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TECHNICAL REPORT

FD-19

STUDY OF THE APPLICATION OF RELATIVE HUMIDITY AND MOISTURE VAPOR PRESSURE MEASUREMENTS FOR THE DETERMINATION OF THE MOISTURE CONTENT OF DEHYDRATED FOODS

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by

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EVANS RESEARCH AND DEVELOPMENT CORPORATION
New York, N. Y.

Contract No. DA 19-129-AMC-55 (N)

August 1965

U. S. Army Materiel Command
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts

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FOREWORD

The moisture-relative humidity relationships of dehydrated foods are of importance to the food scientist in (a) studies of storage stability, (b) calculation of moisture transfer among foods of a multi-component ration, and (c) use of the moisture sorption isotherm as a "standard curve" for moisture measurement.

The present Final Report of Phase I of the contract "Study of the Application of Relative Humidity and Moisture Vapor Pressure Measurements for the Determination of the Moisture Content of Dehydrated Foods" deals with comparative studies of manometric and electrical hygrometric techniques, for utilizing the moisture sorption isotherm as a non-destructive method of determining moisture. It represents work conducted by Evans Research and Development Corporation, between 15 February 1963 and 15 February 1964.

The Contractor's Official Investigators were Mr. A. Block, Mr. F. E. Ellison, and Dr. E. J. Hewitt.

The U. S. Army Natick Laboratories Project Officer was Dr. John G. Kapsalis, and the Alternate Project Officer was Mr. Max Wolf, both of the Food Division.

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SUMMARY

Data obtained in a comparative study of the manometric and electrical hygrometric techniques for using the relative humidity-moisture content relationships of dehydrated foods as a convenient and rapid method for obtaining the moisture content of these foods is presented. Dehydrated cabbage, non-fat milk, red bell peppers, potatoes, rice, chicken, shrimp, mixed fruit, peaches, and apples were used. The lower limits for moisture content determination, the temperature requirements, and the precision (0.1 percent moisture content) for both methods were generally comparable. The elapsed time required for the manometric technique is generally about 0.8 hours as opposed to the 2 hours generally required by the equilibrium hygrometric technique. The actual time spent by personnel per sample for the hygrometric technique was about 0.1 hours as opposed to about 0.3 hours for the manometric technique.

The hygrometric method was somewhat more convenient and had better lot-to-lot reproducibility with the dehydrated chicken samples tested where this factor was studied.

Work on an exchange study of the moisture sorption-desorption process in chicken is reported. The results show an increasing accessibility of adsorption sites above 2.3 percent moisture content and indicate a promising approach to defining critical moisture content values in connection with food stability problems.

INTRODUCTION

On February 15, 1963 Evans Research and Development Corporation w authorized by the U. S. Army QM Research and Engineering Center to conduct a comparative study of the relative humidity and moisture vapor pressure method the determination of the moisture content of dehydrated foods to be made u g samples of starchy foods, protein foods, high sugar-content foods and foo with both high sugar-content and high molecular weight constituents.

These techniques, calibrated by the Association of Official Agric ural Chemists' vacuum oven method, were to be compared in terms of accuracy repro-ducibility, specificity, sensitivity, workable moisture-content range, me, temperature and calibration requirements.

Both procedures have potential advantages over the standard vacuu oven method for determining the moisture content of dehydrated food in not quiring sample preparation and weighing, and in considerably shortening the el ed time of the analysis. Both are based on the relationship between the isture content of dehydrated foods and the relative humiditidy in equilibrium with i. One method measures this relative humidity with an electrical hygromet while the other employs a manometric apparatus.

This final report covers work carried out from February 15, 1963 February 15, 1964 under Evans Research Project No. 9383-621.

EXPERIMENTAL DISCUSSION

I. PREPARATION OF FOODS

All foods examined in this project, which are listed in Table I (APPENDIX), were ground to 20 mesh unless - as in the case of the milk and potatoes - they were already in granular form. The cabbage, peppers, rice, chicken, and shrimp were ground in a Wiley Intermediate Mill. The cabbage was dried before grinding in the vacuum oven for 5-1/2 hours at 45°C using a method similar to that used by B. Makower et al.* to prevent gumming and clogging in the mill. The dried fruits were ground by placing just less than one ounce of sample in a Waring Blender for 10 seconds. The product was then passed through a 20 mesh screen. Seventy-five-gram samples were then placed on evaporating dishes and their moisture content either decreased by placing them in a desiccator containing magnesium perchlorate or increased by placing them in a desiccator containing water or saturated potassium chloride (85 percent R.H.) as indicated in Table I (APPENDIX). The samples were then transferred to 16-ounce, screw-cap jars which were mixed on a roller mill for one hour.

II. METHODS OF ANALYSIS

A. Vacuum Oven Method

The procedure used was the official A.O.A.C. method (Association of Official Agricultural Chemists, 9th. Edition 1960). The milk and rice were run for 5 hours at 100°C, while the cabbage, peppers, potatoes, chicken, and shrimp were run for 20 hours at 70°C. The dried fruits were mixed with asbestos and dried for six hours at 70°C according to A.O.A.C. Method 20.008. Moisture content determinations are expressed as weight percent on a dry basis.

B. Electrical Hygrometer Method

An Electrical Hygrometer Indicator, made by Hygrodynamics, Inc., Silver Springs, Maryland catalog No. 15-3000 was used in conjunction with factory-calibrated, narrow-range, Dunmore-type, humidity-sensing elements (type TH). These elements are warranted accurate to ± 1.5 percent R.H. for one year of normal usage. Two elements in each of the seven narrow R.H. ranges from 1.6 to 59 percent were used.

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*Industrial and Engineering Chemistry 38, 725 (1946)

The food under examination was placed in a wide mouth 16-ounce bottle (Fisher Scientific Co., catalog No. 3-316) to a depth of about 0.5 inches. This bottle was approximately 3 inches wide by 4 inches high.

Holes were drilled through the plastic caps that were supplied with these bottles and the element mounts were screwed into them. The elements were plugged into the mounts and suspended above the food in a closed system by screwing the caps on the bottles. The element mounting terminals were connected to a six position rotary switch which was in turn connected to the indicator.

Once the element with the proper relative humidity range had been selected, readings were taken on the indicator at short intervals until the readings fluctuated around a constant value. At this time the water vapor in the jar was in equilibrium with the water sorbed on the food. The relative humidity in the bottle was obtained from the indicator readings by referring to the calibration chart that was provided with each element. Figure 1 (APPENDIX) shows this apparatus in use.

C. Manometric Method

The design of the apparatus, which is shown in Figure 2 (APPENDIX), closely followed the description of the equipment used by J. F. Vincent and K. E. Bristol.*

At the left of the picture is a Dubrovin Vacuum Gauge which was made by the Welch Scientific Co. The pressure is read directly on a scale calibrated from 0 to 20 mm of Hg in graduations of 0.2 mm of Hg.

The cold trap at the right of the picture is immediately followed by a vacuum pump which is not shown.

The glassware in the center of the picture was fabrica . by Fisher Scientific Co. Its overall length is 9.5 inches. In use, a 100 ml round bottom flask containing the dried food under examination is attached to the apparatus. To the right of this flask is a permanently attached freeze-out trap which has a volume of 100 ml.

The following procedure was followed when a determination was made.

---

*Industrial and Engineering Chemistry, Analytical Edition 17, 465 (1945)

A one hundred ml round bottom flask, which contained the dried food, was attached to the apparatus and the system was evacuated by means of the vacuum pump for three minutes. Although specially designed experiments showed that the period of evacuation was not critical, this value was kept constant for the sake of consistency. At the end of this time the pressure in the system, as measured by the Dubrovin Gauge, was less than one mm of Hg.

The stopcock between the two freeze out traps was closed and the apparatus was left undisturbed until the pressure had increased to a constant value. This value was recorded. At this time the water vapor above the food was in equilibrium with the water sorbed on the food.

The stopcock between the round bottom flask containing the food and the rest of the apparatus was not closed and the 100 ml cold trap was immersed in a dry ice/ethanol bath. The pressure in the system decreased as the water vapor was frozen out in the cold trap. When the pressure became constant, its value was recorded. The difference between the two vapor pressures that were recorded was the vapor pressure of water in the system. Any air that was desorbed from the food would not be condensed in the cold trap and, therefore, its partial pressure was not erroneously added to the partial pressure of the water vapor.

The relative humidity in equilibrium with the food was calculated from the experimentally determined partial pressure of water vapor above the food and the vapor pressure of water at the temperature of the determination. The last value was obtained from the Handbook of Chemistry and Physics, (43rd ed.; Cleveland, Ohio: Chemical Rubber Publishing Co., 1961-2).

III. COMPARISON OF METHODS

A. Curves of Moisture Content vs Relative Humidity

Figures 3 to 11 (APPENDIX) show the effect of varying the moisture content as determined by vacuum oven analysis of individual foods on the relative humidity in equilibrium with these foods. In the lower curves the relative humidity values have been determined using the electrical hygrometer while for the curves just above them the values were determined with the manometric apparatus. At any given humidity the moisture content of the food was greater when determined with the manometric samples than with the hygrometric samples. The most probable explanation for this is the fact that in the manometric

procedure, which is run in the absence of other gases, equilibrium is established between the water vapor and the food samples without the competition of other gases. This enables the readsorption of greater amounts of water than in the hygrometric apparatus, where this competition does exist.

Since the manometric procedure employed an initial evacuation, moisture was initially partially desorbed off the food samples. Moisture contents of the samples after use in the manometric apparatus were determined in order to obtain the actual equilibrium relationship between the moisture content and relative humidity. However, for the analytical use the relationship between the moisture contents of the samples before use in the manometric apparatus, and the relative humidity was obtained. These are the top curves in the graphs.

B. Lower Limits of Moisture Content Determination

The lowest R.H. that can be measured with the electrical hygrometer is 1.6 percent R.H. as opposed to 0.00 percent for the manometric method. However, because for a given moisture content the R.H. is lower by the manometric technique, the lower limits for moisture content determination by both methods are comparable.

C. Sensitivity

The hygrometer is sensitive to changes in R.H. of 0.15 percent R.H. In some of the steeper portions of the curves of R.H. vs. moisture content this would correspond to 0.03 percent moisture content. On the other hand the manometer is sensitive to 0.01 percent changes in R.H.

D. Deviation of Results from Vacuum Oven Analyses

Values for the moisture contents of the various samples were obtained using the relative humidity values and the appropriate calibration curves which are plotted in Figures 3-13. Deviations of these values from the vacuum oven analysis values for the individual samples are indicated in the last column of Tables 2-12 (APPENDIX). A summary of the standard deviation of these values from the vacuum oven values as well as the standard deviation of the vacuum oven analyses is given in Table 13 (APPENDIX). These results indicate that the standard deviation from the vacuum oven values of the two methods of analysis were generally comparable with the exception of the peach results and close to the standard deviation of the vacuum oven analyses.

The results of the moisture determinations run simultaneously on lots 2P and 5P of precooked freeze-dried chicken are summarized in Tables XI and XII, respectively. In Figure 12 the relative humidity of the chicken, as measured by the hygrometric method, is plotted as a function of the actual moisture content, as measured by the vacuum oven method. This graph indicates that, for the hygrometric method, the data for the two lots falls on one curve. On the other hand, when relative humidity of the two lots, as measured by the manometric method, is plotted as a function of food moisture content (Figures 13 and 14), separate curves are obtained for the two lots. (The actual moisture content used for Figure 14 is based on vacuum oven analyses carried out after the run and that for Figure 13 is based on analyses before the run). A possible explanation of this lot-to-lot difference in the manometric method is that the number of desorption sites exposed by air desorption varied from lot-to-lot.

The accuracy of the two methods when applied to the chicken was determined by reading the various moisture contents of each of the two lots off the calibration curve prepared from the data for the other. These values are shown in Tables XI and XII. The deviation of these values from the vacuum oven analyses are also shown. The standard deviation of the moisture content for the hygrometric method is 0.12 percent moisture content and that for the manometric method is 0.57 percent moisture content.

E. Temperature Requirements

The manometric and hygrometric procedures for the shrimp, chicken and dried fruit were run using a temperature controlled bath of 25°C ± 0.2°C.

The results for the cabbage, milk, peppers, potatoes and rice were obtained without special temperature control in a room having an average temperature of 26°C with an average deviation of ± 1.3°C. The average calculated error in the moisture content values for the various foods caused by this deviation is indicated in column 2 of Table XIV (APPENDIX). These values were obtained from moisture sorption isotherms at 72 and 100°F supplied by the U. S. Army Quartermaster Research and Engineering Command. Calculations of the errors of the two techniques without the error caused by (a) temperature, and (b) temperature and vacuum oven analysis deviations were made as indicated by the equations in Table XIV (APPENDIX). After correction for the effect of temperature the average calculated deviation of the hygrometric results was 0.09 percent moisture content while the value for the manometric technique was 0.06 percent moisture content. Table XII indicates that there was no significant difference in the standard deviations of the foods run at 26° ± 1.3°C and those run at 25° ± 0.2°C. However, it is felt that it is better practise to employ temperature control.

F. Distinction Between Water and Other Volatile Compounds

The hygroscopic film of the Dunmore Sensor used in the electrical hygrometer is sensitive only to water vapor pressure. While the manometric technique measures the pressure of all dry ice bath (-80°C) condensable vapors it is extremely unlikely that this would be anything but water vapor pressure under the room temperature conditions of the analysis.

G. Calibration Requirements

The Dunmore Sensors used were factory calibrated and warranted to be accurate to ± 1.5 percent. The manometric apparatus used was checked with saturated magnesium chloride and potassium acetate salt solution and found to be accurate to within 0.6 percent R.H.

Dunmore type sensors do exhibit a slight change of calibration with time. Page 614 of the Hygrodynamics, Inc. catalog states that one group of sensors changed by 1.8 percent R.H. in six years. G. O. Handegord et al.* states that "Storage over dessicant with occasional use over a period of two years resulted in a shift in calibration that exceeded 1 percent R.H. for approximately half the sensors." On the other hand the manometric apparatus would not exhibit any such change in accuracy.

H. Time Requirements

The elapsed time for an analysis by the hygrometric technique varied from 0.5 to 20 hours with most samples taking about 2 hours. The actual time spent by personnel per sample was about 0.1 hour. There was no apparent relationship between the sample's moisture content and its rate of attainment of equilibrium.

The time required for the manometric technique varied from 0.3 to 1.3 hours with most samples taking about 0.8 hours. The actual time spent per sample was about 0.3 hours. Samples with the lower relative humidity took the shorter time while those with the higher R.H. values took the longest. Representative curves for the rate of attainment of equilibrium for this method are shown in Figures 15 and 16.

---

*Paper C4.1.3, 1963 International Symposium on Humidity and Moisture, May 20-3, 1963, Washington D. C.

IV. STUDY OF HYDROGEN EXCHANGE DURING MOISTURE SORPTION

A. Preparation of Samples

Glass jars, 6.0 cm high by 5.0 cm in diameter, having an 89 ml capacity were used for this experiment. The jars were equipped with plastic screw caps having a hard paraffin liner. Two-gram samples of lot 5P dehydrated chicken (1.687 percent moisture content) were weighed into the jars, after which the samples were covered by 2-centimeter squares of aluminum. Different amounts of water (see column No. 1, Table XV) labelled with the tritium radioisotope of hydrogen (at a specific activity of 87 microcuries* per gram) were then added to the jars by desposition onto the foil squares. Those amounts smaller than 100 mg were added using "Microcap" disposable pipettes,** after which the pipettes were added to the jars. Standard pipettes were used for addition of those amounts of tritiated water larger than 100 mg. The caps were then screwed on the jars and the caps sealed with one layer of tape. After one day of equilibration, no water was left on the foil. The jars were then rotated for 1/2 hour at 25 R.P.M. and allowed to equilibrate for a total number of days indicated in Table XV, during and at the end of which they were again rotated.

B. Measurement of the Water Vapor Radioactivity

Following the equilibration of the food with the tritium-labelled water, the isotopic dilution of the water vapor by the food was determined by measuring the radio-activity of the water vapor in equilibrium with the food. For this measurement the jar containing the food was swiftly removed from its cap and screwed on to a cap which had an inlet and outlet tube leading to the radioactivity measuring instrument. The jar with the connection is shown in Figure 17. The 1/8 inch O.D. threaded, stainless steel tubing was secured through the cap using a lock nut and gasket. After reinforcement of the cap by cementing on a 6 mm-thick piece of lucite, two holes were bored 3 cm apart on the diameter. The inlet tube penetrated 4 cm into the jar while the exit tube penetrated 2 cm. Both tubes extended 3 cm above the cap. The exit tube contained a small plug of glass wool. The air above the food was pumped into the 275 ml flow Cary Tolbert ionization chamber***

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*One microcurie = 2.22×10^6 disintegrations per minute.

