

DEVELOPMENT OF A SLURRY PROCESS FOR THE
PRODUCTION OF DEHYDRATED MASHED
POTATO GRANULES

by

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B. S., Northeastern University,
Boston, 1949

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Chemical Engineering

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1950

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INTRODUCTION

The Potato Granule process, originally developed by Green et al. (3), has been under investigation for some time. It has received enough attention to warrant the construction of a plant for the production of granules in Sweden and the projection of others in this country.

Although the original process gives a product of excellent quality, it contains some undesirable features, particularly from an economic point of view. These features were realized by the original workers, and the slurry process was invented. The slurry process consists essentially of thawing the frozen potatoes in a 2-5 per cent brine solution. It was hoped by this method that certain advantages, such as the elimination of hand trimming to save labor costs, the reduction of waste products, the use of lower grade of raw material, and the adoption of a precise chemical control, would be met.

Some difficulties were encountered with the slurry process and no further work was done by the inventors. Instead, all of the work since then has been concerned with the improvement of the original process.

Two facts concerning the slurry process are available. First, that cell rupture is reduced by adding the frozen potatoes to a 2 per cent brine solution instead of to untreated water and second, the product obtained by the slurry process is notice-

ably darker (or grayer) than samples prepared by the original process. This was thought to be due to either presence of peel or metallic contamination. It was assumed at the beginning of this work that results obtained from previous research on the production of potato-granules would be applicable here. The drying and granulating operations therefore will not be treated here. Some work was done, but its aim was simply to see if the previous data and results could be applied to slurry process potatoes. These will be discussed later.

One of the most objectionable characteristics of slurry process potatoes was the resulting grayish color. Since the aim of any process of this type is to make a product which is both palatable and appealing, studies of the color reaction were undertaken with the idea of controlling the color in the final product by chemical means.

THEORETICAL ANALYSIS

Darkening in potatoes may be attributed to two types of reactions:

1. Reaction between enzymes and reducing agents to form a pigment which is called enzymatic browning;

2. Reaction between ammino acids and reducing sugars which is called non-enzymatic browning, or the Millard Reaction.

Since the high-temperature cooking of the potatoes during the preliminary stages of preparation should be sufficient to inactivate most of the enzymes, it was concluded that nonenzymatic browning (or pinking) was the source of discolor in the product obtained by the slurry process.

In 1912, Millard (9) pointed out that solutions containing ammino acids and reducing sugars turned brown when heated. Several studies have been reported in which the nonenzymatic browning action has been shown to be the same (9, 14, 17, 15). Other theories are also available (1, 20).

The entire darkening reaction in potatoes is probably a composite of all possible darkening reactions. It remains, therefore, to postulate a method of control. There are several patents and papers which describe methods of pretreating potatoes for evaporation or for chip manufacture by blanching them in various slightly acidic solutions (14, 17, 1). The feature common to all of these reactions or processes is possibly the reduction in pH. Possibly, if the slurry is kept at a low

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enough pH, the Millard reaction will not occur.

The normal pH of a potato slurry varies between 5.3 and 6.4. The higher value occurs when a brine solution is employed. Since noticeable darkening occurs at both pH's, the problem is to discover the optimum pH for practical use. The choice in pH must be weighted by two specific considerations:

1. The amount of acid remaining in the final product should never be great enough to give the characteristic acidic taste.

2. The amount of acid added should not be enough to hydrolize the starch.

The first is self-evident since a sour taste is undesirable in any food product. Secondly, if starch is hydrolized, the resulting granule will be coarse and grainy.

Several acids were employed to give various pH values, and the product was evaluated for taste and color. No adequate and accurate evaluation of taste is possible since it varies with the individual. Color can be evaluated as a function of several factors as will be described below.

This paper constitutes one step in the process of trying to evaluate the product quantitatively and improve its quality.

EQUIPMENT

The equipment will be divided into two classes.

1. The equipment used in making experimental runs with the slurry process.

2. The equipment used in making the color determinations.

The equipment for carrying the slurry process will be described in some detail. A brief description of the colorimeter will be given.

Theoretically the slurry process can be carried out with the simplest of equipment. The earliest runs on this process were made using glass jars as mixing vessels, a press for dewatering and a rotary drum drier for drying. Later on a centrifuge was employed in the dewatering slip. This equipment had several disadvantages:

1. The glass jars were subject to breakage and were too small for the purpose to which they were put.

2. The press failed to give a uniformly dewatered product. The edges were much wetter than the center.

3. The rotary drum dryer was not designed to dry a product of this type and hence the problems of high wastage and poor particle size were encountered.

Most of these difficulties were surmounted by building the small pilot plant shown in the accompanying photographs. Two wash tubs were converted to tanks suitable for the mixing of the slurry and for collecting the screened pulp. They were arranged

so as to make use of gravity flow. The pulp was removed from the collecting tank by means of a glass pump and conducted through 1 1/2" aluminum pipe to a centrifuge where it was dewatered. Granulation was done by hand through an #18 mesh stainless steel screen.

The rotary dryer was replaced by a vertical pneumatic dryer after qualitative tests on the experimental alfalfa dryer of this type showed the desirability of a dryer of this type. With this in mind a dryer was constructed of 6" galvanized iron stove pipe. This dryer was considerably smaller than the alfalfa dryer. The dryer consists of a combustion tube, horizontal section, vertical section, cyclone, and blower. The blower was placed on the outlet side in order that a negative pressure might be maintained in the dryer.

Very careful attention was paid to the detail of keeping the slurry away from such materials as iron and copper, as these materials catalyze darkening reactions in the process. All piping was constructed of either aluminum or stainless steel. The mixing vessels were enameled in order that none of the iron underneath would come in contact with the slurry. The pump which fed the slurry into the centrifuge was constructed of glass.

Color measurements were made with a photovolt photoelectric reflection meter (Mod #610). This instrument consists of two photocells connected to a galvanometer. The circuit is adjusted so that reflected light may be read directly through a series of

three filters. The photocells are contained in a search unit which has provisions for mounting the various filters. Readings of the colorimeter are converted to standard I. C. I. notation by the following equations:

$$X = 0.8A + 0.18B$$

$$Y = G$$

$$Z = 1.18B$$

Where A, G, & B are the reflectance values obtained by measuring with the amber, green and blue filters, respectively. It will be noted that the reading with the green filter is identical with the I. C. I. Y value.

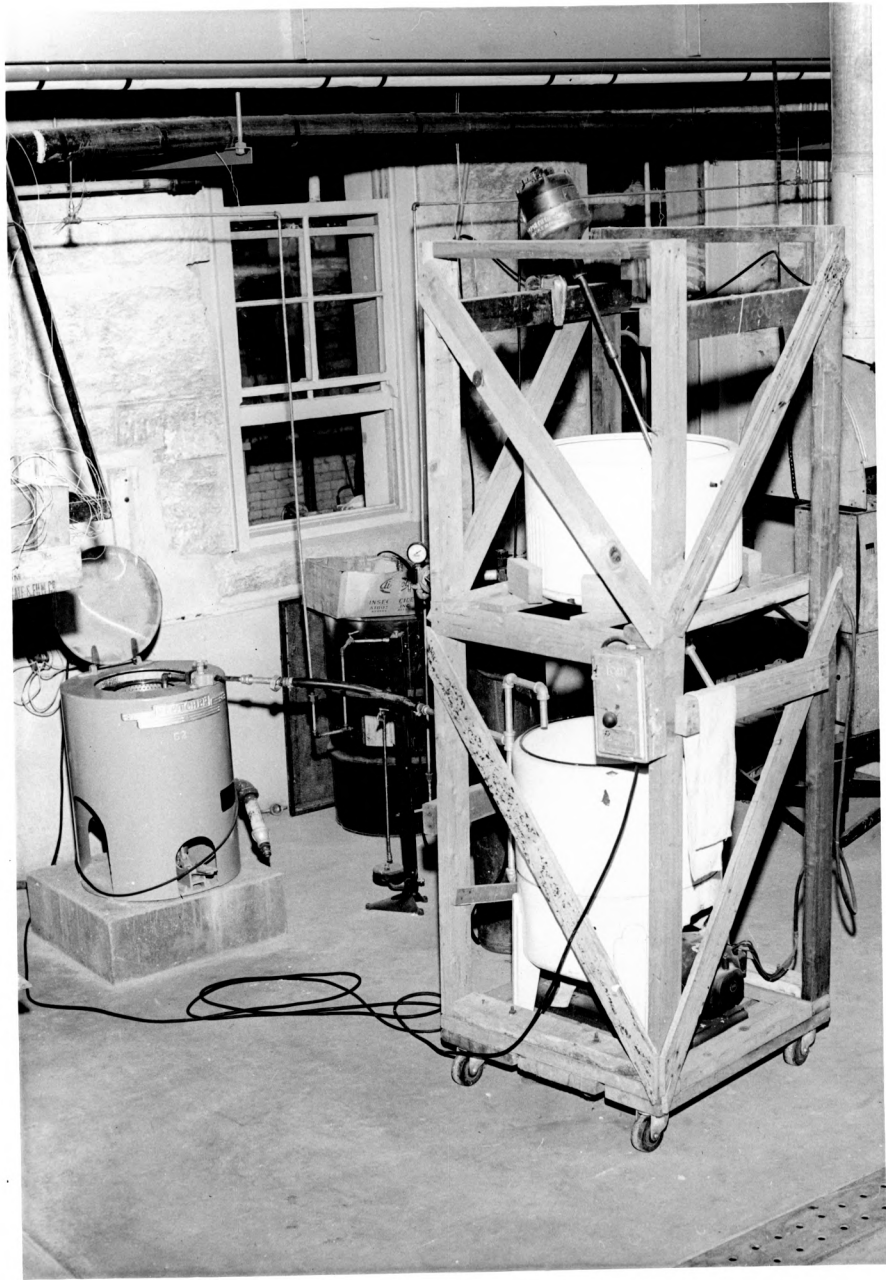
Working standards were obtained from the Munsell Color Company. These standards were employed in conjunction with those supplied with the instrument. The dark standard as supplied with the colorimeter was taken to have a reflectance of zero.

