SKIN REMOVAL FROM SPANISH PEANUTS
BY HEATING TO MODERATE
TEMPERATURES

By

PAT STEVENS SHACKELFORD, JR.

Bachelor of Science in
Agricultural Engineering
The University of Georgia
Athens, Georgia
1958

Master of Science
The University of Georgia
Athens, Georgia
1972

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
December, 1974

SKIN REMOVAL FROM SPANISH PEANUTS

BY HEATING TO MODERATE

TEMPERATURES

Thesis Approved:

Bobby L. Clary
Thesis Adviser

Gerald Brusewitz

Charles E. Rice

Gerald D. Parker

George V. Odell

N. N. Durham
Dean of the Graduate College

PREFACE

This study was concerned with blanching or removing the skin from raw Spanish peanut kernels. The broad objectives were to define the conditions under which peanut kernels can be blanched by heat treatment without impairing the quality attributes of the raw kernels.

The research reported in this study was partially supported by funds from the Southern Marketing and Nutrition Research Division, U.S.D.A., A.R.S., New Orleans, Louisiana.

The author is especially grateful to his major adviser, Dr. Bobby L. Clary, for his faith, guidance, encouragement, and patience during the course of this project.

Appreciation is extended to the other members of the Advisory Committee, Dr. Gerald H. Brusewitz, Dr. Charles E. Rice, Dr. Jerald D. Parker, and Dr. George V. Odell, Jr. Their advice and criticisms have given valuable assistance throughout this project. Dr. Odell is especially thanked for his assistance in the chemical aspects of the project.

Appreciation is extended to Professor E. W. Schroeder, former Head of the Agricultural Engineering Department, for allowing my studies to continue.

The taste panel studies by Dr. James S. Kirby and Mrs. James A. Choate are greatly appreciated.

Dr. Robert D. Morrison is sincerely thanked for his design and analysis of taste panel studies.

I wish to thank Mr. Jack Fryrear and Mr. David Derryberry for their assistance in the preparation of the figures.

The assistance of Mr. Clyde Skoch and Mr. Norvil Cole in construction and operation of equipment is appreciated.

I wish to extend my thanks to Mr. Ronnie G. Morgan for his help in constructing equipment and running tests, and to Miss LaDonna Moore for her assistance in analyzing data.

To Mrs. Michael A. Coughlin I wish to express my thanks for her expert typing of this manuscript.

To my wife, Virginia, and my children whose sacrifices made this study possible, I dedicate this thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

B_S - Blanchability standardized to eight percent initial and five percent final moisture content - %

M - Moisture content - % - wet basis

M_E - Equilibrium kernel moisture content - % - wet basis

M_F - Final kernel moisture content - % - wet basis

M_I - Initial kernel moisture content - % - wet basis

M_L - Moisture loss - % - wet basis

M_S - Steinlite moisture content - % - wet basis

T_A - Heating air temperature - °F

T_F - Final kernel temperature - °F

e - Base of natural logarithm

α - Probability of a Type I error

β - Blanchability - % by weight

β_S - Blanchability standardized to eight percent initial and five percent final kernel moisture content - %

Ψ - Whole kernels - % by weight

CHAPTER I

INTRODUCTION

The Problem

Peanuts are an important crop in the United States, furnishing a high protein food for human and livestock consumption, and a high quality oil. Processing the peanuts used for human food is an industry to which much research interest has been directed recently (11) (14) (16) (21).

One problem in the processing of peanuts is removal of the red skin (or testa) of the kernel. It is desirable to remove the skins because they produce undesirable characteristics in peanut butter and other peanut products.

The skin also may hamper detection of aflatoxin contamination in peanuts. The cotyledon color, but not the skin color, is reported by Golumbic (6) to be changed by aflatoxin contamination. Removal of skins should aid in separating contaminated from noncontaminated kernels.

Aflatoxin, a carcinogenic substance produced by the mold *Aspergillus flavus*, is usually present in only a small percentage of the peanut kernels in a contaminated lot of peanuts (5). These contaminated kernels make the entire lot unfit for human or animal food. If this small proportion of contaminated kernels could be separated from the noncontaminated kernels, the noncontaminated kernels could be safely marketed for human or animal foods.

A method of removing the peanut skins without mechanically damaging the kernels, harming the taste or chemical properties, or reducing the storage life of raw kernels is needed. Blanching by heating to moderate temperatures might be one way to achieve these results. Blanching in this study refers to the removal of the skin from peanut cotyledons.

Objectives

The need to remove the skins of raw Spanish peanut kernels so that optical properties can be used for detection of aflatoxin contamination brought about this research. The broad objectives were to define the conditions under which raw Spanish peanut kernels can be blanched by heat treatment without impairing the quality attributes of the raw kernels.

Specifically the objectives of this research were to determine the effect that initial kernel moisture content, final kernel moisture content, heating air temperature, kernel cooling time, and final kernel temperature will have upon kernel blanchability, kernel mechanical damage as evidenced by separation of the kernel cotyledons, and taste properties of roasted kernels and peanut butter made from the treated kernels.

CHAPTER II

LITERATURE REVIEW

Peanut skins (or testa) are undesirable in peanut butter and other food products manufactured from peanuts. Stansbury, et al. (20) found that red peanut skins contain about seven percent catechol-type tannin. This tannin may impair taste and appearance properties of peanut products.

One method of reducing the harmful effects of peanut skins is to remove the tannin. Burnett (4) reported on a pilot plant project in which unblanched peanut kernels were dipped in a sodium hydroxide solution to remove skin color. These kernels were found to be suitable for producing light colored protein products. Pominski, et al. (14) also investigated dipping peanut kernels in sodium hydroxide solutions. They found that lipid and protein losses were low when using this treatment, but damaged kernels in oil mill stock peanuts would impart color to protein treated with sodium hydroxide.

Blanching or removing the skins from peanut kernels is another method of reducing their harmful effects on peanut products. Woodroof (23) describes four blanching methods; dry blanching, water blanching, alkali blanching, and blanching with hydrogen peroxide.

The customary procedure for dry blanching is to heat the kernels to 280°F for up to 25 minutes. After cooling, the kernels are blanched by a thorough but gentle rubbing between brushes or ribbed rubber belting. Blanching performance of this method is satisfactory, but the blanched kernels have a relatively short storage life.

Willich et al. (22) reported on the blanching of peanuts which had been roasted for making peanut butter. The maximum kernel temperature varied from 275°F to 320°F, and roasting times were varied from 17 to 29 minutes. Within these conditions, they concluded that the percentage of skins removed was approximately the same regardless of the length of time and temperature of roasting. Data on initial and final moisture content and percentage of kernels accepted and rejected for producing peanut butter was presented.

Another dry blanching procedure is called spin blanching. Reeve (16) reports that the kernel skin is slit on opposite sides by a blade and the kernels are quickly dehydrated at a lower than roasting temperature. The kernels are then fed through a spin blanching machine in which, by cross-feeding onto belts, the kernels are made to spin and unwrap the skins. This is a proprietary process and is not well documented.

Shackelford, et al. (17) investigated dry blanching using moderate temperatures, from 100°F to 160°F. They found that blanching was strongly affected by the ratio of initial kernel moisture content (before heating) to final kernel moisture (after heating). The effect of heating temperature on blanching was inconclusive.

Pominski, et al. (15) investigated a method of pre-treating peanut kernels by dipping in water and drying at low temperatures (120°F and 180°F) prior to mechanical blanching. High rates of blanching were achieved. Lawler (11) reported on a commercial operation using a water spray pre-treatment similar to that of Pominski, et al. Woodroof (23) writes that water blanched peanuts have a longer shelf-life than that of unblanched nuts. The spray of hot water dissolves some of the surface protein, and a glaze is formed on the kernel surface during drying which protects against oxidation and mechanical injury.

Alkali blanching is accomplished by first dipping the kernels in a sodium hydroxide solution, as was done to remove tannin from the skins. Kernels are then dipped in a neutralizing solution. Skins may be removed from the wet peanuts, or the kernels dried and then mechanically blanched. Shackelford, et al. (18) found that the taste and appearance of peanuts treated with sodium hydroxide was adversely affected by this treatment.

Hydrogen peroxide blanching was introduced in Japan by Takeuchi and Mazumoto (21). The kernels are immersed in a hydrogen peroxide solution. The hydrogen peroxide is said to decompose into water and oxygen between the skin and cotyledon, loosening the skin and facilitating removal.

Herrold (9) and Morgan (12) reported on the effect of slitting the skin on blanching of peanut kernels. Both investigators concluded that slitting the skin improved blanching rate, with improvement being greater at lower initial kernel moisture contents.

Woodward (24) found that tensile strength of peanut skins decreased with increasing drying air temperature in the range from 90°F to 130°F. He also reported that over 90 percent of the resistance to separation of cotyledons came from the skin tensile strength.

Beasley and Dickens (2) reported that increasing the drying rate of peanuts during the curing operation increased split and skinned kernels. Temperature at which the kernels were dried did not appear to have an effect nearly as great as the rate at which moisture was removed.

CHAPTER III

EQUIPMENT AND INSTRUMENTATION

Skin Slitter

The skin of each kernel was slit by passing it between two spring-loaded knife blades which placed two longitudinal slits 180 degrees apart in the skin of each kernel. The blades were mounted on a frame in such a position that kernels were forced between the blades by two wheels, one of which had one face fitted with one-half inch thick foam rubber to minimize mechanical damage to the kernels. The skin slitter is shown in Figures 1 and 2, and working drawings are presented in Appendix A.

Laboratory Dryer

A laboratory dryer was designed and constructed to dry the peanut kernels (Figures 3 and 4). Air flow was provided by a fan with a nominal air flow rate of 60 CFM, or 15 CFM per square foot of drying area. Drying air was heated by four electric heaters, thermostatically controlled, capable of heating the drying air to a maximum temperature of 210°F and of maintaining the drying air within ±1°F of the design temperature. Drying air temperature was monitored by a type T thermocouple and

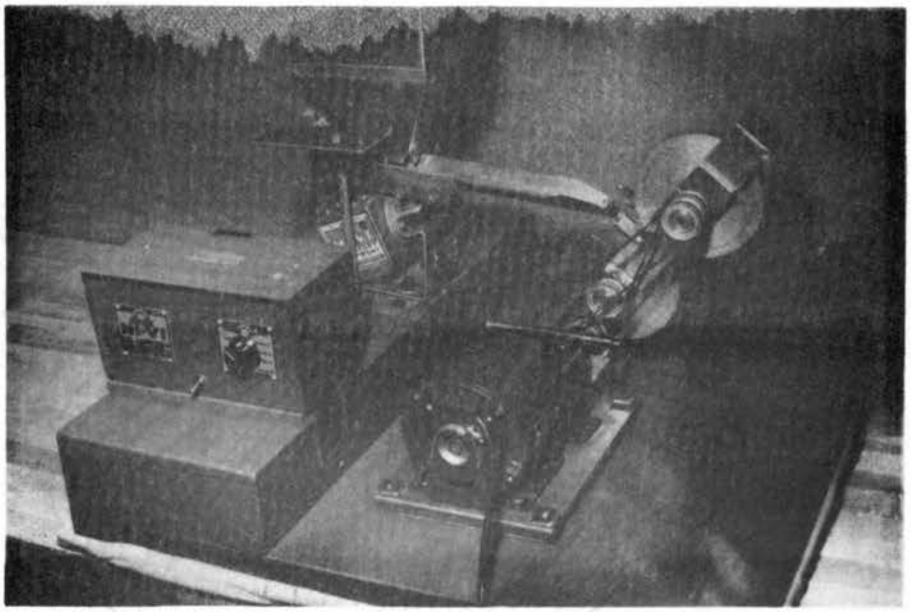


Figure 1. Skin Slitter

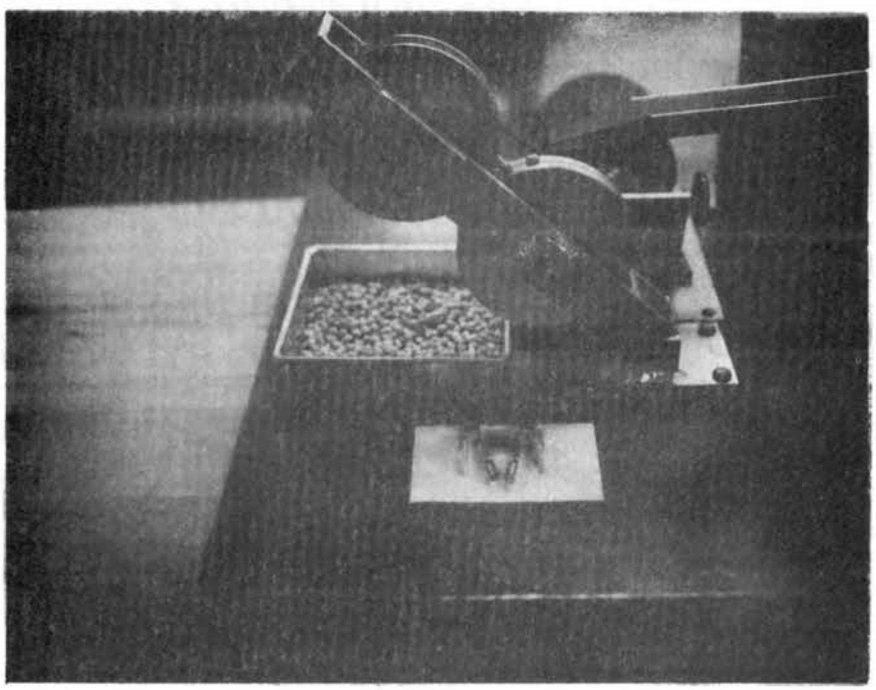


Figure 2. Skin Slitter With Blades Removed

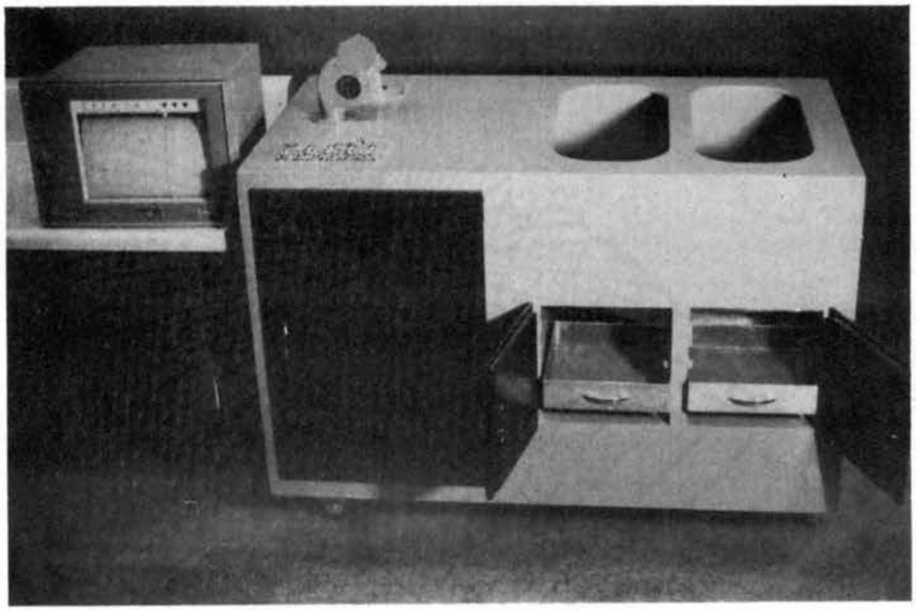


Figure 3. Laboratory Dryer

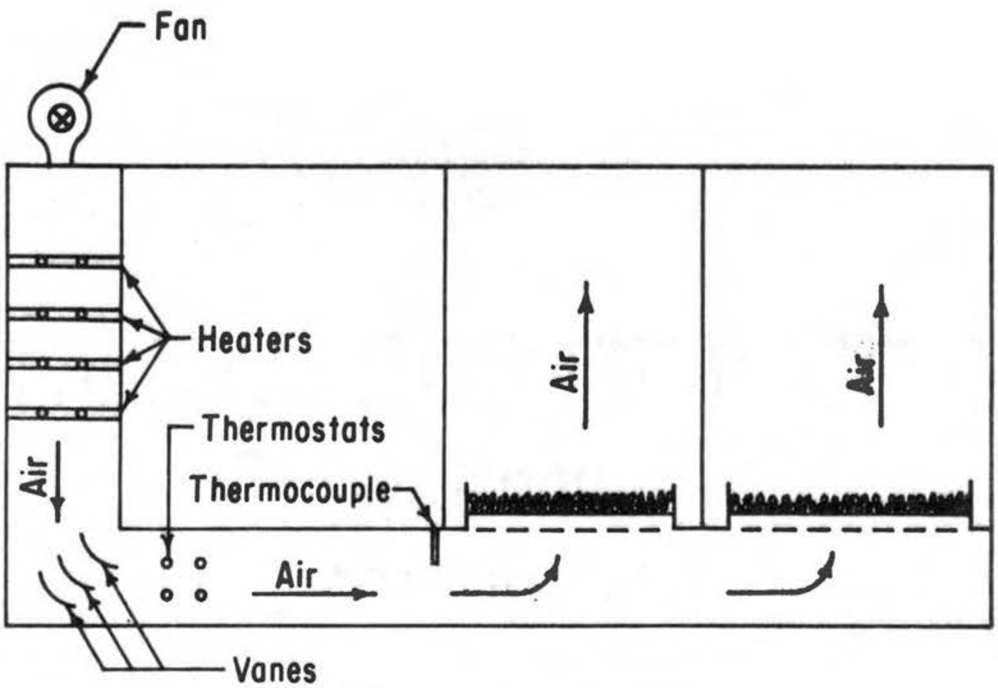


Figure 4. Schematic of Laboratory Dryer

recorded by a Honeywell Electronic 16 recording potentiometer. Laboratory dryer working drawings are shown in Appendix B.

Blancher

A whole nut blancher was constructed to blanch the treated peanut kernels. This blancher, shown in Figure 5, removes skins by tumbling along two rollers surfaced with an abrasive material. A large proportion of whole kernels are produced in the blanched sample.

Rollers were 14 inches long, 2.5 inches in diameter, and mounted with one roller slightly higher than the other. Both rollers rotate in the same direction with speeds of 1280 RPM and 1060 RPM for the higher and lower roller respectively. Working drawings of the blancher are presented in Appendix C.

Moisture Determination

Moisture content of the peanut kernels was determined using a Steinlite electronic tester, model 400G. This instrument was calibrated against oven-dried samples which were dried at 105°C overnight, a period varying from 18 to 24 hours. Calibration information and a detailed procedure for oven-dry moisture determination are shown in Appendix D. In this report all moisture contents were determined on wet basis unless stated otherwise.

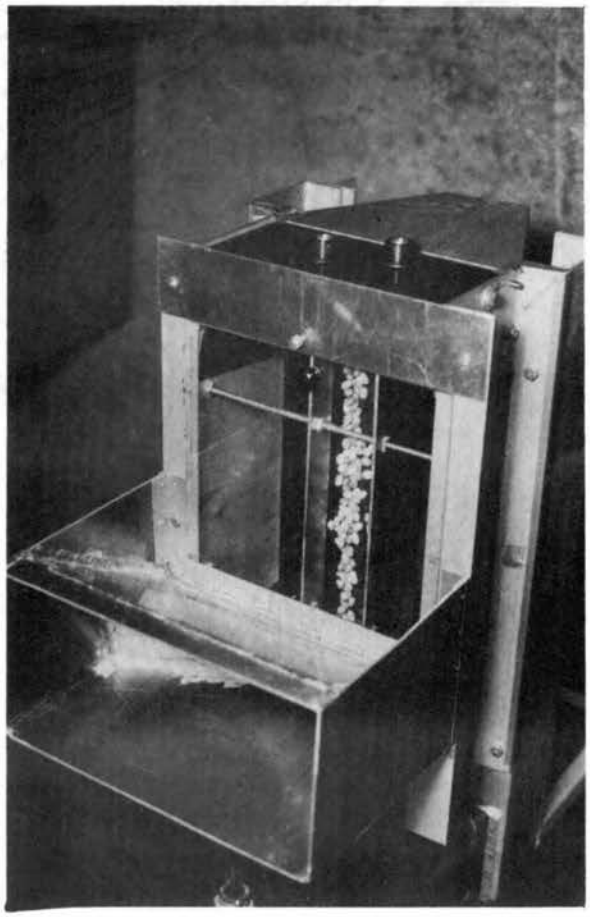


Figure 5. Whole Nut Blancher

CHAPTER IV

EXPERIMENTAL MATERIAL AND PROCEDURE

Peanuts

Kernels used in this project were U. S. Number One Shelled Spanish type purchased from a commercial sheller. Moisture content of kernels when received was about seven percent, wet basis. Kernels were manually sorted, removing split kernels and those with less than two-thirds of the skin attached, and stored in airtight containers in a 40°F atmosphere prior to testing. In this report a kernel will consist of two cotyledons and the accompanying germ covered by the skin.

Experimental Procedure

Final Temperature

Previous work had indicated that the temperature to which kernels were cooled before blanching, hereafter referred to as final temperature, might be a significant variable in blanching peanut kernels. Tests were run to determine the final temperature which would provide the highest blanching rate. These tests were conducted using one level of heating air temperature (180°F), initial moisture content (eight percent), and final moisture content (five percent). These levels were selected as being intermediate among those which were to be used in later tests. Temperature after cooling was varied from 65°F to 90°F.

