A STUDY OF NEWER METALS USED FOR QUANTITY COOKERY UTENSILS

THESIS FOR THE DEGREE OF M. S.

Marcia Slipher

1931

THESIS

Kitchen utensils

Home Economics

A STUDY OF NEWER METALS USED
FOR QUANTITY COOKERY UTENSILS

A thesis submitted to the Faculty of Michigan State College in partial fulfillment of the requirements for the degree of Master of Science.

By

Marcia Slipher
Department of Institution Management
Division of Home Economics

1931

Acknowledgements

The writer wishes to acknowledge with gratitude the helpful advise and criticisms given by Mrs. Mabelle Ehlers and Dr. Marie Dye.

Contents

I. INTRODUCTION

A. Object of Study

Of recent years more consideration has been given the materials used in cooking utensils than for hundreds of years preceding. There are several reasons for this sudden interest in the materials in which our foods are cooked. The standards of proper food preparation are growing more exacting so that we are inquiring whether a given metal or combination of metals is deleterious in any respect to the food cooked in it. Institutions have become vitally interested in more efficient and hence more economical production of cooked foods, and have ceased to accept without question the utensils which tradition prescribed. If some newer metal or alloy made a cheaper or a more durable utensil the institutions have been ready to try it out. Some of the metals which have been tried out in recent years with a view particularly to their use in cooking utensils for institutions are: aluminum both cast and spun, nickel, stainless steels, and Monel Metal. Many aluminum alloys have been experimented with and also various modifications of the original stainless steel.

This study was undertaken to determine the comparative values of aluminum, one of the stainless steels, and monel metal first as to the speed of cooking, second as to discoloration of the utensil, third as to discoloration of the food, fourth as to the effect on the flavor of the food, and fifth as to the solubility of the metal container in the alkalis or acids in the liquor from the boiled foods. A sixth consideration was a comparative study of aluminum and stainless steel steamtable jars with the more usual steamtable jar of earthenware or vitrified china to determine holding quality. This study gives consideration only to conductivity of heat, effect of the container upon the food and the effect of the food upon the container. The cost and the durability of aluminum, monel metal, and stainless steel would give excellent opportunity for further study. Monel metal and stainless steels are so new in their use as cooking utensils that little information on their length of life in relation to their price is to be obtained.

B. Review of Literature.

In reviewing the literature little can be found which has any direct bearing upon the present investigation. The materials studied, with the exception of aluminum, are little used for cooking purposes outside of institutions. The literature is chiefly confined to articles published in institution magazines and advertising booklets of the metal manufacturing companies. Numerous metallurgical books deal with the properties of these metals, but have little direct connection with their use in cooking utensils.

1. Aluminum

In the article "Things you should know about aluminum" in The American Restaurant Magazine, July, 1929, the discovery and process of manufacture of aluminum is discussed in detail ending with the following summary: "From every viewpoint, lightness, economy in first cost, and economy due to extremely long life, economy in fuel due to heat-conducting and heat-retaining qualities, and finally in safety from all harmful action of food acids, aluminum utensils for cooking are in keeping with the modern progressive and scientific spirit of the twentieth century." (1)

Booklets advertising different makes of aluminum utensils tell the history of its manufacture (2) and the qualities which make it give enduring service in kitchens. There are three main reaons why aluminum is able to present an attractive argument to buyers: Its comparative lightness, comparative cheapness and resistance to attack by fruit and vegetable acids.

2. Stainless Steels

Few magazine articles have been published about stainless steels because their use in institution kitchens is so new. The Home Economics News, October, 1930 has an article by Doris W. McCray, which describes Allegheny metal as a stainless, easily cleaned ware having no effect upon food cooked or stored in it. (3)

Many booklets published about Allegheny steel and Enduro describe their "Shiny surface, the ease with which they can be cleaned and kept clean, and their immunity to all forms of food and fruit acids." (4)

3. Monel Metal

Two very similar articles describing the manufacture of Monel Metal by the International Nickel Company were published, one in The American Restaurant Magazine, (5) June, 1929, and the other in The Hotel Monthly, (6) August, 1930. "In the hotel and restaurant business the name Monel Metal has become synonymous with quality, durability and clean, shining surfaces for kitchen equipment." (6) "Today the restauranteur point with equal pride to the 'front' and the 'back' of his house. Bright shiny equipment has made the kitchen a place of beauty, pleasant to look at and more pleasant to work in, maintenance and replacement costs have been reduced to a minimum and the kitchen is no longer eating up the profits." (5)

The International Nickel Company has published numerous illustrated booklets telling of the manufacture and uses of Monel Metal. "Twenty Years of Monel Metal" by Robert C. Stanley gives the many improvements made upon the metal since its discovery in 1905. (7) In "Modern Kitchens" (8) attractive illustrations of the metal are shown and an article explaining its desirable characteristics is printed. The unusual combination of properties found in Monel Metal results in definite economies: saving in cleaning, repair, replacements, and depreciation. (8)

C. Methods Used in Making the Study

The methods used in making this study consisted of a survey of the common metals used in cooking utensils, and of observing foods cooked by various methods in containers made of aluminum, stainless steels, and Monel Metal.

