A STUDY OF THE BIOLOGICAL ASPECTS OF TRANSPORTATION OF FRUIT FROM CHILE TO THE UNITED STATES

by

Signature Redacted  Signature Redacted

Course IX  Class of 1924

Submitted to the faculty of the Massachusetts Institute of Technology in partial fulfillment of the requirements for the degree of Bachelor of Science.
ACKNOWLEDGEMENTS.

We wish to express our grateful appreciation of the kind assistance and interest of Professor Samuel C. Prescott, under whose supervision this thesis was performed. We also desire to thank Mr. Riley of the Biology Department, and Mr. Broussard, assistant in the laboratory for the aid which they kindly gave.
INTRODUCTION

Up to the present time very little fruit has been brought to this country from Chile. Climatic and soil conditions in that country are very favorable to fruit culture, and it is quite generally agreed among people who have visited Chile that the quality of the fruits is far superior to that of any North America has been able to produce. Also, the seasons in North and South America are in opposition, so that when fruits are harvested in Chile, there is a minimum supply in the United States. These factors make it very desirable to bring fruits from that country to the United States, provided that they can be successfully transported, and can compete in price with California products. Almost every fruit found in the United States is grown in Chile.

The cost of transportation is rather high, being at present, $1.07 per cubic foot. However, the cost of labor in Chile is very low, so that it is probable that the cost of the fruits would be low enough to prevent price competition from California becoming a serious factor. The problem of transportation, aside from costs, offers a great obstacle, however, and it was to determine the possibility of successfully transporting fruits with transportation facilities now available that this study was undertaken. The study is centered chiefly on grapes and apples, which are two of the most important fruit products of Chile.

At present, one steamer leaves Valparaiso for New York every week. These steamers offer plenty of hold space for the transportation of cargo, but have no refrigeration space whatever. In addition to these weekly steamers, there is a monthly boat which does have refrigeration space. In view of this, it was necessary
to determine whether fruits could be shipped at all without refrigeration, and if refrigeration were necessary, what temperature would be required.

There are many factors which must be taken into account in considering the problem of transportation of the fruits. The time required from Valparaiso to New York is twenty days. Climatic conditions are variable with the season. The ship must cross the equator where the temperature is from 35 to 45 °C. The ship is in this hot zone for from three to five days. At the season when the fruit would be shipped, the temperature from the port of origin to the equator would be between 30 and 35 °C. The fruit would arrive in New York in the cold season, when the temperature would be between -5 °C, and about 0 °C. The relative humidity also varies considerably, being fairly low in Central Chile, and very high around the equator. North of the equator, it again becomes low. Both temperature and humidity are by no means constant, both conditions being subject to extreme variations from month to month, and even from week to week. Conditions in the hold of the ship, where the fruit would be kept, would closely approximate conditions outside. However, there would be very little ventilation. None of the conditions mentioned would enter into the problem if refrigeration were used. All of them must be taken into account however to determine whether it is possible to ship fruits successfully without refrigeration.

The problem is one of devising some means of transporting fruits, if possible without refrigeration, so that they will not be so injured as to make them unsalable. Judging from the dearth of material on the subject, one is led to believe that little if any
work has been done on it in the past. Refrigeration is used in the transportation of fruits, requiring much time or involving high temperatures. In fact, refrigeration is in almost universal use now for the transportation of fresh fruits even regardless of time or temperature. From a practical standpoint, the problem is much complicated by the multiplicity of variables which affect it. These include not only external conditions, but differences in the fruits as well. It is necessary that any method devised for preserving fresh fruits should be so certain in its results that not only will one sample of a fruit be well preserved, but that all samples will be perfectly preserved. In addition to actual preservation, it is necessary that the natural taste of the fruit should remain unchanged.
It is necessary for a solution of the problem to consider all the factors which enter into the spoilage of fruits. A review of the present practice in the storage of fruits in warehouses is instructive. Apples, for example, are kept as long as eight months with temperatures of 0-20 C, and relative humidity of 95%. Good ventilation at all times is required. They must be so packed that they will not be injured by excessive pressure. Conditions for the storage of grapes are about the same, although ventilation is not quite so important.

