THE EFFECT OF ROASTING ON THE CHEMICAL COMPOSITION OF PORK LOIN

by

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INTRODUCTION

The general subject of food analysis is one that should be of interest not only to the doctor and dietitian, but to all consumers of food. Ordinary individuals should have an intelligent conception of the role played by the various nutrients in the metabolism of matter and energy in the body.

During the past two decades, the study of the principles of dietetics has been given increased attention in the curricula of many of the technical schools and colleges of our country. Much has been accomplished along this line by many State Experiment Stations working often in connection with the United States Department of Agriculture.

Investigations of this character are especially valuable and are indeed rendered necessary by the general tendency of the modern physician to regard the hygienic treatment of disease, especially with reference to the matter of diet, as of far greater importance than the mere administering of drugs.

In spite of the attention that has been given to the study of nutrition in the past twenty years, there is still much to be accomplished in this field. There is a need for

more analyses of cooked foods, at least of those foods generally consumed in this way, and also of more analyses comparing the chemical composition of various foods before and after cooking. Such analyses would be valuable to the dietitians and nutritionists who are in need of such information at the present time.

In view of the extent to which meat is used in our American diet, there has been surprisingly little work reported on meat, and particularly on pork. Hence, with a desire to supplement other analyses of similar nature sponsored by the Department of Food Economics and Nutrition of this college in the study of the chemical composition of meats before and after cooking, the present work is devoted to the effect of roasting on the chemical composition of pork loin.

REVIEW OF LITERATURE

As early as 1852 von Liebig (14) gave percentage tables containing analyses of various body tissues. His analyses consisted of determinations for nitrogen, carbon, hydrogen, oxygen, phosphorus and sulfur. While he mentioned that animal tissues also contain the "inorganic constituents of iron, lime, magnesia, common salt and the

alkalies", no quantitative findings were given. He also gave empirical formulas for various body tissues determined by Mulder and Scherer. Von Liebig's investigations were not of a purely chemical nature, his object being to show the relation between the chemistry and the physiology of the body, especially in the formation of tissue from blood. Liebig was certainly one of the earliest investigators in the field of tissue analysis which led up to the analysis of various food products.

However, the history of systematized food analysis dates back only about sixty-five years. The earliest investigator to publish comprehensive tables appears to have been König (12) who compiled from his own analyses and those of others a very large number of figures. This work was for many years one of the chief sources of information of food analyses of American food products, but they were not grouped by themselves, nor were they readily available for American use.

Until about 1880 those desiring data concerning the chemical composition and nutritive values of food materials were compelled to depend upon analyses of European products.

The first extended series of investigations of American food products was made in the years 1878-1881 by Atwater (2) under the auspices of the United States Fish Commission.

This included a large number of analyses of fishes and invertebrates. In connection with his work, analyses of meats and other food materials were made under the auspices of the Smithsonian Institution.

In 1896, Atwater and Woods (4) published tables giving the maximum, minimum and average of all the analyses which had been made of American food products up to that date. This bulletin has since then been revised and has provided the basis for most dietary calculations in this country. The tables included analyses for refuse, water, protein, fat, carbohydrates, ash and fuel value per pound.

In the same year Atwater and Bryant (3) reported the results of an investigation made of four dietary studies, three of the dietaries being those of a club of forty-one students connected with the University of Tennessee and the fourth, that of a typical mechanic's family in eastern Tennessee. The report included the analyses of all food materials of nutritive value in the house at the beginning, those purchased during, and those which remained at the end of the experiment, as well as all the kitchen and table wastes.

About 1913 the systematic study of foods received a great impetus when Dr. Camien Funk, a Polish biochemist, doing research work on foods at the Lister Institute in

London, gave the name "vitamines" to those substances found to be so vital for life. The rapidly growing interest in vitamins, their value and their source, has brought about a decided change in the whole outlook of the nutritional problem, hence a greater interest in the study of foods. Great strides have been made since that time in the study of the principles of dietetics.

With the recognition of rickets as a vitamin deficiency disease, attention was drawn to other aspects of the illness; and analyses of calcium and phosphorus in food materials began to be made. The study of parathyroid glands has maintained interest in calcium and phosphorus metabolism. Determinations of iron have also been carried out in recent years, owing to the interest now taken in the anemias. All recent food tables have included some figures for these inorganic elements.

