A comparative study of baking effects produced by electric, gas and coal range ovens on yeast rolls
by Martha Johnson Haynes

A Thesis submitted to the Graduate Committee in partial fulfillment of the requirements for the Degree of Master of Science in Home Economics
Montana State University

Abstract:
1. In this study a comparison was made of the baking qualities of three commonly used types of fuels; electricity, gas and coal. The product used for these baking tests was a standard Parker House roll and comparisons were made in each case with rolls baked In the electric oven.

2. Tests were made for loss in weight during the baking process in each of the ovens. The electric ones showed a loss of 11.2%; the gas, 12.8%,; and the coal range 11.2%. These data agree with other studies which dealt with meat shrinkage. In scoring the rolls, the opinions of the judges were that the bottom crusts of the rolls coming from the gas oven were drier than those from the other two ovens.

2. Measurements of volume of rolls baked in the three ovens showed that the greatest increase was with the rolls from the coal range, being 2.4% greater than the volume of rolls from the electric oven. The rolls baked in the gas oven had a 4% smaller volume than the electric.

4. A definite correlation was found between color of crust and tenderness. The Munsell color system was used to determine color and for the tenderness a mechanical device to measure breaking strength. The crusts that were darkest in color were the least tender.

5. The rolls baked in the gas oven had lighter colored and more tender top crusts but darker colored and less tender bottom crusts than the rolls baked in the electric oven. Rolls baked in the coal range oven had a very light brown bottom crust but a darker brown top crust in spite of the fact that they were baked on the bottom of the oven.

conclusions In comparing the three kinds of ovens studied it may be concluded that there is no outstanding advantage of any one kind of fuel or energy source as far as the final product is concerned if conditions are controlled to the same degree. However, the electric range seemed to give the most uniform results as to desirable color and quality of both top and bottom crusts.

A COMPARATIVE STUDY OF BAKING EFFECTS PRODUCED BY ELECTRIC, GAS AND COAL RANGE OVENS ON YEAST ROLLS

BY

MARTHA J. HAYNES

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Montana State College
Bozeman, Montana

June, 1932

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INTRODUCTION

Within the past few years there has been developed a wide variety of cooking ranges for home use. In most cases they employ one of the three principal kinds of fuel or energy,- electricity, gas or coal.

The construction of different kinds of ranges has been improved to a large degree, the manufacturers aiming to have them give equal performance in all cooking operations. However, many homemakers feel that in the baking process they have not obtained similar results in the coal range, gas and electric ovens. The homemaker wishing to purchase a new range has very little definite information upon which to base her choice. While there have been studies made of the comparative costs and efficiency of operating these ranges, very little data are available in regard to their relative performance, especially in baking.

One reads many conflicting statements in advertising literature about the good qualities of each kind of range and extravagant claims are made for each by enthusiastic salesmen. Since so little has been reported on their relative performance, the purchaser is unduly influenced by such factors as cost and appearance.

The recent increasing interest among Home Service workers, dealers and homemakers in regard to kinds of fuels used for cooking has led to a demand for research studies comparing the performance of the various ranges using these different fuels or energy sources. In this connection it has seemed advisable to make a study of the comparative baking effects produced in coal range, gas and electric ovens, as they utilize the three sources of energy available in this community.

HISTORY

Baking of food may be described as an operation in which certain physical and chemical changes take place in the food under controlled conditions. Primitive man baked his food by covering it with hot ashes and allowing it to stand for a time. Later food was baked by placing hot stones around it. Wood was probably the first fuel used and with coal was the only fuel used for several centuries. Within comparatively recent times other fuels have been developed by modern scientists; i.e. oils, gas and electricity.

The first oven was probably a "Dutch oven", a covered container of heavy material that could be imbedded in coals. With the development of the cooking stove or range, the oven eventually became a part of this equipment and has been perfected until we have the efficient ovens of today. An oven is a chamber in which materials are artificially heated in an air medium. The air occupying the space between the heat source and the material to be baked is a medium through which the heat must be transmitted (1 p.286).

There are three methods by which heat can be transmitted from one point to another, which are termed respectively, convection, conduction and radiation (2).

Convection is a mode of distributing heat through a mass of either liquid or gas by motion of the fluid, the currents being usually produced by differences in density due to expansion caused by the source of heat itself.

Conduction is that method of transmitting heat in which the heat passes from the hotter particles of a body to the colder ones lying in contact with them, and so throughout the whole body. Some substances conduct heat much more rapidly than others.

Radiation is heat passing from one body to the other by electromagnetic waves. This is known as "radiation" of heat, and is independent of the temperature of the medium through which it occurs. Radiation takes place in straight lines, in all directions from the body which is evolving heat and follows the same general laws of reflection as those which govern light. At the same temperature different bodies radiate heat at different rates. The rate of radiation is affected both by the nature of the radiating material and also the condition of its surface, whether rough or smooth. Highly polished surfaces radiate less rapidly than those which are roughened.

Baking, therefore, is the cooking by application of heat to food in an oven by convection of heated air, by radiation of heat from the walls of the oven and by the conduction of heat from the pans in which the food is being baked.