Munsell color standards used in this work were, N 9/, N 8.5/, 5Y 9/6 and, 5Y 9/1. The choice of the standard depended upon the sample under test.

EXPLANATION OF PLATE I

Mixing vessels and centrifuge

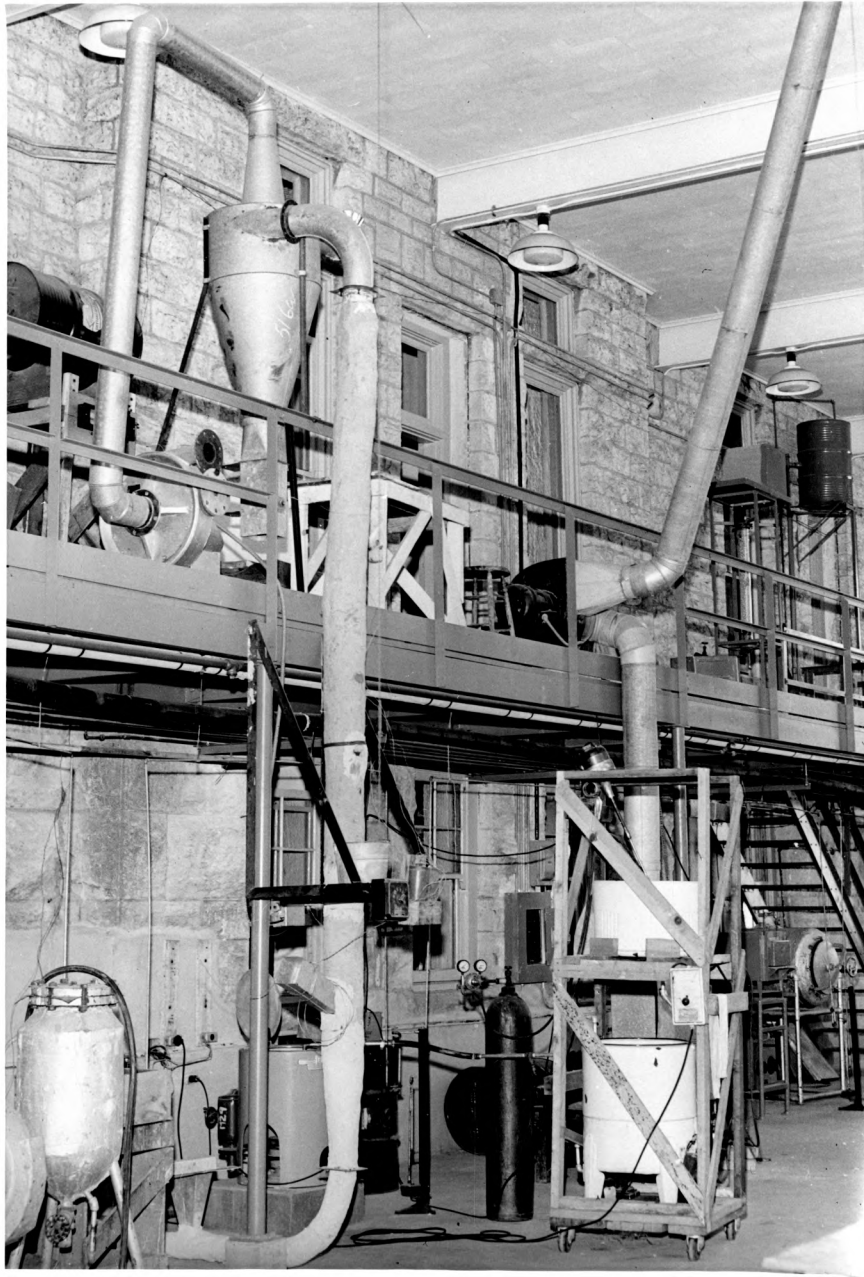
PLATE I



EXPLANATION OF PLATE II

Slurry process pilot plant showing mixing
vessels, centrifuge and vertical pneumatic
dryer

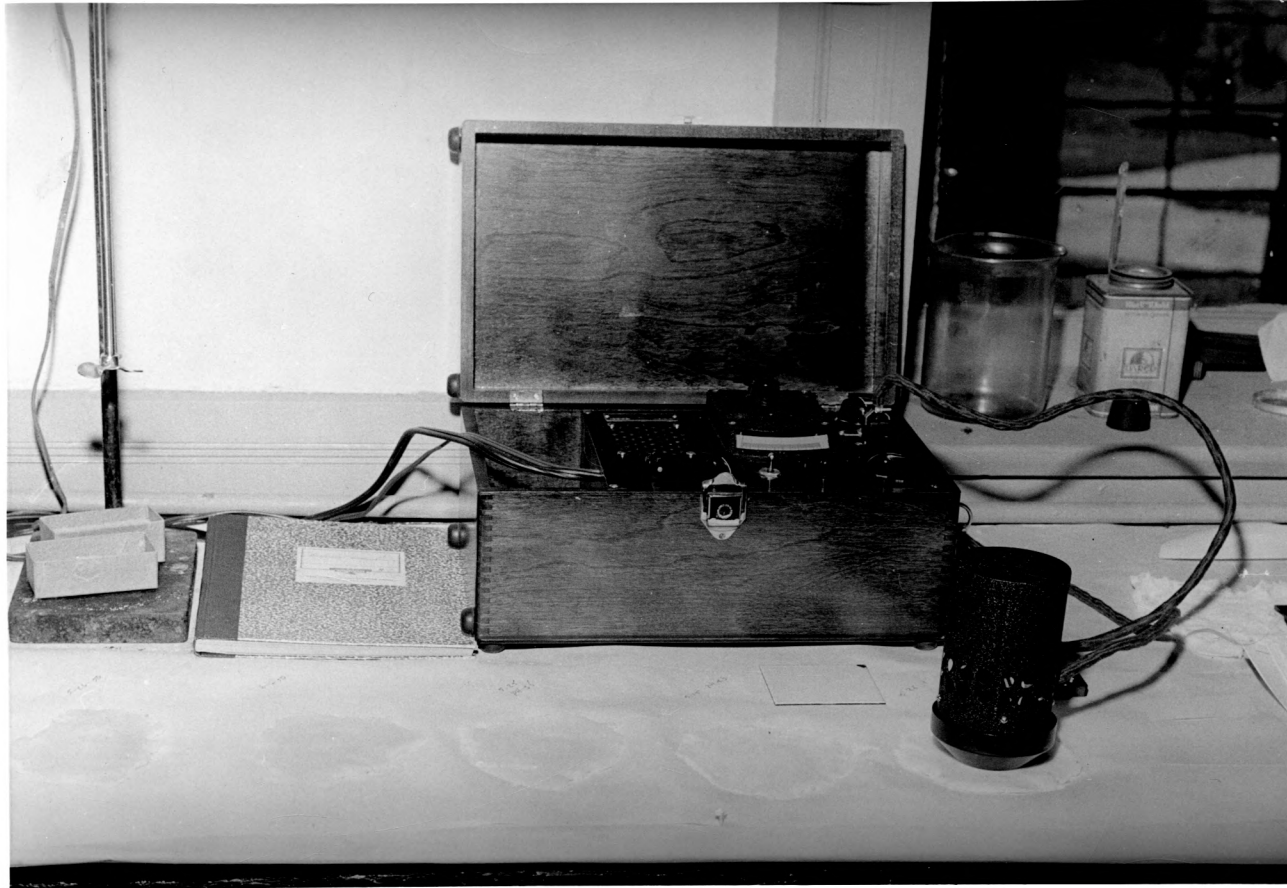
PLATE II



EXPLANATION OF PLATE III

View of photovolt tristimulus colorimeter
showing search unit in place for determining
the color of a sample

PLATE III



EXPERIMENTAL PROCEDURE

Experimental runs made with the slurry process adhere to the following procedure.