1. Survey of metals used in cooking utensils.

Evidently little has been recorded during the past few centuries about the utensils used for cooking. Archaeologists tell in some of their writings about the means of cooking by primitive man. Careful reading of many books on medieval history and on European modes of living gave some information on the use of copper. Encyclopedias were studied as the best source for information on enamel ware, tin, iron, and retinned steel, and old cook books published in the latter part of the nineteenth century recommend the use of such containers.

Material about the later metals; such as aluminum, nickel, stainless steels, and Monel Metal in cooking utensils was easily obtained from the manufacturing companies and from a few magazine articles. These were read to determine the methods of manufacture and the advantages and disadvantages of each material.

2. The cooking of foods

Various foods were boiled, steamed or baked in the metal containers and scored by judges for tenderness, texture, color, flavor, and in the case of creamed foods for the lack of curdling. Aluminum and stainless steel containers were used for the boiling of vegetables. Monel Metal was omitted in this series of experiments as a container of this metal for boiling foods is not manufactured. Baking and steaming experiments on these same kinds of vegetables were carried out using stainless steel, aluminum and Monel Metal utensils. Cooked foods were placed in vitrified china, stainless steel and aluminum jars and kept on the steamtable for two hours to determine the relative time when deterioration sets in and the rapidity of such deterioration. Creamed foods and mashed potatoes were used as they curdled or deteriorated more rapidly than do others.

3. Chemical tests

Liquor from the foods boiled in aluminum was tested chemically to determine whether there was a solvent action upon the metal. Samples of the foods darkened by steaming in Monel Metal were ashed and tested chemically for the presence of copper and nickel.

D. Source of Information

Little information pertaining directly to the present investigation could be secured from sources other than advertising books or interviews. Although experience has taught individuals the effects of these newer metal containers upon foods, no data has been collected, organized, and published.

Booklets from the International Nickel Company, Allegheny Steel Company, Republican Steel Corporation, and the Aluminum Cooking Utensil Company give definite information as to the procedure of manufacture of the metal, and the proper gages for cooking utensils. The properties which make the different metal containers desirable were discussed. Illustrations of the utensils were used showing its many styles at various prices. Much reliable information was obtained from these sources.

An interview with Mr. Addison, Chairman of the Board of Directors of the Stearnes Company, an institution equipment firm, furnished further interesting information. He has done some experimental cookery using different kinds of metals for utensils in steaming foods. He was kind enough to give his results from his study and also some effects of cooking foods in metal utensils which had been given him by his customers.

II. METALS USED IN THE FABRICATION OF COOKING UTENSILS

A. History

The earliest cookery was probably accomplished without the aid of any utensils, the food being roasted by burying it in hot ashes or cooked by the aid of heated stones. (9) Later wooden vessels carved from pieces of cedar logs were used for boiling foods. Hot stones were put into the vessel to heat the contents. Pottery was made from clay and also used for cooking utensils. "There were an abundance of seething pots all over the world composed of wood, grass, clay, or stone." (10) Of course utensils of such material could not be placed over a fire but they could be filled with water and hot stones thrown into the water which heated it sufficiently to cook any food which might be placed therein. Seething is a term used to describe this method since it is not quite the same as boiling.

During the Bronze Age people learned how to smelt copper and tin from ores, but it is doubtful if any of the metal was used for cooking utensils, since it is known that they considered them valuable enough for ornaments.

Iron has been used by man for more than 2000 years. Aristotles (384-322B.C.) described the manufacture of Indian steel. (11) In ancient times, 5000 B.C. to A.D. 476, food was roasted over the fire in pots probably made of wood or copper. In Assyria and Babylonia very elaborate utensils of gold and silver were used. In medieval times until the reign of Charlemagne it is useless to try to trace race characteristics among the hordes which swept down from northern Europe upon Rome. Roman culture was lost and for food customs one must turn back to barbaric people. (12)

After the Renaissance elaborate utensils of copper, gold, and silver were again used. During modern times, 1500 to the present, the restaurants have been developed, and iron and copper kettles used for cookery. In 1893 Ella Kellogg writes in her book "Science in the Kitchen", "Modern cookery necessitates the use of a greater or less variety of cooking utensils to facilitate the preparation of food. Most of these utensils are manufactured from some kind of metal as iron, tin, copper, brass or retined steel." (9) Porcelain or granite ware was introduced in the form of cooking utensils in the later part of the nineteenth century and was considered safe and very desirable. Since 1900 great changes have been made in the kinds of metals used for cooking utensils and now aluminum has become a very popular metal for containers. Still newer are stainless steels and Monel Metal made into containers for cooking foods. So far the two latter are little used except in institution kitchens. Nickel has been tried in a few institution kitchens, but has not been very successful.

