MIYAMOTO

AN ABSTRACT

Submitted to the School of Graduate Studies of
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Ventilation and modified atmospheres were applied to Russet Rural potatoes during conditioning, after storage at 40 or 50°F, and their effect on potato chip color was determined. Poor ventilation did not produce satisfactory chips, and was accompanied by serious decay if very high relative humidity resulted.

Ventilation to give a relative humidity of about 85% gave far more satisfactory chips than did ventilation with air near 100% relative humidity. Carbon dioxide in relatively high amounts (10% in air) seemed detrimental to good conditioning even in an atmosphere at satisfactory relative humidity. A drier atmosphere, that produced notable shrinkage, was provided by use of large quantities of $CaCl_2$. This was not effective in conditioning to produce good chips. Nitrogen gas was highly detrimental to good conditioning.

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1. INTRODUCTION

Improving the color of potato chips is a very important subject for the potato chips industry. Potatoes are stored at a low temperature in order to prevent decay, sprouting and loss of weight. Potatoes taken directly from 40°F storage produce dark colored chips. Such potatoes must be conditioned at 70° to 80°F until they have recovered sufficiently for use.

Much research has been done on the conditioning, but still further studies are required. For example, Smith (13) remarked that an accurate study is needed of the following factors as effecting quality of chips. (a)storage and conditioning temperatures (b)storage and conditioning humidity (c)use of chemicals for retarding sprout growth of potatoes (d)use of modified atmosphere, carbon dioxide, nitrogen, etc., for influencing reducing sugar content and sprouting (e)use of steam, ethylene and other methods which result in increased respiration as affecting reducing sugar content of potatoes and possibly improving the color of chips.

This thesis deals with an investigation of some of those problems, especially conditioning humidity, modified atmosphere, etc.

2. REVIEW OF LITERATURE

Sweetman(15) reported that chips made from tubers stored between 32° and 37°F were darker than those made from tubers stored between 40° and 55°F.

The fact that the sugar content of potatoes increases when they are stored at comparatively low temperatures was first demonstrated by Müller-Thurgan(11). It was supported by Appleman (1).

Wright(18) studied extensively the relationship between storage temperatures and potato sugar contents. He put tubers in storage at controlled temperatures of 32°, 36°, 40°, 50°, 60° and 70°F. He found that the lower the temperature, the higher the sugar content.

Barker(3) demonstrated the sugar content gradually increased in potatoes when transferred to low temperatures. If, however, potatoes which were rendered sweet by prolonged storage at low temperatures, or partially sweet by storage for short periods, were transferred to 15°C a rapid desweetening occured. He found that on changing the temperature to 15°C the respiration increased rapidly, and after 18 hours reached a peak value which was roughly seven times the previous respiration at -1°C.

Denny and Thornton(7) found that the brown color correlated well with the reducing sugar, less satisfactorily with the total sugar, and not at all with the sucrose content. In that test tubers of Russet Rural that produced chips very light in color were low in reducing sugar but not in sucrose.

Denny and Thornton(9) reported that the value 5.0 mg of reducing sugar per cc of juice was found to be the dividing line. Tissue with amounts higher than this furnishing chips too dark brown in color. For a really satisfactory commercial color the value should probably be as low as 3.0 mg. Their experiment showed the temperature of 7°C was a favorable one for storage for potato chip manufacture since many of the varieties were maintained at low reducing sugar values for periods of 108 to 131 days after start of storage.

Wright et al(20) acquired evidence showing that storage below 40 F for more than a few days was likely to result in potatoes that were unsatisfactory for processing--regardless of subsequent attempts to condition them.

According to Arreguin-Lozano and Bonner(2), the decomposition of starch is accomplished by phosphorylase which attacks starch at low (32°F) temperatures producing glucose-1-phosphate. But at high temperatures(68° to 86°F) the starch remains unattacked by phosphorylase.

Effects of modified atmospheres on potatoes have been studied for many years.

Thornton (16)treated tubers with 30% and 60% of carbon dioxide in the presence of 20% oxygen for various periods up to 21 days at 21°C. He observed that the rate of respiration and specific conductivity of leaching from the treated potato tissue increased. Also, the catalase activity, PH, reducing sugar content, and sucrose in the extracted juice were greatly increased over that found in the control.

Denny and Thornton(8) reported the rapid increase in reducing sugar which occurs in potato tubers stored at 5°C was prevented by storing the tubers in an atmosphere containing 5% of carbon dioxide. At the end of two months at 5°C, the reducing sugar content of the carbon dioxide treated lot was approximately one-fifth of that of the control lot in air.