**Supplied by Drummond Scientific Company, Broomall, Pa.

***Supplied by the Applied Physics Corporation, Monrovia, Calif.

connected to the Cary 32 Vibrating Reed Electrometer* to measure its radioactivity. The pumping was done using a "Kinetic Clamp" model OV20.** This is a peristaltic type pump, the flow rate of which was 50 ml per minute in this experiment. The exit tube was connected by 20 cm of vinyl tubing (2.8 mm I.D., 6 mm O.D.) and 10 cm of glass tubing to a glass socket which was greased and clamped to one of the two 18 mm diameter ball joints of the ionization chamber. The inlet tube was similarly connected by 40 cm of the vinyl tubing, part of which was wound through the "Kinetic Clamp" to the other joint.

Pumping was then started and the jar placed in a thermostatically controlled bath at 25° ± 0.2°C. The atmosphere in the jar was allowed to equilibrate with the air in the ion chamber for two hours, during which time the jar was periodically shaken by hand to expose fresh food surface. Before each run the air in the ion chamber and connections was dried by circulating it for one hour through a drying tower containing "Drierite". The radioactivity was determined by measuring the rate of charge build-up expressed in millivolts per minute. The greater the radioactivity in the ion chamber, the greater the ionization, and the greater the millivolts per minute. The results are shown in column No. 6 of Table XV.

C. Calculation of the Amount of Exchange

The amount of radioactivity added to the individual food jars was obtained by multiplying the amount of radioactive water added, by the radioactivity per given amount of radioactive water. The latter, expressed as mv/min/R.H., was determined by measuring the radioactivity in the ion chamber when the air in the ion chamber is in equilibrium with the air over saturated salt solutions at 25°C ± 0.2°C, the salt solutions being contained in the jars instead of the food. The solutions were made with the undiluted, tritiated water (87 microcuries per gram). The lithium chloride solution, which has an R.H. of 11.05 percent*** gave 21.5 mv/min; the potassium acetate solution, which has an R.H. of 22.45 percent, gave 502 mv/min; and the sodium bromide solution, which has an R.H. of 57.7 percent, gave 1244 mv/min. Figure 18 is a plot of R.H. versus radioactivity. The slope of this line is 21.5 mv/min/R.H.

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*Supplied by the Applied Physics Corporation, Monrovia, Calif.

**Made by Sigmamotor Incorporated, Middleport, N. Y.

***R.H. Stokes and R.A. Robinson, Industrial and Engineering Chemistry 41, 2013 (1949)

The amount of radioactivity present after equilibration of the food with the tritiated water is obtained by multiplying the amount of water present in the vapor plus the exchangeable hydrogens (expressed as an equivalent amount of water) by the final radioactivity per given amount of water. The amounts of various groups in chicken protein which contain potentially exchangeable hydrogens equivalent to 18 mgs of water are 34 mgs of OH, 16 mgs of NH_2, 30 mgs of NH, 90 mgs of COOH, and 60 mgs of SH.

The initial total activity is equal to the final total activity. Using this equality we can solve for the number of hydrogens exchanged, expressed as equivalent milligrams of water in the following fashion.

$$\begin{bmatrix} H_2^3O \text{ Added} \\ \text{(mgs)} \end{bmatrix} \begin{bmatrix} \text{Initial specific} \\ \text{radioactivity} \\ \text{(mv/min/R.H.)} \end{bmatrix} = \begin{bmatrix} \text{Total } H_2O + \text{Exchange H} \\ \text{(Equiv. mgs of } H_2O) \end{bmatrix} \begin{bmatrix} \text{Final specific} \\ \text{radioactivity} \\ \text{(mv/min/R.H.)} \end{bmatrix}$$

$$\begin{bmatrix} \text{Exchange H} \\ \text{(Equiv. mgs of } H_2O) \end{bmatrix} = \frac{\begin{bmatrix} H_2^3O \text{ Added} \\ \text{(mgs)} \end{bmatrix} \begin{bmatrix} \text{Initial specific} \\ \text{radioactivity} \\ \text{(mv/min/R.H.)} \end{bmatrix}}{\begin{bmatrix} \text{Final specific} \\ \text{radioactivity} \\ \text{(mv/min/R.H.)} \end{bmatrix}} - \begin{bmatrix} \text{Total } H_2O \\ \text{(mgs)} \end{bmatrix}$$

The results of this calculation for the various samples are shown in Table XV and the polar group accessibility, expressed as equivalent amount of moisture content, is plotted as a function of moisture content in Figure 20. This plot shows an increased accessibility of groups which are considered* to be water sorption sites with increasing moisture content. A similar increase in accessibility was found by Bettelheim** in his work on mucopolysaccharides. He attributed this increase to a zipper mechanism,"... Water molecules ... penetrate into the whole matrix by occupying the free sites causing partial swelling, next breaking existing hydrogen bonds between polymer chains and establishing new ones with the sorbate".

---

*L. Pauling, Journal of the American Chemical Society 67, 555 (1945)

**F. Bettelheim and S.H. Ehrlich, Journal of Physical Chemistry 67, 1948-1960 (1963)

The plot in Figure 20 shows an increase in accessibility of adsorption sites at 2.3 percent moisture content, with a still more rapid increase beginning at 3.0 percent moisture content.

The results obtained in the present work on adsorptive site accessibility are interesting in connection with the use of moisture sorption isotherms and the B.E.T.* equation in food stability problems. It may be that the point at which site accessibility increases rapidly is a critical point in food stability.

---

*S. Brunauer, P.H. Emmett, and E. Teller, Journal of the American Chemical Society 60, 309 (1938)

APPENDIX

Tables I-XV

Figures 1-20

TABLE I

DESCRIPTION OF FOODS

Food	Description	Lot Number	Supplier	Original Moisture Content (%)	Exposure Period (days) to		
					$MgClO_4$	H_2O	Sat'd KCl
Cabbage	Unblanched dices (3/8")		California Vegetable Concentrates Inc., Modesto, California	-	6	0.79	
Red Bell Peppers	dices (1/4")		California Vegetable Concentrates Inc., Modesto, California	7.0	0.79	0.79	
Non-Fat Milk	Carnation Instant		-	3.7	14	0.27	
Potatoes	French's Instant Mashed		-	7.6	15	2.5	
Rice	Uncle Ben's New Quick Pre-Cooked		-	11.4	14	[illegible]	
Chicken Lot 1	Cooked-diced (3/8") freeze-dried meat (in natural proportions)	057L3 5P520	United Fruit & Food Corp., Boston, Mass.	2.84	-		6
Chicken Lot 2	Cooked-diced (3/8") freeze-dried meat (in natural proportions)	057L3 2P520	United Fruit & Food Corp., Boston, Mass.	2.04	-		6
Shrimp	Cooked, whole, freeze-dried	1232-40 L4	United Fruit & Food Corp., Boston, Mass.	3.68	-		0.75
Apples	Perforated slices	-	Vacu-Dry Co. Oakland, Calif.	3.7	14		0.13
Peaches	slices	124MO A04A2	Vacu-Dry Co. Oakland, Calif.	3.3	21		3
Mixed Fruit	Fruit Galaxy	136X0 85364	Vacu-Dry Co. Oakland, Calif.	3.4	21		3

TABLE II

VARIATION OF EQUILIBRIUM RELATIVE HUMIDITY

WITH SAMPLE MOISTURE CONTENT FOR

UNBLANCHED CABBAGE

Technique	* M.C.	** Dev.	Aver. M.C.	Aver.** Dev.	Technique	R.H.	Aver. R.H.	Derived M.C.	Deviation from Vacuum Oven M.C.	
	2.393	0.053				4.2		2.49	0.10	
	2.515	0.022	2.454	0.061		4.0	4.1	2.45	0.07	
	3.557	0.043				12.1		3.53	0.03	
Vacuum Oven (on Untreated Sample)	3.650	0.013	3.604	0.046		12.9	12.5	3.69	0.04	
	6.085	0.064				24.3		5.95	0.14	
	6.318	0.035	6.202	0.116	Hygrometric	26.1	25.2	6.43	0.11	
	8.921	0.042				36.5		8.93	0.01	
	8.928	0.070	8.925	0.003		36.5	36.5	8.93	0.00	
Std. Dev.		0.050			Std. Dev.				0.08	
	2.593	0.005	2.593			0.356	0.356	2.59		
	3.472	0.074				3.52		3.47	0.00	
Vacuum Oven (on Sample after Determination of M.C. by Manometric Method)	3.466	0.067	3.469	0.003		3.52	3.52	3.47	0.00	
	5.868	0.097				17.8		5.78	0.09	
	5.643	0.059	5.756	0.112	Manometric	17.1	17.5	5.65	0.01	
	6.407	0.0[illegible]				20.8		6.28	0.14	
	6.190	0.147	6.299	0.109		21.4	21.1	6.39	0.20	
	8.273	0.028				28.0		8.06	0.21	
	8.065	0.006	8.169	0.104		28.4	28.2	8.25	0.18	
			2.454			0.356	0.356	2.45		0.00
						3.52		3.60		0.00
Vacuum Oven (on Untreated Sample)			3.604	0.046		3.52	3.52	3.60		0.00
					Manometric	17.8		6.28		0.08
			6.202	0.116		17.1	17.5	6.12		0.08
						28.0		8.85		0.07
			8.925	0.004		28.4	28.2	9.00		0.07
					Std. Dev.					0.06

*Moisture content (average of two samples)

**Deviation between the moisture contents of the two samples tested.

***Deviation between M.C. and Aver. M.C.

TABLE III

VARIATION OF EQUILIBRIUM RELATIVE HUMIDITY

WITH SAMPLE MOISTURE CONTENT FOR

CARNATION INSTANT NON-FAT MILK

Technique	M.C.	Dev.	Aver. M.C.	Aver. Dev.	Technique	R.H.	Aver. R.H.	Derived M.C.	Deviation From Vacuum Oven M.C.	
	2.514	0.018				1.7		2.48	0.03	
	2.517	0.092	2.516	0.002		2.1	1.9	2.54	0.02	
Vacuum Oven (on Untreated Sample)	3.356	0.002				8.8		3.45	0.09	
	3.467	0.014	3.412	0.056		8.1	8.45	3.38	0.09	
	3.875	0.002			Hygrometric	16.0		3.96	0.08	
	3.826	0.003	3.851	0.025		13.4	14.7	3.79	0.04	
	5.769	0.032				30.5		5.74	0.03	
	5.711	0.020	5.740	0.029		30.5	30.5	5.74	0.03	
	7.197	0.021				36.0		7.09	0.11	
	7.276	0.250	7.237	0.040		37.0	36.5	7.39	0.11	
Std. Dev.		0.090			Std. Dev.				0.07	
	3.244	0.125				2.79		3.21	0.03	
	3.241	0.089	3.243	0.002		3.59	3.19	3.28	0.04	
Vacuum Oven (on Sample After Determination of M.C. by Manometric Method)	3.789	0.048				6.99		3.70	0.09	
	3.741	0.032	3.765	0.024	Manometric	7.55	7.27	3.79	0.05	
	5.401	0.099				19.5		5.21	0.19	
	5.334	0.029	5.368	0.034		21.5	20.5	5.46	0.13	
	6.610	0.018				30.4		6.65	0.06	
	6.697	0.066	6.654	0.044		30.4	30.4	6.65	0.05	
						2.79		3.40		0.01
			3.412	0.056		3.59	3.19	3.48		0.07
Vacuum Oven (on Untreated Sample)						6.99		3.83		0.02
			3.851	0.025	Manometric	7.55	7.27	3.90		0.05
						19.5		5.58		0.16
			5.740	0.029		21.5	20.5	5.88		0.14
						30.4		7.24		0.00
			7.237	0.040		30.4	30.4	7.24		0.00
					Std. Dev.					0.09

TABLE IV

VARIATION OF EQUILIBRIUM RELATIVE HUMIDITY

WITH SAMPLE MOISTURE CONTENT FOR

RED BELL PEPPERS

Technique	M.C.	Dev.	Aver. M.C.	Aver. Dev.	Technique	R.H.	Aver. R.H.	Derived M.C.	Deviation from vacuum oven M.C.	
	5.050	0.070				16.0		4.96	0.10	
	4.959	0.075	5.009	0.049		17.5	16.8	5.04	0.08	
	5.818	0.042				25.5		5.82	0.00	
Vacuum Oven (on Untreated Sample)	5.958	0.074	5.888	0.070		25.8	25.7	5.93	0.03	
	6.656	0.079				28.0		6.53	0.13	
	6.680	0.096	6.673	0.017	Hygrometric	28.5	28.3	6.65	0.04	
	7.022	0.059				29.0		6.80	0.22	
	6.905	0.103	6.964	0.059		29.0	29.0	6.80	0.11	
	8.171	0.037				34.0		8.17	0.00	
	8.049	0.136	8.110	0.061		34.1	34.1	8.19	0.14	
Std. Dev.		0.077			Std. Dev.				0.11	
	5.195	0.092				7.96		5.03	0.17	
	4.863	0.081	5.029	0.166		8.76	8.36	5.04	0.17	
	5.562	0.052				14.4		5.43	0.13	
Vacuum Oven (on Sample after Determination of M.C. by Manometric Method)	5.446	0.041	5.504	0.058		15.6	15.0	5.58	0.13	
	6.623	0.084				23.9		6.73	0.11	
	6.607	0.137	6.615	0.008	Manometric	22.6	23.3	6.53	0.08	
	7.589	0.013				28.4		7.60	0.01	
	7.618	0.009	7.604	0.015		28.4	28.4	7.60	0.02	
	9.963	0.046				37.7		10.30	0.34	
	10.11	0.03	10.04	0.08		36.2	37.0	9.70	0.41	
						7.96		4.96		0.05
			5.009	0.049		8.76	8.36	5.08		0.07
						14.4		5.79		0.10
Vacuum Oven (on Untreated Sample)			5.888	0.070		15.6	15.0	5.95		0.06
						23.9		7.08		0.12
			6.964	0.059	Manometric	22.6	23.3	6.88		[illegible]
						28.4		8.11		0.[illegible]
			8.110	0.061		28.4	28.4	8.11		0.00
						37.7		11.18		0.36
			10.82	0.05		36.2	37.0	10.50		0.32
Std. Dev.					Std. Dev.					0.18

TABLE V

VARIATION OF EQUILIBRIUM RELATIVE HUMIDITY

WITH SAMPLE MOISTURE CONTENT FOR

FRENCH'S INSTANT POTATOES

Technique	M.C.	Dev.	Aver. M.C.	Aver. Dev.	Technique	R.H.	Aver. R.H.	Derived M.C.	Deviation From Vacuum Oven M.C.	
Vacuum Oven (on Untreated Sample)	3.919	0.005			Hygrometric	5.0		3.99	0.07	
	3.943	0.034	3.931	0.012		5.4	5.2	4.06	0.12	
	5.213	0.069				13.6		5.37	0.16	
	5.212	0.035	5.213	0.001		13.4	13.5	5.34	0.13	
	7.496	0.005				26.5		7.44	0.05	
	7.676	0.008	7.586	0.090		26.7	26.6	7.48	0.20	
	8.658	0.084				35.5		8.89	0.23	
	8.853	0.044	8.756	0.098		36.0	35.8	8.97	0.12	
	9.413	0.026				38.0		9.27	0.14	
	9.442	0.103	9.428	0.015		38.5	38.3	9.37	0.07	
Std. Dev.		0.055			Std. Dev.				0.15	
Vacuum Oven (on Sample After Determination of M.C. by Manometric Method)	3.923	0.015			Manometric	0.54		3.83	0.09	
	3.847	0.033	3.885	0.038		1.10	0.87	3.95	0.10	
	4.975	0.109				7.20		4.96	0.02	
	4.863	0.053	4.919	0.056		7.55	7.38	5.03	0.17	
	6.870	0.108				17.8		6.83	0.04	
	7.070	0.010	6.970	0.100		19.1	18.5	7.03	0.04	
	7.698	0.012				21.3		7.43	0.27	
	7.431	0.527	7.565	0.135		22.3	21.8	7.69	0.26	
	8.798	0.041				24.9		8.62	0.18	
	8.759	0.024	8.779	0.019		25.7	25.3	8.83	0.07	
	12.13	0.06				44.7		12.05	0.08	
	11.82	0.08	11.98	0.16		43.8	44.3	12.88	0.06	
Vacuum Oven (on Untreated Sample)					Manometric	0.64		3.86		0.07
			3.931	0.012		1.10	0.87	3.96		0.03
						7.20		5.18		0.03
			5.213	0.001		7.55	7.38	5.24		0.03
						17.8		7.40		0.19
			7.586	0.090		19.1	18.5	7.80		0.21
						21.3		8.53		0.23
			8.756	0.098		22.3	21.8	8.83		0.07
						24.9		9.38		0.05
			9.428	0.015		25.7	25.3	9.58		0.15
						44.7		13.48		0.08
			13.40	0.01		43.8	44.3	13.30		0.10
					Std. Dev.					0.13