1. Washing
2. Cooking (Slicing)
3. Freezing
4. Thawing (in brine solution with mixing)
5. Screening (to remove the peels)
6. Centrifuging (dewatering)
7. Granulation
8. Drying

Potatoes were prepared for the slurry process by washing, slicing in 1" slabs, and cooking in live steam at approximately 220° F. for a period of 30 minutes. After this cooking period was completed they were removed to a sharp freeze and completely frozen. They were then stored at the temperature of the sharp freeze until needed for the next step.

For the beginning of the slurry process the frozen potatoes were removed from the refrigerator and placed in a brine solution (2-5 per cent) and thoroughly agitated.

During the mixing samples were withdrawn at intervals of one minute in order to determine the pH. This was done until a constant desired pH value was obtained. This value was determined before the beginning of the run and maintained as closely as possible. This was accomplished by adding either acid or

sodium carbonate (Na_2CO_3). After the fixed value of pH was reached readings were taken at frequent intervals and the adjustments made to maintain the pH at the set value. The duration of this operation was, on the average, about 30 minutes.

Upon completion of this operation the slurry, containing both peel and pulp, was allowed to run into a stainless steel screen (#18 mesh) where the peel was separated from the pulp. The peel was discarded as waste.

The lower tank now contained only the potato pulp. This slurry was then pumped into a centrifuge which dewatered the pulp. The slurry in the feed tank should be continually stirred while the mixture is being fed to the centrifuge in order to obtain a homogeneous feed. Failure to do this would result in unbalancing the centrifuge.

Upon the completion of the centrifuging operation the cake is granulated by brushing through an #18 mesh stainless steel screen by hand. The resultant granules are then ready for the drying operation.

Best results for drying were obtained by predrying the granules in the cyclone separator. If the wet granules were fed directly into the vertical section of the drier they tended to fall to the bottom and collect there. This resulted in clogging and produced serious scorching. This effect was minimized by passing the wet granules through the cyclone four times before introducing them into the vertical section (Fig. 6-Feeds #1 & 2)*. The granules are then subjected to as many passes as

needed to achieve the desired moisture content.

After the completion of the drying operation the granules are sieved and stored for color tests and other examinations.

Samples were prepared for color testing by adding to 10 gms of the sample 40 cc of boiling water. After rehydration was complete the mashed potatoes were spread out on paper. Colorimetric readings were taken then with the colorimeter. Proper thickness of the samples was obtained by taking several different thicknesses. When a constant reading was obtained for at least two thicknesses the background exerts no influence on the readings. This is the proper thickness.

* Fig. 6 in appendix.

EXPLANATION OF DATA

Application of the Theory of Color

Color has been defined as "consisting of the characteristics of light other than spatial and temporal inhomogeneities: light being that aspect of radiant energy of which a human observer is aware through the visual sensations which arise from the stimulation of the retina of the eye" (6). Color can be represented by three different systems.

1. Physical
2. Pshchophysical
3. Psychological

The first two systems have the virtue of being objective and hence not dependent upon the characteristics of the observer. These methods, therefore, represent methods by which it is possible to get a precise definition of color.

In choosing between two systems of color measurement, an idea of the result should be kept in mind. Application of physical methods to an orange peel will show two completely different series of spectral energy, depending on the illumination of the sample. Thus the orange illuminated by a sodium lamp (589.0 & 589.6 $m\mu$) and daylight (380 to 770 $m\mu$) will give two entirely different spectral composition curves. This technique does not take into account the properties of the observer since an orange peel under any kind of light will to an observer have an orange color. The broader concepts of color

which find much use today are based on spectrophotometry interpreted according to the properties of an observer. This work was originated by Wright (22), Smith (19), and Smith and Guild (18). Further nomenclature concerning this subject is given in the appendix.

Basically any color can be reproduced by mixing three primary colors (Red, Green and Blue) in different proportions. Thus, three colors present the irreducible minimum for color matching. Since three colors are both necessary and sufficient, it follows that color vision is tridimensional. It seems logical then, that color can be specified by three numbers. This can be done for Red, Green and Blue, viz.,

$$cC = rR + gG + bB.$$

where c , r , g , and b are known as the trichromatic coefficients.

This system has been supplemented in recent years by another which has found almost universal use. It is based on the work of Smith and Guild (18), Wright (22), and Judd (8) with a normal observer and was adopted by the International Committee on Illuminations (I. C. I., C. I. E.) in 1931 (23). It can be shown that the R. G. B. system can be converted to the I. C. I. system. This technique is explained thoroughly by Wright (22).

The I. C. I. system of notation can be represented by the equation:

$$cC = xX + yY + zZ,$$

where x , y , & z are measured by a spectro photometer, and are called tristimulus values. The values of x , y , and z are computed

by the following equations:

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z}$$

These quantities are called trichromatic coefficients or trichromatic coordinates. It should be noted that only two of these coefficients are independent, the other being defined by the equation:

$$x+y+z = 1,$$

regardless of the values assigned to x , y , & z .

An interesting feature of this system comes in the use of Y , the luminosity coefficient. This factor can be related to the presence or absence of color.

In this paper two methods of representing data will be employed:

1. The I. C. I. system
2. The d, β chromaticity system as developed by Schofield, Judd & Hunter (16).

The α, β chromaticity system is particularly useful in the reduction of data and for determining color differences. This system is easily correlated with a photoelectric tristimulus colorimeter. Hunter (5) has evaluated the use of this type of instrument and applied the techniques of the α, β system to reduction of data obtained from a colorimeter similar to the one employed here. The use of these methods for this paper was

suggested by Judd (7).

Evaluation of trichromatic values is not sufficient for a paper of this type. These particular values do not tell the entire story since they are limited to specifying hue and chroma. If one desires to determine the amount of greyness in a sample it is necessary to express these results as a function of two things:

1. Decrease in luminosity
2. Decrease in whiteness

Luminosity may be evaluated directly from colorimetric determinations since Y equals the reading of the sample with the green filter in a photoelectric tristimulus colorimeter by definition. No further reduction is necessary.

Whiteness may be evaluated by the method suggested by Judd (6). If MgO is assumed to be a perfect white then the whiteness of an unknown may be defined by

$$W = 1 - \frac{\Delta E \text{ MgO to specimen}}{\Delta E \text{ MgO to black}}$$

this equation can be converted to

$$W = \left\{ \left[30\sqrt{\alpha^2 + \beta^2} \right]^2 + \left[\frac{1.00 - Y}{2} \right]^2 \right\}^{1/2}$$

This equation is given by Hunter (5).

The data as presented refers to color. In presenting this data two systems described above were employed:

1. The International Committee on Illuminations System.
2. The Uniform Chromaticness Scale System.

The former system is the standard method for designating color.

The other system as defined by Schofield, Judd, and Hunter (16) is based on the I. C. I. system and is used to determine color differences.

Reduction of data obtained by the photoelectric tristimulus colorimeter is accomplished using the methods described by Hunter (5) and suggested by Judd (7).

Values of Y (the luminosity coefficient) are tabulated without alteration. Complete definition of a color is obtained by specifying Y , x , and y . (x and y are the trilinear coordinates).

In this work all samples were measured relative to magnesium oxide. Magnesium oxide is the standard white in photoelectric colorimetry. Its reflectance is taken as 100 and all values are expressed in per cent MgO. The same principals are adhered to in specifying whiteness on the α, β uniform chromaticness system. Magnesium oxide is expressed as one, and all other values are given in fractions of unity.