However, Denny and Thornton(10) stored potato tubers at 2°,5° and 7°C in atmospheres containing 0, 5, and 20% of carbon dioxide and 21% of oxygen, and determined the sucrose content of the juice at intervals of 30, 60 and 90 days. They found the general effect of carbon dioxide upon the sucrose content was to greatly increase it, about six-fold at 5° and 7°C. At 2°C treatment with carbon dioxide first retarded sucrose increase, as compared with the untreated, and then greatly increased it.

Barker and Saifi(4) studied the effects of nitrogen on potato tubers at 10°C. Changes in the rate of carbon dioxide production, sucrose and hexose contents, lactic acid content, alcohol-soluble solids, PH, and alcohol content were investigated. In nitrogen, the carbon dioxide production showed a complex form, the initial phase consisting of an increase followed by a marked decrease to a minimal rate after 6 to 9 days. In air, sucrose and hexose contents changed little, but in nitrogen, sucrose content decreased markedly and the hexoses were either stable or increased. Under anaerobic conditions, lactic acid accumulated progressively; alcohol content did not increase until after about 7 days. Subsequently, the rate of accumulation of lactic acid decreased and that of alcohol increased. During the period in which lactic acid content increased, an approximately equivalent increase occured in a non-sugar, non lactic, alcohol-soluble fraction.

Although early researchers considered that the reducing sugar in tuber tissue caused the dark brown color of chips, the idea has been modified to some extent.

According to Watada and Kunkel(17), amino acids combine with reducing sugar to form the undesirable color which often occurs in the process of making potato chips and french fries.

In order to store potato tubers without decay other factors than the low temperatures and modified atmospheres have been studied by many workers.

Burton(5) suggested that the tubers should be kept in the dark in a ventilated storage, although there should not be rapid air movement over them; the atmosphere should be neither so moist that fungal growth is encouraged, nor so dry that water loss is excessive.

Wright and Whiteman(21) recommended that the relative humidity of a potato-storage house should be 85 to 90%, to prevent undue shrinkage through loss of water. Insulation was also suggested to prevent the condensation of moisture on the walls and ceilings and the consequent undesirable wetting of stored stock, which favors the development of decay.

Schilletter and Richey(12) noticed that when the potato tubers are stored in open-mesh sacks the lower tier of sacks should rest upon a slatted or false floor of wood, because burlap next to a concrete or earthen floor will rot.

Smith(14) reported that control of temperature and ventilation is particularly important for potatoes to be made into chips. It was also found the greatest amount of decay occured in the lots which had been most severely bruised during harvesting operations.

Since most of the papers concerning storage were concerned with problems of decay, sprouting or shrinkage rather than with potato chip quality as such, it seemed worthwhile to investigate the matter further.

3. MATERIALS

Russet Rural potatoes were used in both Experiment I and II. The potatoes for Experiment I were produced at Lake City Experiment Station and kept in a house basement at about 50°F for 70 days.

The tubers used for Experiment II were harvested at Lake City and stored at 40°F for 70 days. Only sound tubers were used for the tests.

4. METHODS

Experiment I

Metal cans were prepared as shown in Figure 1, the covers being made air-tight with pressure-sensitive tape. The volume of a can was 15.70 liters. Forty tubers which occupied about 6.53 liters were put into the can on December 24. Fourteen cans were used and tubers in each can were treated in different ways. No replication was made because Experiment I was conducted as a preliminary test. All the cans were kept in the laboratory of Farm Crops Department under the room temperature of 65° to 75°F. The treatments were as follows:

a) Ventilated with 1% CO_2.

A mixture of 99% of air and 1% of CO_2 was passed through the can at a rate of 120cc per minute. Apparatus for this is described in Figure 2. A known concentration of sulfuric acid was dropped into a concentrated solution of sodium carbonate at a calculated rate so as to get the constant mixture of air and CO_2.

b) Ventilated with 5% CO_2.

A mixture of 95% of air and 5% of CO_2 was similarly prepared and passed through the can.

c) Ventilated with 10% CO_2 as above.

d) Ventilated with air alone, as above.

e) Moistened with water and slightly ventilated.

The tubers were moistened with water, before placing in the can. Both of the ventilation pipes attached in the can were closed by screw cramps, so no air passed through those pipes. Scotch tape was not used on the boundary of container and cover, so some air could pass through that boundary. The cover was removed once a week when the sample was taken out,

Figure 1. Container of Potatoes

then put on again.

f) Not moistened with water and slightly ventilated.

The tubers not moistened with water were put into the can. Conditions of the can were prepared the same as (e). Perfect ventilation was also only once a week.

g) Poorly ventilated with air.

The cover was sealed by scotch tape and ventilation pipes were closed by screw cramps. Air change was made once a week when the sample was taken out.

h) Poorly ventilated with 2.5% CO_2 and 97.5% air.

