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Digestibility of Meats

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THE DIGESTIBILITY OF MEAT

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

T. Mojonnier under Dr. Grindley

ENTITLED The Digestibility of Meat

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF B. S. in Chemistry,

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HEAD OF DEPARTMENT OF Chemistry.

THE DIGESTIBILITY OF MEAT.

THE IMPORTANCE OF MEAT PRODUCTS IN THE FOOD ECONOMY OF MAN.

In the United States we find a greater production of meat products than in any other country in the world. Our animal products are second only in importance to our cereal culture. During the fiscal year ending June 30, 1900, our exports and imports of cattle, sheep and hogs together with the dressed packinghouse products, amounted in the aggregate to $222,124,601. In addition there must be added the immense value of the varius meat products consumed at home. The total value of all the various products of the iron and steel industery exported and imported during the same period of time amounted to $143,968,340.[2] By assuming the same value for the iron and steel products as for the meat products that are used for home consumption, we would still have the meat industry very much in the lead.

Since meat plays such an important role in the welfare of man, it would be enough reason to justify any study, however extended, which would throw light upon any of the many various phases which concern this broad subject.

OBJECT OF THE PRESENT STUDY.

The object of the present study was to determine some facts concerning the digestibility of meat, principally beef. The experimental part of the study consisted in determining such factors in the digestibility of meat as,-the influence of cooking by different methods, influence of age of animals, the time element, and the completeness of the digestion of meat in the body. The time element was studied by means of an artificial pepsin solution in HCl, while the last factor was studied by means of both the pepsin solution, and by robust subjects, whose diets during the experiment consisted largely of meat.

HISTORICAL.

From a very early date the stomach has been considered the principal organ engaged in the process of digestion. Hippocrates[3] and many other philoscphers who lived nearer to our own time believed that changes in the food we eat, were brought about largely by the action of heat. Some be-

lieved the process to be one of putrefaction, while others looked upon it as being entirely of a mechanical nature.

It was in the seventeenth century that digestion began to be considered in the light of a fermentation process. Johan Baptiste van Helmont[4] was the first one who associated fermentation with digestion.

The mathematician and philosopher Rene Descartes(1596-1650)[5] was of the opinion that an acid comparable to HNO_3 in strength was generated in the stomach as a result of a peculiar fermentation.

About the same time that the digestive process was being explained by fermentation,, another school of thinkers, known as the iatro-mathematicians advanced the theory that the digestive process was due entirely to mechanical principles.

The chief of this school was Borelli (1608-1679).[6] He compared the stomach of man with that of different birds, and he estimated the strength of it to be equal to a force that would lift a weight of 1350 pounds. Pitcairn[4] estimated the power of the muscular walls to be equal to a force that would lift a weight of 12,951 pounds.

The next important step toward the enlightenment of this subject was the work done by the French naturalist, Reaumur (1683-1757),[7] during the first half of the seventeenth century. He experimented upon a tame buzzard. Various articles of food were placed in metallic tubes, sealed at one end and covered by muslin at the other, and these he administered to the bird. Such a device precluded the possibility of the trituration of the food, and yet permitted the action of the gastric juice.

When meat was enclosed in the tube, it was found digested after some hours. Bones were found to be softened and somewhat dissolved by the action of the gastric juice. Reaumur was much perplexed to find that vegetable foods escaped the action of the gastric juice, and so failed to learn that gastric juice acts only upon certain of the constituents of food.

Dr. Stevens[8] in 1777 further elucidated the studies of Reaumur. He experimented with a Hungarian who was in the habit of swallowing stones, and regurgitating them as a means for gain in public exhibition. Stevens caused this man to swallow small silver balls perforated like a sieve and constructed so as to be filled with food, and then closed by screwing. The food enclosed was found to be dissolved, and sometimes completely disappeared. In addition to this work Stevens obtained gastric juice from the stomach of a dog, and he found that a piece of meat was digested by it outside of the stomach in eight hours, provided the vessel in which it was placed was kept warm.

In the same year that Stevens published the result of his investigation

Spallanzani[9] commenced his investigations upon digestion. He showed conclusively that gastric juice was capable of effecting the same changes when removed from the body as in the stomach itself, provided the conditions for its activity were maintained. He recognized the acidity of the gastric juice, and asserted the opinion that the acid reaction ceases when digestion is complete.