Munsell color standards and their various specifications are tabulated for reference. The trichromatic values were obtained from the literature (2, 11) and the tristimulus filter values were calculated from the following equations:

$$A = 1.25 x - 0.19z$$

$$G = Y$$

$$B = 0.852z$$

These equations are included in the instructions for use of the photovolt colorimeter.

All readings were made at suppressed zero in order to gain more accuracy in reading the instrument. In this manner the scale is expanded so that maximum and minimum deflections of the galvanometer correspond to the reflectivity of the high and low standards, respectively. Supressed zero, therefore, is a method of expanding the galvanometer scale by varying the reference standards. This should not be regarded as a fixed procedure but subject to the demands of the sample. The greatest utility occurs when all the samples have approximately the same reflectivity. Corrections to normal scale readings were made by using the following equation:

$$rx = rd + \frac{gx}{100} (re - rd)$$

The light supplied with the colorimeter corresponds to I. C. I. illuminant C.

Certain other data are also included for clarification of the reader. In each case they serve to define the color more specifically.

Values of $\sqrt{\alpha^2 + \beta^2}$ and $\sqrt{w_c^2 + w_1^2}$ were evaluated graphically.

Table 1. I. C. I. specifications for Munsell color standards

Munsell:	X	Y	Z	x	y	A	G	B
5Y 9/6	.7541	.7956	.5137	.366	.386	.8450	.7956	.4377
9/4	.7532	.7864	.6448	.345	.360	.8190	.7864	.5494
9/3	.6642	.6920	.5742	.344	.358	.7212	.6920	.4892
9/2	.7694	.7936	.7566	.332	.341	.8180	.7936	.6446
9/1	.6910	.7108	.7398	.323	.332	.7232	.7108	.6303
7.5Y								
9/6	.7754	.8370	.4670	.373	.403	.8806	.8370	.3979
9/4	.7929	.8440	.6182	.352	.374	.8738	.8440	.5267
9/2	.7823	.8160	.7698	.330	.345	.8316	.8160	.6559
2.5Y								
9/4	.8208	.8353	.7147	.346	.352	.8902	.8353	.6089
N 9/	.7095	.7256	.8367	.3123	.3194	.7511	.7256	.7129
N 8.5/	.6205	.6365	.7266	.313	.321	.6375	.6365	.6191

Table 2. Slurry color data I.

Sample:	Y	x	y	z	V	α	β	$\sqrt{\alpha^2 + \beta^2}$	w_c	w_1	$\sqrt{w_1 + w_c}$	$1 + \sqrt{w_1 + w_c}$	pH	A	G	B	Temp	Remarks
1	.5133	.3122	.3198	.3680	7.54	.00243	.00249	.0035	.105	.2434	.246	.754	6.15	.5138	.5133	.5005	18°C	Tray dried
2	.5574	.3174	.3226	.360	7.805	.0178	.00544	.0186	.557	.2213	.600	.400	5.5	.5667	.5574	.5271	18°C	" " citric acid
3	.4195	.3290	.3017	.3884	6.92	.00379	-.00911	.0099	.297	.2903	.417	.583	7.0	.4354	.4195	.4577	18°C	" "
4	.4792	.3160	.3090	.3750	7.325	.0117	.00284	.0121	.363	.2604	.450	.550	5.0	.5017	.4792	.4928	18°C	Same
5	.4742	.3112	.3092	.3796	7.29	.00597	-.00405	.0073	.219	.2629	.500	.500	5.0	.4855	.4742	.4934	18°C	Same
6	.5453	.3157	.3204	.3650	7.735	.00360	.00347	.0050	.150	.2274	.275	.725	3.5	.5532	.5453	.5264	18°C	Same
7	.5596	.3198	.3180	.3617	7.82	.00965	.00375	.0105	.315	.2202	.377	.623	4.5	.5812	.5596	.5386	18°C	Same
8	.6328	.3173	.3296	.3531	8.23	.000198	.00921	.0092	.276	.1886	.290	.710	3.5	.6323	.6328	.5745	18°C	Same
9	.5975	.3176	.3219	.3605	8.036	.0186	.00536	.0194	.582	.2170	.620	.380	6.2	.6093	.5975	.5671	18°C	Na HSO ₃ HCl (SO ₂)
10	.2832	.3435	.3338	.3227	5.85	.0254	.0181	.0320	.960	.3584	1.03	- 0	9.5	.3120	.2832	.2320	18°C	Tray dried
11	.4207	.3085	.3064	.3850	6.93	.00475	-.00649	.0081	.243	.2897	.380	.620	4.5	.4287	.4207	.4480	52°C	No comment
12	.4425	.3203	.3201	.3595	7.08	-.0205	.00353	.0056	.168	.2707	.320	.680	5.2	.4587	.4425	.4211	52°C	Elevated temp. -HCl
13	.5363	.3178	.3234	.3587	7.68	-.00429	.00601	.0074	.222	.2319	.322	.678	3.3	.5455	.5363	.5041	18°C	No comment
14	.4791	.3181	.3155	.3664	7.325	.00965	.00161	.0099	.297	.2130	.360	.640	5.6	.4976	.4791	.4714	18°C	SO ₂
15	.5741	.3151	.3248	.3601	7.905	.000314	.00606	.0061	.183	.2605	.320	.680	5.8	.5748	.5741	.5393	18°C	HCl
16	.5045	.3210	.3212	.3577	7.487	.00877	.00560	.0104	.312	.2478	.400	.600	1.5	.5232	.5045	.4763	18°C	SO ₂
17	.5664	.3197	.3283	.3519	7.86	.00318	.00921	.0097	.291	.2668	.400	.600	2 approx	.5736	.5664	.5143	18°C	HCl
18	.4897	.3050	.3216	.3733	7.392	-.0090	.0016	.00915	.274	.2552	.375	.625	5.7	.4721	.4897	.4818	18°C	SO ₂
19	.4360	.3015	.3083	.3901	7.04	-.00466	.00725	.0087	.261	.2820	.382	.618	6.2	.4278	.4360	.4676	18°C	No acid added
20	.5741	.3103	.3291	.3622	7.90	-.00776	.00674	.0103	.309	.2160	.379	.621	5.9	.5563	.5741	.5355	18°C	Na ₂ CO ₃ added during wash
21	.5522	.3203	.3242	.3557	7.778	.00648	.00705	.0097	.291	.2239	.370	.630	5.0	.5665	.5522	.5133	18°C	No comment
22	.4814	.3173	.3159	.3667	7.34	.00842	.00912	.0125	.375	.3593	.460	.540	4.5	.4976	.4814	.4376	18°C	" "

Table 2. (concl.).

Sample:	Y	x	y	z	V	d	β	$\sqrt{d^2 + \beta^2}$	W_c	W_1	$\sqrt{W_1 + W_c}$	$1 + \sqrt{W_1 + W_c}$	pH	A	G	B	Temp	Remarks
23	.4938	.3148	.3182	.3670	7.42	.00421	.00225	.0048	.144	.2531	.295	.705	4.0	.5021	.4938	.4827	18°C	No comment
24	.5387	.3190	.3235	.3575	7.70	.00451	.00635	.0084	.252	.2307	.340	.660	4.0	.5506	.5387	.5045	18°C	" "
25	.4443	.3118	.3103	.3779	7.09	.00592	.00322	.0067	.198	.2779	.340	.660	5.4	.4549	.4443	.4586	18°C	Some scorching
26	.4620	.3074	.3128	.3797	7.21	-.000757	-.00286	.0030	.090	.2690	.275	.725	5.4	.4606	.4620	.4752	18°C	Some Na ₂ CO ₃ added during wash
27	.3788	.3153	.3263	.3609	6.63	.00437	.00550	.0071	.213	.3106	.375	.625	6.2	.3854	.3788	.3580	18°C	Natural pH - no acid added
28	.4195				6.92								6.5	.4447	.4195		18°C	Dark specks due to scorching
*I	.4678	.3190	.3167	.3643	7.25	.00957	.00383	.0104	.312	.2393	.395	.605		.4864	.4678	.4650		Old process visual comparison
*II	.5315	.3285	.3272	.3443	7.65	.01385	.01082	.0181	.542	.2568	.600	.400		.5602	.5315	.4740		Old process standards

* Idaho Russets

** Red McClures

Table 3. Slurry color data II.