For baking it is very desirable to have a temperature that is constant and not fluctuating. This is now accomplished in well-insulated gas and electric ranges equipped with automatic temperature controls and also in the coal range by manually regulating the drafts and amount of coal used. It was formerly estimated that as much as 90 per cent of the heat supplied for baking in ovens was uselessly lost through the sides of the oven (3). This is not the case with the modern well-insulated ovens. The principal advantage of insulation is that it keeps the heat well within the oven. The oven that is insulated with the idea of conserving fuel has the spaces between its walls lined with mineral wool, asbestos or some equally effective material. Some ranges incorporate two of these materials with a dead-air space between them and thus really achieve a high degree of insulation. So thoroughly insulated are some ovens that the gas may be shut off after two-thirds of a long-time cooking job has been done, utilizing the retained heat to finish the work. This type of oven cannot help but save on fuel costs. A modern electric oven is so well insulated that, when once heated to the desired temperature, most of the baking is done on the stored heat.

The coal range oven is heated by currents of hot air circulating around the oven. Most coal ranges are made of heavy iron with an interlining of asbestos, which helps to retain heat and makes possible the maintenance of a more constant temperature.

An examination of the literature available has shown that considerable work has been done on the comparison of costs of baking with electricity and gas, but very little has been reported concerning the comparative results.

In a piece of research by Kloeffler (6) at Kansas State Agricultural College in 1917 several types of electric cooking appliances were studied mainly from the standpoint of mechanical and economic efficiency. A brief part of the work included a comparison of shrinkage of meats in coal, gas and electric ovens. As the author states, the tests were not very extensive and the indications were that "there is an actual difference of from 4 per cent to 8 per cent in favor of the electric oven."

A more recent study somewhat similar to Kloeffler's was made in 1931 by the American Gas Association (7). They consider their work a "tentative study for comments of member companies" but again it deals mainly with cost and efficiency from the economic and time standpoints. A brief comparison of meat shrinkage in electric and gas ranges showed a 17.8 per cent average shrinkage in the former type of oven and 19.5 per cent average shrinkage in gas ovens. From the standpoint of quality little difference existed between gas and electric ranges.

The American Gas Association also carried on an extensive study of the application of heat to bread baking (13). This work was done in the large commercial types of bread ovens for the "purpose of determining the best method of bread baking and the part which fuel gas played in such application". Their conclusions were that heat application for bread baking could be achieved through either low temperature radiation or convection or a combination of the two and that when one considers the economically low rate at which gas is available it would be the most suitable fuel for wholesale bread baking. This study is of interest because gas and coal ovens heat mainly by convection while electric ovens heat mainly by radiation (13).

Since yeast rolls, a form of bread, were chosen as the product to be used in studying the relative baking effects of these three kinds of ovens, it seemed necessary to make a preliminary study of the established processes involoved in bread making.

The four most important ingredients used in the preparation of bread are flour, yeast, fat and liquid. The bread-making value of different types of wheat flour depends on the quantity and quality of the gluten that can be developed in them. Flours are called "strong" if they have a comparatively large quantity and good quality of gluten, and "weak" if their gluten is low in quantity or poor in baking quality. The nature and amount of gluten in flour depends both on the kind of wheat from which it is made and on the milling. Strong flour made from hard wheat is considered best for yeast bread because it contains more of the protein called "gluten". Gluten is a substance that has the ability of stretching and expanding and forms the framework of bread. "Chemical analysis has shown that this gluten consists mostly of two proteins, gliadin and glutenin. The dough is a colloidal mass of starch and protein particles covered by thin films of water. The surface tension forces inherent in these films of water bind the starch particles together as the particles of clay are held together. The assumption is made that the protein particles form chains or strands which have a rubber-like elasticity and these strands are matted together in a mass known as 'gluten'. The quality of dough is determined by the number of particles present which form the strands, by their inherent structure and also by the environment of the particles. The number of particles is related to the quantity of protein in the flour, and their structure to the quality." (4 p.269)

The formation of the gluten is due to the stickiness of the moist gliadin binding together the insoluble and elastic particles of glutenin. It is the tenacity of the gluten in the dough that holds the bubbles of gas introduced by the leavening process and gives "lightness" to the bread.

There are two kinds of yeast commonly used--compressed and dry yeast.

Dry yeast is a mass of dried yeast plants. Although alive, these plants are inactive and even after warmth, moisture, food and air are supplied they require some time to become active again.

A compressed yeast cake is a mass of a million or so yeast plants in which only one of the requirements for activity is furnished; that is, moisture. As soon as food, warmth and air are supplied to these yeast plants they are ready to grow.

A little sugar is added to give additional food to the yeast and also for flavoring the bread.

The raising of the dough is caused by the growth in it of the yeast plants. The diastase in the dough, produced by action of the yeast on part of the soluble protein of the flour, converts some of the starch into sugars. Then the yeast-cells, feeding on these sugars and the sugar which has been added, produce alcoholic fermentation, converting them into alcohol and carbon dioxide. These, in gaseous form, being distributed all through the dough, cause it to raise as the gas expands in thousands of little pockets. When the bread is placed in the oven, the heat kills the yeast cells and stops the fermentation but at the same time causes the gas already formed to expand, thus the dough raises still further. Later, as the walls of these pockets harden and crack, the gas escapes and the result properly controlled is a light, porous bread.

Salt is used in the making of bread for two reasons:--first, to give the necessary flavor, without which bread would be tasteless and insipid. In the second place, salt actively controls some of the chemical changes which proceed during fermentation, exerting solvent influence on some of the insoluble proteins of flour; but in the quantities employed in bread-making it produces a decidedly binding effect on the gluten of the dough. It further checks diastatic action and so retards the conversion of the starch of the flour into dextrin and maltose. Salt also checks alconolic fermentation and extends a retarding influence to the other ferments, thus tending to prevent injurious fermentation going on in the dough (2).