The variables which enter into the problem of storing or preserving fresh fruits, in the probable order of their importance, are: temperature, time, initial condition, humidity, ventilation, and the method of packing.

Temperature is extremely important because, within certain limits and neglecting other variables, the growth of microorganisms in the fruits is almost a direct function of the temperature.

Time is of course, the factor on which all else depends, since any storage problem must be considered from the standpoint of the length of time of storage which is desired. The time factor in this study is in most cases about one month. In addition to the twenty days required for transportation, it will allow for unloading and sale.

The initial condition must take into account the kind of fruit, the stage of ripening, the length of time since picking, condition of the skin, and the conditions under which the fruit
was kept from time of picking up to storage. Each kind of fruit requires different storage conditions, and the keeping qualities of one fruit under certain conditions have no necessary bearing upon the keeping qualities of another fruit under the same conditions. For example, berries may be kept for only a few days where citrus fruits might be kept for months without spoiling. There is also a variation for different types of the same fruit. The stage of ripening also has great importance. Apples, according to authorities on cold storage, should be picked from eight to ten days before ripening, and grapes, about five days. If picked before this time they will not be ripe when sold, and if picked later, they will not keep well in storage. The longer fruit is kept from the time of picking to the time of storage, the greater will be the opportunity for the growth of microorganisms to begin, and the more difficult preservation will be in storage. The skin should preferably be without cuts or bruises which will serve as a point of entrance for microorganisms in the air or on other fruits. It is important that the conditions under which the fruits are kept before storage should be such as to prevent the entrance and growth of any microorganisms.

The external humidity should be sufficiently high to prevent evaporation of the water in the fruit, but it should not be high enough to greatly encourage organic growth. One of the purposes of ventilation is to prevent moisture from gathering on the surface of the fruits.

The requirements of packing, which have already been mentioned, are that the pressure on the fruits shall not be excessive.
and that direct contact which will permit the spreading of infection shall be avoided as much as possible. In addition to these of course, the method of packing must permit the requirements of ventilation and temperature to be followed.
MICROBIOLOGICAL BASIS OF THE PROBLEM

All the conditions which have been thus far considered are important only in their relation to the organisms and enzymes which cause spoilage in fruits. The composition of the fruits is of fundamental importance. Apples, in their fresh state, contain 82.5% water, .4% proteid, .5% ether extract, 12.5% sugar, .4% ash, 2.7% cellulose, and 1.0% acids. The acids are chiefly malic and tartaric. The composition of the grapes is very similar to this, and need not be separately considered. All fresh fruits constantly undergo respiration. That is, they take in oxygen which combines with the sugars, and they give off carbon dioxide.

The organisms which are responsible for the spoilage of fruits are primarily, molds, and to a comparatively slight extent, yeasts and bacteria. Penicillia and Aspigili are perhaps the most important of the molds concerned in the spoilage of fruits, although numerous others may cause spoilage. The natural skin of grapes and apples is resistant against all these organisms, so that if the skin remains unbroken, they can usually cause no damage. The spores of all of them may be present on the surface of the skin, however, so that once a break occurs, they may easily enter. If considerable moisture collects on the surface of a fruit, the spores may vegetate and force their way even through an unbroken skin. The cell walls of the fruit offer no obstacle to the growth of molds, although few yeasts and bacteria can penetrate them. If nothing has occurred to break down the cell walls, the growth of yeasts and bacteria, if any are present, would be confined to the cells near a break in the skin.
Decomposition may also be caused by the action of the enzymes which are always present in greater or less quantity in all living cells. If conditions are such as to induce activity of the enzymes, autolytic decomposition will sometimes take place.

