A STUDY OF THE RELATION OF PHOSPHORUS TO KEEPING QUALITY OF PORK ADIPOSE TISSUE AND RENDERED LARD

by

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INTRODUCTION

In the last few years, attention has been drawn to the minimum requirement of specific minerals by farm animals. In an effort to ascertain the effect of high as well as low levels of separate minerals in animal diets, a series of experiments are now in progress at Kansas State College. Hitherto, little work of this kind has been done with the object in mind of studying the quality and keeping properties of meat. Much has been learned about energy requirements and the optimum balance among the many energy yielding constituents, but many questions remain as to the color, texture, palatability and keeping quality.

Of the mineral elements required for growth in farm animals, phosphorus has been found to be important. If any correlation exists between rapid growth, other outward manifestations of health, and meat quality, then perhaps some variation may exist in the meat, measurable by chemical means. Due to the interrelationship that exists between phosphorus, calcium, and vitamin D, it is important that proper consideration be given all three in any attempt to study the requirements of any one of them.

REVIEW OF LITERATURE

In a review of the literature, it was found that, although much work has been done on phosphorus and its relation to growth, development, bone formation and composition of various organs and parts of the body, little study has been made on the phosphorus level of the ration as related to the quality and keeping properties of adipose tissue and the lard rendered from such tissue in swine. Some work has been done at this College concerning the effect of the phosphorus content of the ration on the quality of the meat as will be shown later.

Swartz (1) reported that moisture in lard caused spattering in deep fat frying when present in amounts in excess of 0.2 per cent. No measurable differences were found in cooler aged samples of lard carrying different amounts of added distilled water up to one per cent, in the rate of free fat acid formation, lowering of the smoke point, or the development of rancidity.

Hoglund (2) found that high phosphorus rations may raise the phosphorus content of adipose tissue. This may express an effect on the keeping quality of the meat, since

the same investigator also observed that low phosphorus rations tended to the formation of tissue more permeable to water. This latter observation, however, is in contrast with work done by Forbes (3) in that he reported the ration lowest in phosphorus produced muscles which were especially low in water, both in whole tissue and in fat free substance. Hoglund was reporting on the analysis of beef while Forbes was reporting on pork.

ANIMALS FROM WHICH SAMPLES WERE TAKEN

The animals used were all pure-bred Hampshires and closely related. All were castrated males and either half or full brothers. Their average weight was about 43 pounds and were uniform throughout. The animals from which the samples were taken were the three lots of pigs studied by Aubel, Hughes and Lienhardt (4) in Experiment II of the series of three phosphorus feeding experiments carried out at Kansas State College.

The levels of phosphorus fed were a low, an intermediate, and a high and were fed to lots 4, 5 and 6, respectively. It was decided to feed levels of phosphorus of 0.15 per cent in lot 4 for the low group, of 0.23 per cent

in lot 5 for the intermediate group, and of 0.3 per cent in lot 6 for the high group.

The level of calcium fed was about 0.7 per cent which is well above the lower limit for the normal development of swine, as reported by workers in the field of nutrition.

The animals were slaughtered in three groups, two animals from each lot were taken per group. Group one, consisting of six animals, was slaughtered at the end of 8 weeks, group two, at 16 weeks. Samples from group three were either not taken or accidentally lost.

The samples were taken from the back fat between the eighth and thirteenth rib. If sufficient sample was not obtained from between the ribs indicated, some tissue posterior to the thirteenth rib was included. The skin was removed as closely as possible and a layer of fat about one-fourth inch thick was left over the ribs.

METHODS OF PROCEDURE

Adipose Tissue

Chemical Analyses. General. The adipose tissue was ground in a standard meat grinder. It was found necessary

to chill the tissue thoroughly before grinding or the material would become so soft that it would not go through. Cooling the grinder with cold water, after which the parts were carefully dried, was found to be helpful.

The ground sample was mixed by hand in a porcelain evaporating dish. Approximately a 40 gram portion of the thoroughly mixed sample was transferred to a 50 c.c. capacity weighing bottle and all but moisture and peroxide number samples were weighed out by difference.

Moisture. A 2-4 gram sample was weighed out into a previously weighed 6 cm. porcelain evaporating dish, care was taken to expose a maximum surface of the ground tissue to insure rapid loss of moisture. The samples were placed in a desiccator over concentrated sulfuric acid which was then evacuated. The weights were recorded at frequent intervals until they reached constant weight. The moisture was reported in per cent on the original basis. These samples were then carried on for the determination of ash.

Ash. The samples from the moisture determination were placed on a hot plate and the bulk of the fatty material burned off. This was accomplished by placing in each dish a piece of ashless filter paper to serve as a wick. The residue consisted of ash and charred organic material.

The dishes were then transferred to a muffle furnace and ignited just below dull red heat. The dishes were then cooled and weighed in the usual manner and the ash reported in per cent of undried tissue.

Protein. A modification of the official method (5) for the determination of total nitrogen was used. Samples of 1.5-2.5 grams were used in the determination of protein. The samples were weighed out onto ashless filter papers and transferred to 800 c.c. pyrex Kjeldahl flasks, 62 c.c. of concentrated sulfuric acid, 18-20 grams of a mixture of mercuric oxide, potassium sulfate and anhydrous copper sulfate, and several pyrex glass beads were added. The sample was heated gradually, care being taken to prevent foaming over, until the solution was clear. The time required for digestion took 2-3 hours. When digestion was complete, 400 c.c. of tap water was added and the flasks were cooled in running tap water. The solution was then neutralized with sodium hydroxide solution containing potassium sulfide and sodium thiosulfate and an excess added. Extreme caution must be observed when neutralizing the solution or the sample may be lost. A pinch of granulated zinc was then added to prevent bumping and the ammonia was distilled and titrated in the usual manner.

