DRYING AND RIPENING OF SOYBEANS FOR BENEFICIATION OF SOYBEAN PRODUCTS

BY

CHARLES H. WORSHAM

A Thesis Submitted to the Graduate Committee

For the Degree of

MASTER OF SCIENCE

in

Chemical Engineering

Approved:

_____

Head of Department

_____

Dean of Engineering

_____

Chairman, Graduate Committee

Virginia Polytechnic Institute
Blacksburg, Virginia
1938

ACKNOWLEDGMENT

The author wishes to express his appreciation to Dr. F. C. Vilbrandt for his valuable suggestions and cooperation in this investigation.

Charles H. Worsham

TABLE OF CONTENTS

I. INTRODUCTION

In 1933 (9) the total quantity of soybeans gathered in the United States was 11,177,000 bushels while the total in 1935 (6) was 36,000,000 bushels.

The soybean (10) has assumed great importance in recent years which lies largely in the fact that the seeds can be produced more cheaply than those of any other leguminous crop. This is due to its high yielding capacity and to the ease of harvesting. These facts alone insure the increasing importance of the crop in the future.

It is likely that increased culture of the crop in the United States will be largely for oil and cake. Since about 1908 large quantities of soybean oil have been used by the United States in the manufacture of soap and paints. However, considerable quantities are used in the manufacture of lard and butter substitutes, and in salad oils. Before the oil can be used in food products it must be refined and deodorized.

After the soybean oil has been converted into its products, there is the problem of rancidity which presents itself. The object of this investigation is to first ripen the immature beans and then dry then by the use of ethylene gas thus eliminating the green taste and the peroxidases action which is thought to be the cause of the rancidity in the oil.

II. THE REVIEW OF LITERATURE

The literature on soybeans seems to be divided among two types of writers. The first type of writer looks at the value and use of the soybean and its products optimistically and, from their articles, do not give the smallest hint as to the problems or difficulties that arise in soybean processing. The second type consists of those who are actually employed in the soybean industry and are familiar with the difficulties that arise from day to day.

Although the literature is very extensive in its discussion on ways of improvement of soybean oil and other soybean products after the beans have been processed, there is very little discussion to be found on treatment of the beans before they have been processed, in an attempt to prevent the formation of bad taste and odor in the products.

The object of this investigation is to ripen and dry soybeans in such a way as to prevent the formation of bad taste and odor in the oil. Only the literature on this phase of soybean processing will be reviewed.

SO_2 Treatment.-- The British patent number 364,309 was granted to Gabriel P. Toussund (11) on December 16, 1930, on his process to enhance the dietetic and keeping qualities of seeds, particularily in soybeans. In this

treatment the beans are first soaked in water and then subjected to SO_2 at 110-140°F., preferably until the moisture content is below normal.

Inflammability of Ethylene.-- H. F. Coward and G. W. Jones (5) in their article give the limits of inflammability of ethylene in mixtures of carbon dioxide and air.

In air the limits are from 3.05 to 28.6% by volume of C_2H_4
In O_2 the limits are from 3.10 to 79.9% by volume of C_2H_4
With 5% CO_2 the upper limit of C_2H_4 is 23% by volume
With 10% CO_2 the upper limit of C_2H_4 is 18% by volume
With 20% CO_2 the upper limit of C_2H_4 is 11% by volume
With 30% CO_2 the upper limit of C_2H_4 is 7% by volume.

Steaming and Drying of Soybeans.-- On June 1, 1933, Ladislaus Berczeller (3) was granted the British patent number 393,146 on his method of treating soybeans. This process consisted of repeated alternate action of subjecting the beans to steam and drying until the substances of the nature of ethereal oils that cause bad taste, smell, and rancidity are removed. Ammonia, alkalies, sugar or other substances with an anti-coagulating effect were also admixed with the steam or dissolved in the liquid used to bring about the initial swelling of the bean.

Vacuum and Ammonia Treatment.-- The Japanese patent number 101,895 was granted to Tugio Asari (2) on July 7,

1933, on a process for preserving soybeans. In this process the soybeans are kept subjected to a vacuum to remove water and other volatile matter. NH_3 or NH_4OH is introduced into the vessel, and by absorption of NH_3 the beans are preserved in good state.

Oil Immersion Treatment.-- On January 16, 1935, Ernst Lieberherr (8) was granted the Swiss patent number 172,720 on a method of treatment for improving soybeans. In this method of treatment the soybeans are improved for consumption by heating without oxidation so as to break down the glucoside substances contained. The heating is carried out by immersion of the beans in hot oil or fat.

Oxygen Free Combustion Gas Treatment.-- The United States patents, numbers 1,988,677-8, on an apparatus for drying soybeans, were granted to Gerald D. Arnold (1) on January 22, 1935. In this apparatus a current of combustion gases nearly free from oxygen is used as the drying agent to preserve the natural properties of the beans.

Conditioning Soybeans for the Hydraulic Press.-- W. L. Burlison (4) in his article on "Soybeans", July 1936, gives a method for conditioning soybeans before the extraction of oil by the hydraulic press method. The beans are crushed, dried to a moisture content of about 3%, and passed through a steam-jacketed trough which heats the beans to about 150°F. before they are pressed.

III. EXPERIMENTAL

A. OBJECT

The object of this investigation is to ripen and dry soybeans in such a way as to prevent the formation of bad taste and odor in the oil.

B. PLAN OF INVESTIGATION

In the past, the main object in the drying of the soybeans for storage has been to get the moisture out of them in the easiest, quickest, and cheapest way possible. The method used was that of passing hot air through a rotary dryer to sweep out the moisture. This method usually afforded an excellent condition for peroxidases action which resulted with the formation of impalatable products.

This investigation was a continuation of that carried out by C. C. Waddell (12). It dealt with the manner in which soybeans are dried by using air, ethylene, and mixtures of ethylene and carbon dioxide as the drying agents. The purpose of the ethylene was to first ripen the immature beans and then dry them, thus eliminating the green taste and the peroxidases action. Different mixtures of ethylene and carbon dioxide were used in order to determine how much of the ethylene was necessary to ripen

the beans and to prevent the enzymic action. The carbon dioxide was used with the ethylene to reduce the hazards of ethylene handling. The soybeans were also dried in air for the purpose of comparison.

C. MATERIALS

Soybeans.-- The soybeans used in this investigation were obtained from a branch of the Virginia Agricultural Experiment Station through Mr. Coxe near Williamsburg, Virginia. These soybeans were obtained directly from the threshing machine, before they had been sized. On December 6, 1937, one week after they were threshed, they were stored in garbage cans to prevent the loss of moisture.

Ethylene and Carbon Dioxide.-- The ethylene and carbon dioxide were obtained in standard pressure cylinders from Carbide and Carbon Chemicals Corp., South Charleston, W. Va., and from Fowler Carbonic Co., Rosslyn, Va., respectively. A picture of these cylinders is shown in plate 2.

D. APPARATUS

Drying Apparatus.-- The drying apparatus available consisted of nine separate drying silos, each being provided with a fan for circulating the gases and heating coils for varying the temperature. Each silo and fan was

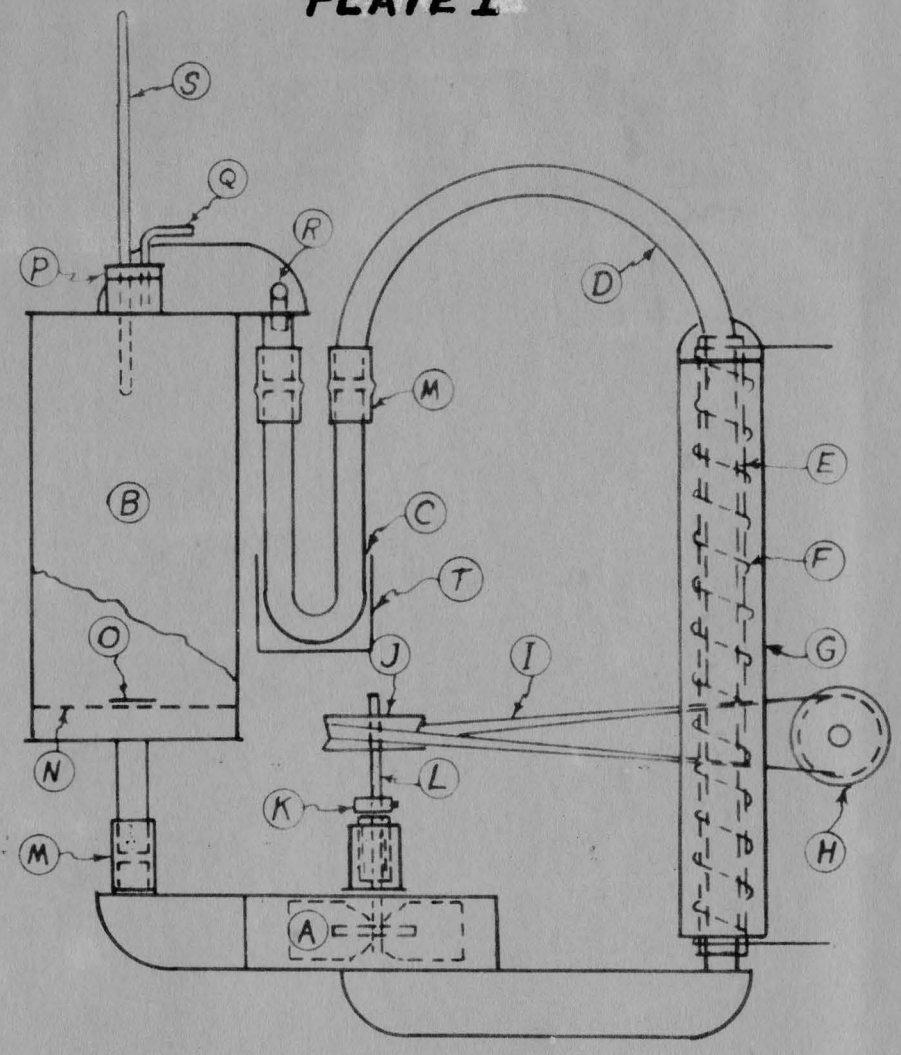
air-tight, oil seals being used for the fan drive shafts. The entire apparatus was inclosed with beaver board to prevent air currents from effecting the temperature. Grease cups were provided for lubricating the main shaft. In order to provide a constant relative temperature drop for the drying of the soybeans, a cooling trough for circulating water around the drying tubes was installed. The drying tubes were provided with longer rubber tube connections and clamps so that the water collected could be emptied without the loss of gases. A sketch of one unit and photographs of the equipment are shown in plates 1, 2, 3, and 4 respectively.

Soybean Oil Press.-- A Carver laboratory hydraulic press No. 4905-20 was used for pressing the oil from the soybeans after they had been treated with the gases and flaked. The press was manufactured by Fred S. Carver, N.Y.

Laboratory Roll Mill.-- A Sturtevant laboratory roll mill, Serial No. 634, was used for flaking the soybeans before they were heated and pressed. This roll mill was manufactured by Sturtevant Mill Co., Boston, Mass.

Hot Plate.-- Before the flaked soybeans were pressed they were placed in a bucket on a hot plate and heated to a temperature of from 45 to 60°C., the temperature being controlled by means of a water-jacket.

PLATE I



Side Elevation

LEGEND

A	Cycloidal Fan With Oil Seal	K	Stop Collar With Set Screw
B	Bean Container	L	Fan Shaft Bearing Space
C	Drying Tube	M	3/4" Heavy Wall Rubber Tubing
D	3/4" Copper Heating Tube	N	Copper Screen Bean Support
E	Sheet Asbestos Insulation	O	Metal Disc
F	22 Gague Chromel A Resistance Wire	P	No 10 Two Hole Rubber Stopper
G	3/4" Asbestos Pipe Insulation	Q	1/8" Copper Tubing Gas Outlet
H	Drive Pulley On Main Drive Shaft	R	1/8" Copper Tubing Gas Inlet
I	Leather Belt	S	Thermometer
J	Fan Drive Pulley With Set Screw	T	Cooling Trough

CHEMICAL ENGINEERING DEPARTMENT
VIRGINIA POLYTECHNIC INSTITUTE
BLACKSBURG, VIRGINIA, March 12, 1938
SIDE ELEVATION OF SOYBEAN DRYING APPARATUS
SCALE 2" = 1'-0"
DRAWN BY: C.C. WADDELL 5/15/37
REDRAWN BY: C.H. WORSHAM

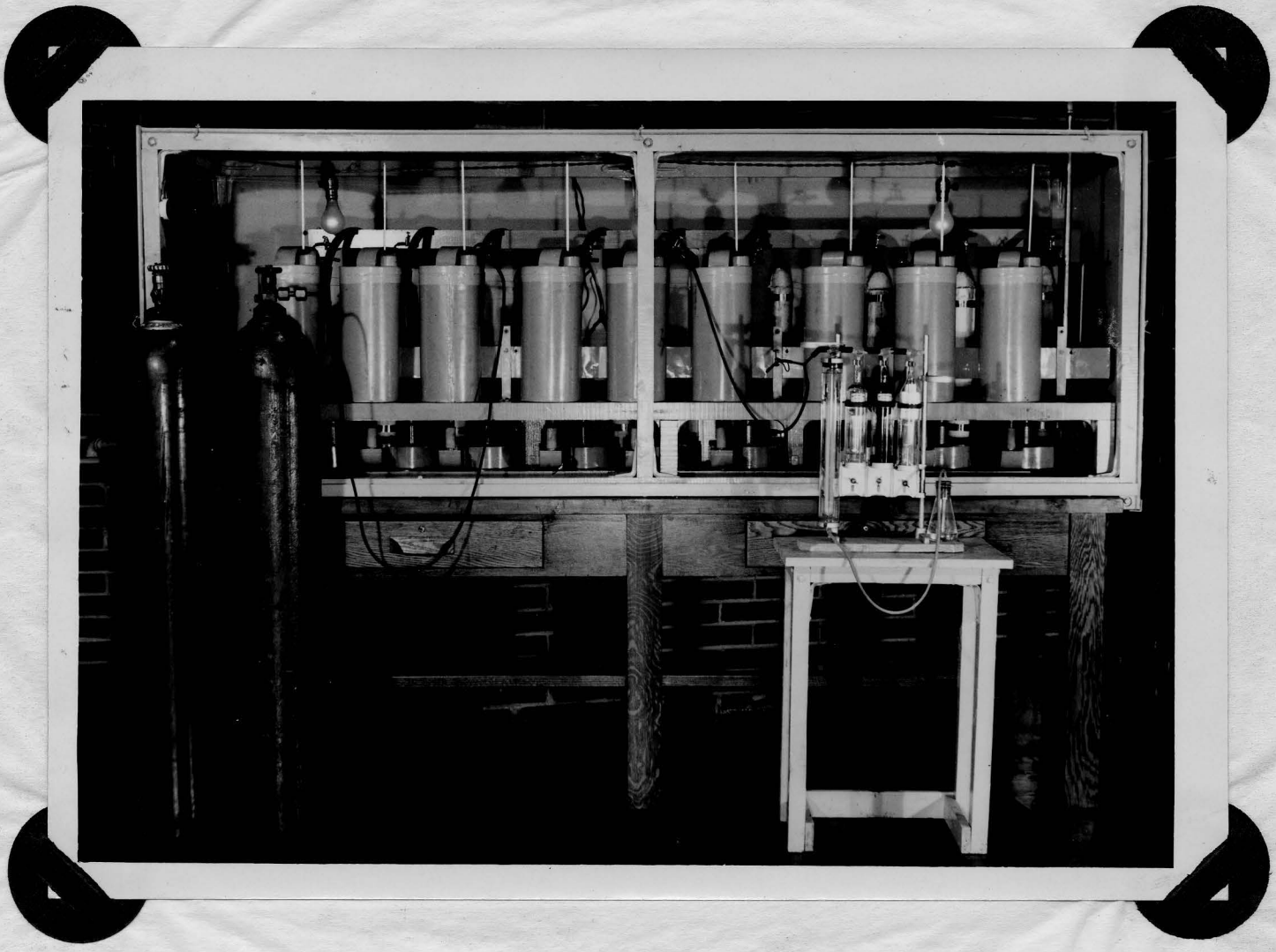


PLATE II

Front View of Soybean Drying Apparatus.