It has been recognized by such authorities as the American Institute of Baking and other cereal chemists (16) that methods of manipulation are also significant in the production of standard bread. Mixing and kneading the dough give even distribution of the yeast plants and therefore have a great deal to do with the texture and quality of the bread. Kneading also adds oxygen from the air to the dough and this is essential to the plant growth and develops the gluten in flour, making the dough more tenacious.

Obviously it is essential to have the same proportion of ingredients each time a product is made and the only way to be sure of this is to weigh all ingredients and not to depend on measuring alone.

Although the correct ingredients may be supplied in proper proportions and the most satisfactory methods of manipulation used in bread making it is still very essential that the dough shall be subjected to controlled baking temperature for a given time in order that the product shall be of standard quality. The question of "How does heat act" has been pondered over by all inquiring minds and we are still confronted with many unanswered questions such as "How does food absorb heat; at what rate; is that rate the same for all kinds of food or does it differ for masses of widely different character; and does the pan have an effect on the rate of heat?" These questions are problems for physicists. In this study, however, an attempt has been made to answer only the question as to the comparative effects of baking yeast rolls with the three energy sources, coal, gas and electricity under uniform conditions of temperature, time and manipulation.

EXPERIMENTAL PROCEDURE

Many different recipes for plain and sweet rolls were collected and studied. Several were tried but for the reason that a Parker House roll may be considered a standard type it was chosen as the product to be used in these baking tests. A richer roll is more like cake and might be affected by altitude and is also more expensive, an item which had to be considered.

Various methods of procedure were tested using both straight dough and sponge methods, and while both gave good results it was decided to use the sponge method in these experiments because it was thought to be the one most commonly used.

Some of the manipulation factors which were varied were: position in oven, baking temperature and time, fermentation time and temperature, number of beating and kneading strokes, and kinds of pans and utensils. In addition to these factors various proportions as recommended in the different recipes were tried.

The purpose of this preliminary work being only to attain a satisfactory method and proportions for making Parker House rolls these factors were not studied in detail. Thus no data are being reported on this phase of the work as they would not represent conclusive evidence. These preliminary bakings were done in the electric oven.

The electric oven used throughout the problem was on a new Hotpoint range, Model No. 210RA74. The oven measured 16 inches wide, 14 inches high and 18½ inches deep, was well insulated and lined with enamel. It was equipped with upper and lower elements, automatic heat control and a vent, which was kept open one notch all during these bakings.

The gas oven was on a new Tappan Cabinet range, Model No. K916NR.9. The oven measured 16 inches wide, 13 inches high and 18½ inches deep, was insulated and the lining was of chromium plate. It was equipped with a Robert Shaw heat control and a vent which led into the chimney of the building.

The coal oven was in a Majestic range, Model No. 956, which had been in a foods laboratory of Montana State College several years. The oven measured 22 inches wide, 15½ inches high and 23 inches deep. It had the usual drafts of a coal range. The temperature was registered by a Taylor oven thermometer placed inside the oven as close as possible to the spot where the rolls were baked.

The three ranges were located in the same laboratory and all tests were made in this room. The first series of bakings was conducted in the electric and gas ranges and the second series in the electric and coal ranges. The proportion of ingredients used in making Parker House rolls, measured both by volume and weight are found in Table I and the manipulation finally adopted is described in the following paragraphs.

TABLE I.--PROPORTION OF INGREDIENTS USED IN MAKING PARKER HOUSE ROLLS, MEASURED BY VOLUME AND BY WEIGHT.

Ingredients	Volume	Wt. gms.
Sweet whole milk	2 c.	488
Granulated sugar	4 T.	50
Crisco	4 T.	50
Salt	1½ t.	6
Fleischman's yeast	1 cake	18.2
Tap water	¼ c.	59.2
Bread flour	5½ c.	682.9
Butter	2½ T.	31.2

The flour used for the entire experiment was Ceretana, a hard wheat flour made from the blend of several different kinds of wheat and milled in Bozeman, Montana. It was stored in the laboratory where the room temperature varied only from 73-80° C. Consequently the flour always ranged between these temperatures. The milk, fat and yeast were kept in an electric refrigerator.

The bottle of milk was tipped over and back 10 times to mix it thoroughly. Then the bottle cap was removed and the milk stirred with a fork 10 times. Milk, 488 grams, was weighed and poured into an aluminum pan. Sugar, 50 grams; Crisco,50 grams; and salt, 6 grams; were added to the milk. The pan was then placed on the speed unit of the electric range and the heat turned on. While this material was heating, 59.2 grams of water at 28° C. were weighed out, and into it was broken a fresh, compressed yeast cake (18.29 grams). The milk was heated to the scalding point (78° C.) to prevent a bacterial type of fermentation, and then cooled to 28° C., the optimum temperature for fermentation (5). While cooling it was stirred several times to thoroughly dissolve the sugar, salt and Crisco. When the temperature of this mixture was reduced to 28° C., it was poured into the white porcelain mixing bowl and the dissolved yeast was added. Then 273.5 grams of flour which had been sifted once and weighed were mixed into the liquid with a wire whisk using 150 strokes to mix it well. The bowl containing the bread-sponge was set in a dish pan of warm water of a temperature just necessary to keep the temperature of the sponge at 28° C. and the bowl covered with a towel. A thermometer was kept in the sponge and the temperature was maintained by careful watching. The sponge was allowed to raise for 38 minutes, at the end of which time 355.2 grams of sifted flour were mixed in with a wooden spoon, using 30 strokes. From 54.7 - 60 grams of flour had previously been weighed out and placed on a bread board. The dough was then turned onto the floured bread board and kneaded for 65 strokes by pushing the dough down with the palm of the hand and turning it one-quarter way round with each push.