Ether Extract. The official method for the determination of ether extract (6) was used with slight modifications. A 2.5-3.5 gram sample was weighed out by difference and spread in a thin layer, three inches by four inches, of fat free cotton. The cotton containing the sample was then folded in and rolled and placed in fat free paper thimbles which were then placed in the desiccator with the moisture samples. When the moisture samples had ceased losing weight, the thimbles were extracted with anhydrous ether for 72 hours. The extract was dried in a vacuum oven to constant weight and weighed.

Calcium. Ten gram samples were weighed out onto ashless filter papers and transferred to 800 c.c. pyrex Kjeldahl flasks, as described by Forbes et al. (7). Ten c.c. of concentrated sulfuric acid and 10 c.c. of concentrated nitric acid were then added and the flasks placed in an inclined position. Heat was applied, gently at first, but more strongly as the oxidation proceeded. Several c.c. of nitric acid were added from time to time. To remove the more stable fraction of organic material from pork lard by this method, it is necessary to heat until the sample starts to char. This occurs near the boiling point of concentrated sulfuric acid. Introduction of a few c.c. of

nitric acid, by means of a pipette, at this point brings about vigorous oxidation. The oxidation is complete when the boiling sample will not darken, after all nitric acid and water have been driven off as shown by the evolution of dense white fumes of sulfur trioxide.

Fiske and Logan (8) and Wang (9) reported that in order to obtain complete precipitation of calcium steps must be taken for the removal of sulfate. For this purpose, a wire rack was devised which holds four Kjeldahl flasks and a sheet metal box open on one side so that the assembly may be placed on a hot plate. The purpose of the metal box is to hold the temperature sufficiently high to prevent condensation of sulfuric acid in the upper parts of the flasks. Removal of sulfate in the manner just described was not considered complete enough, however, so the mineral residue was dissolved in 20 per cent hydrochloric acid and transferred to 100 c.c. beakers. The solutions were evaporated to dryness on a hot plate, then placed in a muffle furnace and heated to 500-600° C. for 15 minutes. This evaporation and heating was repeated three times. The calcium was then determined by the method described by Stearns (10) but was modified slightly. To the entire mineral residue from the 10 gram sample, 25 c.c. of distilled water was added. Then

1 c.c. of 0.016 per cent brom-cresol green indicator and 10 c.c. of 2.5 per cent oxalic acid were added. The acidity was adjusted with 1.5 M. acetic acid and 1:3 ammonium hydroxide so that the color just matched an equal volume of standard pH 5 solution containing the same amount of indicator. The solution was permitted to stand over night and was then filtered off with suction, using Jena fritted glass filtering crucibles. The precipitate and beaker in which precipitation was carried out were then washed with a saturated solution of calcium oxalate in 0.5 per cent ammonium hydroxide. The crucible and precipitate were then transferred to the precipitating beaker and the precipitate dissolved in 10 c.c. of normal sulfuric acid, heated to 90° C. and titrated with 0.01 N potassium permanganate. The remainder of the procedure and the calculation follow the usual technic of permanganate titrations.

Total Phosphorus. Sampling and oxidation of organic matter were carried out in the same manner as that described for calcium, except that more care was taken when the sample was heated strongly to char the organic material. Forbes (3) reported that the oxidation mixture must not be permitted to boil at the temperature of boiling sulfuric acid any longer than is necessary to slightly char

the material because of the danger of losing phosphoric acid. The clear digest solution was then transferred to a 400 c.c. beaker and neutralized to litmus, using first concentrated and then dilute 1:3 ammonium hydroxide solution. If the neutral point was passed, dilute hydrochloric acid was used. The neutral solutions were then transferred to 500 c.c. volumetric flasks.

For the estimation of total phosphorus, Koch's colorimetric method (11) was used. In the comparison, microcups were used on the colorimeter.

To a 5 c.c. aliquot from the 500 c.c. flask which represented the 10 gram sample, sufficient water was added to bring the volume to 6.5 c.c. To this solution, 0.4 c.c. of ammonium molybdate reagent was added and the solution was shaken after which 0.16 c.c. of amino naphthol sulfonic acid was added and the solution was shaken again. The solution was then let stand for 5 minutes and was compared with a standard phosphorus solution similarly made up.

Ether Extractable Phosphorus. The ether extract was transferred from the fat flasks to Kjeldahl flasks by dissolving in ether. The oxidation and estimation of phosphorus was identical to the method used in determining total phosphorus, except that the solution was made up to 100 c.c. instead of to 500 c.c.

Rendered Lard

Rendering. The lard was rendered by taking a portion of the well mixed sample, placing it on a fluted filter paper in a funnel which delivered into a 50 c.c. Erlenmeyer flask. The assembly was then placed in a vacuum oven at 90° C. and the pressure reduced to several cm. of mercury. About one hour was required to collect sufficient of the sample for analysis. When sufficient samples had been obtained, the samples were removed from the oven and placed in an ice bath and stirred constantly as solidification took place. The latter step was taken to insure homogeneity.

Chemical Analyses. Phosphorus. Samples for phosphorus were weighed, oxidized and estimated as for the adipose tissue, except that the solutions containing the mineral residues were made up to 100 c.c. instead of 500 c.c.