TABLE VI

VARIATION OF EQUILIBRIUM RELATIVE HUMIDITY

WITH SAMPLE MOISTURE CONTENT FOR

UNCLE BEN'S INSTANT RICE

Technique	M.C.	Dev.	Aver. M.C.	Aver. Dev.	Technique	R.H.	Aver. R.H.	Derived M.C.	Deviation From Vacuum Oven M.C.	
Vacuum Oven (on Untreated Sample)	3.976	0.102			Hygrometric	4.60		3.90	0.08	
	3.601	0.003	3.789	0.187		4.40	4.50	3.70	0.10	
	5.996	0.034				8.40		5.94	0.06	
	5.892	0.022	5.944	0.052		8.40	8.40	5.94	0.05	
	9.938	0.019				26.0		9.82	0.12	
	9.916	0.061	9.927	0.011		28.0	27.0	10.01	0.09	
	11.31	0.03				43.0		11.39	0.08	
	11.47	0.02	11.39	0.08		43.0	43.0	11.39	0.08	
	12.99	0.02				49.5		12.62	0.37	
	12.98	0.04	12.99	0.01		52.0	50.8	13.40	0.42	
Std. Dev.		0.046			Std. Dev.				0.20	
Vacuum Oven (on Sample After Determination of M.C. by Manometric Method)	3.560	0.174			Manometric	0.76		3.76	0.20	
	3.951	0.009	3.756	0.196		0.76	0.76	3.76	0.19	
	5.587	0.010				4.33		5.59	0.00	
	5.559	0.010	5.573	0.014		4.06	4.20	5.49	0.07	
	8.764	0.093				15.1		8.69	0.07	
	8.606	0.089	8.685	0.079		15.1	15.1	8.69	0.08	
	10.27	0.03				25.4		10.27	0.00	
	10.24	0.15	10.26	0.02		25.8	25.6	10.31	0.07	
	11.32	0.01				32.2		11.21	0.11	
	11.16	0.19	11.24	0.08		32.6	32.4	11.28	0.12	
	13.90	0.02				44.0		13.83	0.07	
	13.72	0.07	13.81	0.09		43.8	43.9	13.75	0.03	
Vacuum Oven (on Untreated Sample)					Manometric	0.76		3.79		0.00
			3.789	0.187		0.76	0.76	3.79		0.00
						4.33		6.00		0.06
			5.944	0.052		4.06	4.20	5.89		0.05
						15.1		9.93		0.00
			9.927	0.011		15.1	15.1	9.93		0.00
						25.4		11.32		0.07
			11.39	0.08		25.8	25.6	11.43		0.04
						32.2		12.93		0.06
			12.99	0.01		32.6	32.4	13.03		0.04
						44.0		15.97		0.05
			15.92	0.08		43.8	43.9	15.86		0.06
					Std. Dev.					0.05

TABLE VII

VARIATION OF EQUILIBRIUM RELATIVE HUMIDITY

WITH SAMPLE MOISTURE CONTENT FOR

SHRIMP

Technique	M.C.	Dev.	Aver. M.C.	Aver. Dev.	Technique	R.H.	Aver. R.H.	Derived M.C.	Deviation From Vac. Oven M.C.
Vacuum Oven (on Untreated Sample)	3.525	0.025			Hygrometric	7.2		3.68	0.15
	3.827	0.006	3.676	0.151		7.0	7.1	-	-
	4.751	0.063				12.2		4.70	0.05
	4.845	0.041	4.798	0.047		13.3	12.8	4.90	0.05
	-	-				18.4		-	-
	-	-	5.991	0.008		18.3	18.4	-	-
	8.242	0.003				33.4		8.38	0.14
	8.221	0.040	8.232	0.010		32.5	33.0	8.23	0.01
	9.460	0.102				41.0		9.50	0.04
	9.692	0.129	9.576	0.116		41.8	41.4	-	-
Std. Dev.		0.071			Std. Dev.				0.10
Vacuum Oven (on Sample After Determination of M.C. by Manometric Method)	2.757	0.030			Manometric	1.05			
	2.801	0.002	2.779	0.022		1.68	1.37		
	5.443	0.114				8.00			
	5.560	0.032	5.502	0.059		8.00	8.00		
	7.455	0.017				17.3			
	7.435	0.030	7.445	0.010		16.4	16.8		
	8.320	0.069				26.1			
	8.423	0.069	8.372	0.051		23.6	24.8		
Vacuum Oven (on Untreated Sample)					Manometric	1.05		-	
			3.676	0.151		1.68	1.37	3.90	0.22
						8.00		6.00	0.00
			5.991	0.008		8.00	8.0	6.00	0.00
						17.26		8.15	0.08
			8.232	0.010		16.41	16.8	8.33	0.10
						26.09		-	-
			9.576	0.116		23.59	24.8	9.43	0.15
					Std. Dev.				0.13

TABLE VIII

VARIATION OF EQUILIBRIUM RELATIVE HUMIDITY WITH SAMPLE MOISTURE CONTENT FOR MIXED FRUIT

Technique	M.C.	Dev.	Aver. M.C.	Aver. Dev.	Technique	R.H.	Aver. R.H.	Derived M.C.	Deviation From Vac. Oven M.C.
Vacuum Oven (on Untreated Sample) Δ	0.717	0.127			Hygrometric	3.10		0.72	0.00
	0.663	0.053	0.690	0.027		2.80	2.95	0.68	0.02
	3.537	0.015				22.7		3.35	0.19
	3.248	0.329	3.393*	0.145		23.2	23.0	3.43	0.18
	4.987	0.139				29.6		5.02	0.03
	5.249	0.092	5.118	0.131		29.6	29.6	5.02	0.23
	7.754	0.010				38.0		7.55	0.20
	7.741	0.130	7.748	0.007		39.7	38.9	7.95	0.21
Std. Dev.		0.157			Std. Dev.				0.17
Vacuum Oven (on Sample After Determination of M.C. by Manometric Method) O	1.209	0.068			Manometric	0.42			
	0.981	0.0416	1.095	0.114		0.84	0.63		
	3.284	0.219				21.7			
	3.510	0.084	3.397	0.113		21.7	21.7		
	4.814	0.018				30.7			
	4.996	0.248	4.905	0.091		30.3	30.5		
	8.625	0.068				37.0			
	9.236	0.206	8.931	0.306		37.0	37.0		
Vacuum Oven (on Untreated Sample) ◇					Manometric	0.42		0.68	0.01
			0.690	0.027		0.84	0.63	0.70	0.01
						21.7		3.39	0.00
			3.393	0.145		21.7	21.7	3.39	0.00
						30.7		5.15	0.03
			5.118	0.131		30.3	30.5	5.10	0.02
						37.0		7.75	0.00
			7.748	0.007		37.0	37.0	7.75	0.00
					Std. dev.				0.015

*Moisture Content Analysis
Vacuum oven drying of this sample for 16 hours instead of the A.O.A.C. recommended 6 hours gave a moisture content value of 5.2 ± 0.3%.

TABLE IX

VARIATION OF EQUILIBRIUM RELATIVE HUMIDITY WITH SAMPLE MOISTURE CONTENT FOR DRIED APPLES

Technique	M.C.	Dev.	Aver. M.C.	Aver. Dev.	Technique	R.H.	Aver. R.H.	Derived M.C.	Deviation From Vac. Oven M.C.
	1.728	0.240				5.00		1.79	0.06
	1.871	0.048	1.800	0.072		5.20	5.10	1.81	0.06
Vacuum Oven (on Untreated Sample)	3.682	0.008			Hygrometric	18.7		3.70	0.02
	3.745	0.007	3.714	0.032		19.0	18.9	3.75	0.00
Δ	4.818	-				23.2		4.75	0.07
	4.687	-	4.753	0.066		23.2	23.2	4.75	0.06
Std. Dev.		0.141			Std. Dev.				0.057
	1.612	0.037				4.21			
Vacuum Oven (on Sample After Determination of M.C. by Manometric Method)	1.651	0.088	1.631	0.019		4.21	4.21		
	3.622	0.042			Manometric	12.6			
	3.575	0.063	3.599	0.028		12.4	12.5		
	4.418	0.046				18.5			
O	4.328	0.063	4.373	0.045		18.5	18.5		
						4.21		1.80	0.00
			1.800	0.072		4.21	4.21	1.80	0.00
Vacuum Oven (on Untreated Sample)						12.6		3.73	0.02
			3.714	0.032	Manometric	12.4	12.5	3.68	0.03
						18.5		4.75	0.00
◇			4.753	0.066		18.5	18.5	4.75	0.00
					Std. Dev.				0.016

TABLE X

VARIATION OF EQUILIBRIUM RELATIVE HUMIDITY

WITH SAMPLE MOISTURE CONTENT FOR

PEACHES

Technique	M.C.	Dev.	Aver. M.C.	Aver. Dev.	Technique	R.H.	Aver. R.H.	Derived M.C.	Deviation From Vac. Oven M.C.
	0.85	0.06				8.10		0.50	0.35
	0.17	-	0.51	0.34		8.65	8.38	0.53	0.36
	3.491	0.089				34.0		4.40	0.91
	3.183	0.160	3.34	0.15		34.2	34.1	4.50	1.32
Vacuum Oven (on Untreated Sample)	4.717	0.056			Hygrometric	30.8		3.52	1.20
	5.00	0.24	4.86	0.14		31.8	31.3	3.75	1.25
Δ	8.96	0.26				41.3		9.30	0.34
	8.99	0.55	8.98	0.02		40.7	41.0	8.70	0.29
Std. Dev.		0.28			Std. Dev.				0.93
	0.45	-				2.53			
	1.11	-	0.78	0.33		2.53	2.53		
	4.02	0.21				23.2			
Vacuum Oven (on Sample After Determination of M.C. by Manometric Method)	3.50	0.64	3.76	0.26	Manometric	23.6	23.4		
	5.09	0.09				29.5			
	5.04	0.19	5.07	0.03		29.9	29.7		
O	7.34	0.33				37.9			
	6.68	0.06	7.01	0.33		37.0	37.5		
						2.53		0.51	0.00
			0.51	0.34		2.53	2.53	0.51	0.00
						23.2		3.32	0.01
			3.34	0.15		23.6	23.4	3.41	0.07
Vacuum Oven (on Untreated Sample)					Manometric	29.5		4.84	[illegible]
			4.86	0.14		29.9	29.7	5.00	0.14
◇						37.9		9.10	0.12
			8.98	0.02		37.0	37.5	8.60	0.38
					Std. Dev.				0.16

TABLE XI

VARIATION OF EQUILIBRIUM RELATIVE HUMIDITY

WITH SAMPLE MOISTURE CONTENT FOR DEHYDRATED CHICKEN

Lot 2P

Technique	M.C.	Dev.	Aver. M.C.	Aver. Dev.	Technique	R.H.	Aver. R.H.	M.C. Derived from Calib. Curve for		Dev. from Vac. Oven M.C. of M.C. Der. from Cal Curve for	
								Lot 2	Lot 5	Lot 2	Lot 5
Vacuum Oven (on Untreated Sample)	2.032	0.111			Hygrometric	2.15		1.95	-	0.08	-
	2.048	-	2.040	0.008		2.65	2.40	2.25	-	0.20	-
	5.708	0.036				22.2		5.80	5.80	0.09	0.09
	5.830	0.056	5.769	0.061		21.4	21.8	5.73	5.73	0.10	0.10
	7.916	0.031				41.0		7.93	7.93	0.01	0.01
	7.933	0.020	7.925	0.008		41.0	41.0	7.93	7.93	0.00	0.00
Std. Dev.		0.067			Std. Dev.					0.11	0.08
Vacuum Oven (on Sample After Determination of M.C. by Manometric Method)	1.700	0.064			Manometric	0.631					
	1.888	0.020	1.794	0.094		0.841	0.74				
	4.866	0.013				10.52					
	4.919	0.012	4.893	0.027		10.94	10.7				
	6.737	0.024				20.20					
	6.828	0.005	6.783	0.046		20.62	20.4				
	12.69	0.03				63.55					
	12.74	0.05	12.72	0.03		61.66	62.6				
Vacuum Oven (on Untreated Sample)					Manometric	0.631		1.35	2.90	0.09	0.86
			2.040	0.008		0.842	0.74	2.15	3.05	0.11	1.01
						10.52		5.73	6.05	0.04	0.28
			5.769	0.061		10.94	10.7	5.80	6.13	0.03	0.36
						20.20		7.85	8.25	0.08	0.32
			7.925	0.008		20.62	20.4	7.95	8.35	0.02	0.43
						63.55		-	-	-	-
			16.58	0.02		61.66	62.6	16.43	-	0.15	-
					Std. Dev.					0.09	0.67

TABLE XII

VARIATION OF EQUILIBRIUM RELATIVE HUMIDITY

WITH SAMPLE MOISTURE CONTENT FOR DEHYDRATED CHICKEN

Lot 5P

Technique	M.C.	Dev.	Aver. M.C.	Aver. Dev.	Technique	R.H.	Aver. R.H.	M.C. Derived from Calib. Curve for		Dev. from Vac. Oven M.C. of M.C. Der. from Cal. Curve for	
								Lot 2	Lot 5	Lot 2	Lot 5
Vacuum Oven (on Untreated Sample)	2.715	0.034			Hygrometric	4.1		2.86	2.86	0.14	0.14
	2.969	0.002	2.842	0.127		3.9	4.0	2.73	2.73	0.24	0.24
	6.728	0.041				30.7		6.73	6.73	0.00	0.00
	6.729	0.012	6.729	0.001		30.7	30.7	6.73	6.73	0.00	0.00
	9.558	0.045				52.6		-	9.50	-	0.06
	9.591	0.053	9.574	0.016		53.5	53.1	-	-	-	-
Std. Dev.		0.040			Std. Dev.					0.16	0.14
Vacuum Oven (on Sample After Determination of M.C. by Manometric Method)	2.545	0.030			Manometric	0.421					
	2.669	0.019	2.607	0.062		0.210	0.32				
	5.325	0.137				14.30					
	4.319	0.054	4.822	0.503		12.63	13.5				
	7.603	0.009				25.67					
	7.947	0.003				25.67					
	7.741	0.017	7.764	0.122		28.20	26.51				
	12.14	0.06				57.66					
	12.04	0.04	12.09	0.05		57.24	57.5				
Vacuum Oven (on Untreated Sample)					Manometric	0.421		1.90	2.85	0.94	0.01
		2.842	0.127			0.210	0.32	-	-	-	-
						14.30		6.53	6.90	0.20	0.17
		6.729	0.001			12.63	13.5	6.15	6.55	0.58	0.18
						25.67		9.05	9.45	0.52	0.12
						25.67		9.05	9.45	0.52	0.12
		9.574	0.016			28.20	26.5	9.57	9.95	0.00	0.38
						57.66		15.65	-	0.15	-
		15.80	0.00			57.24	57.5	15.60	15.70	0.20	0.10
					Std. Dev.					0.52	0.20

Table XIV

SUMMARY OF STANDARD DEVIATIONS

Std. Dev. (Pct.)	Mixed Fruit	Apples	Peaches	Cabbage	Non-fat Milk	Peppers	Rice	Potatoes	Chicken (#5)	Chicken (#2)	Shrimp	Total Vac. Oven	Total Hygrometer
0.00												0	
0.01												0	
0.02	M	M										0	
0.03												0	
0.04									V			1	
0.05				V			VM					2	
0.06		H		M				V				1	1
0.07					H					V	V	2	1
0.08				H		V						1	1
0.09					VM					M		1	0
0.10											H	0	1
0.11						H				H		0	2
0.12												0	0
0.13								M			M	0	0
0.14		V							H			1	1
0.15								H				0	1
0.16	V		M									1	0
0.17	H											0	1
0.18						M						0	[illegible]
0.19												0	0
0.20							H		M			0	1
0.21												0	0
0.22												0	0
0.23												0	0
0.24												0	0
0.25												0	0
0.26												0	0
.27												0	0
0.28			V									1	[illegible]
Average without peaches												0.08	0. 0.12
0.93			M										1
Average with peaches												0.10	0. [illegible]