In 1904 Leach (13) prepared many tables of food composition, a number of them being taken from König (12), and published these along with detailed procedures of analyses. His foremost purpose, however, was to furnish the government, state or municipal analyst with standard methods of detecting adulteration.

In 1911 Sherman (20) published a number of valuable food tables. Some were determined by himself, but the

majority were taken from the tables of composition of American food materials compiled by the United States Department of Agriculture. All the data given were for uncooked material.

Chatfield (5) in 1926 collected the data in this country, both published and unpublished, on the physical and chemical composition of beef. She analyzed fifty-four carcasses of beef. With these data in hand, she issued department Circular 389, setting forth her findings in graphs and other forms particularly interesting to doctors and hospital dietitians.

McCance and Shipp (16) made a very extensive and valuable study of the chemical effects of cooking on flesh foods and published their results in 1933. They were urged to undertake this problem as it was felt that all former food tables were "unsatisfactory when individual dietaries are being considered, as all the data are for raw materials, most of which are never eaten in that state." They felt this was a most unsatisfactory state of affairs for "physicians who have to arrange for the diets of individual patients, as there are practical reasons why these diets can seldom be weighed or measured until after they have been cooked." Feeling that the value of food tables is greatly increased when accompanied by descriptions of the analytical

methods used, they included a detailed description of their procedures.

They studied and reported the cause and extent of the various losses brought about by cooking. They showed why and how different methods of cooking, such as roasting, boiling and steaming, can modify the losses caused by equal degrees of shrinkage. The authors described how the rate and extent of shrinkage vary in different organs, and how they may be altered by change of temperature, time of heating, etc.

Analyses were made for protein, total nitrogen, purine nitrogen, non-protein nitrogen, fat, carbohydrates, sodium, potassium, calcium, magnesium, iron, the phosphates and the chlorides. They analyzed 144 varieties of fish and meat, all analyses but 10 being on cooked material.

Their tables differ from most of the tables in that protein is considered as the figure obtained by "subtracting the extractive nitrogen from the total nitrogen and multiplying the difference by 6.25"; and that the fat reported was not the usual ether extraction, which they felt contained material "which from a dietetic point of view cannot be regarded as fat, e.g. sterols" (15). They employed a saponification method in which the fatty acids were set free and then titrated. Their figures on mineral content on pork

loin were considerably higher than those reported in this present work.

In 1933 Loy (15) studied the mineral constituents of certain animal tissues in relation to shrinkage, palatability and other qualities of meat. He made analyses for protein, fat, water content, calcium, phosphorus, iron and total ash on raw material, giving in detail his methods of procedure. This latter fact makes his work of service to others undertaking similar work in the future.

Rogers (17) completed in 1935 a study of the composition of certain beef cuts as affected by grade and method of cooking. Her conclusions, like those reached in this present work, were based on the analyses of only one set of identical samples, and were, therefore, only suggestive of the effect of cooking on the chemical composition of certain cuts of meat.

Rogers, Gillum, Kunerth and Pittman (18) made studies in 1937 similar to the one made by Rogers (17). While obtaining data concerning the composition of certain cuts of cooked beef was the main purpose of these investigations, in three cases the corresponding uncooked portion from the other side of the carcass was also analyzed in order to observe any changes that actually resulted from the cooking. Top shoulder clod, rib, and top and bottom round of beef

were the cuts used for analysis. They found considerable variation in composition in the various cuts depending on the section from which the sample was taken. They found that the actual fat losses were highest in the fat cut and more or less proportional to the amount contained in the uncooked meat.

PROCEDURE

Source and Preparation of Cuts

Because of the need of further comparative determinations of pork, two paired loins of good grade pork were purchased from the Animal Husbandry Department of this college, and were prepared for analysis. Each loin was cut into five roasts. The end roasts were approximately four inches long and the center about seven inches. Only the end roasts and the center roast of each loin were analyzed. As Rogers (17) compared two braised paired cuts of beef, and found but little difference in chemical composition, it was presumed at the beginning of the experiment, that similar portions of the paired cuts were of practically the same chemical composition.

The right loin was analyzed after being roasted. The

left loin was analyzed in the raw state. The right loin roasts were numbered one to five, number one being the blade end, number five the loin end and number three the center loin. The left loin roasts were numbered one A to five A, in the same order as in the right loin. Only roasts one, three, five, one A, three A and five A were analyzed. The roasts were indiscriminately trimmed of skin fat as they would be for preparation for counter sale.