B. Metals Used for Institution Cooking

1. Decrease in the use of Copper, Enamel, retinned Steel, Iron and Tin.

From the early restaurants in 1500 to almost the present time copper has been used for cooking utensils. Containers made of copper are not to be recommended because of the discoloration of some foods and their metallic flavor, although many cooks esteem them because copper is a very good conductor of heat. Copper is very heavy and now that women are being employed in institution kitchens it is being discriminated against for that reason. It is also a well-known fact that copper discolors and turns some food green which means that care must be taken to keep the copper refinished and clean. Regardless of these facts it is still used in many institution kitchens especially where foreign chefs are employed and most jam kitchens use it exclusively.

Tin and iron have been and are still used for many purposes in institution kitchens, however, not to so great an extent as formerly. What is called tin in kitchen utensils is really a sheet of iron plated with tin. Retinned steel is the same, except that steel has been used in place of the iron and an extra heavy coating of tin placed on the steel. Tin is still used a great deal for such utensils as: bread pans, pie pans, muffin pans, cake pans, etc. Iron especially cast iron is used today for deep frying kettles, frying pans, and griddles, but it has the disadvantages that it is heavy and rusts easily.

Porcelain, enamel, or granite ware are all sheet iron containers coated with a hard smooth enamel. Enamel ware of even the highest grade is likely to be injured by excessive heat which by making the iron expand faster than the glaze cracks the latter. It is also liable to be affected by acids whenever there is the slightest break in the continuity of the surface of the enamel. When once acid penetrates the surface so that it can act on the iron underneath, it will gradually undermine the glaze so that it peels off. (13) Care must be taken in handling enamel ware so that bumps do not cause the enamel to break off. A chipped enamel pan is dangerous to cook food because the enamel may break off into the food at any time. Enamelware when intact is a very satisfactory material in which to cook since there is no action on the enamel by food acids or alkalis. It is inexpensive, light in weight and may be very attractive in color. Since it does not wear well, however, it is less and less used by institutions.

Retinned steel is used rather more now than either copper or enamelware. Acids do affect the tin and care must be taken to keep the utensil well covered with tin or the steel will rust and corrode, but it still has its place in the institution kitchen. It is heaview and more expensive than tin or enamel-ware, but less so than copper or aluminum.

Recently nickel has been tried for utensils in institution kitchens, because it is not affected by food acids and alkalis and because of its great durability. It is very heavy, however, and so far few institutions have used it.

2. Present trends in metals used for institution cooking.

Three relatively new matals are being made now to replace the older copper, iron, tin, enamel and retinned steel utensils used in institutions. Alumiinum has been known and used for several decades, but it is becoming constantly more popular due to improvements in its fabrication. Stainless steels are alloys made by several companies each using a different per cent of composition of steel and chromium.

Only very lately has it been made into cooking utensils. Monel Metal is an alloy metal made from an ore containing Nickel and copper and is controlled entirely by one company in the United States. Some types of cooking utensils are now being made from Monel Metal for institutions. It is heavier than aluminum and stainless steel so is not so desirable as them for large kettles which must be lifted often.

a. Aluminum.

Aluminum is never found native, but in the form of oxides. All the commercial supply comes from a clay called bauxite. Aluminum has a great affinity for oxygen and is covered almost immediately with an oxide. In 1824 it was first produced when Oersted succeeded in making it by heating aluminum chloride with potassium amalgam. It was Charles Hall who first extracted aluminum in commercial quantities from a clay-like ore. It was in his mother's woodshed, back of the rambling old homestead in Oberlin, Ohio that he set out in 1885 to discover a process for making aluminum cheaply. Up to this time aluminum had been obtained only with chemicals, slowly and at a prohibitive cost. In February 1886 Hall began his new series of original experiments, passing a current of electricity through his liquified mixture of clay and carbon and so produced aluminum. (2) It cost five dollars a pound until 1887 when inventions in other fields were applied to aluminum and the cost fell to twenty cents a pound. (14)

Aluminum is fabricated in two forms for cooking utensils; sheets and cast. "The sheet aluminum is cut into shapes, round and rectangular, the sizes being determined by the sizes of the utensils to be made from them. The pieces of sheet metal are taken to large presses or stamping machines. The machines are provided with a stationary socket, having the form of the exterior of the utensil to be shaped in it, and a solid steel die fastened to a moving piston. The operator places a piece of sheet metal over the socket, presses a lever, and down comes the die with enormous force, stamping the disk into the socket. Thus the sides and bottom of a utensil are made without seam or solder--are one continuous piece of metal." (15) Cast aluminum is said by some manufacturers to be superior to sheet, because it is thicker, will not dent and has no parts upon which there is a strain. Aluminum utensils made from sheets have a strain where the sides are bent up from the bottom, but cast aluminum avoids this strain by being molded. (16) Cast aluminum has been much improved in the last few years and has a better finish than was formerly the case. Aluminum alloys are being experimented with and some are appearing on the market in the form of cooking utensils having very desirable properties.

b. Monel Metal.