The action of cold is to retard the development of microorganisms, and to cause the enzymes to act very slowly, the normal activity of living cells being greatly reduced. Yeasts and bacteria require plenty of moisture for their growth. Molds, however, require much less moisture, and will often grow where moisture is fairly low. Strong acidity and alkilinity are unfavorable to the growth of bacteria, the growth of which is also retarded by a high sugar content. Yeasts and molds are favored by some acidity, although their growth also will be retarded if the sugar content is very high. Most molds will grow only in the presence of oxygen. Yeasts and molds are easily killed by heat, although their spores, like those of bacteria will resist fairly high temperatures.
PLAN OF RESEARCH

Both grapes and apples were subjected to numerous different conditions to find their effects upon the keeping qualities. The various tests which are outlined below, were all run with the purpose of seeing whether the spoilage of the fruits through the action of the microorganisms and enzymes could be stopped or retarded. The different series of tests dealt primarily with temperatures, atmospheres, packing, humidity and coating.

CONDITIONS OF TEMPERATURE.

Nearly all the tests were run at both refrigeration temperatures of 12°C, and incubator temperatures of 37°C. Although it is known that fruits will keep at refrigeration temperatures of 0-2°C, it was the purpose of this test to determine whether the fruits would keep so as to remain in salable condition for the test period of 30 days at the higher temperature of 12°C, which could be more easily obtained in practice. Because of the extreme variations in conditions which would be met with in practice, it was deemed advisable to run the high temperature test at 37°C, since any means other than refrigeration, devised to keep the fruits, could be considered of practical use only if it could pass successfully through this extreme test.

KINDS OF ATMOSPHERES.

To determine the effects of ventilation, tests were run in an atmosphere of air in sealed glass jars, and also in jars through which a current of air was continuously passing. To find what the effect of oxygen is upon the fruits, tests were also run
in atmospheres of carbon dioxide, sealed, and in mixed carbon dioxide and air, sealed.

**PACKING.**

The fruits were packed separately in compartments of wooden boxes in cotton, paper, sawdust and hay. The purpose of this was to learn whether the kind of packing has any effect upon the keeping qualities of the fruits or upon their taste.

**HUMIDITY.**

To test the effect of humidity upon the keeping quality of the fruits, sawdust with five different moisture contents was used for packing. For each one, 350 grams of sawdust, with an original moisture content of 8% was mixed with 0, 100, 200, 400 and 750 grams of water, respectively. Sawdust was used for this test in preference to other packings since water is most easily mixed with it. To further determine the effect of moisture, in the ventilation test, two different series of jars were used, one with a current of air of the same humidity as the atmosphere of the room, and the other with a current of air which had been bubbled through water.

**COATING.**

Since a good protective coating would prevent evaporation, exclude oxygen, and also prevent the entrance of microorganisms, apples were coated with shellac, paraffine, collodion, beeswax and gum arabic, to determine the value of each of these in preventing spoilage. These tests, which were performed subsequent to the rest were run at incubation temperature and at room temperature.
Because of the results obtained in the previous tests, it was considered unnecessary to run them at refrigeration temperature also. It was deemed inadvisable to try the effect of coating on grapes, since it would render them inedible.
PROCEDURE

The tests were started in winter, when it was necessary to use cold storage fruit. All the fruit used was very carefully sorted, only that which appeared to be in perfect condition being retained for the tests. The tests in different atmospheres were made in quart glass jars with metal tops. Two pieces of copper tubing were soldered into the cap of each jar. The jars were made perfectly air-tight with sealing wax after the fruits had been placed in them. In the tests with carbon dioxide, the gas was passed through the jars for several minutes to assure positive exclusion of air, before the jars were sealed. A Richards pump was used to secure circulation of air for the ventilation tests. The air was moistened by bubbling it through water before it entered the jars.

The boxes for the packing tests were each divided into four compartments, one for each different kind of packing. During the test the boxes were completely enclosed.

Coatings were applied by dipping.