The bone and all inedible portions of the left loin were removed and discarded. Weight records were made of both edible and inedible fractions as shown by Table 1. The edible portions were prepared at once for analysis. Each roast was put through an electric food grinder three times. This grinding was followed by very thorough hand mixing until as uniform a mixture as possible was procured, so that a representative sample might be taken from any portion of the mixture. Each roast was prepared as quickly as possible and stored in four small glass, water and air-tight jars. The jars were placed at once in the freezing unit of the Department of Dairy Husbandry where they were as soon as possible brought to a temperature of -20° F. In order to reduce the possibilities of decomposition to a minimum, they were held at this temperature until about 18 to 24 hours before they were needed for analysis, at which time they were removed to

an ice box and allowed to thaw slowly.

The right loin was roasted. The roasting was done under the direction of Dr. Gladys Vail of the Department of Food Economics and Nutrition. The three cuts were roasted at a constant oven temperature of 350° F. to an internal temperature of 185° F. After being roasted they were cooled to room temperature, then placed in the refrigerator in the Department of Animal Husbandry and thoroughly chilled. They were then weighed before and after removing inedible portion. After grinding, they were stored in the same way as were the left loin roasts. When the samples were ready for analysis, the meat was removed from the storage jars, again thoroughly hand-mixed and placed in weighing bottles.

Four samples from each roast were weighed out as follows:

Sample 1 (2-3 gm.) for fat determination

Sample 2 (1-2 gm.) for nitrogen (protein) determination

Sample 3 (20 gm.) for digest preparatory to calcium, phosphorus and iron determinations

Sample 4 (2-3 gm.) for moisture and ash determinations

Triplicates were run on all samples and repetitions were made where close agreement did not occur. Blanks were run on all determinations and corrections were made accordingly.

Table 1. Weight and cooking record

	Roast number					
	One	Three	Five	One A	Two A	Three A
Hours roasted	2 1/4	2 1/4	1 5/6			
Weight of roast (gm.)	1052.0	1357.9	1117.2	1031.0	1321.0	1013.0
Loss due to evaporation during cooking (gm.)	164.6	123.0	110.4			
Loss due to evaporation (%)	15.6	9.0	9.8			
Loss as drippings (gm.)	62.3	145.0	60.3			
Loss as drippings (%)	5.9	10.7	5.4			
Total loss during cooking (gm.)	226.9	268.0	170.7			
Total loss during cooking (%)	21.5	19.7	15.2			
Wt. of roast after cooking	791.0	1036.0	907.0			
Wt. of inedible portion (gm.)	152.0	188.0	178.0	210.0	300.0	245.0
Wt. of edible portion (gm.)	639.0	848.0	729.0	821.0	1021.0	768.0
Drippings by volume (cc.)	63.0	155.0	60.0			
Fat in drippings (%)	95.0	95.0	78.0			
Melanoidin fraction (%)	5.0	5.0	22.0			

Chemical Analysis

Sample 1 Fat or Ether Soluble Fraction. A 2-3 gm. portion of the sample was spread out in a thin layer over surface of a thin sheet of fat-free absorbent cotton, then rolled, placed in an extraction thimble and dried along with the sample for moisture in a vacuum desiccator over fresh sulfuric acid. When the moisture sample was found to be dry, the fat sample was also considered to be dry. The thimble was then placed in the extraction cone and the ether soluble fraction was extracted with anhydrous ether for seventy-two hours, according to the method of the Association of Official Agricultural Chemists (1) and dried one and one-half hours in a vacuum oven and then weighed.

Sample 2 Nitrogen (protein). The protein value was not determined directly, but was obtained by multiplying the total nitrogen by the factor 6.25. Rose (19) and others agree that this method is not strictly accurate, "but inasmuch as calculation of food values are made on average analyses and are only approximately correct in any given case, the convenient factor 6.25 has been widely adopted and is satisfactory if it be borne in mind that estimations of protein in food made in this way tend to indicate somewhat more

protein than is probably available to the body."