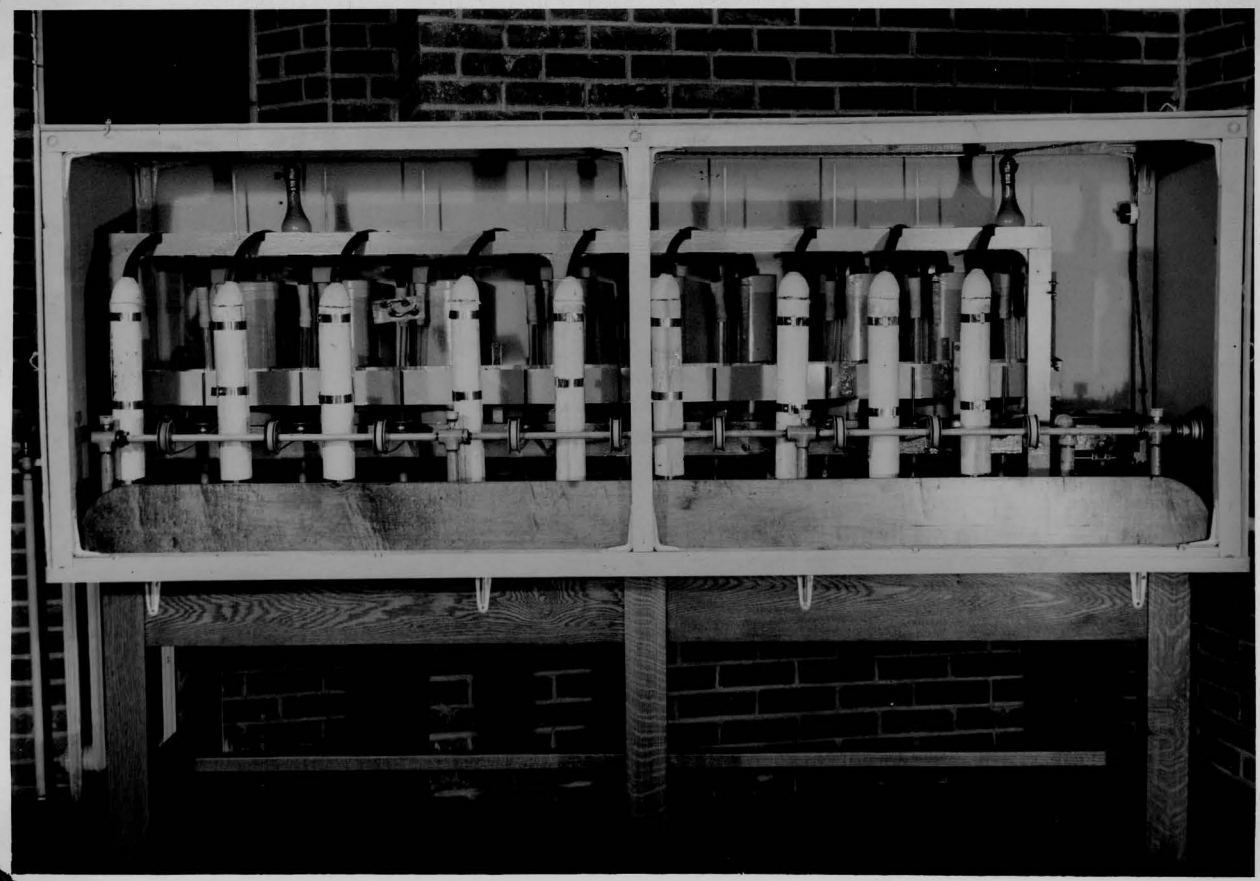


PLATE III

Back View of Soybean Drying Apparatus.

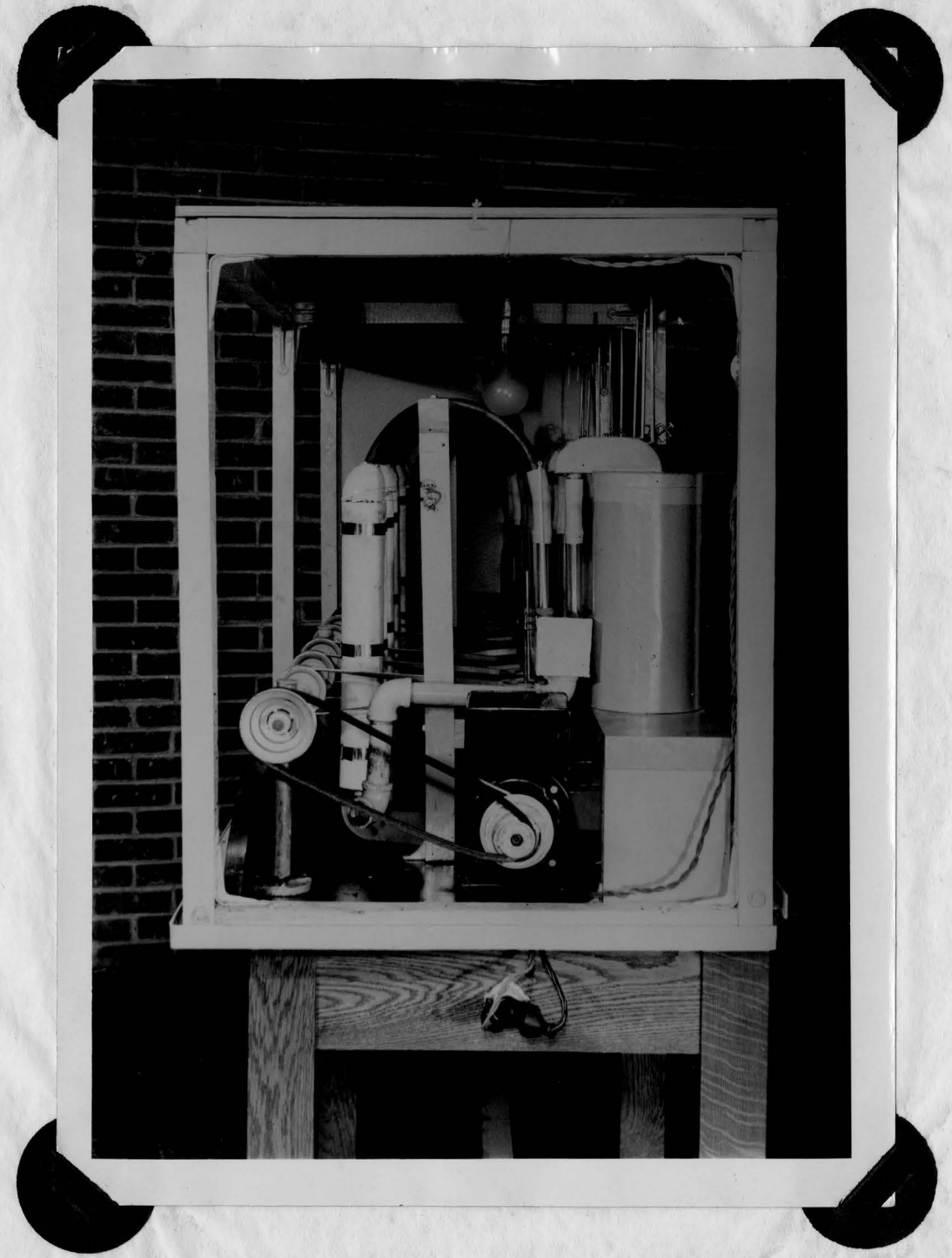


PLATE IV

Side View of Soybean Drying Apparatus.

E. METHOD OF PROCEDURE

Gas Composition.-- The gas or gases that were circulated through each of the silos were as follows:

1. Air
2. 90% ethylene and 10% carbon dioxide and air
3. 80% ethylene and 20% carbon dioxide and air
4. 70% ethylene and 30% carbon dioxide and air
5. 65% ethylene and 35% carbon dioxide and air
6. 55% ethylene and 45% carbon dioxide and air
7. 50% ethylene and 50% carbon dioxide and air
8. 45% ethylene and 55% carbon dioxide and air
9. 35% ethylene and 65% carbon dioxide and air

The ratios of CO_2 to air were 50/50 and 75/25 as shown by the various runs.

Various Runs.-- Four runs were made at room temperature in the following order using whole beans:

1. For 24 hr. with 50/50 ratio of CO_2 to air
2. For 48 hr. with 50/50 ratio of CO_2 to air
3. For 24 hr. with 75/25 ratio of CO_2 to air
4. For 48 hr. with 75/25 ratio of CO_2 to air

The temperature was then raised to about 37°C. and the same series of four runs repeated. The runs were also repeated at a temperature of 50°C. A run at 50°C. was also made showing the relative drying between carbon dioxide and ethylene.

Flushing With Carbon Dioxide.-- In starting a run, 4.5 lb. of the beans were placed in the drying silo and the stoppers containing the thermometers pressed tightly into the openings. The system was checked for leaks. As soon as the fans were started, eight of the containers were flushed with carbon dioxide as quickly as possible. This was done by connecting the gas cylinder to the silo by means of rubber tubing and letting the desired amount flow in, driving the air out the gas outlet.

Addition of Ethylene.-- After the silos had been flushed with carbon dioxide, ethylene was flushed into eight of them in the same manner as was the carbon dioxide. The carbon dioxide was flushed through the silo before the ethylene was added in order to prevent the possibility of an explosion, since an ethylene-in-air mixture of from 2.75 to 28.60 per cent by volume of ethylene (7) is explosive. The limits of inflammability of ethylene in carbon dioxide are given on page 5, in the section, "Review of Literature". By the use of carbon dioxide the explosion and combustion limits of ethylene are reduced. The equipment was grounded to prevent the building up of static charges which may have caused an explosion.

After the gases had been added they were analyzed and adjusted to the desired value as soon as possible and the run started.

Method of Analyzing the Gases.-- The gases placed in the silos were analyzed at the beginning and at the end of each run in order to determine the correct gas mixture and the amount absorbed by the soybeans. An Orsat apparatus containing two pipets were used for analyzing the gas. One of the pipets contained a 33% solution of KOH, and the second one contained a saturated solution of bromine water with liquid bromine in the bottom to keep it saturated. The gas inlet to the Orsat apparatus was connected to the arm of a three-way tube connection, and the second arm was connected to the gas outlet of the drying silo by means of rubber tubing. A rubber tube with a pinch cock was connected to the third arm leading to the atmosphere. A sample of the gas was drawn into the measuring buret of the Orsat apparatus, the pressure equalized by opening and closing the pinch cock of the tube leading to the atmosphere, and then the sample was forced back into the silo. The next sample drawn into the Orsat apparatus was taken for analysis. In order to obtain a representative sample the fan was allowed to run while the samples were being taken. In order that the percentages might read directly, 100 c.c. samples of the gases were always taken.

Drying of the Beans.-- The amount of drying done by the various gases was determined by measuring the c.c. of water collected in the drying tubes.

Pretreatment for Oil Pressing.-- A Carver laboratory hydraulic press was used for pressing the oil from the soybeans after they had been treated with the gases. The soybeans were first flaked in crushing rolls then placed in a bucket on a hot plate and heated to a temperature of from 45 to 60°C., the temperature being controlled by means of a water-jacket. The cylinder on the press was washed and dried between each sample to prevent contamination of one sample by another.

Oil Samples.-- From each sample of oil were taken two samples and placed in 8 c.c. specimen vials fitted with aluminum caps. The cap on one sample was screwed tightly in place to keep the air out while the other was left open to the air. The rancidifying tendency of the soybean oil was determined by allowing various persons to smell and taste these samples

The samples of oil left by C. C. Waddell were tested in the same manner in order to determine the tendency to rancidify over a longer period of time.

F. DATA AND RESULTS

Absorbability of CO_2 and CH_2CH_2 by Soybeans.--
The results of the absorbability of carbon dioxide and ethylene by whole soybeans are shown in tables 1 through 12 and in figures 1, 2, and 5 through 9. These results may be summarized as follows:

1. An increase of temperature caused a slight decrease in the amount of carbon dioxide and ethylene absorbed by the beans when compared at the same gas composition with no drying taking place.

2. The amount of carbon dioxide and ethylene absorbed was much greater with the beans being dried than with no drying, when compared at the same gas composition.

3. The beans absorbed more carbon dioxide than ethylene when compared at the same gas composition and with no drying taking place.

4. The beans absorbed approximately the same amount of CO_2 as CH_2CH_2 at 37°C. and absorbed more CH_2CH_2 than CO_2 at 50°C. when compared at the same gas composition and with drying taking place.

5. The beans absorbed more CO_2 and CH_2CH_2 during the 48 hour runs than during the 24 hour runs, with the general tendency being to absorb more of the gas when the composition of the gas in the bean containers was the highest.

Replacement of H_2O by CO_2 and CH_2CH_2 in Whole Soybeans.-- The results of replacement of H_2O by CO_2 and CH_2CH_2 in whole soybeans at 37°C. are shown in tables 5b through 8 and in figures 3 and 4. It is shown that the water was replaced by more CH_2CH_2 than CO_2 when the drying of soybeans was taking place at 37°C.

Drying of the Whole Soybeans.-- The results of the drying of whole soybeans are shown in tables 5b through 13 and in figures 10 through 12. These results may be summarized as follows:

1. The amount of water collected in the drying tubes at 37 and 50°C. for the containers having air in them, was considerably less than for those containing ethylene and carbon dioxide.

2. The drying rate of the soybeans at 50°C. was approximately eight times that at 37°C. when a mixture of ethylene and carbon dioxide was used.