Two tests were run for each different condition. In the case of the apples, two fruits were used for each test in the glass jars, and four for each test in the boxes.

All the cultures which were made were on potato medium at room temperature with 24 hours allowed for growth. Tests for enzymes were made with gum guiac solution and hydrogen peroxide.

All tests, unless otherwise states, were run for the regular test period of about thirty days.
<table>
<thead>
<tr>
<th>TEMPERATURE</th>
<th>12°C</th>
<th>27°C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>APPLES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test started - Feb.4</td>
<td>Completed - Mar.8</td>
<td>TESTS WITH DIFFERENT ATMOSPHERES</td>
</tr>
<tr>
<td><strong>TEMPERATURE</strong></td>
<td><strong>ATMOSPHERE</strong></td>
<td><strong>APPEARANCE &amp; TASTE</strong></td>
</tr>
<tr>
<td></td>
<td>AIR (CIRCULATING)</td>
<td>(Test omitted)</td>
</tr>
<tr>
<td></td>
<td>CARBON DIOXIDE</td>
<td>&quot;</td>
</tr>
</tbody>
</table>
### Apples

**Test started:** Feb. 6  
**Completed:** Nov. 3

#### Tests with different packings

<table>
<thead>
<tr>
<th>Temperature</th>
<th>PACKING</th>
<th>Appearance &amp; Taste</th>
<th>Microbiological Analysis</th>
<th>Appearanc &amp; Taste</th>
<th>Microbiological Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PAPER</td>
<td>Perfect</td>
<td>Perfect</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>COTTON</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>HAY</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>SAWDUST</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
<td>&quot;</td>
</tr>
</tbody>
</table>

- **12°C**
  - PAPER: Perfect
  - COTTON: "
  - HAY: "
  - SAWDUST: "

- **37°C**
  - COTTON: "
  - HAY: "
### TESTS WITH DIFFERENT ATMOSPHERES

- **Test started**: Feb. 6
- **Completed**: Mar. 7

<table>
<thead>
<tr>
<th>TEMPERATURE</th>
<th>ATMO SPHERE</th>
<th>12°C</th>
<th>37°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>APPEARANCE &amp; TASTE</td>
<td>MICROBIOLOGICAL ANALYSIS</td>
<td>APPEARANCE &amp; TASTE</td>
</tr>
<tr>
<td>AIR (SEALED)</td>
<td>Perfect</td>
<td>No microorganisms or enzymes present.</td>
<td>Covered with mold growth. Taste moldy with absence of sugar</td>
</tr>
<tr>
<td>AIR (CIRCULATING)</td>
<td>(Test omitted)</td>
<td>--------</td>
<td>Appearance perfect Taste indicates absence of sugar.</td>
</tr>
<tr>
<td>CARBON DIOXIDE</td>
<td>Appearance perfect Taste moldy; very bitter.</td>
<td>Culture showed slight mold growth not seen with microscope.</td>
<td>&quot;</td>
</tr>
</tbody>
</table>
**GRAPE TESTS WITH DIFFERENT PACKINGS**

<table>
<thead>
<tr>
<th>TEMPERATURE</th>
<th>12°C</th>
<th>37°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>PACKING</td>
<td>APPEARANCE &amp; TASTE</td>
<td>MICROBIOLOGICAL ANALYSIS</td>
</tr>
<tr>
<td>PAPER</td>
<td>Perfect</td>
<td>Perfect</td>
</tr>
<tr>
<td>COTTON</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>HAY</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>SAWDUST</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
</tbody>
</table>
# APPLES