The next important contribution to the subject was the classical series of observations, carried on by Dr. Beaumont,[10] a surgeon in the United States army from 1825-1833. The studies were made upon Alexis St. Martin, a patient in whom as a result of a gun shot wound, a gastric fistula had become established which allowed both of the collection of the gastric juice, and of the observation of the processes which go on in the stomach. The observations made upon this remarkable case can be considered as the beginning of our positive knowledge concerning the digestive process.

On account of the importance of this case to the subject under study, a little detailed account of it should be of interest.

On June 6, 1822, Alexis St. Martin, a Canadian, eighteen years old, while in good health, was accidentally wounded by the discharge of a musket. The charge, consisting of powder and duck shot, was received in the left side, - the man being at a distance of not more than a yard from the muzzle of the gun. "The contents entered posteriorly, and in an oblique direction, forward and inward, literally blowing off integuments and muscles to the size of a man's hand, fracturing and carrying away the anterior half of the sixth rib, fracturing the fifth, lacerating the lower portion of the left half of the lung and the diaphram, and perforating the stomach." From this injury the patient recovered, but twelve months after the accident there still remained a perforation in the stomach two and a half inches in diameter. Subsequently a small fold of the mucus membrane of the stomach appeared, which gradually increased in breadth until it filled the aperture, and acted as a valve opening from without, inwards.

Dr. Beaumont conceived the idea of using his patient for the sake of science. The first series of observations were started in May, 1825-nearly three years after the infliction of the injury, and the experiments were continued at irregular intevals until 1833. The results of the observations were published by Beaumont in the latter year.

The following quotations taken from Beaumont's account of the case reveal the facilities which he had for the investigations which he carried on.

"The valve, -already referred to, is formed by a slightly inverted portion of the inner coats of the stomach fitted exactly to fill the aperture.

Its free portion hangs pendulous,and fills the aperture when the stomach is full,and plays up and down simultaneously with the respiratory muscles when empty."

"On pressing down the valve,when the stomach is full,the contents flow out copiously. When the stomach is nearly empty and quiescent,the interior of the cavity may be examined to the depth of five or six inches,if kept distended by artificial means,and the food and drinks may be seen entering it,if swallowed at this time through the ring of the oesophagus. When entirely empty the stomach contracts upon itself,and sometimes forces the valve through the orifice,together with an additional portion of the mucus membrane,which becomes completely inverted,and forms a tumor as large as a hen's egg. After lying on the left side,and sleeping a few hours,a still larger portion protrudes,and spreads out over the external integuments,five or six inches in circumference,fairly exhibiting the natural rugae,villous membrane,and mucus coat lining the gastric cavity."

"Mode of extracting the gastric juice. The usual method of extracting the gastric juice,for experiment,is by placing the subject on his right side, depressing the valve within the aperture,introducing a gum elastic tube of the size of a large quill,five or six inches into the stomach,and then turning him on the left side until the orifice becomes dependent. The quantity of fluid obtaindd is from about 14 to 56 grams,varying with the circumstances and conditions of the stomach".

Asaresult of his experiments,Dr.Beaumont found that digestion varied according as the food was more minutely divided,whereby the extent of the surface coming in contact with the gastric fluid is proportionatelyincreased. Liquid substances are for the most part dissolved by the vessels of the stomach at once,and any solid matters suspended in them as in soup are concentrated to a thicker material before the gastric juice operates upon them. Solid matters are effected so rapidly during health,that a full meal consisting of animal and vegetable substances may be converted into chyme in about one hour,and the stomach left empty in about two hours and a half.

ARTIFICIAL DIGESTION.

In the year 1834,Eberle announced the fact that by treating the mucus membrane of the stomach by means of dilute HCl anartificial gastric juice can be obtained with which food can be digested,as by the natural gastric juice experimented upon by Spallanzani and Beaumont. Soon again Schwan came to the conclusion that gastric juice owed its peculiar activity to a principle which he called pepsin,-although he was unable to separate it.

He pointed out the fact that the mucous membrane of the stomach alone is capable of yielding an artificial gastric juice, and that other mucous membranes did not share this property as Eberle had first thought.