The dough was then returned to the mixing bowl which had been slightly oiled with melted butter. The bowl was returned to the pan of water and the temperature of the dough was kept at 28° C.

The dough was again allowed to raise 38 minutes. At the end of that time it was turned out onto the bread board and kneaded for 65 strokes. With 18 strokes it was rolled out with a rolling pin to approximately ½ inch thickness and cut with a 3 inch aluminum biscuit cutter.

Butter, 50 grams, had previously been weighed out and melted. A small amount of it was used to oil the mixing bowl and baking sheets, and the remainder was used on the rolls. Each roll was creased in the middle, rubbed with melted butter, folded over in pocket-book style and the top brushed with butter.

Six rolls were cut and accurately weighed to 40 grams each, to be used later for volume test. Three of these were placed at the end row of each of the two baking sheets. The remainder of the rolls were divided evenly between the two baking sheets but were not weighed individually. Small internal maximum-temperature thermometers 2¾ inches in length with temperature scale range of 200-280° F. were placed inside of two rolls and one each of these rolls placed in the center of each baking sheet.

These sheets with rolls on them were placed across a dish pan of warm water and covered with clean white paper. The rolls were allowed to stand thus for 26 minutes, and thn put in the various ovens which had been preheated to 390° F. The rolls were baked for 14 minutes on a rack at approximately the middle of the oven for the electric and gas ranges and on the bottom of the coal range oven. Despite the fact that so many directions for making Parker House rolls give 425° F. as the correct temperature and 15-20 minutes as the time for baking, the author found this temperature too high for good results and the time too long.

The baking sheets plus the rolls were weighed just before going into the oven and immediately upon coming out of the oven and the percentage of loss in weight figured. The thermometers were removed from inside the rolls and the internal temperatures recorded. Mechanical tests for tenderness and volume were made. An attempt was made to score the rolls according to the following score card:

here

SCORE CARD FOR ROLLS

		Perfect Score	Your Score	Criticism
General appearance	-	10		
Size 5				
Shape 5				
Crust	-	20		
Top 12				
Color 3				
Character 2				
Depth 2				
Texture 2				
Tenderness 3				
Bottom 8				
Color 2				
Character 1				
Depth 2				
Texture 1				
Tenderness 2				
Crumb	-	35		
Lightness 10				
Character (elasticity) 10				
Texture and grain 10				
Color 5				
Flavor and odor	-	35		
Totals	-	100		

As the personal factor in scoring was so variable and a sufficient number of judges could not be regularly secured to eliminate this factor, only the mechanical tests are considered as significant.

To compute the volume of the baked rolls, a standard method of seed displacement was used. Rape seed was allowed to fall into a stone jar with straight sides from a funnel which rested upon an iron ring fastened to a ring stand so that the seed left the funnel just above the mouth of the stone jar. The bottom of the jar was covered with seed, one of the rolls that had been weighed before baking was placed in the jar and the seed was allowed to fall until the roll was completely covered. Then the second roll was put in and covered with seed and the third roll was handled in the same manner. When the jar was full of seed a straight-edged spatula was used to strike off the excess seed, the straight edge resting simultaneously on the opposing edges of the jar. The seed that surrounded the rolls was then weighed and volume computed in the following manner.

The empty jar was filled with rape seed and the contents were found to weigh 1290 grams. Then the jar was filled with tap water from a graduate to find the amount necessary to fill it, which was 1928 c.c. Therefore 1290 grams of seed = 1928 c.c. volume, and 1 gram of seed = $\frac{1928}{1290}$ = 1.494 c.c. which is the volume represented by 1 gram of seed. The weight of seed surrounding three rolls was subtracted from 1290 grams, the weight of the jar full of seed. This gave the number of grams of seed displaced by the three rolls. Multiply this number by 1.494 and the resulting figure is the volume of the rolls in c.c.

A device was also set up for testing the breaking strength of the upper crusts and lower crusts of the rolls. An agate-bearing trip balance was fastened near the top of an iron tripod support and on the left hand side was adjusted a universal clamp. Into this clamp was fastened a test tube clamp with its jaws pointing upward toward the trip balance. From the lower left hand side of the trip balance was suspended by a stout cord another test tube clamp with its jaws hanging down toward and parallel to the jaws of the lower test tube clamp. The jaws of these two clamps were about 3 inches apart. The apparatus was then balanced to the zero mark. Soon after baking, a strip of crust one inch wide was cut through the center of the top and bottom of a roll. One piece was then fastened by each end in the jaws of the two test tube clamps tightly enough so that the balance was kept on zero. Two beakers which had previously been balanced were then placed on either side of the balance. Sea sand was poured into the beaker on the right hand side of the balance until the crust sample broke into two parts. The sea sand was then weighed and its weight recorded as the breaking strength of that particular sample of crust. Therefore the greater the weight of sand the less tender was the roll. Three samples of top crust and three of bottom crust were thus tested for each baking from each range, being taken from what appeared to be good average rolls. (Illustration 2 p.20)