"An interesting example of the inadvertent pro duction of a useful alloy is the smelting of a nickel-copper compound, known to-day as German silver, that was smelted in ancient days from a complex sulfide ore by the Chinese in Yunnan. They made this alloy, which was named peitung or paktong meaning white copper, in the time of the Hou dynasty from 221 B.C to A.D. 25. "It contained 16% nickel and 80% copper. The percent of composition in German silver is very nearly the reverse of that of Monel Metal, however, it is interesting to know that an alloy of copper and nickel was made in ancient times. Monel Metal is made only by the International Nickel Company as they have exclusive rights to the matte coming from the Sudbury district, Canada, the only place it occurs in large quantities. It is a natural alloy made from refining a nickel-copper ore instead of separating the respective metals. At first no attempt was made to regulate the amounts of each metal which went into the alloy, but now those are made relatively the same for all the refined alloy, being approximately two-thirds nickel and one-third copper. The ore is shipped from Canada to the refineries in Huntington, West Virginia for manufacture. The first step in refining the ore or matte is to crush it. The matte is then passed into furnaces of tremendous heat which transforms the sulfide ore into an oxide ore. This ore is then refined by the electric furnace or open hearth process much as iron ore. It is possible to make Monel metal synthetically, but the process is so expensive that it is not practical.

Monel Metal is ductile, flexible, and easily worked, and can be readily soldered or brazed. The combined properties of ease to clean, hard dense surface, and rust and corrosion resistance have made Monel Metal containers desirable in institutions dealing with food. It is fabricated into sheets and then made into cooking utensils from these. Since it is necessary to solder the parts of the utensils together it has not yet been made into round utensils as steamtable jars and kettles. The gages of Monel Metal vary from twenty-five to ten so that it can be fabricated for many uses. (8)

c. Stainless steels

Stainless steels are the newest metal alloy used for institution equipment. "The production of chromium steel is not by any means new, in fact the literature of iron and steel metallurgy during the nineteenth century and the first ten years of the present century contains many references to the preparation of chromium steels and to some of their properties." (18) An alloy called ferro-chromium was made in 1876 by Baur a German chemist. Alloys of this type were first produced commercially by Dr. Benno Strauss, of the Krupp Work, Essen, Germany. They have been extensively used in Germany since their introduction, particularly the well-known alloy V2A, but until recently have attracted little or no attention in this country. The Enduro ware known as KA2 manufactured by the Republic Corporation is similar to the German alloy used in the Krupp works except that it contains some nickel which gives it a greater resistance to corrosion. There are now seven formulas by which stainless steels are made. Six of these are of German origin and the seventh an English formula is now used by the Allegheny Steel Corporation in the United States.

Stainless steel was first introduced to the public in 1914 in the form of cutlery. However, this use of stainless steel has not been found satisfactory for institutions since such knives do not hold an edge. Since 1919 much progress has been made in the manufacture of stainless steel kitchen equipment and utensils.

Table 1 gives in comparative form the properties and relative prices of aluminum, stainless steel and Monel Metal.

Table 1. Comparison of Aluminum, Stainless Steels and Monel Metal

Substances	Composition	Corrosion	Specific Gravity	Hardness	Effects of Acids & Alkalies	Thermal conductivity	Color	Cost
Aluminum	Element	Most corrosive aluminum oxide forms to prevent further corrosion. Acid air or alkaline water corrodes aluminum.	2.70±	Brinnel 25	Not affected by organic acids. Alkalis readily decompose it.	Good conductor of heat.	Whiteish blue Does not take high polish.	Relatively inexpensive.
Monel Metal	Alloy of Copper and nickel Nickel 68-72% Copper 26.5-30.5% Iron 1.5%	Great resistance corrodes slightly by some inorganic acids.	8.80	Brinnel 120-250	Resists all organic acids and alkalis.	Similar to Allegheny Steel, but heats somewhat quicker.	Bluish takes fairly high polish	almost as expensive as Stainless steels
Stainless steel	Alloy of iron Chromium and often nickel Nickel 0-8% Chromium 9-16% Iron Varies with other metals Carbon below 0.4%	Least Corrosive	7.65	Brinnel 151-365	Little effect	Retains heat, but not a very good conductor.	Like nickel in color. takes a very high polish	The most Expensive.

(19, 20, 21, 22)

III. Comparison of Aluminum, Stainless Steel, and Monel Metal for Quantity Use.

Five series of experiments were carried out to determine the effect of metals and foods upon each other. New containers of aluminum, stainless steel, and Monel metal were used for all the studies. In two of the cases it was necessary to omit Monel Metal, because it was impossible to purchase it in steam-table jars. All foods were prepared for cooking under standard conditions, only fresh vegetables being used. Such vegetables as carrots, potatoes and rutabagas were peeled in an institution vegetable peeler. The food, with the exception of that boiled, was prepared in quantities large enough to serve from 125 to 140 people. The foods in each container were cooked under as nearly the same conditions and temperature as possible.