Schwan[11] set to work trying to isolate the principle which gave to dilute acid the power of dissolving certain of the food constituents. The mucous membrane of the stomach was digested with water and treated with K_4FeCN_6. The fluid thus obtained was filtered, neutralized with K_2CO_3 and treated with $HgCl_2$. The precipitate thus obtained was suspended in dilute HCl, and decomposed by means of H_2S. The solution filtered from the HgS possessed intense proteolytic activity. Schwan gave the name of pepsin to this principle, but he laid no claim to having separated it.

Since that time many investigators have given this problem their best attention. Von Wittich[12] discovered the fact that pepsin shared the common property of many enzymes, of being dissolved by glycerine. In order to prepare a glycerine extract of the pepsin, the finely divided and well cleaned mucous membrane of the fundus of the stomach is placed for eight to ten days in concentrated glycerine. On subsequent straining and filtering a glycerine solution of pepsin of considerable activity is obtained.

Methods for the purification of pepsin have been proposed. These are based upon its non-diffusibility through parchment paper. The pepsin solution to be analysed is placed in a parchment bag which is closed at one end and suspended in a running stream of water. If it is desirable to remove the last traces of diffusible substance such as peptone from the solution, the process must be carried for a period of eight to fourteen days, - and in order to avoid putrefactive changes, thymol may be added to the dialysing liquid, or the acid which has diffused away must be restored from time to time.

Ever since pepsin has been isolated, attempts have been made to use it to test the digestibility of different food stuffs out side of the body. It has been, however, largely since 1880, that artificial digestive methods have come into practical use. At that time Stutzer[13] published the results of investigations upon the solubility of proteids in pepsin solution, and from his investigations he believed that he had found a method of determining the digestible proteids of foods with great accuracy. Stutzer's method consisted in treating two grams of the food with ether, then digesting for twenty-four hours with 250cc of acid pepsin solution, filtering upon asbestos; treating the residue and the asbestos with alkaline solution of the pancreatic extract, and finally determining the N in the residue left undissolved.

Since that time Stutzer's method has undergone many modifications and it has been the source of a great deal of close and painstaking study both abroad,-principally in Germany,and in our own country.

Niebling[14] treated two grams of the food after extracting with ether with 100cc of 2% Hcl. Contents of flask were heated to boiling and kept at that temperature for 15 minutes,and then neutralized after cooling with Na_2Co_3. 100cc of Stutzer's pancreatic solution were added without filtering and the flasks then kept in the water bath at 37°-40° for six hours. Residues were filtured off,washed and Kjeldahled.

Wilson[15] used the same kind of pepsin solution that Stutzer did. The pancreas solution was made by dissolving 1 1/2 grams of Merck's pure pancreatin and 3 grams of Na_2Co_3 in 1 liter of water. The well washed residue from the pepsin solution was digested for twelve hours in 100cc of the pancreatic solution at about 40° and frequently stirred. The residue was filtered,washed and the nitrogen determined by the Kjeldahl method.

Pfeiffer[16] found that sheep digested more nitrogenous matter than Stutzer's method indicated. He used the alkaline pancreatic solution in addition to the acid pepsin solution. He proved that the soda used in the pancreatic solution dissolved substances in the food itself. He belived that the acid pepsin solution dissolved all of the digestible nitrogenous matter,and that the treatment with pancreatic solution was unnecessary.

Kühne[16a] found that some pepsin soluble material needed to be heated for 48 hours in 500cc of pepsin solution in order to dissolve the soluble nitrogenous matter.

Kohler,Bornstein and Zietsterff[17] simplified previous methods for making the HCl of a definite strength by adding 15cc of 10% HCl at the beginning,and 25cc at the end of 24 hours instead of in smaller quantities at shorter intevals. In most cases they found it unnecessary to remove the fat before digestion.

The method that is now largely employed,and which was found to give the best results in our experiments is as follows: 2.5 gram of Merck's pepsin,(a smaller amount for some foods is sufficient) are dissolved in 1 liter of 33% HCl. 100cc of this solution are used in treating the dry foods. The flask or beaker containing the food and the solution is heated for 24 hrs.,at 38°-42° and finally contents filtered,washed,and the residues Kjeldahled.

NATURAL DIGESTION.

The first observations made upon the quantity of a mixed diet di-

gested were made by Bencke in 1854[18]. Rancke[19] published the results of quantative tests upon the digestibility of meat in 1862, but little importance is attached to his results as the methods in use at that time were poorly elaborated.