## TESTS WITH DIFFERENT COATINGS

Test started - Apr. 4.  
Completed - Apr. 30

<table>
<thead>
<tr>
<th>TEMPERATURE</th>
<th>20°C</th>
<th>37°C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COATING</strong></td>
<td><strong>ANALYSIS</strong></td>
<td><strong>ANALYSIS</strong></td>
</tr>
</tbody>
</table>
| **NONE** | Taste somewhat flat.  
Appearance good.  
Slight enzyme reaction. | Taste flat.  
Appearance evaporated.  
Enzymes in large quantity |
| **SHELLAC** | Taste somewhat flat.  
Appearance excellent.  
Slight enzyme reaction. | No evaporation.  
Breakdown of cells.  
Advanced decomposition.  
Enzymes in large quantity |
| **PARAFFINE** | Flat taste.  
Surface in good condition.  
Enzymes in large quantity. | Advanced evaporation and autolytic decomposition. |
| **BEESWAX** | Advanced autolytic decomposition.  
No evaporation. | Almost complete destruction by enzyme action. |
| **GUM ARABIC** | Coating in form of powder.  
Indication of evaporation.  
Flat taste.  
Slight enzyme reaction. | Advanced evaporation and decomposition.  
Some enzymes. |
| **COLLODION** | Flat taste.  
Advanced evaporation.  
Slight enzyme activity. | Almost complete evaporation.  
Some enzymes. |
DISCUSSION OF RESULTS

REFRIGERATION TESTS.

All tests with refrigeration, both with apples and grapes, were eloquent testimony of the effectiveness of refrigeration in keeping fresh fruits in good condition while in storage. The temperatures used were 10 to 12 C. higher than those used in commercial practice. Yet, in all the many dozen apples, and the kilograms of grapes, there was not a single case of spoilage. These results might not have been obtained had the fruits been in other than perfect condition when the tests were started, but the important thing is, that by careful selection, fruits can be kept for long periods even at refrigeration temperatures as high as 12 C. Further to determine the efficacy of storage at this temperature, some of the tests were continued after the regular 30 day period, and the fruits were found to be still in perfect condition as to appearance and taste at the end of two months.

The tests showed that the use of carbon dioxide is not only unnecessary but undesirable. Although in no refrigeration test were any microorganisms in the fruits revealed by the microscope, yet cultures indicated very slight mold growth. This growth was sufficient to affect the taste of the fruit, when accentuated by carbon dioxide.
INCUBATOR TEMPERATURE TESTS.

Yeasts, molds and bacteria were all partially responsible for the spoilage which occurred in many of the tests under the higher temperature. None of these organisms, however, caused the greatest trouble. The enzymes contained in the cells of the fruit were responsible for most of the spoilage which occurred. This was especially so in the case of the apples. Tests of every apple which had been kept at incubator temperature showed great enzyme activity. The temperature of 37 C. was evidently very favorable to them, and all the fruits suffered from autolytic decomposition as well as a breaking up of the sugars. The result was more or less softening, and the flat taste caused by the lack of sugar.

In the case of the apples sealed in air, the cell walls were broken down, and there was a considerable growth of molds throughout. In the other tests with apples, however, decomposition seemed to be almost entirely due to the action of the enzymes, no microorganisms being revealed by microscopic examination. It was evident that in these cases, either the unbroken outer skin or the absence of oxygen was sufficient to prevent the growth of the organisms.

All the apples kept in boxes at the higher temperature showed evidence of evaporation. This was least in the case of the sawdust packing, which in the case of the grapes also, seemed to be the best medium. There was no organic growth whatever, but the action of the enzymes was sufficient to make the fruits inedible. The value of the sawdust in preventing evaporation may have been
due to a high original moisture content. This would not detract from its greater desirability, however, since the moisture content of sawdust may be most easily regulated. Paper, cotton and hay all served equally well as packing media, but not as well as sawdust. It is probable that sawdust would also protect the fruit best from crushing due to the motion of the ship.