Legend: V - vacuum oven analysis

H - hygrometric analysis

M - manometric analysis

TABLE XIV

REPRODUCIBILITY AND ACCURACY

OF MOISTURE CONTENT ANALYSES

Food	Error in Percent Moisture Content*							
	V	T	S_H	S_M	h	m	H	M
Cabbage	0.043	0.000	0.063	0.043	0.047	0.000	0.063	0.043
Milk	0.045	0.025	0.063	0.056	0.037	0.082	0.058	0.050
Peppers	0.062	0.057	0.085	0.116	0.028	0.084	0.068	0.104
Potatoes	0.042	0.067	0.130	0.100	0.100	0.061	0.111	0.074
Rice	0.035	0.059	0.150	0.036	0.130	0.000	0.138	0.035
Average	0.045	0.040	0.098	0.070	0.068	0.033	0.088	0.061

*Moisture content error

V - in vacuum oven analysis

T - caused by variation of temperature

S_H - in hygrometric analysis

S_M - in manometric analysis

h - in hygrometric analysis by factors other than temperature or vacuum oven analysis

m - in manometric analysis by factors other than temperature or vacuum oven analysis

H - in hygrometric analysis by factors other than temperature

M - in manometric analysis by factors other than temperature

TABLE XIV (Continued)

REPRODUCIBILITY AND ACCURACY

OF MOISTURE CONTENT ANALYSES

(1a) $S_H^2 = V^2 + T^2 + h^2$

(1b) $h = \sqrt{S_H^2 - (V^2 + T^2)}$

(2a) $S_H^2 = H^2 + T^2$

(2b) $H = \sqrt{S_H^2 - T^2}$

Similarly

(3) $m = \sqrt{S_M^2 - (V^2 + T^2)}$

$M = \sqrt{S_M^2 - T^2}$

TABLE XV

POLAR GROUP ACCESSIBILITY (MEASURED BY HYDROGEN EXCHANGE)

AS A FUNCTION OF MOISTURE CONTENT

Equilibration Time (days)	Column No. 1	2	3	4	5	6	7	8	9	10	11
	H^3_2O Added (mg)	Total H_2O (mg)	M.C. (%)	R.H. (%)	Gross Radioactivity (mv/min)	Net Radioactivity (mv/min)	Specific Radioactivity [mv/min / R.H.]	Initial Total Radioactivity (mv)(mg) / (min)(R.H.)	8/7 (mg)	Access. Polar Groups (mg H_2O)	Access. Polar Groups (M.C. %)
16	1	34.2	1.74	-	5.20	1.27	-	21.5	-	-	-
14	5	38.2	1.94	-	9.34	5.48	-	108	-	-	-
14	10	43.2	2.20	2.60	17.0	13.1	5.04	215	42.7	-0.5	-0.03
- *	15	48.2	2.45	3.10	-	20.0	6.45	323	50.0	1.8	0.09
11	25	58.2	2.96	4.50	40.1	36.2	8.04	538	66.9	8.7	0.44
8	50	83.2	4.23	11.0	69.1	65.2	5.93	1075	181	98	4.97
4	100	133	6.77	31.3	179	175	5.59	2150	385	252	12.8
- *	140	173	8.80	47.5	-	273	5.75	3010	523	350	17.8
4	200	233	11.9	-	461	457	-	-	-	-	-

*Interpolated from Figure 19

1. The weight of tritiated water which gives 21.5 mv/min/R.H. in the 275 ml ion chamber (Figure 18) This weight of tritiated water was added to 2.00 grams of dehydrated chicken (moisture content 1.687 percent by weight on a dry basis).

2. The total weight of water present. This figure is the sum of the weight added (column No. 1) and the 33.2 mgs of water present initially.

3. The moisture content (percent by weight on a dry basis) of the food after adding the tritiated water. This figure is obtained by dividing the total water present (column No. 2) by 1.97 (the dry weight of the food).

4. The relative humidity of the air above the food. This value is obtained from Figure 12 using the moisture content entered in column No. 3.

5. The radioactivity measured in the 275 ml ion chamber connected to the exchange vessel.

6. The net activity. This value is obtained by subtraction of background from the total radiation listed in column No. 5.

7. The specific radioactivity of the water in equilibrium with the food sample (activity per given amount of water). This figure is obtained by dividing column No. 6 by column No. 4.

8. The initial total activity. This activity is obtained by multiplying column No. 1 by 21.5 mv/min/R.H.

9. The figure obtained by dividing column No. 8 by column No. 7.

10. Accessible, exchangeable groups, expressed as equivalent mgs of water in 1.97 g of dry chicken. This figure is obtained by subtracting column No. 2 from column No. 9.

11. Accessible, exchangeable groups in 1.97 g of chicken. This figure is obtained from the figure in column No. 9 and is expressed as M.C. in percent by weight on a dry basis.