A 1-2 gm. portion of the sample was placed in a 800 cc. Kjeldahl flask. To the flask was added 18 gm. sodium sulfate, 10 cc. of 10 per cent copper sulfate and 30 cc. of concentrated sulfuric acid. The mixture was placed on the rack and digested for three to four hours or until clear. After the mixture cooled, 300 cc. of water was added, then cautiously 70-75 cc. concentrated sodium hydroxide. The flask was connected at once to the distillation apparatus. The ammonia formed was distilled over into 50 cc. of 0.1 N hydrochloric acid in a 500 cc. Erlenmeyer flask. After distillation was complete, 7 drops of methyl orange was added and excess hydrochloric acid was back titrated with 0.1 N sodium hydroxide. (1)

Sample 3 Calcium, Phosphorus and Iron. The 20 gm. sample was placed in a 500 cc. Erlenmeyer flask and 5 cc. sulfuric-nitric acid (1:1) mixture was added. The flask was placed on a hot plate (below 300° F.) and small portions of nitric acid were added from time to time until digestion was complete and the solution was clear. The digest was then washed into a 100 cc. volumetric flask and made up to volume.

Calcium. A modified McCrudden method was used for the determination of calcium. A 25 cc. aliquot of the digest

was placed in a 100 cc. beaker, and then evaporated to dryness on a hot plate. All the sulfuric acid was thus fumed off. The residue was taken up in 1 cc. of 20 per cent hydrochloric acid. As a small amount of the ash appeared not to dissolve in the acid, the solution was filtered through a small piece of filter paper and washed directly into a 15 cc. centrifuge tube. Then 1.5 cc. of 5 N ammonium chloride (in order to hold magnesium in solution), and 5 cc. of 2.5 per cent oxalic acid solution were added, then 1 drop of mixed indicator (giving a pH of 5). The solution was made slightly alkaline with 1:1 ammonium hydroxide and then immediately made just acid with oxalic acid. The solution was allowed to stand over night. In the morning it was placed in a centrifuge for fifteen minutes at moderate speed. The supernatant solution was decanted cautiously. The sides of the tube were washed down with 2 cc. of the ether-alchohol-ammonium hydroxide wash and the precipitate stirred up with a fine glass rod. This process was repeated three times, alternately centrifuging at high speed for five minutes, and washing with the above mentioned wash.

After the last decanting, 2 cc. of 0.1 N sulfuric acid was added to the centrifuge tube to dissolve the precipitate. The tube was then placed for two minutes in a bath of boiling water. While the solution was hot, it was

titrated with 0.02 N potassium permanganate. (11)

Phosphorus. A modified Fisk-Subbarrow colorimetric method was used in the determination of phosphorus. A 1 cc. aliquot part of the digest was placed in a 50 cc. volumetric flask. The solution was made neutral to phenolphthalein with 1:3 ammonium hydroxide, then just acid with dilute acetic acid. Then 2 cc. of ammonium molybdate and 0.8 cc. of amino naphthol sulfonic acid were added to the solution for every 1 cc. of (0.08 mg./1cc.) standard used. The solution was mixed well, made up to 50 cc., allowed to stand for five minutes, then compared with standard set at 20 mm. in a Dubosq colorimeter. (10)

Iron. No precautions against iron contamination were taken in the preparation of samples for analysis. Forbes and Swift (8) recommend the use of bronze or iron-free instruments in obtaining tissue samples. However, Kennedy (10) states that in his work no material difference could be detected when bright instruments were used or when the material was removed at autopsy by means of broken glass. However, if any iron were added by the instruments used, it would probably not exceed that amount usually added in the ordinary preparation of meat.

The thiocyanate colorimetric method was employed in the determination of iron. It is the most rapid and accurate

method for estimation of iron in organic materials according to Snell (21) and attains an accuracy limited only by the optical measurement of color according to Kennedy (10).

A 10 cc. aliquot of the digest, taken for the iron determination, was placed in a large test tube, neutralized with sodium hydroxide and made up to about 20-25 cc. Then 0.2 cc. of nitric acid (to which hydrogen peroxide had been added in order to convert any nitrous acid present to nitric) was added and the tube placed in a boiling water bath for 40 minutes. After being cooled, 10 cc. of amyl alcohol and 5 cc. of 20 per cent potassium thiocyanate were added. The contents were well shaken and the alcohol layer was withdrawn by means of a pipette, placed in a dry colorimeter cup and compared with standard at 20 mm. in a Dubosq colorimeter.