These same samples were next matched for color with the Munsell Color disks and apparatus described on page 33. For this work a piece of gray cardboard was set up, onto which a single sample of crust could be fastened, the surface of the crust to be in the same plane with the disks used as standards, as will be seen in illustration 1. The person matching the colors stood approximately 5 feet away. The use of a reading lens put the crust surface sufficiently out of focus so that the result appeared as one solid color even though the crust itself was irregular in character or spotted in appearance. Adjustments were made by changing the areas of the disks until there was a perfect match between the color of the crust and that of the rotating disk when viewed through the eyepiece. The readings were recorded by noting the percentage of the exposed area of each color. These percentage areas of standard color were converted into hue, brilliance and chroma by the Munsell system and formulae recorded on page 34.

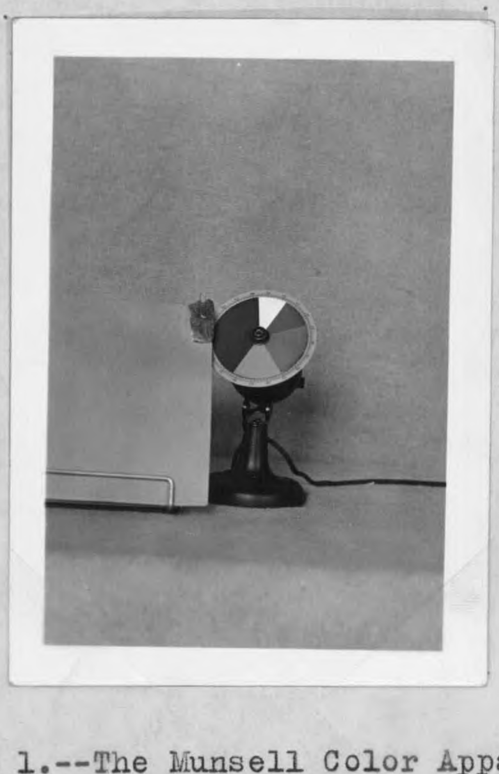

Illustration 1.--The Munsell Color Apparatus as it was set up for matching the color of rolls.