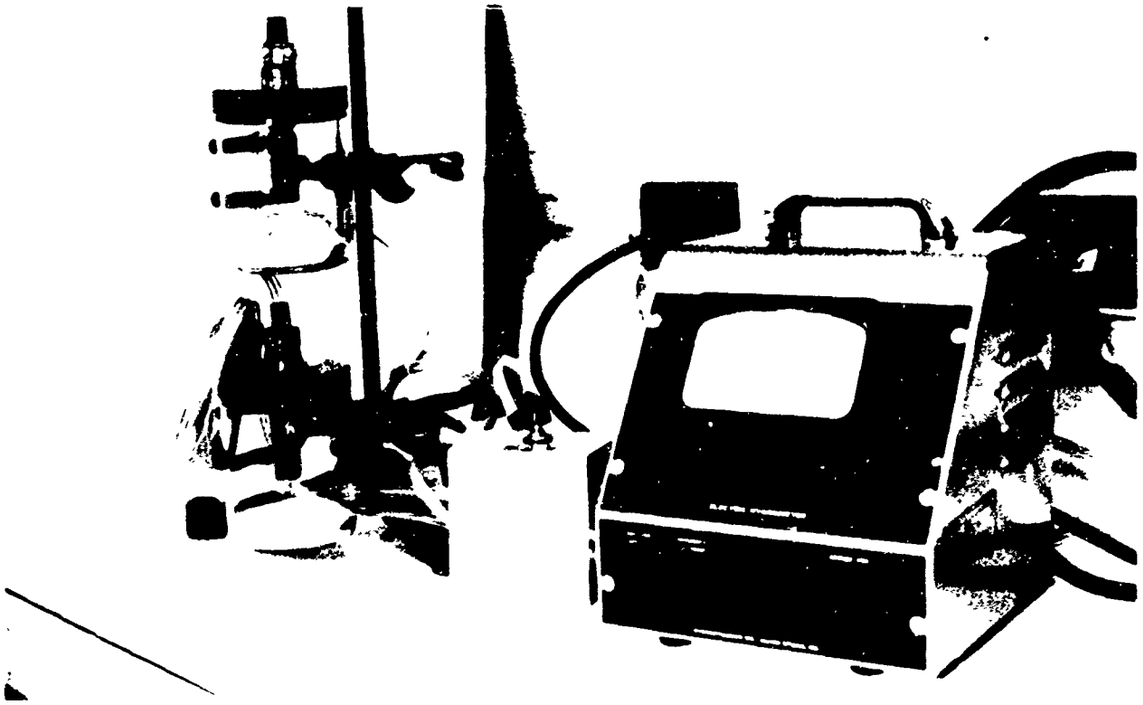

FIGURE 1
ELECTRICAL HYGROMETER
MOISTURE CONTENT APPARATUS

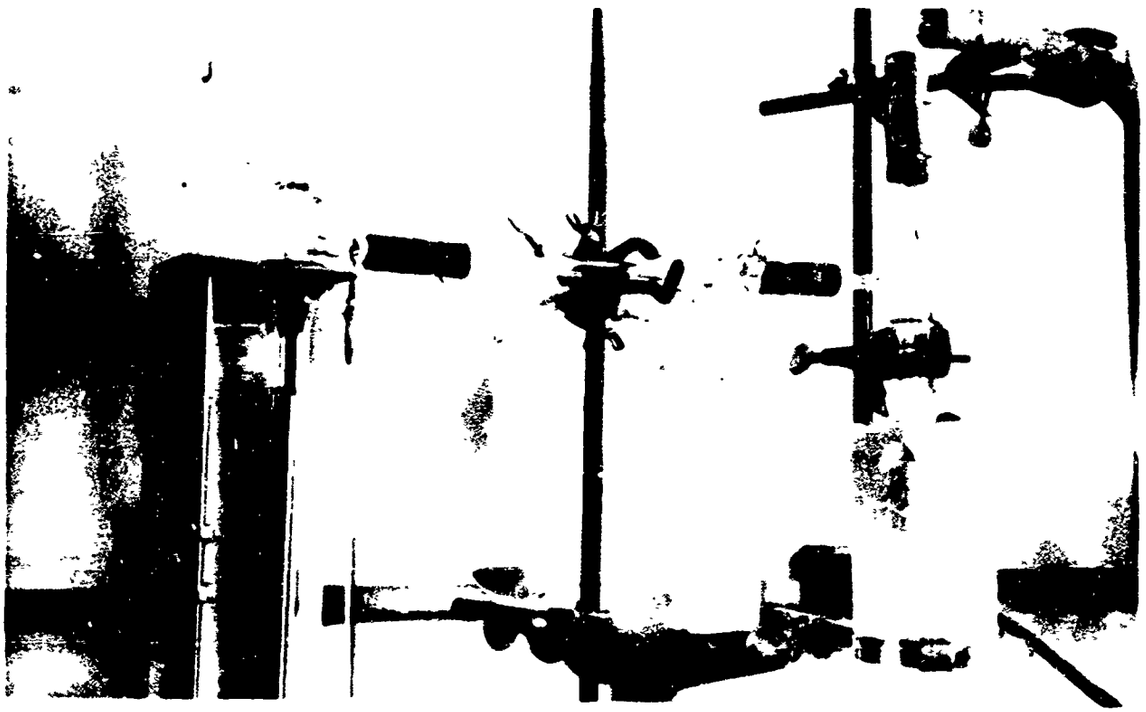

FIGURE 2
MANOMETRIC MOISTURE CONTENT APPARATUS

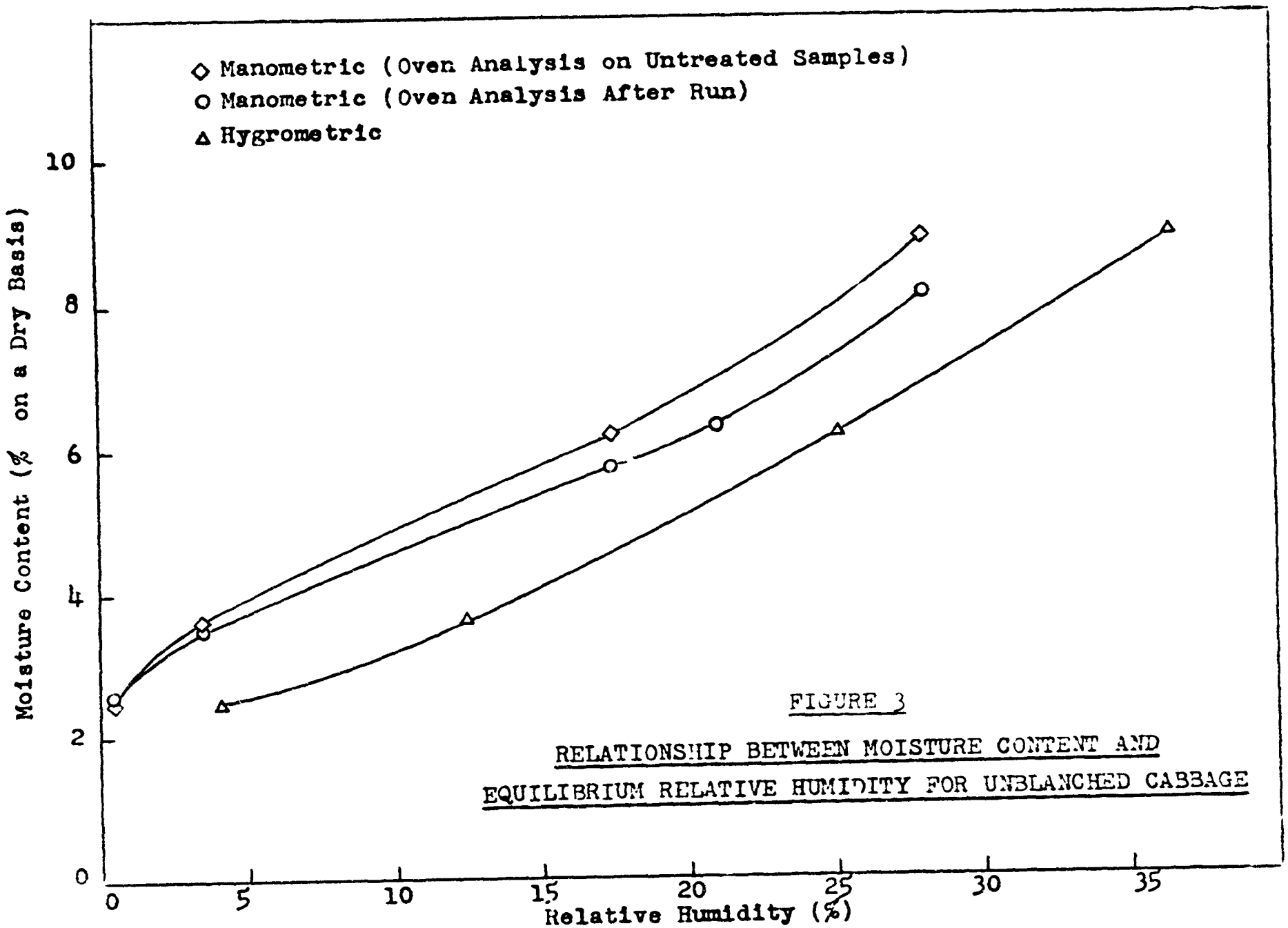

FIGURE 3

RELATIONSHIP BETWEEN MOISTURE CONTENT AND EQUILIBRIUM RELATIVE HUMIDITY FOR UNBLANCHED CABBAGE

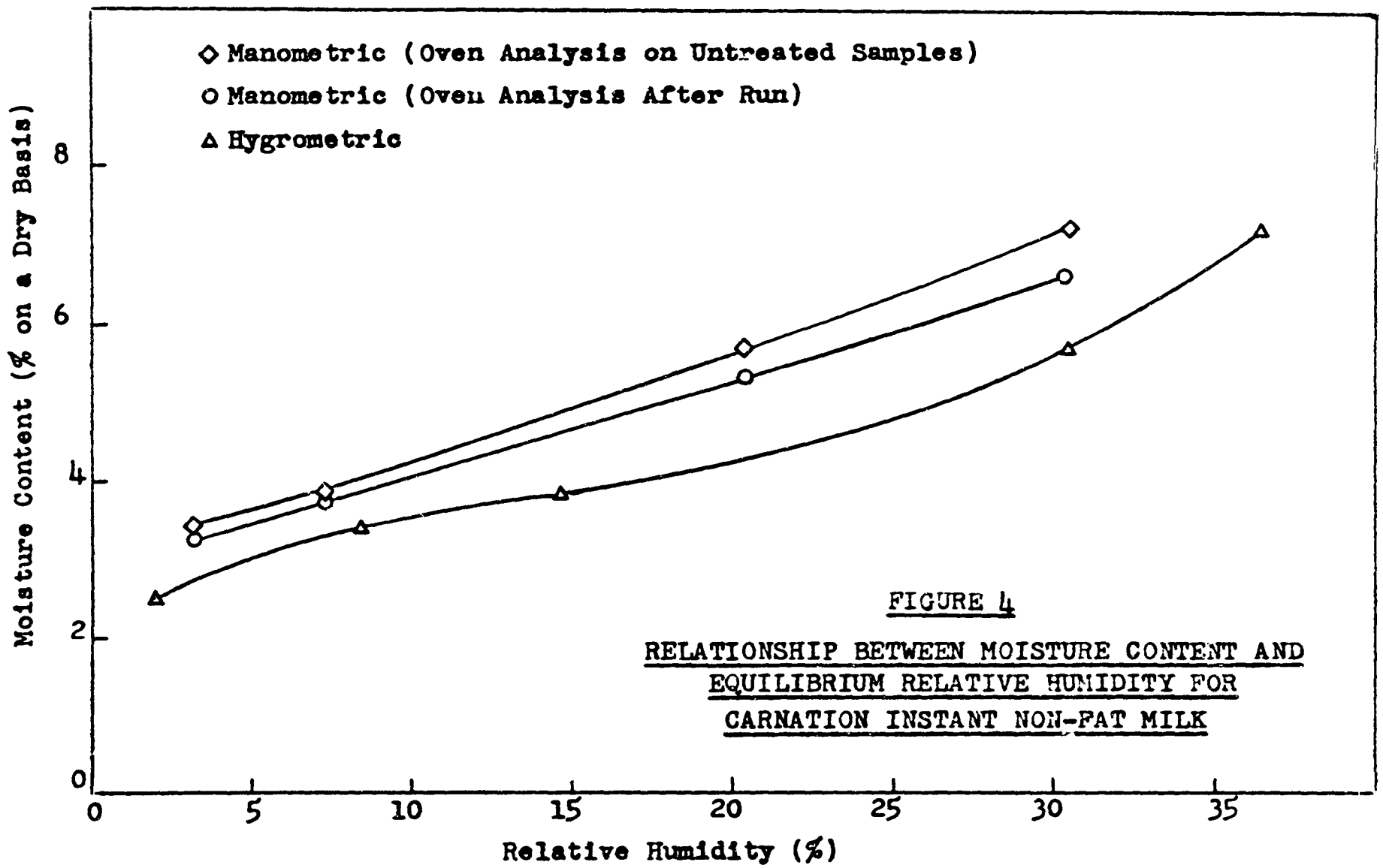

FIGURE 4

RELATIONSHIP BETWEEN MOISTURE CONTENT AND EQUILIBRIUM RELATIVE HUMIDITY FOR CARNATION INSTANT NON-FAT MILK

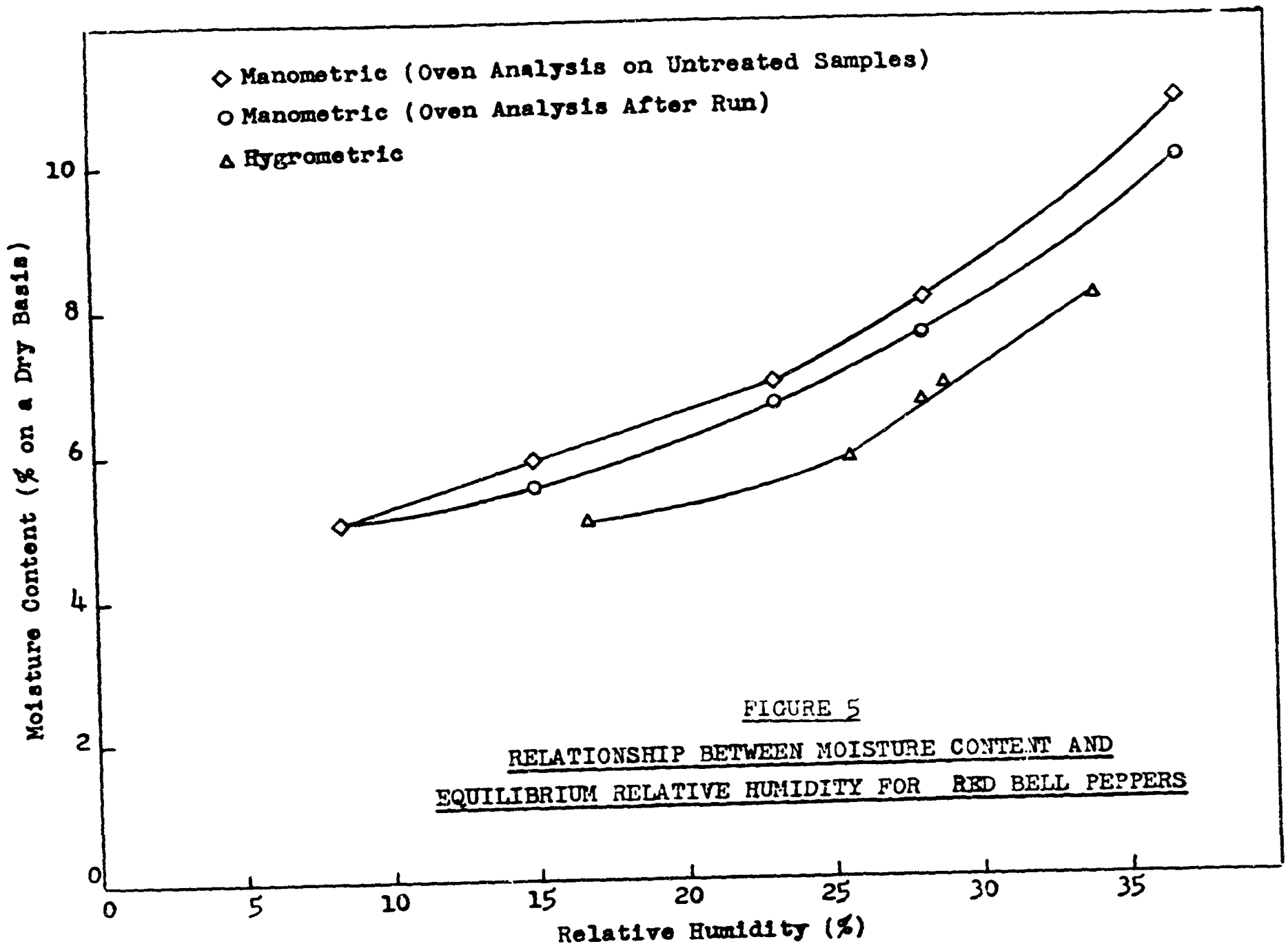

FIGURE 5

RELATIONSHIP BETWEEN MOISTURE CONTENT AND EQUILIBRIUM RELATIVE HUMIDITY FOR RED BELL PEPPERS

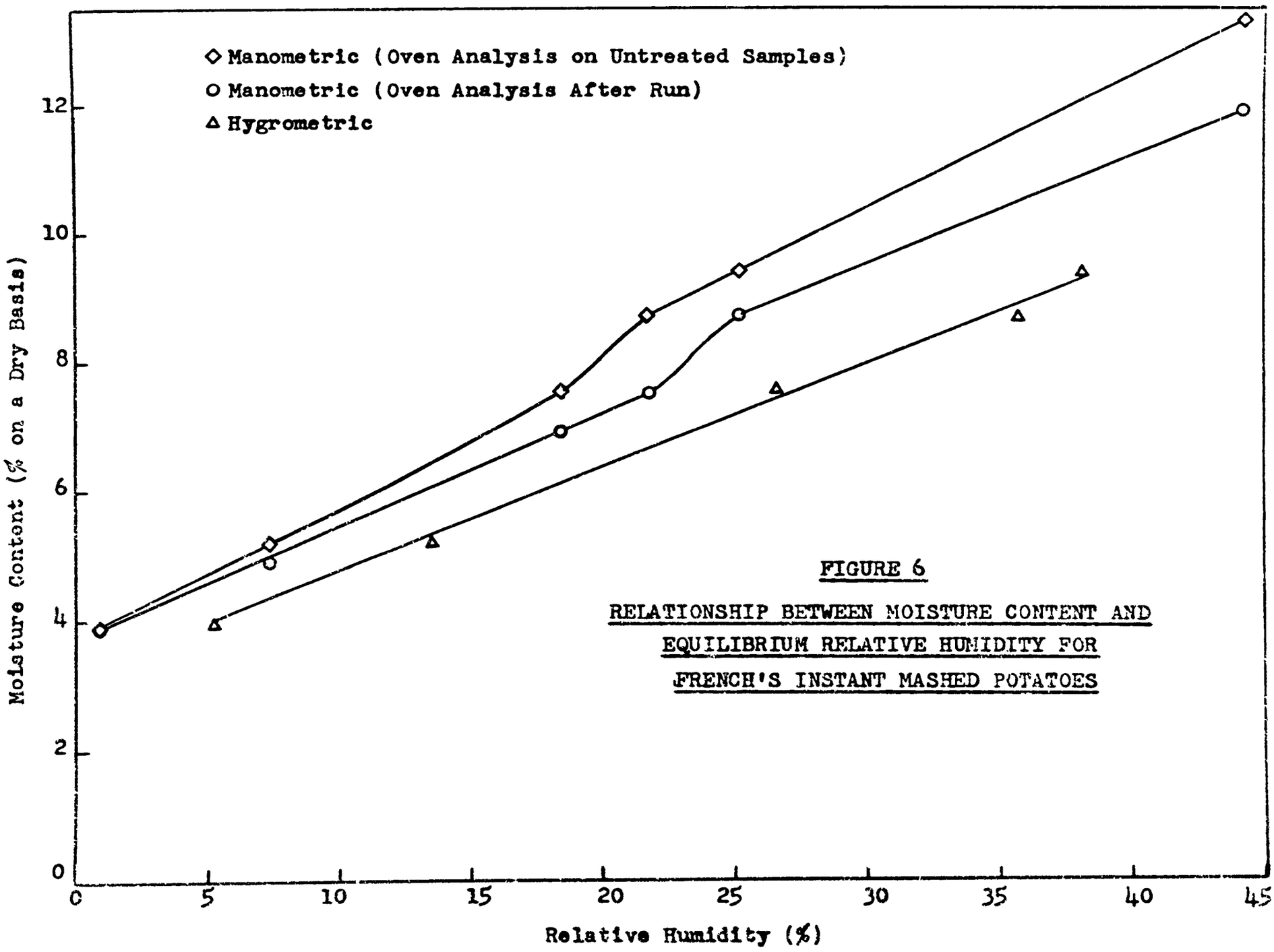

FIGURE 6

RELATIONSHIP BETWEEN MOISTURE CONTENT AND EQUILIBRIUM RELATIVE HUMIDITY FOR FRENCH'S INSTANT MASHED POTATOES

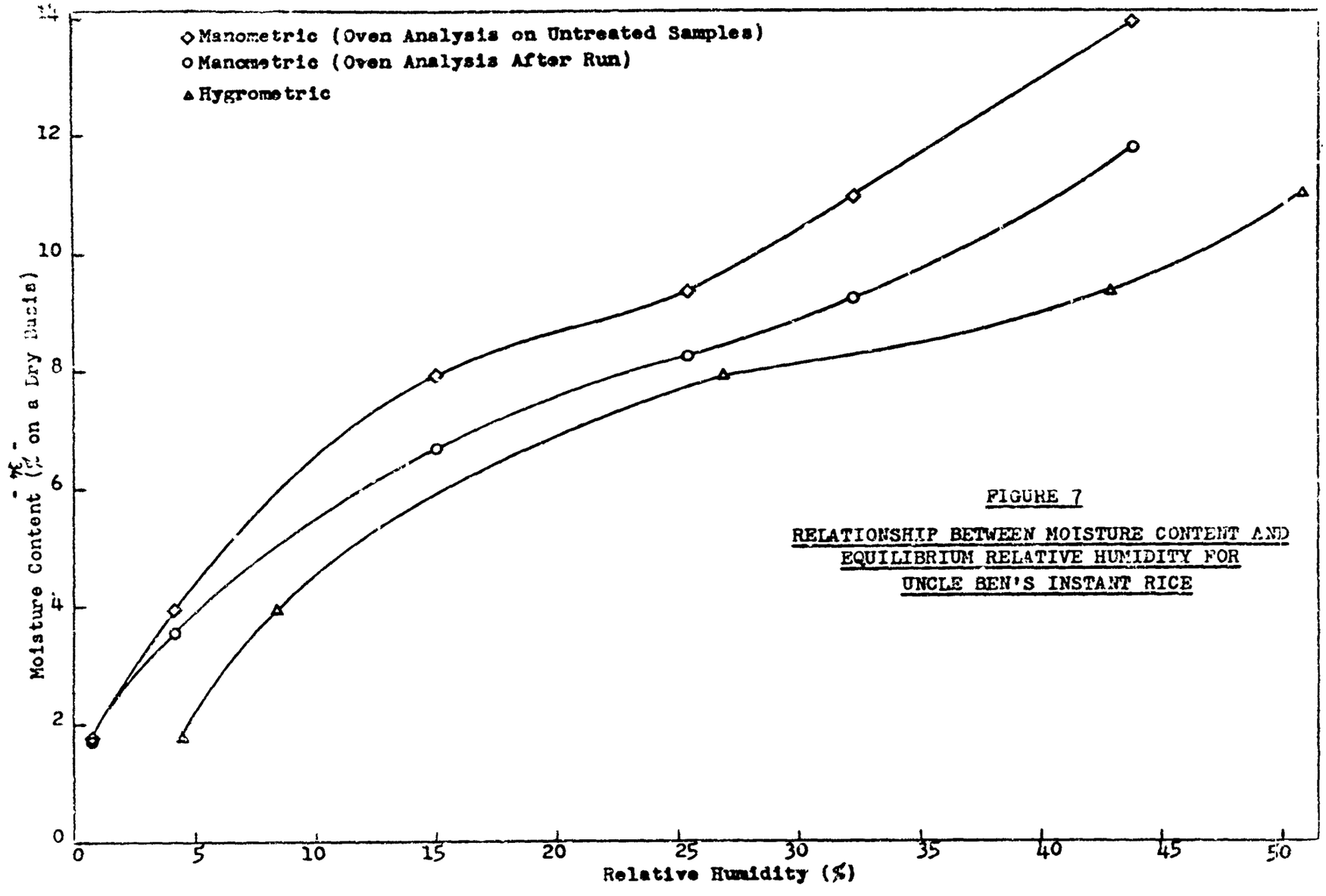

FIGURE 7