Tests involved six main operations. They are: slitting the skin, conditioning to desired initial moisture content, drying to desired final moisture content, cooling, blanching and separating blanched from not blanched kernels. Skins were slit in the skin slitter. Conditioning to an initial moisture content greater than seven percent was accomplished by placing the kernels in a controlled temperature and humidity chamber. The peanuts absorbed moisture hygroscopically to the desired initial moisture content. Conditioning required from two to six hours. The peanuts were then placed in airtight plastic bags in a 40°F (±2°F) atmosphere and allowed to equilibrate for at least 48 hours before testing. Initial kernel moisture content of six percent was attained by drying the kernels with air at 95°F, then storing and allowing them to equilibrate as above.

On the day of testing kernels were removed from storage, divided into 600 gram samples, replaced in airtight bags, and allowed to reach room temperature of 75°F to 80°F. Initial moisture content was then determined using the Steinlite electronic tester. Samples were deposited in trays with wire mesh bottoms and placed in the laboratory dryer.

After drying to the desired final moisture content, kernels were removed from the dryer, but left in the trays. Trays of dried kernels were placed in one of four environments. These were an adjacent room maintained at 88°F (±2°F), the laboratory at 76°F (±2°F) and a conditioning chamber at either 60°F or 70°F (±3°F). Location was chosen at random for samples to be cooled in the 88°F, 76°F, and 60°F environments. Due to change in experimental design, all samples cooled in the 70°F environment were tested after samples in other environments. Kernels remained in their cooling environments for a period of two hours. Temperature of the kernels after cooling and final moisture content were determined, and the kernels were blanched by one pass through the whole nut blancher. The first 100 grams of kernels passing through the blancher was discarded as not being typical of the blanched product.

The blanched sample was manually separated into blanched and not blanched kernels. A kernel was classified as blanched if it had no visible skin attached. Blanchability was defined as the percentage by weight of peanut kernels which had skins totally removed by one pass through the blancher.

Cooling Time

Cooling time, the time which elapsed between removing kernels from the dryer and blanching the kernels, was thought to be a significant variable. Tests were run to determine the cooling time which would provide the highest blanching rate. Experimental procedure was similar to that used for tests on final temperature. Final temperature was below 80°F, based on the results of tests on final temperature. Cooling time was varied from one-half hour to 4.5 hours at approximately one-half hour increments. Tests at one-half hour cooling time were run by circulating ambient laboratory air over trays of kernels with a fan. Tests at other cooling times were run by placing trays of dried kernels in the ambient laboratory air with no forced circulation. Procedure in all other respects was the same as that shown in final temperature section.

Effects of Heating Air Temperature, and Initial and Final Moisture Content

After completing and analyzing the results of tests on final kernel temperature and cooling time, tests were run to determine the effect of heating air temperature, initial moisture content, and final moisture content on blanchability and percent whole kernels. The experimental design shown in Table I gives the treatments and levels investigated.

Experimental procedure was similar to that shown for final temperature tests. Final temperature was maintained below 80°F. Cooling time was not controlled. Peanuts were cooled in ambient laboratory air without forced circulation. Procedure otherwise was the same as that shown in the final temperature section. Blanched kernels were separated into whole and split kernels. A whole kernel is defined as one with cotyledons joined. Percent wholes was defined as the percentage by weight of blanched kernels which were whole after blanching.

TABLE I

EXPERIMENTAL PLAN FOR HEAT TREATMENTS

Treatment	Level
Temperature, °F	160, 180, 200
Initial Moisture Content % wet basis	6, 8, 10
Final Moisture Content* % wet basis	4, 5, 6, 7

* Only 4 and 5 percent final moisture content with 6 percent initial moisture content

CHAPTER V

RESULTS AND DISCUSSION

Heating Air Temperature

Data for effect of heating air temperature is presented in Appendix F. Mean blanchabilities of all samples treated with heating air temperatures of 160°F, 180°F, and 200°F were 88.8, 90.6, and 89.7 percent respectively. Higher blanchability at 180°F than at 160°F, and lower blanchability at 200°F than at 180°F, were evident at every initial and final moisture content, as shown in Table II.

Analysis of variance, shown in Appendix E, indicated a significant difference (α=0.02) in blanchability due to different heating air temperatures. Least significant difference tests (α=0.05) showed that blanchability at 180°F was significantly better than blanchability at 160°F. Mean blanchability at 180°F was higher than that at 200°F, but this difference was not statistically significant.

Linear regression was undertaken to find an equation which would describe the effect of heating air temperature on blanchability. A second order polynomial was found to pass through the mean blanchability of each temperature.

TABLE II

EFFECT OF HEATING AIR TEMPERATURE ON BLANCHABILITY

Initial Moist. %	Final Moist. %	Temp. °F	Mean* Blanch. %
6	All	160	87.0
		180	88.2
		200	86.6
8	All	160	86.4
		180	89.1
		200	88.7
10	All	160	92.0
		180	93.3
		200	92.1
All	4	160	92.5
		180	93.6
		200	93.3
All	5	160	89.7
		180	90.1
		200	88.7
All	6	160	90.7
		180	91.2
		200	90.4
All	7	160	79.8
		180	86.3
		200	84.8

* Averaged over all other treatments

This equation was

$$\beta = 1.27T_A - 0.0347T_A^2 - 25.8 \qquad (1)$$

where,

β = blanchability, %

T_A = heating air temperature, °F

Equation 1 had a correlation coefficient (R^2) of 0.02 and standard error of 5.4 percent. Analysis of variance of regression is shown in Appendix E.

Figure 6 shows observed blanchability at each heating air temperature. As can be seen from this graph, the effect of heating air temperature on blanchability was very small when compared to the range of blanchabilities at each heating air temperature. This range was due to the effects of initial and final moisture contents, discussed in the next section, which were found to have a much greater effect on blanchability than did heating air temperature.

It was concluded that heating air temperature had a small but real effect on blanchability. Blanchability at heating air temperature of 180°F was higher than that at 160°F. Blanchability at 180°F was also higher than that at 200°F, but this difference may be due to experimental error. Due to the small correlation coefficient and large standard error associated with Equation 1, it was decided not to include effects of heating air temperature in any prediction equations developed.

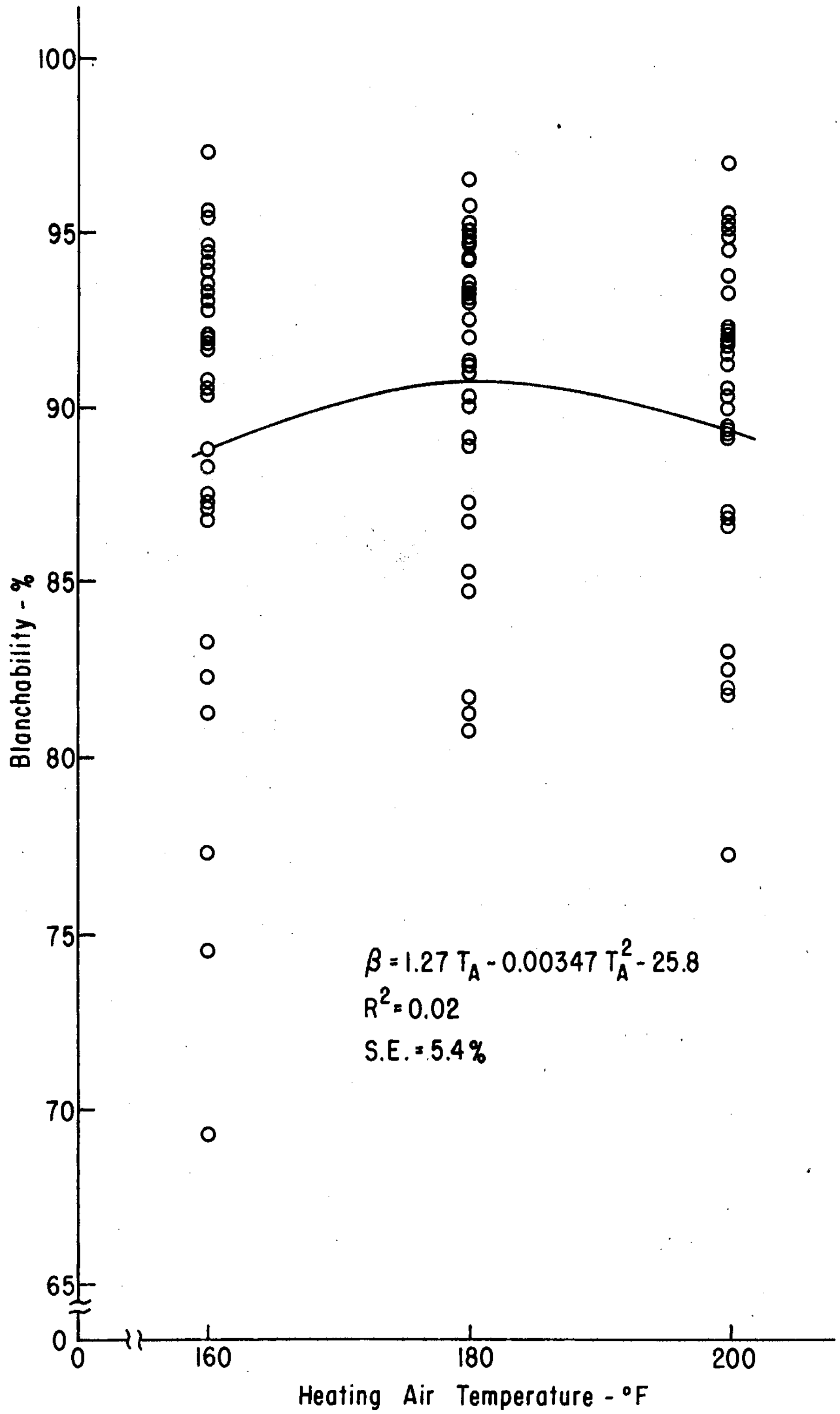


Figure 6. Effect of Heating Air Temperature on Blanchability

Initial and Final Moisture Content

The tests were designed to provide initial kernel moisture contents of six, eight, and ten percent. Observed initial moisture contents were generally within ±0.5 percent of the design value. The notable exceptions were samples in the third replication which should have had ten percent initial moisture content. The initial moisture content of these samples ranged from 9.1 to 9.3 percent. At a given heating air temperature and final moisture content, lower initial moisture content should result in lower blanchability, but these low initial moisture contents should not have affected the results of these tests since analysis was carried out on the ratio of final to initial moisture contents.

Design final moisture contents were four, five, six and seven percent. Observed final moisture contents were within ±0.5 percent of design values with the exception of two samples. Observed values of initial and final moisture contents and associated blanchabilities are shown in Appendix F.

Previous work had indicated that blanchability might be a function of the ratio of final moisture content to initial moisture content. Two equations incorporating this ratio were investigated. These were

$$\beta = 100 - ae^{b(M_F/M_I)} \qquad (2)$$

and

$$\beta = 100 - ae^{b\left[\frac{M_F - M_E}{M_I - M_E}\right]} \tag{3}$$

where,

β = blanchability, %

a = constant, dimensionless

b = constant, dimensionless

e = base of natural logarithm

M_F = final kernel moisture content, %, wet basis

M_I = initial kernel moisture content, %, wet basis

M_E = equilibrium kernel moisture content, %, wet basis

Equilibrium moisture content, the moisture content which a peanut kernel would approach after exposure to air of a given temperature and relative moisture for a relatively long period of time, was calculated from Henderson's (7) equation as modified by Beasley and Dickens (2) and Agrawal and Clary (1). Equilibrium moisture contents for drying air at 160°F, 180°F, and 200°F were found to be 0.8, 0.5, and 0.3 percent respectively.

Linear regression was used to determine whether Equation 2 or 3 best described the effect of initial and final kernel moisture contents on blanchability. Regression coefficients, correlation coefficients, and standard errors were found for each design initial moisture content (6, 8, and 10 percent) and for all samples. Regression coefficients and statistics of fit are shown in Table III. Standard error is in percent not blanched.

TABLE III

REGRESSION COEFFICIENTS AND STATISTICS OF FIT FOR EQUATIONS 2 AND 3

Equation No.	Initial Moist. % - w.b.	a	b	R^2	Std. Error %
2	6%	0.67	3.81	0.78	2.0
	8%	1.23	3.19	0.77	3.2
	10%	1.14	3.22	0.78	1.6
	All	1.16	3.20	0.81	2.5
3	6%	1.07	3.30	0.73	2.2
	8%	1.60	2.91	0.75	3.3
	10%	1.38	3.03	0.77	1.6
	All	1.43	3.00	0.80	2.6

Based on linear correlation coefficient and standard error, Equation 2 was chosen as best representing the effect of initial and final moisture content on blanchability of kernels. Either Equation 2 or 3 could be used, since both equations generally predicted a blanchability within 0.5 percent of the same value. Graphs of data transformed according to Equations 2 and 3 are presented as Figures 7 and 8.

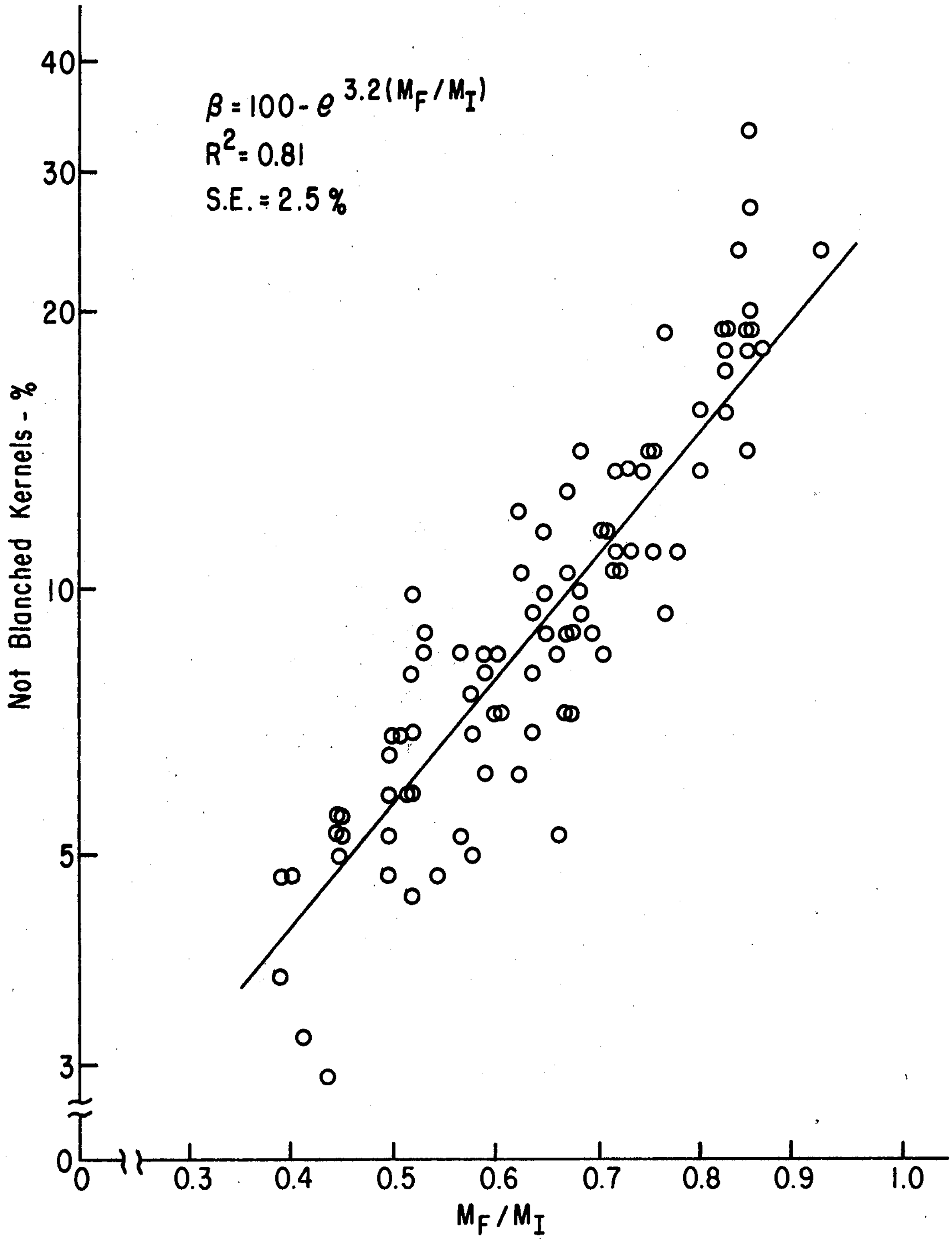


Figure 7. Graph of Equation 2

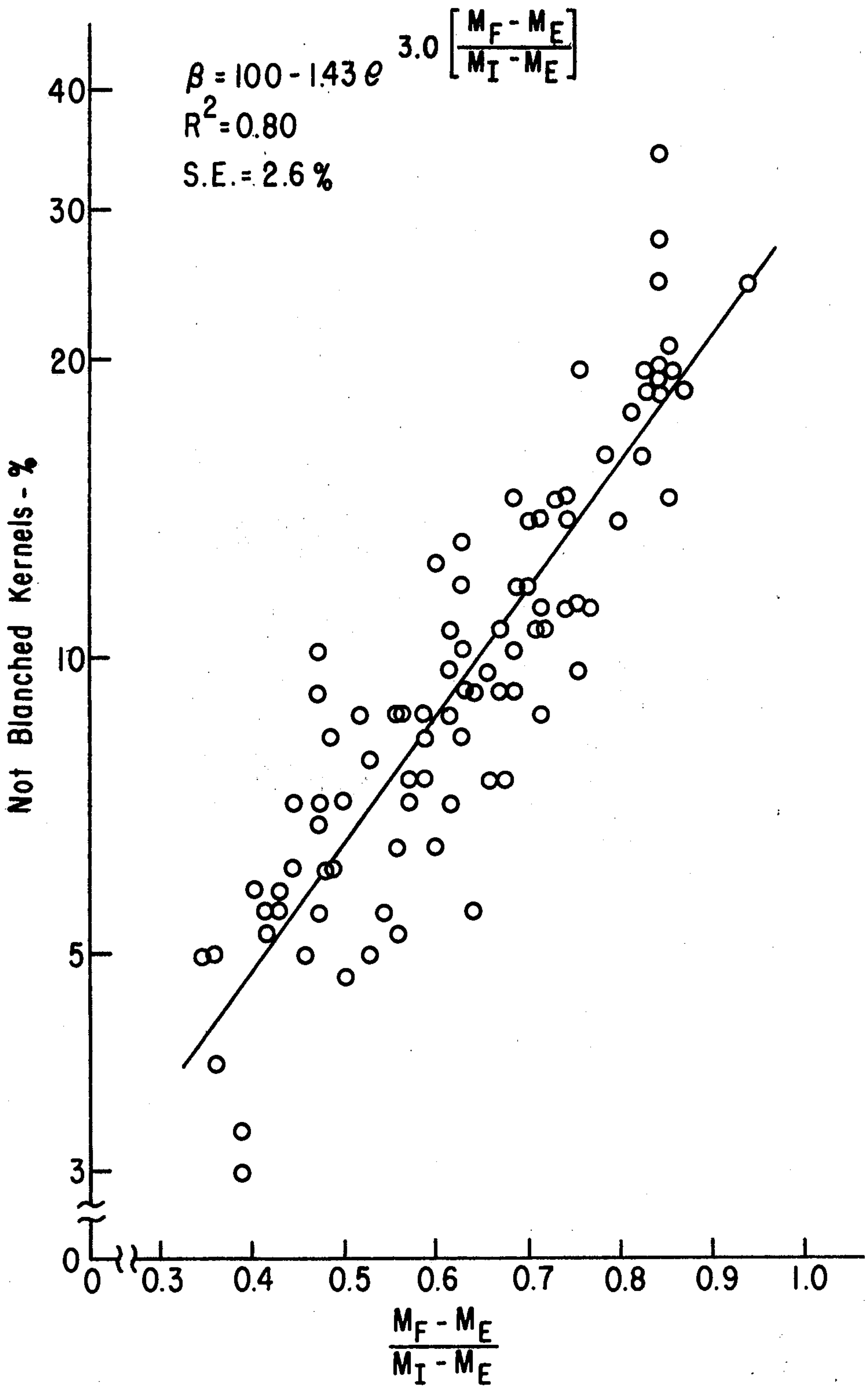


Figure 8. Graph of Equation 3

Since temperature effects will not be considered in a prediction equation, as stated earlier, the prediction equation for blanchability, based on Equation 2, is

$$\beta = 100 - 1.16e^{3.2(M_F/M_I)} \qquad (4)$$

Confirming Test Results

Three sets of data were available with which to test conclusions on the effect of heating air temperature, initial moisture content, and final moisture content on blanchability. One set was from tests on kernels from the same lot as those used in the project. These kernels were tested at the initial moisture content at which they were received from the sheller, hereafter called natural moisture content. The second set of data was from tests reported in Shackelford, et al. (17). The third set was contained in Willich, et al. (22).