pH	W av	Y av	G av	B av
1.5 - 2.0		.5045		
2.0 - 2.5	.600	.5664	.400	.4336
3.5 - 4.0	.704	.5715	.296	.4285
4.0 - 4.5	.683	.5163	.317	.4837
4.5 - 5.0	.622	.4872	.378	.5128
5.0 - 5.5	.674	.4785	.376	.5215
5.5 - 6.0	.601	.5227	.399	.4773
6.0 - 6.5	.594	.5138	.406	.4862
6.5 - 7.0		.4195		.5805
7.0 - 7.5	.583	.4195	.417	.5805
8.5 - 9.0		.3788		.2832
9.0 - 9.5		.6212		.7168

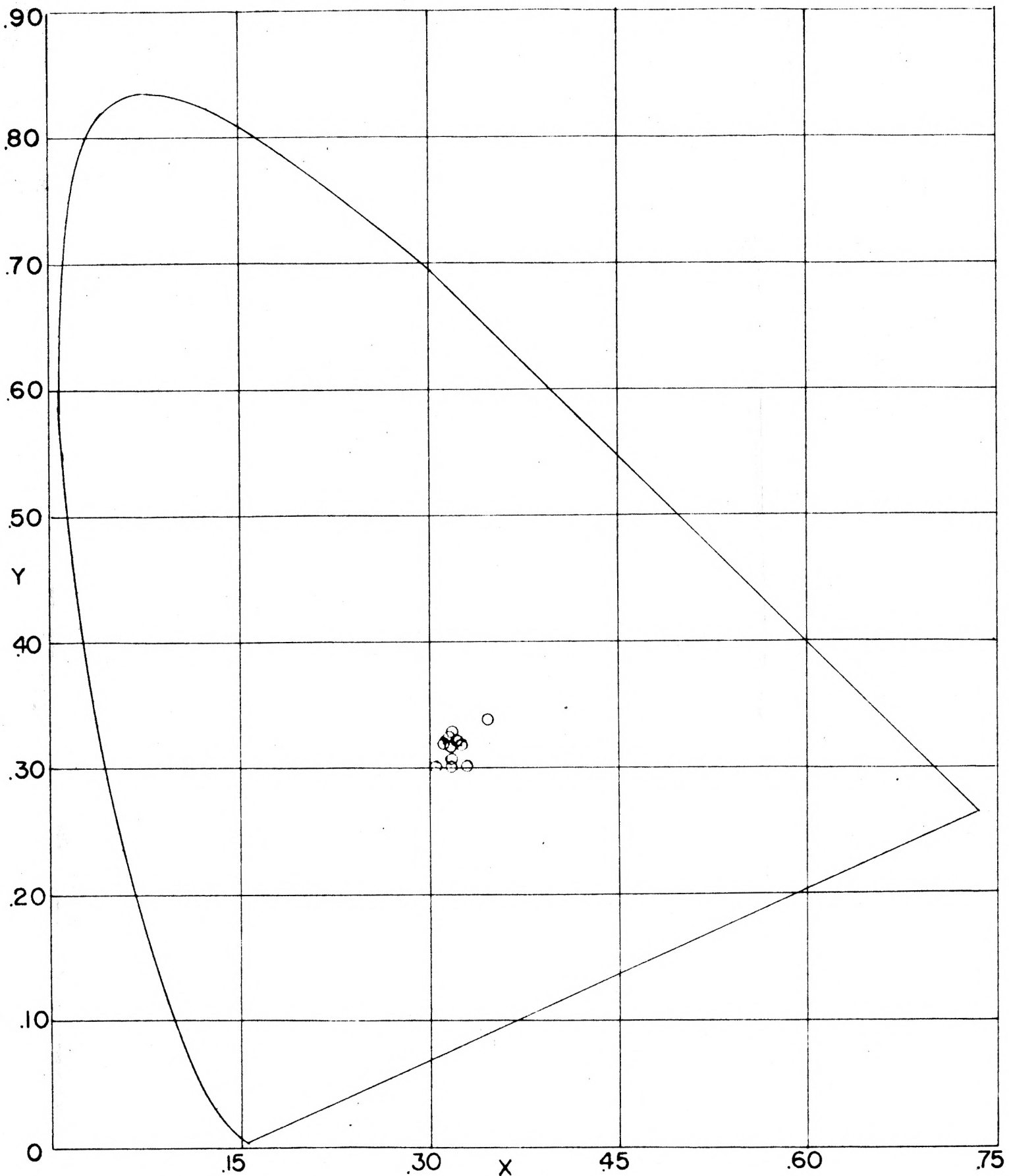


FIG 1.