Sample 4 Moisture and Ash. Moisture. A 2-3 gm. portion of original sample was spread out in a thin layer in a flat 8 cm. porcelain evaporating dish and placed in a vacuum desiccator over fresh sulfuric acid, along with samples for fat determination. After the first week a fresh supply of sulfuric acid was placed in the desiccator. At this time samples were removed and weighed. They were, thereafter, weighed at intervals of a few days until constant weight was reached (1).

Ash. The sample taken for moisture determination was ignited below dull redness in a muffle furnace, cooled in a desiccator and weighed. The process was repeated until constant weight was reached (1).

Drippings. The drippings left after the roasting was completed were placed, while warm, in a graduated cylinder. After they were allowed to cool, the volume of the fat and melanoiden fractions were thus obtained. No chemical analysis was made of the drippings.

DISCUSSION OF RESULTS

The results are assembled in Table 2 and are shown graphically in Figures 1 to 3 inclusively.

Comparisons of cooked with uncooked roasts as to composition are shown in Figures 1 to 3. Figure 1 shows the comparison of roast one A, which was analyzed raw, with roast one, which was analyzed after roasting. The water content decreased during cooking from 45.6 per cent to 38.2 per cent. The protein increased from 13.2 per cent to 19.9 per cent. These results are consistent with the general tendency in meats during cooking for the change in protein to be inversely proportional to the change in water content.

The fat was concentrated during cooking, being 14 per

Table 2. The effect of roasting on the chemical composition of pork loin*

	Roasted			Raw		
Roast Number	One	Three	Five	One A	Three A	Five A
Protein (Nx 6.25)	19.9	21.6	21.9	13.2	15.9	18.3
Fat	40.3	40.9	40.8	35.2	34.2	35.0
Total Solids	61.8	55.8	49.2	54.4	48.8	40.2
Moisture	38.2	44.2	50.8	45.6	51.2	59.8
Total Ash	1.032	0.95	1.068	0.795	0.86	1.012
Calcium	13.2	11.3	15.2	11.7	12.4	12.2
Phos-phorus	132.1	121.7	143.0	91.9	114.6	136.9
Iron	1.65	0.825	1.113	1.096	0.747	1.069

* Results are given in gm. per 100 gm. of meat with the exception of the minerals which are given in mg. per 100 gm. of meat.

cent greater after than before cooking.

The total ash likewise increased during cooking going from 0.795 per cent to 1.032 per cent. Therefore, as might be expected, the percentage of each mineral was higher in the cooked sample than in the raw. Each increase in protein was accompanied by a corresponding increase in ash.

The calcium showed an increase of 13 per cent, phosphorus of 43 per cent and iron of 50 per cent. This would indicate that calcium retention during cooking is considerably less than that of either phosphorus or iron. If the drippings had been analyzed the calcium percentage would undoubtedly have been found to be the greatest.

Even though the roasts varied in composition from the blade to the loin end, yet the same general relations held in each paired cut when compared before and after cooking. This similarity is seen from Figures 2 and 3.

A comparison of the data for roast one and one A, five and five A, with that furnished by Rose (19) on pork loin chops lean analyzed uncooked and after broiling and by Sherman (20) on pork chops analyzed uncooked, is as follows:

Uncooked

	Protein	Fat	Calcium	Phosphorus	Iron
Rose	20 gm.		9 mg.	198 mg.	1.5 mg.
Sherman	10 gm.		6 mg.	108 mg.	1.5 mg.
Roast one A	13 gm.	35 gm.	11 mg.	91 mg.	1.09 mg.
Roast five A	18 gm.	35 gm.	12 mg.	136 mg.	1.07 mg.

Cooked

Rose	29 gm.		10 mg.	359 mg.	2.9 mg.
Sherman (no report)					
Roast one	20 gm.	40 gm.	13 mg.	132 mg.	1.65 mg.
Roast five	22 gm.	41 gm.	15 mg.	143 mg.	1.11 mg.

These figures are in gm. and mg. per 100 gm. of meat.

A good comparison of these analyses is rather difficult. In the first place, identical cuts were not used. There is a considerable variation in the protein and the percentage of fat in the cuts used for comparison is not given by either Rose or Sherman. The protein-fat ratio largely determines the mineral ratio.

However, the calcium is higher in both roasts one and one A than in either of the other two reported, and the phosphorus and the iron lower.