The cooked foods were scored by three judges, all in the college institution management department. The following score card was used with twenty-eight representing a perfect product. The score card was adapted from the grading chart suggested by Marion D. Sweetman in her article "Scientific Study of Palatability of Food." (23)

A. Boiling Experiments

An aluminum and a stainless steel steamtable jar having a diameter of eight inches and a capacity of four and one half quarts were used as containers in which to boil the vegetables. The foods were

Table 2. SCORE CARD

	7	6	5	4	3	2	1	score
Tenderness	Very tender	tender	moderately tender	slightly tough	tough	very tough	extremely tough	
Texture	extremely fine	very fine	fine	slightly coarse	moderately coarse	coarse	very coarse	
Color	excellent	very good	good	mediocre	poor	very poor	extremely poor	
Flavor	excellent	very good	good	flavorless	poor	very poor	extremely poor	
Total								

cleaned, peeled when necessary, and divided in half, one half being put into each utensil. The same amount of soft water, at the same temperature, usually from 25° to 35° Centigrade was put on each vegetable. An institution sized gas range was used to cook the food, care being taken to have both containers receive as nearly the same amount of heat as possible. The vegetables were cooked in each container the same length of time. It was not considered necessary to boil more vegetables then was needed for good scoring samples since many vegetables are not cooked by boiling in most institutions and hotels. Records were kept of the temperature of the water when the food was placed on the range, the length of time it took the food in each container to come to a boil, and the length of cooking time. The boiled foods were placed on plates immediately after taking from the stove and scored by three judges. Any discoloration of the kettles on the food was noted and the degree of intensity in either case. The color of the liquor in which the foods were boiled was also observed. The following list of vegetables were boiled, scored, and studied in this manner; potatoes, rice, spinach, cabbage, cauliflower, rutabagas, asparagus, and rhubarb.

B. Baking Experiments

In the baking of vegetables, pans made from the three metals, aluminum, stainless steel, and Monel Metal measuring 12 x 20 were used. The aluminum baking pan was cast ware, but the stainless steel and Monel Metal ones were made of metal sheets of nearly the same gage. The foods were prepared by standard methods, a vegetable peeler being used for the potatoes. In the case of au gratin foods medium white sauce and bread crumbs were used. The rice pudding was made with eggs, sugar, milk, and rice which had been boiled in an enamel utensil. The same amount of food was put into each container and baked in an electric oven of even temperature throughout. The vegetables in each pan were cooked the same length of time and were judged by the score card used for boiled foods except that special attention was given to curdling when milk was used in the preparation of the food. Records were kept of the baking time, amount of curdling, discoloration of the food and container, and distribution of tenderness throughout the pan. The foods studied by baking were; escolloped potatoes, cabbage au gratin, onions au gratin, sweet potatoes, rice pudding, and tomatoes.

C. Steaming Experiments

Metal steamers 8 1/2 x 8 1/2 x 17 inches made of aluminum, Monel Metal and stainless steel were used for the series of experiments on steamed foods. All vegetables were prepared by the standard methods, some being skinned by the vegetable peeler. The same amount of food was put into each of the containers which were placed in a sectional steamer for cooking. Care was taken to have the same temperature for all the steamers of food. When the food was done portions of it were removed and scored by the judges as in the previous experiments. The time necessary for steaming the food, and the discoloration of both the food and the metal was recorded. Potatoes, rice, cabbage, carrots, onions, spinach, cauliflower, and asparagus were steamed in the manner explained above.

D. Steamtable Experiments

Jars made of vitrified china, aluminum, and stainless steel having a capacity of four and one half quarts were used for holding foods on the steam-table. The foods were prepared by standard methods in the kitchen. The vegetables were steamed and seasoned as for usual serving. Medium white sauce was used for the creamed vegetables. Fresh spinach, creamed potatoes and creamed cabbage were allowed to stand on the steam table for two hours. Mashed potatoes were tested three times, twice using common storage potatoes of the Green Valley variety, and the third time using new spring potatoes shipped in from the south. Milk and salt were added to the mashed potatoes. Two hours is as long as any one container of food would be likely to stand on a steamtable during the serving period, so that was considered a reasonable time limit for the vegetables to be kept. The mashed potatoes, however, were held on the steamtable at least three hours so that more marked results in the deterioration could be noted. The foods were scored by the judges every half hour the first hour they were kept on the steamtable and every fifteen minutes thereafter. This procedure for scoring was used because food appears to deteriorate much faster after the first hour than before.

E. Chemical Tests

1. Aluminum

The liquor from the foods boiled in the aluminum steam table jar was collected and put through a series of three fluted filters to eliminate the insoluble matter. The filtrate was tested for aluminum as follows. To five cubic centimeters of the filtrate five cubic centimeters of Normal hydrochloric acid, five cubic centimeters of three normal ammonium acetate and five cubic centimeters of aluminon reagent or alizarin red was added. After mixing to allow the lake formation to take place the solution was made alkaline by the addition of a solution containing equal parts of ammonium hydroxide and ammonium carbonate. A bright red precipitate persisting in the alkaline solution indicated the presence of aluminium. (24) The liquid from all the boiled vegetables; potatoes, rice, cabbage, carrots, celery, cauliflower, onions, rutabagas, spinach, tomatoes, rhubarb, and asparagus was tested by this method.

