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I am submitting herewith a thesis written by Linda Ellen Watson entitled "Energy Consumption of Percolator Coffeemakers in Relation to Wattage, Brewing Time, Quality of Beverage, and Other Variables." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Home Management Equipment and Family Economics.

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ENERGY CONSUMPTION OF PERCOLATOR COFFEEMAKERS IN RELATION TO WATTAGE, BREWING TIME, QUALITY OF BEVERAGE, AND OTHER VARIABLES

A Thesis

Presented for the

Master of Science

Degree

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ABSTRACT

The purpose of this study was to analyze the energy consumption of coffeemakers in relation to wattage, brewing time, quality of beverages, and other variables. The following eight coffeemakers were tested: two 490, two 660, two 1,000 wattage electrics and two non-electrics tested on conventional and smooth-top ranges. Two of the replications were prepared with hard, Knoxville tap water and the others with soft, distilled water.

The variables of the experiment were perking time, beginning temperature of water, and end temperature of water. Factors controlled were type and amount of water, voltage of circuit, and wattage of coffeemaker.

It was hypothesized that watt-hour consumption of selected low, medium, high wattage electric and non-electric coffeemakers would be equal when preparing similar products. The second hypothesis was that the beverages prepared in the various coffeemakers would have similar pH's, amounts of soluble solids, and color index readings. An additional hypothesis was that the hardness of water would not change the quality of the coffee product. All three hypotheses were rejected after the data were analyzed by analyses of variance and Duncan's New Multiple Range Comparison Tests.

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CHAPTER I

INTRODUCTION

Coffee is one of the nation's most popular beverages and over 440 million cups are drunk every day (1, p. 2). Approximately 93% of all electrically wired dwellings in the United States possessed a coffeemaker in 1972 as compared to 94.8% saturation in December 1973 (16, p. 17) (13, p. 32). According to Merchandising Week (7, p. 31) the average wattage of today's coffeemakers is 894 and each consumes an estimated 106 kilowatt-hours annually. Therefore, it is important that research be conducted concerning coffee products and the use of related equipment.

Most of the coffee related research has focused on the quality of the finished product, rather than the energy consumption of the coffeemaker. The findings of the energy consumption studies that have been done are somewhat out-dated since they involved models not commonly used in today's homes. Because of the limited amount of research available, the Association of Home Appliance Manufacturers has requested that home economists conduct studies involving the utilization of energy by kitchen equipment. Since the nation is in an "energy crisis," it is important from an economical and a power standpoint that the efficiency of present coffee making appliances be examined.

I. STATEMENT OF THE PROBLEM

The purpose of this study was to compare the quality of beverages prepared in various wattage and non-electric or surface-unit coffeemakers in relation to (1) electrical energy consumed, (2) time of brewing, (3) pH of beverage, (4) amount of soluble solids, (5) color index of product, (6) hardness of water, and (7) beginning and end temperature of the liquid. The appliances used in the study were six electric coffeemakers; two 490, two 660, and two 1000 wattage, and two surface-unit coffeemakers used in conjunction with conventional and smooth-top ranges. All models, regardless of size, were operated using the same amount and kind of water and coffee.

II. HYPOTHESES

The following hypotheses were tested:

1. The energy consumption of selected low, medium, and high wattage and non-electric coffeemakers is equal when preparing similar products.

2. The beverages prepared in various wattage and surface-unit coffeemakers are similar in pH, amount of soluble solids, and color indexes.

3. The hardness of the water used in coffee preparation does not alter the quality of the final product.

III. DEFINITIONS OF TERMS

The following definitions were based on the Handbook of Household Equipment Terminology (10).

1. Automatic percolator--A coffeemaker that heats a small amount of water building up pressure which forces the hot water through a tube to be distributed over the ground coffee.

2. Distilled water--Evaporation and recondensation have been used to remove all minerals, such as iron and other contaminants from the water.

3. Model--An appliance distinguished from others of the same brand by differences in size, style, materials, or heating mechanism.

4. Smooth-top--Heating units located under the continuous surface of a range.

5. Surface-unit or non-electric coffeemaker--A container wherein the water for the coffee is heated by means of an exterior source such as a range or hot plate. These coffeemakers are made from a variety of materials including glass, aluminum, and pyroceram.

6. Tubular unit--A heating element composed of resistance wire(s) encased in a metal alloy tube and used in an oven or range surface unit.

7. Hard water--Water which has an abundance of calcium and magnesium present. The water hardness is stated in terms of grains of hardness per gallon or parts per million (1 grain per gallon = 17.1 parts per million).

8. Watt--A unit of electric power which is calculated by multiplying amperes and volts.

CHAPTER II

REVIEW OF LITERATURE

The "energy crisis" has become a common household phrase within the past few months. Concern about future power sources was stimulated through research conducted by industries and various individuals. Stewart Udall, Secretary of the Interior during the Kennedy and Johnson Administrations, pointed out in his speech of October 2, 1973, that one-third of the electricity and oil consumed in the United States is "wasted" (21). With the use of so many kitchen appliances, the public has placed increasing demands on the electrical power resources. The outlook for cooking (energy) requirements in the 1980's is that 780 trillion BTU's will be needed (11, p. 104). Thus, individuals are becoming concerned about the utilization of electrical power to its fullest through wise selection and use of appliances. Types of coffee making equipment and their relationship to a quality product and consumption of energy will be explored in the following paragraphs.