Moisture. Determination of moisture was the same as for adipose tissue, except that the air was displaced by nitrogen. This was accomplished by evacuating the desiccator, removing the hose which was attached to the vacuum pump and substituting a thin walled rubber tube connected

to a tank of nitrogen. Before this tube was attached to the desiccator, all air was swept out by opening the valve slightly. The tube was then attached and the desiccator valve opened. The thin walled tube collapsed immediately and the nitrogen tank valve was then opened slightly. As soon as the pressure in the desiccator nearly equals atmospheric pressure, the tube resumes its normal shape. At this point, the valves were closed and the vacuum line reattached and the desiccator evacuated again. This was repeated once.

Rancidity. The method used for predicting the susceptibility of the fat to oxidation is the method proposed by Lea (12, 13, 14). The principle invloved depends on the acceleration of oxidation of the unsaturated constituents by atmospheric oxygen at an elevated temperature. Each sample was tested at four lengths of time of oxidation at 110° C. namely; 0, 15, and 45 minutes. The extent of oxidation was then determined as follows: previously weighed fat free filter papers, 5.5 cm., were saturated with the melted sample of lard and the excess blotted away. The papers were suspended by means of previously weighed fat free cotton threads and weighed again to obtain weight of lard sample.

The oxidation was carried out in 2-quart glass jars fitted with lids to the under side of which had been soldered two wire hooks. The hooks were so placed that when the saturated papers were suspended from them, they would touch neither each other nor the sides of the jar. The jars with lids on were placed in an air oven at 110° C. until equilibrium had been established. Then three jars were withdrawn, one at a time, charged with their duplicate samples and returned to the oven.

At the end of 15, 30, and 45 minutes, jars number 1, 2, and 3 respectively were withdrawn in order, the samples removed and placed in pyrex test tubes into which had been placed 2-3 grams of solid potassium iodide and 20 c.c. of 2:1 glacial acetic acid and chloroform mixture. The tubes were fitted with one-hole rubber stoppers and glass plugs. The stoppers were inserted with the plugs removed and the air was swept out with nitrogen. The tubes were then placed in a boiling water bath. When the nitrogen and remaining oxygen had been swept out by the acid-chloroform vapors, the tubes were closed and shaken vigorously for a few seconds and then let stand for 15 to 20 minutes. When the reaction was complete, the samples together with the filter papers and threads were transferred to 150 c.c. Er-

lenmeyer flasks, the tubes were rinsed with 20 c.c. portions of 5 per cent potassium iodide. The free iodine was titrated with standard, 0.002 N, sodium thiosulfate solution, using starch as an indicator.

DISCUSSION OF RESULTS

It will be observed in Table 1 that the phosphorus content of the adipose tissue appears to vary directly with the phosphorus level of the ration. This is in agreement with work done by Hoglund (2). The per cent of moisture also tends to increase with the increased phosphorus content, Figure 1. Emery and Henley (15) found that the direct part taken by moisture in the development of rancidity is negligible as compared with the effect of oxygen, light and the catalytic effect of metals. This apparent trend in phosphorus and moisture might lead to the question as to whether moisture might be a factor in keeping quality. The susceptibility to rancidity in the naturally aged samples, as shown by peroxide numbers, Table 3 and Figure 2, does not show a definite trend with respect to phosphorus or moisture content of the tissue. However, in the artificially aged samples a definite trend was found. The low phosphorus animals in both kills gave the highest peroxide

values for the initial artificial aging period. The high phosphorus animals gave the lowest and the medium phosphorus animals gave values which fall in between. The longer periods of artificial aging did not give such consistent results. The average rancidity for the three periods of artificial aging show the same general trend as the initial artificial aging period, Table 3. It is of interest to note that the peroxide values for total artificial aging and natural aging periods, Table 3, decrease as the phosphorus level increases for the group slaughtered at the end of 8 weeks, while the same value increased with the phosphorus level in the animals slaughtered at the end of 16 weeks.

Differentiation between the samples on which peroxide numbers were taken as they came from the coolers and samples which were subject to accelerated oxidation is indicated by use of the terms natural aging and artificial aging. This must not be construed to mean that the samples designated as artificially aged were fresh samples, artificially aged. These samples were aged naturally and in addition were subjected to the accelerated oxidation. The peroxide values recorded as due to artificial aging were obtained by subtracting the peroxide values obtained

without artificial aging from the values obtained after such aging had taken place. This point must not be overlooked because entirely different results might be obtained had the accelerated oxidation tests been carried out on fresh samples.

The calcium content of the adipose tissue increased as the phosphorus increased. No explanation is offered for the low values found for calcium and phosphorus as compared with values found in the literature for beef adipose tissue.

The animals slaughtered at the end of 8 weeks will be observed to give somewhat lower values for ether extract than the animals slaughtered at the end of 16 weeks which is normally the case as finishing progresses. The animals slaughtered at the end of 16 weeks made a mean gain of about 40 pounds for the preceding period of 8 weeks, and possessed a higher degree of finish than the animals slaughtered at the end of 8 weeks.

The sum of per cents of protein, ether extract, and moisture were found to total more than 100. Had this been anticipated, more ether extractions would have been made and nitrogen determined in the extract to determine whether an appreciable amount of proteolysis had occurred. It must

be borne in mind that the samples had been naturally aged for about three and one-half years. Any protein cleavage which yielded ether soluble nitrogen containing products would give false values for fat. The extremely high values for ether extract, ranging from 88 per cent to 95 per cent, indicate that the above may be the correct explanation.

The phosphorus content of the rendered lard and of the ether extract was found to be in the same order as shown by Tables 1, 2 and Figure 4. Since the phosphorus extracted with ether is largely that bound up in phospholipids and because of the hydrophilic properties of these compounds, the moisture would be expected to vary at least in part with the ether extractable phosphorus. This relation is shown in Figure 3. Although the points are scattered somewhat, an enclosed area including all of the points indicates that an increased ether extractable phosphorus content is accompanied by a slight increase in moisture content in the whole adipose tissue. For the same reason, the phosphorus content of the rendered lard might be expected to vary directly with moisture content. That this is true may be seen from Figure 5 in which rendered lard phosphorus is plotted against tissue moisture.