2. Copper and Nickel.

A sample of all the foods which were discolored when steamed in Monel Metal containers was collected and a raw sample of each of the foods was also prepared to use as a check. The samples were evaporated to dryness in a Freas electric oven and ignited in an electric muffle furnace to a white ash. The ashed material was dissolved in concentrated nitric acid. Five cubic centimeters of this solution was neutralized with ammonium hydroxide, then a slight excess was added. A blue color at this point indicated the presence of copper. If a red precipitate appeared when five cubic centimeters of dimethyl glyoxine was added, nickel also was present. (24)

IV. Discussion

The cooking of food in aluminum, stainless steel, and Monel Metal showed very definite advantages and disadvantages in the use of each metal for containers. The score card used was found successful, since in most cases the judges were in close agreement.

A. Boiling Experiments.

Records of the time it required the vegetables in aluminum and stainless steel to reach a boil show very definite results.

A study of Table 3 shows very clearly that foods in all cases boiled more quickly in aluminum than in stainless steel. It must be remembered that in both utensils the water was at the same temperature when placed on the range, but that the temperatures were not the same for all kinds of vegetables. During cooking the vegetables in the stainless steel utensil boiled more vigorously around the edge and burned to the sides of the container. Nothing of the sort could be noted in the aluminum utensil. Considering the fact that food boiled more slowly and that it burned to the sides of the stainless steel utensil it is evident that it does not conduct the heat as readily as aluminum.

Table 4 showing the average score of all the judges for the boiling experiments indicates that although in more cases the vegetables cooked in aluminum received the highest score the differences were not in most cases very great and stainless steel evidently does not always affect the vegetables which

Table 3. Minutes Required to Reach Boiling Point

Vegetables	Aluminum	Stainless Steel	Difference in time
Asparagus	11	13	+2
Cabbage	11	13	+2
Carrots	3	4	+1
Cauliflower	3	4	+1
Celery	5	6	+1
Onions	2 1/2	3	+0.5
Potatoes	12	16	+4
Rice	4	6	+2
Rhubarb	3	4	+1
Rutabagas	3	4	+1
Spinach	3	4	+1
Tomatoes	3	4	+1
		Total difference	+17.5
		Average Difference	+ 1.5

Table 4. Average Scores for Boiled Vegetables

Vegetables	Aluminum	Stainless Steel	Difference in time
Asparagus	27	24	+3
Cabbage	25	28	-3
Carrots	23	21	+2
Cauliflower	28	25	+3
Celery	25 1/2	22	+3 1/2
Onions	20	25 1/2	-5 1/2
Potatoes	28	26	+2
Rice	13	14 1/2	-1 1/2
Rhubarb	23	20 1/2	+2 1/2
Rutabagas	16 1/2	15	+1 1/2
Spinach	26	23 1/2	+2 1/2
Tomatoes	28	23	+5

Total difference +15
Average difference +1.25

are cooked in it. The scoring of vegetables cooked in aluminum indicates that in nine cases out of the twelve they had better, flavor, color, texture and were more tender than those cooked in stainless steel.

The records kept of boiling vegetables in aluminum and stainless steel show discoloration of the utensil in many cases. From Table 5 an objection to aluminum is evident since it shows discoloration in more cases and many times in a greater degree than stainless steel. This darkening of the kettle is harmless and can easily be taken out by boiling acid foods in it or vinegar may also be used successfully. Foods which contain a large amount of starch as rice and potatoes discolor aluminum much more readily than do such acid foods as rhubarb and tomatoes. No like conclusion can be drawn for stainless steel since potatoes discolor it intensely, but rice has no more effect on it than do the acid foods.

B. Baking Experiments

Results of significance were obtained from baking foods in aluminum, stainless steel, and Monel Metal pans, although little discoloration of the utensils was found. The average scores for baked vegetables (Table 6) does give one fairly obvious result; that foods which were baked in an aluminum pan had the best color, texture, quality, and flavor. It was noted that foods baked in stainless steel and Monel Metal pans cooked or even burned around the sides and remained raw or partially done near the center of the

Table 5. Utensil Discoloration from Boiled Vegetables

Vegetable	Aluminum	Stainless Steel
Asparagus	No discoloration	No discoloration
Cabbage	No discoloration	very dark discoloration
Carrots	No discoloration	very slight discoloration
Cauliflower	slight discoloration	slight discoloration
Celery	slight discoloration	no discoloration
Onions	dark discoloration	no discoloration
Potatoes	slight discoloration	very dark discoloration
Rice	very dark discoloration	no discoloration
Rhubarb	no discoloration	no discoloration
Rutabagas	slightly discolored	no discoloration
Spinach	discoloration	no discoloration
Tomatoes	no discoloration	no discoloration

Table 6. Average Scores for Baked Vegetables

Vegetables	Aluminum	Stainless Steel	Monel Metal
Escalloped Potatoes	26	26	26
Cabbage Au Gratin	28	25	24
Onions Au Gratin	28	26	24
Sweet Potatoes	26	24	24
Rice Pudding	23	24	22
Tomatoes	24	24	24

utensil. Indicating that these metals did not conduct the heat in a suitable manner for cooking foods. The only discoloration noted was in the case of rice baked in Monel Metal.