I. COFFEE EQUIPMENT

For almost one thousand years man has experimented with alternate ways of designing equipment and brewing the coffee bean to perfection (6, p. 20). The progress of the invention can be followed from the advent of the first drip coffeemaker to modern day non-electric or

surface-unit, vacuum, and electric percolators.

The drip and vacuum coffeemakers allow exposure to the coffee grounds through the filtration process (16, p. 128). According to Peckham, author of Foundations of Food Preparation,

> Drip coffee is prepared by first heating the pot and then pouring boiling water over finely ground coffee held in a suitable sieve--such as a perforated container--usually lined with a filter paper. The hot water is poured over the coffee and the coffee infusion filters into the lower container. This container may be kept over hot water to keep the beverage hot. (16, p. 128)

The vacuum type equipment is very similar to the drip, however, the measured water is placed in the lower bowl of the coffeemaker and is gradually pushed to the upper bowl by means of steam pressure (16, p. 128). Thus, the water quickly makes contact with the coffee grinds and descends to the lower chamber through means of a vacuum.

Percolators are used for the production of the coffee beverage by placing grinds in a perforated basket attached to a slender, open stem (16, p. 128). Heated water in the base of the equipment progresses up the tube and reaches the grounds, thus, allowing extraction of the beverage (16, p. 129). Percolators may be either electric or surface-unit styles (9, p. 96). The automatic, electric models perk until the product reaches approximately 187°F., the unit cuts-off and the product is heated by a cycling unit (9, p. 97). However, non-automatic coffee-makers, whether electric or non-electric, must be timed by the operator until the desired product is attained (9, p. 96). According to Ehrenkranz and Inman, "What constitutes 'good' coffee varies with personal taste, there are numerous factors that influence the flavor of coffee" (9, p. 96). The factor of time of coffee preparation will be

described next.

II. TIME

The Coffee Brewing Center of the Pan-American Coffee Bureau stated the importance of this preparation factor in the following, "The Center has come to consider brewing time as the most important single factor in beverage preparation" (5, p. 9). The period of brewing will vary according to the grind of the coffee being used in preparation. For instance, when using regular grind, six to eight minutes is required; drip grind takes four to six; and fine grind, four minutes brewing time (5, pp. 7 and 9).

Merritt and Proctor reported that the longer the preparation period the greater the extraction rates for the soluble solids, color, and chloragenic acid in the beverage (14, p. 9). However, the first two minutes of the process seemed to be the most crucial to the beverage. The author stated, "Extraction rates of the components studied decreased in the following order: trigonelline, caffeine, soluble solids, chlorgenic acid, tannin and color" (14, p. 9).

Prescott mentioned the fact that over-extended brewing periods produce a product having a bitter quality (10, p. 1). The extraction rate is directly influenced by the amount of time the grounds are in contact with the water. In addition, the composition of water can have some influence on the quality of the finished beverage and increases the preparation time (10, p. 5). According to D. G. Gardner,

> Softening increase[s] brewing time . . . An increase in the concentration of carbonate or bicarbonate ions does cause an increase in the filtration time of water through coffee. (10, p. 5)

Thus, the use of unsoftened water not only reduces the energy consumption required for coffee brewing but also results in a more palatible product.

The Consumers' Union conducted a study comparing models requiring seven minutes to brew and those taking twice as much time (4, p. 458). In this study it was found that, "Speed . . . [has] little relation to coffee quality" (4, p. 458). However, little data were included to document the statement and no tests were conducted to compare the kilowatt-hour consumption of various coffeemakers. In contrast, Peckham stated that the average time for perking of coffee products should be between seven and ten minutes (16, p. 129). The Coffee Brewing Institute advocates a six to eight minute brewing period and a holding period of no more than one hour (3, pp. 21-2). Thus, an accurate comparison of energy efficiencies of various models should not be based on the Consumers' Union data.

III. TEMPERATURE

The Coffee Brewing Center of the Pan-American Coffee Bureau advocates maintenance of a coffee brewing temperature between 185°F. and 205°F. (5, p. 8). To produce a desirable product the temperature should be stabilized between the stated range for a minimum of 90 percent of the preparation period. For the maintenance of a desirable product, the holding temperature should stay between 185°F. and 190°F. for approximately one-half hour after the beverage is brewed (5, p. 8). A study conducted by Segall, Silver, and Bacino showed that reheating

beverage coffee was detrimental to organoleptic acceptance (18, p. 3). The length of time between preparation and reheat is not as important as the initial reheat itself. Thus, coffee products are most acceptable when subjects receive the beverage immediately after brewing.