Rubner[20] did a great deal of valuable work in testing the digestibility of different foods at the Munich physiological laboratory, and he published his results between 1879-1882. The subjects which he used followed various occupations and nearly all of them were Bavarians.

Bread, meat, milk, eggs and other articles of food were studied. Since then investigations along this line have been very active. In addition to Rubner, Ranke, Atwater and Malfatti[21] have all reported results with meat, which will be referred to again.

EXPERIMENTAL METHODS.

The method in common use for testing the quantity of nutrients digested in a given food diet is usually as follows:-[22] When the diet has been selected, and the subject chosen, samples of the food are analyzed by the ordinary methods of food analysis. If practicable the determinations are made upon the fresh substance direct. Otherwise the food is air dried at a low temperature and the water, fat, nitrogen and ash are determined in this sample, and the carbohydrates are estimated by difference. The weight of all the food eaten during the experiment is carefully recorded, as well as the weight of the excreta derived from the food used in the experiment.

In order to obtain good results the experiment should last not less than two or three days. The longer the experiment the less will be the error which are due principally to the imperfect separation of the undigested portion of the food used in the experiment from that coming from the food used before and after the experiment. The accuracy of these tests depend largely upon the separation of the feces. Two methods of separation are in general use. In one, the subject takes no food but milk during the twenty four hours preceding the experiment, and for twenty four hours or thereabouts following the experiment. The feces due to the milk are of a whitish color and of a characteristic texture, so that they can be separated from the portion belonging to the test. The second method which is the one that is in use almost altogether at the present time consists in giving the subject a quantity, -about .5 of a gram, of lamp black preferably put up in gelatin capsules, the meal before and the meal after the experiment. The lamp black imparts a very black color to the feces. We have found in the course of our work that a combination of the two methods

gave the most satisfying results.

SOURCES OF ERROR.

The errors entering in the food used are limited practically to the diffuculty in the way of getting representative samples for analysis, and in the imperfections in the method of analysis. As already observed the greatest errors are likely to occur in the separation of the feces and in their analysis. The feces contain metabolic products in addition to the undigested residue coming from the food.

The undigested residue contains fragments of "muscular fiber, tendon, ligament, elastic fiber, blood vessels, chlorophylloid matter, vegetable fiber, granules of starch, masses of fat, calcium and magnesium salts of the fatty acids, magnesium ammonium phosphates, and cleavage products of proteids, including skatol and indol."

According to Atwater, the metabolic products include "epithelium, mechanically separated from and mucus separated by the walls of the alimentary canal, and residues of the digestive secretions. The chief of these latter are those coming from the salivary, pectil and pancreatic glands, and the bile. Pepsin and trypsin furnish considerable nitrogenous matter. The bile furnishes the bile acids, and probably coloring matters. Whether cholesterin which is normally present, comes from undigested residue or from metabolic products or from both is not definitely known."

It is evident from a mere consideration of the large number of substances present in the feces, that large errors in the analysis are likely to enter, if the same methods are employed as in the case of the analysis of foods. Only a small portion of the nitrogen in either the undigested residue or in the metabolic products is in the form of proteids. The usual method is to multiply the percent., of nitrogen found by the proteid factor, 6.25, which gives a figure that is far from representing either the actual amount of proteid or the total nitrogenous substance. The ether extract may contain all the neutral fats and probably more or less of cleavage products, material from the bile and coloring matter. Ether will not remove these completely, nor will it alone remove the fatty acids which are in combination with calcium and magnesium. The carbohydrates are estimated by difference, and such an estimation must necessarily include the combined errors of all the others except in cases where the latter compensate each other.

Aside from the imperfect methods of analysis, the errors due to meta-

bolic products may be considerable. These errors are derived principally from the proteids and the fat. The amount of nitrogen digested is found by subtracting the nitrogen in the feces from that in the food eaten. Since the total nitrogen in the feces represents the nitrogen in both the undigested residue and in the products of metabolism, it would be necessary to subtract the nitrogen from the latter source from the total nitrogen in order to get the true amount of nitrogen undigested. This latter value subtracted from the total nitrogen in the food would give the amount of nitrogen actually digested. The figures for the digestibility of nitrogen as ordinarily computed from experiments are too small by the amount of the metabolic nitrogen in the feces. An error may be introduced in the ether extract on account of the bile acids and like products present. When the quantity of fat is large as is the case usually with meats, such factors as the above would not vitiate the results very much; but when the total fat is very small as in the case of most vegetable foods, a small error due to the metabolic products in the ether extract, would be likely to impair the results a good deal.