3. The amount of water collected in the drying tubes for the containers having ethylene and carbon dioxide in them was the same for the various concentrations of ethylene.

4. The water collected from the containers having carbon dioxide in them varies with the carbon dioxide content in the containers, the higher the carbon dioxide content the more water collected in the drying tubes.

5. The amount of water collected in the drying tubes for the containers having from 70 to 90 % carbon dioxide in them was approximately the same as was collected for the ones having a mixture of ethylene and carbon dioxide.

6. The amount of water collected in the drying tubes for the containers having a 75/25 ratio of carbon dioxide to air in them was slightly greater than for those containing a 50/50 ratio of carbon dioxide to air. No drying was accomplished on any of the bean samples at room temperature.

Effect of Gas Treatment on the Taste and Odor of the Oil Produced.-- After standing from 7 to 15 weeks the final taste and odor tests were made. The results of the taste and odor of the oil samples may be summarized (see table 16) as follows:

1. The oil samples from the beans treated with ethylene had less odor than those treated with air.

2. The oil samples from the whole beans treated for 24 hours had considerably less ldor than those treated for 48 hours, when the samples were compared at the same temperature, same ratio of CO_2 to air, and the same gas composition.

3. The oil samples from the beans treated with 75/25 ratio of CO_2 to air had less odor than those

treated with 50/50 ratio of CO_2 to air, when the samples were compared at the same temperature, same length of run, and the same gas composition.

4. After standing from 8 to 15 weeks, the samples of oil taken at 24 and 37°C. had developed no pronounced taste and very little odor, the ones at 24°C. being slightly better than those at 37°C. After standing from 7 to 8 weeks, the samples of oil taken at 50°C. had developed considerably more odor than those at 24 and 37°C.

5. The amount of ethylene present in the containers appeared to have a slight effect on the odor of the oil obtained from the beans, the container having 90 % ethylene present giving slightly better odors than the one having 35 %.

6. The oil samples that were stored without caps on the specimen vials accumulated less odor than the oil in the vials fitted with caps.

Final Results of the Taste and Odor Tests on Oil Samples Obtained by C. C. Waddell.-- After standing from 10½ to 12 months the final taste and odor tests were made on the samples of oil left by C. C. Waddell. The results which did not agree with the results of this investigation and the final results (see table XVII) may be summarized as follows:

1. The oil from the beans for the series of

runs at 37°C. had the least odor for any one series, the run at room temperature gave the next best results, and the run at 50°C. gave the most rancid oil.

2. After standing from 10½ to 12 months it was found that for the majority of the oil samples from the beans treated with ethylene and carbon dioxide had developed as much odor as those from the beans treated with air. After standing from 8½ to 10 months the oil samples from the beans treated with ethylene and carbon dioxide had less odor than those from the beans treated with air.

TABLE I

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans
Ratio of CO_2 to Air -- 50/50
24 Hours -- Low Temperature

December 7, 1937 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in % — Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2
1	26.0	24.4	25.1	100	--	--	100	--	--	--	--
6	25.0	23.8	24.4	9.0	6.5	84.5	15.5	7.1	77.4	-0.6	7.1
5	24.5	23.5	24.0	10.4	7.7	81.9	15.6	9.6	74.8	-1.9	7.1
4	24.8	23.7	24.2	15.0	14.9	70.1	20.5	13.9	65.6	1.0	3.5
8	25.0	23.5	24.1	14.3	18.5	67.2	20.0	17.4	62.6	1.1	4.6
7	25.0	23.8	24.3	24.8	22.8	52.4	33.5	20.9	45.6	1.9	6.8
3	25.0	23.5	24.2	25.9	23.5	50.6	31.4	21.6	47.0	1.9	3.6
2	25.2	23.9	24.6	29.0	28.1	42.9	38.5	23.9	37.6	4.2	5.3
9	25.1	23.6	24.3	31.0	33.3	35.6	38.0	30.0	32.0	3.3	3.6

Time of pressing beans: December 9, 1937
Weight of beans in each container: 4.5 pounds

TABLE II

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans

Ratio of CO_2 to Air -- 50/50

48 Hours -- Low Temperature

December 11, 1937 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in %: Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2
1	26.7	25.0	25.8	100	--	--	100	--	--	--	--
6	25.5	24.0	24.8	4.0	2.6	93.4	18.3	2.4	79.3	0.2	14.1
5	25.5	24.0	24.5	10.2	8.9	80.9	22.0	7.2	70.8	1.7	10.1
9	25.0	24.0	24.4	16.0	16.5	67.5	32.5	12.7	54.8	3.8	12.7
2	25.6	24.1	25.0	15.0	19.6	65.4	30.0	15.4	54.6	4.2	10.8
7	25.7	24.1	24.9	25.5	22.5	52.0	36.0	18.0	46.0	4.5	6.0
3	25.5	23.8	24.8	26.4	25.9	47.7	36.5	20.9	42.6	5.0	5.1
8	25.0	23.8	24.4	31.0	24.6	44.4	42.0	19.4	38.6	5.2	5.8
4	25.5	24.0	24.8	28.0	32.2	39.8	39.5	26.0	34.5	6.2	5.3

Time of pressing beans: December 14, 1937

Weight of beans in each container: 4.5 pounds

TABLE III

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans

Ratio of CO_2 to Air -- 75/25

24 Hours -- Low Temperature

December 14, 1937 — C. H. Worsham

Order of containers in machine:	Temp. of Run in °C: High	Low	Average	Gas Composition in % — Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2
1	26.5	23.9	25.2	100	--	--	100	--	--	--	--
4	25.5	22.7	24.4	6.1	6.4	87.5	13.1	7.3	79.6	-0.9	7.9
9	26.0	22.7	24.6	4.3	18.1	77.6	16.2	16.3	67.5	1.8	10.1
2	25.8	23.0	24.4	10.4	19.2	70.4	20.7	15.9	63.4	3.3	7.0
3	25.5	22.8	24.2	9.0	27.1	63.9	16.6	24.1	59.3	3.0	4.6
6	25.7	22.8	24.4	9.0	31.5	59.5	16.0	27.9	56.1	3.6	3.4
5	25.4	22.6	24.1	18.4	33.5	51.5	21.0	29.7	49.3	3.8	2.2
7	26.0	23.0	24.6	9.9	47.2	42.9	17.0	42.7	40.3	4.5	2.6
8	25.8	22.7	24.4	15.2	49.1	35.7	23.3	44.2	32.5	4.9	3.2

Time of pressing beans: December 16, 1937

Weight of beans in each container: 4.5 pounds

TABLE IV

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans
Ratio of CO_2 to Air -- 75/25
48 Hours -- Low Temperature

December 20, 1937 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in % — Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2
1	27.0	23.8	25.6	100	--	--	99.8	0.2	--	-0.2	--
2	26.1	23.0	24.7	3.7	5.2	91.1	19.0	4.7	76.3	0.5	14.8
9	25.6	22.6	24.4	7.9	13.6	78.5	24.8	10.5	64.7	3.1	13.8
8	25.5	22.5	24.3	7.9	23.1	69.0	19.0	19.7	61.3	3.4	7.7
3	25.6	22.7	24.4	5.7	27.4	66.9	17.2	22.5	60.3	4.9	6.6
6	25.8	22.7	24.4	13.0	31.1	55.9	24.5	25.7	49.8	5.4	6.1
4	25.6	22.4	24.3	13.3	35.4	51.3	26.9	27.6	45.5	7.8	5.8
7	25.8	22.9	24.6	9.3	46.6	44.1	20.0	39.5	40.5	7.1	3.6
5	25.6	22.5	24.1	11.7	55.0	33.3	23.1	46.8	30.1	8.2	3.2

Time of pressing beans: December 23, 1937
Weight of beans in containers: 4.5 pounds

FIGURE I

Absorbability of CH_2CH_2 by Whole Soybeans at 24°C

I Treated for 24 Hours with 50/50 Ratio of CO_2 to Air
II Treated for 48 Hours with 50/50 Ratio of CO_2 to Air
III Treated for 24 Hours with 75/25 Ratio of CO_2 to Air
IV Treated for 48 Hours with 75/25 Ratio of CO_2 to Air

C. H. Worsham March 2, 1938

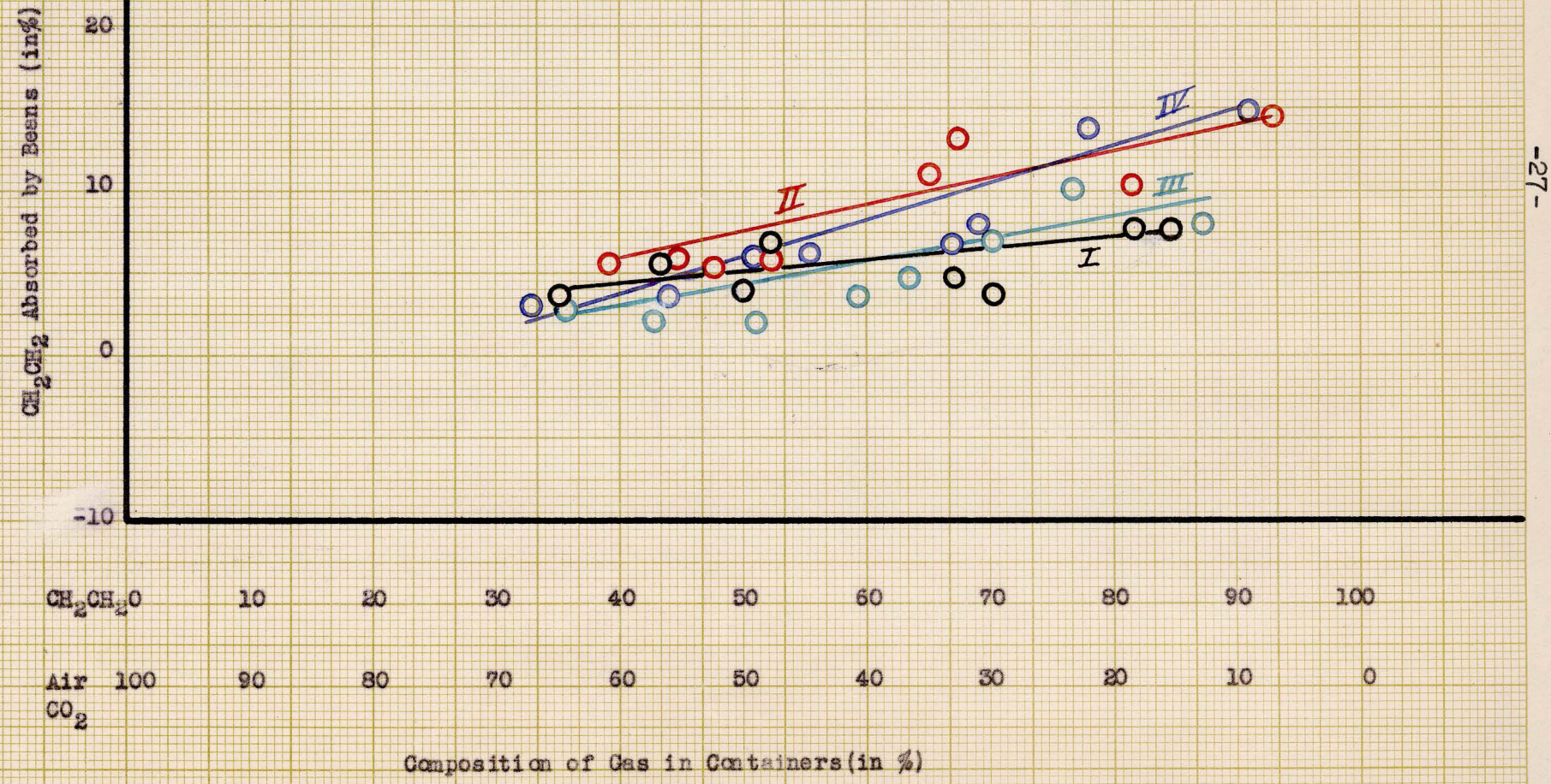
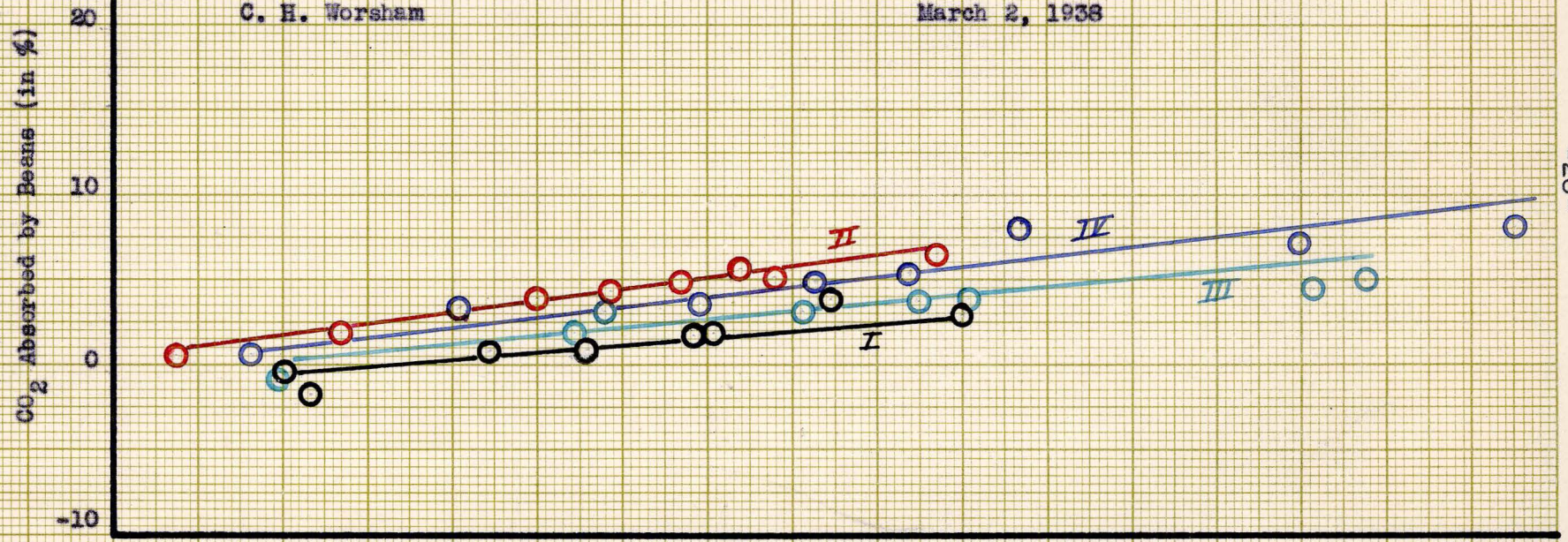


FIGURE II

Absorbability of CO_2 by Whole Soybeans at 24°C

I Treated for 24 Hours with 50/50 Ratio of CO_2 to Air
II Treated for 48 Hours with 50/50 Ratio of CO_2 to Air
III Treated for 24 Hours with 75/25 Ratio of CO_2 to Air
IV Treated for 48 Hours with 75/25 Ratio of CO_2 to Air