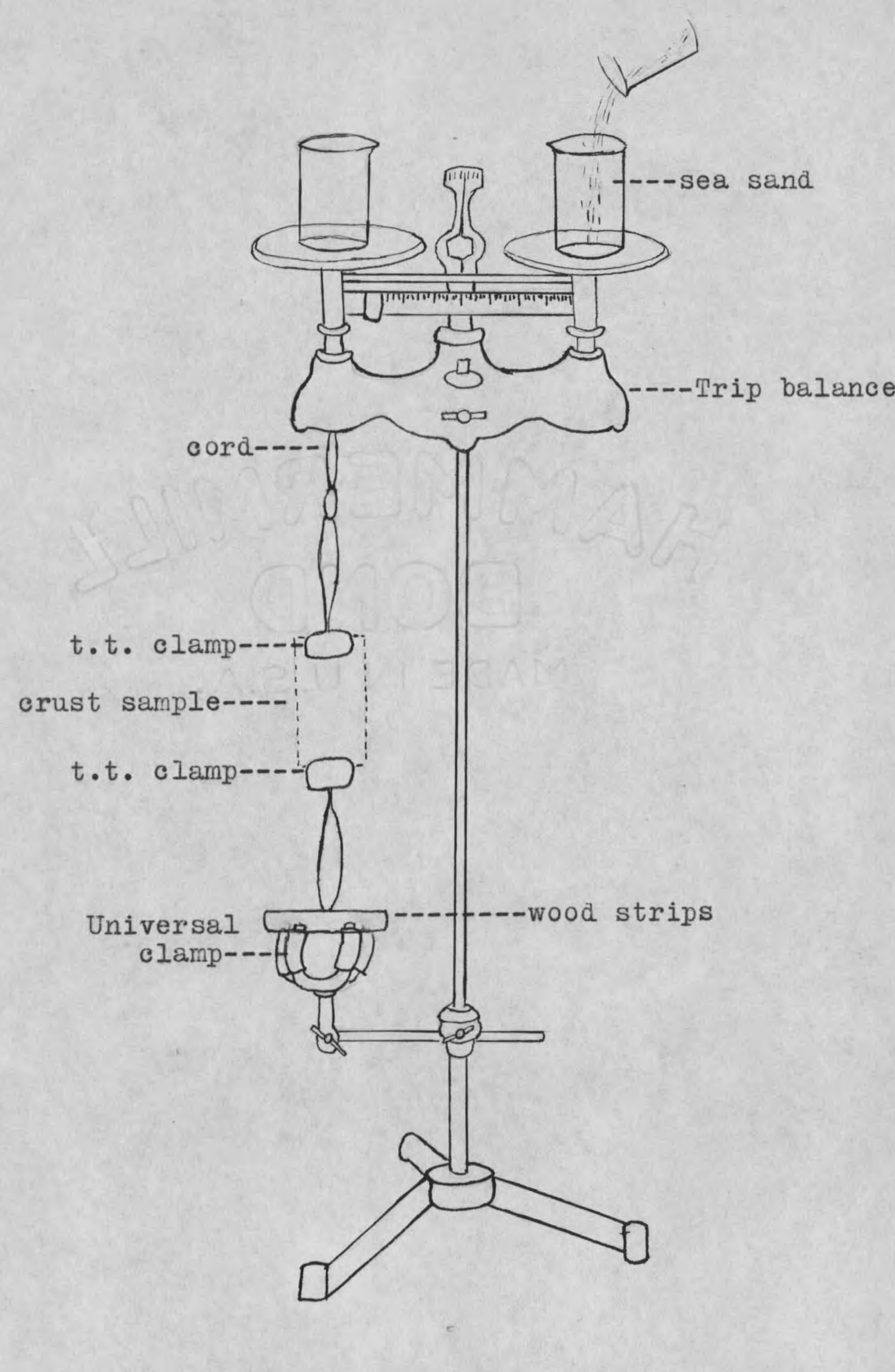

Illustration 2.--Device used for testing the breaking strength of the crusts of Parker House rolls.

RESULTS

In this comparison of yeast rolls, baked in three kinds of ovens, namely, electric, gas and coal, all of the various factors were studied for which measuring devices could be set up. Loss in weight was computed by recording the weights of the rolls before and after baking; volume was measured by seed displacement, and internal temperatures were recorded with maximum oven thermometers. Determinations were made for the tenderness of the crusts and crust colors were matched by use of standard Munsell color disks. Tables II, III, and IV show the loss in weight of yeast rolls baked in electric, gas and coal range ovens.

TABLE II.--THE LOSS IN WEIGHT OF PARKER HOUSE ROLLS WHEN BAKED IN AN ELECTRIC OVEN EQUIPPED WITH AN AUTOMATIC HEAT CONTROL.

Date	Kind of oven	Temp. of oven	Wt. of rolls before baking gms.	Time of baking min.	Wt. of rolls after baking gms.	Loss in wt. gms.	Loss in wt. %
Feb. 9	Electric	390° F.	627.6	12	567.1	60.5	9.6
Feb. 11	"	390	593.1	12	526.8	66.3	11.2
Feb. 12	"	390	681.0	14	594.9	86.1	12.6
Feb. 16	"	390	676.3	14	606.5	69.8	10.2
Feb. 18	"	400	641.6	12	572.4	69.2	10.2
Feb. 19	"	400	645.9	12	576.4	69.5	10.8
Mar. 3	"	390	651.9	14	580.4	71.5	11.0
Mar. 4	"	390	667.4	14	597.4	70.0	10.5
Mar. 5	"	390	667.4	14	597.4	70.0	10.5
Mar. 8	"	390	674.0	14	596.0	78.0	11.6
Mar. 12	"	390	667.4	14	592.4	75.0	11.3
Mar. 15	"	390	644.1	14	563.4	80.7	12.4
Mar. 28	"	390	611.5	14	536.5	75.0	12.3
Mar. 29	"	390	662.5	14	593.5	69.0	10.4
Mar. 31	"	390	713.3	14	628.5	84.8	11.9
Mar. 31	"	390	676.7	14	608.5	68.2	10.1

TABLE II (Cont'd)

Date	Kind of oven	Temp. of oven	Wt. of rolls before baking gms.	Time of baking min.	Wt. of rolls after baking gms.	Loss in wt. gms.	Loss in wt. %
Apr. 1	Electric	390° F.	610.2	14	533.4	76.8	12.6
Apr. 5	"	390	671.4	14	601.6	69.8	10.4
Apr. 7	"	390	675.4	14	605.4	70.0	10.4
Apr. 8	"	390	677.5	14	607.3	70.2	10.4

Avg. % loss in wt. = 11.2

TABLE III.--THE LOSS IN WEIGHT OF PARKER HOUSE ROLLS WHEN BAKED IN A GAS OVEN EQUIPPED WITH AN AUTOMATIC ROBERT SHAW HEAT CONTROL.

Date	Kind of oven	Temp. of oven	Wt. of rolls before baking gms.	Time of baking min.	Wt. of rolls after baking gms.	Loss in wt. gms.	Loss in wt. %
Feb. 9	Gas	390° F.	635.8	12	578.5	57.3	9.0
Feb. 11	"	390	543.5	12	466.1	77.4	14.2
Feb. 12	"	390	638.5	14	545.4	93.1	14.6
Feb. 16	"	390	654.3	14	573.1	81.2	12.4
Feb. 18	"	400	684.0	12	610.5	73.5	10.7
Feb. 19	"	400	619.4	12	535.5	83.9	13.5
Mar. 1	"	390	677.0	14	581.4	95.6	14.1
Mar. 3	"	390	663.4	14	578.4	85.0	12.8
Mar. 4	"	390	648.4	14	570.4	78.0	12.0
Mar. 5	"	390	648.4	14	570.4	78.0	12.0
Mar. 8	"	390	651.4	14	572.4	79.0	12.1
Mar. 12	"	390	634.9	14	556.9	78.0	12.3

Avg. % loss in wt. = 12.8

TABLE IV.--THE LOSS IN WEIGHT OF PARKER HOUSE ROLLS WHEN BAKED IN A COAL RANGE OVEN.