Samples 1-6 inclusive had a distinctly rancid odor. The odor was stronger in 1 and 2 than in 5 and 6, with 3 and 4 falling in between. Also a brown coloration was noted in samples 1-6 inclusive, 1 and 2 had a darker color than did 5 and 6, with 3 and 4 again falling in between. Samples 7-12 inclusive were white in color and no variation in odor was noted. All smelled sweet with no hint of rancidity. No explanation is offered for the difference in the condition of the two groups of samples, except that perhaps at some time during the natural aging period, samples 1-6 inclusive were permitted to remain at an elevated temperature for some time. As to the differences in color and odor within this group, no such explanation is logical since all six were taken at one time and were kept together. The differences observed must have been in the samples themselves and not in the way they were handled.

Samples 1-6 inclusive, which were obtained from pigs weighing about 80 pounds, have an apparent dependence upon phosphorus for keeping quality. Samples 7-12 inclusive were taken from heavier pigs and in such weights no such variation is apparent.

The per cent of ash was found to be slightly lower in the more highly finished animals, as shown by Table 1. The

difference is not considered to be significant, however, because in order to arrive at significant differences in ash content of adipose tissue the results would have to be reported on a fat free basis. It may be clearly seen that if this were done, negligible differences would be obtained.

SUMMARY AND CONCLUSIONS

Three lots of pigs were fed on three levels of P. The levels were 0.15, 0.23, and 0.30 per cent. Half of the pigs were slaughtered at the end of 8 weeks, the remainder at the end of 16 weeks. The adipose tissue was analyzed in an endeavor to learn something of the relation of phosphorus to the keeping quality of the tissue and lard rendered from it. All factors except the phosphorus level of the ration were maintained as nearly as possible at a level which should promote normal growth and development. The low level of phosphorus was insufficient to maintain normal growth and development, the high level was considered adequate and the medium level falls somewhere in between, as shown by Aubel, Hughes and Lienhardt in the observation of these animals and previous work.

The analyses on the whole tissue included moisture, ash, protein, ether extract, calcium, total phosphorus, and ether extractable phosphorus. The total phosphorus content of the tissue was observed to vary directly with the phosphorus level of the ration. The per cent of moisture was also observed to vary directly with the phosphorus level. The calcium content of the tissue was found to increase as the phosphorus content increased. The ether extractable phosphorus was found to be very low in the low phosphorus animals but was somewhat higher in the two higher level animals. Values for ash, protein and ether extract showed no tendency to a regular variation.

Samples of adipose tissue were rendered and moisture, phosphorus and peroxide tests were carried out.

The phosphorus content of the rendered lard was found to vary in the same order as the phosphorus in the ether extract which indicated that the phosphorus, which may be removed by ether, may also be removed by rendering. From this fact, it may be inferred that this phosphorus is bound up in phospholipids. Since the moisture content was found to vary directly with the phosphorus content and because of the hydrophylic properties of phospholipids, the above inference is borne out.

Peroxide numbers which were taken on the lard immediately after rendering shall be designated as natural aging. Peroxide numbers taken on samples after any of the three periods of accelerated oxidation by heating and from which the values obtained for the natural aging period have been subtracted shall be designated as artificial aging.

No correlation was found between phosphorus or moisture and susceptibility to rancidity in the naturally aged samples. However, in the artificially aged samples, a definite trend was found. The low phosphorus animals gave the highest rancidity values and the high phosphorus animals gave the lowest rancidity values. The sum of the peroxide values for the total artificial and natural aging periods decreased as the phosphorus level increased for the group slaughtered at the end of 8 weeks, while the same value increased with the phosphorus level in the animals slaughtered at the end of 16 weeks.

The samples from the group slaughtered at the end of 8 weeks had a distinctly rancid odor. The odor was stronger in the low phosphorus samples than in the high phosphorus samples with the medium group falling in between. This group of samples was slightly colored; the order of inten-

sity coincided with the strength of the odor. The samples from the group slaughtered at the end of 16 weeks were white in color and no variation was noted in the odor. The 8 weeks slaughter pigs weighed about 80 pounds and the 16 weeks slaughter pigs weighed about 120 pounds. Apparently, pigs of the lighter weight are dependent on phosphorus for keeping quality while the heavier group is not.

CORRECTION

The values for calcium given on page 23 should be doubled.

Table 1. Analyses of adipose tissue.

P level	Animal number	Moisture per cent	Ca per 100 grams tissue mg.	P per 100 grams tissue mg.	Ether extract per cent	Ash per cent	Protein per cent	$\frac{P}{Ca}$ ratio	P in ether extract per 100 grams tissue mg.
Animals slaughtered at the end of 8 weeks									
Low	1	7.46	1.96	14.84	90.63	0.209	9.24	7.55	2.8
Low	2	8.14	4.54	13.18	90.29	0.212	9.97	2.88	3.1
Medium	3	7.26	3.90	15.00	91.15	0.198	8.10	3.84	3.2
Medium	4	7.26	5.04	17.33	91.23	0.174	9.00	3.80	3.9
High	5	9.10	5.06	21.12	88.08	0.133	10.80	4.40	3.6
High	6	8.98	4.67	22.14	87.75	0.167	10.34	4.74	3.5
Animals slaughtered at the end of 16 weeks									
Low	7	6.71	5.27	15.66	93.68	0.076	4.78	2.97	2.9
Low	8	6.46	*	17.81	95.02	0.065	3.90	*	3.3
Medium	9	7.47	5.74	17.35	93.90	0.104	5.78	3.03	3.6
Medium	10	7.73	3.54	18.60	93.04	0.086	5.53	5.27	3.6
High	11	7.78	3.10	21.33	93.08	0.086	5.50	7.49	3.9
High	12	9.11	2.84	16.59	91.95	0.108	5.64	6.02	4.2

* Sample was lost.