C. H. Worsham March 2, 1938



CO_2	0	5	10	15	20	25	30	35	40	45	50
Air CH_2CH_2	100	95	90	85	80	75	70	65	60	55	50

Composition of Gas in Containers (in %)

TABLE V (a)

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans
Ratio of CO_2 to Air -- 50/50
24 Hours -- Intermediate Temperature

December 28, 1937 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in %: Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2
1	39.7	34.8	36.2	100	--	--	99.7	0.3	--	-0.3	--
2	41.2	35.8	36.0	5.2	2.4	92.4	16.0	2.6	81.4	-0.2	11.0
3	40.1	35.1	36.6	9.4	11.6	79.0	17.0	10.6	72.4	1.0	6.6
4	38.8	34.7	36.3	14.0	15.4	70.6	22.0	13.7	64.3	1.7	6.3
9	38.2	35.8	37.8	20.0	15.0	65.0	28.2	14.4	57.4	0.6	7.6
5	38.0	35.2	36.2	21.5	23.3	55.2	27.7	21.1	51.2	2.2	4.0
6	37.2	35.0	36.2	25.0	25.0	50.0	32.0	21.9	46.1	3.1	3.9
7	39.3	35.7	36.4	25.0	29.6	45.4	29.8	27.1	43.1	2.5	2.3
8	38.6	35.8	37.3	33.0	35.0	32.0	39.0	31.5	29.5	3.5	2.5

No pressing
Weight of beans in each container: 4.5 pounds

TABLE V (b)

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans

Ratio of CO_2 to Air -- 50/50

24 Hours -- Intermediate Temperature

January 1, 1938 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in %: Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2	Water condensed in Drying Tube in cc: Actual	Corrected (Calculated)
1	37.4	34.7	35.8	100	--	--	100	--	--	--	--	10.3	10.0
2	38.8	35.4	36.7	6.0	2.4	91.6	39.2	1.9	58.9	0.5	32.7	13.5	14.1
4	39.7	35.1	37.3	9.0	12.5	78.5	28.0	10.3	61.7	2.2	16.8	10.5	9.2
5	39.4	35.0	36.8	15.4	12.5	72.1	40.0	9.3	50.7	3.2	21.4	15.0	11.9
9	40.0	35.1	36.1	15.9	20.6	63.5	69.9	8.5	21.6	12.1	41.9	34.2	22.1
3	39.4	34.9	36.7	19.8	23.0	57.2	47.7	15.6	36.7	7.4	20.5	12.5	12.8
7	42.0	36.7	38.1	22.8	27.4	49.8	56.8	16.3	26.9	11.1	22.9	34.9	23.6
8	41.4	35.9	37.1	27.0	29.9	43.1	63.5	15.7	20.8	14.2	22.3	31.5	19.6
6	40.8	35.3	37.1	28.1	34.9	37.0	47.2	26.1	26.7	8.8	10.3	16.2	10.9

Time of pressing beans: January 3, 1938
Weight of beans in each container: 4.5 pounds
Cooling water: Inlet - 24.4°C. Outlet -25.7°C.

TABLE VI

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans

Ratio of CO_2 to Air -- 50/50

48 Hours -- Intermediate Temperature

January 3, 1938 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in %: Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2	Water condensed in Drying Tube in cc: Actual	Corrected (Calculated)
7	38.7	34.3	37.1	100	--	--	99.5	0.5	--	-0.5	--	55.2	25.0
1	40.0	35.5	37.1	5.3	7.7	87.0	27.1	6.1	66.8	1.6	20.2	30.0	28.6
2	38.5	34.5	36.7	11.3	11.4	78.3	34.5	8.3	57.2	3.1	21.1	30.0	30.4
3	38.0	34.6	37.2	12.2	17.7	70.1	32.3	13.6	54.1	3.1	16.0	30.0	29.4
4	38.0	34.1	37.0	15.9	19.4	64.7	34.5	14.7	50.3	4.1	14.4	26.6	22.0
5	37.6	34.1	36.5	23.4	21.9	54.7	36.4	17.4	46.2	4.7	8.5	39.6	29.5
9	37.7	34.0	36.2	27.8	22.1	50.1	74.6	8.6	16.8	13.5	33.3	72.6	39.4
6	38.1	34.0	37.1	27.0	28.4	44.6	57.2	16.6	26.2	4.5	18.4	37.0	21.2
8	38.5	34.0	37.4	33.5	33.1	33.4	73.5	14.0	12.5	19.1	20.9	70.6	39.2

Time of pressing beans: January 6, 1938
Weight of beans in each container: 4.5 pounds
Cooling water: Inlet - 24°C. Outlet 25.2°C

TABLE VII

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans
Ratio of CO_2 to Air -- 75/25
24 Hours -- Intermediate Temperature

January 16, 1938 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in %: Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2	Water condensed in Drying Tube in cc: Actual	Corrected (Calculated)
7	38.5	36.0	37.5	100	--	--	99.4	0.6	--	-0.6	--	34.1	10.0
1	38.5	34.0	35.6	6.1	8.1	85.8	20.2	6.9	72.9	1.2	12.9	22.8	16.5
4	37.8	35.0	36.4	6.4	16.4	77.2	22.9	12.9	64.2	3.5	13.0	24.5	16.2
3	37.6	35.0	36.4	6.0	22.5	71.5	34.0	15.6	50.4	6.9	21.1	20.1	14.2
2	37.5	34.0	35.7	12.2	24.7	63.1	35.2	17.7	47.1	7.0	16.0	14.1	8.8
5	37.8	35.0	36.4	14.0	32.0	54.0	27.4	26.2	46.4	5.8	7.6	26.6	15.4
9	38.5	35.2	37.4	18.5	33.1	48.4	70.0	12.6	17.4	20.5	31.0	37.5	12.0
8	38.8	36.0	38.0	18.1	36.9	45.0	51.5	21.1	27.4	15.8	17.6	39.4	14.3
6	38.2	36.0	37.5	15.1	47.2	37.7	27.0	39.6	33.4	7.6	4.3	34.4	19.7

Time of pressing beans: January 18, 1938
Weight of beans in each container: 4.5 pounds
Cooling water: Inlet - 24.2°C. Outlet - 25.4°C.

TABLE VIII

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans
Ratio of CO_2 to Air -- 75/25
48 Hours -- Intermediate Temperature

January 25, 1938 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in %: Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2	Water condensed in Drying Tube in cc: Actual	Corrected (Calculated)
7	38.2	35.1	37.2	100	--	--	99.6	0.4	--	-0.4	--	62.5	25.0
2	37.2	35.0	36.3	6.2	7.2	86.6	35.0	5.1	59.9	2.1	26.7	49.2	46.3
1	36.5	34.0	35.4	7.0	15.7	77.3	34.9	10.5	54.6	5.2	22.7	54.7	50.3
3	37.8	34.5	36.5	6.8	21.9	71.3	48.0	11.9	40.1	10.0	31.2	49.7	45.6
9	39.0	36.0	36.8	15.3	23.9	60.8	91.3	3.4	5.3	20.5	40.3	74.0	34.2
4	37.1	34.2	36.0	15.0	32.8	52.2	37.0	23.7	39.3	9.1	12.9	43.8	35.3
8	39.1	35.6	38.0	14.6	34.5	50.9	74.9	10.7	14.4	23.8	36.5	76.3	37.3
5	37.6	34.0	36.0	22.5	34.7	42.8	31.8	29.5	38.7	5.2	4.1	48.2	34.4
6	38.1	35.2	37.2	21.0	46.0	33.0	38.2	35.1	26.7	10.9	6.3	58.8	38.7

Time of pressing beans: January 28, 1938
Weight of beans in each container: 4.5 pounds
Cooling water: Inlet - 23.7°C. Outlet - 25.7°C.

FIGURE III

Replacement of Water by CH_2CH_2 in Whole Soybeans at 37°C
Vb Treated for 24 Hours with 50/50 Ratio of CO_2 to Air
VI Treated for 48 Hours with 50/50 Ratio of CO_2 to Air
VII Treated for 24 Hours with 75/25 Ratio of CO_2 to Air
VIII Treated for 48 Hours with 75/25 Ratio of CO_2 to Air