Table 7 shows the amount of curdling found in baked foods which contained milk. When just the word curdling is used in the table a stage between slight and extreme is meant. This curdling would not be significant if the food had not been cooked for the same length of time and at the same temperature. It is evident that foods curdled most in Monel Metal and least in stainless steel. Some distinct property of a metal cannot be given as a cause of the curdling, however, the results would indicate that metals may have some influence upon the curdling of foods containing milk.

C. Steaming Experiments

Table 8, the averages of the scores for steamed vegetables shows very clearly that foods cooked by steaming in aluminum are superior or equal in all cases studied to those cooked in stainless steel or Monel Metal. In the cases of most of the vegetables those cooked in the Monel Metal steamer were much inferior to those from the other two utensils.

Table 9 shows that much of this inferiority was due to the decided affect upon the color of the foods. In no case did aluminum affect the color of the food and stainless steel did only slightly in two cases. The Monel Metal steamer was more easily discolored than the other two. Mr. Addison of the Stearnes

Table 7. Curdling of Baked Foods Containing Milk

Vegetables	Aluminum	Stainless Steel	Monel Metal
Escalloped Potatoes	no curdling	no curdling	no curdling
Cabbage Au Gratin	curdling	slight curdling	extreme curdling
Onions Au Gratin	no curdling	no curdling	slight curdling
Rice Pudding	curdling	slight curdling	extreme curdling

Table 8. Average Scores for Steamed Vegetables

Vegetable	Aluminum	Stainless Steel	Monel Metal
Potatoes	26	24	16
Rice	27	22	10
Cabbage	26	25	23
Carrots	27	27	27
Onions	26	26	24
Spinach	27	27	27
Cauliflower	27	27	23
Asparagus	23	23	23

Table 9. Discoloration of Steamed Vegetables by Utensil

Vegetables	Aluminum	Stainless Steel	Monel Metal
Potatoes	no discoloration	no discoloration	very dark grey
Rice	no discoloration	dark grey	no discoloration
Cabbage	no discoloration	no discoloration	light grey
Cauliflower	no discoloration	no discoloration	light grey
Spinach	no discoloration	no discoloration	no discoloration
Carrots	no discoloration	no discoloration	no discoloration
Onions	no discoloration	no discoloration	dark grey
Asparagus	no discoloration	light grey green	dark grey

Company said that some of his customers reported that potatoes, rice, and cabbage were discolored when steamed in Monel Metal containers. Table 10 supports his statement. It was found that rice was the only food when steamed in aluminum which was discolored and that cabbage was the only one affected in a like manner by stainless steel.

D. Steamtable Experiments

Spinach, creamed potatoes, and creamed cabbage when kept on the steamtable two hours in vitrified china, aluminum and stainless steel jars showed a marked deterioration in all containers. The color and flavor deteriorated most and rather rapidly after the first hour and a half. The food in the vitrified china and stainless steel kept much better than did that in the aluminum container. Vegetables in the aluminum jar began deteriorating before foods in the other containers and cooked to the sides of the utensil before the end of two hours. Mashed potatoes were tested three times keeping them on the steamtable three hours. By the end of two hours and a quarter the food in all containers had discolored and lost flavor and fluffiness. Like the other foods tested the mashed potatoes cooked to the sides of the aluminum jar.

Table 11 shows the average scores for the food kept on the steamtable. It is evident from these scores that food does not keep well in aluminum on the steamtable, but that vitrified china does hold it

Table 10. Utensil discoloration from Steamed Vegetables

Vegetable	Aluminum	Stainless Steel	Monel Metal
Potatoes	no discoloration	no discoloration	very extreme discoloration
Rice	very extreme discoloration	no discoloration	very extreme discoloration
Cabbage	no discoloration	slight discoloration	very extreme discoloration
Carrots	no discoloration	no discoloration	no discoloration
Onions	no discoloration	no discoloration	slightly discolored
Spinach	no discoloration	no discoloration	no discoloration
Cauliflower	no discoloration	no discoloration	no discoloration
Asparagus	no discoloration	no discoloration	no discoloration

Table 11. Average Scores for Steamtable Vegetables

Vegetables	Aluminum	Stainless steel	Vitrified China
Cabbage (Creamed)	23	25	26
Potatoes (Creamed)	24	26	27
Spinach	23	26	28
Potatoes (Mashed)	23	24	27

well and that stainless steel is rather superior to aluminum also but not as good as vitrified china. This should be noted as the first time aluminum did not come first in the scored foods and in this case it is not even first in relation to the metal container. Further experimental work on holding foods in metal jars on the steamtable should be carried out to determine more conclusively the best material to use for such containers. If possible for use on the steamtable, metal containers are economical, because the food can be cooked in them and the jars transferred from the range to the steamtable without the use of an extra utensil.