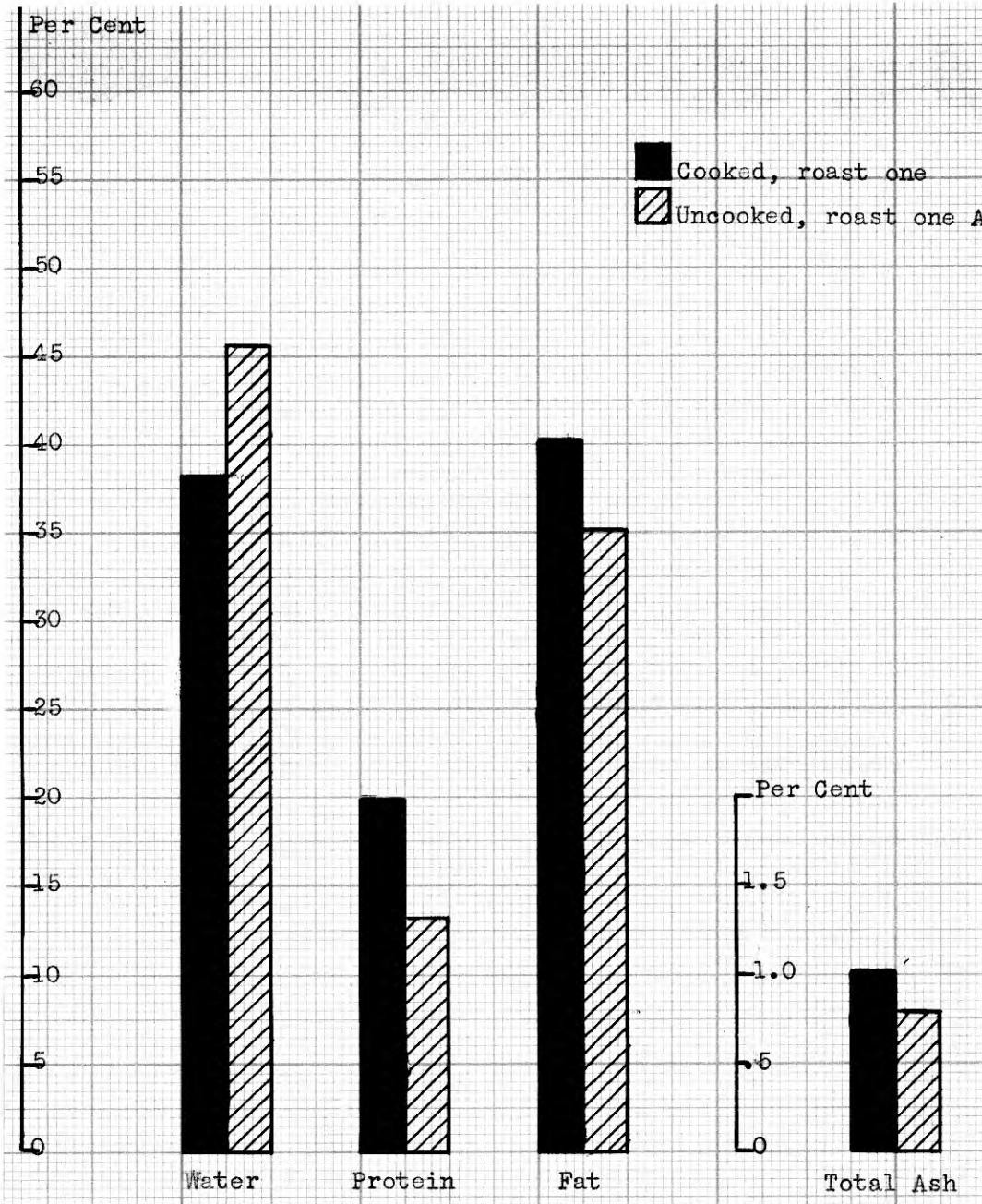

Fig.1. Comparison of roast one with roast one A as to composition

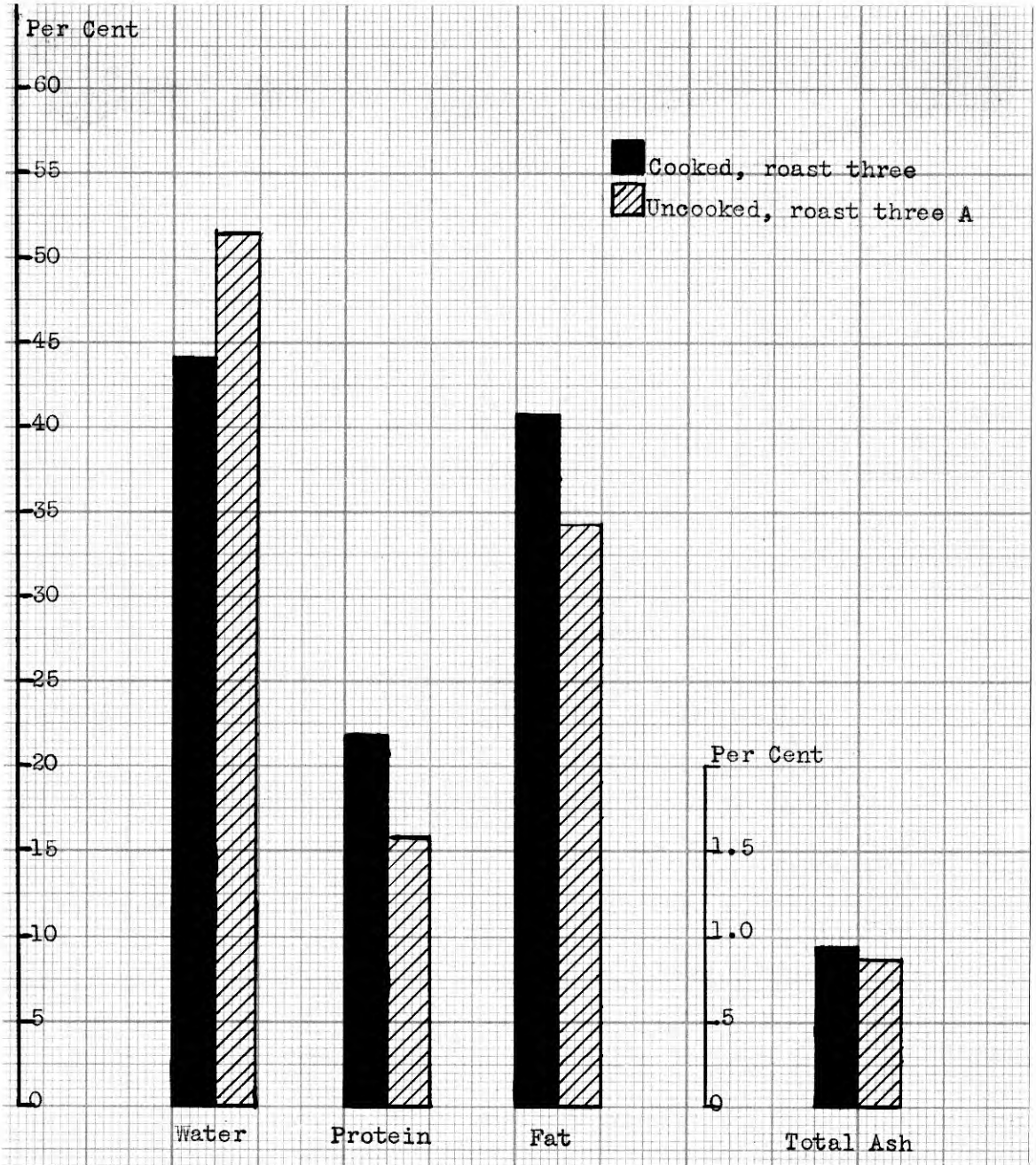

Fig.2. Comparison of roast three with roast three A as to composition

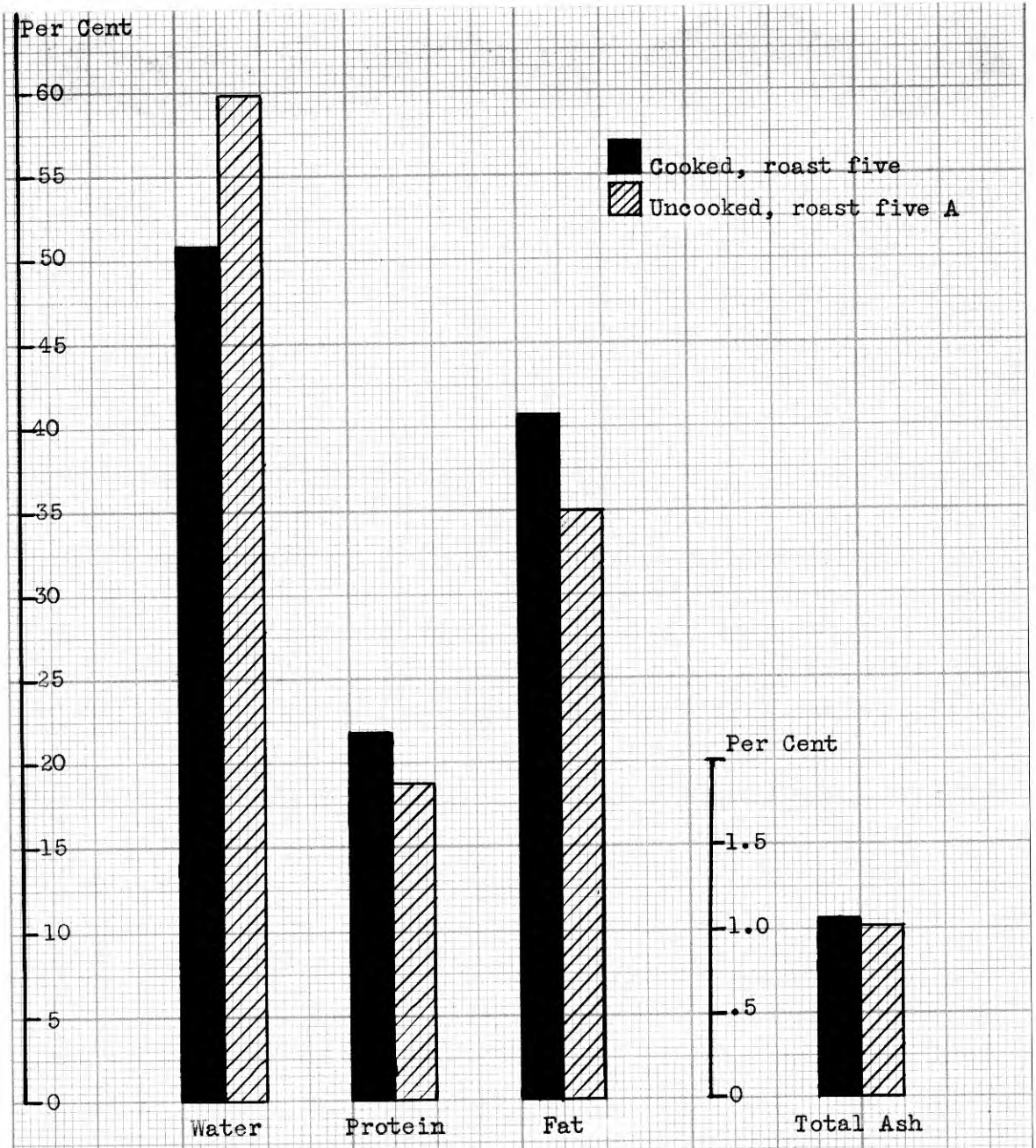

Fig.3. Comparison of roast five with roast five A as to composition

"As calculation of food values are made on average analyses and are only approximately correct in any given case" (19), much chemical analysis still needs to be done in the field of meat, especially in pork.

There was a considerable variation in the three uncooked roasts depending on the part of the loin from which the roast was taken.

From the blade end to the loin end there was a gradual increase in moisture from 38.2 per cent to 50.8 per cent, a small increase in protein from 19.9 per cent to 21.9 per cent, and only a slight variation in the total ash and fat. The fat varied only from 40.3 per cent to 40.9 per cent. These same general directions of change also took place in the cooked roasts. However, the water variation was a little less and the protein and ash a little more, the protein changing from 13.2 per cent to 18.3 per cent. The fat value again showed a remarkable consistency.

CONCLUSIONS

1. Each roast lost water with a resulting gain in percentages of protein, fat, and total ash during cooking.
2. Both phosphorus and iron showed a considerably higher retention during cooking than calcium.

3. In going from the blade to the loin end, both cooked and uncooked roasts showed an increase in water, protein, and total ash, while the fat showed a negligible variation.
4. Each increase in total ash percentage during cooking was accompanied by a corresponding increase in the calcium phosphorus and iron with but one exception in calcium.
5. Even though only a slightly higher fat fraction was reported for roast one A than for either roasts three A or five A, still the low protein, the low total ash, and low moisture of the roast would indicate that it had considerably more fat than the others.

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