IV. CLARITY

Standards of turbidity vary from person to person. The increased use of filter paper as a part of the brewing process and the acceptance of instant coffee have given the public higher levels of clarity for coffee products (5, p. 11). Thus, the homemakers and food service operators have tried to improve quality according to consumer demands.

The Coffee Brewing Center explained that the grind of coffee, amount of water, and filtering mechanism could affect the amount of sediment in the product (5, p. 12). Ten grams of regular grind coffee in conjunction with six ounces of water are recommended as a formula for beverages made in an electric percolator (5, p. 9). Those coffeemakers housing a perforated metal plate filter less efficiently than ones using woven wire screen, cloth or paper (5, p. 12).

The turbidity obtained using various brewing methods and coffeemakers can be evaluated by either the use of a coffee hydrometer or the oven dehydration method (3, p. 1). The average amount of soluble solids in the ideal coffee product ranges from 1.18 to 1.32 percent (5, p. 11). The Center stated, "No single value . . . should be less than 1.09 or greater than 1.42" (5, p. 11).

V. ACIDITY AND FLAVOR

Michael Sivetz, a chemical engineer and coffee consultant stated, "In general, the more acid-tasting the coffee, the better the flavor and aroma" (19, p. 70). The desirable pH range for brewed coffee is between 4.95 and 5.15 when milk and cream are not added (19, p. 76). Readings below 4.90 are too acid-tasting and those above 5.20 are too flat tasting (19, p. 77). So significant is the effect of acidity upon taste, that a .025 unit change in pH yields a noticeable taste difference. The importance of water in coffee preparation was emphasized in the following statement,

> Almost all U.S. brands of roast and ground coffee give pH values above 5.15 with water of over 60 ppm alkalinity and 5.25-5.50 with water of 110 ppm alkalinity. Such a change in pH with consequent loss in acid taste is accompanied by loss in taste appeal (19, p. 77).

Thus, the higher the alkalinity of the water, the more alkaline tasting the coffee, regardless of the type of coffeemaker, time of perking, temperature of water, or room conditions.

VI. KILOWATT-HOUR CONSUMPTION

Research conducted by Potter and Fuller at the Virginia Agricultural Experiment Station contrasted various methods, temperatures, models of coffeemakers, grinds of coffee, and the cost of making the product (17, pp. 8-12). However, they did not compare different wattage coffeemakers, since only two electric percolators were used in the study. Thus, the data collected refer to results tabulated using a 550 watt electrical hotplate or built-in heating unit of equal

wattage, held at 115 volts by a rheostat for the 15 coffeemakers. Researchers found that for equivalent amounts of brewed coffee surface-unit coffeemakers used twice as many kilowatt-hours as electric coffeemakers (17, p. 17). As previously stated, kilowatt-hour consumption of small appliances is an open avenue for research.

CHAPTER III

COLLECTION OF THE DATA

I. DESIGN OF EXPERIMENT

The methodology of the experiment was based primarily on the Coffee Brewing Center publications of Equipment Evaluation-Home Coffeemakers (5), Extraction Rates for Selected Components in Coffee Brew (14), and The Soluble Solids in Beverage Coffee as an Index to Cup Quality (12). In addition, the research of P. B. Potter and Amelia H. Fuller was consulted when setting-up the testing procedure (18).

The beverages were prepared in eight different coffeemakers, six automatic electric and two surface-unit used in conjunction with conventional and smooth-top ranges. The equipment was tested in a control laboratory at the University of Tennessee, Knoxville. The coffeemakers were labeled with numbers one through ten to facilitate randomization of testing and tabulation of findings.

The study was designed to correspond as nearly as possible to home conditions of coffee preparation, therefore the beginning temperature of the water, temperature of the brew, and the perking time were not controlled. Each model was operated at a capacity of six 6-ounce cups of water with 10 grams of regular grind coffee per cup (5, pp. 7 and 9). Two replications each were conducted using distilled water

with zero parts per million hardness and the tap water with varying hardness (20).

Factors which were controlled were type and amount of coffee used, type and amount of water, voltage of circuit, and wattage of coffeemaker. The following data were recorded for each coffee sample: hardness of water, beginning temperature of water, end-temperature of brew, energy consumption in watt-hours, humidity and temperature of control room. In addition, pH's of the beverage, the percent of soluble solids, and color indexes were measured and recorded.

II. PRETESTING

Preliminary tests were conducted so that the researcher could become familiar with the methodology advocated by the Pan-American Coffee Bureau, P. B. Potter and Amelia H. Fuller and make changes necessary for the experiment. Laboratory work included: (1) deciding the amount of coffee needed per cup, (2) determining the amount and hardness of water needed, (3) establishing a procedure for obtaining the pH, soluble solids, and color index, (4) arranging a randomized system for testing the equipment, and (5) setting a brewing time and temperature for the non-electric coffeemakers. In addition, twenty samples (two replications) were tested so that the performance of the equipment could be studied and a method of recording data could be established.