Date	Kind of oven	Temp. of oven	Wt. of rolls before baking gms.	Time of baking min.	Wt. of rolls after baking gms.	Loss in wt. gms.	Loss in wt. %
Mar. 1	Coal	390° F.	636.2	14	564.4	71.8	11.3
Mar. 15	"	390	675.3	14	608.5	66.8	10.0
Mar. 28	"	390	639.9	14	567.5	77.4	12.1
Mar. 28	"	390	705.4	14	627.7	77.7	11.0
Mar. 31	"	390	603.4	14	538.4	65.0	10.8
Mar. 31	"	390	628.4	14	565.5	62.9	10.0
Apr. 5	"	390	648.5	14	578.5	70.0	10.8
Apr. 7	"	390	652.5	14	576.5	76.0	11.7
Apr. 8	"	390	633.4	14	558.4	75.0	11.8

Avg. % loss in wt. = 11.2 avg.

The results in Tables II, III, and IV indicate that there is a slight variation in loss in weight of rolls baked in the three different ovens; 11.2% for the electric oven; 11.2% for the coal range oven and 12.8% for the gas oven. The amount of difference between the gas oven and the two others is probably too small to be significant.

Volume is generally used in standard bread baking tests as an indication of "flour strength". However, in these studies flour from the same sack was used and portions of the same lot of dough were baked in the different ovens. Thus, eliminating other variables, in these tests volume can safely be attributed to differences in baking.

Volume tests were made by rape seed displacement as described on page 17. In Tables V, VI, and VII will be found the results obtained in these tests.

TABLE V.--THE VOLUME OF PARKER HOUSE ROLLS BAKED IN AN ELECTRIC OVEN EQUIPPED WITH AN AUTOMATIC HEAT CONTROL.

Date	Kind of oven	Temp. of oven	Wt. per roll before baking gms.	No. of rolls	Wt. of seed displaced by 3 rolls after baking gms.	Vol. of 1 gm. seed c.c.	Vol. of 3 rolls after baking c.c.
Mar. 3	Electric	390° F.	40	3	190.0	1.494	283.86
Mar. 4	"	390	40	3	174.3	1.494	260.4
Mar. 5	"	390	40	3	174.3	1.494	260.4
Mar. 8	"	390	40	3	161.0	1.494	240.5
Mar. 12	"	390	40	3	179.4	1.494	268.0
Mar. 15	"	390	40	3	192.7	1.494	287.9
Mar. 28	"	390	40	3	204.3	1.494	305.2
Mar. 26	"	390	40	3	202.7	1.494	302.8
Mar. 29	"	390	40	3	209.0	1.494	312.2
Mar. 31	"	390	40	3	189.3	1.494	282.8
Mar. 31	"	390	40	3	229.0	1.494	342.1
Apr. 1	"	390	40	3	194.2	1.494	290.1
Apr. 5	"	390	40	3	191.3	1.494	285.8
Apr. 7	"	390	40	3	197.0	1.494	294.3
Apr. 8	"	390	40	3	208.3	1.494	311.2

Avg. volume of three rolls = 288.5
S. D. = ±24.3
P. E. = ±16.4

TABLE VI.--THE VOLUME OF PARKER HOUSE ROLLS BAKED IN A GAS OVEN EQUIPPED WITH AN AUTOMATIC ROBERT SHAW HEAT CONTROL.

Date	Kind of oven	Temp. of oven	Wt. per roll before baking gms.	No. of rolls	Wt. of seed displaced by 3 rolls after baking gms.	Vol. of 1 gm. seed c.c.	Vol. of 3 rolls after baking c.c.
Mar. 1	Gas	390° F.	40	3	195.0	1.494	291.33
Mar. 3	"	390	40	3	183.0	1.494	273.40
Mar. 4	"	390	40	3	175.6	1.494	262.30
Mar. 5	"	390	40	3	175.6	1.494	262.30
Mar. 8	"	390	40	3	173.2	1.494	258.80
Mar. 12	"	390	40	3	210.0	1.494	315.70

Avg. volume of three rolls = 277.0c.c.
S. D. = ±19.7 "
P. E. = ±13.3 "

TABLE VII.--THE VOLUME OF PARKER HOUSE ROLLS BAKED IN A COAL RANGE OVEN.

Date	Kind of oven	Temp. of oven	Wt. per roll before baking gms.	No. of rolls	Wt. of seed displaced by 3 rolls after baking gms.	Vol. of 1 gm. seed c.c.	Vol. of 3 rolls after baking c.c.
Mar. 1	Coal	390° F.	40	3	170.0	1.494	254.0
Mar. 15	"	390	40	3	210.2	1.494	314.4
Mar. 28	"	390	40	3	213.7	1.494	319.3
Mar. 28	"	390	40	3	201.7	1.494	301.3
Mar. 31	"	390	40	3	189.3	1.494	282.8
Mar. 31	"	390	40	3	218.0	1.494	325.7
Apr. 1	"	390	40	3	190.0	1.494	283.9
Apr. 5	"	390	40	3	177.0	1.494	264.4
Apr. 7	"	390	40	3	202.0	1.494	301.8
Apr. 8	"	390	40	3	192.0	1.494	286.8

Avg. volume of three rolls = 295.6 c.c.
S. D. = ±22.2 "
P. E. = ±15.0 "

From the data recorded in Tables V, VI, and VII it is interesting to note that the greatest volume of rolls (295.6 c.c.) was obtained when they were baked in the coal range oven. The rolls from the electric oven had a volume of 288.5 c.c. and those from the gas oven, 277.0 c.c. To further test these data to see if the findings were significant, the standard deviations were calculated and from these the probable errors were derived. The results showed in each instance that 50% of the cases did not fall within one times the probable error but were within two times the probable error. Therefore, according to statistical interpretation, the chances are 4½ to 1 that the findings are significant.