Table 2. Analyses of rendered lard.

P level	Animal number	P per 100 grams rendered lard mg.	Moisture* per cent
	Animals slaughtered at end of 8 weeks		
Low	1	0.4	0.16
Low	2	0.9	0.30
Medium	3	1.4	0.27
Medium	4	1.6	0.00
High	5	2.9	0.23
High	6	2.4	0.19
	Animals slaughtered at end of 16 weeks		
Low	7	0.2	0.00
Low	8	0.6	0.00
Medium	9	2.3	0.00
Medium	10	2.4	0.00
High	11	2.4	0.00
High	12	3.0	0.00

* Samples given zero moisture started gaining weight slowly.

Table 3. Peroxide numbers on rendered lard.

c.c. 0.002 N $Na_2S_2O_3$ per mg. lard

P level	Animal number	Rancidity developed: Time intervals (average values) 0 min.	15 min.	30 min.	45 min.	0-15 min.	15-30 min.	30-45 min.	Average aging: Natural*	Artificial**	Total***
Animals slaughtered at the end of 8 weeks											
Low	1	30.6	118.4	214.8	220.3						
Low	2	41.9	62.1	130.3	153.8	54.0	87.3	14.5	36.2	155.8	192.0
Medium	3	44.1	83.6	124.4	159.7						
Medium	4	34.2	67.1	88.1	143.1	36.2	30.9	45.1	39.1	112.2	151.3
High	5	22.7	53.3	83.8	116.7						
High	6	40.8	52.6	90.2	96.7	21.2	34.0	19.7	31.7	74.9	106.6
Animals slaughtered at the end of 16 weeks											
Low	7	25.6	56.9	68.6	101.4						
Low	8	16.0	34.6	31.2	65.2	24.9	5.8	33.4	20.8	64.1	84.9
Medium	9	9.6	18.4	33.0	57.8						
Medium	10	20.7	56.5	115.2	127.5	22.3	36.6	18.5	15.1	77.4	92.5
High	11	45.2	48.1	64.1	99.5						
High	12	55.8	60.5	80.9	121.8	3.8	18.2	38.1	50.5	60.1	110.6

* Average values on freshly rendered samples.