Kernels tested at natural initial moisture were not conditioned, but had skins slit, were heated with air at 160°F, 180°F, and 200°F, dried to four, five, and six percent final moisture content, cooled, blanched, and separated as outlined in Chapter III. Data from kernels tested at natural initial moisture content is shown in Table IV.

Mean blanchabilities of kernels with natural initial moisture content tested at 160°F, 180°F, and 200°F heating air temperature were 83.1, 85.3, and 87.0 percent

TABLE IV

DATA FOR KERNELS AT NATURAL INITIAL MOISTURE CONTENT

	Design		Obs. Moist			
Obs. No.	Temp. °F	Final Moist. %	Initial %	Final %	Whole %	Blanch. %
1	160	4	6.8	4.1	71.4	88.6
2	160	4	6.8	3.9	71.7	91.5
3	160	4	6.9	4.2	73.3	90.0
4	160	5	6.9	5.0	79.6	86.4
5	160	5	6.9	4.8	79.6	87.8
6	160	5	6.9	4.7	77.8	87.5
7	160	6	6.9	6.2	92.4	64.9
8	160	6	6.8	6.0	90.6	72.0
9	160	6	7.0	6.0	85.9	79.4
10	180	4	6.9	4.3	67.6	91.2
11	180	4	6.8	3.9	65.4	90.0
12	180	4	7.0	4.2	68.9	93.4
13	180	5	6.8	5.0	78.2	88.1
14	180	5	6.8	5.0	76.2	88.1
15	180	5	7.0	5.1	78.9	87.3
16	180	6	6.8	6.1	90.8	77.3
17	180	6	6.9	5.9	88.5	76.4
18	180	6	6.9	5.9	89.5	76.3
19	200	4	6.9	4.1	70.1	92.5
20	200	4	6.9	4.2	66.8	91.9
21	200	4	7.0	4.4	71.8	93.8
22	200	5	6.9	5.3	81.3	86.3
23	200	5	6.9	5.2	77.7	86.6
24	200	5	6.9	5.2	76.9	91.3
25	200	6	6.9	5.8	88.6	86.5
26	200	6	6.9	6.1	91.8	74.0
27	200	6	6.9	6.0	89.3	80.2

respectively. The increase of 2.2 percent in blanchability when heating air temperature was increased from 160°F to 180°F was similar to the 1.8 percent reported earlier. The 1.8 percent increase in blanchability when heating air temperature was increased from 180°F to 200°F was in contrast to the 0.9 percent decrease in earlier tests at the same temperatures. This increased mean blanchability with increasing heating air temperature was found at every final moisture content, as shown in Table V.

Tests on kernels at natural initial moisture content confirmed that increasing heating air temperature from 160°F to 180°F increased blanchability. The determination of the effect on blanchability of increasing heating air temperature from 180°F to 200°F was inconclusive due to conflicting response indicated by two sets of tests.

Data from Table IV on the effect of moisture content on blanchability is shown graphically in Figure 9 and compared with Equation 4. It can be seen that Equation 4 predicted the blanchability of kernels at natural initial moisture content within 4.5 percent of observed blanchability when the M_F/M_I ratio was below 0.8. When the M_F/M_I ratio was larger than 0.8, Equation 4 generally predicted a higher blanchability than was observed.

Standard error between Equation 4 and the observed blanchability of kernels at natural initial moisture content was 4.4 percent, while the standard error between Equation 4 and the data from which it was developed was

2.5 percent. At M_F/M_I ratios less than 0.8, Equation 4 fits the data from tests at natural initial moisture content with accuracy comparable to the fit of data from which it was developed. Since it is expected that most blanching will be performed on kernels at natural initial moisture content and with the intention of obtaining high blanchability, Equation 4 is verified for kernels in the same lot as those used to develop it for conditions of most probable use.

TABLE V

EFFECT OF HEATING AIR TEMPERATURE ON BLANCHABILITY OF KERNELS TESTED AT NATURAL INITIAL MOISTURE CONTENT

Final Moist. %	Temp. °F	Mean* Blanch. %
4	160	90.0
	180	91.5
	200	92.7
5	160	87.2
	180	87.8
	200	88.1
6	160	72.1
	180	76.7
	200	80.2

* Averaged over three replications

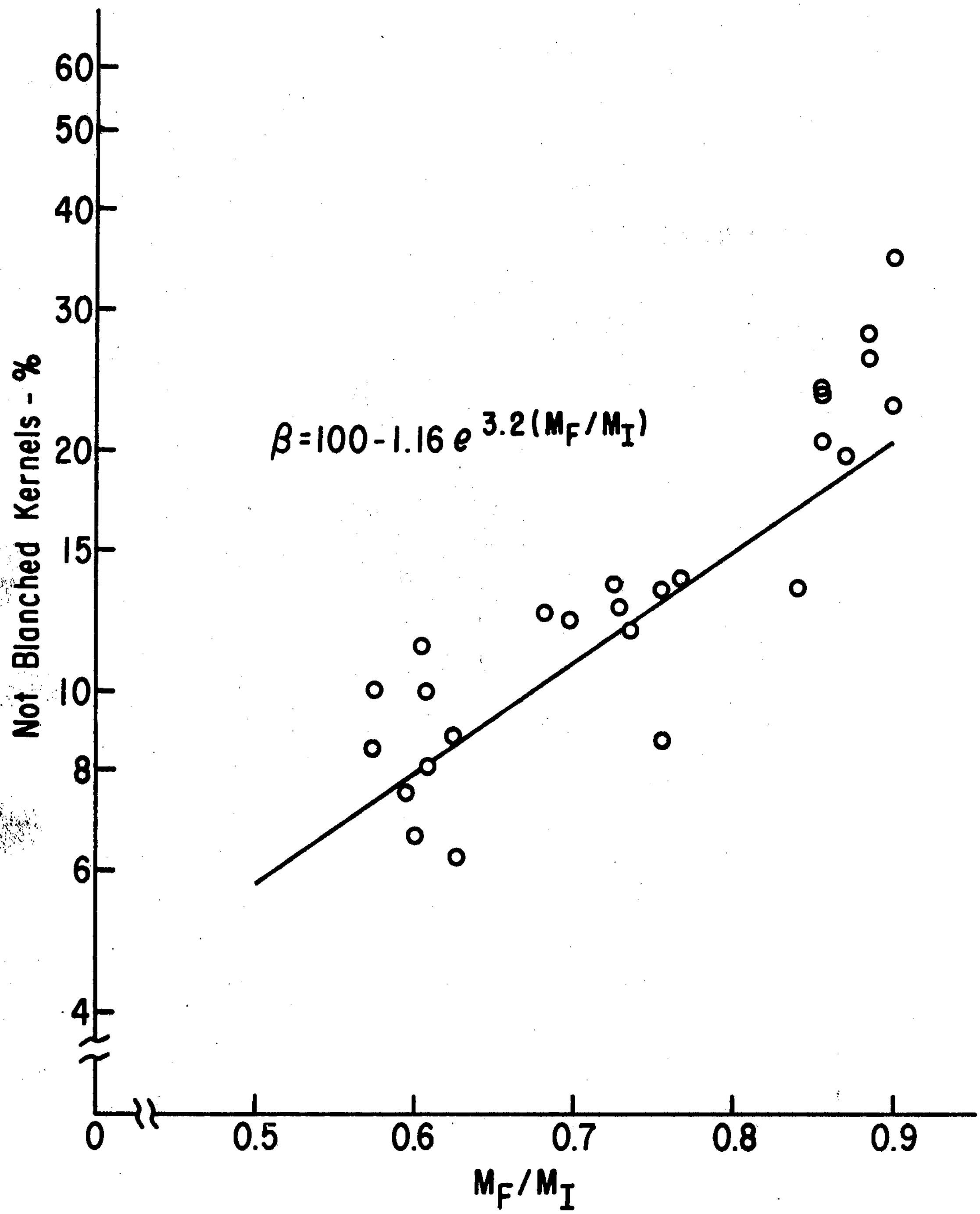


Figure 9. Blanchability at Natural Initial Moisture Content Compared With Equation 4

The difference in predicted and observed blanchabilities of kernels with natural initial moisture content when the M_F/M_I ratio was greater than 0.8 may be that Equation 4 was developed from kernels which had been conditioned to some moisture content different from natural moisture content. The conditioning process may have improved blanchability either through some phenomenon associated with changing the moisture content or by mechanical action involved in the conditioning process.

The effect of initial and final moisture content on blanchability had been investigated in previous work (17). Kernels were conditioned to a design initial moisture content of eight percent, and dried at 160°F to design final moisture contents of four, five, six, and seven percent. Equipment was essentially the same as for this study. Kernels were dried in 2000 gram samples, instead of the 600 gram samples of this study. Drying layer thickness was approximately two inches, which approximates thin layer drying, so the different sample size should not affect blanchability (8).

Figure 10 graphically presents data from previous work (17). The best fit (least squares) equation for this data, together with the line of Equation 4, is shown. Figure 10 shows that the best fit equation from previous work has a greater slope in semi-log space than does Equation 4. At lower M_F/M_I ratios the blanchabilities predicted by the two equations approach the same value.

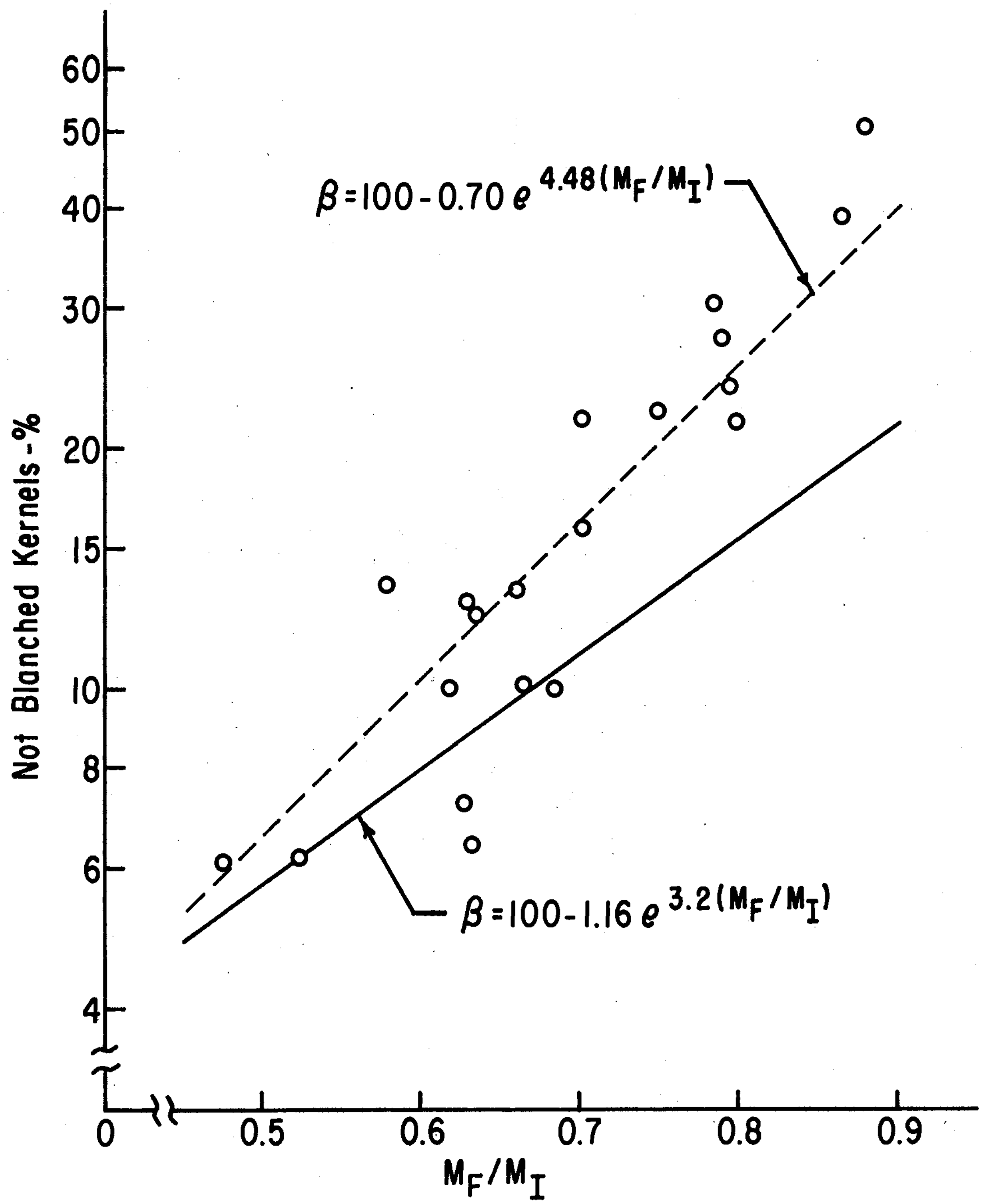


Figure 10. Blanchability Observed in Previous Work (17) Compared With Equation 4

Therefore, both equations predict essentially the same blanchability in the range of most probable use.

Two explanations are reasonable for the variation in blanchability from previous work and that predicted by Equation 4. The first is that a difference in blanchability may be caused by a difference in crop years. Previous work was done on peanuts grown in 1971, with Equation 4 being developed using peanuts grown in 1972. The second explanation may be a difference in blanchability due to difference in lots of peanuts. Different lots may be grown under different conditions, with variations in harvesting, curing, and storing which may affect blanchability.

Willich, et al. (22) reported on kernels which had been roasted for making peanut butter. Roasting temperatures varied from 275°F to 320°F, initial moisture contents ranged from 5.6 to 7.0 percent, and final moisture contents from 1.0 to 2.3 percent. Roasted kernels were blanched in a split nut blancher. Results were reported as kernels accepted for production of peanut butter (assumed here to be blanched) and rejected (used here as not blanched). Rejected kernels in Willich, et al. (22) included kernels which were not blanched and those which were discolored.

A graph of data from Willich, et al. (22) is shown as Figure 11, with Equation 4 plotted. Equation 4 fitted this data very well, with only two observations being more than one percent from the predicted value. The fact that Equation 4 predicted blanchability of kernels heated at

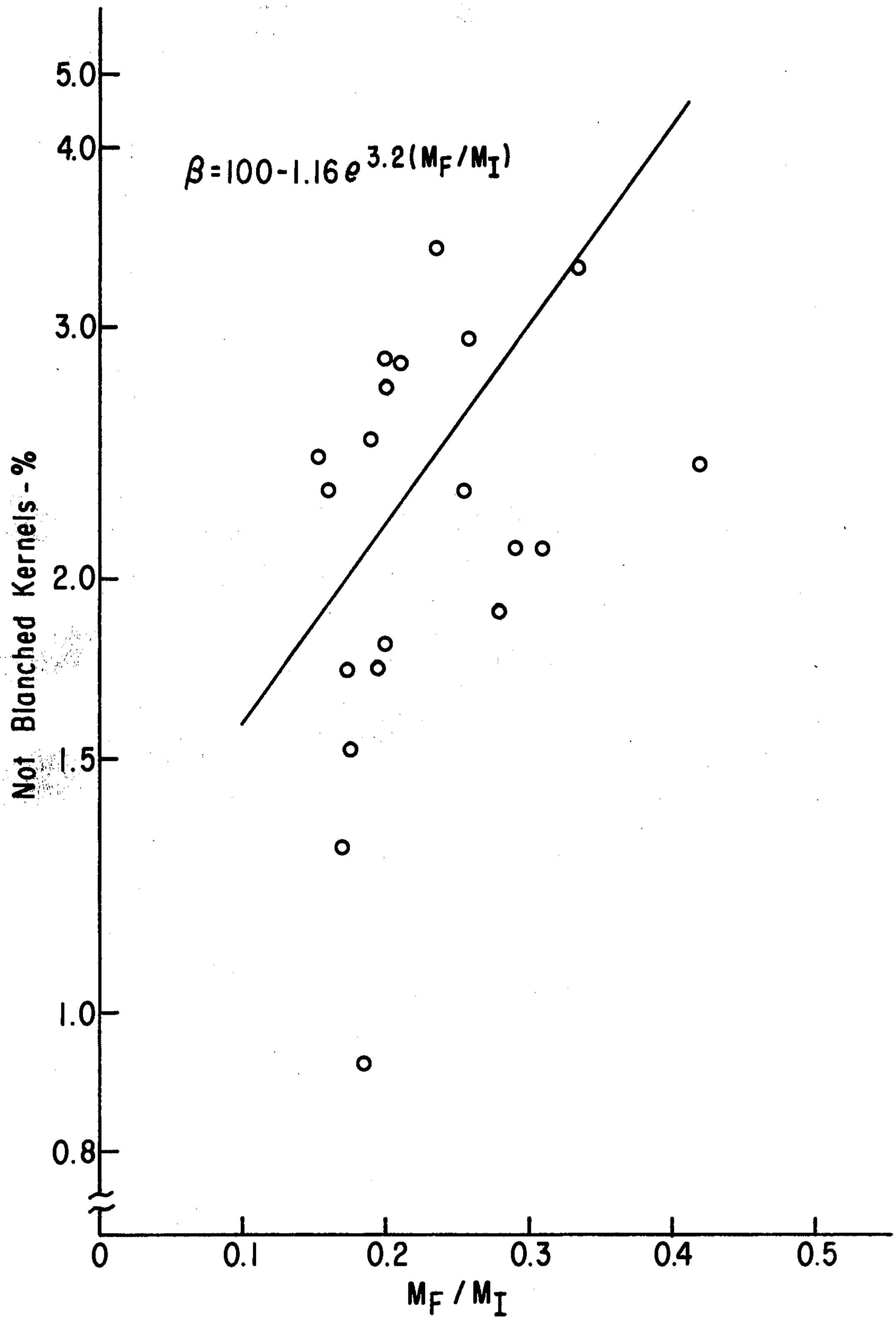


Figure 11. Blanchability From Willich, et al. (22) Compared With Equation 4

temperatures much greater than 200°F would tend to indicate that increasing the heating air temperature beyond 200°F may not improve blanchability substantially.

Final Temperature

To test the effect of final temperature on blanchability, peanut kernels were cooled in four environments, approximately 88, 76, 70, and 60°F, before blanching. Actual environmental conditions, final temperatures of kernels, and blanchability are shown in Table VI. Figure 12 is a plot of blanchability versus final temperature.

Blanchability of all samples cooled to approximately 90°F was lower than the blanchability of any other samples in Table VI. Analysis of variance, shown in Appendix E, indicated a significant difference in blanchability (α=0.5) due to differences in final temperature. Least significant difference test (see Appendix E) showed a significant difference (α=0.05) in mean blanchability of peanuts cooled to approximately 90°F and those cooled to both 80°F and 65°F. Mean blanchability of kernels cooled to approximately 73°F was 2.9 percent higher than mean blanchability of kernels cooled to approximately 90°F, but this difference in blanchability was not statistically significant (α=0.05).

Preliminary analysis of data on the effect of final temperature on blanchability indicated that final temperatures in the range from 65°F to 80°F would have essentially the same effect on blanchability. All subsequent tests

TABLE VI

DATA FOR EFFECT OF FINAL TEMPERATURE ON BLANCHABILITY

Obs. No.	Final Temp. °F	Ambient Air Temp. °F	Ambient Air Rel. Hum. %	Kernel Moist. - % - wb Initial	Kernel Moist. - % - wb Final	Blanch. %
1	89	88	51	7.9	4.7	87.8
2	89	87	53	7.7	4.7	88.6
3	90	88	53	7.8	4.0	91.1
4	82	79	38	8.0	4.4	95.5
5	81	78	41	7.7	4.5	92.5
6	78	76	53	7.9	4.7	92.5
7	73	70	73	8.0	5.1	92.3
8	72	70	73	8.0	5.4	91.6
9	75	70	73	8.0	5.3	92.2
10	67	60	56	8.0	5.4	95.1
11	65	61	63	7.9	5.6	93.1
12	65	62	66	7.7	5.6	92.1

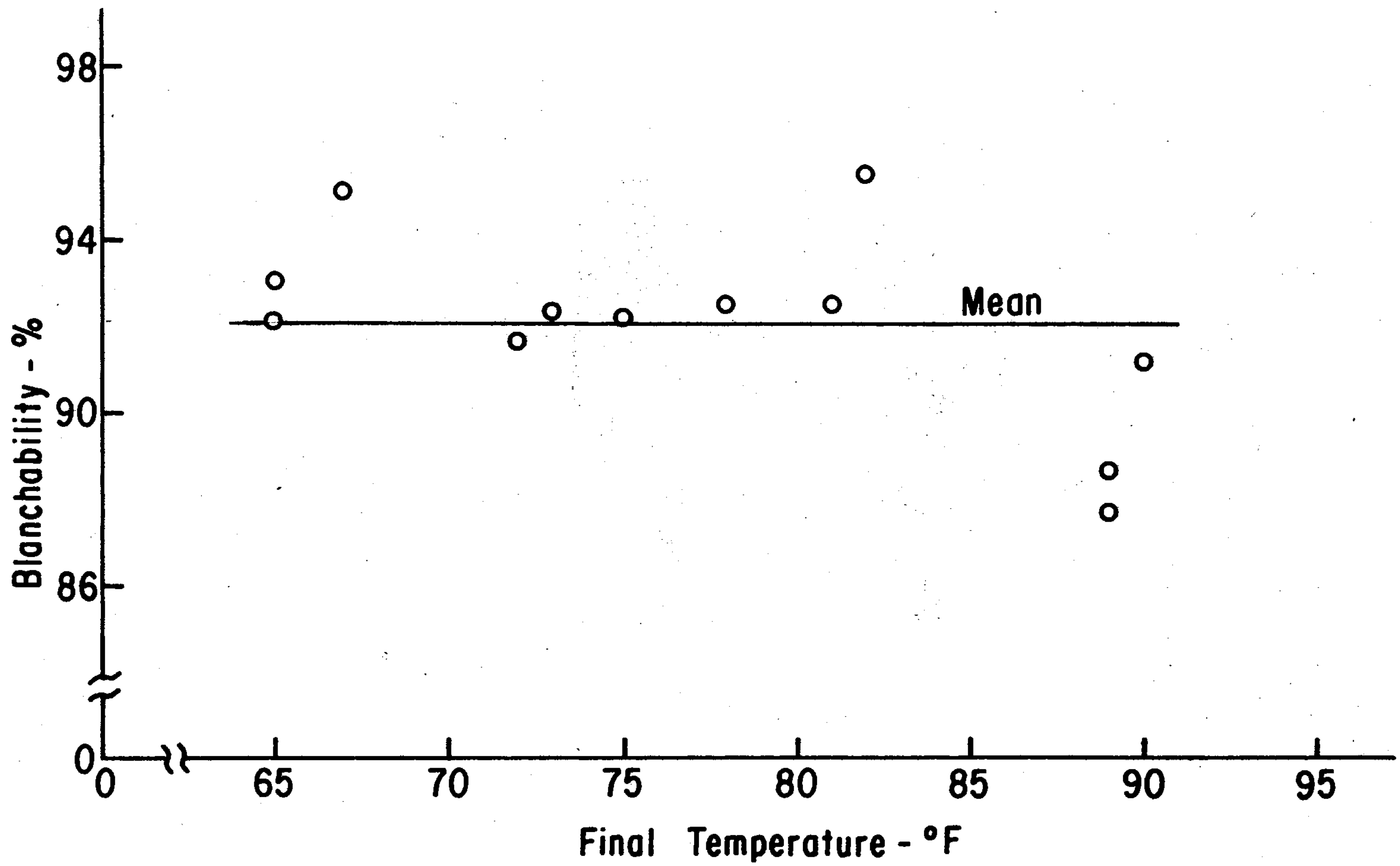


Figure 12. Effect of Final Temperature on Blanchability

were conducted using a final temperature obtained in ambient laboratory air below 80°F, usually approximately 75°F.