The can for that treatment was prepared in the same way as (g). In order to make the mixture of gas the pipes of potato filled can was opened, then suitable amount of carbon dioxide was introduced from the upper pipe. After the substitution of air by 2.5% of carbon dioxide was fulfilled, the pipes were closed by screw cramps. The can was opened and tubers were exposed to air once a week while the sample was taken. After that the inside atmosphere was made the same as its previous state.

i) Poorly ventilated with oxygen.

Tubers were kept in oxygen using can prepared as in (g). Change of gas was once a week.

j) Poorly ventilated with 2.5% CO_2 and 97.5% oxygen.

That lot was prepared like (h). First the can was filled with oxygen. Carbon dioxide was then added to the can so as to make a mixture of 2.5% CO_2 and 97.5% oxygen. Change of gas was once a week.

k) Poorly ventilated with nitrogen.

Method was similar to (i).

l) Poorly ventilated with 2.5% CO_2 and 97.5% nitrogen.

Method was like (j).

m) Poorly ventilated with air and dried with $CaCl_2$.

The can was prepared like (g). A dish containing 250g of $CaCl_2 \cdot H_2O$ was put inside of the can in order to take out moisture. Air and calcium chloride were changed once a week.

n) Poorly ventilated with air and CO_2 was removed by $Ca(OH)_2$.

Whole tuber surfaces were coated with 1% of $Ca(OH)_2$ then stored in the can. Air was changed once a week.

o) Shocked the top part of tubers.

Moistened blotter was laid on a flat cement block and tubers were dropped from a height of 7 feet. Shocked part was moistened and marked. The top part referred to the dominant part of polarity. Tubers shocked the top part were selected and marked, then put into a hemp sack and stored in the room.

p) Shocked the end part of tubers.

Treated same as (o). The end part referred to the opposite of the top part.

q) Shocked the side part of tubers.

Treated same as (o) and (p). The side part referred to neither top part nor end part.

r) Pressed by 17 pounds on sides of tubers.

Three tubers were laid on a cement block and another cement block was laid on the tubers. The block weighed 50 pounds.

s) Pressed by 33 pounds on sides of tubers.

Treated same as (r), and two blocks were put on the tubers.

t) Pressed by 50 pounds on the sides of tubers.

Treated same as (r) and (s). Three blocks were put on the tubers.

The next Experiments were conducted to determine the losses from decay in different conditions after five weeks of conditioning.

u) Sprinkled with water once a week.

Twenty tubers were put into a 7.68 l. metal can after sprinkling with water. The cover was sealed by scotch tape. The can was opened and tubers were sprinkled once a week.

v) Sprinkled with water once a day.

Treated same as (u). The can was opened and tubers were sprinkled with water once a day.

w) Removed inside moisture with calcium chloride.

A dish containing the chemical at a rate of 5% of the weight of the tubers was renewed once a week.

x) Just sealed.

No chemical was applied. The can was opened and the air changed once a week. A little water was condensed on the surfaces of tubers and cans.

y) Kept in open air.

The cover was not put on.

Experiment II

The same cans were used as in Experiment I. Fifty tubers were put into each can. As the potatoes occupied 7.30 liters, the unoccupied space was calculated to be 8.40 liters. Conditioning tests were conducted in the laboratory of Farm Crops Department under the temperature of 65° and 75°F. The cans were treated in the different ways which were described as follows:

Figure 2. Ventilation apparatus for dry air.