** Average values on artificially aged samples.

*** Sum of average natural and artificial aging.

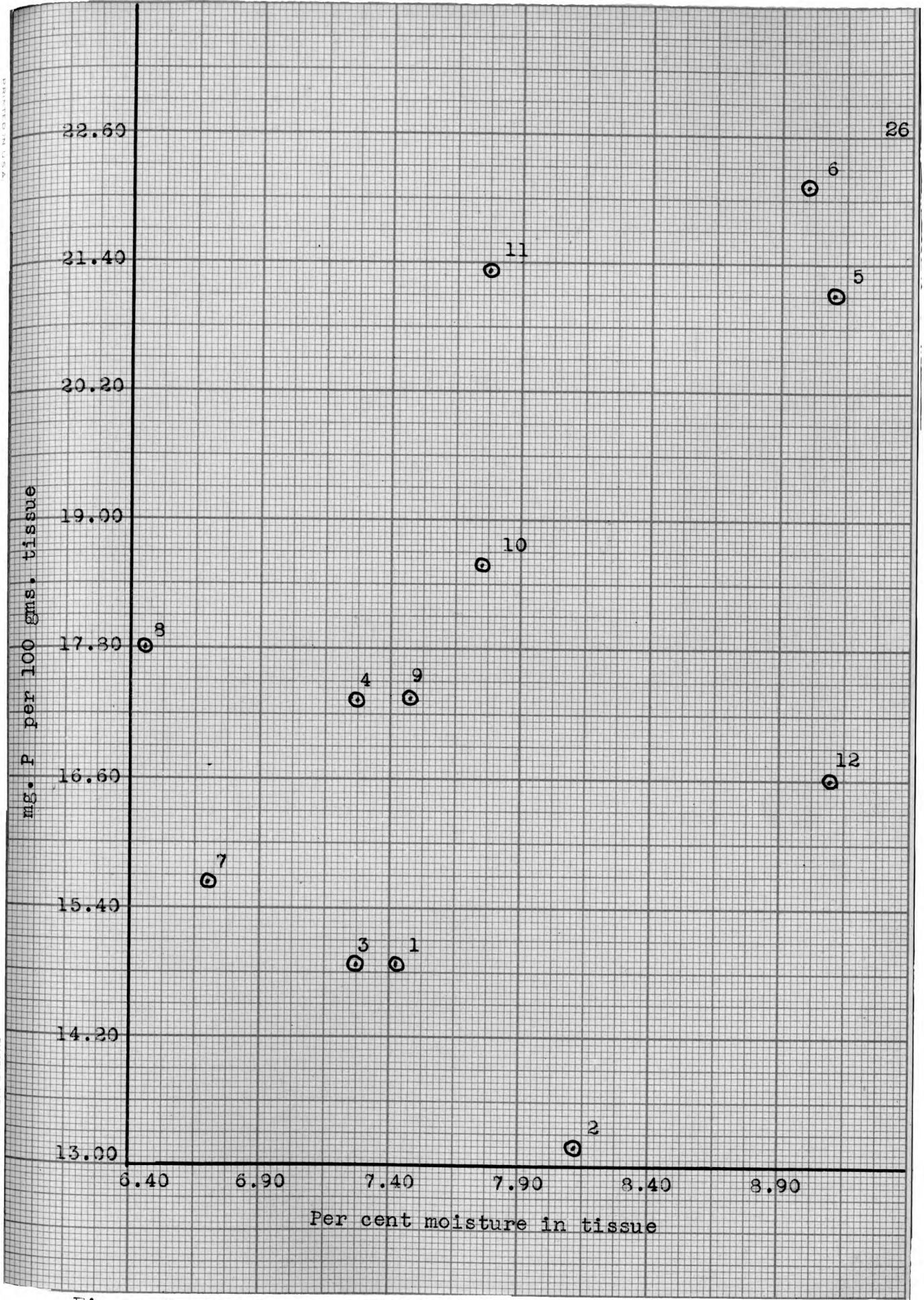

Figure 1. Variation of tissue phosphorus with tissue moisture.

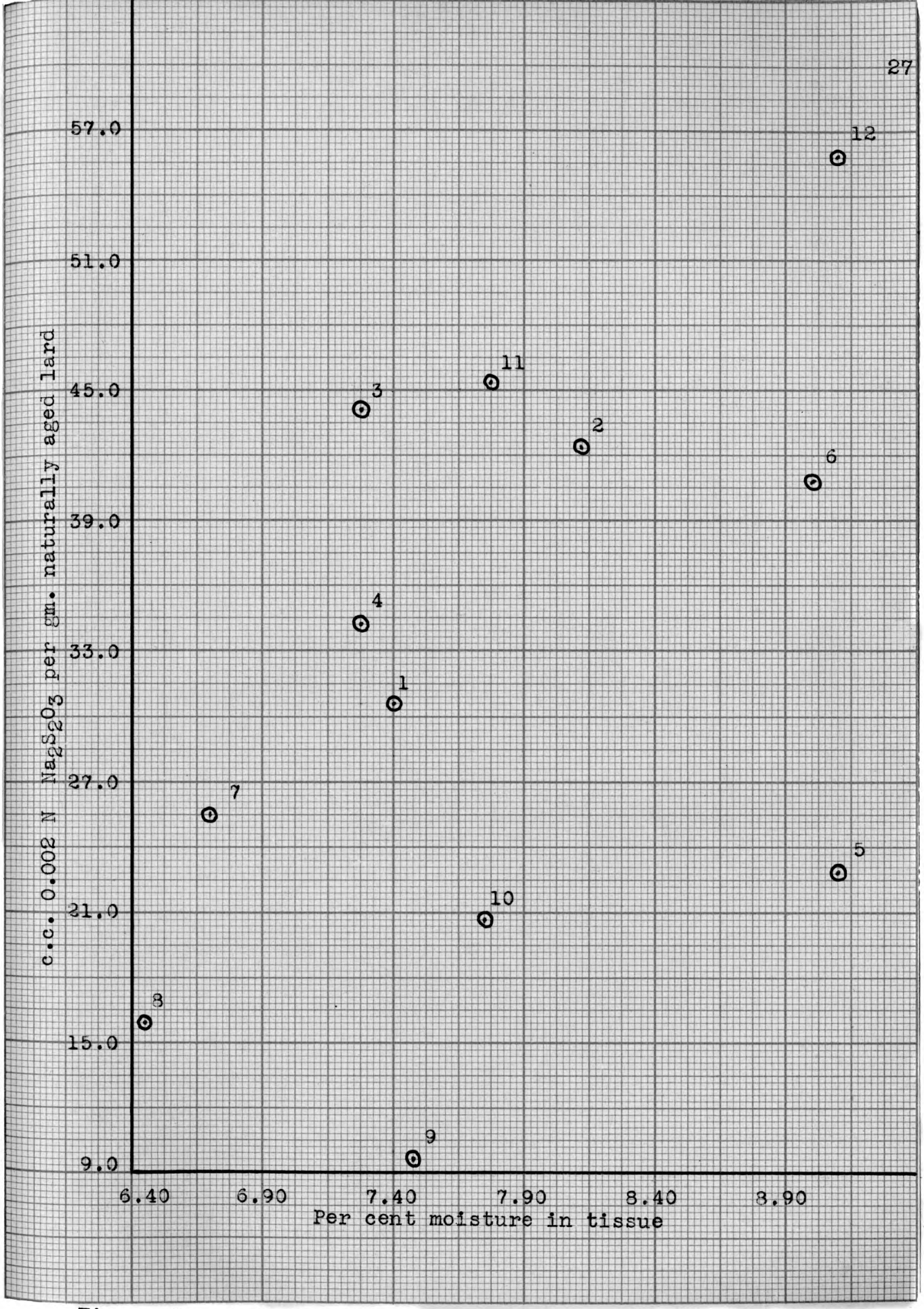

Figure 2. Variation of peroxide numbers with tissue moisture.