Further analysis showed that effects of final temperature might be confounded with effects of initial and final moisture contents. It can be seen in Table VI that the desired eight percent initial and five percent final moisture contents were not attained, with discrepancy between desired and actual values as high as 0.3 percent for initial and one percent for final moisture contents.

To minimize the effect of variability in initial and final moisture contents in tests on final temperature, blanchability was standardized to a value closer to that which would have been found had the desired initial and final moisture contents been attained. Standardization was obtained by adjusting the observed blanchability of a sample by a correction factor. To obtain the correction factor, the blanchability of an ideal sample with eight percent initial and five percent final moisture was calculated according to Equation 4. Then blanchability predicted by Equation 4 was calculated for each sample in Table VI. The correction factor was found by subtracting blanchability predicted for a sample from the predicted blanchability of an ideal sample. Equation 4 predicted that kernels with eight percent initial and five percent final moisture content would have a blanchability of 91.4 percent. The predicted blanchability, according to

Equation 4, for each sample in Table VI was calculated, and this predicted blanchability was subtracted from 91.4 percent to obtain the correction to be applied to the observed blanchability of that sample. A sample calculation is shown in Appendix F, and Table VII presents standardized blanchabilities for all samples in Table VI.

A graph of standardized blanchability versus final temperature is presented as Figure 13, which showed that a linear relationship in semi-log space might exist between standardized blanchability and final temperature. Linear regression produced a least squares fit equation as shown below,

$$\beta_S = 100 - 0.293e^{0.0414T_F} \qquad (5)$$

where,

β_S = blanchability standardized to eight percent initial and five percent final moisture - %

e = base of natural logarithm

T_F = final kernel temperature - °F

Correlation coefficient (R^2) was 0.83 and standard error was 1.2 percent blanchability.

From standardized results it was concluded that, in the range of 65°F to 90°F, lower final temperature will result in improved blanchability. Variation may have been introduced into subsequent tests due to variation in final temperature. Kernels were cooled in ambient laboratory

TABLE VII

STANDARDIZED BLANCHABILITY OF KERNELS COOLED TO VARIOUS FINAL TEMPERATURES

Obs. No.	Equilib. Moist. % - w.b.	Obs. Blanch. %	Blanch at 8-5* %	Pred.** Blanch. %	Correction %	Std. Blanch. %
1	5.3	87.8	91.4	92.2	-0.8	87.0
2	5.5	88.6	91.4	91.8	-0.4	88.2
3	5.5	91.1	91.4	94.0	-2.6	88.5
4	4.5	95.5	91.4	93.3	-1.8	93.7
5	4.8	92.5	91.4	92.5	-1.0	91.5
6	5.7	92.5	91.4	92.2	-0.8	91.7
7	7.5	92.3	91.4	91.1	+0.3	92.6
8	7.5	91.6	91.4	89.9	+1.5	93.1
9	7.5	92.2	91.4	90.3	+1.1	93.3
10	6.2	95.1	91.4	89.9	+1.5	96.6
11	6.8	93.1	91.4	88.8	+2.6	95.7
12	7.0	92.1	91.4	88.1	+3.3	95.4

* Blanchability predicted by Equation 4 for eight percent initial and five percent final moisture contents, wet basis.

**Blanchability predicted by Equation 4 for sample initial and final moisture contents.

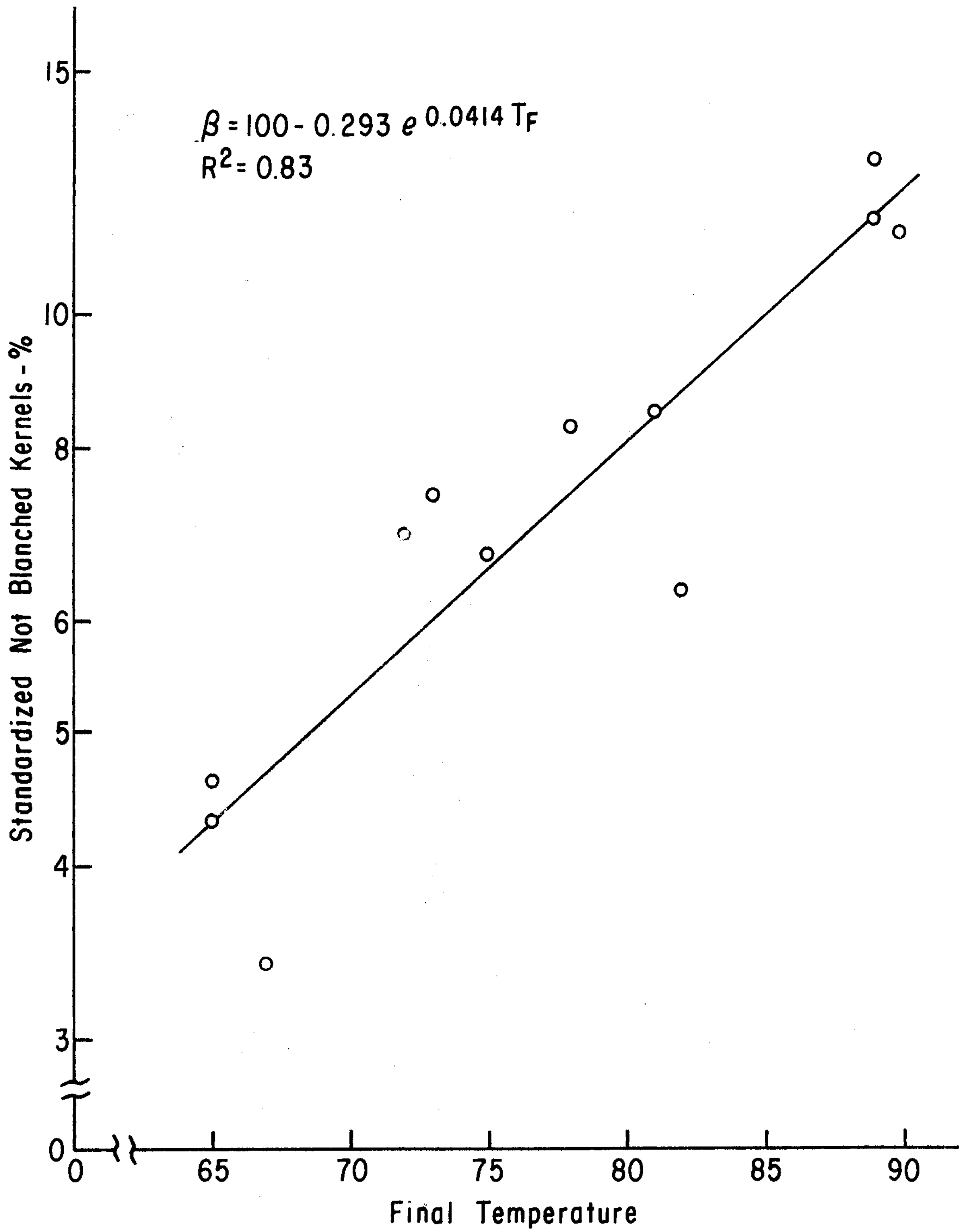


Figure 13. Final Temperature Versus Blanchability Standardized to Eight Percent Initial and Five Percent Final Moisture Contents

air which was maintained at approximately 75°F, but varied from 72°F to 80°F. Variation in final temperature could have resulted in a variation in blanchability of 2.3 percent, according to Equation 1. This variation was randomly distributed and did not seriously affect the results of subsequent tests.

Relative humidity of ambient air used in cooling varied from 38 to 73 percent, as can be seen in Table VI. To investigate the effect of relative humidity on blanchability apart from the effect of final kernel temperature, the equilibrium moisture content of ambient air used to cool each sample was calculated. Equilibrium moisture contents, the moisture content which a peanut kernel would approach after exposure to air of a given temperature and relative humidity for a period of time, were calculated from Henderson's equation as modified by Beasley and Dickens (2), and Agrawal and Clary (1). Equilibrium moisture contents for each sample are shown in Table VII.

Examination of equilibrium moisture values of various atmospheres used to cool kernels failed to reveal any effect of equilibrium moisture on blanchability. When tests with a final temperature of approximately 89°F are compared with tests with final temperatures of 80°F, a small decrease in mean equilibrium moisture is accompanied by a relatively large increase in blanchability. Comparing tests at approximately 80°F final temperature with those at about 73°F, a relatively large increase in mean equilibrium moisture is accompanied by a rather small increase in mean blanchability. When final temperature was lowered from about 73°F to approximately 65°F, a small decrease in mean equilibrium moisture goes with a relatively large increase in mean blanchability. Since difference in temperature accounted for a major part of the variability of these tests, and no consistent effect of equilibrium moisture could be discovered, it is concluded that relative humidity of the cooling air was not shown to have a substantial effect on blanchability.

Cooling Time

Based on results of tests on final temperature, laboratory air at approximately 75°F was chosen as the environment in which to test the effect of cooling time on blanchability. Cooling time was the elapsed time between removing kernels from the dryer and blanching the kernels. Data on final temperatures, cooling times, and blanchability are shown in Table VIII. Figure 14 is a plot of blanchability versus cooling time.

Mean blanchability for tests on cooling time was 93.2 percent, with standard deviation of 1.3 percent. Eleven out of fourteen observations were within one standard deviation of the mean. Analysis of variance, shown in Appendix E, did not show any significant variation ($\alpha=0.05$) in blanchability due to difference in cooling time. It is concluded that cooling times of from one-half to 3.5 hours

TABLE VIII

DATA FOR EFFECT OF COOLING TIME ON BLANCHABILITY

Obs. No.	Cooling Time Hrs.	Final Temp. °F	Ambient Air Temp. °F	Ambient Air Rel. Hum. %	Kernel Moist., % wb Initial	Kernel Moist., % wb Final	Blanch. %
1	0.5	76	74	47	7.8	5.3	94.6
2	0.5	77	75	46	8.0	4.7	92.2
3	1.0	75	73	47	7.9	5.1	93.9
4	1.0	76	75	46	8.1	4.9	92.6
5	1.5	75	73	46	7.9	5.1	94.5
6	1.5	77	74	46	8.0	4.9	92.2
7	2.0	75	73	47	7.9	5.4	93.0
8	2.0	77	75	46	8.1	5.0	92.6
9	2.5	75	74	46	7.9	5.0	94.6
10	2.7	76	75	46	8.0	4.9	90.1
11	3.0	75	73	46	7.9	5.0	94.6
12	3.2	76	74	46	8.0	4.5	91.9
13	3.5	73	73	48	7.9	5.1	94.1
14	3.7	76	74	46	8.1	4.7	93.2

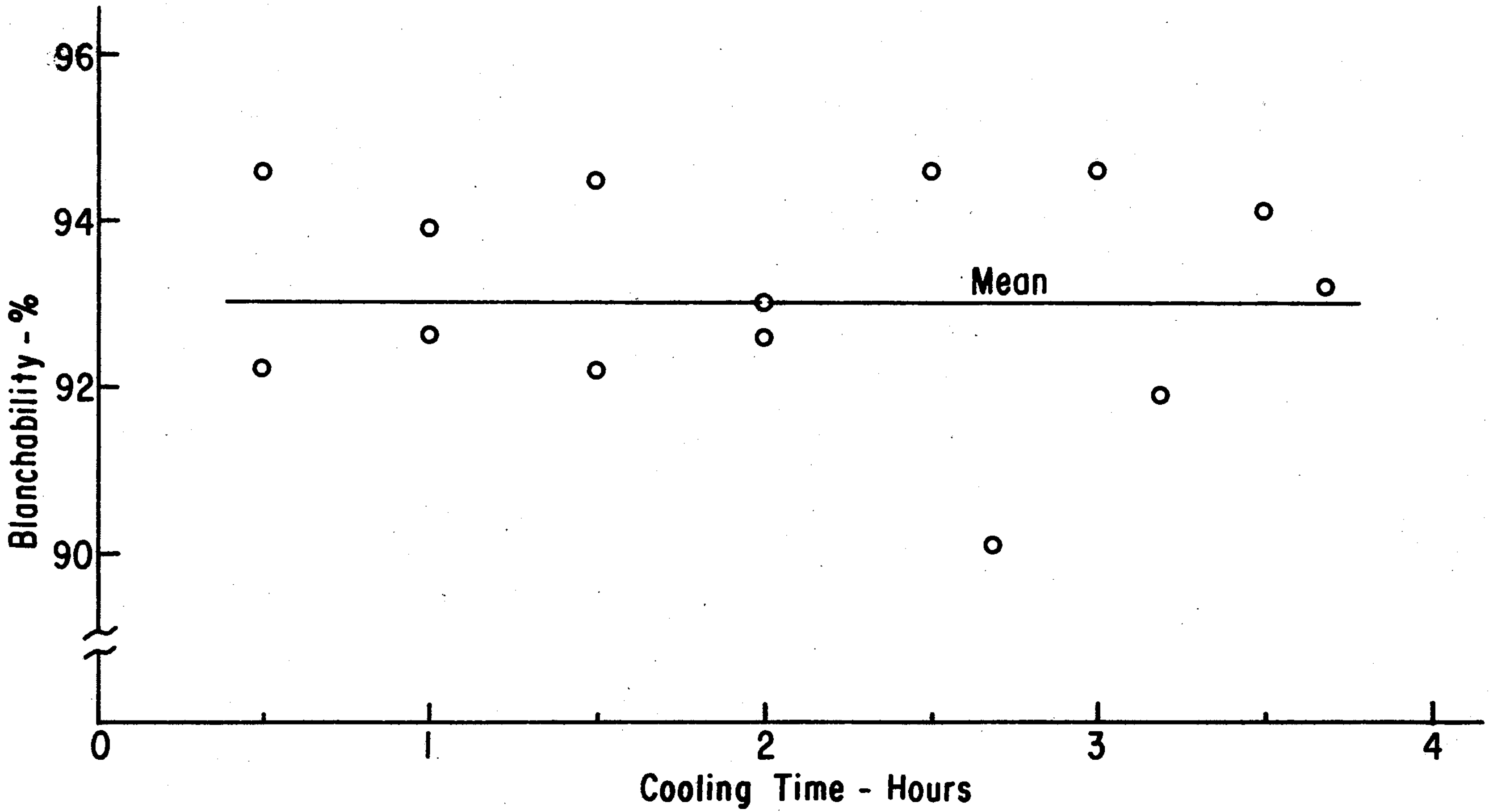


Figure 14. Effect of Cooling Time on Blanchability

do not significantly affect blanchability of peanuts cooled to 75°F.

Discussion of Results

Several phenomena have been observed which may help explain why peanut kernels are blanched or fail to be blanched under given conditions. Most of these observations have not been verified but are presented as hypotheses only.

Peanut kernels may be roughly divided into three groups based on blanching characteristics. Skin on kernels in the first group is very weakly attached to the cotyledons and is held in place mainly by tensile strength of the skin. When the skin is cut or otherwise ruptured, it may be easily removed by rubbing gently between the fingers. A large proportion of kernels in the first group may be blanched by slitting the skin and passing through a whole nut blancher, with no other treatment needed. These kernels appear to comprise between 25 and 50 percent of the kernels in a sample.

The second group of kernels is made up of those whose skin is more strongly attached to the cotyledons. When the skin of these kernels is cut and they are rubbed gently between the fingers, some but not all of the skin may be removed. Skin remaining attached to the cotyledons may be removed by more vigorous rubbing with the fingers. These kernels will usually be partially blanched and some may be fully blanched by slitting the skin and passing them through the blancher with no other treatments.

The remainder of a sample, comprising the third group and usually about 10 to 25 percent of the sample, is made up of kernels with skins firmly attached to the cotyledon. Skins are difficult to remove by rubbing between the fingers and may be difficult to scrape off with a knife. This group contains a disproportionately large quantity of immature, misshapen, and insect damaged kernels, although some appear to be sound mature kernels. It is toward this third group that blanching treatments are directed.

The basic problem in a blanching operation is to break the bond between skin and cotyledon. The nature of this bond has not been established, but observations on the behavior of skins under heat treatment have been made. When kernels are being heated, cut or broken skin can be seen to curl away from the cotyledon, indicating heat stress, stress from moisture loss, or both are present in the skin. Skins appear to become thinner and to lose tensile strength, although these observations have not been verified by tests.

It is hypothesized that the effect of heating on blanchability may be connected with moisture loss in the skin and accompanying stress between skin and cotyledon. Karon and Hillery (10) reported that the equilibrium moisture content of skins is approximately twice the equilibrium moisture content of cotyledons for a given environment. Therefore a relatively large quantity of moisture is available to be removed from skins at the beginning of heat treatment. At six percent cotyledon moisture content the skins will be at approximately 14 percent moisture content. Although Karon and Hillery did not investigate equilibrium moisture at high air temperatures and low relative humidities, it would be reasonable to assume that equilibrium moisture content of the skin may approach one percent when heating air temperature is 200°F and relative humidity is two percent, the conditions which cause an equilibrium moisture content of 0.3 percent in the kernel.

Since the skin is relatively thin, and is in contact with the heating air, it can be expected to approach equilibrium moisture content at a more rapid rate than the cotyledon. The approach of skin to equilibrium moisture would probably be slowed by moisture from the cotyledon being absorbed by the skin.

If the skin tends to shrink as it loses moisture, tensile stress will be set up in the skin, due to a slower rate of moisture loss and a possible slower reduction in volume of the cotyledons. If the skin is broken at any point, it will attempt to move relative to the cotyledon to relieve this stress, and if the bond between cotyledon and skin is weak enough, the skin may move relative to the cotyledon, breaking the bond and making the skin relatively easy to remove. It was assumed throughout this argument that skin and cotyledon are at approximately the same temperature, and that the effects of different coefficients of thermal expansion will be much less than the effects of moisture loss.

If it is true that moisture loss sets up tensile stress in the skin which separates skin and cotyledon, the observation that drying the peanuts to a lower M_F/M_I ratio improves blanchability can be explained. As the kernel dries, a moisture gradient is set up in the cotyledons, with the center of the kernel closer to initial moisture content, and the outer edge closer to equilibrium moisture content. The rate of moisture leaving the cotyledon is reduced at increasing drying time. As the rate of moisture loss from the cotyledon is reduced, the skin can approach more closely the equilibrium moisture content, the skin shrinks more, and blanchability is improved. Since, according to Henderson and Perry (8), the ratio of moisture content at any time to initial moisture content is a logarithmic function of heating time, a logarithmic relationship between the ratio of initial and final moisture content and blanchability would be reasonable.

Increased blanchability has been associated with increased heating air temperature. This relationship can be explained by the fact that, starting with air at a certain temperature and relative humidity, air heated to a higher temperature will have a lower relative humidity, and kernels exposed to it will have lower equilibrium moisture content (8). This lower equilibrium moisture content should lead to higher blanchabilities.