ICI. CHROMATICITY DIAGRAM

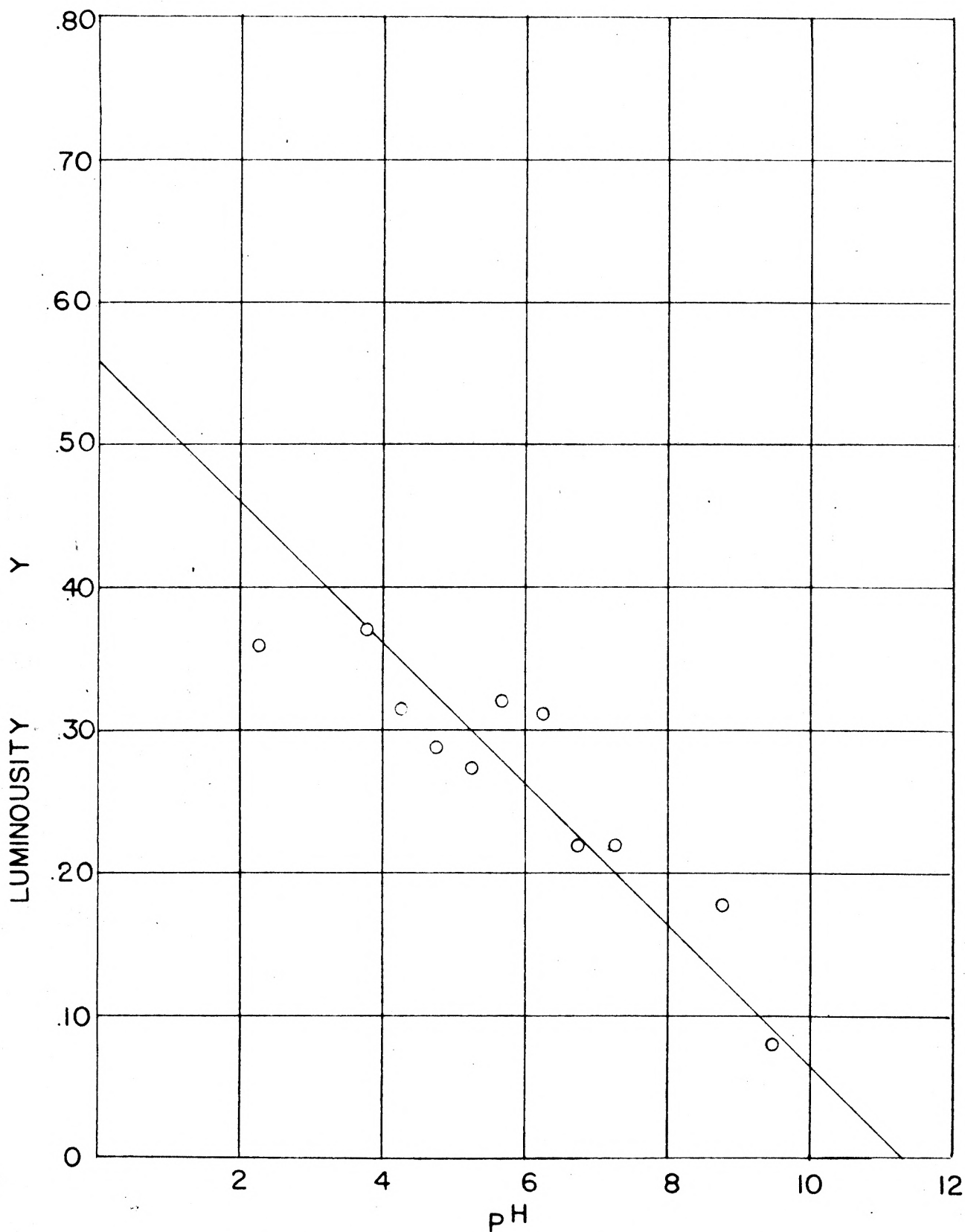


FIG 2 LUMINOUSITY VS pH

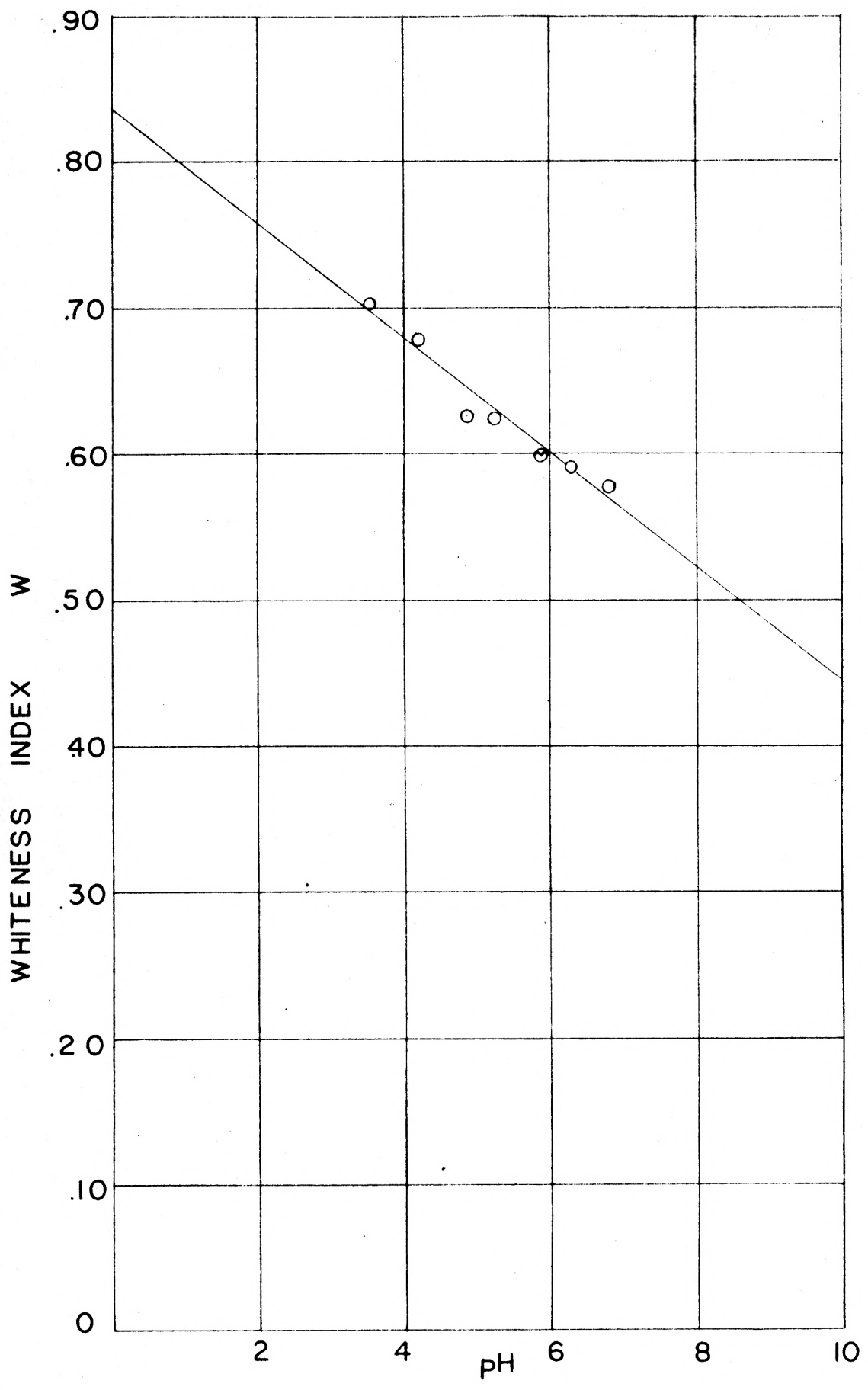


FIG 3 WHITNESS INDEX VS pH

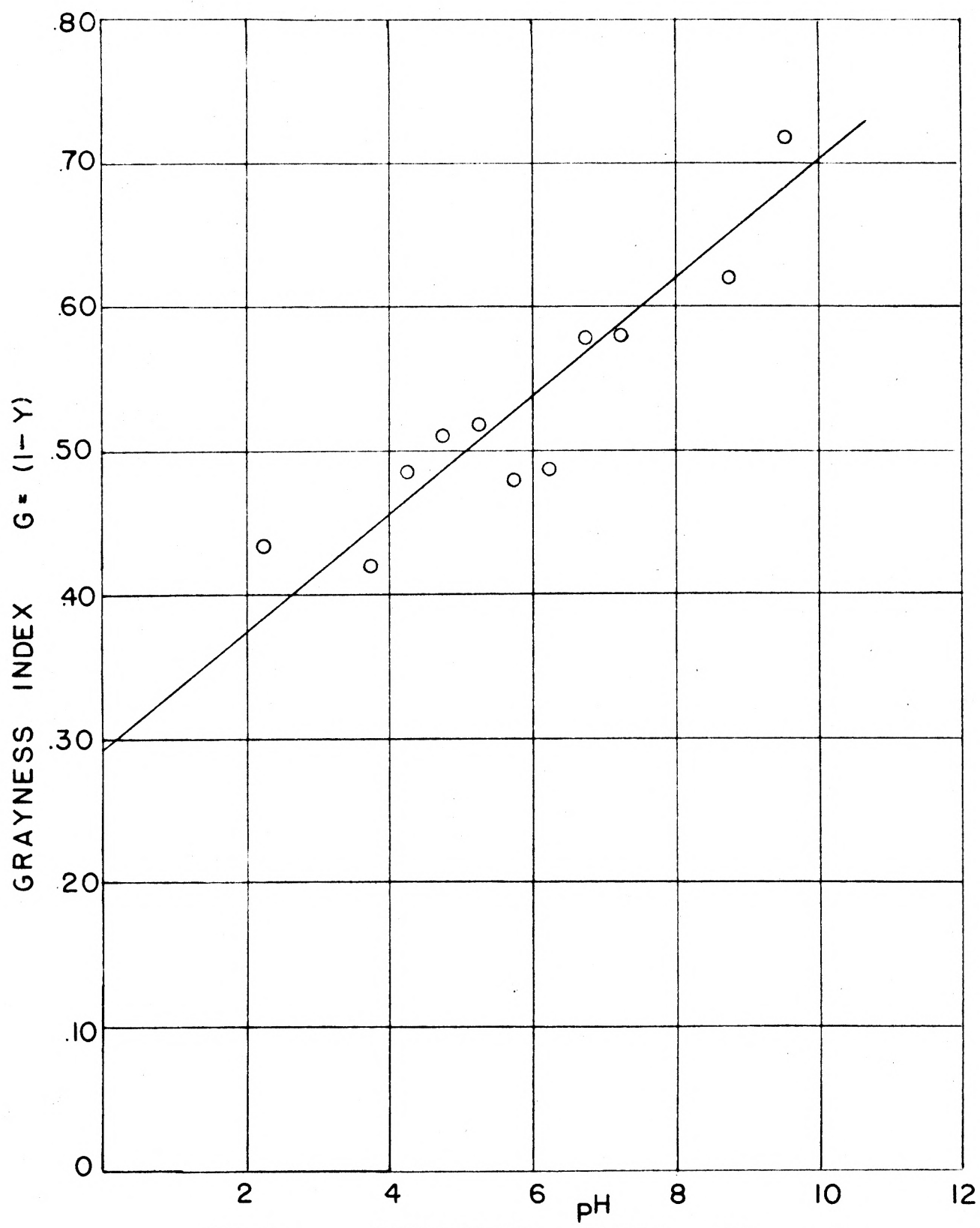


FIG 4 GRAYNESS INDEX VS pH

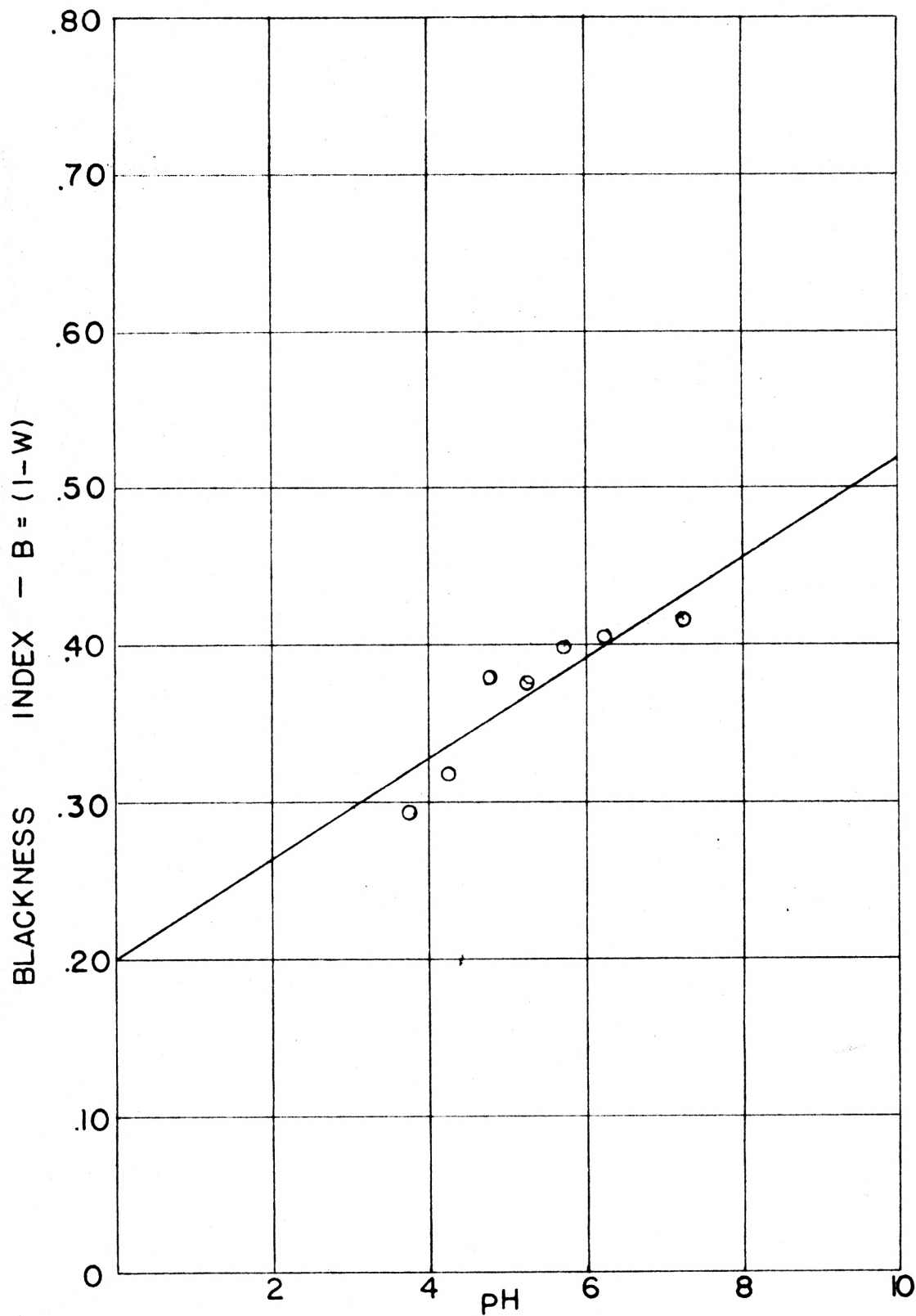


FIG 5 BLACKNESS INDEX VS pH

DISCUSSION OF RESULTS

Colors obtained by measurement of the samples are plotted on a large I. C. I. diagram (Fig. 1). An inspection of this diagram shows that all points representing results of this work fall very close to the value of white. This justifies the use of the photoelectric colorimeter as explained by Judd (5) and Hunter (6) in which they showed that discrepancies are less than .001 in x or y for comparison of near white surface with magnesium oxide. This particular graph in Fig. 1 does not illustrate greyness but hue and chromaticity. To gain a complete picture of the interrelation of these items would require three dimensions. The purpose of this diagram is merely for orientation of the colors.

Graphs of pH vs whiteness and luminosity (Figs. 2 and 3) show a marked decrease in whiteness and luminosity with increasing pH. In order to obtain a clearer picture of the data, values of whiteness and luminosity were averaged over 0.5 increments of pH. These average values were then plotted against an average pH. A linear relationship is discernable and the equation of these lines were determined by graphical analysis.

If the curve is assumed to follow the relationship

$$y = mx + b$$

then the equations for the two lines assume the forms

$$w = -0.0427 \text{ pH} + 0.835$$

$$Y = -0.0493 \text{ pH} + 0.757$$

These two equations give a direct relationship of whiteness to pH. Since the luminosity (Y) in the I. C. I. system is based on 1.00 for a perfect white to 0 for a perfect black, various intermediate shades of grey are discernable between these two extremes. From this information it is possible to define a Blackness index as

$$B = 1 - W \text{ (Fig. 5.)}$$

or for luminosity it maybe called a greyness index (G)

$$G = 1 - Y \text{ (Fig. 4.)}$$

From graphs of these two functions as plotted against pH (Figs. 4 and 5) two empirical equations maybe derived.

For B - the blackness index

$$B = 0.0322 \text{ pH} + 0.200$$

For G - the greyness index

$$G = 0.0414 \text{ pH} + 0.290$$

A consideration of these two graphs will give a particular value of these quantities for a particular value of pH. These two equations are not equivalent since the quantities are defined differently.

The whiteness of pH 9.5 does not correlate with the other values. This is due to the low reflectance (.3) of this particular sample. Hunter (5) limits the validity of the formules used in the determination of whiteness to samples having an apparent reflectance of 0.60 to 1.0.

Standards for judging whiteness and greyness should be determined by eye. At the present time no known instrument can

equal the eye for determining color differences. Under excellent viewing conditions a trained observer can distinguish ten million different colors. The eye is particularly sensitive in differentiating between various shades of grey, hence visual selection appears to be best for this purpose.

Investigations of a qualitative nature were conducted on various pieces of equipment particularly the granulator as designed by Wood (21). Several attempts were made to use this device with slurry process potatoes. Failure resulted in every case. No granulation occurred. When the machine was disassembled it was discovered that potatoes had been formed into a homogeneous mass having some of the properties of India rubber. This indicates that slurry process potatoes have properties different from the potatoes as prepared by the old process. From this it may be concluded that this granulator is inadequate for use with the slurry process.