III. TEST PROCEDURE

Coffee

The coffee selected was Maxwell House regular grind (5, p. 9). No attempt to scrutinize among various brands was made. A sufficient

quantity of lot number J4026 was purchased to complete all the replications. The amount of coffee to be used per 6 ounce (170.1 grams) cup was determined according to the Pan-American Coffee Bureau. The coffee was refrigerated in the control room between uses to help retain its quality.

Water and Water Hardness

A sufficient amount of water for each replication was drawn and stored to facilitate comparison of performance among coffeemakers. Two replications were conducted using distilled water of zero parts per million hardness and two with Knoxville tap water having various hardnesses (18). Before the water was stored the following procedure was used to check the hardness (20, p. 26):

1. A 10 ml. sample of cold water was mixed with three drops of Hack Chemical Solution.
2. One Hack ManVer II Powder Pillow was added and the ingredients mixed.
3. The solution was titrated with the Hack TitraVer liquid until there was a color change from pink to blue.
4. The amount of Hack TitraVer solution used in step 3 was included in the following formula to determine grains per gallon hardness:

$$\frac{\text{ml. of TitraVer used in titration} \times 100}{17.1}$$

In addition, hardness in parts per million can be calculated by multiplying the grains per gallon hardness times 17.1.

Temperature

The temperature of the water was taken with a Centigrade mercury-in-glass thermometer that was inserted in the spout of the coffeemaker before the perking process was started. The thermocouple of the recording potentiometer was inserted in the spout at a depth of approximately one-half inch from the bottom of the coffeemaker so that Fahrenheit readings could be recorded throughout the perking process.

Energy Consumption

An electrical instrument panel containing a Variac (to control voltage), voltmeter, and a watt-hour meter (to measure energy consumed) was used for each of the forty samples. The voltage of the automatic electric coffeemakers was maintained at 120 volts and the ranges at 240 volts. Energy readings were recorded at the beginning and end of each test and the total watt-hours actually consumed was obtained by subtraction of the two figures.

General Procedure

The following procedure was followed for each of the forty samples in the experiment:

1. The date, time, water hardness, watt-hour reading, room temperature and humidity were recorded.
2. The six 6-ounce cups of water and 10 grams of coffee per cup were weighed with a triple beam balance (5, pp. 9-10).
3. The ingredients were placed in the respective coffeemakers; the water temperature taken; the stopwatch set

on zero; the potentiometer's thermocouple placed in the spout; and the equipment turned on.

4. The non-electric coffeemakers were heated on the range setting of high until the first perk and then placed at 425°F. (medium high) for six minutes (3, pp. 21-22). Electric coffeemakers were allowed to complete their perking cycle in accordance with their individual thermostat.
5. The Variac was adjusted to maintain 120 volts for the electric coffeemakers and 240 volts for the ranges used with the surface-unit ones.
6. The watt-hour reading, stopwatch time, and end-point temperature were recorded.
7. A portion of coffee from each coffeemaker was allowed to cool and two ounces (56.7 grams) weighed on the triple beam balance (12, pp. 2-3).
8. The weighed beverage was filtered by means of a 65 cm. funnel and #1 Whatman filter paper (12, p. 8).
9. Ten milliliters of the clarified solution was transferred to a shallow aluminum container which had been heated 1 hour. This was placed in a desiccator for 15 minutes and weighed on an analytical balance (12, p. 2).
10. The containers with beverage were then placed in a 100°C. drying oven for one and one-half hours and then were transferred to a desiccator to cool for 15 minutes.
11. The containers were then weighed to the nearest tenth of a milligram on an analytical balance and the findings

were recorded.

12. The difference between the first and second reading was multiplied by a conversion factor of 13.4 to obtain percent of soluble solids per one gallon. This data was then recorded (12, p. 9).
13. Two one-ounce (28.35 grams) samples of coffee were placed in collecting bottles and cooled to 20°C. or 68°F. and their pH measured. The average of the two readings was recorded.
14. Two, 1:10 dilutions of coffee and distilled water were made for each sample and placed in spectrophotometer test tubes (14, p. 2).
15. The spectrophotometer was standardized at 405 mu to distilled water and readings were taken for the two samples.
16. The color index readings for the two samples were averaged and recorded.

IV. INSTRUMENTS AND EQUIPMENT USED IN THE STUDY

Coffeemakers

The eight coffeemakers used were numbered one through ten for ease in tabulation of findings. Numbers one through six were given to the automatic, electric coffeemakers and seven through ten to the non-electric, surface-unit ones. The various models used are listed below according to identifying number, name, wattage and model:

1. West Bend, 490 wattage, 1830
2. West Bend, 490 wattage, 1829
3. General Electric, 660 wattage, A1P15, adjustable thermostat
4. General Electric, 660 wattage, 11P33, adjustable thermostat
5. Sunbeam, 1000 wattage, AP20, adjustable thermostat
6. Hoover, 1000 wattage, 8801
7. Glass, non-electric, tested on conventional range
8. Glass, non-electric tested on smooth-top range
9. Aluminum, non-electric, tested on conventional range
10. Aluminum, non-electric, tested on smooth-top range.