C. H. Worsham March 2, 1938

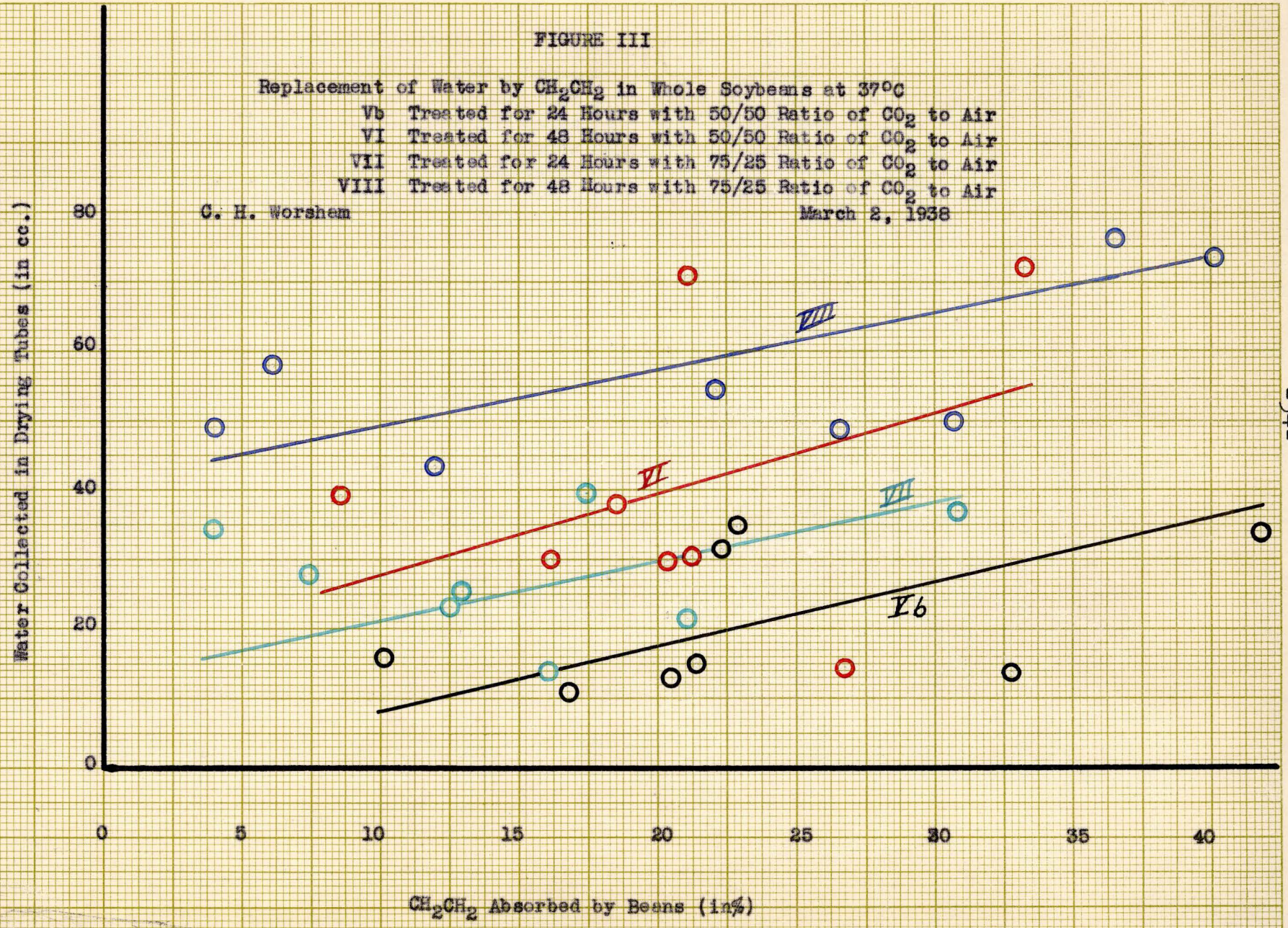


FIGURE IV

Replacement of Water by CO_2 in Whole Soybeans at 37°C

Vb Treated for 24 Hours with 50/50 Ratio of CO_2 to Air

VI Treated for 48 Hours with 50/50 Ratio of CO_2 to Air

VII Treated for 24 Hours with 75/25 Ratio of CO_2 to Air

VIII Treated for 48 Hours with 75/25 Ratio of CO_2 to Air

C. H. Worsham March 2, 1938

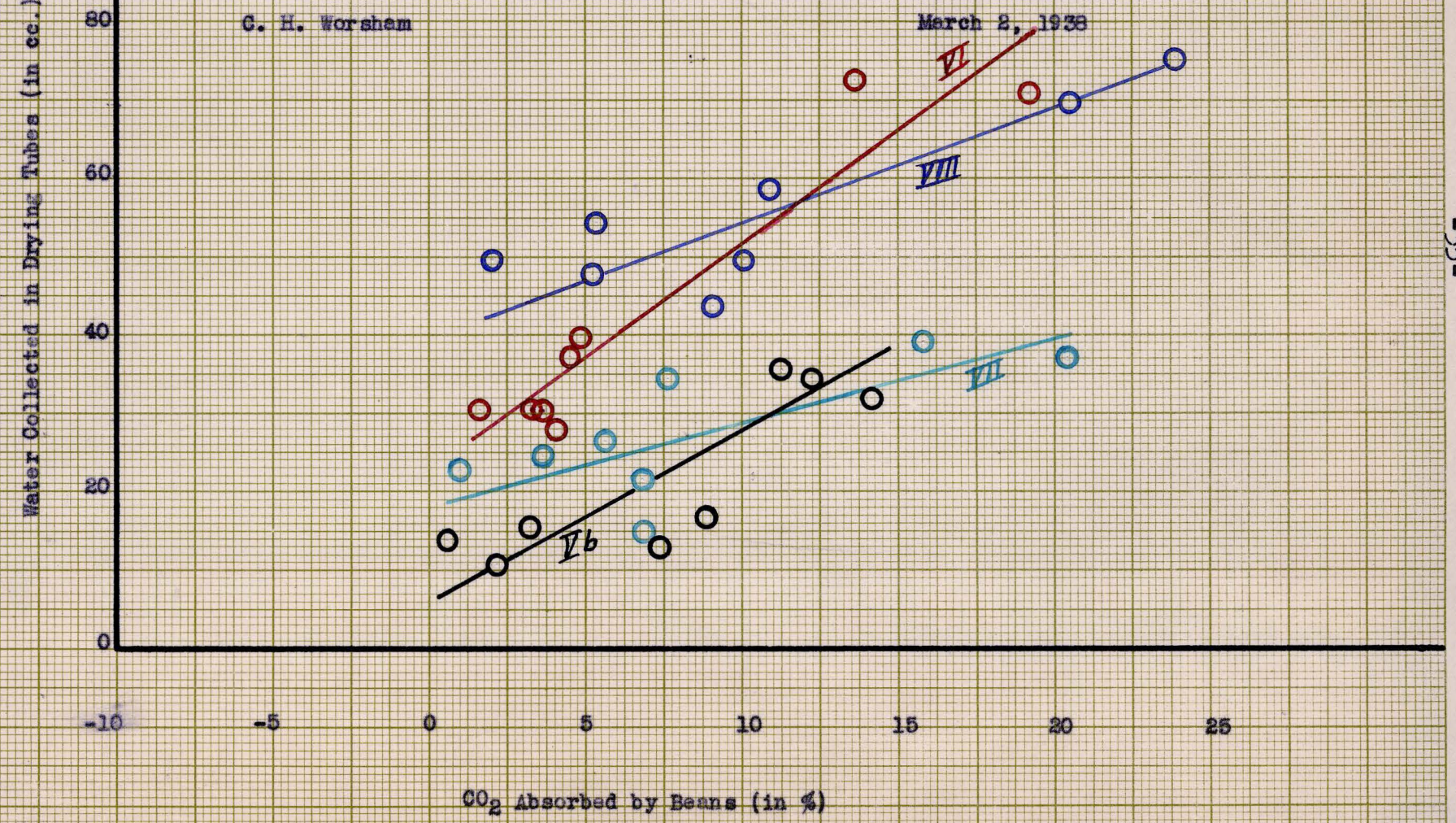
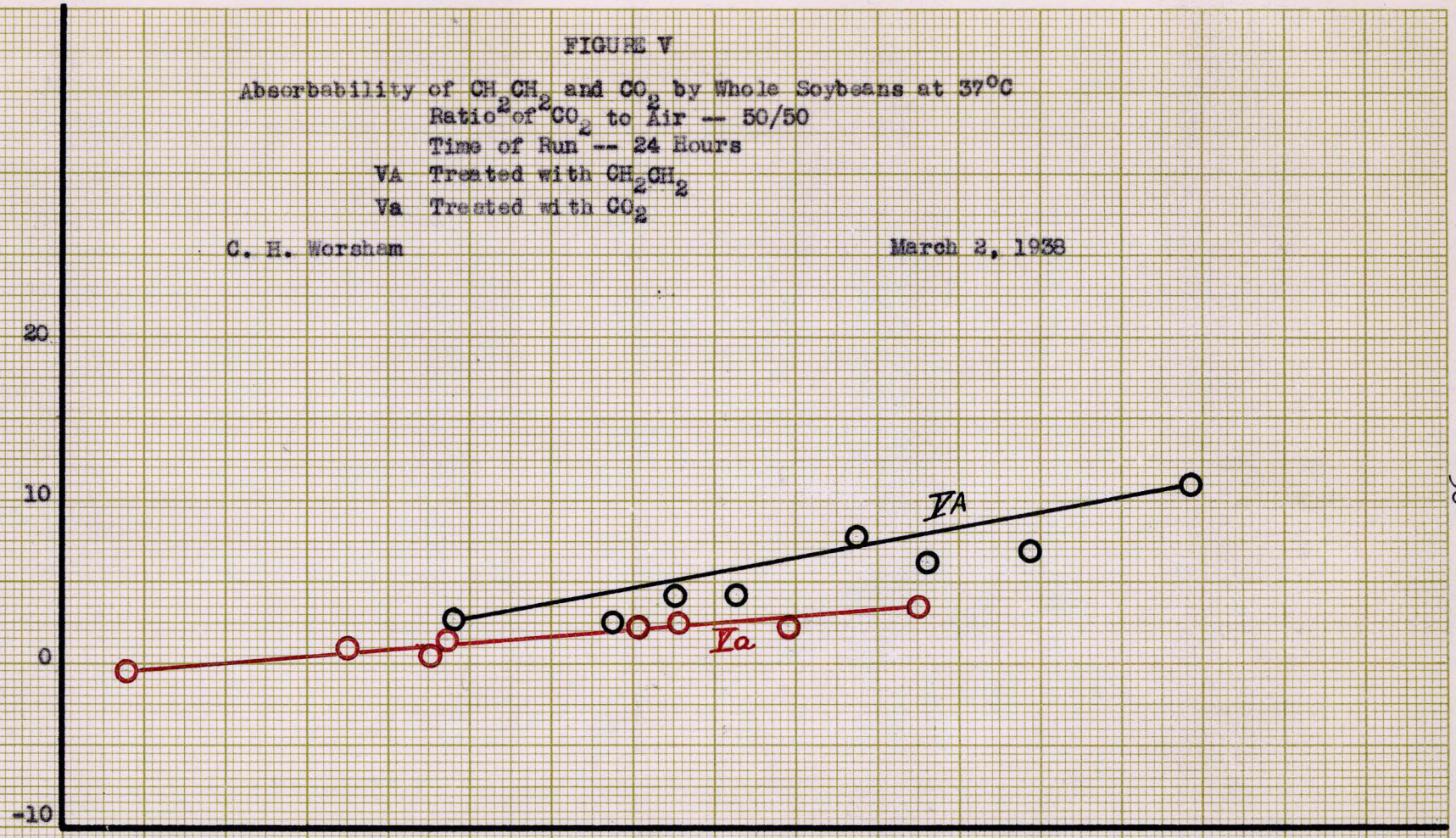


FIGURE V

Absorbability of CH_2CH_2 and CO_2 by Whole Soybeans at 37°C
Ratio of CO_2 to Air -- 50/50
Time of Run -- 24 Hours
VA Treated with CH_2CH_2
Va Treated with CO_2

C. H. Worsham March 2, 1938



CH_2CH_2 or CO_2 Absorbed by Beans (in %)

For Curve V A (CH_2CH_2)	0	10	20	30	40	50	60	70	80	90	100
(Air + CO_2)	100	90	80	70	60	50	40	30	20	10	0
For Curve V a (CO_2)	0	5	10	15	20	25	30	35	40	45	50
(Air + CH_2CH_2)	100	95	90	85	80	75	70	65	60	55	50

Composition of Gas in Containers (in %)

FIGURE VI

Absorbability of CH_2CH_2 by Whole Soybeans at 37°C

Vb Treated for 24 Hours with 50/50 Ratio of CO_2 to Air
VI Treated for 48 Hours with 50/50 Ratio of CO_2 to Air
VII Treated for 24 Hours with 75/25 Ratio of CO_2 to Air
VIII Treated for 48 Hours with 75/25 Ratio of CO_2 to Air

C. H. Worsham March 2, 1938

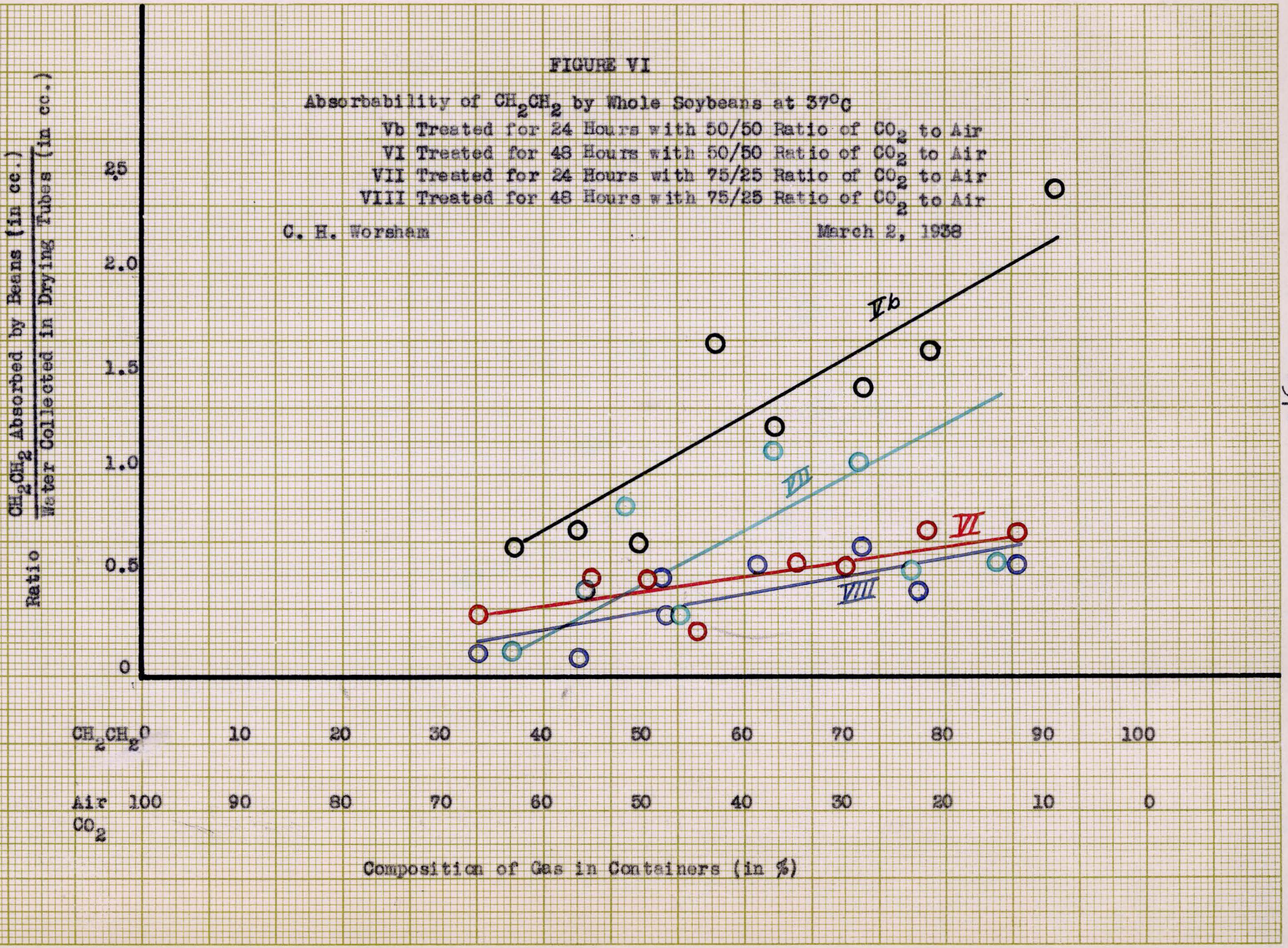


FIGURE VII

Absorbability of CO_2 by Whole Soybeans at 37° C

Vb Treated for 24 Hours with 50/50 Ratio of CO_2 to Air

VI Treated for 48 Hours with 50/50 Ratio of CO_2 to Air

VII Treated for 24 Hours with 75/25 Ratio of CO_2 to Air

VIII Treated for 48 Hours with 75/25 Ratio of CO_2 to Air

C. H. Worsham March 2, 1938

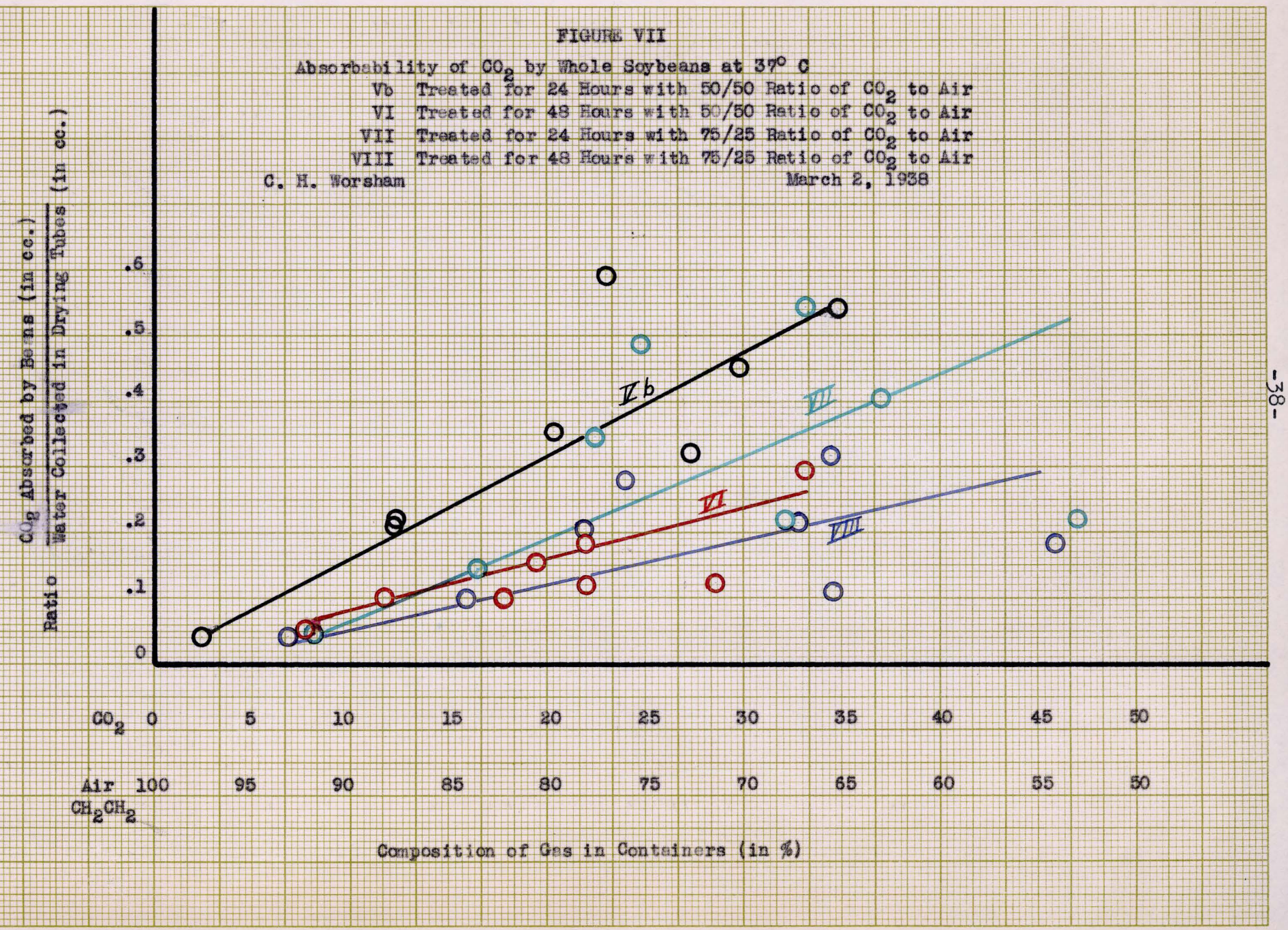


TABLE IX

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans
Ratio of CO_2 to Air -- 50/50
24 Hours -- High Temperature

January 29, 1938 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in %: Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2	H_2O condensed in drying tube in cc. (Calculated)
4	51.0	46.9	49.2	100	--	--	99.5	0.5	--	-0.5	--	88.8
1	50.2	46.0	48.1	4.1	5.1	89.8	40.8	4.6	54.6	0.5	35.2	124.3
3	50.4	47.0	49.4	11.1	10.9	78.0	50.5	4.9	44.6	6.0	33.4	116.1
2	50.3	46.0	48.9	13.5	18.3	68.2	49.5	10.4	40.1	7.9	28.1	117.1
6	50.4	48.1	50.0	20.9	15.2	63.9	51.3	8.5	40.2	6.7	23.7	123.4
9	50.2	46.0	48.4	24.7	22.7	52.6	59.4	14.4	26.2	8.3	26.4	123.8
7	51.2	48.0	49.9	24.2	26.6	49.2	58.9	14.5	26.6	12.1	22.6	120.5
5	50.8	47.5	49.7	24.3	31.5	44.2	58.5	17.4	24.1	14.1	20.1	124.8
8	50.6	46.3	49.0	30.9	35.9	33.2	59.2	20.7	20.1	15.2	13.1	118.6

Time of pressing beans: January 31, 1938
Weight of beans in each container: 4.5 pounds
Cooling water: Inlet - 21.5°C. Outlet - 23.2°C.