RELATIONSHIP BETWEEN MOISTURE CONTENT AND EQUILIBRIUM RELATIVE HUMIDITY FOR UNCLE BEN'S INSTANT RICE

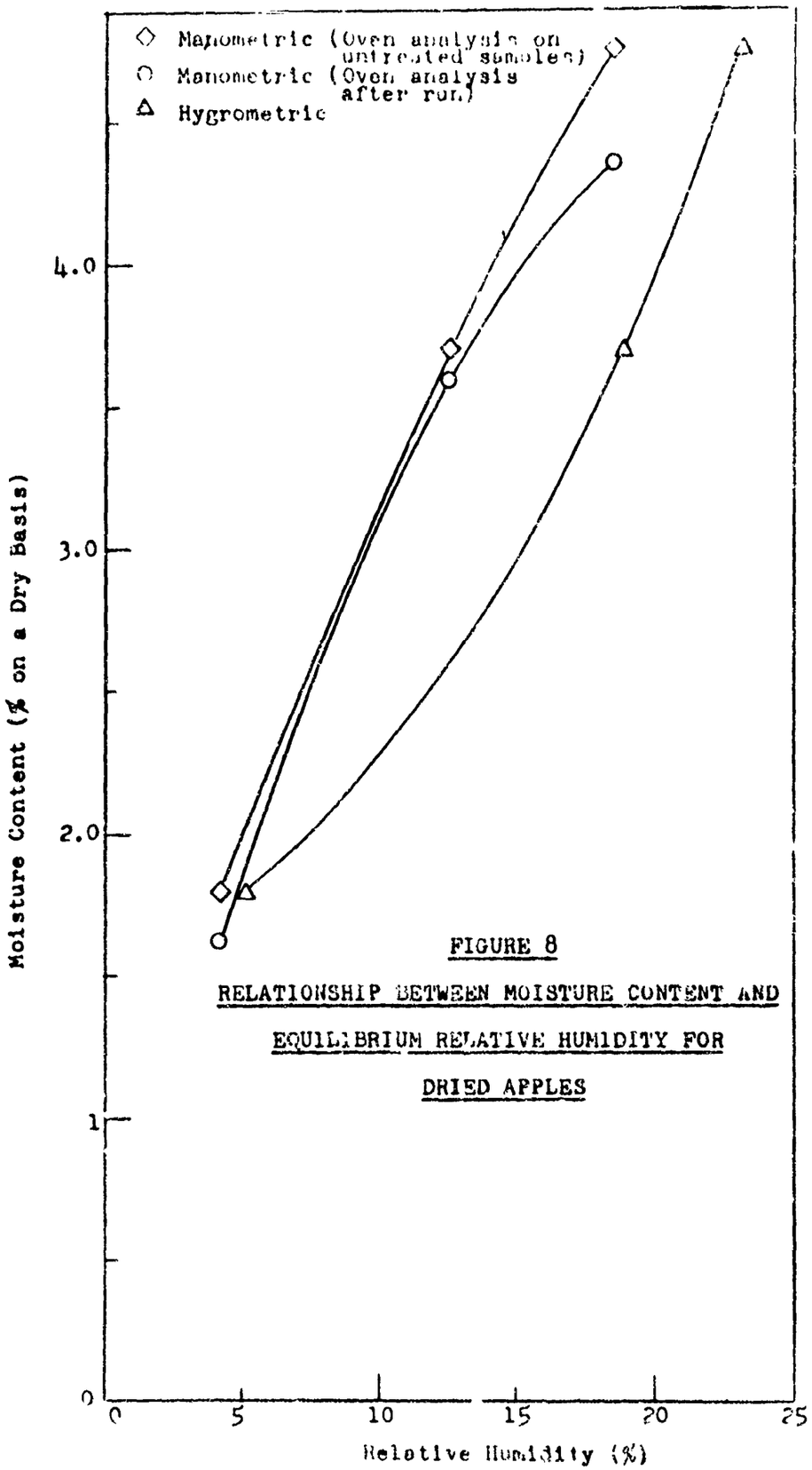

FIGURE 8

RELATIONSHIP BETWEEN MOISTURE CONTENT AND EQUILIBRIUM RELATIVE HUMIDITY FOR DRIED APPLES

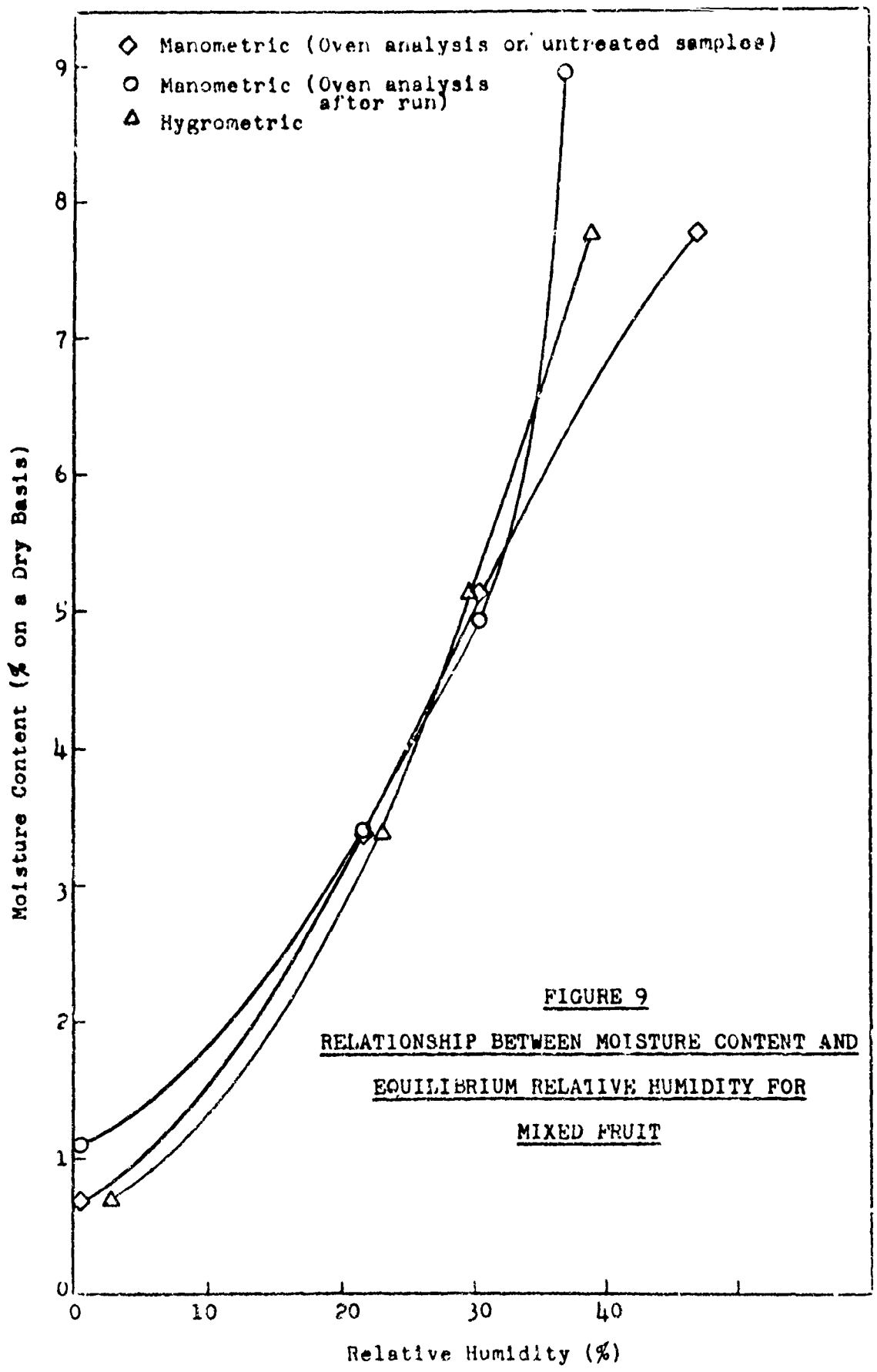

FIGURE 9

RELATIONSHIP BETWEEN MOISTURE CONTENT AND EQUILIBRIUM RELATIVE HUMIDITY FOR MIXED FRUIT

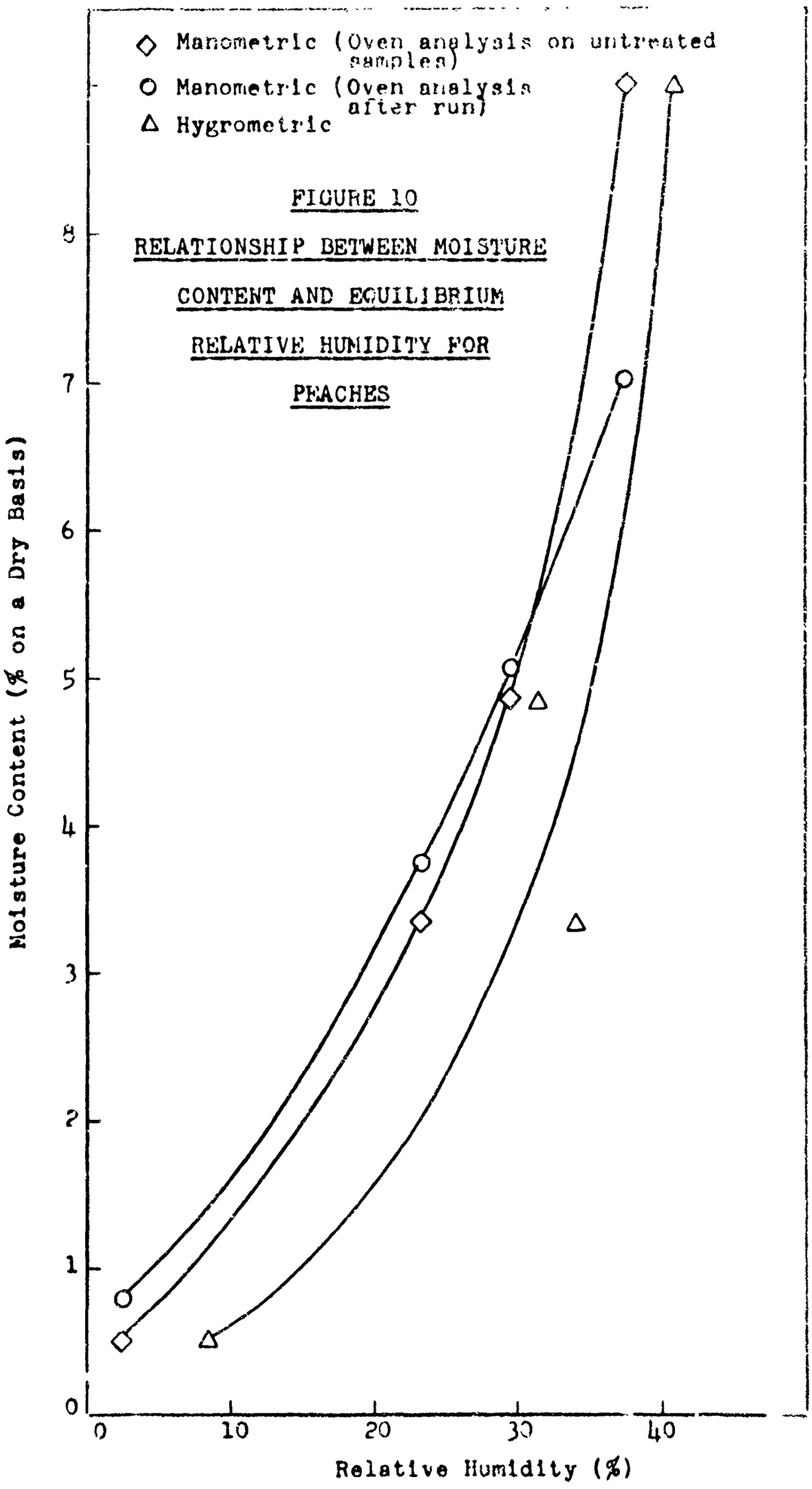

FIGURE 10

RELATIONSHIP BETWEEN MOISTURE CONTENT AND EQUILIBRIUM RELATIVE HUMIDITY FOR PEACHES

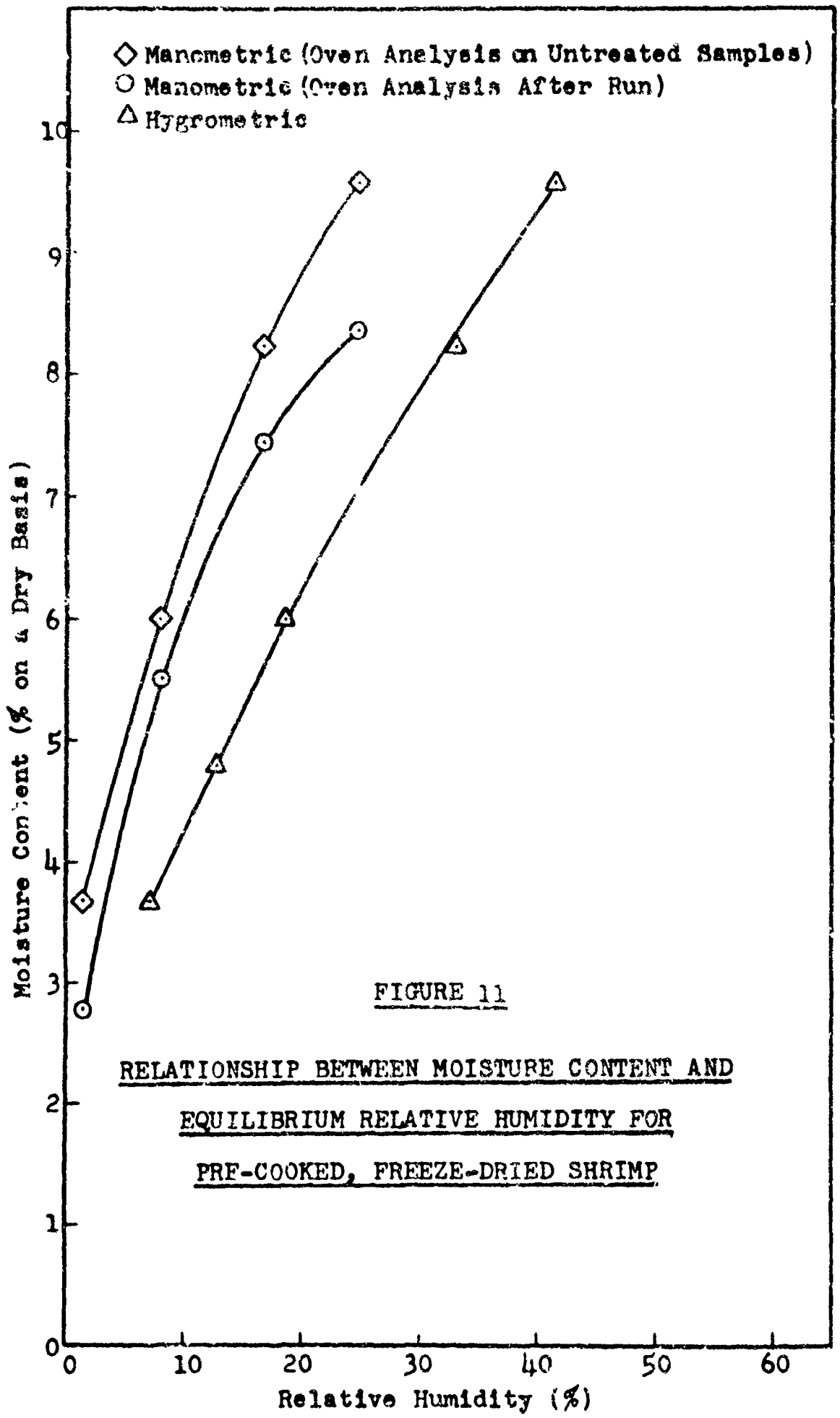

FIGURE 11

RELATIONSHIP BETWEEN MOISTURE CONTENT AND EQUILIBRIUM RELATIVE HUMIDITY FOR PRE-COOKED, FREEZE-DRIED SHRIMP

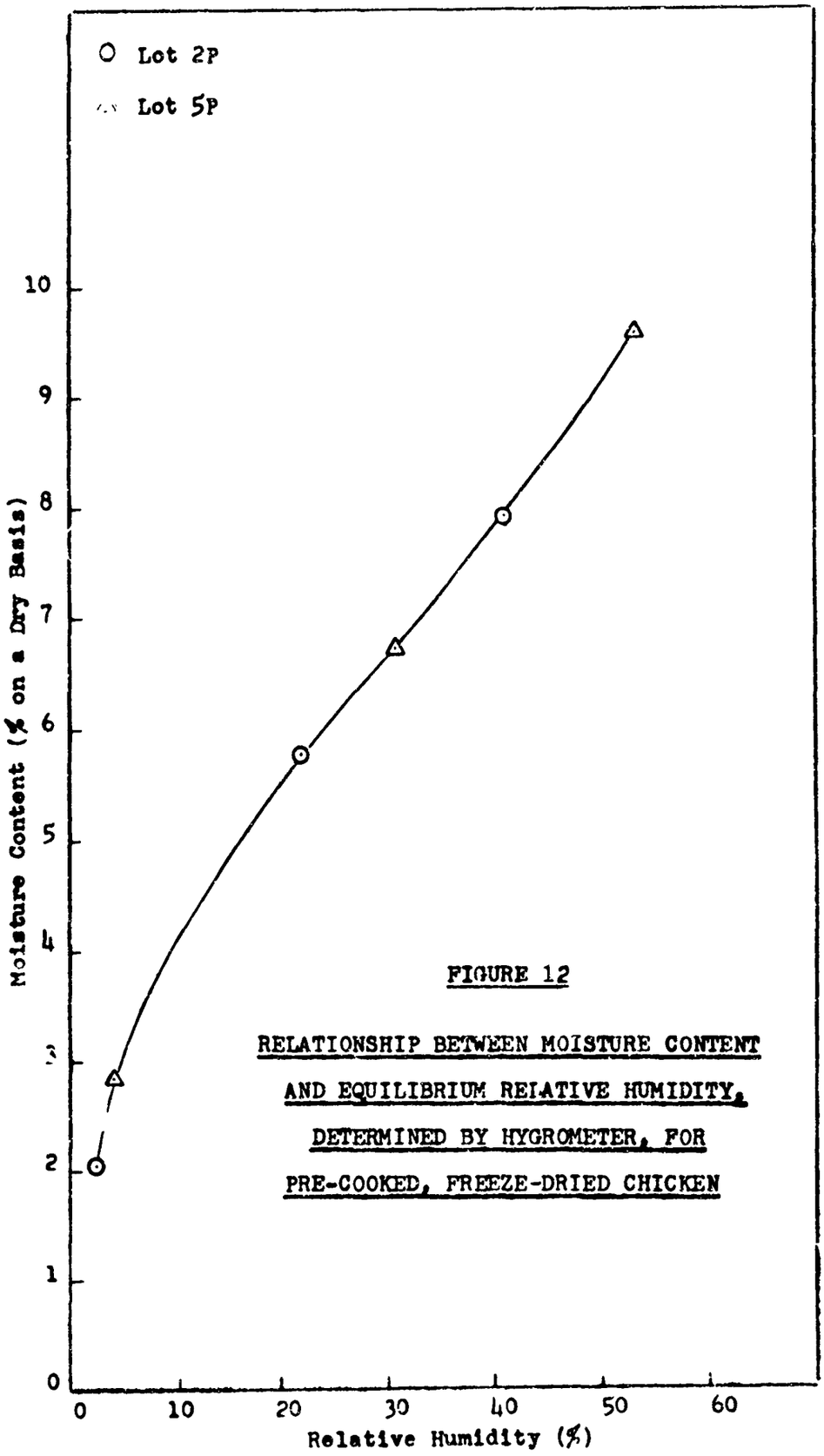

FIGURE 12

RELATIONSHIP BETWEEN MOISTURE CONTENT AND EQUILIBRIUM RELATIVE HUMIDITY, DETERMINED BY HYGROMETER, FOR PRE-COOKED, FREEZE-DRIED CHICKEN