Electric Instrument Panel

Two panels, both containing a Variac, voltmeter, and watt-hour meter were used in conjunction with the coffeemakers. One panel was equipped for use with 120 voltage and the other for use with 240 voltage. The Variac was used to regulate voltage to the manufacturers recommended level and the energy consumed was indicated by the watt-hour meter.

pH Meter

A Beckman Zeromatic pH meter was used to determine the acidity of the beverages prepared in the four replications. The mechanism has a scale from 0-14 and can measure acidity and alkalinity of substances of 0°-100°C.

Stop Watch

A Meylan stop watch, number 25 and precision built in Switzerland was used to measure the time required in the perking process for each

coffeemaker. The instrument measured time in minutes and one-hundredths of a minute.

Gram Balance

An Ohaus Triple Beam Balance was used to weigh the ground coffee and water. Glass beakers of equal size were balanced on the platforms with fractional weights. The ingredients were always weighed in the same beaker to the nearest tenth of a gram.

Analytical Balance

A W. M. Ainsworth and Son analytical balance, type BB and number 37011 was used to weigh aluminum containers to tenths of a milligram before and after 10 ml. coffee samples had been dried in them.

Potentiometer

A Honeywell Brown Electronik potentiometer, model 153X60P16-X-61F1 with a range of 0-800°F. was used to record the temperature of the coffee brew throughout the perking process. The mechanism manufactured by the Brown Instruments Division of Philadelphia, PA. operates on 115 volts at 60 cycles. This instrument recorded the temperature every 30 seconds.

Hygrometer

Humidity and temperature in the control room were recorded by a Honeywell hygrometer, Model 612X9-HT-II-III-IE16-L. Temperatures of 0-100°F. were indicated by means of a needle with green ink and relative humidity of 0-100% on a corresponding needle using purple ink.

Spectrophotometer

The absorbance of color index of each of the 40 samples was obtained through use of a Beckman Spectrophotometer, Model B, at 405 mu wave length with a sensitivity of 1.

Drying Oven

A Thelco oven, serial number 17-608, manufactured by Precision Scientific Company of Chicago, Illinois, was used to dry the 10 ml. coffee samples in the soluble solids portion of the experiment. The oven maintained a heat of 100°C. and operated on 110 volts.

Ranges

The front-left surface unit of a Frigidaire, model RS-10P and the rear-left surface unit of a Corning Counter-range, model P30AB were used for perking the beverages in the non-electric coffeemakers. Both models were operated on 240 volts and 60 cycles of AC current. The coffee was brought to a perk on the high setting of each range and then reduced to 425° or medium high for six minutes.

Refrigerator

A General Electric refrigerator, model 1B3LS was operated on setting one to store the water, ground coffee, and coffee samples during the experiment. The appliance was operated on 50/60 cycles with 115 volts of AC current.

Laboratory Items

The items that follow were used in conjunction with the testing of the samples: desiccator and tongs, shallow aluminum containers,

60 cm. funnels, graduates, pipettes, Centigrade thermometer, titration tube, collecting bottles, stirring rod, #1 Whatman filter paper, and test tubes designed for use with the spectrophotometer.

V. ANALYSIS OF EXPERIMENT

The data collected in the experiment were analyzed statistically with the aid of a statistican, computer programmer, and computer facilities of the University. Analysis of variance (at the .05 level) was used to compare brewing times, and temperatures, temperature differences, pH's, soluble solids, and color indexes resulting from the use of 490, 660, 1000 wattage, and non-electric coffeemakers at two levels of water hardness. The performance of the individual coffeemakers was further analyzed through use of Duncan's New Multiple Range Comparison Test.

CHAPTER IV

RESULTS OF TESTS

I. FINDINGS ON ENERGY CONSUMPTION

The number of watt-hours consumed in the replications using distilled water was similar to the energy used by the two replications using Knoxville water (169.90 watt-hours as compared to 169.95). Thus, hardness of water does not affect the energy consumption of a coffeemaker. The mean watt-hours used by the coffeemakers during their perking cycle was 169.92. The difference in energy consumption by individual coffeemakers was found to be very highly significant, since an F value of 918.4 (probability < .0001) was indicated through the analysis of variance. Values are shown in Table I.

Duncan's New Multiple Range Test was used to separate individual means as the data in Table II show. The results showed that the glass surface-unit coffeemaker tested on the conventional range used significantly more watt-hours than any other maker, whereas the General Electric 660 wattage, model 11P33 used significantly less. In fact, the energy used by the glass coffeemaker with the conventional range was more than triple that used by the aforementioned General Electric model. Each of the six electric coffeemakers used significantly less energy than the non-electric ones. Although there was a significant difference within the electrics, the magnitude of this difference was

TABLE I

F RATIOS FROM THE ANALYSES OF VARIANCE FOR WATT-HOURS, TIME, END TEMPERATURE, TEMPERATURE DIFFERENCE, COLOR INDEX, AND OTHER QUALITY VARIABLES