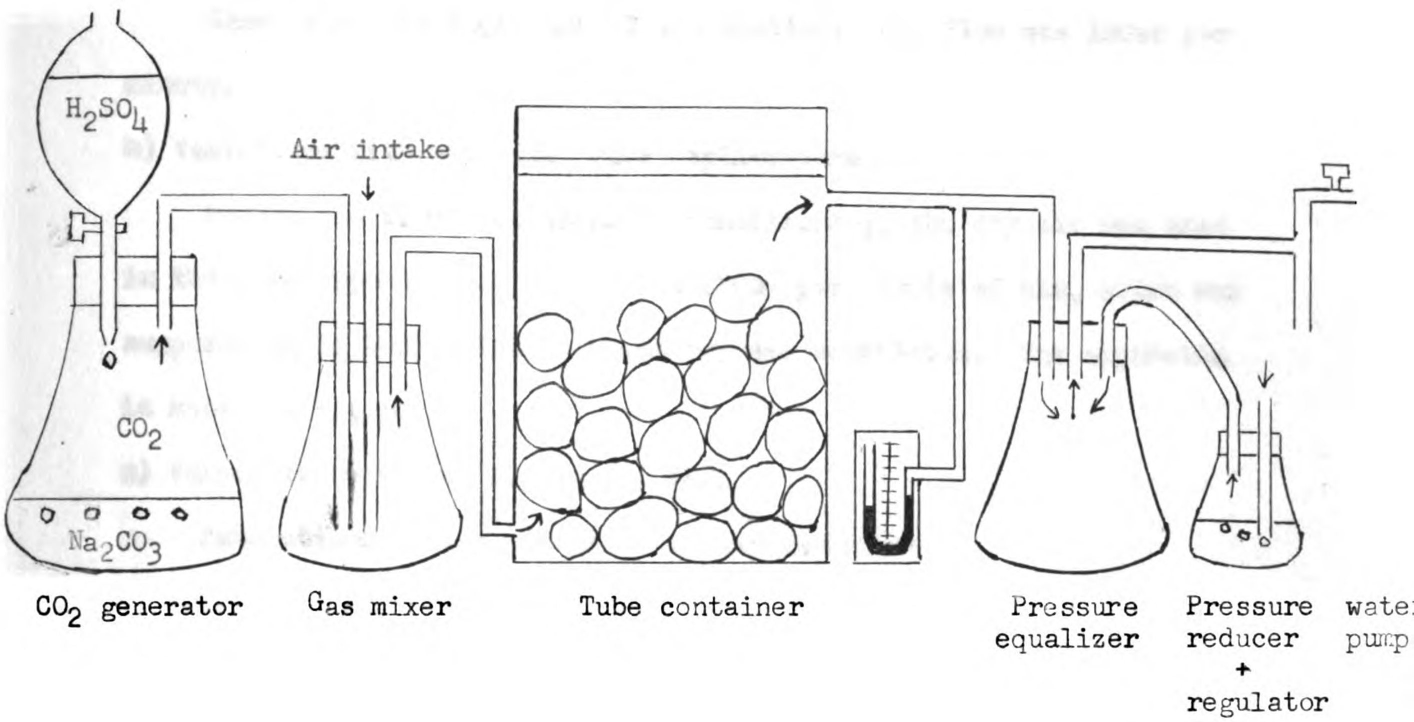
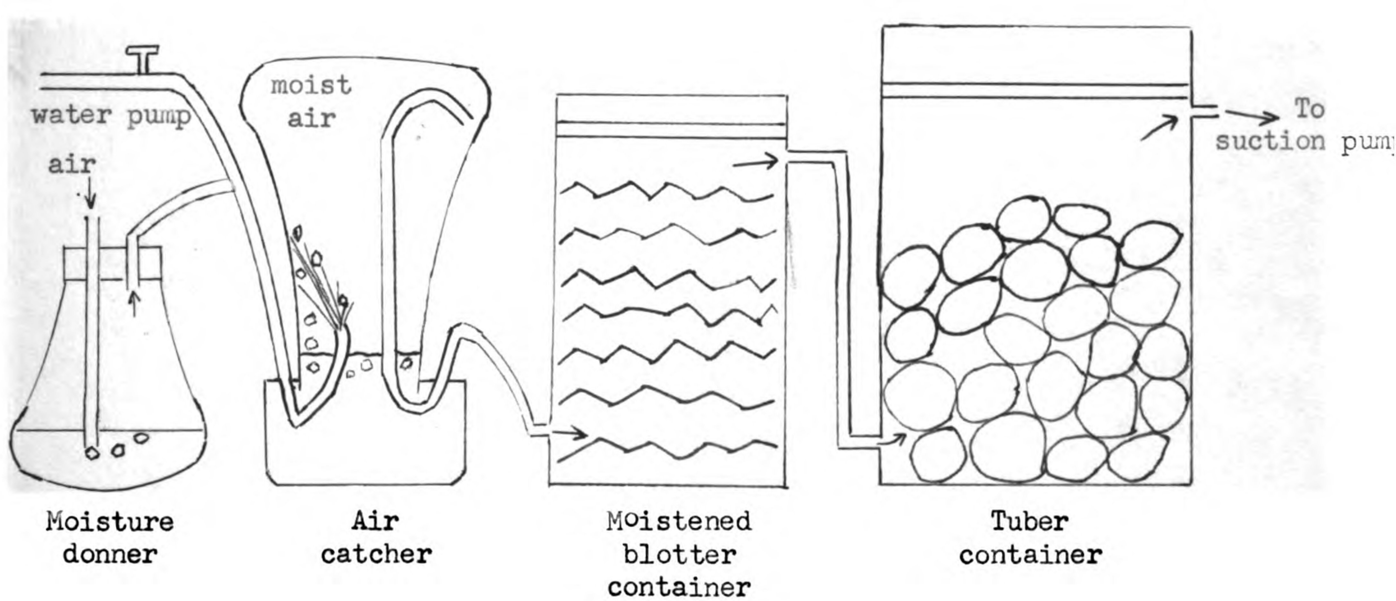


Figure 3. Ventilation apparatus for wet air.



a) Ventilated with dry air. Four replications.