The grapes which were kept in jars suffered from the growth of molds as well as from the action of enzymes. The growth of molds was least in the case of the grapes kept in an atmosphere of circulating air. It was greatest in the grapes sealed in air, and fairly great in both the grapes kept in carbon dioxide, and in those kept in a mixture of carbon dioxide and air. The growth of molds on the grapes kept in circulating air was small probably because conditions other than the presence of oxygen were unsuited to their growth. No moisture collected inside the jars, as it did in the other cases, and as the skins were in perfect condition, there was probably little opportunity for mold growth. Where carbon dioxide was used, on the other hand, a centimeter or more of moisture collected at the bottom of each grape jar, and all conditions, except for the lack of oxygen favored the growth of molds.

Analysis of the moisture contained in the jars in which carbon dioxide was used showed a ten per cent solution of fermentable sugars. There was a vacuum of from 5 to 10 centimeters of water in each of these jars and the great evaporation probably resulted from this vacuum. The jars were filled at room temper-
ature, and the tests run at incubator temperature, so that the pressure might have been expected to be higher instead of lower than atmospheric pressure. The vacuum may have been caused, however, by absorption of the carbon dioxide by the liquid.

The grapes which were kept in the boxes underwent almost complete evaporation. This had the effect of inhibiting the growth of microorganisms. However, as grapes and not raisins were desired, the test was a failure. The evaporation was evidently the result of low moisture content in either the packing media or in the air.

From the test with sawdust media with different moisture contents, it was found that the grapes could be kept without evaporation by having a fairly high moisture content in the medium. Thirty-five per cent moisture was in this case found to be best. This test was run for only ten days, since a longer time was unnecessary to discover evaporation. The moisture did not prevent the action of enzymes. No change in taste due to the moistened sawdust was noticeable. The sawdust of some woods, when moistened, would undoubtedly impart their taste to the fruits, however, and care would have to be exercised in selecting sawdust to be used as a packing medium.

COATING TESTS.

Shellac was the only one of the coating media which preserved the fruits better than they were kept without coating. But even in this case the gain through the use of shellac was so slight that its use would not be worth while in practice. The advantage of the use of this medium was noticeable only in the tests at room
temperature. In all the other tests at room temperature, and in every test with coating at incubator temperature, the fruits were found to be in worse condition with coating than without. In no case did the coating seem to be effective in preventing or retarding autolytic decomposition of the cells. Therefore, spoilage from this source went on just as though there were no coating on the apples. The effect of some of the coating media seemed to be to allow moisture to pass outward from the apples without allowing any to pass in, so that evaporation went on at a rate much greater than under normal conditions. Although the apples were coated by dipping, so that the coating substances were applied to every part of the fruits, it is by no means certain that there were no air holes or cracks. However, in view of the superior condition of the apples which were not coated, it is unlikely that this could have been the cause of spoilage. The shellac coating was probably able to prevent evaporation, and gave good results for this reason.

Considering the tests at incubator temperature as a whole, it is evident that where excessive evaporation did not prevent the activity of the enzymes, they were able to cause spoilage. The problem of evaporation is important, since a dried fruit, however free it may be from spoilage, is valueless in the fresh fruit market. In the tests, in every case where the moisture was low in the medium or in the surrounding atmosphere, some evaporation resulted. There was no trouble whatever from bacteria, and yeasts were unimportant. Molds caused complete spoilage in the case of the tests in sealed air. This was due to the combined effect of the presence of oxygen, excessive moisture, and high
temperature. The best results were with circulating air. The absence of excessive moisture in this case evidently prevented growth of the mold spores on the skins of the fruits, so that penetration to the insides of the fruits was impossible. In the apple tests at incubator temperature, the carbon dioxide atmosphere was able to prevent the growth of molds, and the fruit was in better condition than the apples in sealed air, but not as good as those in circulating air. In the grape tests, however, the carbon dioxide did not prevent the growth of molds, and although the grapes were in slightly better condition than those kept in sealed air, they were in far worse condition than those kept in circulating air. There was practically no difference in results in the tests in carbon dioxide, and in a mixture of carbon dioxide and air.

Two tests were run for each different condition and temperature, both with jars and with boxes. There was an absolute uniformity of results throughout, both samples for each test showing the same final condition, and giving the same microscopic analysis.
VENTILATION TESTS.