SOURCE	VARIABLES						
	Watt-Hours	Time	End Temperature	Temperature Difference	Color Index	Soluble Solids	pH
Maker	918.42***	16.62***	119.08***	63.53***	159.11***	373.86***	18.61***
Water Hardness	<1	<1	15.07**	<1	38.42***	75.19***	22.73***
Inter-action	1.54	<1	6.17***	2.37**	1.67	4.41**	5.15**

* = (significant) indicates significance at the 95% probability level

** = (highly significant) indicates significance at the 99% probability level

*** = (very highly significant) indicates significance at the 99.9% probability level

TABLE II

MEAN WATT-HOURS, TIME, END TEMPERATURES, TEMPERATURE DIFFERENCES AND QUALITY INDICATORS OBTAINED USING EIGHT COFFEEMAKERS

Maker	Watt-Hours	Time	End Temperatures	Temperature Differences	pH's	Soluble Solids	Color Indexes
Electric:							
(#4)	096.25[a]	08.47[ab]	156.25[a]	104.00[a]	5.170[d]	1.3175[b]	.510[ab]
(#3)	106.50[b]	07.14[a]	180.00[d]	123.50[b]	5.2125[d]	1.0900[a]	.464[a]
(#5)	113.00[bc]	05.43[a]	172.00[c]	118.25[ab]	5.0750[b]	1.4520[c]	.570[b]
(#1)	115.50[bc]	12.52[ab]	165.70[b]	110.75[a]	5.0875[b]	1.5975[d]	.655[b]
(#6)	118.25[c]	14.95[ab]	188.75[e]	133.00[c]	5.1500[e]	1.3175[b]	.536[ab]
(#2)	132.50[d]	14.46[ab]	181.25[d]	124.00[b]	5.0375[b]	1.7725[d]	.846[d]
Non-Electric							
(#10)	182.75[e]	39.90[c]	207.259[h]	154.50[de]	5.0250[b]	1.6925[de]	.799[e]
(# 8)	205.50[f]	34.07[c]	198.75[f]	146.75[d]	5.0750[b]	1.6050[d]	.626[bc]
(# 9)	306.75[g]	15.20[ab]	210.00[h]	157.25[e]	4.9375[a]	1.8625[de]	.816[d]
(# 7)	322.25[h]	16.52[b]	203.75[g]	152.75[de]	5.6500[b]	1.6750[d]	.700[c]

Numbers lettered the same are not significantly different at the .05% probability level.

Numbers lettered differently are significantly different at the .05% probability level.

less than the difference between the highest electric and the lowest non-electric. Among the electrics, the West Bend 490 wattage, model 1829 used the most energy. Among the non-electrics, the aluminum surface-unit coffeemaker tested on the smooth-top range was the most efficient. Hypothesis one, that the energy consumption of selected low, medium, and high wattage electric and non-electric coffeemakers is equal when preparing similar products, is rejected.

II. FINDINGS FOR VARIABLE TIME

Data showed that the mean time required for all coffeemakers to complete their perking cycle was 16.27 minutes. The range of times was from 5.43 minutes for the 1000 wattage Sunbeam coffeemaker to 34.07 minutes for the glass surface-unit coffeemaker used in conjunction with the smooth-top range. The average time for the aluminum surface-unit coffeemaker was 0.17 minutes less on the smooth-top range and 1.32 minutes less on the conventional range than for the glass surface-unit coffeemaker. Differences in time required for each coffeemaker to complete its perking cycle were found to be very highly significant (probability > .0001) indicating that the amount of time required is directly related to the individual maker.

Duncan's New Multiple Range Comparison revealed that all of the electric coffeemakers and the aluminum non-electric used on the conventional range used significantly less time than either the glass or aluminum surface-unit coffeemakers used with the smooth-top range; in fact, the time required was more than double that of the conventional range which was next highest in time required.

All non-electrics used more time, but those using the conventional range were not significantly greater than the two 490 wattage West Bends, the 660 wattage General Electric, model 11P33, or the 1000 wattage Hoover among the electrics.

III. FINDINGS ON END TEMPERATURE AND TEMPERATURE DIFFERENCE

The mean end temperature for all the coffeemakers was 186.375 and the mean temperature difference was 132.50. The end temperature ranged from 156.25 from the 660 wattage General Electric, model 11P33 to 210°F. for the aluminum surface unit coffeemaker used with the conventional range. Significant differences were found in end-point temperatures of the individual makers with different water hardness (Table I). Among the non-electric coffeemakers, the aluminum coffeemaker used on the conventional or smooth-top range and the glass coffeemaker tested on the conventional range produced significantly higher end-point temperatures than the glass coffeemaker used in conjunction with the pyroceram smooth-top range. The conductivity of aluminum may account for the higher end-point temperatures than the other coffeemakers. The Hoover 1000 wattage coffeemaker reached a significantly higher end-point temperature and the General Electric 660 wattage, model 11P33, a significantly lower end-point temperature than the other electrics.