Whole Kernels

After the kernels had been separated into blanched and not blanched groups and each fraction weighed, the blanched kernels were further separated into whole kernels and splits. A whole kernel was a blanched kernel with cotyledons joined. Whole kernels and splits were weighed, and the percent whole kernels calculated. Data for whole kernels is presented in Appendix F.

Mean percent whole kernels for all samples heated at 160°F, 180°F, and 200°F were 69.2, 66.6, and 66.2 percent respectively. Analysis of variance, presented in Appendix E, did not show that differences in whole kernels due to differences in heating air temperature to be significant.

Mean percent whole kernels for all samples with design final moisture contents of four, five, six, and seven percent were 54.5, 65.8, 72.2, and 84.0 percent respectively. Care must be taken in comparing these means to each other, since all initial moisture contents are not represented in each mean. However, a linear relationship between percent whole kernels and final moisture content is indicated.

Mean percent whole kernels for all samples with design initial moisture contents of six, eight, and ten percent were 67.2, 73.4, and 61.3 percent respectively. Again, all final moisture contents are not contained in each mean, so comparison of these means requires caution. The decrease in percent wholes when design initial moisture content increased from eight to ten percent agreed with previous work which indicated that usually any treatment which improved blanchability also decreased the percent whole kernels (17). The fact that mean percent wholes at six percent initial moisture was more than 5.2 percent lower than that at eight percent initial moisture content was unexpected.

Various combinations of initial moisture content, final moisture content, and moisture loss were investigated as the independent variable in linear regression equations. Moisture loss was the difference in initial and final moisture content. Regression equations and statistics of fit are shown in Table IX.

The independent variable which gave the best fit, based on correlation coefficient and standard error, was the ratio M_L/M_F, M_L being the moisture loss, and M_F the final moisture content. A graph of percent whole kernels versus the ratio M_L/M_F is shown in Figure 15.

It can be seen in Figure 15 that samples with design initial moisture contents of six percent generally had a lower percent whole kernels at a given M_L/M_F ratio than those with design initial moisture contents of eight and ten percent. This tendency for samples with design initial moisture contents of six percent to have a lower blanchability at a given value of the independent variable was also evident when the independent variable was M_F/M_I and M_L/M_I. Further analysis was carried out using only data from samples with design initial moisture contents of eight and ten percent. The results of this analysis are shown in Table IX.

TABLE IX

REGRESSION COEFFICIENTS AND STATISTICS OF FIT FOR WHOLE KERNELS

Equation Form	All Samples				8% and 10% M_I Only			
	a	b	R^2	Std. Error %	a	b	R^2	Std. Error %
$\Psi = a + b(M_I)$	90.9	- 2.84	0.07	13.7	141.8	- 8.44	0.24	13.2
$\Psi = a + b(M_F)$	8.5	11.20	0.61	8.9	1.7	12.20	0.67	8.7
$\Psi = a + b(M_L)$	89.9	- 7.40	0.58	9.2	102.2	- 10.20	0.85	5.9
$\Psi = a + b(M_F/M_I)$	11.9	85.90	0.68	8.0	2.3	105.30	0.86	5.7
$\Psi = a + b(M_L/M_I)$	97.9	-85.90	0.68	8.0	107.6	-105.30	0.86	5.7
$\Psi = a + b(M_L/M_F)$	87.2	-31.60	0.71	7.7	93.0	- 36.70	0.87	5.5
$\Psi = a + b\left[\frac{M_F - M_E}{M_I - M_E}\right]$	17.5	80.30	0.67	8.2	9.7	97.30	0.83	6.3

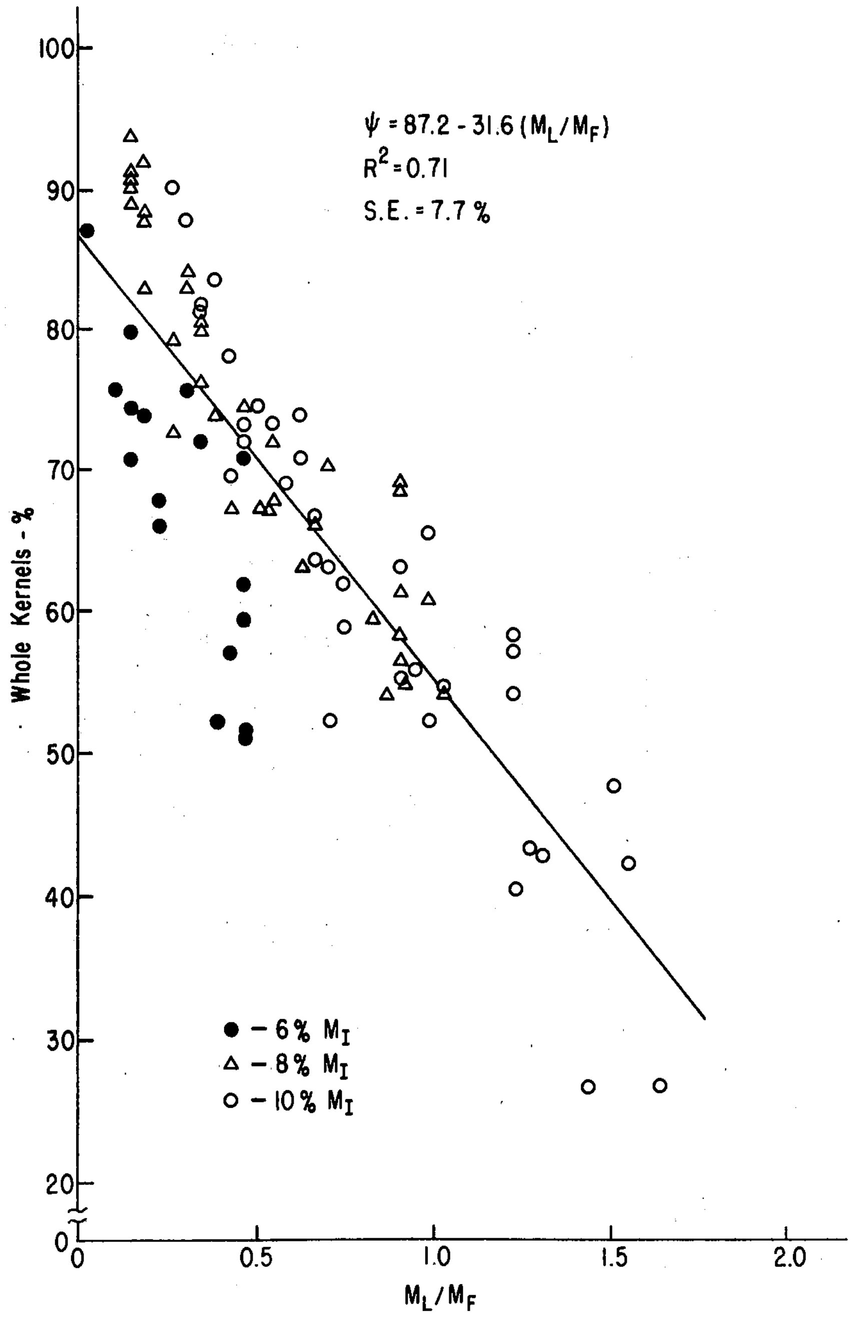


Figure 15. Whole Kernels Versus Ratio of Moisture Loss to Final Moisture Content, Including Samples at All Design Initial Moisture Contents

Figure 16 shows a graph of whole kernels versus the ratio M_L/M_F for samples with design initial moisture contents of eight and ten percent only. The exclusion of data from samples with design initial moisture content of six percent improved the correlation coefficient (R^2) from 0.71 to 0.87, and standard error was reduced from 7.7 to 5.5. Four of the six other equation forms in Table IX showed similar improvement in statistics of fit, with none showing detriment.

It would appear that none of the equation forms investigated will properly account for the percent whole kernels produced by samples with design initial moisture content of six percent. This may be due either to not perceiving the proper equation form or that kernels at the design initial moisture content of six percent are somehow different in their reaction to treatments than those at other design initial moisture contents. If the samples with design initial moisture content do react differently, one explanation could be that they were conditioned by drying while those at other design initial moisture contents had moisture added.

Due to the unexpectedly low mean percent wholes at six percent design initial moisture content, not finding an equation form which represented them, and the possibility that these samples may not react the same as those at other initial moisture contents, it was decided not to include data from samples with design initial moisture

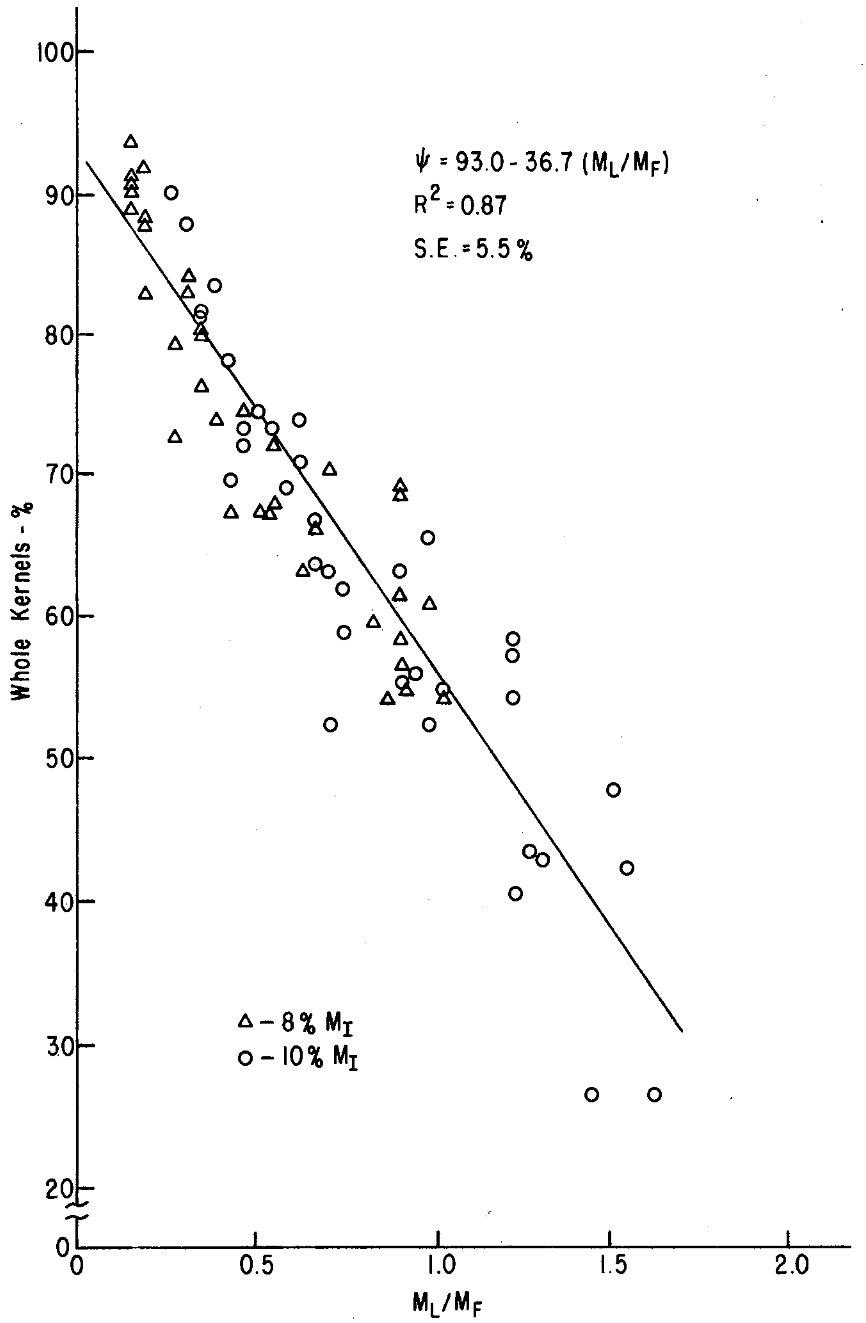


Figure 16. Whole Kernels Versus Ratio of Moisture Loss to Final Moisture Content, Samples With Eight and Ten Percent Design Initial Moisture Content Only

content of six percent in that used to develop the prediction equation for percent whole kernels. The prediction equation, selected on the basis of correlation coefficient (R^2) and standard error, is

$$\Psi = 93.0 - 36.7(M_L/M_F) \qquad (6)$$

where

Ψ = whole kernels, %

M_L = moisture loss, %, wet basis

M_F = final moisture, %, wet basis

Correlation coefficient (R^2) = 0.87, and standard error = 5.5 percent.

The form of Equation 6 limits application to cases in which initial moisture content is greater than final moisture content. If moisture loss is negative, Equation 5 may predict a percent whole kernels greater than 100 percent. This equation should also be used with caution for M_L/M_F ratios greater than 1.5.

Confirming Whole Kernel Test Results

Data on whole kernels from tests at natural initial moisture content is shown in Table VII. Mean whole kernels at heating air temperatures of 160°F, 180°F, and 200°F were 80.3, 78.2, and 79.4 percent respectively. This small difference in whole kernels confirms the preceding findings that heating air temperature was not shown to significantly affect the percent whole kernels in a sample.

Figure 17 presents whole kernels of samples with natural initial moisture content versus the ratio M_L/M_F, with the prediction line of Equation 6. Standard error of observations in Figure 17 with Equation 6 was 2.8 percent whole kernels, compared with a standard error of 5.5 percent for data from which Equation 6 was developed. The close agreement between percent whole kernels observed in tests on kernels at natural initial moisture content and percent whole kernels predicted by Equation 6 indicates that Equation 6 was capable of adequately predicting the percent whole kernels for the lot of peanuts used in these tests.

Data on percent whole kernels was also available from previous work (17). Figure 18 shows this data graphically together with the line of Equation 6. Standard error of observed whole kernels with whole kernels as predicted by Equation 6 was 12.7 percent whole kernels. As can be seen in Figure 18, observed percent whole kernels was greater than predicted by Equation 6. This difference appeared to be larger at higher values of M_L/M_F ratio than at lower values. The difference between observed whole kernels in previous work and whole kernels predicted by Equation 6 may be due to differences in crop years or differences between lots of peanut kernels by different growing, curing, and storage conditions.

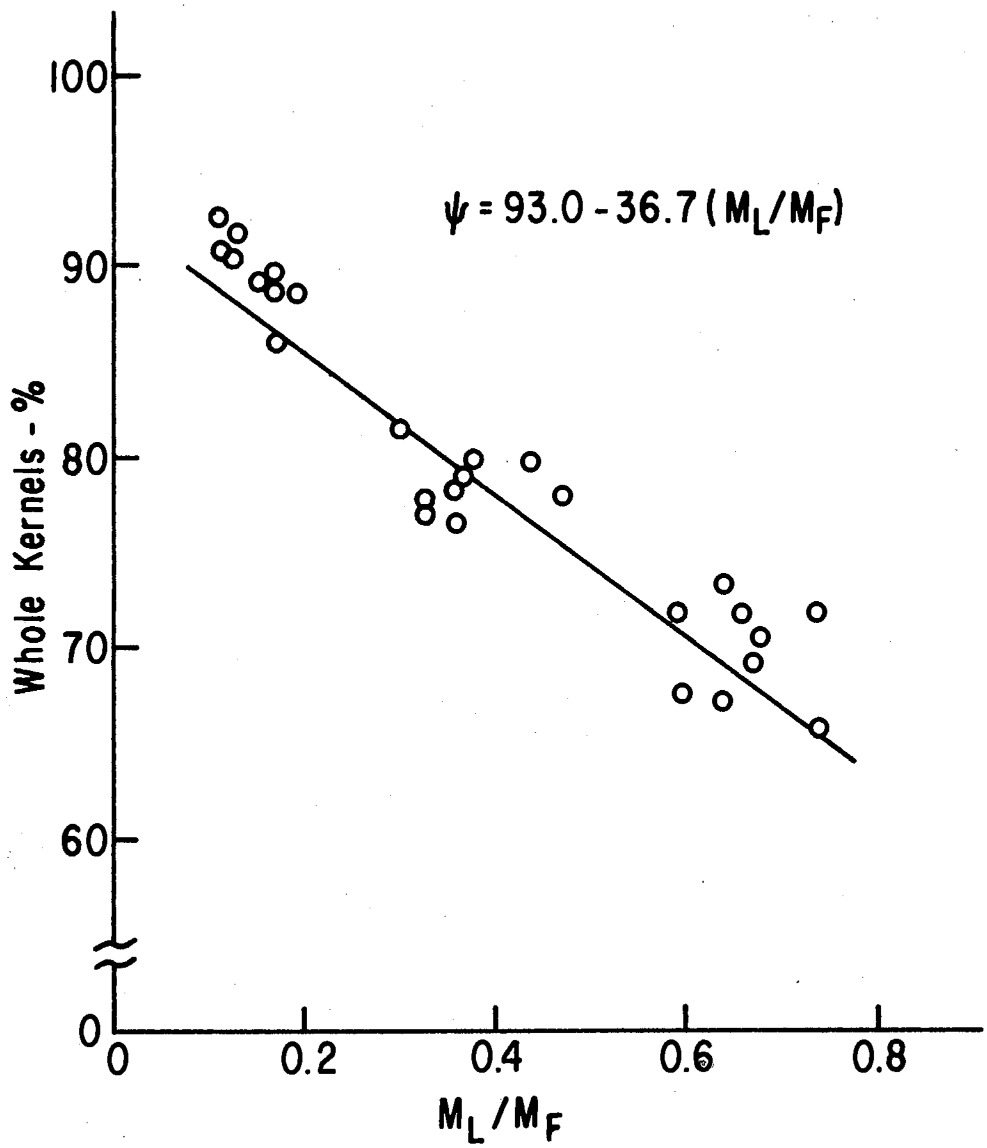


Figure 17. Whole Kernels With Natural Initial Moisture Content. Line Shown Is Plotted From Equation 6

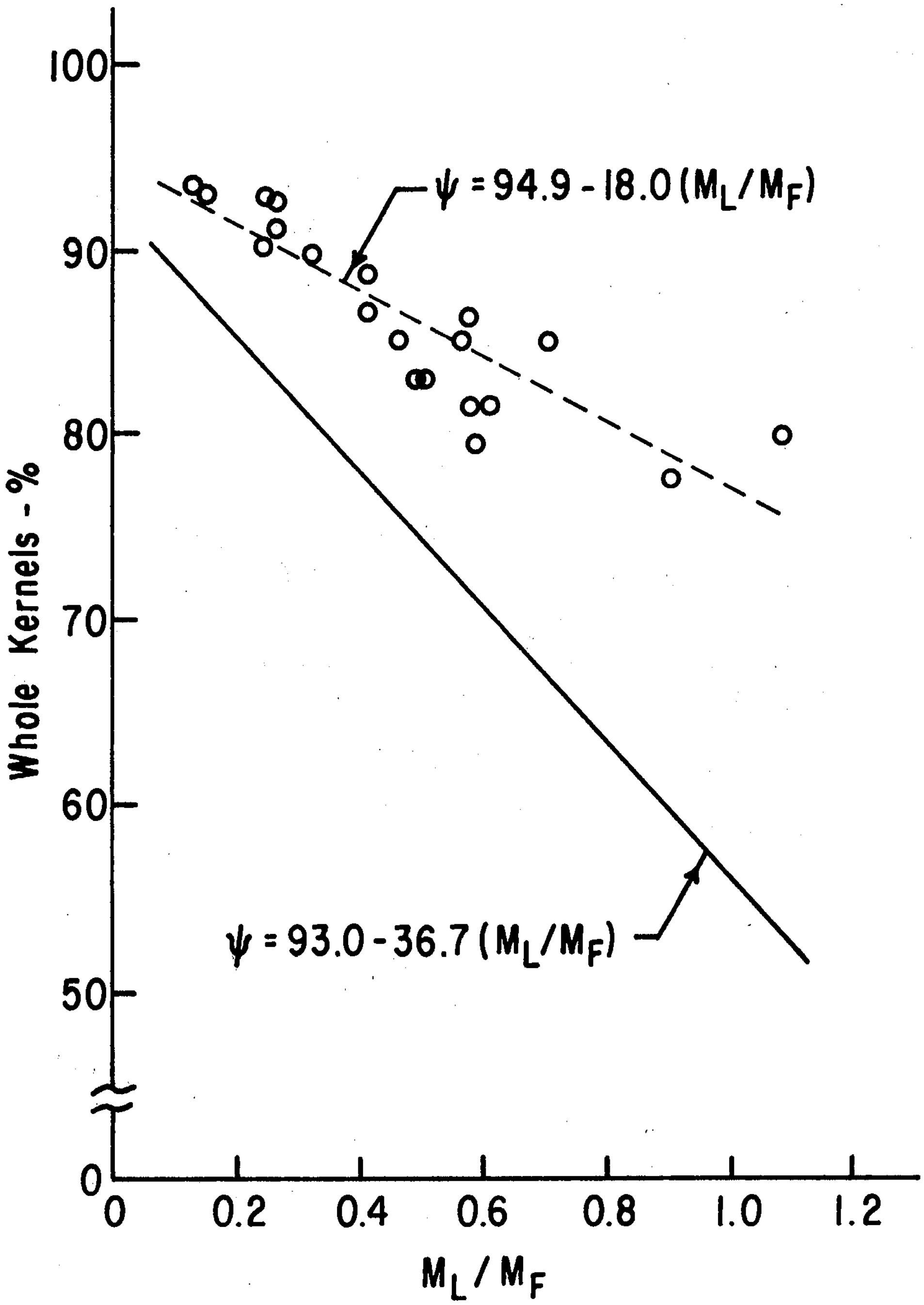


Figure 18. Whole Kernels From Previous Work (17) Compared With Equation 6

Discussion of Results for Whole Kernels

Woodward (24) reported that over 90 percent of the strength in a kernel available to resist separation of cotyledons was in the skin, with less than 10 percent of the strength to resist separation in the juncture of cotyledon and heart or germ. When the skin is removed, resistance to cotyledon separation is almost totally dependent on the bond between cotyledon and heart, with practically no bond between cotyledons being present.