TABLE X

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans
Ratio of CO_2 to Air -- 50/50
48 Hours -- High Temperature

February 1, 1938 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in % — Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2	H_2O condensed in drying tube in cc. (Calculated)
4	52.0	44.9	49.1	100	--	--	96.5	3.5	--	-3.5	--	171.9
2	54.0	47.0	50.6	5.6	2.0	92.4	51.0	3.5	45.5	-1.5	46.9	217.9
1	53.4	47.8	49.4	8.2	7.8	84.0	57.5	5.7	36.8	2.1	47.2	237.1
6	53.2	47.1	50.6	9.4	19.7	70.9	69.7	7.3	23.0	12.4	47.9	264.0
5	53.5	47.0	50.6	13.3	19.9	66.8	68.5	8.9	22.6	11.0	44.2	254.4
7	53.4	47.2	50.6	17.4	27.4	55.2	72.7	10.7	16.6	16.7	38.6	255.4
9	50.0	45.3	48.1	27.6	25.8	47.2	74.1	11.0	14.9	14.2	32.3	240.0
3	53.5	46.5	50.2	25.4	28.1	46.5	56.7	18.0	25.3	10.1	21.2	213.1
8	52.5	45.5	49.7	31.5	38.3	30.2	70.0	18.6	11.4	19.7	18.8	246.7

Time of pressing beans: February 4, 1938
Weight of beans in each container: 4.5 pounds
Cooling water: Inlet -22.8°C. Outlet - 24.6°C.

TABLE XI

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans
Ratio of CO_2 to Air - 75/25
24 Hours -- High Temperature

February 5, 1938 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in %: Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2	H_2O condensed in drying tube in cc. (Calculated)
6	51.8	46.0	49.9	100	--	--	99.0	1.0	--	-1.0	--	92.7
2	52.6	47.1	50.7	6.2	4.9	88.9	39.0	4.5	56.5	0.4	32.4	110.5
1	50.9	47.4	49.7	8.8	10.6	80.6	43.2	7.4	49.4	3.2	41.2	126.2
4	52.8	47.0	51.0	7.8	22.8	69.4	45.0	14.7	40.3	8.1	29.1	125.1
3	53.4	47.0	51.3	6.3	29.3	64.4	39.0	20.9	40.1	8.4	24.3	116.8
8	53.3	46.4	50.9	15.2	28.0	56.8	54.5	15.9	29.6	12.1	27.2	128.3
7	53.5	47.0	51.4	18.0	32.6	49.4	51.5	19.2	29.3	13.4	20.1	128.3
5	52.8	47.0	51.0	15.5	43.5	41.0	54.0	24.3	21.7	19.2	19.3	122.0
9	51.8	46.0	49.1	24.9	45.0	30.1	55.9	26.9	17.2	18.1	12.9	115.7

Time of pressing beans: February 8, 1938
Weight of beans in each container: 4.5 pounds
Cooling water: Inlet - 22.7°C. Outlet - 25.3°C.

TABLE XII

Absorbability of CO_2 and CH_2CH_2 in Whole Soybeans

Ratio of CO_2 to Air -- 75/25

24 Hours -- High Temperature

February 5, 1938 — C. H. Worshem

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in % — Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2	H_2O condensed in drying tube in cc. (Calculated)
3	50.8	46.0	49.6	100	--	--	97.7	2.3	--	-2.3	--	163.9
1	52.0	46.8	49.8	7.0	5.7	87.3	53.4	4.4	42.2	1.3	45.1	250.0
4	52.0	47.5	50.7	7.1	13.6	79.3	60.9	6.7	32.4	6.9	46.9	252.5
2	53.6	46.6	50.2	11.8	21.2	67.0	54.1	14.3	31.6	6.9	35.4	250.9
5	52.4	47.8	51.0	16.4	21.9	61.7	65.6	10.9	23.5	11.0	38.2	265.9
9	50.8	47.0	49.0	14.5	30.4	55.1	73.6	11.0	15.4	19.4	39.7	246.7
7	52.0	48.6	51.0	10.5	40.9	48.6	67.4	16.6	16.0	24.3	32.6	248.4
8	51.6	48.0	50.5	14.5	41.2	44.3	66.8	17.6	15.6	23.6	28.7	255.9
6	51.8	48.0	50.8	20.1	44.3	35.6	76.2	14.7	9.1	29.6	26.5	262.6

Time of pressing beans: February 11, 1938
Weight of beans in each container: 4.5 pounds
Cooling water: Inlet - 22.1 °C. Outlet - 24.4°C.

TABLE XIII

Relative Drying of Whole Soybeans by CO_2 and CH_2CH_2

Ratio of CO_2 to Air -- 75/25 with CH_2CH_2
12 Hours -- High Temperature

February 7, 1938 — C. H. Worsham

Order of containers in machine	Temp. of Run in °C: High	Low	Average	Gas Composition in % — Beginning of Run: Air	CO_2	CH_2CH_2	End of Run: Air	CO_2	CH_2CH_2	Gas absorbed by beans in %: CO_2	CH_2CH_2	H_2O condensed in drying tube in cc.
4	49.0	45.6	47.2	100	--	--	99.4	0.6	--	-0.6	--	44.4
5	50.4	47.0	48.4	11.4	88.6	--	41.3	58.7	--	29.9	--	55.5
2	50.0	45.6	47.7	24.0	76.0	--	49.0	51.0	--	25.0	--	52.7
7	50.0	46.8	48.23	52.3	47.7	--	68.9	31.1	--	16.6	--	51.5
9	48.9	45.4	47.2	66.4	33.6	--	77.6	22.4	--	11.2	--	49.3
1	50.0	47.4	48.5	6.5	7.7	85.8	37.0	5.3	57.7	2.4	28.1	54.5
3	50.0	47.0	48.3	9.1	19.0	71.9	30.0	14.9	55.1	4.1	16.8	50.9
6	50.8	47.5	48.9	14.0	25.8	60.2	48.9	16.3	34.8	9.5	25.4	56.4
8	49.7	46.3	47.8	42.8	31.9	26.3	63.2	20.6	16.2	11.3	10.1	54.2

No pressing
Weight of beans in each container: 4.5 pounds
Cooling water: Inlet - 20.7°C. Outlet - 23.2°C.

FIGURE VIII

Absorbability of CH_2CH_2 by Whole Soybeans at 50°C

IX Treated for 24 Hours with 50/50 Ratio of CO_2 to Air
X Treated for 48 Hours with 50/50 Ratio of CO_2 to Air
XI Treated for 24 Hours with 75/25 Ratio of CO_2 to Air
XII Treated for 48 Hours with 75/25 Ratio of CO_2 to Air

C. H. Worsham March 2, 1938

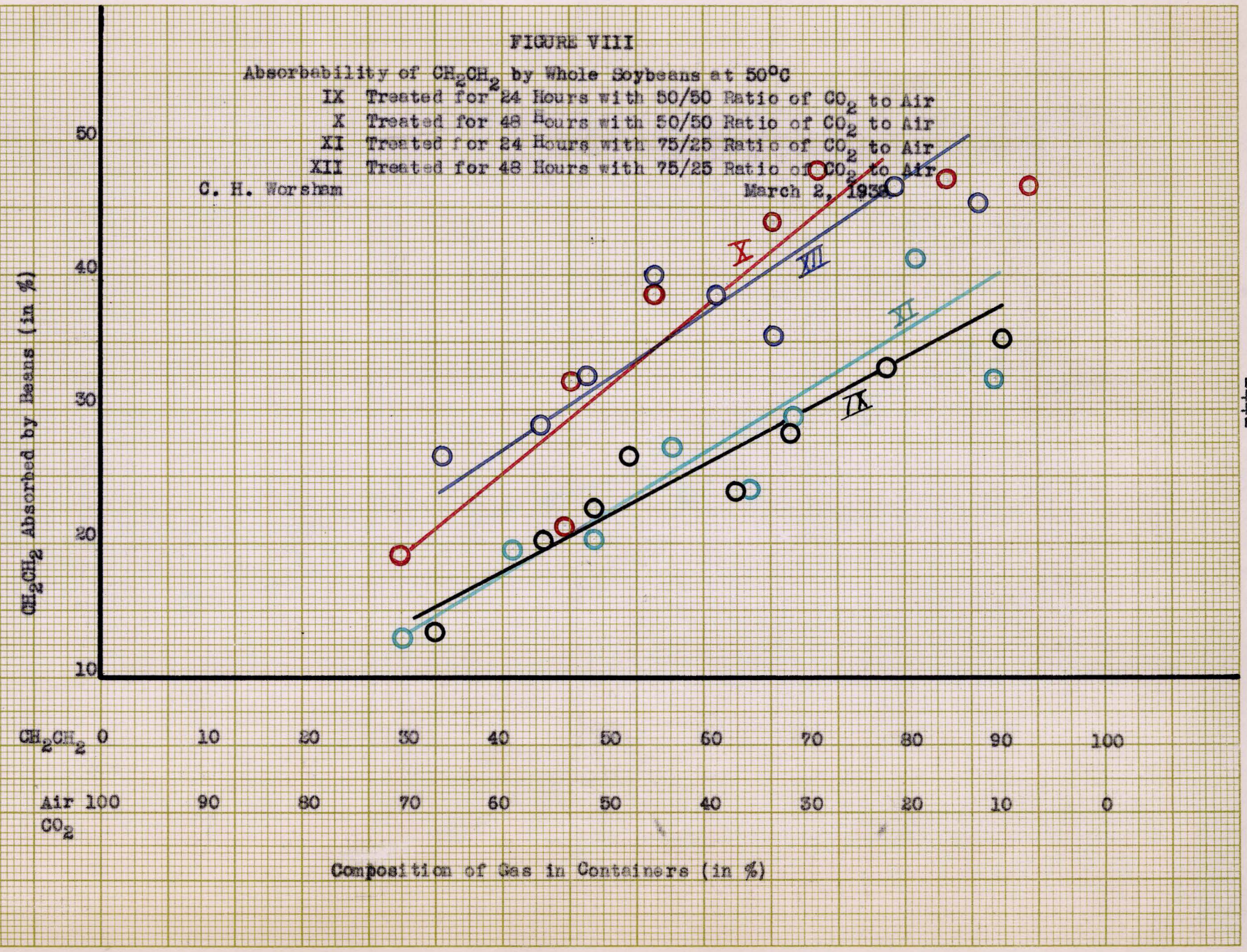


FIGURE IX

Absorbability of CO_2 by Whole Soybeans at 50°C

IX Treated for 24 Hours with 50/50 Ratio of CO_2 to Air
X Treated for 48 Hours with 50/50 Ratio of CO_2 to Air
XI Treated for 24 Hours with 75/25 Ratio of CO_2 to Air
XII Treated for 48 Hours with 75/25 Ratio of CO_2 to Air