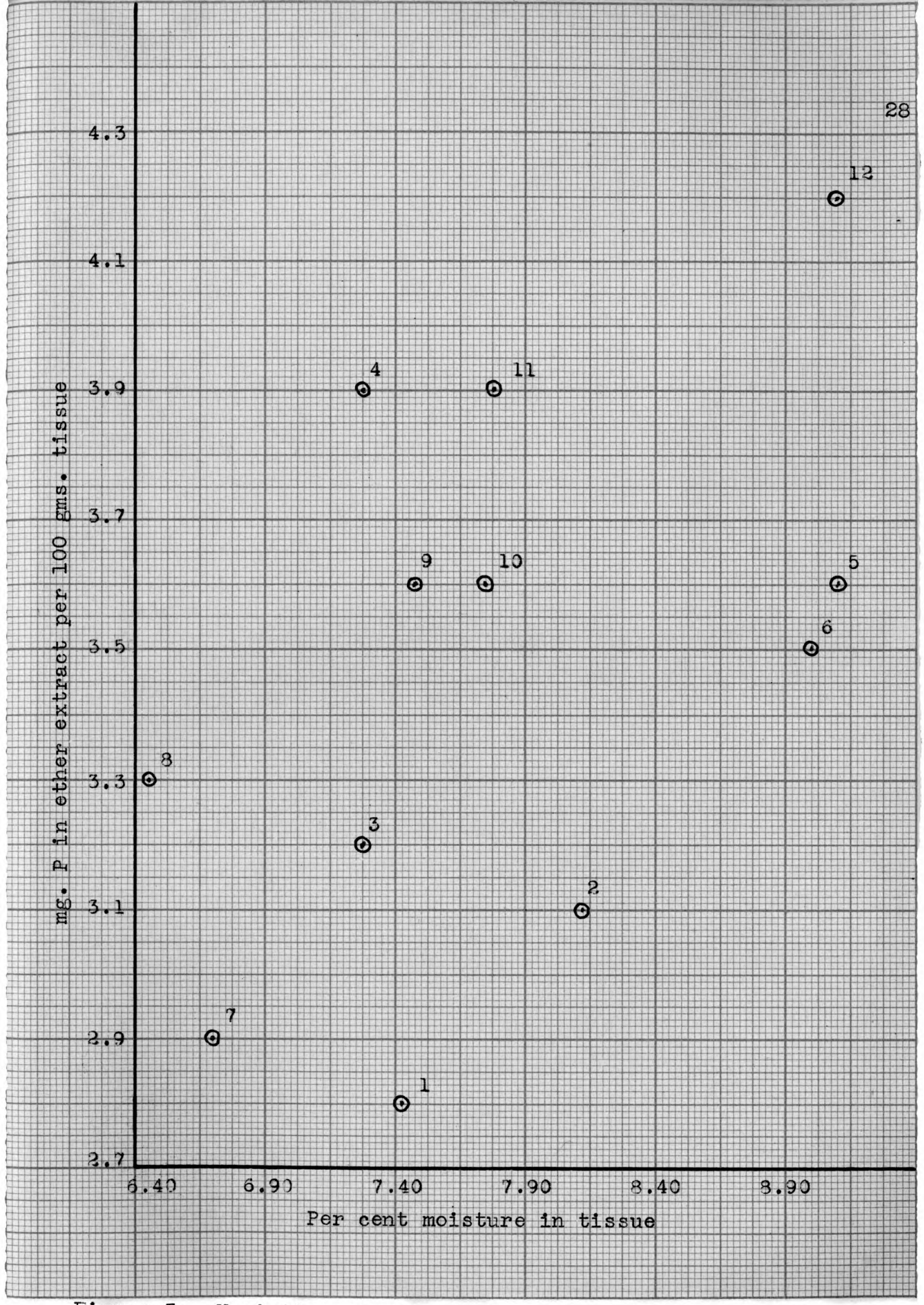

Figure 3. Variation of ether extractable phosphorus with tissue moisture.