Same method as Experiment I was applied. Air flow was 120cc per minute.

b) Ventilated with wet air. Four replications.

During the first two weeks of conditioning, the dry air was used in the same way as (a). After that 120cc per minute of air, which was supposed to be 100% relative himidity, was ventilated. The apparatus is shown in Figure 3.

c) Ventilated with 10% CO_2 in dry air.

Same method as Experiment I (c) was applied.

d) Poorly ventilated with dry air.

Container was sealed with scotch tape.

e) Poorly ventilated with wet air.

Potatoes were moistened with water then put into can. The can was sealed with scotch tape.

f) Poorly ventilated with 10% CO_2.

g) Five grams of $CaCl_2$ was put into can. No ventilation.

h) Ten grams of $CaCl_2$ was put into can. No ventilation.

5. RESULTS

Experiment I

a) Grade of chips.

Three tubers were taken from each lot three weeks after starting test, and five tubers at 4 and 5 weeks. The middle portion of the tuber was sliced by the chip slicer. Three pieces were picked up from each tuber, then soaked in cold water for 10 minutes. After that they were fried in cotton seed oil at starting temperature of 385°F until they were sufficiently cooked. When bubbling ceased, indicating the completion of removal of water, the slices were well fried.

These chips were individually scored according to the standard of Coughlin and an average was calculated. The lower the grade, the better the quality. Grades of 1 - 3 are desirable and below 5 is acceptable for selling. Results are shown in Table I.

TABLE 1

The chips produced after the storage conditions in Experiment I were given the following chip grades.

Treatment	Start	1 week	2 weeks	3 weeks	4 weeks	5 weeks
a) Vent. 1% CO_2	5.66	5.00	5.66	5.20	5.25	4.80
b) Vent. 5% CO_2	5.66	6.00	5.00	6.46	5.40	4.60
c) Vent. 10% CO_2	5.66	6.66	4.33	5.60	5.40	6.00
d) Vent. air	5.66	5.46	5.33	5.20	5.00	3.80
e) Moist H_2O	5.66	6.00	5.33	5.60	6.00	6.20
f) Not moist	5.66	6.00	5.66	5.00	5.40	5.60
g) Poor vent. air	5.66	5.00	4.66	6.00	6.50	6.60
h) Poor vent. CO_2 and air	5.66	6.00	5.00	6.00	5.40	6.20
i) Poor vent. O_2	5.66	5.00	5.00	5.60	5.20	5.60
j) Poor vent. $CO_2 + O_2$	5.66	6.00	5.33	5.80	7.00	6.20
k) Poor vent. N_2	5.66	5.33	4.66	6.20	6.40	—
l) Poor vent. $CO_2 + N_2$	5.66	6.00	5.66	6.20	7.80	—
m) Poor. vent, air and $CaCl_2$	5.66	5.66	5.00	5.20	7.00	6.40
n) Poor vent., air and $Ca(OH)_2$	5.66	6.66	5.66	5.40	5.60	5.60
O) Shock top	5.66	—	5.00	6.00	—	—
p) Shock end	5.66	5.33	5.00	6.33	—	—
q) Shock side	5.66	5.33	5.66	5.33	—	—
r) Press 17 lbs.	5.66	5.33	4.66	5.66	—	5.66
s) Press 33 lbs.	5.66	6.00	4.66	5.00	—	5.33
t) Press 50 lbs.	5.66	5.00	5.00	6.00	—	6.33
No shock no press	5.66	6.50	6.50	5.66	—	—

b) Decay test 1.

Number of tubers decayed during each period was divided by the number of tubers at the beginning of each period to give the degree of storage. The results were shown in Table 2 as percentages.

TABLE 2

Decay test 1

Percentage of decay after intervals of storage.

	0-2 weeks	2-3 weeks	3-4 weeks	4-5 weeks
Vent. 1% CO_2	0%	0%	0%	0%
Vent. 5% CO_2	0	0	0	4.2
Vent. 10% CO_2	0	0	0	0
Vent. air	0	0	0	0
Moist H_2O	0	0	0	16.7
Not moist	0	0	0	0
Poor vent. air	0	0	10.3	47.6
Poor vent. CO_2 + air	0	0	0	29.2
Poor vent. O_2	0	0	0	8.4
Poor vent. CO_2 + O_2	0	0	0	16.7
Poor vent. N_2	0	32.3	85.7	100
Poor vent. CO_2 + N_2	0	29.4	100	—
Poor vent. air + $CaCl_2$	0	0	0	0
Poor vent. air + $Ca(OH)_2$	0	0	0	4.2

c) Decay test 2

Same kind of treatment as (b) was conducted using twenty tubers per lot. The data were taken at five weeks after starting test. Results are shown in Table 3.