As kernels are dried, the cotyledons tend to separate at the center of adjacent sides, with the edges of the cotyledons remaining in contact with each other. This separation appears to be dependent on moisture content, and is more evident as kernels are dried to a lower moisture content.

It is hypothesized that cotyledon separation associated with moisture loss from the kernel weakens the bond between cotyledon and heart, making the cotyledons more likely to be separated during the blanching process. This hypothesis would be compatible with the finding that both moisture loss and final moisture content affect the percent whole kernels, since both could affect the amount of cotyledon separation. The apparently lower percent wholes at six percent initial moisture content would be explained since these kernels had been dried almost one percent, but this drying was not taken into account when calculating the moisture loss for these samples. If moisture loss for these samples was calculated from natural moisture content the M_L/M_F ratio would increase, and the percent whole kernels associated with these recalculated M_L/M_F ratios would be closer to the percent whole kernels found for similar M_L/M_F ratios for samples with design initial moisture content of eight and ten percent.

Taste Panel Evaluation

The primary purpose of taste tests in this project was to evaluate taste effects of different heating air temperatures on kernels. The taste panel was designed to test three treatments, so one treatment combination utilizing each heating air temperature was chosen. This combination contained initial moisture content of eight percent, and final moisture content of four percent. The eight percent initial moisture content was chosen as being the middle value tested. Four percent final moisture content was chosen as being the most severe final moisture content tested. A coded standard was included as a fourth treatment. This standard was prepared from untreated kernels from the same lot as the treated kernels.

The taste test was set up as described by Bradley and Terry (3), with block size 2. Three replications of each of the three treatment combinations were tasted. Both roasted peanuts and peanut butter were tested. A panel of five judges was used for each test, with different panels for roasted kernels and peanut butter. Each panel tasted two trials on each of three days. Each trial consisted of three replications of the three treatment combinations and the standard.

Table X shows the order of sample presentation to one judge for one replication in one trial on one day. In Table X row was the tray row on which the peanuts were presented to the judges. Order of presentation of samples was obtained by randomizing the blocks to the rows. For example, block six could be in any of the six rows. Location of each sample within a block was further randomized as to position, left or right, in the tray. This setup tastes each treatment combination 270 times.

TABLE X

ORDER OF TASTE PANEL SAMPLE PRESENTATION

Judge	Rep.	Trial	Day	Block	Row	Treat. No.			
						1	2	3	4
1	1	1	1	6	1			X	X
				4	2		X	X	
				3	3	X			X
				1	4	X	X		
				2	5	X		X	
				5	6		X		X

Rank analysis was used to test differences among treatments. Statistical analysis was made assuming a chi-square distribution. Tables XI and XII show means and chi-square values for each of the taste responses.

Significant differences (α=0.05) were indicated in flavor, taste, and dryness of peanut butter made from peanuts heated at different temperatures. Since the mean scores of the coded standard showed it as least desirable for all responses, it was concluded that heating kernels at 160°F, 180°F, and 200°F prior to blanching would not adversely affect the taste of peanut butter made from these kernels. It may be possible that heating peanuts prior to blanching improved taste properties of peanut butter made from these kernels.

No significant differences in flavor or roast of roasted kernels were found. It was concluded that heating peanuts to 160°F, 180°F, and 200°F did not adversely affect the flavor or roast of roasted kernels produced from these kernels.

TABLE XI

SUMMARY OF TASTE TEST RESULTS OF ROASTED KERNELS

Response	Treat.	Mean Score*	Chi-Sq.**
Flavor	160°F	1.44	2.87
	180°F	1.47	
	200°F	1.54	
	Standard	1.54	
Roast	160°F	1.48	2.16
	180°F	1.47	
	200°F	1.56	
	Standard	1.48	

* Preferred = 1, Not Preferred = 2
** Chi-Square (α=0.1, df=3) = 6.25

TABLE XII

SUMMARY OF TASTE TEST RESULTS
OF PEANUT BUTTER

Response	Treat.	Mean Score*	Chi-Sq.**
Flavor	160°F	1.39	10.33
	180°F	1.55	
	200°F	1.46	
	Standard	1.60	
Taste	160°F	1.41	10.67
	180°F	1.54	
	200°F	1.44	
	Standard	1.61	
Odor	160°F	1.44	5.22
	180°F	1.54	
	200°F	1.45	
	Standard	1.57	
Texture	160°F	1.42	4.87
	180°F	1.53	
	200°F	1.48	
	Standard	1.55	
Dryness	160°F	1.36	11.44
	180°F	1.56	
	200°F	1.53	
	Standard	1.59	

* Preferred = 1, Not Preferred = 2
** Chi-Square (α=0.05, df=3) = 7.81

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Spanish peanut kernels were treated by heating with air at temperatures of 160, 180, and 200°F. Initial moisture contents varying from six to ten percent, wet basis, were investigated. Kernels were dried to final moisture contents varying from four to seven percent, wet basis. Blanchability was determined by blanching the kernels in a whole nut blancher, separating fully blanched kernels from those not fully blanched, and calculating the percentage by weight of blanched kernels. Percentage of whole kernels was determined by separating blanched kernels into whole kernels and splits, and calculating the percentage by weight of whole kernels.

Conclusions

Blanchability is improved by lower final kernel temperatures in the range 65°F to 90°F. The logarithm of percent not blanched kernels was found to be a linear function of final kernel temperature. This relationship is described by the following equation.

$$\beta_S = 100 - 0.293e^{0.0414T_F} \tag{5}$$

where,

β_S = blanchability standardized to eight percent initial and five percent final moisture content - %

e = base of natural logarithms

T_F = final kernel temperature - °F

Blanchability of peanut kernels cooled at 75°F (±2°F) is not affected by cooling times in the range from 0.5 to 3.5 hours.

Both initial and final moisture content of peanut kernels significantly affect blanchability. The logarithm of percent not blanched kernels is a linear function of the ratio of final kernel moisture content to initial kernel moisture content. The following equation was found to describe this relationship.

$$\beta = 100 - 1.16e^{3.2(M_F/M_I)} \tag{4}$$

where,

β = blanchability - %

e = base of natural logarithms

M_F = final kernel moisture content - % - wet basis

M_I = initial kernel moisture content - % - wet basis

Increasing heating air temperature from 160°F to 180°F gave a small but statistically significant increase in blanchability. The effect of increasing heating air temperature from 180°F to 200°F was not established, but the prediction equation developed from data using heating air temperatures from 160°F to 200°F successfully predicted blanchabilities of kernels heated in the range of 275°F to 320°F, indicating that increasing heating air temperature beyond 200°F may not improve blanchability substantially.

Heating air temperature did not significantly affect the proportion of whole kernels.

Whole kernels were found to be affected by both moisture loss and final moisture content of the kernels. Percent whole kernels was found to be a linear function of the ratio of moisture loss to final moisture content, as shown in the following equation.

$$\Psi = 93.0 - 36.7(M_L/M_F) \quad (6)$$

where,

Ψ = whole kernels - %

M_L = moisture loss - % - wet basis

M_F = final moisture content - % - wet basis

Taste properties of roasted peanut kernels and peanut butter from kernels treated at heating air temperatures of 160°F, 180°F, and 200°F, design initial moisture content of eight percent, wet basis, and design final moisture content, wet basis, were determined by a taste panel. No adverse taste effects in roasted kernels or peanut butter were found for any treatment combination tasted.

Recommendations for Future Work

The nature of the bond between skin and cotyledon needs to be determined. This knowledge could benefit curing operations in which it is desired that the skin remain on the cotyledons as well as blanching operations.

Further work needs to be done to determine the general effect of heating air temperature on blanchability.

Long term storage tests should be run to find the effects of heat treatment of peanut kernels on storage life.

SELECTED BIBLIOGRAPHY

(1) Agrawal, K. K., B. L. Clary, and G. L. Nelson. "Investigation into the Theories of Desorption Isotherms for Rough Rice and Peanuts." Journal of Food Science, Vol. 36 (1971), pp. 919-924.

(2) Beasley, E. O., and J. W. Dickens. Engineering Research in Peanut Curing. Technical Bulletin No. 155. North Carolina Agricultural Experiment Station, 1963.

(3) Bradley, R. A., and M. E. Terry. "Rank Analysis of Incomplete Block Designs. I. The Method of Paired Comparisons." Biometrika, Vol. 39 (1952), pp. 324-345.

(4) Burnett, R. S. "Manufacture and Use of Peanut Protein." Chem. and Eng. N., Vol. 24 (1946), pp. 478-480.

(5) Cucullu, Alva F., Louise S. Lee, Ruth Y. Mayne, and L. A. Goldblatt. "Determination of Aflatoxins in Individual Peanuts and Peanut Sections." Am. Oil Chem. Soc. J., Vol. 43 (1966), pp. 89-92.

(6) Golumbic, Calvin. "Post-Harvest Appearance of Aflatoxins." Proceedings Third National Peanut Research Conference. Auburn University, 1964, pp. 122-127.

(7) Henderson, S. M. "A Basic Concept of Equilibrium Moisture." Agr. Eng., Vol. 33 (1952), pp. 29-32.

(8) Henderson, S. M., and R. L. Perry. Agricultural Process Engineering. New York, NY: John Wiley and Sons, 1966.

(9) Herrold, Bethel J. "Pneumatic Peanut Skin Slitter." (Unpub. M. S. Thesis, Oklahoma State University, 1974.)

(10) Karon, Melvin L., and Barbara E. Hillery. "Hygroscopic Equilibrium of Peanuts." Am. Oil Chem. Soc. J., Vol. 26 (1949), pp. 16-19.

(11) Lawler, Frank K. "Ingenuity Creates New Process." *Food Engr.*, Vol. 33 (1961), pp. 38-40.

(12) Morgan, R. G. "Improved Blanching of Raw Spanish Peanuts." (Unpub. Report, Oklahoma State University, 1973.)

(13) Morris, N. J., R. K. Willich, and A. F. Freeman. "Peanut Butter. III. Effect of Roasting, Blanching, and Sorting on the Content of Oil and Free Fatty Acids of Peanuts." *Food Tech.*, Vol. 7 (1953), pp. 366-369.

(14) Pominski, J., E. J. McCourtney, M. F. Stansbury, E. L. D'Aquin, and H. L. E. Vix. "Lye-Dipping for the Removal of Objectionable Skin Color from Various Grades of Shelled Spanish Peanuts." *Am. Oil Chem. Soc. J.*, Vol. 28 (1951), pp. 513-516.

(15) Pominski, J., E. L. D'Aquin, L. J. Molaison, E. J. McCourtney, and H. L. E. Vix. "Pre-Treatment of Peanut Kernels for Effective Skin Removal." *Am. Oil Chem. Soc. J.*, Vol. 29 (1952), pp. 48-51.

(16) Reeve, Keith J. "Split Skins Spun Off in New Nut Blancher." *Food Engr.*, Vol. 34 (1962), p. 51.

(17) Shackelford, P. S., B. L. Clary, G. H. Brusewitz, G. V. Odell, and Joseph Pominski. "Skin Removal from Spanish Peanuts by Heating to Moderate Temperatures." ASAE Paper No. 72-893. American Society of Agricultural Engineers, 1972.

(18) Shackelford, P. S., B. L. Clary, G. H. Brusewitz, G. V. Odell, and Joseph Pominski. "Skin Removal from Spanish Peanuts by Chemical Treatment." ASAE Paper No. 73-339. American Society of Agricultural Engineers, 1973.

(19) Snedecor, George W., and William G. Cochran. *Statistical Methods*. Ames, Iowa: The Iowa State University Press, 1967.

(20) Stansbury, Mack F., Elsie T. Field, and John D. Guthrie. "The Tannin and Related Pigments in the Red Skins (Testa) of Peanut Kernels." *Am. Oil Chem. Soc. J.*, Vol. 27 (1950), pp. 317-321.

(21) Takeuchi, A. K., and Y. Mazumoto. "New Skinning Process." Peanut J. Nut World, Vol. 50 (1970), p. 12.

(22) Willich, R. K., A. S. Hall, N. J. Morris, and A. F. Freeman. "Peanut Butter. I. Roasting, Cooling, Blanching, and Picking of Peanuts." Food Tech., Vol. 6 (1952), pp. 71-73.

(23) Woodroof, Jasper G. Peanuts: Production, Processing, Products. Westport, CT: The AVI Publishing Co., Inc., 1973.

(24) Woodward, John D. "The Relationship of Peanut Milling Quality to Kernel Tensile Strength." American Peanut Research and Education Association Journal, Vol. 5 (1973), pp. 169-174.

APPENDIXES

APPENDIX A

SKIN SLITTER WORKING DRAWINGS

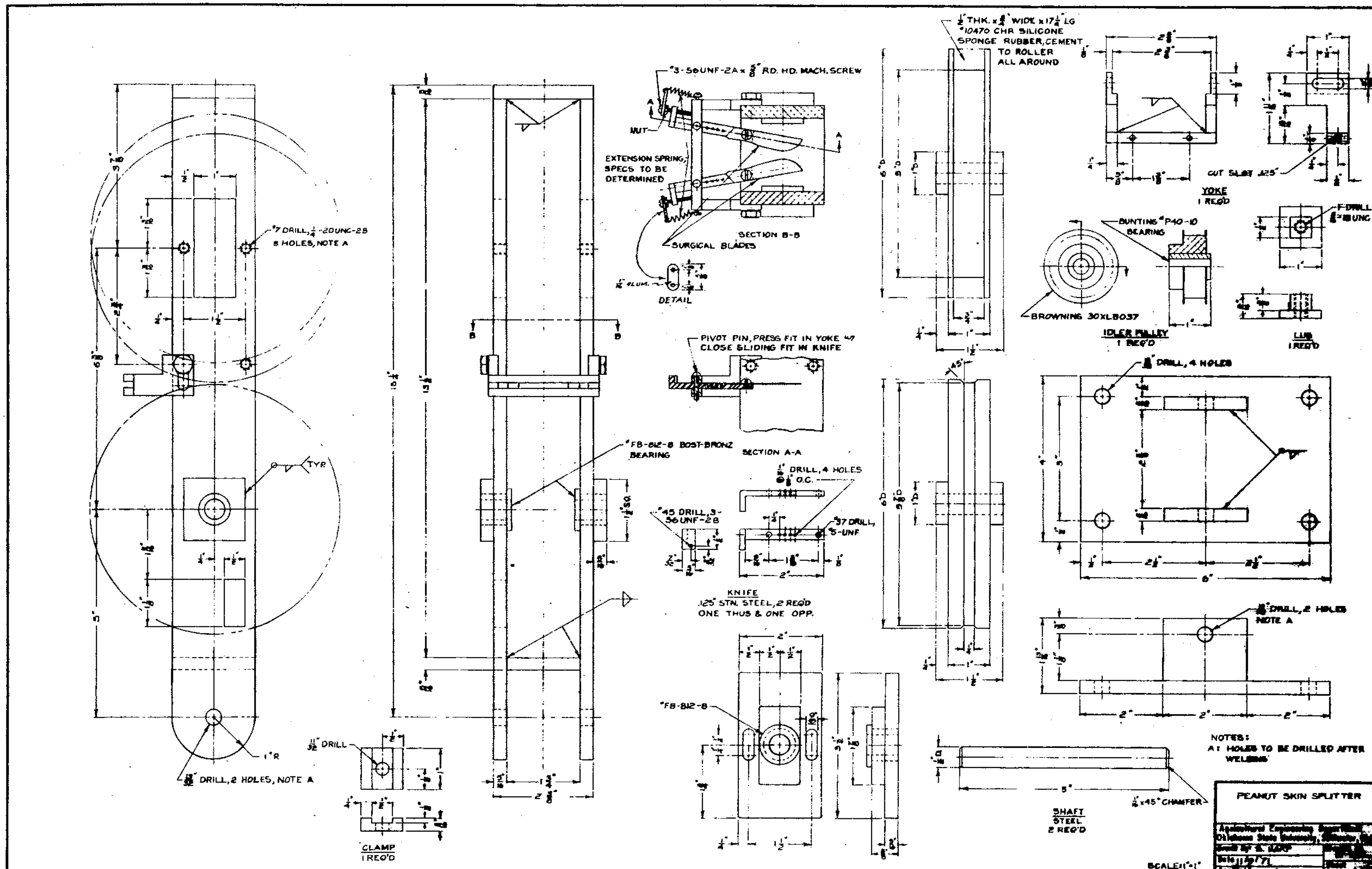


Figure 19. Skin Slitter Working Drawing

APPENDIX B

LABORATORY DRYER WORKING DRAWINGS

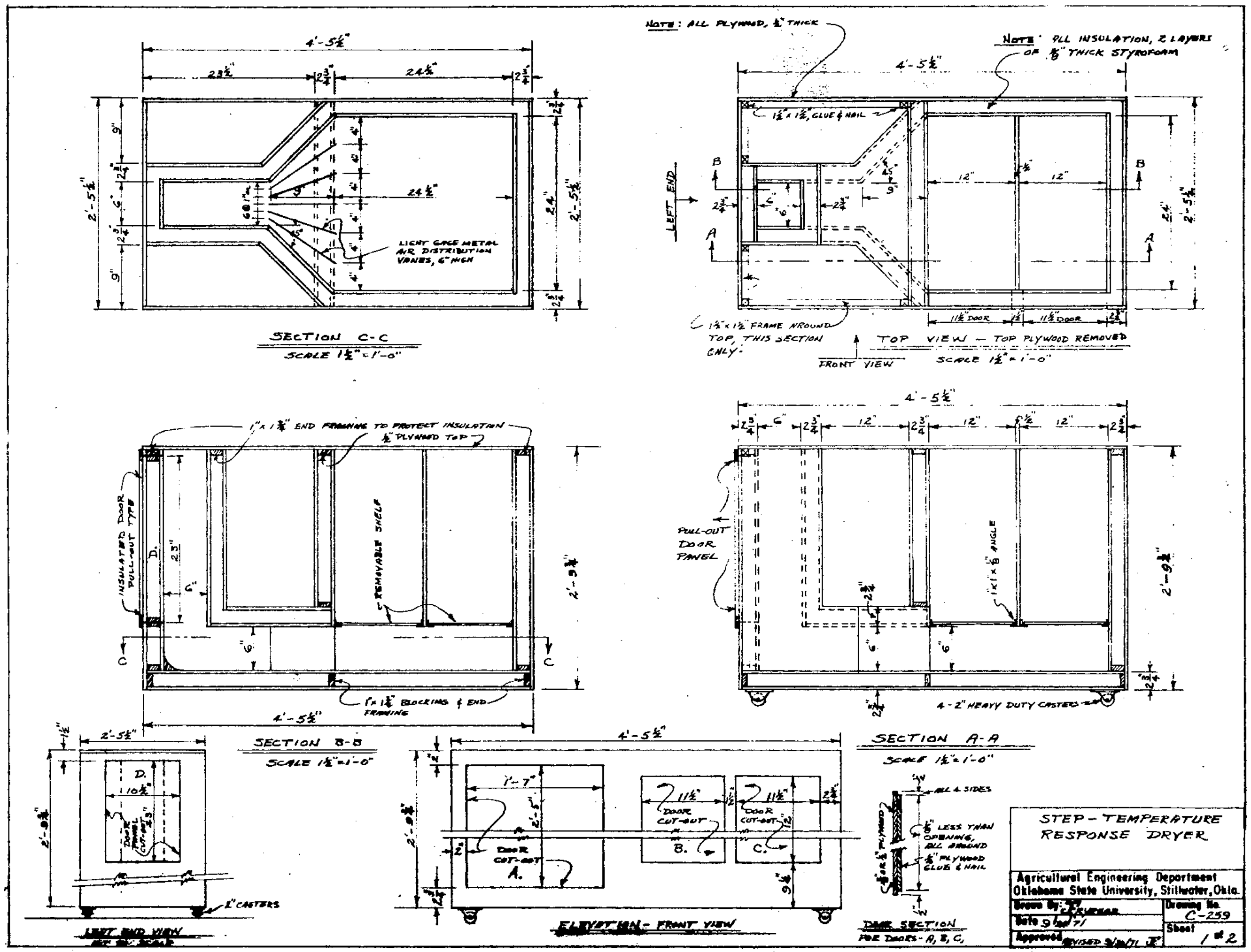
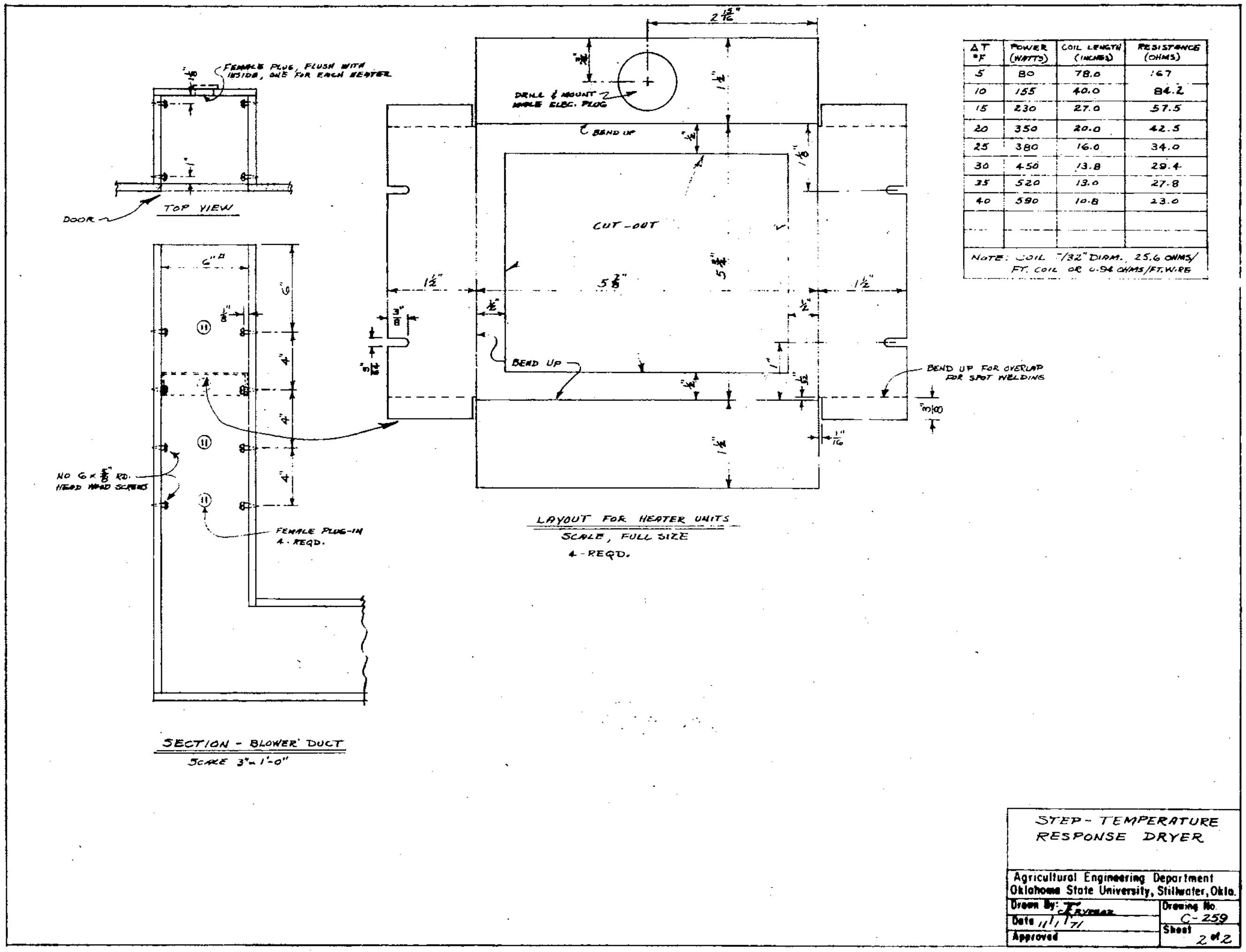