In order to keep the number of variables down to a minimum most of the runs were made at constant temperature. This temperature was approximately 18°C. or as low as possible using only tap water. It was decided to see if Millard's theory applied to this reaction, so, for two runs the temperature was increased to about 50°C. The pH was maintained at two values which usually gave good visual results.

The luminosity and whiteness index show a marked decrease for these samples which is not common for this pH value. If Millard's (9) work is taken as a basis for explanation, the

solution becomes apparent. Millard (9) obtained his results by elevating the temperature of the ammino acids and reducing sugars. As the temperature was increased a corresponding increase in darkening was observed. The indications from this experiment conducted with potatoes were in agreement with what was expected.

CONCLUSIONS

From the results obtained in this work it may be concluded:

1. The darkening reaction in the slurry process for the dehydration of white potatoes can be controlled by decreasing the pH of the solution.
2. The increase in greying is directly proportional to the pH of the solution.
3. The present design of the granulator is inadequate for the feed obtained in the slurry process.

RECOMMENDATIONS FOR FUTURE WORK

The potato granule process has reached a stage of development where four main lines of research are apparent. These are:

1. Evaluation of the effect of the color reactions upon various different species of potatoes.
2. Attempts to improve the quality of the granule itself.
3. Studies in the drying operation in order to determine the most desirable type and size of drier.
4. Redesign of the existing granulator in order that a wider range in moisture content of the feed may be permitted. This work has been concerned with only one particular variety of potato -- the Idaho Russet. Since this was the initial work done on the subject it was felt that better results could be obtained in the preliminary studies if the number of variables were cut to a minimum. This was done with the realization that many types of potatoes exists but variations in the raw material of this one species was great. Further studies along this line should try to include the effect of controlling the pH of the slurry for such variety as Cobblers, McClures, etc. Color control of the final product should correlate with what has already been obtained.

Dr. Barham, of the Department of Chemistry, (24) is of the opinion that a slurry held at a slightly acid pH and at a temperature of 68°C. for a period of several hours would produce a granule of greatly improved texture. This particular reaction

would result in the hydration of the starch. (The starch would chemically add one molecule of water). If these suppositions were found to be applicable to this process the product could be considerably improved.

One of the major difficulties experienced in this research is the lack of adequate dryer design information. Olsen (13) did some work on this problem but his work was restricted to horizontal pneumatic dryers. Experience has since proven that vertical pneumatic dryers are to be preferred. Such items as dryer temperature, air velocity, dryer diameter, length and the free settling velocity should all be investigated.

The granulation step, particularly for the slurry process, needs further research. Wood (21) designed a granulator which allowed the sample a critical moisture content of 60 per cent. This was found to be a serious handicap when working with a slurry process sample. The sample when fed to the granulator was made into a pulpy homogeneous mass which did not undergo any granulation but remained inside the machine. Consequently all granulation was done by hand.