C. H. Worsham March 2, 1938

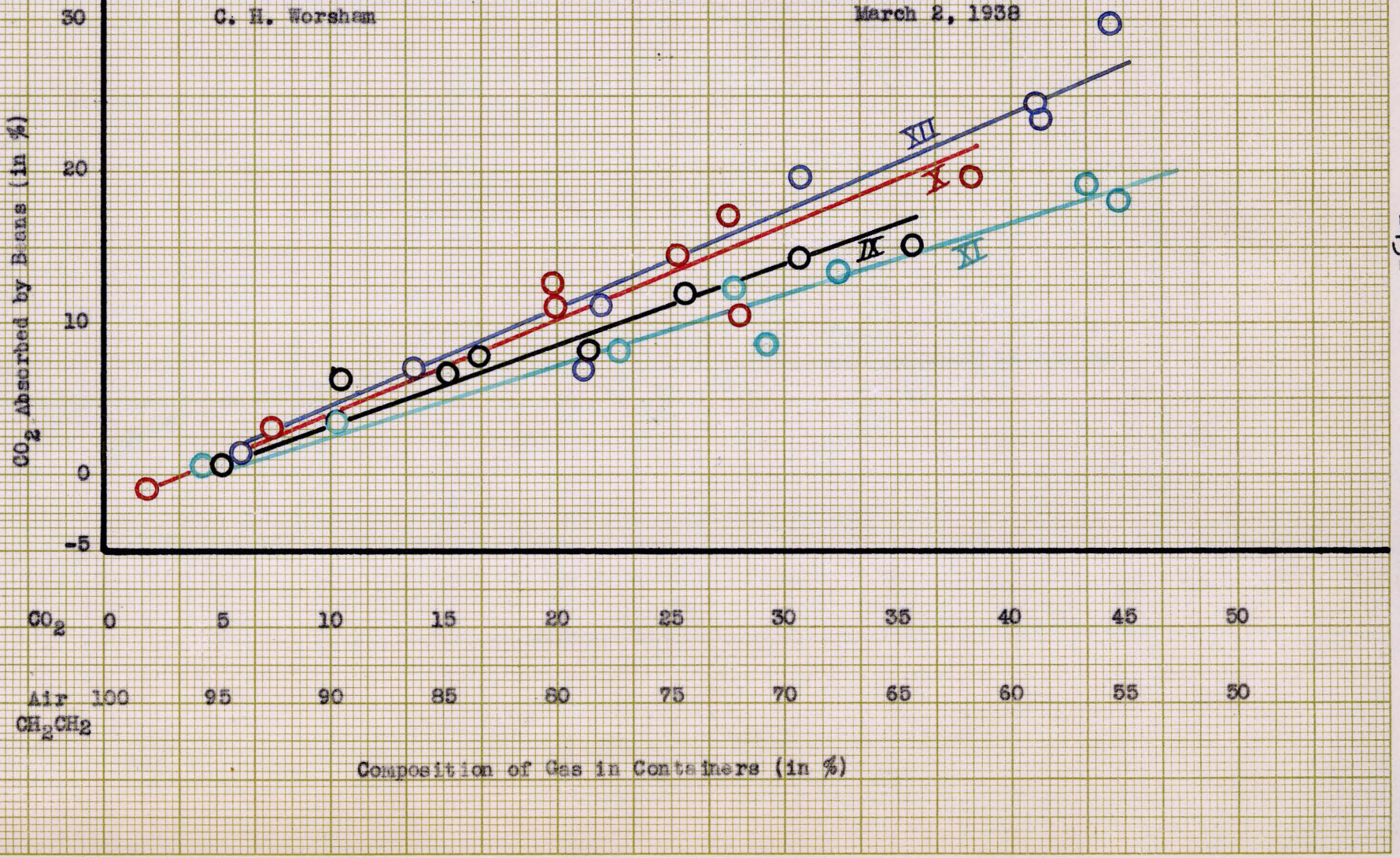


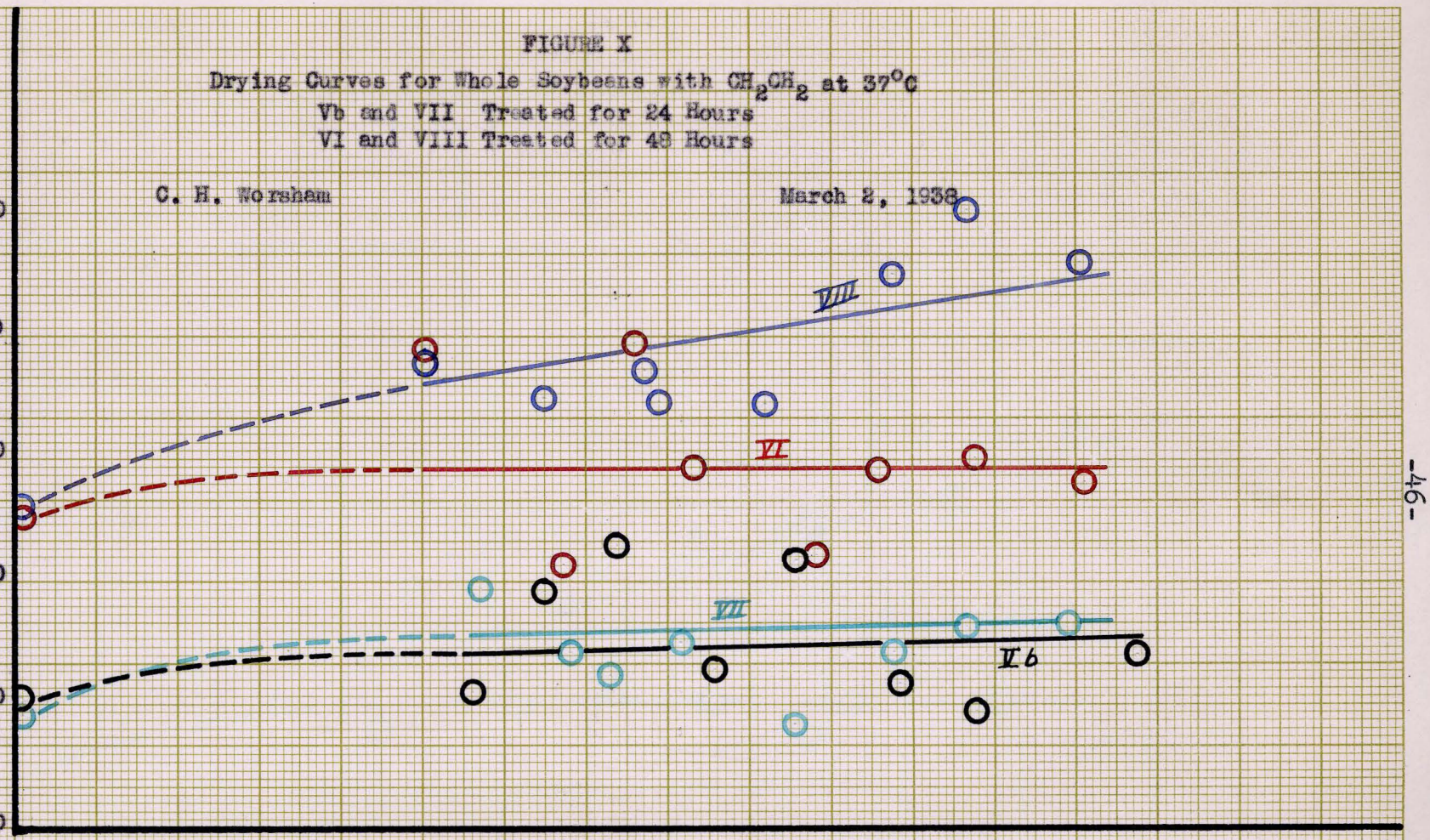
FIGURE X

Drying Curves for Whole Soybeans with CH_2CH_2 at 37°C

Vb and VII Treated for 24 Hours

VI and VIII Treated for 48 Hours

C. H. Worsham March 2, 1938

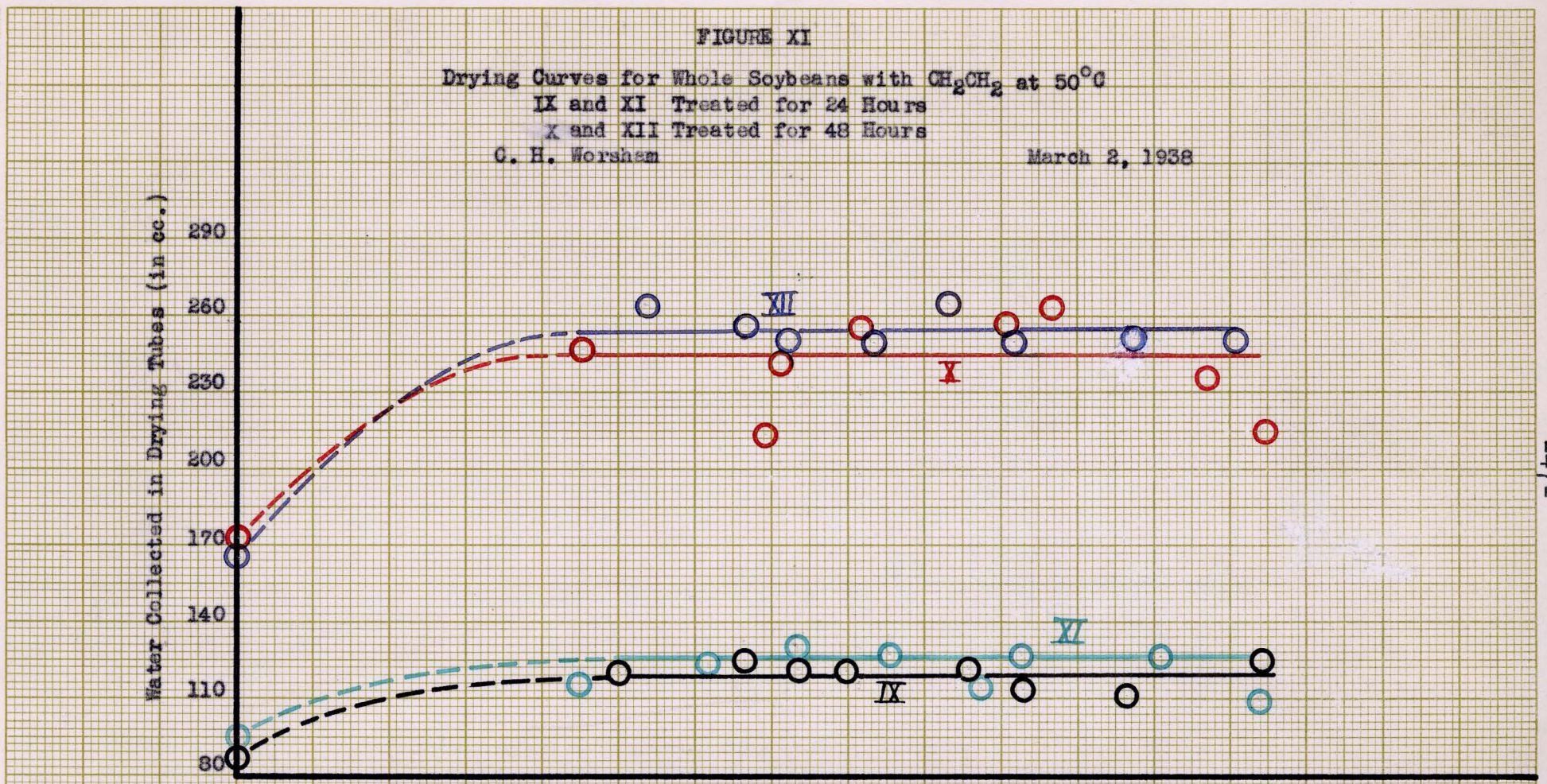


CH_2CH_2	0	10	20	30	40	50	60	70	80	90	100
For Curves Vb & VI (CO_2	0	45	40	35	30	25	20	15	10	5	0
Air	100	45	40	35	30	25	20	15	10	5	0
For Curves VII & VIII (CO_2	0	67.5	60	52.5	45	37.5	30	22.5	15	7.5	0
Air	100	22.5	20	17.5	15	12.5	10	7.5	5	2.5	0

Composition of Gases (in %)

FIGURE XI

Drying Curves for Whole Soybeans with CH_2CH_2 at 50°C
IX and XI Treated for 24 Hours
X and XII Treated for 48 Hours
C. H. Worsham March 2, 1938



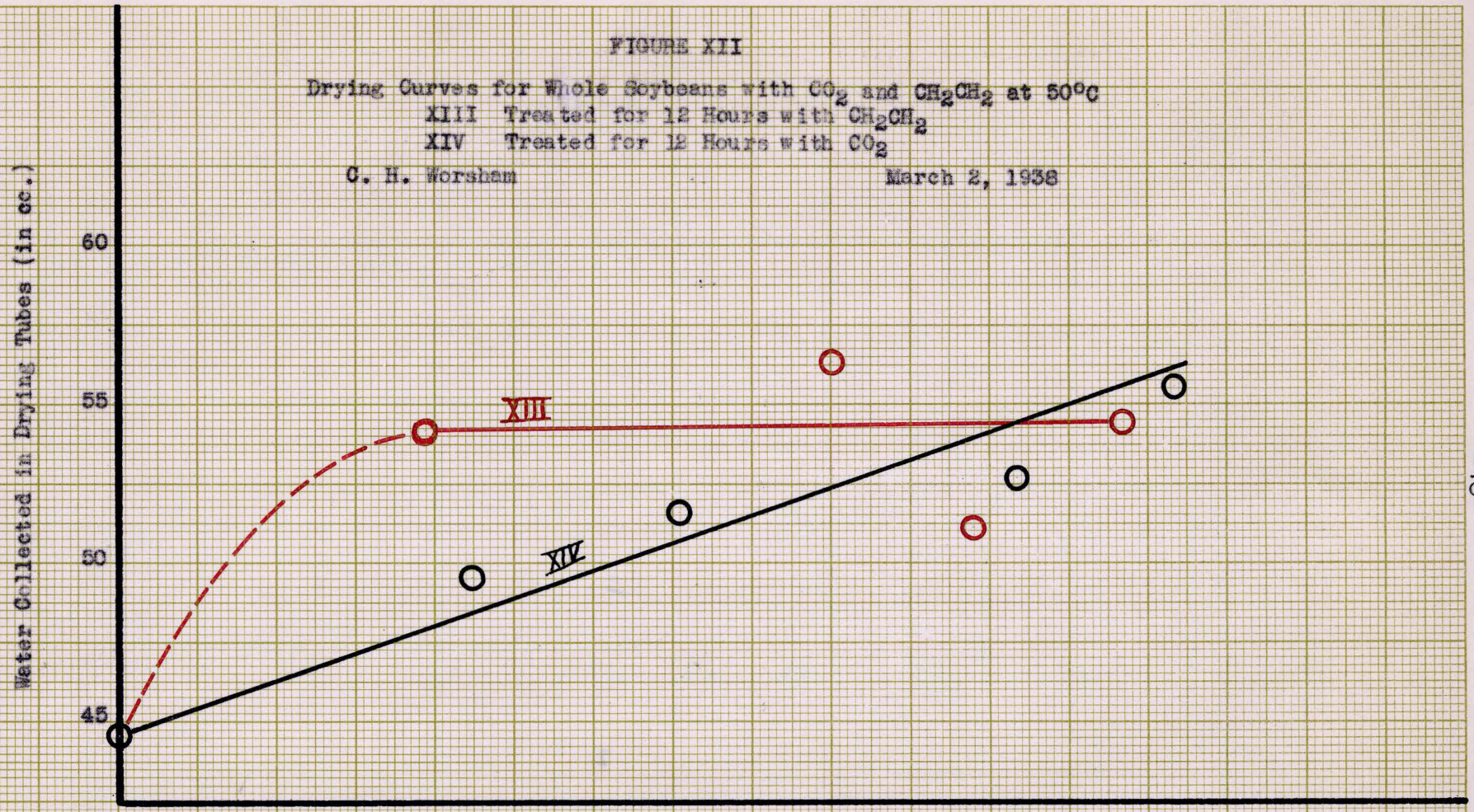
For Curves IX & X	CH_2CH_2	0	10	20	30	40	50	60	70	80	90	100
	Air	100	45	40	35	30	25	20	15	10	5	0
	CO_2	0	45	40	35	30	25	20	15	10	5	0
For Curves XI &XII	Air	100	22.5	20	17.5	15	12.5	10	7.5	5	2.5	0
	CO_2	0	67.5	60	52.5	45	37.5	30	22.5	15	7.5	0

Composition of Gas in Containers (in %)

FIGURE XII

Drying Curves for Whole Soybeans with CO_2 and CH_2CH_2 at 50°C
XIII Treated for 12 Hours with CH_2CH_2
XIV Treated for 12 Hours with CO_2

C. H. Worsham March 2, 1938



For Curve XIII	CH_2CH_2	0	10	20	30	40	50	60	70	80	90	100
	CO_2	0	67.5	60	52.5	45	37.5	30	22.5	15	7.5	0
	Air	100	22.5	20	17.5	15	12.5	10	7.5	5	2.5	0

For Curve XIV	CO_2	0	10	20	30	40	50	60	70	80	90	100
	Air	100	90	80	70	60	50	40	30	20	10	0

Composition of Gas in Containers (in%)

TABLE XIV

Machine Calibration
On the Air Drying of Whole Soybeans at
Intermediate Temperature

January 19, 1938 — C. H. Worsham

Order of containers in machine:	Temp. of Run in °C: High	Low	Average	% Air in each container	H_2O condensed in drying tubes in cc
1	37.2	35.0	36.4	100	7.9
2	37.5	35.4	36.4	100	7.5
3	37.6	34.7	36.5	100	7.8
4	37.6	35.2	36.4	100	9.0
5	37.6	35.1	36.6	100	10.4
6	38.1	36.3	36.9	100	12.1
7	38.0	37.0	37.4	100	16.8
8	38.7	36.5	37.3	100	17.2
9	37.7	35.5	36.6	100	17.4

No pressing
Time of run: 6 hours
Weight of beans in each container: 4.5 pounds
Cooling water: Inlet - 21.9°C. Outlet - 23.4°C.