TABLE 3

Decay test 2

Treatment		Decay Percentage
Sprinkled once a week.	Wet	100%
Sprinkled once a day.	Wet	65
Dried by $CaCl_2$	Dry	0
Ventilated once a week.	Dry	35
Control, put in open air.	Dry	0

Experiment II

a) Grade of chips.

Five tubers were taken for sample from each of the four replicated cans. Grades of chips were made in the same as Experiment I. Results are shown in Table 4.

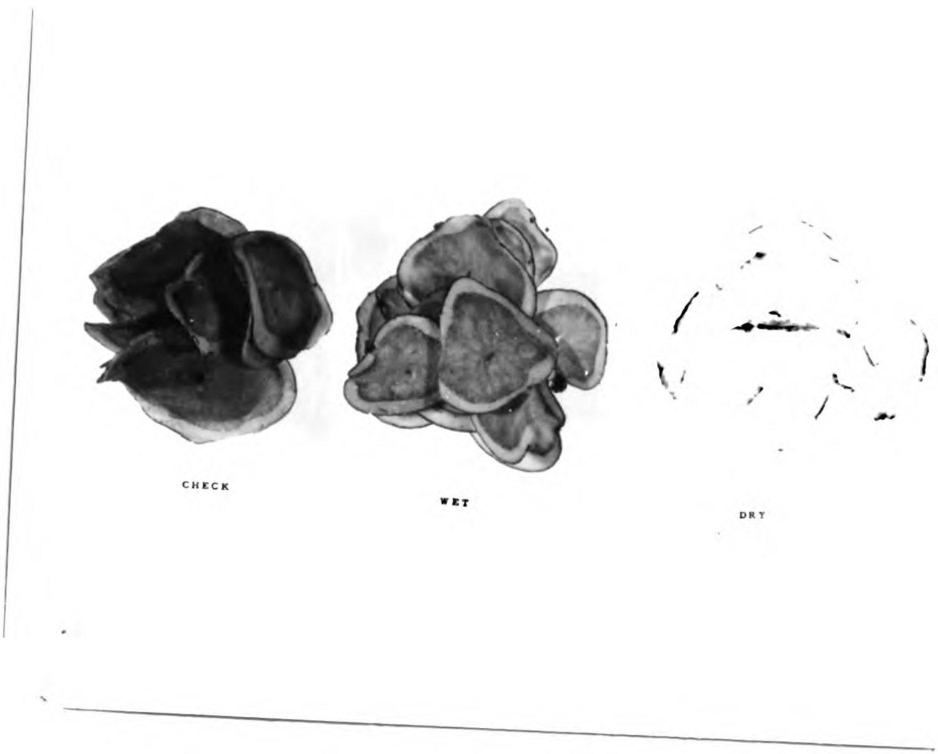
TABLE 4

Results of scoring chips in Experiment II

	Start	3 weeks	5 weeks	7 weeks	9 weeks
Vent. dry air 1	9.50	6.80	5.60	3.20 (2.60)*	2.60
2	9.50	8.64	6.40	3.48 (4.00)	4.00
3	9.50	7.40	5.00	2.69 (3.25)	3.40
4	9.50	6.8-	5.60	3.20 (3.40)	3.60
Average	9.50	7.40	5.65	3.12 (3.31)	3.40
Vent. wet air 1	9.50	7.60	6.20	5.80 (5.60)	--
2	9.50	7.25	5.80	6.40 (5.40)	--
3	9.50	7.20	6.20	6.00 (6.00)	--
4	9.50	7.40	6.80	6.20 (5,80)	--
Average	9.50	7.36	6.25	6.10 (5.70)	--
Vent. 10% CO_2	9.50	6.00	6.40	6.80 (7.00)	--
Poor vent. dry air	9.50	7.75	--	--	--
Poor vent. wet air	9.50	7.40	--	--	--
Poor vent. 10% CO_2	9.50	--	--	--	--
Poor vent. 5g $CaCl_2$	9.50	7.80	--	--	--
Poor vent. 10g $CaCl_2$	9.50	8.40	--	--	--

*Cooked at starting temperature of 370°F.

Figure 4. Improvement of chips color after seven weeks of conditioning in moist air and dry air in comparison to check made at start of experiment.