The writer is of the firm opinion that a small laboratory scale apparatus should be developed for carrying on the various lines of research suggested. Such a system would result in the saving of considerable time and effort. If texture studies were pursued the need for constant temperature apparatus would be felt. This could best be accomplished on a small scale. In addition to the advantages already cited it is thought that

better controls over the conditions of the experiment could be exercised.

ACKNOWLEDGMENT

To the Engineering Experiment Station for sponsoring this research.

To Dr. Henry T. Ward without whom this thesis would not be possible.

To Dr. R. G. Taecker, Dr. H. N. Barham, Prof. W. H. Honstead and Mr. Grant Marburger for their generous assistance and kind cooperation.

To Mr. William L. Cramer for his assistance in taking the data.

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APPENDIX

Definition of Terms (5, 6)

- Lightness:** The lightness of a perceived surface color is that attribute which permits it to be classed as equivalent to some member of a series of grays ranging from black to white.
- Hue:** The hue of a perceived color is that attribute which permits it to be classed as red, yellow, green, blue, purple, or an intermediate.
- Achromatic surfaces:** Those such as whites, grays and blacks which are perceived to possess no hue.
- Saturation:** That attribute of a perceived surface color which determines the degree of its difference from gray of the same lightness.
- Tristimulus Colorimeter:** A device which measures a color stimulus in terms of three selected stimuli called primaries.
- Tristimulus designation of an unknown stimulus consists of the amounts of X, Y, Z or x, y, & z of the three primary stimuli required to produce a color match for it.
- The Y or y component of the tristimulus designation represents the luminous component of that color.
- The settings A, G, & B with the colorimeter employing amber, green and blue filters, are, for surface color, apparent reflectances for illumination at 45°

and viewing at 0° relative to MgO .

The chromaticity of a color is its characterization by either:

1. Dominant wave length and purity
2. Hue angle and saturation index
3. A pair of trilinear coordinates (x & y or α, β)

The dominant wave length (λ) and the hue angle (ϕ) of a color are obtained from the tristimulus specification to indicate hue.

The purity (p) and the saturation index (S) of a color are obtained from tristimulus specification to indicate what is variously called saturation or strength.

The trilinear coordinates ($x, y, & z$ or α, β) are the amounts of the three primary stimuli expressed as fraction of their total. They may be further defined as

$$x + y + z = 1$$

Hence the specification of any two determines the third.

A chromaticity diagram is a plot according to trilinear coordinates in which position of a point indicates chromaticity of the stimulus represented.

V = The term value in the Munsell Color System.

5Y 9/6 Munsell Notation

Hue = 5Y

Value = 9

Chroma = 6

W = Whiteness

pH = $\log \frac{1}{H^+}$

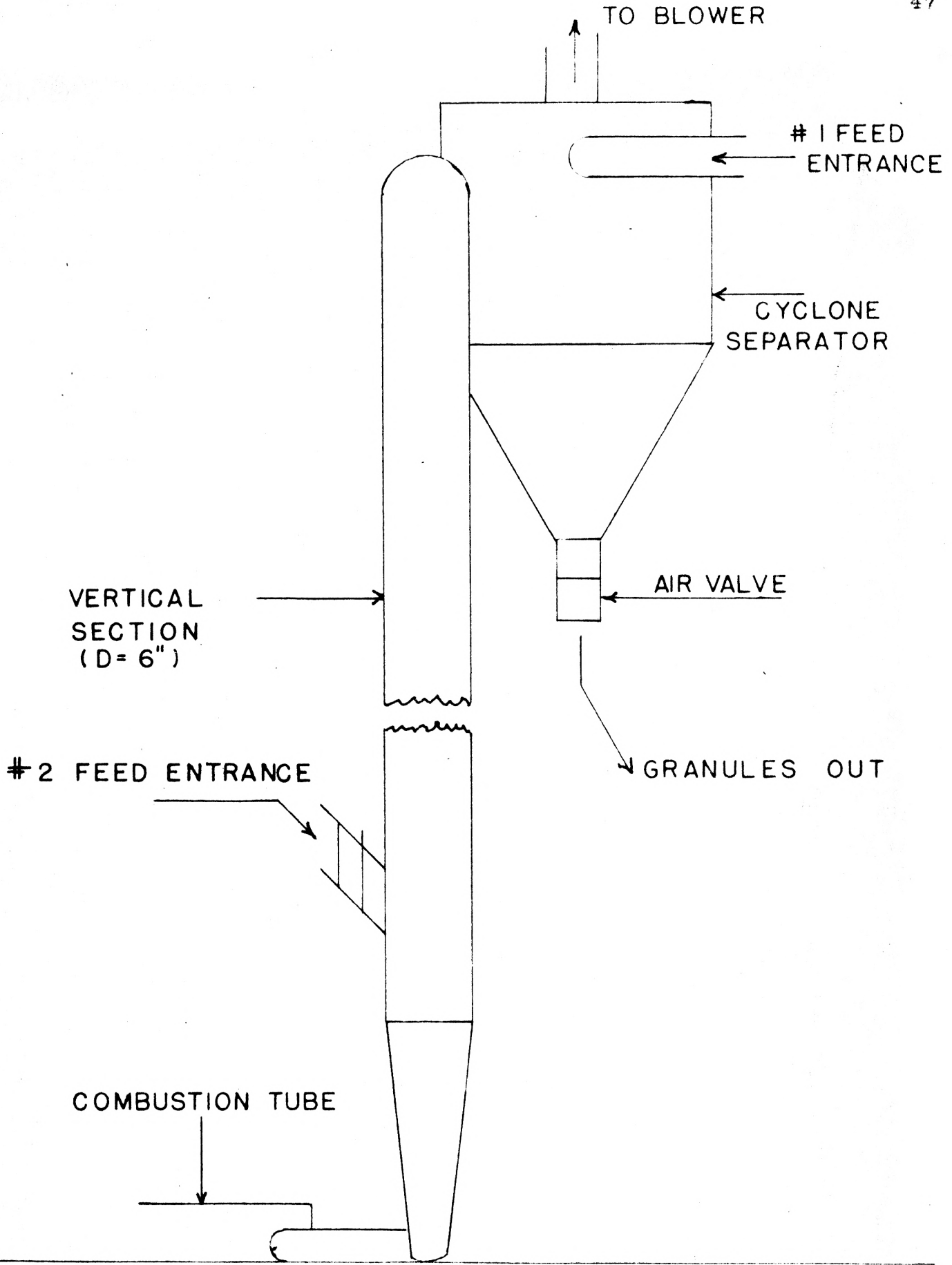


FIG 6

PICTORIAL VIEW OF THE
VERICAL PNEUMATIC DRYER

Sample Calculation

Given:

Tristimulus reading

$$A = .5138$$

$$G = .5133$$

$$B = .5005$$

Calculate the Trichromatic Coefficient and the Whiteness Index

1. Calculation of trichromatic coefficient (x, y, & z)

$$x = \frac{0.80A + 0.18B}{G + 0.80A + 1.36B} = \frac{0.80A + 0.18B}{\text{Denominator}}$$

$$= \frac{.4110 + .0909}{.5133 + .4110 + .6807}$$

$$= \frac{5012}{1.6050}$$

$$= \underline{.3122}$$

$$y = \frac{G}{\text{Denominator}} = \frac{5133}{1.6050} = \underline{.3198}$$

$$z = \frac{1.18B}{\text{Denominator}} = \frac{.5906}{1.6050} = \underline{.3680}$$

2. Calculation of whiteness

$$= \frac{2.5 (A-G)}{10 G}$$

$$= \frac{G - B}{10 G}$$

$$= \frac{2.5 (.5138 - .5133)}{(10) (.5133)} = \frac{2.5 (.0005)}{5.133} = .00243$$

$$= \frac{.5133 - .5005}{5.133} = \frac{.0128}{5.133} = .00249$$

$$W_c = 30 \sqrt{\alpha^2 + \beta^2}$$

is evaluated graphically

$$= .0035$$

$$30 \sqrt{\alpha^2 + \beta^2} = 30 (.0035) = .105$$

$$W_1 = \frac{1.00 - G}{2} = \frac{.4867}{2} = .2434$$

$$\sqrt{W_c^2 + W_1^2} \text{ is evaluated graphically}$$

$$= .246$$

$$W = 1 - \sqrt{W_c^2 + W_1^2} = \underline{.754}$$