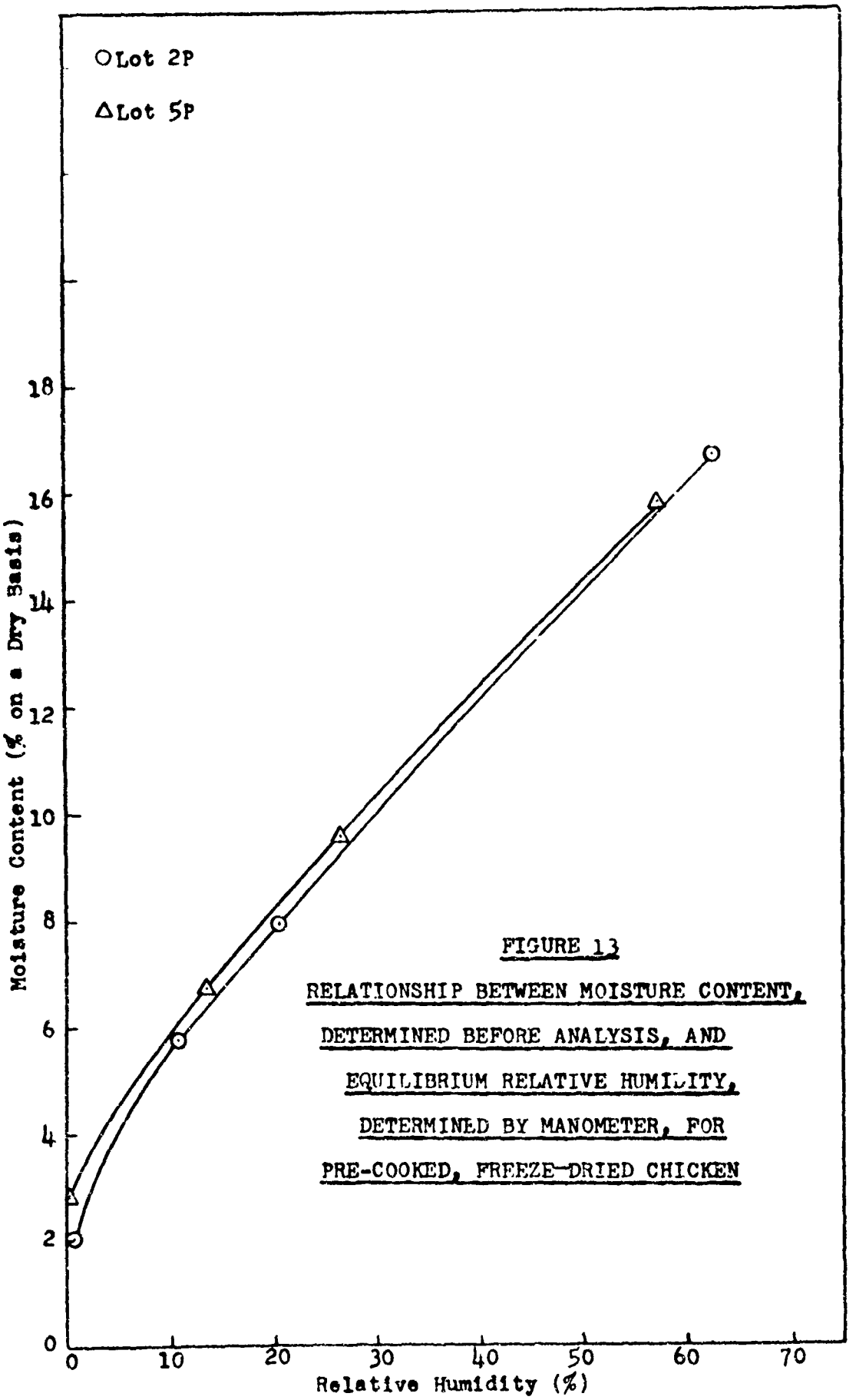

FIGURE 13

RELATIONSHIP BETWEEN MOISTURE CONTENT, DETERMINED BEFORE ANALYSIS, AND EQUILIBRIUM RELATIVE HUMIDITY, DETERMINED BY MANOMETER, FOR PRE-COOKED, FREEZE-DRIED CHICKEN

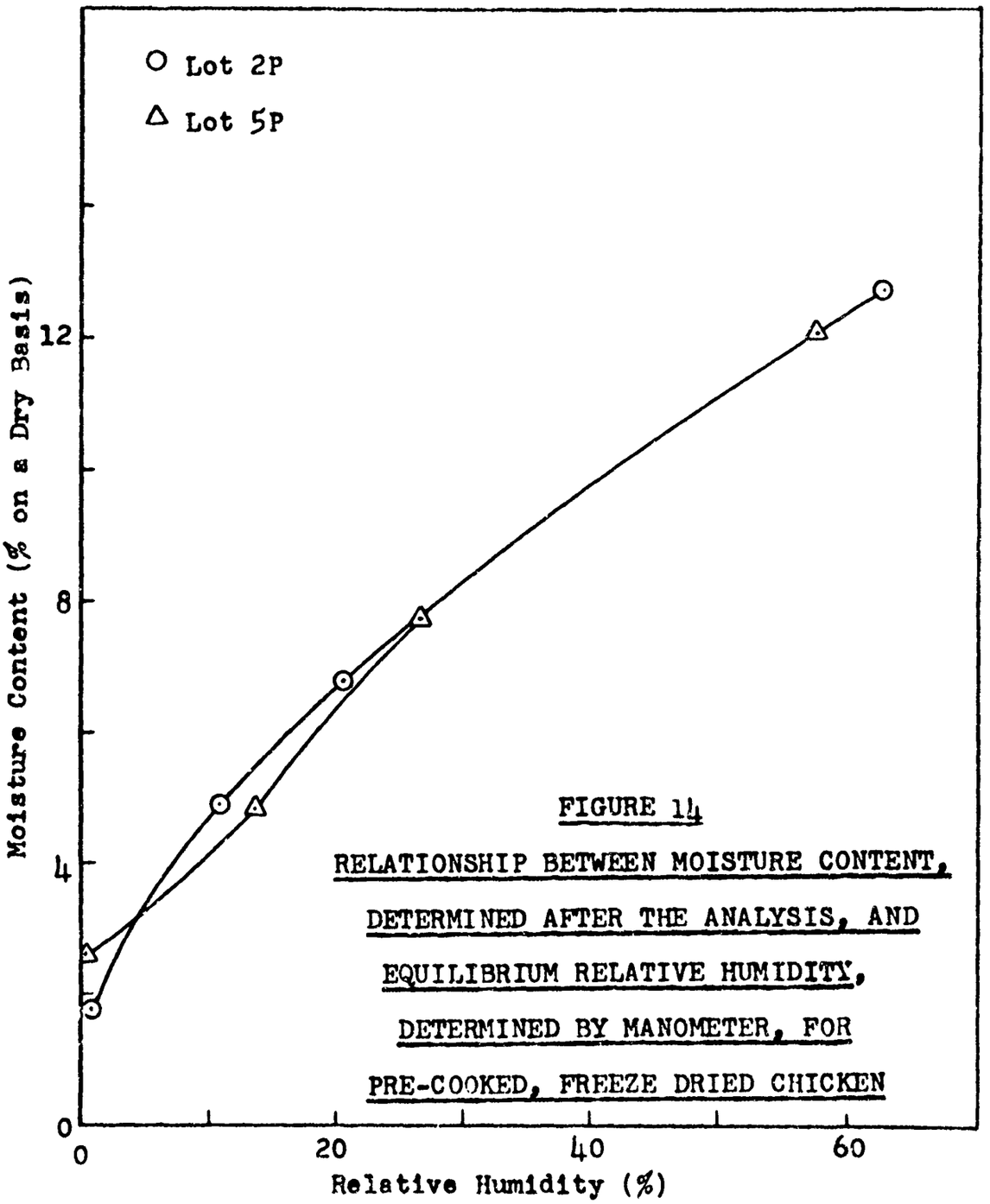

FIGURE 14

RELATIONSHIP BETWEEN MOISTURE CONTENT, DETERMINED AFTER THE ANALYSIS, AND EQUILIBRIUM RELATIVE HUMIDITY, DETERMINED BY MANOMETER, FOR PRE-COOKED, FREEZE DRIED CHICKEN