Since coffeemakers may produce a relatively constant temperature change rather than go to a constant end temperature, this variable was also analyzed. Temperature change or difference was also found to be

dependent on the individual maker. No significant difference in temperature change was found among the four non-electric coffeemakers. However, it should be noted that the aluminum coffeemaker used in conjunction with the conventional and smooth-top ranges ranked first and second, respectively in having produced the greatest temperature change of any of the coffeemakers tested. The 1000 wattage, Hoover coffeemaker yielded a significantly greater temperature change than the other electrics, probably because of its longer perking time. In contrast, the Sunbeam, 1000 wattage coffeemaker and the General Electric, 660 wattage, model 11P33A had significantly less temperature change than any other maker except the West Bend, 490 wattage, model 1830. The results of analysis of temperature change were in agreement with the results from analysis of end temperature, except temperature change was not as efficient as a variable for mean separation. End temperature gave better mean separation using Duncan's New Multiple Range Comparison Test.

The use of tap and distilled water was also compared, and significant differences in both temperature and temperature change resulted. Tap water produced the higher end temperature and the greater temperature change than distilled water. However, the effect of water hardness may have been confounded by environmental temperatures, as room temperatures, room humidity, and water temperatures were noted to be higher when tap water was being used.

There was a very highly significant interaction between water hardness and coffeemaker. This interaction was also indicated best by

the variable "end temperature." None of the electric units had lower end temperatures with tap than distilled water, whereas the reverse was true for the non-electrics. None of the non-electrics had higher temperatures with tap water. The mean values for each type of water with electric and non-electric units are shown in Table 3. Tap water gave 8.8°F. greater mean end temperatures with electric makers, but distilled water gave 2.9°F. greater mean end temperatures with the non-electrics. No explanation is proposed for these results.

IV. FINDINGS ON pH OR ACIDITY

The mean pH for all coffeemakers was 5.0825. All the mean pH's fell within the desirable pH range of 4.90 and 5.20, except the General Electric, 660 wattage, model A1P15, with a reading of 5.21. The General Electric models produced significantly higher pH readings (a flatter taste) and the aluminum non-electric tested on the conventional range produced a significantly lower pH. Thus, the individual maker was found to play a significant role in the pH of coffee.

The two replications prepared using hard water had a mean pH of 5.17 and the two with soft water yielded readings of 5.00, thus, the water hardness was indicated as being a significant factor in coffee quality. Regardless of coffeemaker used, the pH was higher when tap water was used. However, the magnitude of the difference was variable. For the General Electric, model 11P33, the pH difference was only .050, whereas for the aforementioned aluminum coffeemaker it was .275. The variability in the magnitude of the pH difference resulted in a highly

TABLE III

MEAN END TEMPERATURES FOR COFFEEMAKERS OPERATED WITH TAP AND DISTILLED WATER

Type Coffee-maker	Distilled Water	Tap Water
Electric	169.9°F.	178.4°F.
Non-electric	206.4°F.	203.5°F.

significant interaction F ratio (5.15**) in the analysis of variance, as the data in Table I show. Hypothesis two, that the beverages prepared in various wattage and surface-unit coffeemakers are similar in pH,is rejected. This is interpreted as indicating that water hardness is an important determinant of pH of coffee produced by some makers, but not as important for others.

Tap water produced beverages with higher pH and lower solids because the harder the water the more minerals present. Substances such as iron, may hinder the filtration process in coffee brewing and yield products that are slightly alkaline, light in color, and low in soluble solids.

V. FINDINGS ON SOLUBLE SOLIDS

The soluble solids were found to depend on the individual maker, the water hardness, and the interaction of the factors. The mean percent for all the makers was 1.538. The soluble solids present in beverages prepared in the various makers ranged from 1.09 for the 660 wattage, General Electric, model A1P15, to 1.8265 for the aluminum non-electric coffeemaker prepared on the conventional range. The aluminum non-electric tested on the conventional range had greater quantities of soluble solids but not significantly more than the other non-electrics or two of the electrics. The General Electric, 660 wattage, A1P15, produced a significantly lower percent than the other models tested. Results of the test are in Table II. The soluble solids obtained in replications using soft water was 1.57 percent as compared

to 1.50 percent for the hard water. The effect of water hardness on soluble solids was that lower solids were obtained from tap water except that tap water produced a nonsignificantly higher percent solids for the aluminum surface-unit coffeemaker tested on the conventional range (difference of .005). Again, the effect of water hardness varied with the type of coffeemaker, but the interaction was one of a degree of increase in soluble solids using distilled water. The General Electric, 660 wattage, models A1P15 and 11P33 and the Hoover, 1000 wattage, model 8801, were the only coffeemakers to produce beverages within the acceptable range of 1.09 and 1.42 percent. Hypothesis two, that the beverages prepared in various wattage and surface-unit coffeemakers are similar in soluble solids, is rejected.