The grapes are shown after one month at incubator temperature. An atmosphere of circulating air was used. The grapes at the left were in moistened air, and those at the right in unmoistened air.
INCUBATOR TESTS.

1. Air sealed
2. Air plus carbon dioxide, sealed
3. Carbon dioxide sealed

The exceedingly poor condition of the grapes in sealed air is to be noted. Decomposition was fairly advanced in all the tests.
HUMIDITY TESTS.

Grapes are shown after ten days at incubator temperature. At the left are the grapes which were packed in sawdust containing 33% moisture, and at the right those packed in sawdust containing 10% moisture. The evaporation in the latter may be easily seen.
PACKING TESTS.

The grapes were kept at incubator temperature for one month. It is to be noted that the evaporation is less in the sawdust medium, the second from the left, than in the other media.
SEALED AIR TESTS.

1. Grapes which were kept at incubator temperature for one month. Note moldiness and change in color.
2. Grapes which were kept at refrigeration temperature for one month. The grapes appear exactly as at the beginning of the test.
REFRIGERATION TESTS.

1. Air sealed
2. Carbon dioxide mixed with air, sealed
3. Carbon dioxide

All appear to be in perfect condition, as they were at the beginning of the tests.
A PART OF THE TESTS IN SEALED JARS.
CONCLUSIONS

It will be impossible to transport fruit from Chile to the United States except in refrigeration chambers. None of the methods used in this study to prevent spoilage of the fruits at incubator temperature was sufficiently effective to make transportation in the hold advisable. Conditions as they would exist, with high temperature, excessive moisture, and lack of ventilation, would probably make any attempt to ship fruits in the hold a complete failure. Although the difficulty of moisture and lack of ventilation might, in the case of the apples, be overcome through the use of carbon dioxide and sealed containers, the gas cannot prevent partial spoilage, and causes the fruit to have a bad taste.

It is of great commercial importance, however, that if the fruits are intended for immediate sale, and not for storage in this country, they can be shipped at as high a refrigeration temperature as 12 °C. This will make it possible to ship small lots of fruit in the same refrigeration chambers with other goods, and it will also result in a considerable saving in transportation charges even in the case of large shipments.

If refrigeration is used, the fruits may be shipped in almost any way. Although sawdust is the best medium for packing, almost any other medium will give good results if the humidity of the refrigeration chamber is carefully regulated. The tests at incubator temperature indicate that ventilation is desirable, but it is evidently not a necessity if the fruits are intended to be sold within a short time after they are unloaded.
The use of carbon dioxide is apparently undesirable for the preservation of fruits. The taste due to a slight moldiness, which ordinarily would not be noticeable, is so accentuated by the carbon dioxide, that the fruit is given a distinctly bad flavor. If it were not for this, the use of carbon dioxide would be very advantageous, since it does retard the growth of molds.

If refrigeration is used, as previously mentioned, ventilation is desirable but not necessary, and any packing medium may be used if the humidity of the refrigeration chamber is correct. Without refrigeration, an atmosphere of circulating air, and sawdust packing is most desirable. Sealed air cannot be used without causing complete spoilage, and carbon dioxide is undesirable for the reason given above.

Although a shellac coating aids somewhat in the preservation of apples, no coating medium was found which had sufficient worth to make its use advisable. Except for shellac, the effect of coating seems to be to hasten spoilage rather than retard it.
BIBLIOGRAPHY

Bacteriology, by Conn and Conn. Williams and Wilkins. 1923
Agricultural Bacteriology, by Conn. Blakiston. 1918
Microbiology of Foods, by Schneider. Blakiston. 1920
Household Bacteriology, by Buchanan. MacMillan. 1913
Bacteriology and Micology of Foods, by Tanner. Wiley and Son. 1919
Microbiology, by Marshall. Blakiston. 1921
Botany, Principles and Problems, by Sinnott. McGraw-Hill. 1923