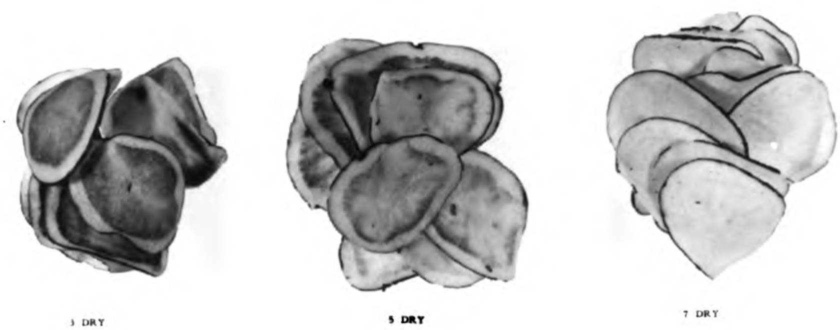


check: start.

wet : wet air ventilated.

dry : dry air ventilated.

Figure 5. Improvement in chip color after 3, 5 and 7 weeks of conditioning in ventilated dry air.

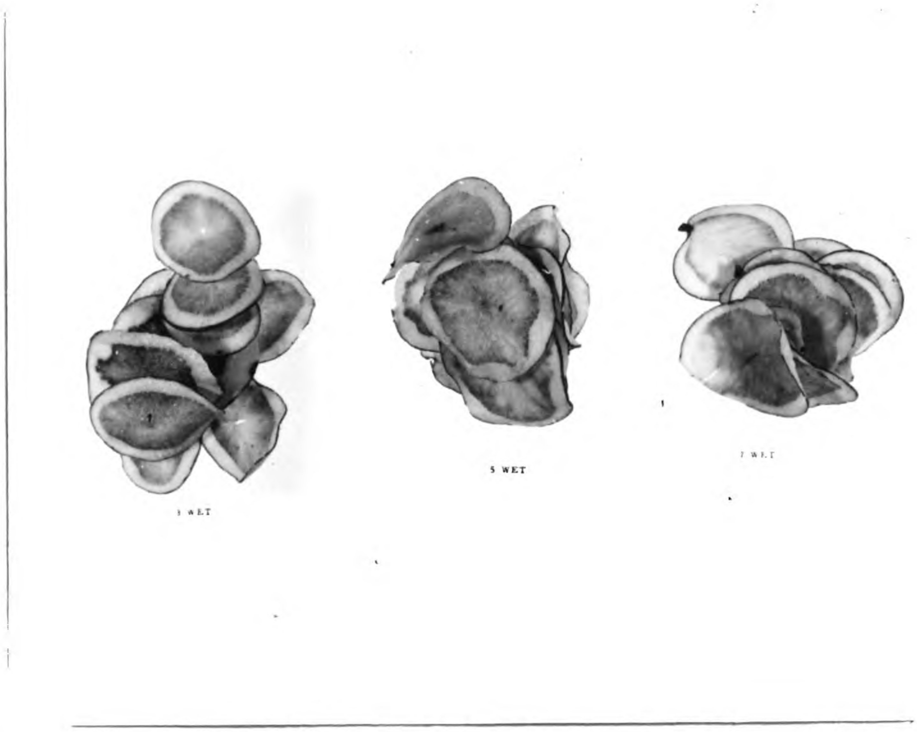


3 : chips were made at 3 weeks after start.

5 : " " " at 5 weeks after start.

7 : " " " at 7 weeks after start.

Figure 6. Results of chip color at 3, 5 and 7 weeks of continuous exposure to moist air.



3 : At 3 weeks after start.

5 : At 5 weeks after start.

7 : At 7 weeks after start.

Figure 7. Comparison of chip color at 7 weeks from 10% CO_2, wet and dry ventilation treatments.

b) Percentage weight loss.

The percentage weight loss during a period was divided by the tubers weighed at the beginning of the period. Results were shown in Table 5.

TABLE 5

Percentage weight loss of potatoes at

3, 5 and 7 weeks after start of Experiment

	Start-3 weeks	3-5 weeks	5-7 weeks	Total
Vent. dry air 1	0.61%	0.36%	0.38%	1.35%
2	0.52	0.17	0.42	1.11
3	0.57	0.31	0.37	1.25
4	0.59	0.47	0.52	1.58
Average	0.57	0.33	0.42	1.32
Vent. wet air 1	0.50	0.14	0.26	0.90
2	0.42	0.16	0.18	0.76
3	0.45	0.11	0.30	0.76
4	0.39	0.10	0.22	0.71
Average	0.44	0.13	0.24	0.78
Vent. 10% CO_2	0.50	0.34	0.33	1.17
Poor vent. dry air	0.08	0.11	0.13	0.32
Poor vent. wet air	0.10	—	—	—
Poor vent. 10% CO_2	0.21	—	—	—
Poor vent. 5g $CaCl_2$	0.73	—	—	—
Poor vent. 10g $CaCl_2$	1.14	—	—	—

c) Percentage loss from decay.