VI. FINDINGS ON COLOR

There was a significant difference in the mean color index of .671 for the replications prepared with distilled water and .630 for those prepared with Knoxville tap water. Among the various makers a color index of .464 for the General Electric, 660 wattage, model A1P15, to .846 for the West Bend, 490 wattage, model 1829, was read. Figures are shown in Table II. The analysis of variance indicated a significant difference in the color index reading obtained from the samples prepared in the various wattage coffeemakers as the data in Table I show. Using Duncan's New Multiple Range Comparison Test, the West Bend, 490 wattage, model 1829, and the aluminum surface-unit coffeemaker used in conjunction with the conventional smooth-top ranges, were found to produce significantly higher color index readings (darker color). The General Electric,

660 wattage, model A1P15 exhibited the lightest color reading although it was not significantly lighter than the General Electric, model 11P33 and the Hoover, model 8801. The results did not conform to differences in perking time, so perking time alone does not account for color. Hypothesis two, that the beverages prepared in various wattage and surface-unit coffeemakers are similar in color indexes, is rejected.

CHAPTER V

SUMMARY AND CONCLUSIONS

This experiment was designed to analyze the energy consumption of percolator coffeemakers in relation to wattage, brewing time, quality of beverages, and other variables. The study included eight coffeemakers, two 490, two 660, and two 1,000 wattage electrics and two non-electric tested on conventional and smooth-top ranges. One-half of the replications were prepared using soft, distilled water and the others with hard, Knoxville tap water. The Pan-American Coffee Brewing Center's recommendation of 10 grams of regular grind coffee for each 6 oz. (177.28 g.) of water was followed in the preparation of each of the 40 samples.

The study was designed to correspond as nearly as possible to home conditions, therefore, the factors of perking time, beginning temperature of water, and end temperature of water were not controlled. Controls were placed on the following factors of the experiment: type and amount of water, voltage of circuit, and wattage of coffeemaker.

It was hypothesized that the energy consumption of selected low, medium, high wattage electric, and non-electric coffeemakers would be equal when preparing similar products. In addition, it was hypothesized that the beverages prepared in the aforementioned coffeemakers would have similar pH's, amounts of soluble solids, and color index readings.

A third hypothesis was that hardness of water would not alter the quality of the final products. All three hypotheses were rejected after analyses of variance and Duncan's New Multiple Range Comparison Tests were used to analyze the data.

The findings of the experiment revealed that the non-electric coffeemakers consumed significantly more electricity than the electrics. For example, the glass coffeemaker tested with the conventional range used more than triple the number of watt-hours than any electric coffeemaker tested. Even though, there was a significant difference in energy consumed among the electrics, it was less than the difference between energy consumption of the highest electric and the lowest non-electric coffeemaker. Among the electrics, the General Electric 660 wattage, model 11P33 used the least amount of watt-hours and among the non-electrics the smooth-top range tested with the aluminum surface-unit coffeemaker was found to be most efficient.

The non-electrics required the most time to complete the brewing process. Coffeemakers used in conjunction with the smooth-top range required more than double the amount of time required with the conventional range. The time factor for the electric coffeemakers varied with the individual maker and was not exclusively dependent on wattage.

The 660 (moderate wattage) coffeemakers and the 1000 (high wattage) with extended perking time produced the most desirable products in terms of soluble solids and lighter color. All coffeemakers, regardless of wattage, produced beverages with acceptable pH values.

Consumer preferences as to darkness of color, clarity of product, and length of perking time may be prime shopping considerations.

The hardness of water affected the quality of the product produced by each coffeemaker. For each coffeemaker, regardless of wattage, the pH was lower, the soluble solids percent was greater, and the color index darker when soft distilled water instead of Knoxville tap water was used. However, the use of hard water did not change the coffeemakers' rank position in the amount of soluble solids produced.

The end-point temperature was significantly higher for tap water than for distilled water. Further research with controlled beginning water temperature would be helpful in discerning significant differences in end-point temperatures produced by the various coffeemakers. Environmental temperature and room humidity further complicated this aspect of the experiment.

Significant differences were found in the end-point temperatures of the various coffeemakers and these could not be related to any single variable such as wattage. The conductivity of the aluminum surface-unit coffeemaker, may account for its producing the highest end-point temperature and the most temperature difference, than any of the other coffeemakers. The Hoover 1000 wattage coffeemaker reached the highest end point and had the greatest temperature difference among the electrics.

The color of the beverage was not dependent exclusively on the perking time. However, the longer perking period of the aluminum surface-unit coffeemaker and the 490 General Electric did produce darker

beverages than the 660 General Electric, model A1P15. The extended perking time of the non-electric coffeemaker yielded beverages with soluble solids outside the acceptable range of 1.09 and 1.42 percent. The two 660 General Electric and the Hoover 1000 wattage were the only coffeemakers to produce desirable beverages in terms of clarity. The wattage and perking time seem to influence the quantity of soluble solids and color of the coffee products more than they affect pH.

The use of an expanded digital pH meter might aid in determining significant differences in taste quality among various coffeemakers (19). An open avenue of research is a standard for desirable color of coffee. An "ideal" range for spectrophotometer use has not been developed. Thus, an experiment concerning this problem would need to address itself to the color indices produced by various grinds, blends, and brands of roasted, ground coffee. Then, a chart of wavelength readings would need to be plotted and a desirable color range determined.

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VITA

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