E. Chemical Tests

1. Aluminum

The liquid from twelve boiled vegetables cooked in aluminum was tested for traces of this metal, and from the results it is evident that aluminum is not soluble in the liquid from most foods (Table 12).

The fact that potatoes, rice and cabbage gave positive tests for aluminum does not mean that these foods when cooked in an aluminum utensil would be in the least injurious or harmful. The test was so delicate that one gram of aluminum in four million liters of water could be detected. This means that the aluminum was present in very minute quantities. Alum baking powders contain more aluminum than could be got from foods cooked in aluminum kettles and people use it every day without harmful results. It

Table 12. Aluminum test

Vegetables	Positive	Negative
Potatoes	+	
Rice	+	
Cabbage	+	
Celery		-
Onions		-
Carrots		-
Tomatoes		-
Cauliflower		-
Rutabagas		-
Asparagus		-
Rhubarb		-
Spinach		-

is an erroneous idea that an injurious amount of aluminum is got from foods cooked in containers of this metal.

2. Copper and Nickel

When foods darkened by steaming in Monel Metal were tested chemically no positive results were obtained although very delicate tests for copper and nickel were used. This would indicate that neither of these metals cause the discoloration of the vegetable.

F. Summary of the Discussion

In general vegetables cooked in aluminum utensils had better flavor, color, texture, and were more tender than those cooked in stainless steels or Monel Metal. However, many of these vegetables discolored the aluminum utensil. In baked creamed dishes less curdling was observed in the aluminum container.

Stainless steel is slightly darkened by cabbage, carrots, cauliflower, and potatoes. When vegetables cooked in stainless steel darken the kettle they seem to acquire a slight metallic taste. Heat is not conducted well by the stainless steel containers and the foods easily burn on the sides while that in the center remains partially cooked.

Monel Metal conducts the heat somewhat better than stainless steel, but is much inferior in that respect to aluminum. Starchy foods as rice and potatoes darken and are darkened when cooked in Monel Metal. Cabbage and onions are also affected in the same way, but to a less degree. In baked dishes containing milk extreme curdling occurred when the food was cooked in Monel Metal.

On the steamtable foods retain their original, flavor, color, and texture longest if kept in vitrified china. Stainless steel however makes a very acceptable substitute. Aluminum is very poor for steamtable jars and Monel Metal cannot be purchased in this style of utensil.

Rice, potatoes, and cabbage when tested chemically show very slight amounts of aluminum present after cooking in a utensil made of that matal. Very delicate nickel and copper tests on foods darkened when steamed in Monel Metal give no results, indicating that these metals do not affect the color of the food.

V. Conclusions

A. Aluminum is the best metal for cooking utensils although it is discolored by some fruits and vegetables. In the case of steaming foods stainless steel may be substituted.

B. Monel Metal and stainless steel do not conduct heat readily enough to be used in cooking utensils where heat conductivity is important.

C. Vitrified china jars hold food on the steamtable better than metal containers, but stainless steel may be used as a substitute.

D. Rice, potatoes, and cabbage after cooking in aluminum show a very faint positive test for this metal, however the aluminum present is not in large enough quantities to be injurious.

VI. Bibliography

1. "Things You Should Know About Aluminum," American Restaurant Magazine, Vol. 12, No. 7, p. 66.

2. "The Aluminum Age," Edward Mott Woolley.

3. "Facts for Food Teachers," Doris McCray, Home Economics News, Oct., 1930, p. 8A.

4. "Soda Fountains, Refrigerators, Cold Beverage, and Food Handling Equipment," Allegheny Steel Corporation.

5. "Manufacture and Uses of Monel," American Restaurant Magazine, Vol. 12, No. 6, p. 84.

6. "How Monel Metal is Manufactured," Hotel Monthly, Vol. 38, No. 449, p. 69.

7. "Twenty Years of Monel Metal," Rovert C. Stanley.

8. "Modern Kitchens," International Nickel Company.

9. "Science in the Kitchen," Ella Kellogg.

10. "Woman's Share in Primitive Culture," O. T. Mason.

11. "Metallurgy," Hatfield.

12. "Outline on the History of Cookery," Barrow and Shapleigh.

13. "Encyclopedia Britannica," Vol. 9.

14. "Encyclopedia Britannica," Vol. 2.

15. "The Story of Wear-Ever," Aluminum Cooking Utensil Company, p. 4.

16. "Wagner Cast Aluminum Hotel Ware," Wagner Aluminum Company, p. 2.

17. "The Early Use of Metals," Rickard, Journal of the Institute of Metals, Vol. 43.

18. "Stainless Iron and Steel," Monypenny.

19. "Corrosion-Resistant, Heat-Resistant, and

-19

Electrical-Resistant Alloys," American Society for Testing Metals.

20. "The Metallurgy of Aluminum and Aluminum Alloys," Anderson.

21. "Principles of Metallurgy," Fulton.

22. "The Metallurgy of the Non-Ferrous Metals," Gowland.

23. "Palatability of Food," Marion Sweetman, Journal of Home Economics, Vol. 23, No. 2, p. 163.

24. "Qualitative Analysis," Baskerville and Curtman.