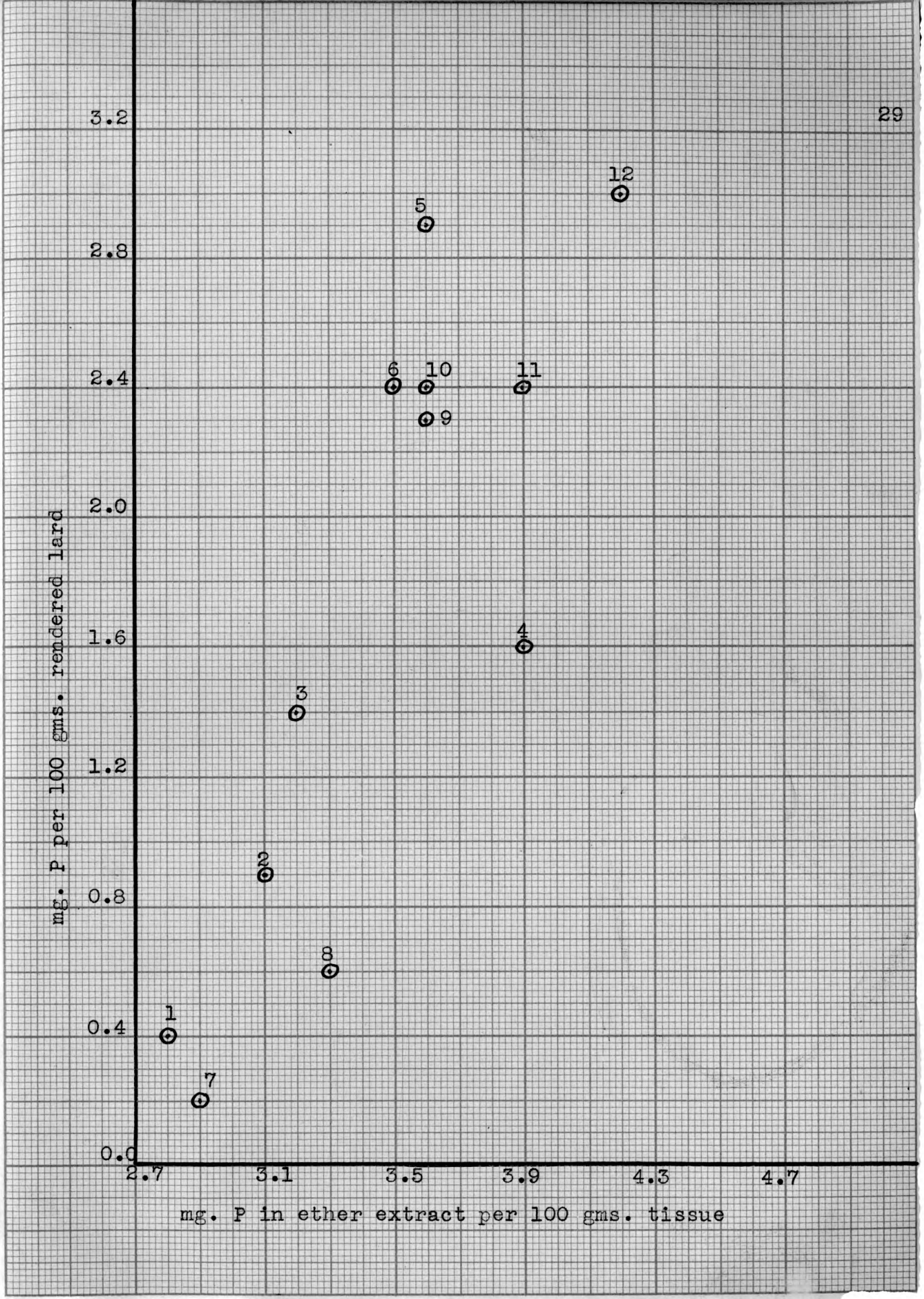

Figure 4. Variation of rendered lard phosphorus with ether extractable phosphorus.

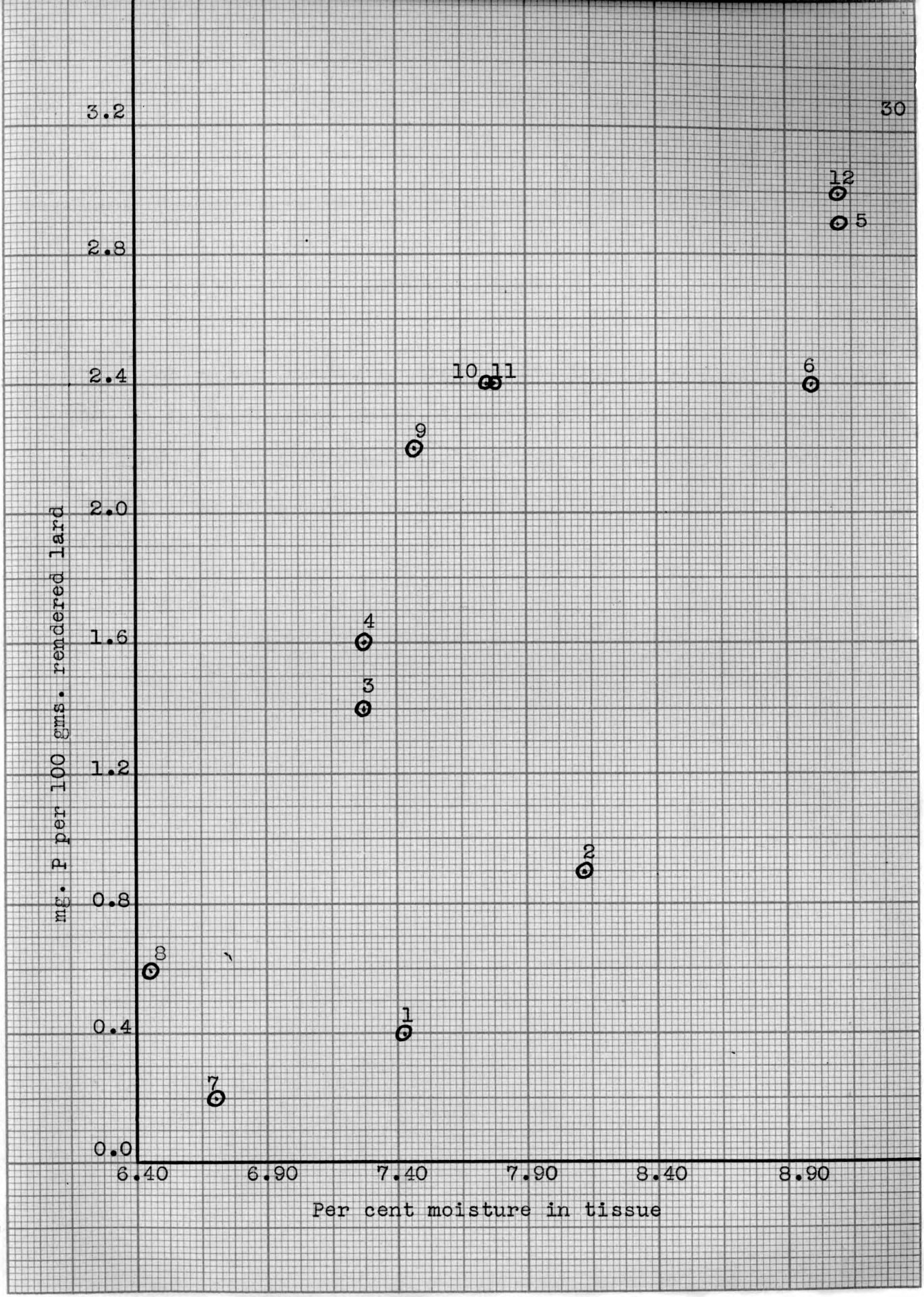

Figure 5. Variation of rendered lard phosphorus with tissue moisture.

ACKNOWLEDGMENT

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