TABLE XV

Effect of Heating Elements on Temperature of Air in Empty Containers At Intermediate Temperature

January 22, 1938 — C. H. Worsham

Order of containers in machine:	Temp. of Run in °C: High	Low	Average	% Air in each container	Temp. drop between air and water in °C
1	37.3	34.0	35.4	100	12.5
2	37.1	34.0	35.7	100	12.9
3	37.5	35.0	36.4	100	13.7
4	37.4	35.3	36.5	100	13.9
5	37.7	35.0	36.7	100	14.3
6	39.2	36.4	38.1	100	15.8
7	42.0	38.8	40.7	100	18.6
8	41.8	38.6	40.6	100	18.6
9	41.0	38.1	40.0	100	18.1

Time of run: 6 hours
Cooling water: Inlet - 21.9°C. Outlet - 22.9°C

TABLE XVI

EFFECT OF GAS TREATMENT ON THE TASTE AND ODOR OF OIL PRODUCED.

March 10, 1938 C. H. Worsham

Number of Run	Composition of Gas in Containers		
	100% Air	90% CH_2CH_2	35% CH_2CH_2
1	3	1	2
2	3	1	2
3	2	3	1
4	1	2	3
5	3	1	2
6	3	2	1
7	3	1	1
8	1	2	3
9	2	1	3
10	3	2	1
11	3	2	1
12	3	1	2
Total	30	19	22
Variation	11	0	3

Note: The increasing order of rancidity is indicated by 1, 2, and 3 respectively. The smallest variation indicates the best oil.

TABLE XVII

FINAL EFFECT OF GAS TREATMENT ON OIL SAMPLES

OBTAINED BY C.C. WADDELL.

March 15, 1938 C. H. Worsham

Number of Run	Composition of Gas In Containers			
	100% Air	90% CO_2	90% CH_2CH_2	25% CH_2CH_2
1	1	3	4	2
2	4	3	2	1
3	1	2	3	4
4	2	1	3	4
5	2	4	1	3
6	1	3	4	2
7	4	3	2	1
8	1	2	3	4
9	4	2	1	3
10	3	4	2	1
11	2	1	3	4
12	4	2	3	1
Total	29	30	31	30

Note: The increasing order of rancidity is indicated by 1, 2, 3, and 4 respectively.

IV. DISCUSSION OF RESULTS

Absorbability of CO_2 and CH_2CH_2 by Soybeans.--The results of the absorbability of carbon dioxide and ethylene by whole soybeans are shown in tables 1 through 12 and in figures 1, 2, and 5 through 9. From these tables and figures it will be seen that the amount of gas absorbed by the soybeans varies with the composition in the containers, with the general tendency toward the greatest amount being absorbed in the containers having the greatest concentration of the gas.

An increase of temperature caused a slight decrease in the amount of carbon dioxide and ethylene absorbed by the beans when compared at the same gas composition with no drying taking place. This may be explained by the fact that there was considerable growing of the soybeans at the lower temperature thus increasing the demand for carbon dioxide. As the temperature was increased the soybeans could not grow as readily and the demand for carbon dioxide was decreased.

The amount of carbon dioxide and ethylene absorbed was much greater with the beans being dried than with no drying, when compared at the same gas composition. This is probably due to the replacement of water by the gas when the soybeans were being

dried.

The beans absorbed more carbon dioxide than ethylene when compared at the same gas composition and with no drying taking place. The beans absorbed approximately the same amount of carbon dioxide as ethylene at 37°C., and absorbed more ethylene than carbon dioxide at 50°C. when compared at the same gas composition and with no drying taking place. This may be explained by means of figures 3 and 4. Since there was no drying of the beans at 24°C. there was no replacement of water by carbon dioxide or ethylene at this temperature. During the drying at 37°C. the water was replaced by more ethylene than carbon dioxide, which tended to equalize the amount of ethylene and carbon dioxide absorbed by the soybeans. More drying took place at 50°C. than at 37°C., and from figures 3 and 4 it can be seen that more water was replaced by ethylene than carbon dioxide, with the result that the beans absorbed more ethylene than carbon dioxide at 50°C.

Replacement of Water by CO_2 and CH_2CH_2 in Whole Soybeans.-- Figures 3 and 4 show that in the drying of soybeans, one c.c. of water was replaced by approximately one c.c. of ethylene and replaced by approximately from three to eight-tenths of one c.c. of carbon dioxide. This means that the water was replaced by more ethylene than carbon dioxide with the drying of the soybeans.

Drying of the Whole Soybeans.-- There was no water collected in the drying tubes for the first four runs at 24°C. The second series of runs was made at a temperature of 37°C. At this temperature there was an excessive drying of the soybeans at one end of the apparatus due to the arrangement of the electrical connections to the heating elements. The effect of heating elements on the temperature of air in the empty containers is shown in table 15. The machine was calibrated (table 14) by making a run at this temperature using air in all of the containers as the drying agent. Using this calibration drying data, the values in tables 5b to 8 were corrected on the basis of air drying 10 to 25 c.c. of water per 24 and 48 hours respectively.

From the drying curves in figures 10 and 11 it can be seen that the amount of water collected in the drying tubes at 37 and 50°C. for the containers having air in them, was considerably less than for those containing ethylene and carbon dioxide. The drying rate of the soybeans at 50°C. was approximately eight times that at 37°C. Since the drying rate was so great at 50°C., the water had to be collected for a period of 7 to 9 hours and calculated on the basis of 24 and 48 hour runs in order that the beans could be rolled and pressed without the addition of more water. Also from these

figures it can be seen that the amount of water collected from the containers having ethylene and carbon dioxide in them was the same for the various concentrations of ethylene. This may be explained by noticing that the total amount of ethylene and carbon dioxide was approximately the same in each container, the percentage of air being small. From this it seems that ethylene and carbon dioxide are equally as good drying agents. This may be verified from figure 12 which shows that approximately the same amount of drying was done by the containers having from 70 to 90 % carbon dioxide in them as was done by the ones having an equivalent total percentage of ethylene and carbon dioxide.

The effect of the carbon dioxide on the drying may be also ascertained from figures 10 and 11 that the amount of water collected in the drying tubes for the containers having a 75/25 ratio of carbon dioxide to air in them was slightly greater than for those containing 50/50 ratio of carbon dioxide to air. This may be explained by the fact that the 75/25 ratio of carbon dioxide to air caused a greater growth of the soybeans than the 50/50 ratio of carbon dioxide to air. This greater growth had a tendency to increase the rate of drying.

Figure 12 shows that the water collected from

the containers having carbon dioxide in them varies with the carbon dioxide content in the containers, the higher the carbon dioxide content the more water collected in the drying tubes.

Effect of Gas Treatment on the Taste and Odor of the Oil Produced.-- The oil samples from the beans treated with ethylene and carbon dioxide had less odor than those treated with air. This seems to uphold the idea that ethylene ripens the beans and prevents the peroxidases action.

The amount of ethylene present in the containers appeared to have a slight effect on the odor of the oil obtained from the beans, the container having 90 % ethylene present giving slightly better odors than the one having 35 %. From an economical standpoint, it would be better to use a low percentage of ethylene because such a small difference in quality of product obtained would not counterbalance the high cost of using a high percentage of ethylene which would also increase the danger of explosion hazards by leaking out into the plant. The drying curves show that just as much drying can be obtained by using a high percentage of low-costing carbon dioxide with the ethylene.

After standing from 8 to 15 weeks, the samples of oil taken at 24 and 37°C. had developed no pronounced taste

and very little odor, the ones at 24°C. being slightly better than those at 37°C. After standing from 7 to 8 weeks, the samples of oil taken at 50°C. had developed considerably more odor than those at 24 and 37°C. This may be explained by the fact that from 24 to 37°C. is near the temperature at which the soybeans grow and nature has made them less susceptible to peroxidases action at this temperature. It was noticed that the oil obtained at 50°C. was slightly darker than that obtained at 24 and 37°C. This indicates that there was some action taking place and it is also probable that the higher temperature had a tendency to accelerate the peroxidases action. From an economical standpoint it would be cheaper to dry the soybeans between 24 and 37°C. where the heat losses would be small and also because a better quality of oil would be obtained.

The oil samples from the whole beans treated for 24 hours had considerably less odor than those treated for 48 hours, when the samples were compared at the same temperature, same ratio of carbon dioxide to air, and the same gas composition. This may be explained by the fact that the 24 hour treatment allowed less time for the peroxidases action or oxidation to take place.

The oil samples from the beans treated with 75/25 ratio of carbon dioxide to air had less odor than those

treated with 50/50 ratio of carbon dioxide to air, when the samples were compared at the same temperature, same length of run, and the same gas composition. This shows that carbon dioxide also aids in preventing peroxidases action of oxidation.

It is probable that if the beans were treated in the presence of ethylene and carbon dioxide alone, with all of the air possible removed, a still better grade of soybean oil would be obtained.

The oil samples that were stored without caps on the specimen vials accumulated less odor than the oil in the vials fitted with caps. This is probably due to the tendency for the volatile components constituting the odor to escape into the air while the vials with caps forced the components of the odor to accumulate.

Final Results of the Taste and Odor Tests on Oil Samples Obtained by C. C. Waddell.-- It was found that the oil from the beans for the series of runs at 37°C. had less odor for any one series, the room temperature gave the next best results, and the run at 50°C. gave the most rancid oil. The results at 50°C. are in agreement with the results obtained in this investigation. Since there was such a small difference in the odors obtained at the two temperatures it is likely that letting

the oil that was obtained from the beans treated at room temperature stand one and one-half months longer than at 37°C., caused the 37°C. oil to be better than that obtained at 24°C. From the previous section it can be seen that in this investigation the 24°C. oil was allowed to stand a little longer than the 37°C. oil and it had better taste and odors than the 37°C. oil. Therefore, it would be better to treat soybeans near 24°C. in order to obtain the best grade of oil.

After standing from 8½ to 10 months the oil samples from the beans treated with ethylene and carbon dioxide had less odor than those from the beans treated with air.

After standing from 10½ to 12 months it was found that for the majority of the oil samples from the beans treated with ethylene and carbon dioxide had developed as much odor as those from the beans treated with air. This may be explained by the fact that the protecting effect of the ethylene and carbon dioxide had broken down by either volatilizing away or entering into a chemical reaction.

V. CONCLUSIONS

The conclusions drawn from the results of this investigation are:

1. Oil from the soybeans that have been treated with ethylene and carbon dioxide mixture have better keeping qualities than oil from beans treated with air.

2. In order to obtain the best grade of soybean oil, the soybeans should be treated near 24°C.

3. The amount of ethylene present in the containers appeared to have a slight effect on the odor of the oil obtained from the beans, the container having 90 % ethylene present giving but slightly better odors than the one having 35 %.

4. When soybeans are dried by using an ethylene-carbon dioxide mixture, the rate of drying is the same for the various concentrations of ethylene.

5. When soybeans are dried by using carbon dioxide the rate of drying varies with the carbon dioxide concentration, the larger the carbon dioxide concentration the greater the rate of drying.

6. Soybeans, when treated with ethylene and

carbon dioxide, absorb varying amounts of the gases, depending on the gas concentration and the water removed.

VI. SUMMARY

The object of this investigation was to ripen and dry soybeans in such a way as to prevent the formation of bad taste and odor in the oil.

Field run soybeans were treated in specially constructed gas-tight silos through which mixtures of air, carbon dioxide, and ethylene in varying concentrations were recirculated for the purpose of maturing and stabilizing the beans and to prevent peroxidases action, the latter being credited with imparting the offensive odor and taste to the oil and meal obtained by processing the bean.

Nine silos were run simultaneously with nine different mixes of gases varying between 90 to 35 % ethylene and 10 to 65 % carbon dioxide and air.

Whole beans were treated for 24 and 48 hours at 24, 37, and 50°C., rolled flat in a roll mill and expressed at 45-60°C. in a Carver hydraulic press at 10,000 lb. per sq. inch.

From each sample of beans pressed was taken two samples of oil. One sample was left exposed to the air while the other one was sealed by means of a cap.

From the taste and odor tests it was found that

whole beans treated with ethylene at 24°C. gave the best oil, being only slightly better than the oil from the whole beans treated at 37°C.

Soybeans, when treated with ethylene and carbon dioxide, absorb varying amounts of the gases, depending on the gas concentration and the water removed.

The drying rate of the soybeans by air was considerably less than the drying rate when ethylene and carbon dioxide were used.

VII. BIBLIOGRAPHY

1. Arnold, Gerald D., Portable Apparatus for Drying Corn, Alfalfa, Grass, Peas, Soybeans, Seaweed, Malt, etc., While Preserving Vitaminic and Other Natural Properties, U. S. Patents No. 1,988,677-8, Jan. 22, 1935. C. A. 29, 1290 (1935)

2. Asari, Tugio, Preservation of Soybeans. Japanese Patent No. 101,895, July 7, 1933. C. A. 28, 5900 (1934)

3. Berczeller, Ladislaus, Treating Soybeans. British Patent No. 393,146, June 1, 1933. C. A. 27, 6,001 (1933)

4. Burlison, W. L., Soybeans. Ind. and Engr. Chem. 28, 772 (1936)

5. Coward, H. F. and G. W. Jones, "Limits of Inflammability of Gases and Vapors". U. S. Bureau of Mines, Bulletin 279 (1931)

6. Funk, E. D., "Soybean as a Farm Crop", Proceedings of the Second Dearborn Conference, The Chemical Foundation, 654 Madison Ave., N. Y., 243 (1936)

7. Jones, T. W., Yant, W.P., Miller, W. E., and Kennedy, R. E.,"Limits of Inflammability of Diethyl Ether and Ethylene in Air and Oxygen". Report of Investigations, Dept. of Interior, Bureau of Mines Bulletin No. R. I. 3278, July (1935)

8. Lieberherr, Ernst, Improving Soybeans, etc. Swiss Patent No. 172,720, Jan. 16, 1935. C. A. 29, 5,539 (1935)

9. McGuire, Ray F., "Soybean Values". Soybean Production Advisory Board, Cedar Rapids, Iowa. 11 (1934)

10. Piper, R. M. and W. J. Morse, "The Soybean", McGraw Hill Book Co., Inc., N. Y. (1923)

11. Toussaud, Gabriel P., Treating Oil and Fat-Bearing Seeds, British Patent No. 364,309, Dec. 16, 1930. C. A. 27, 2324 (1933)

12. Waddell, C. C., Drying and Ripening of Soybeans for Beneficiation of Soybean Products, Unpublished Thesis. Library, Virginia Polytechnic Institute, Blacksburg, Virginia. 1937.