It was thought advisable to compare the color qualities and the breaking strength of the upper and lower crusts of rolls for a possible correlation. This was suggested in preliminary work when it was noticed that the crusts baked to a darker color seemed to possess a greater degree of toughness. The following paragraphs explain how the color was measured and Tables VIII to XIII contain the data recorded on standard colors and breaking strength of upper and lower crusts of yeast rolls baked in the three ovens.

Bailey (9) states that color, one of the significant characteristics of baked products is in all likelihood the most difficult to measure and record. Various expressions and terms are used to describe colors, their line (hue), intensity (brilliance), and purity (chroma), and the conception conveyed to one individual by these terms may differ greatly from that conveyed to another. For example, in judging rolls the term "golden brown" which is an ideal color for rolls gives no definite measure of the brilliance of the color and lacks definiteness so far as the chroma of the color is concerned.

In describing any object definite terms are desirable. The use of the Munsell color system, including formulae and apparatus, for determining the color of agricultural products has been developed by Dorothy Nickerson (15), color technologist, Bureau of Agricultural Economics, and this has been used for measuring the color of bread by Grewe (10 p.60).

The Munsell Color System as described by Grewe (10 p.60) is as follows:

"This system is based upon the psychological fact that color has three attributes: hue, brilliance and chroma.

"Hue is the term which is used to indicate the name of the color, such as red, blue, or green. The 5 principal hues are red, yellow, green, blue, and purple; and the 5 intermediate hues are yellow-red, green-yellow, blue-green, purple-blue, and red-purple. These 10 are known as standard hues. The standard hues are subdivided into 100 hues, and these may be still further subdivided if necessary.

"<u>Brilliance</u> is the value of color--lightness or darkness. Gradations from white to black through a series of grays, each step differing from the next by equal amount. Absolute black, which is unattainable, is given a notation of 0/ and placed at the end of the scale; absolute white is given a notation of 10/ and placed at the top of the scale. All the grays fall between black and white and range from 1/ to 9/ ; 1/ is what is ordinarily called black and is about the color of black velvet, while 9/ is the white ordinarily seen.

"<u>Chroma</u> is intensity of color--brightness or dullness. Chroma describes the distance of the color from gray or neutrality. If the chroma scale of any color is filled in toward the central gray core at the same brilliance at which it was started it becomes less and less intense until it loses all color and becomes gray. If the chroma is extended outward from the gray core of the solid the color becomes stronger until it reaches a maximum. Munsell likens this change in chroma to that of a leaf which, as autumn comes, gradually loses its chroma and fades to neutral gray."

The Munsell apparatus is provided with discs made to represent the principal and intermediate hues, as red, red-yellow, yellow, etc., at each step in brilliance and chroma for the hues that can be produced in permanent pigments. Each disc is marked as to hue, brilliance, and chroma. The index also provides discs ranging from black to white. These are designated with the symbols 1/ to 9/ inclusive.

The color of an object is measured by spinning 2 or more standard colored discs and neutral color discs on a motor shaft at a speed high enough to resolve the colors of the disc into a single color. A straight-line opening is made on the disc from the circumference to the center. When the discs are placed on the shaft for spinning, they are overlapped by means of these openings so that part of each disc is exposed at the surface. The proportions of the different colors of the visible sections can be adjusted until there is a perfect match between the object under test and the rotating discs.

Constant lighting conditions are essential to all careful color work. The objects under investigation should be placed on a container or rack at definite distances from the observer. The apparatus should be set up preferably in a north window or under a north skylight at an angle comfortable to view. For matching the color of the rolls in these experiments the author found it more convenient to use a south window. However, care was taken to have the lighting always the same, working on gray days and never in sunlight. The observer should stand or sit far enough from the discs that a direct line from disc to eye will be about four or five feet.

A calibrated disc graduated at its perimeter in 100 divisions may be used for measuring the amount of space occupied by each disc. After the colors are matched the disc is superimposed upon the color discs and readings of the exposed areas are taken. The sum of the hue disc and the neutral disc should equal 100. The following formulae have been developed for general use in calculating hue, brilliance, and chroma:

x = number of first hue (clockwise on the hue circle).

z = number of second hue (clockwise on the hue circle).

A = area

P = power number (brilliance x chroma).

H = hue resultant.

B = brilliance.

C = chroma.

$$H = z - \frac{A_x P_x}{A_x P_x + A_z P_z} (z - x)$$

$$B = \sqrt{\frac{\Sigma(AB^2_{1.2.3...})}{100}}$$

$$C = \sqrt{\frac{\Sigma(AC_{1.2.3...})}{100}}$$

In following the above plan the first hue or x was yellow-red with a number of 15, and the second hue or z was yellow with a number of 25. The color of rolls fell within these two numbers. The numbers recorded under hue in the following tables mean that the higher the number, the closer it is to yellow.

The brilliance has a scale of 0 to 10. The higher the number, the nearer it is to white.

The chroma also has a range of 0 to 10. The higher the number, the more intense or pure is the color.

Tables VIII to XIII present the data recorded on color and breaking strength.