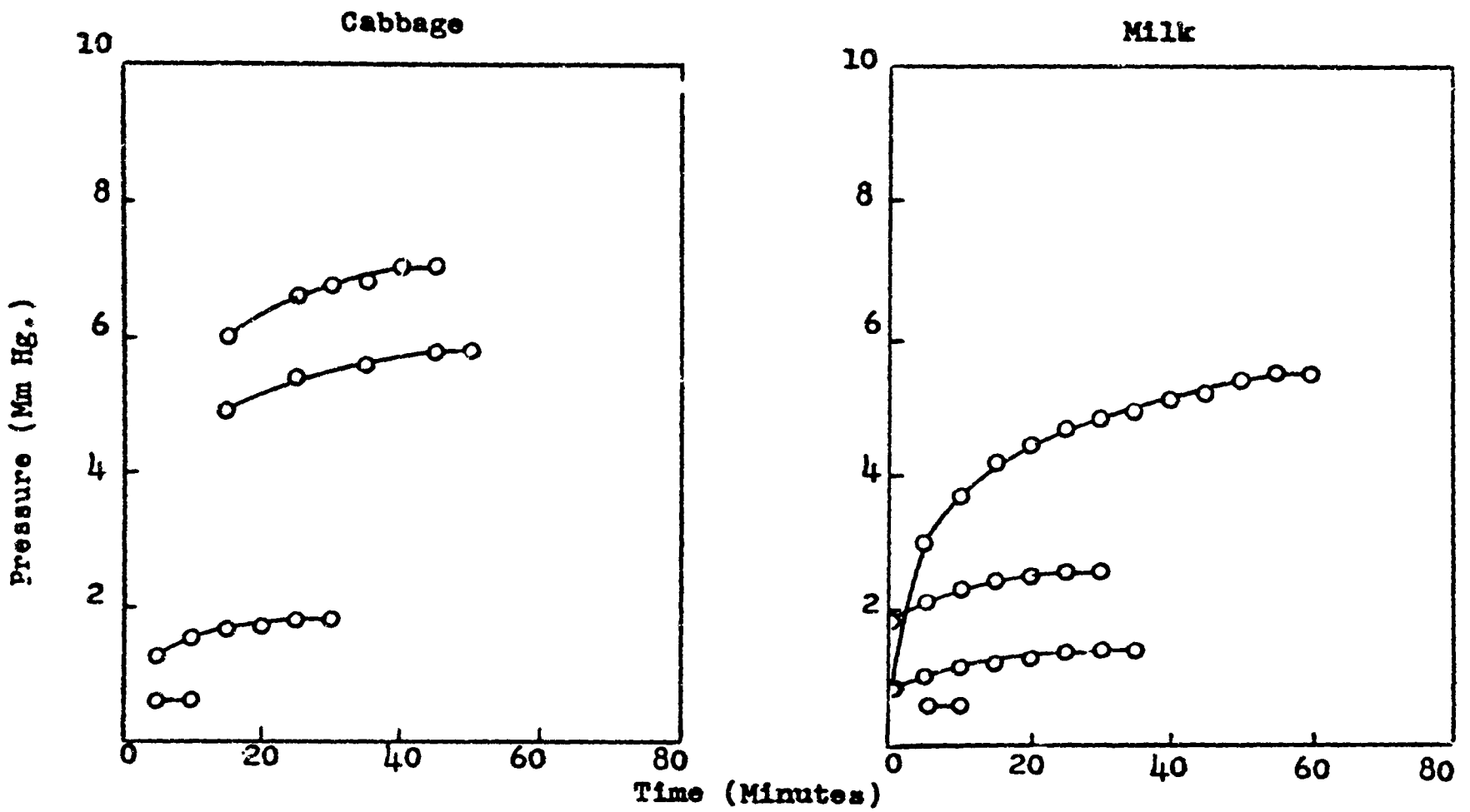

FIGURE 15

RATE OF ATTAINMENT OF MOISTURE EQUILIBRIUM WITH MANOMETRIC METHOD

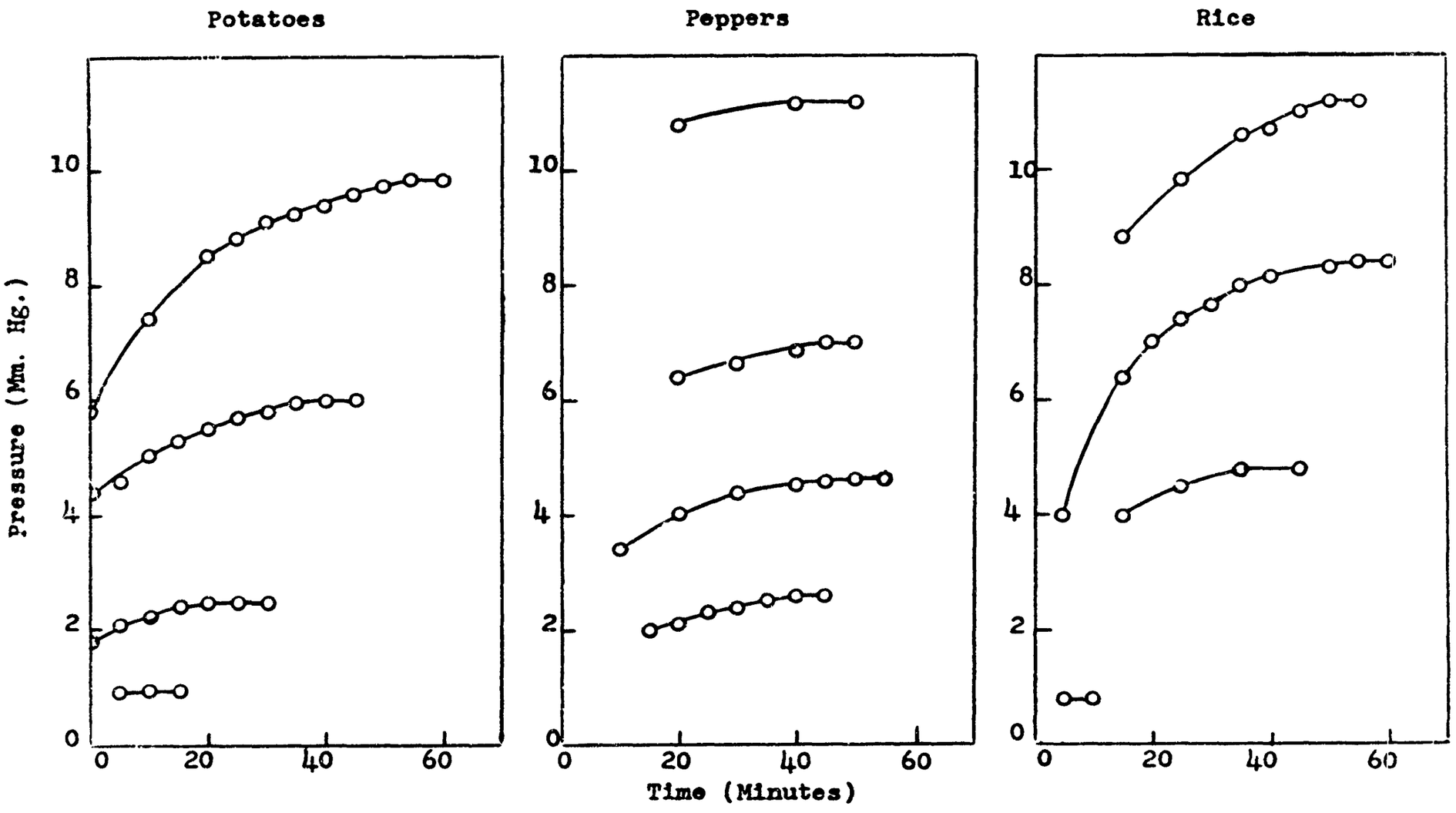

FIGURE 16

RATE OF ATTAINMENT OF MOISTURE EQUILIBRIUM WITH MANOMETRIC METHOD

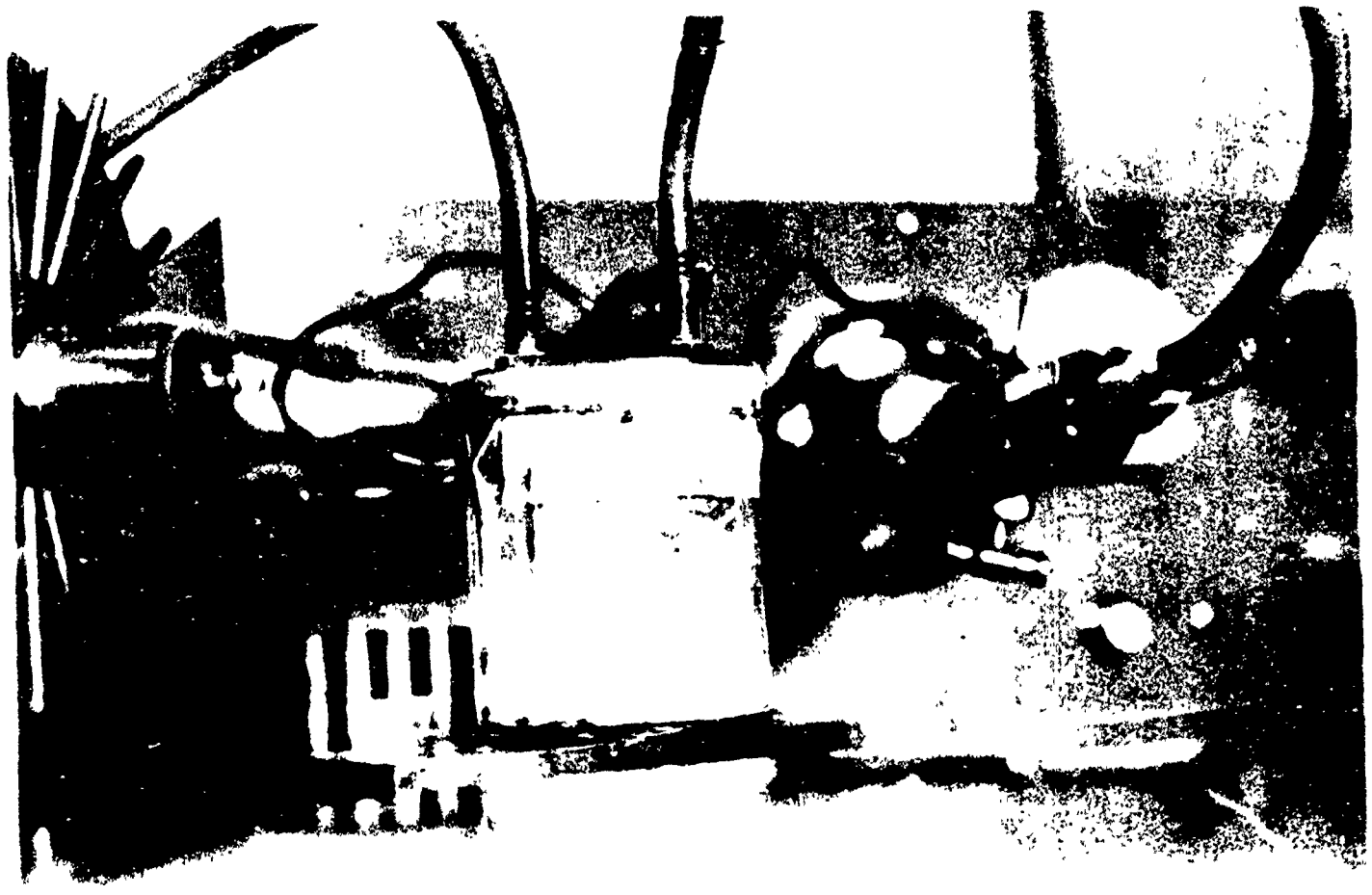

FIGURE 17

CLOSE-UP OF EXCHANGE VESSEL

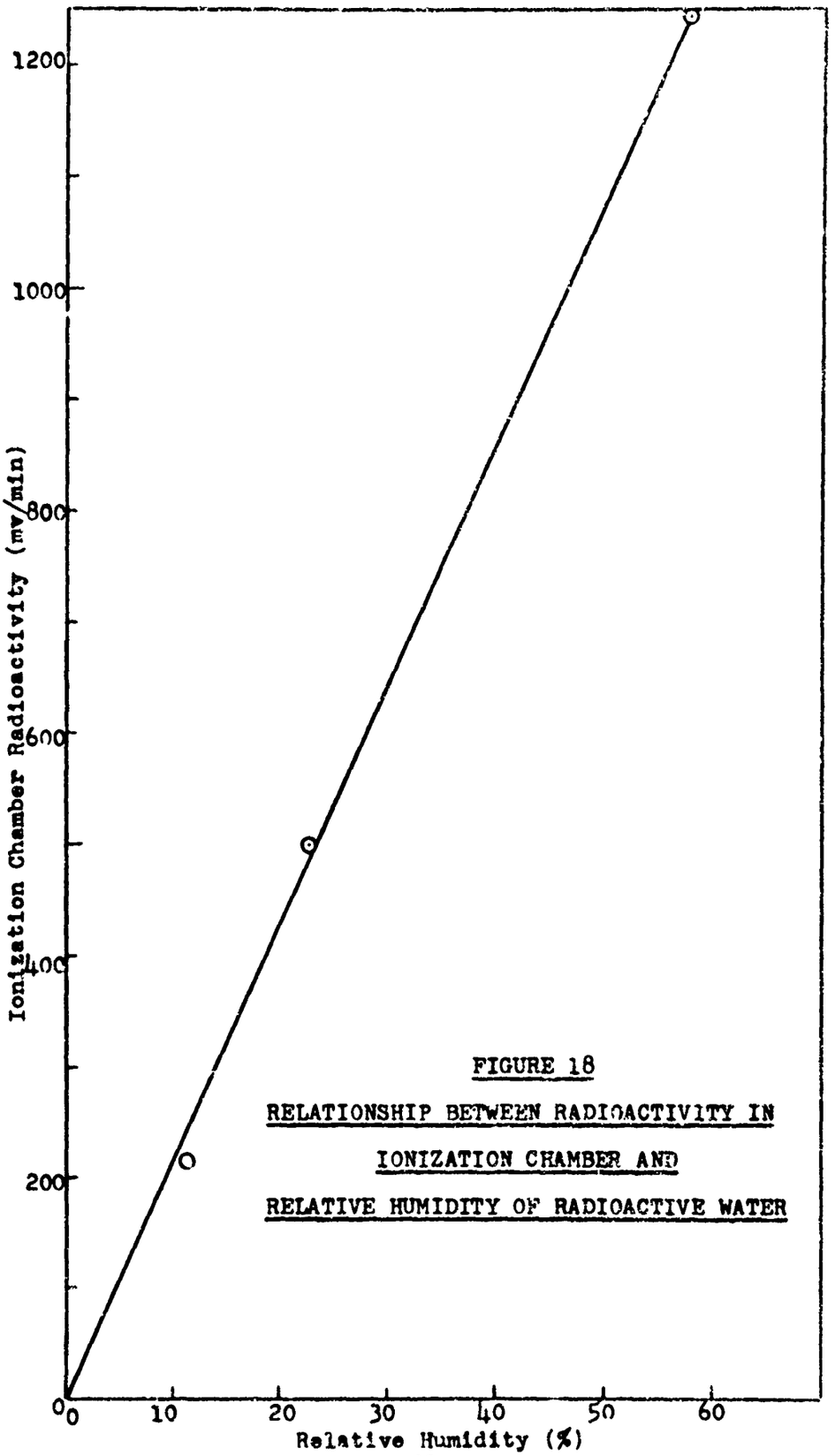

FIGURE 18

RELATIONSHIP BETWEEN RADIOACTIVITY IN IONIZATION CHAMBER AND RELATIVE HUMIDITY OF RADIOACTIVE WATER

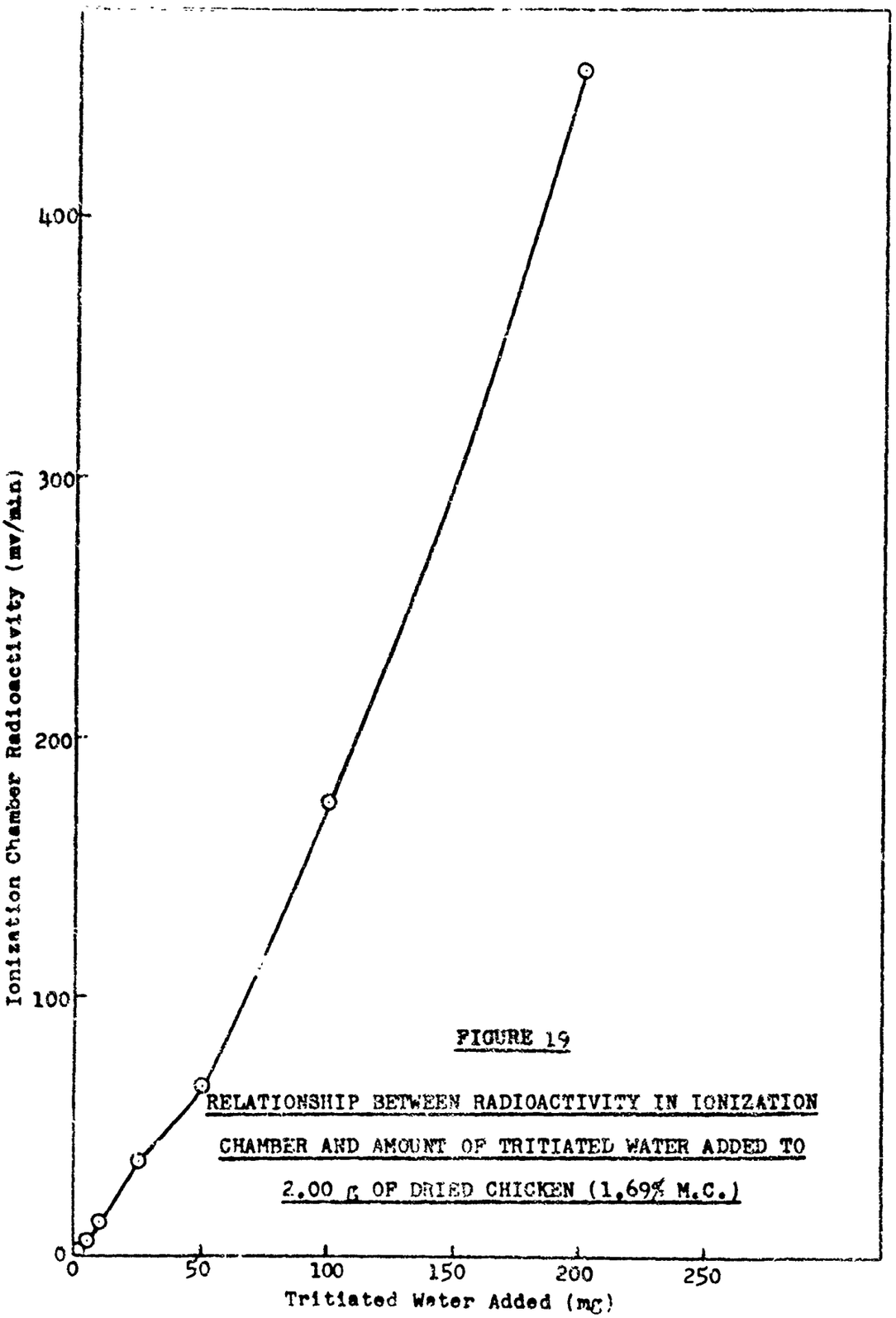

FIGURE 19

RELATIONSHIP BETWEEN RADIOACTIVITY IN IONIZATION CHAMBER AND AMOUNT OF TRITIATED WATER ADDED TO 2.00 g OF DRIED CHICKEN (1.69% M.C.)

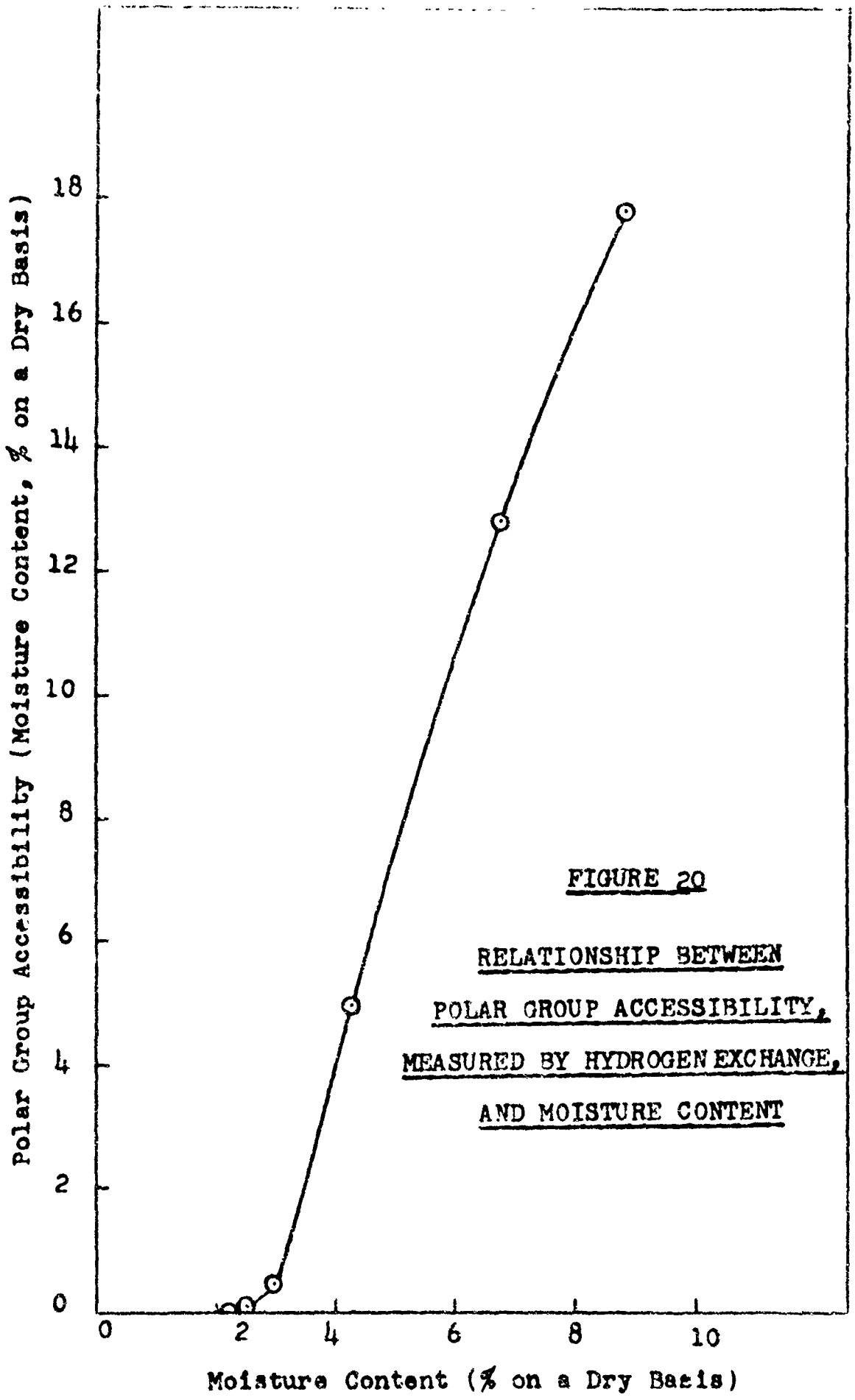

FIGURE 20

RELATIONSHIP BETWEEN POLAR GROUP ACCESSIBILITY, MEASURED BY HYDROGEN EXCHANGE, AND MOISTURE CONTENT