Decay loss was tested in the same way as in Experiment I. The results are shown in Table 6.

TABLE 6

Percentage loss from decay of tubers at

3, 5, 7 and 9 weeks intervals

	Start-3 weeks	3-5 weeks	5-7 weeks	7-9 weeks
Vent. dry air 1	0%	0%	5.0%	0%
2	2.0	4.5	27.0	4.5
3	0	0	0	5.7
4	0	0	0	2.8
Average	0.5	1.1	8.0	3.2
Vent. wet air 1	2.0	0	66.6	100
2	4.0	4.6	69.4	100
3	0	2.3	55.3	100
4	2.0	4.5	56.7	100
Average	2.0	2.8	62.0	100
Vent. 10% CO_2	4.0	0	13.1	53.5
Poor vent. dry air	34.0	96.4	100	—
Poor vent. wet air	100	—	—	—
Poor vent. 10% CO_2	76.0	100	—	—
Poor vent. 5g $CaCl_2$	10.0	97.5	100	—
Poor vent. 10g $CaCl_2$	0	100	—	—

Figure 8. Tubers that were ventilated with dry air, nine weeks from dormant potatoes at beginning of experiment.

6. DISCUSSION

No treatments in Experiment I were replicated. However, some phenomena might be revealed. Tubers ventilated with 120cc per minute of room air gave the best chips score. Generally speaking, carbon dioxide inhibit the improvement of chips color, but 10% CO_2 ventilation resulted in the best at two weeks after start which is worth further testing. Poorly ventilated conditions applied in various atmospheres were undesirable. Nitrogen and nitrogen + CO_2 lots were the poorest. Black spots were noticed in the center portion of chips which were made from the tubers kept in those gases.

Results shown in Table 1 reveals the necessity of aerobic respiration of tubers during conditioning in order to improve chips quality.

Shock must be avoided, because often brownish spots appeared in the chips from shocked tubers, corresponding to the position to which shock was given. This would indicate sound uninjuried potatoes should be used in quality chip manufacture. Pressing must also be avoided because of slow improvement of color. Table 2 shows that it is necessary to apply ventilation or chemicals (i.e. calcium chloride or calcium hydroxide) to prevent the decay. Table 3 shows wet and poorly ventilated tubers tend to decay easily.

Experiment II was attempted to get information about the effects of relative humidities of ventilation air. The tubers which had been kept at 40°F for days were considered very difficult to condition to satisfactory chip color, but they were sufficiently recovered by applying dry air ventilation for seven weeks. The relative humidity of the air above the potatoes that were ventilated with dry air was found to be approximately 85% R.H. Dry air ventilation lot No. 2 should be considered to be a failure because the ventilation pipe was choked by condensed water from second to fourth weeks after starting test.

In the case of ventilation with 100% relative humidity air, the chip color did not recover sufficiently. This fact might be emphasized because some of the commercial conditioning storages are wet. Improving of chips color was fastest at three weeks after starting when 10% CO_2 was ventilated. That fact was analogous to the case of Experiment I.

Table 5 and 6 show that insignificant sportage during conditioning occured when dry air was used in ventilation, but sportage was serious in other cases. Application of 5g or 10g calcium chloride per can did not prevent the decay of tubers. In Experiment I utilizing large amounts of calcium chloride did not help improvement of chip color though it prevented decay perfectly. At the present time, the writer cannot recommend the application of calcium chloride during conditioning. Inside relative humidity was kept 85 to 90 percent when dry air was ventilated. Too dry atmosphere seems undesirable as well as too wet atmosphere. Both shrinkage of potatoes and condensation of water on the surface of tubers must be avoided.

SUMMARY

Ventilation and modified atmospheres were applied to potato tubers during conditioning, after storage of 40 or 50°F, and their effect on potato chip color was determined. Poor ventilation did not produce satisfactory chips, and was accompanied by serious decay if very high relative humidity resulted.

Ventilation to give a relative humidity of about 85% gave far more satisfactory chips than did ventilation with air near 100% relative humidity. Carbon dioxide in relatively high amounts seemed detrimental to good conditioning even in an atmosphere at satisfactory relative humidity. A drier atmosphere, that produced notable shrinkage, was provided by use of large quantities of $CaCl_2$. This was not effective in conditioning to produce good chips. Nitrogen gas was highly detrimental to good conditioning.

LITERATURE CITED

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