Figure 20. Laboratory Dryer Working Drawings, Sheet 1



ΔT °F	POWER (WATTS)	COIL LENGTH (INCHES)	RESISTANCE (OHMS)
5	80	78.0	167
10	155	40.0	84.2
15	230	27.0	57.5
20	350	20.0	42.5
25	380	16.0	34.0
30	450	13.8	29.4
35	520	13.0	27.8
40	590	10.8	23.0

Figure 21. Laboratory Dryer Working Drawings, Sheet 2

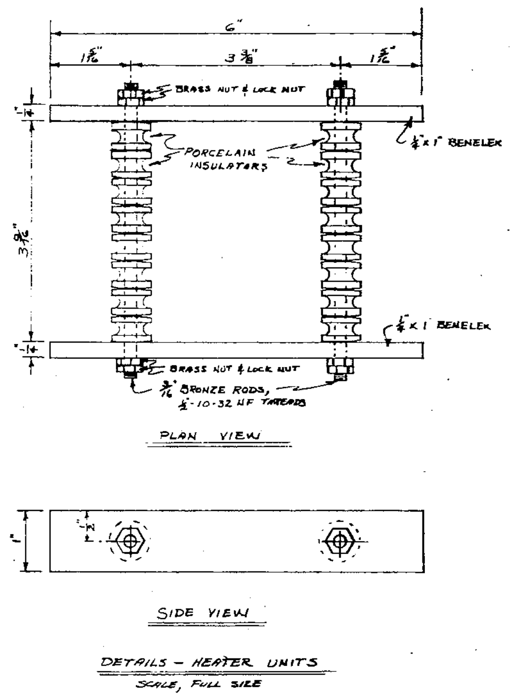


Figure 22. Laboratory Dryer Working Drawings, Sheet 3

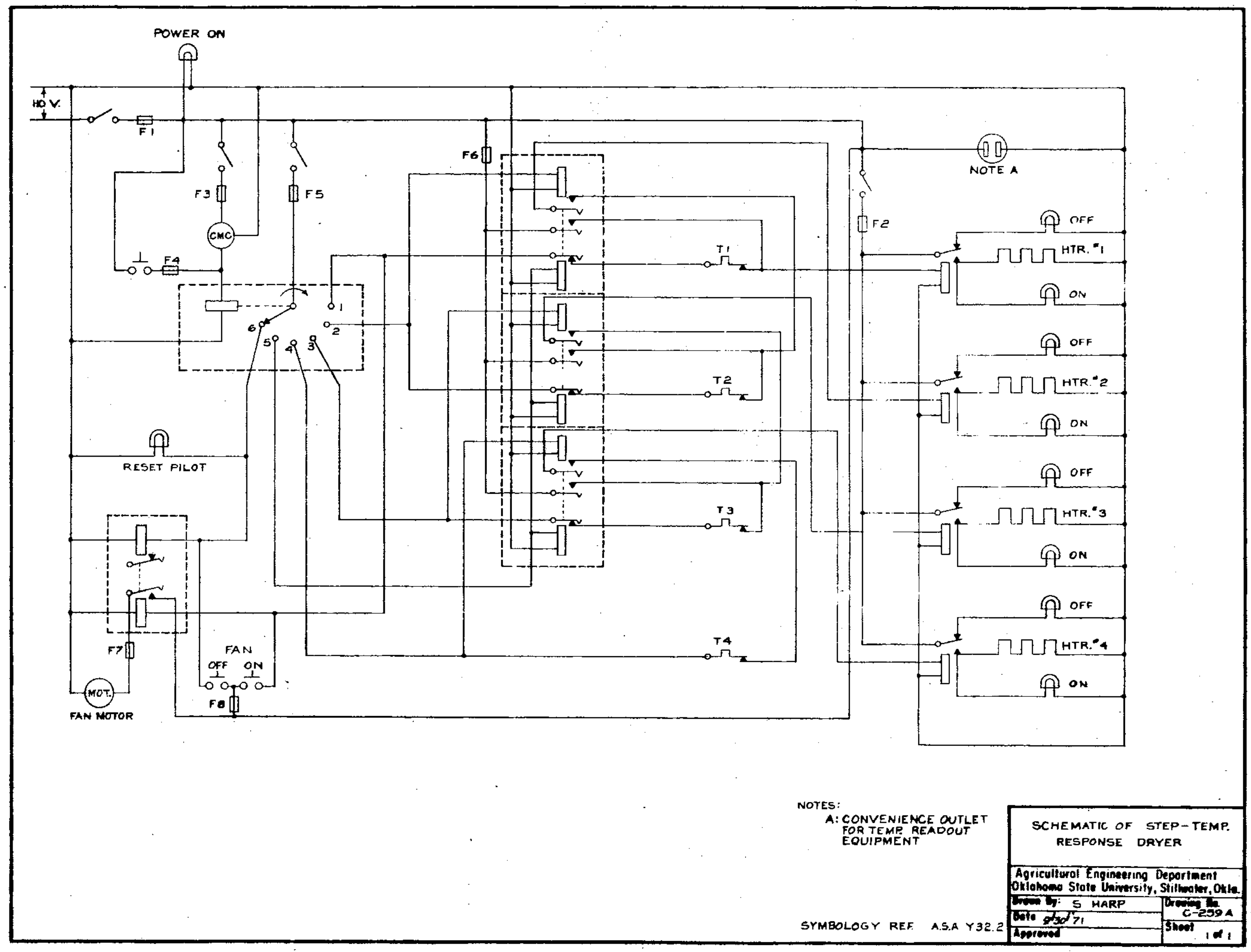


Figure 23. Laboratory Dryer Working Drawings, Sheet 4

APPENDIX C

WHOLE NUT BLANCHER WORKING DRAWINGS

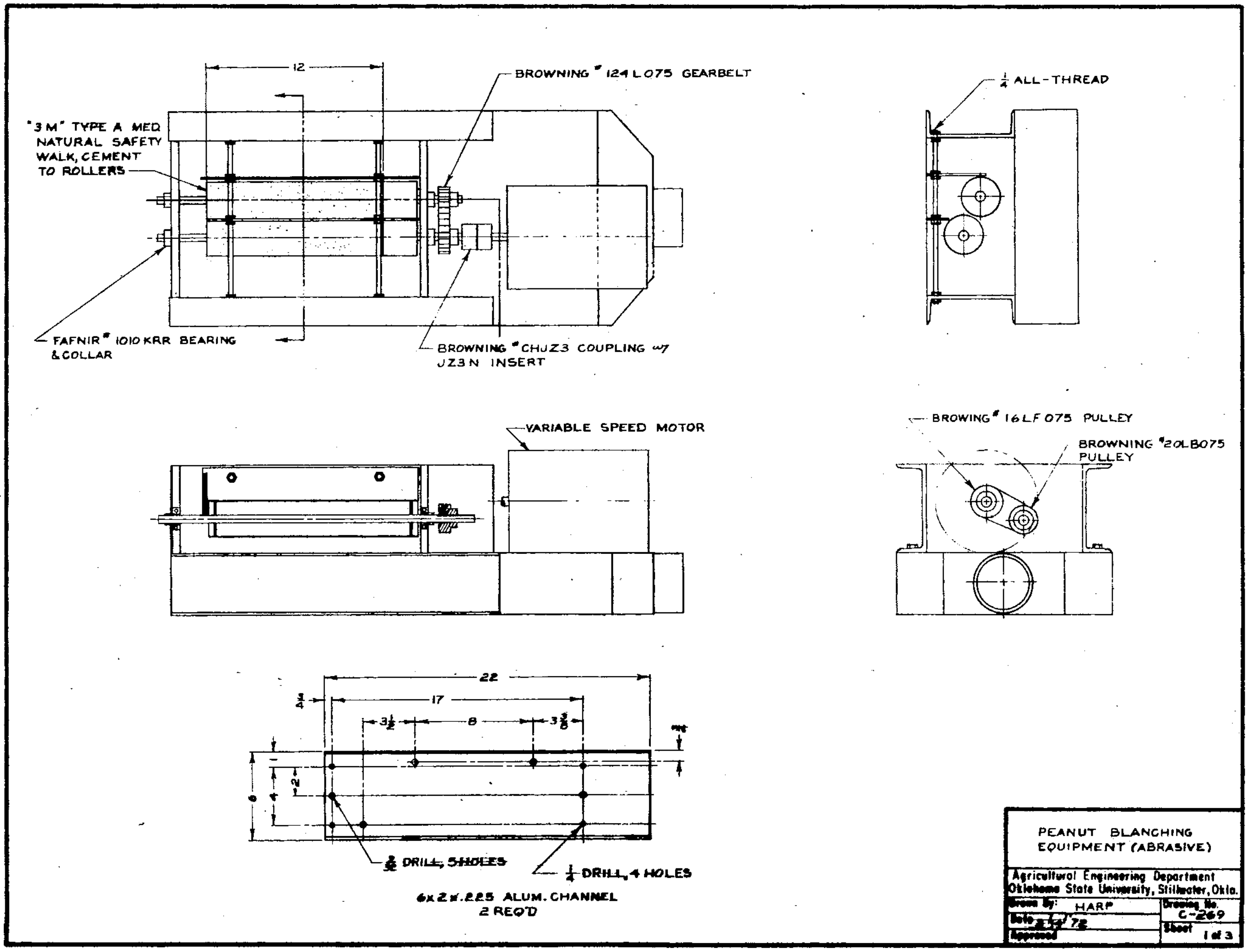


Figure 24. Whole Nut Blancher Working Drawings, Sheet 1

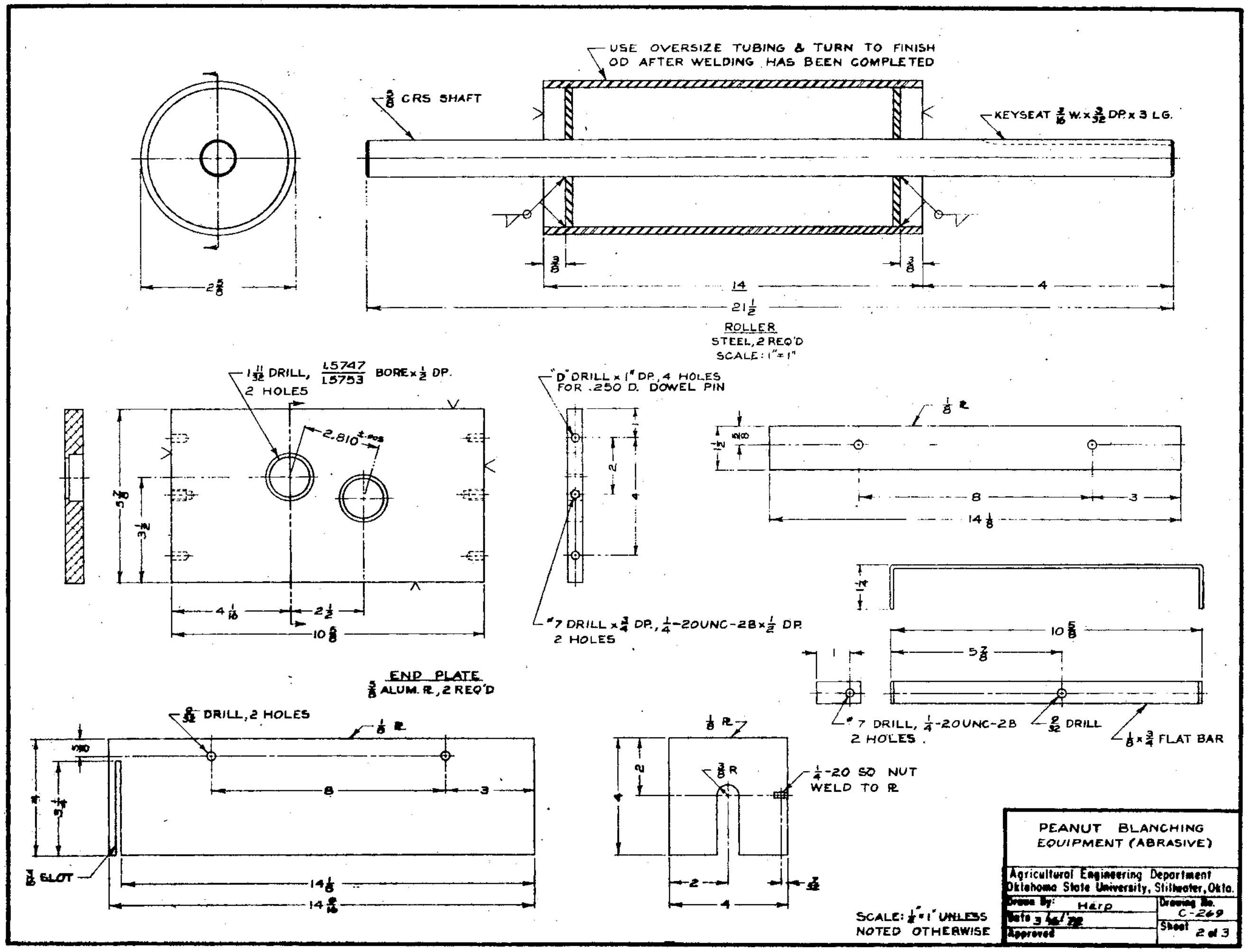


Figure 25. Whole Nut Blancher Working Drawings, Sheet 2

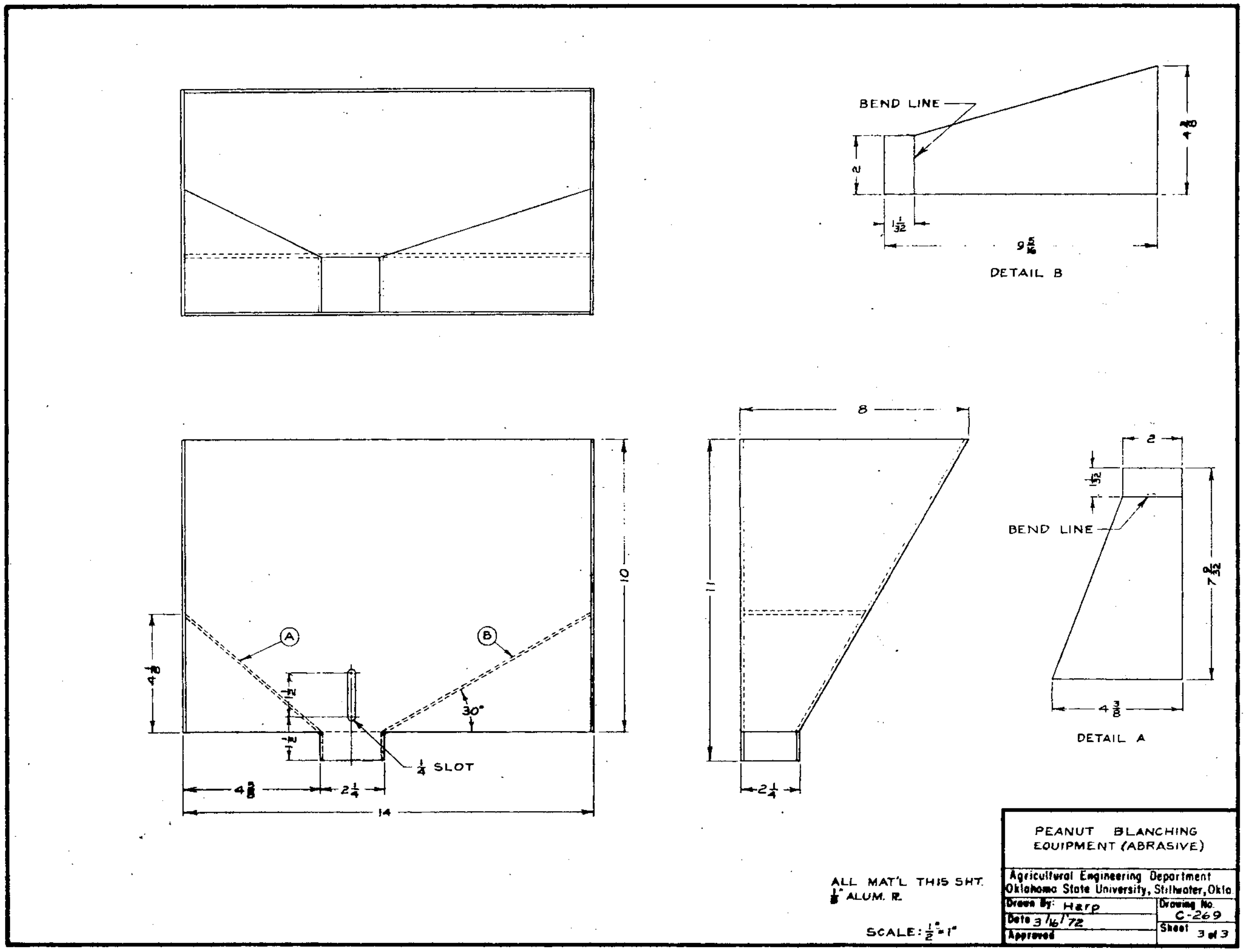


Figure 26. Whole Nut Blancher Working Drawings, Sheet 3

APPENDIX D

CALIBRATION OF STEINLITE ELECTRONIC TESTER

APPENDIX D

CALIBRATION OF STEINLITE ELECTRONIC TESTER

Peanut kernels to be used in calibration tests of the Steinlite electronic tester were from the same lot as used for other tests in this study. To obtain samples with moisture content lower than natural moisture content of seven percent, wet basis, kernels were dried in the laboratory dryer at 160°F. Kernels with moisture contents higher than natural moisture content were obtained by adding moisture by placing them in a controlled temperature and humidity where they absorbed moisture hygroscopically. All kernels were allowed to equilibrate in airtight containers for at least 24 hours before testing.

On the day of testing, the moisture content of the kernels as measured on the Steinlite electronic tester, hereafter called the Steinlite moisture content, was determined as recommended by the manufacturer. Oven-dry moisture content was then determined as follows.

1. Entire 75 gram sample, which had been used to determine Steinlite moisture content, was placed in a tared aluminum drying cup and weighed.

2. Sample was dried overnight (18-24 hours) in a convection oven at 105°C.
3. Sample was removed from oven and weighed.
4. Loss in weight was assumed to be water content of the kernels.
5. All weights found on analytical balance reading to 0.01 grams.

Data for calibration tests is shown in Table XIII. This data is presented graphically in Figure 27.

Least squares regression was used to find an equation which would describe the relationship between oven-dry and Steinlite moisture contents. Polynomial and semi-logarithmic forms were investigated. The equation which best fit the data, based on correlation coefficient and standard error, was found to be

$$M = 15.0M_S - 2.58M_S^2 + 0.213M_S^3 - 0.00656M_S^4 - 29.1 \quad (7)$$

where,

M = moisture content - % - wet basis

M_S = Steinlite moisture content - % - wet basis

Correlation coefficient (R^2) was 0.999 and standard error was 0.11 percent moisture content.

TABLE XIII

DATA FROM CALIBRATION TESTS OF STEINLITE ELECTRONIC TESTER

Obs. No.	Moisture - % - wb	
	Steinlite	Oven-dry
1	7.05	6.70
2	5.50	4.71
3	4.49	2.63
4	7.08	6.80
5	5.51	4.88
6	4.50	2.75
7	6.06	5.64
8	9.32	9.36
9	9.33	9.55
10	5.56	4.55
11	5.59	4.72
12	8.12	8.07
13	8.14	8.05
14	7.05	6.63
15	7.01	6.82
16	10.61	10.79
17	10.01	10.41
18	10.30	10.54
19	6.22	5.70
20	6.21	5.72
21	11.11	11.27
22	11.14	11.25
23	10.75	10.77
24	10.56	10.78
25	4.74	3.47
26	4.73	3.32

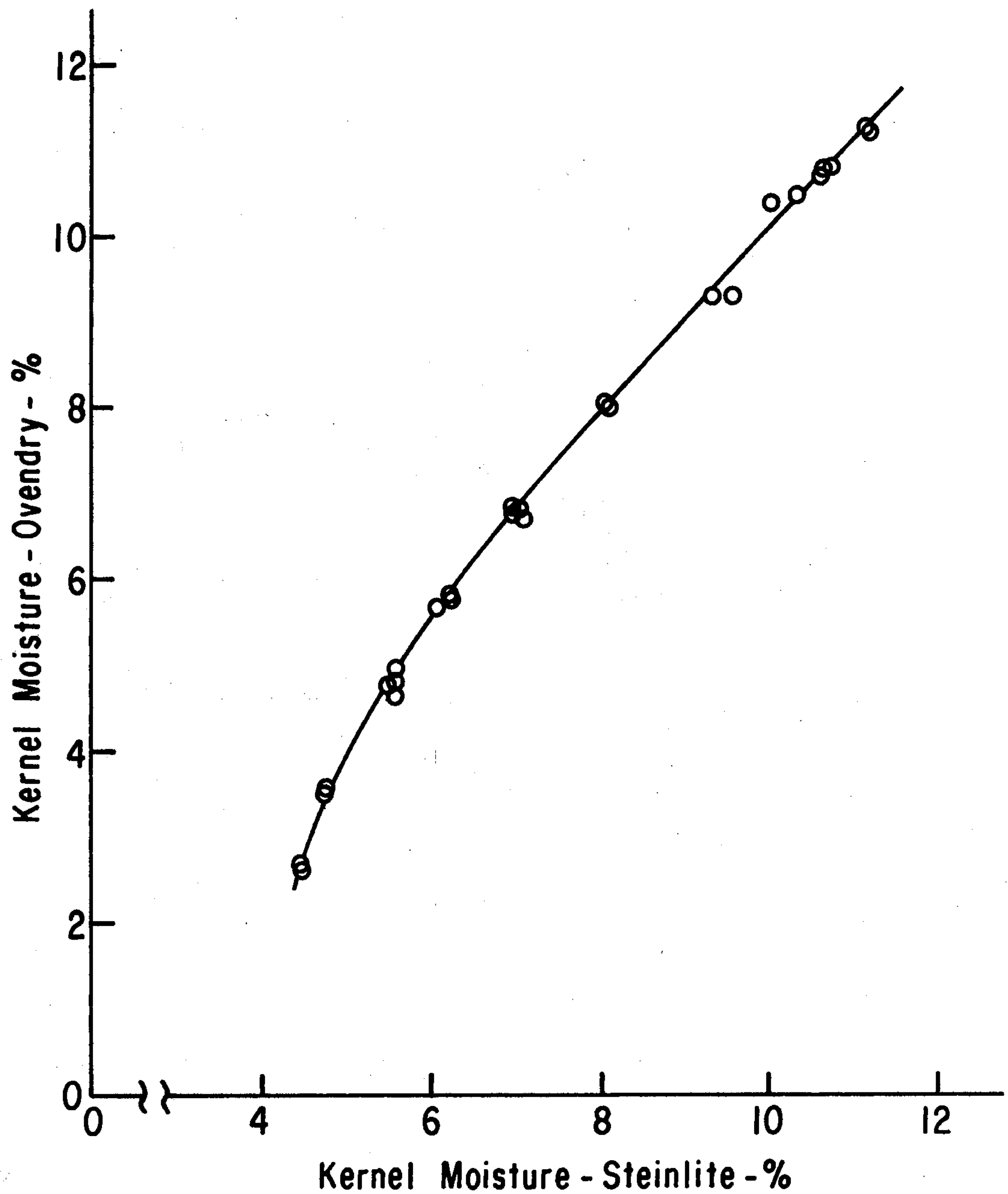


Figure 27. Oven-dry Moisture Content From Steinlite Electronic Tester Readings

APPENDIX E

STATISTICS

APPENDIX E

STATISTICS

Least Significant Difference (LSD) is calculated by Snedecor and Cochran (17) as

$$LSD = t_{\alpha, df}\sqrt{\frac{2s^2}{n}}$$

where,

s^2 = sample variance = mean squares for error used to test significance of treatment differences in the Analysis of Variance

n = number of observations in each mean

t = student's t for a two-tailed test with degrees of freedom for error.

If the difference in two means exceeds the value of LSD, then the means are declared significantly different.

The Least Significant Difference between means of blanchability due to different final temperatures for α=0.05 is

$$LSD = 2.447\sqrt{\frac{2 * 2.31}{3}}$$

$$LSD = 3.0$$

The Least Significant Difference between means of blanchability due to difference in heating air temperature for α=0.05 is

$$LSD = 2.120\sqrt{\frac{2 * 4.56}{30}}$$

$$LSD = 1.2$$

The effect of heating air temperature on blanchability was described by the following polynomial regression equation.

$$\beta = 1.27T_A - 0.0034T_A^2 - 25.8$$

where,

β = blanchability, %

T_A = heating air temperature, °F

was fitted to data on blanchability. Correlation Coefficient (R^2) = 0.02, and standard error = 5.4%.

Table XIV shows analysis of variance of regression.

TABLE XIV

ANALYSIS OF VARIANCE OF REGRESSION EQUATION

Source	df	SS	MS	F
Total	89	2540.2		
Regression	2	50.1	25.7	0.87
Error	87	2490.1	28.6	

TABLE XV

ANALYSIS OF VARIANCE OF BLANCHABILITY
DUE TO FINAL TEMPERATURE

Source	df	SS	MS	F
TOTAL	11	53.87		
Temperature	3	36.99	12.33	5.34*
Replications	2	3.03	1.52	0.66
Error (Temp. x Rep.)	6	13.85	.231	

* Significant at $\alpha = 0.05$

TABLE XVI

ANALYSIS OF VARIANCE OF BLANCHABILITY
DUE TO COOLING TIME

Source	df	SS	MS	F
TOTAL	13	22.90		
Cooling Time	6	2.27	0.38	0.13
Error (Within Times)	7	20.63	2.95	

TABLE XVII

ANALYSIS OF VARIANCE OF EFFECT OF HEATING AIR TEMPERATURE, INITIAL MOISTURE, AND FINAL MOISTURE ON BLANCHABILITY

Source	df	SS	MS	F
Total	89	2540.16	28.54	
Replications	2	68.45	34.23	7.51**
Temperature	2	50.08	25.04	5.49*
Initial Moisture	2	483.70	241.85	53.00**
Temp * IM	4	21.58	5.40	
Error A	16	72.89	4.56	
Final Moisture	3	1005.70	335.23	88.20**
Temp * FM	6	108.48	18.08	
IM * FM	4	546.51	136.63	
Temp * IM * FM	8	23.05	2.88	
Error B	42	159.72	3.80	

Note: This analysis is valid for main effects only. Cross product analysis not valid due to unequal number of observations per cell.

* Indicates significance at $\alpha=0.05$
** Indicates significance at $\alpha=0.01$

TABLE XVIII

ANALYSIS OF VARIANCE OF EFFECT OF HEATING AIR TEMPERATURE, INITIAL MOISTURE, AND FINAL MOISTURE ON PERCENT WHOLE KERNELS

Source	df	SS	MS	F
Total	89	17860.94	200.68	
Replications	2	1945.28	972.64	35.90**
Temperature	2	160.09	80.04	2.95
Initial Moisture	2	2636.88	1318.44	48.60**
Temp * IM	4	125.85	31.46	1.16
Error A	16	433.77	27.11	
Final Moisture	3	9927.64	3309.21	234.00**
Temp * FM	6	368.99	61.50	4.35
IM * FM	4	1522.07	380.52	26.90
Temp * IM * FM	8	146.59	18.32	1.30
Error B	42	593.77	14.14	

Note: This analysis is valid for main effects only. Cross product analysis not valid due to unequal number of observations per cell.

** Indicates significance at $\alpha=0.01$

APPENDIX F

DATA

TABLE XIX

DATA ON EFFECTS OF HEATING AIR TEMPERATURE, INITIAL MOISTURE CONTENT, AND FINAL MOISTURE CONTENT ON BLANCHABILITY AND WHOLE KERNELS

SAMPLE IDENTIFICATION*	KERNEL MOIST.-%-WB INITIAL	KERNEL MOIST.-%-WB FINAL	WHOLE %	MEAN WHOLE %	BLANCH. %	MEAN BLANCH. %
160 - 6 - 4 - 1	6.2	4.1	61.1		91.7	
160 - 6 - 4 - 2	6.1	4.1	59.2	63.4	91.4	90.1
160 - 6 - 4 - 3	6.2	4.1	70.0		87.3	
160 - 6 - 5 - 1	6.2	5.1	73.0		83.1	
160 - 6 - 5 - 2	6.1	5.2	74.1	74.2	82.0	83.9
160 - 6 - 5 - 3	6.4	4.8	75.4		86.5	
160 - 8 - 4 - 1	8.1	4.0	60.0		94.2	
160 - 8 - 4 - 2	8.0	4.2	60.9	62.9	91.4	92.0
160 - 8 - 4 - 3	7.8	4.0	67.7		90.3	
160 - 8 - 5 - 1	8.2	4.8	65.5		93.7	
160 - 8 - 5 - 2	8.1	5.1	71.6	69.0	88.1	91.4
160 - 8 - 5 - 3	7.9	4.5	69.8		92.4	
160 - 8 - 6 - 1	8.1	6.2	72.2		90.6	
160 - 8 - 6 - 2	8.1	5.8	73.5	75.3	88.6	88.8
160 - 8 - 6 - 3	7.8	5.7	80.1		87.1	

TABLE XIX (CONTINUED)

SAMPLE IDENTIFICATION*	KERNEL MOIST.-%-WB INITIAL	FINAL	WHOLE %	MEAN WHOLE %	BLANCH. %	MEAN BLANCH. %
160 - 8 - 7 - 1	8.1	6.8	89.5		77.0	
160 - 8 - 7 - 2	8.2	6.9	89.9	90.8	74.3	73.5
160 - 8 - 7 - 3	7.8	6.7	93.1		69.1	
160 - 10 - 4 - 1	10.5	4.1	46.9		95.2	
160 - 10 - 4 - 2	9.5	4.1	42.0	48.9	97.1	95.5
160 - 10 - 4 - 3	9.3	4.1	57.8		94.3	
160 - 10 - 5 - 1	10.4	5.2	55.0		93.1	
160 - 10 - 5 - 2	9.7	4.8	51.8	57.2	95.2	93.9
160 - 10 - 5 - 3	9.2	4.5	64.7		93.3	
160 - 10 - 6 - 1	10.2	6.0	66.2		91.6	
160 - 10 - 6 - 2	9.4	5.8	68.4	69.2	93.7	92.7
160 - 10 - 6 - 3	9.2	5.5	73.1		92.8	
160 - 10 - 7 - 1	10.5	6.8	73.8		90.1	
160 - 10 - 7 - 2	9.6	7.0	81.1	81.5	87.0	86.1
160 - 10 - 7 - 3	9.1	7.0	89.6		81.1	

TABLE XIX (CONTINUED)

SAMPLE IDENTIFICATION*	KERNEL MOIST.-%-WB INITIAL	FINAL	WHOLE %	MEAN WHOLE %	BLANCH. %	MEAN BLANCH. %
180 - 6 - 4 - 1	6.1	4.1	56.7		90.7	
180 - 6 - 4 - 2	6.1	4.0	50.6	59.7	94.7	92.1
180 - 6 - 4 - 3	6.3	4.0	71.7		90.9	
180 - 6 - 5 - 1	6.1	4.9	65.5		87.1	
180 - 6 - 5 - 2	6.3	5.0	67.6	70.8	85.0	84.3
180 - 6 - 5 - 3	6.3	5.4	79.2		80.9	
180 - 8 - 4 - 1	8.1	4.1	57.5		94.0	
180 - 8 - 4 - 2	8.2	4.2	55.8	60.6	94.0	93.4
180 - 8 - 4 - 3	7.8	4.0	68.4		92.2	
180 - 8 - 5 - 1	8.2	4.9	62.7		92.8	
180 - 8 - 5 - 2	8.3	5.4	66.5	66.9	88.7	91.5
180 - 8 - 5 - 3	7.8	4.9	71.5		93.1	
180 - 8 - 6 - 1	8.1	5.9	75.6		89.9	
180 - 8 - 6 - 2	8.1	5.6	66.8	75.0	91.1	89.2
180 - 8 - 6 - 3	7.9	5.9	82.6		86.5	

TABLE XIX (CONTINUED)

SAMPLE IDENTIFICATICN*	KERNEL MOIST.-%-WB INITIAL	FINAL	WHOLE %	MEAN WHCLE %	BLANCH. %	MEAN BLANCH. %
180 - 8 - 7 - 1	8.1	6.7	87.0		81.6	
180 - 8 - 7 - 2	8.2	6.7	82.5	86.7	84.6	82.2
180 - 8 - 7 - 3	7.8	6.6	90.7		80.5	
180 - 10 - 4 - 1	9.9	3.8	41.8		96.2	
180 - 10 - 4 - 2	9.6	4.2	42.8	47.0	94.7	95.3
180 - 10 - 4 - 3	9.2	4.1	56.5		94.9	
180 - 10 - 5 - 1	9.9	4.8	54.2		94.6	
180 - 10 - 5 - 2	9.5	4.9	54.7	57.1	95.4	94.4
180 - 10 - 5 - 3	9.3	4.8	62.4		93.3	
180 - 10 - 6 - 1	9.9	5.6	58.6		94.6	
180 - 10 - 6 - 2	9.6	5.6	62.7	64.0	93.1	93.1
180 - 10 - 6 - 3	9.2	5.5	70.6		91.7	
180 - 10 - 7 - 1	9.9	6.6	71.6		92.8	
180 - 10 - 7 - 2	9.4	6.8	80.6	78.3	89.7	90.4
180 - 10 - 7 - 3	9.1	6.4	82.7		88.8	

TABLE XIX (CONTINUED)

SAMPLE IDENTIFICATION*	KERNEL MOIST.-%-WB INITIAL	FINAL	WHOLE %	MEAN WHOLE %	BLANCH. %	MEAN BLANCH. %
200 - 6 - 4 - 1	6.0	4.0	51.0		92.9	
200 - 6 - 4 - 2	6.0	4.3	51.6	58.1	91.5	91.1
200 - 6 - 4 - 3	6.3	4.5	71.7		89.0	
200 - 6 - 5 - 1	6.0	5.1	74.9		82.7	
200 - 6 - 5 - 2	6.0	5.1	70.5	77.3	86.5	82.0
200 - 6 - 5 - 3	6.2	5.8	86.6		76.9	
200 - 8 - 4 - 1	8.0	4.2	53.7		91.7	
200 - 8 - 4 - 2	8.0	3.9	53.8	55.5	93.5	93.5
200 - 8 - 4 - 3	7.8	4.2	59.0		95.2	
200 - 8 - 5 - 1	8.0	5.2	66.9		91.2	
200 - 8 - 5 - 2	7.9	5.0	67.0	69.3	90.0	90.3
200 - 8 - 5 - 3	7.8	5.2	73.9		89.7	
200 - 8 - 6 - 1	7.9	6.1	78.7		89.1	
200 - 8 - 6 - 2	8.0	5.9	79.3	80.5	89.3	89.2
200 - 8 - 6 - 3	7.8	5.8	83.4		89.3	

TABLE XIX (CONTINUED)

SAMPLE IDENTIFICATION *	KERNEL MOIST.-%-WB INITIAL	FINAL	WHOLE %	MEAN WHOLE %	BLANCH. %	MEAN BLANCH. %
200 - 8 - 7 - 1	8.0	6.8	88.0		81.5	
200 - 8 - 7 - 2	7.8	6.4	87.6	88.9	82.3	81.9
200 - 8 - 7 - 3	7.8	6.5	91.1		81.8	
200 - 10 - 4 - 1	10.3	3.9	25.1		95.1	
200 - 10 - 4 - 2	9.6	3.9	25.3	34.7	96.8	95.4
200 - 10 - 4 - 3	9.2	4.1	53.7		94.3	
200 - 10 - 5 - 1	10.3	4.5	39.8		94.7	
200 - 10 - 5 - 2	9.4	5.4	51.7	50.9	94.8	93.7
200 - 10 - 5 - 3	9.3	5.2	61.3		91.5	
200 - 10 - 6 - 1	9.8	5.7	62.9		91.9	
200 - 10 - 6 - 2	9.5	6.4	72.6	69.3	91.0	91.7
200 - 10 - 6 - 3	9.3	5.8	72.5		92.1	
200 - 10 - 7 - 1	9.8	6.7	77.3		86.4	
200 - 10 - 7 - 2	9.6	6.5	69.4	77.9	90.2	87.8
200 - 10 - 7 - 3	9.3	6.9	86.9		86.7	

* Example of identification - sample 200-6-4-1 was treated with heating air at 200°F, six percent design initial moisture content, four percent final moisture content, replication one

APPENDIX G

SAMPLE CALCULATIONS FOR STANDARDIZED BLANCHABILITY AT VARIOUS FINAL TEMPERATURES

APPENDIX G

SAMPLE CALCULATIONS FOR STANDARDIZED BLANCHABILITY AT VARIOUS FINAL TEMPERATURES

1. Blanchability of kernels at eight percent initial moisture and five percent final moisture was calculated according to Equation 3.

$$\beta = 100 - 1.16e^{3.2(M_F/M_I)}$$

$$\beta = 100 - 1.16e^{3.2(5.0/8.0)} \qquad (3)$$

$$\beta = 91.4\%$$

2. Blanchability predicted by Equation 3 was calculated for initial and final moisture contents of an observation. For Observation 1, Table II,

$$\beta = 100 - 1.16e^{3.2(4.7/7.8)}$$

$$\beta = 92.2\%$$

3. Subtract blanchability found in Step 1 from predicted blanchability in Step 2 to obtain correction.

   Correction = 91.4% - 92.2%

   Correction = -0.8%

4. Add correction to observed blanchability to obtain standardized blanchability.

   Standardized β = 87.8% - 0.8%

   Standardized β = 87.0%

VITA

Pat Stevens Shackelford, Jr.

Candidate for the Degree of

Doctor of Philosophy

Thesis: SKIN REMOVAL FROM SPANISH PEANUTS BY HEATING TO MODERATE TEMPERATURES

Major Field: Agricultural Engineering

Biographical:

Personal Data: Born in Lexington, Oglethorpe County, Georgia, July 30, 1936, the son of Pat Stevens and Lila Edwards Shackelford.

Education: Graduated from Oglethorpe County High School in Arnoldsville, Georgia, in 1954; received the Degree of Bachelor of Science in Agricultural Engineering from the University of Georgia in June, 1958; received the Degree of Master of Science from the University of Georgia in August, 1972; completed requirements for the Doctor of Philosophy Degree at Oklahoma State University in December, 1974.

Professional Experience: Agricultural engineer with the Soil Conservation Service, Department of Agriculture at Athens, Georgia, 1958-1964; construction management engineer with the Corps of Engineers at Buford, Georgia, 1964-1968; Instructor (half-time) in the Agricultural Engineering Department of the University of Georgia at Athens, Georgia, 1968-1970; graduate research assistant in the Agricultural Engineering Department, Oklahoma State University, 1970 to present.

Professional Organizations: Student member of American Society of Agricultural Engineers, Oklahoma Society of Professional Engineers, National Society of Professional Engineers.