ARTIFICIAL VERSUS NATURAL DIGESTION.

Several experimenters have worked with both the artificial and the natural digestion methods to ascertain if the two gave comparable results.

The following factors present in normal digestion are absent in the artificial experiments. (1) Constant movement of contents, (2) constant removal of digestive products, and (3) the continuous addition of portions of digestive fluids. A.S.Lea[23] originated a method for eliminating the first two factors. He used an automatic shaker and a dialyser. He concluded from his experiments that the undigested residue is always greater by the use of flasks than by the use of the dialyser in artificial digestion.

Chittenden and American[24] believed that natural digestion is much different than artificial digestion as carried on in flasks. By the use of Lea's method as above, they found that certain peptones diffused at a much slower rate than others, through membraneous tissue.

A bulletin of the New York Station[25] states that the coefficient of the digestibility of all foods as usually calculated from animal digestion is too low. On the other hand by treating the feces with pepsin, some of the undigested food is dissolved, and thus the coefficient of digestibility becomes too high.

Pfeiffer[26] compared the two methods by means of his experiments with pigs. After taking into account the products of metabolism in the feces

he found a close agreement between the two. In his artificial experiments he used Stutzer's method, as he believed that he obtained better results than by the use of the pepsin solution alone. Hennberg[47] applied a correction of 4 of a gram of nitrogen for every 100 grams of dry matter digested, for the nitrogen excreted in the metabolic products. He found this value to be dependent.-(1) upon the amount of dry matter digested, and (2) upon the amount of undigested dry matter in the food.

THE FUNCTION OF MEAT AS FOOD FOR THE BODY.

Classification of the Nutrients of Food:

The nutrients of foods are usually grouped under the four following heads:-proteids, fats, carbohydrates and ash or mineral matters. Atwater[48] gives the following compounds as being characteristic of each group:-

Protein

- **Proteids**
  - Albuminoids: e.g. albumen of eggs; myosin, the basis of muscle; the albumenoids which make up the gluten of wheat, etc.
  - Gelatinoids: constituents of connective tissue which yield gelatin and allied substances; e.g. collagen of tendon, and ossein of bone.
- "Nitrogenous extractives" of flesh, i.e. of meats and fish. These include creatin and allied compounds that are the chief constituents of most meat extracts.
- Amids:-This term includes the nitrogenous, non-albuminoid substances of vegetable foods.

Fats — Fat of meat; milk; oil of corn, wheat and other vegetable foods. The ingredients of the ether extract of animal and vegetable foods and feeding stuffs which it is customary to group together roughly as fats, include, with the pure fats, various other substances as lecithins and chlorophylls.

Carbohydrates — Sugars, starches, celleloses, gums, wood fiber, etc.

Mineral Matters. — Potassium, sodium, calcium and magnesium chlorides, sulphates and phosphates.

Function of the Nutrients:

Food for the body has two principal uses:-first to form the materials which make up the body,and to repair its wastes,and second to yield energy in the form of heat to keep the body warm and to furnish muscular and other power for the work which it has to do.

The different nutrients act in different ways in meeting these requirements. The albuminoids are the principal tissue formers,while the fats and the carbohydrates supply the fuel constantly used by the body or to be stored away for future use.

The Protein Compounds:

The albumincids furnish the building material which the body needs. In building the body the albuminoids remain either as albumincids or are transformed into gelatincids. Both of these compounds can be broken up,and serve as fuel in the body,after they have served as building material.

Another important use of protein is its ability to form fats and carbohydrates. These latter compounds are produced by the breaking down of the proteid molecules.

The nitrogenous extractives can neither build tissue nor supply fuel and it is believed that they exeert some influence upon the nervous system in the way that stimulants do,and thus help the body to make use of the other materials in its nourishment.

The amids do not appear to serve any purpose as building material in the body. Like the nitrogenous extractives,they are believed to be the products of the cleavage of the complicated proteid compounds. Some of the amids appear to serve as fuel and it is also belived that like the gelatincids,they help to protect the albuminoids of the food and of the body tissues from being consumed.

Fats and Carbohydrates.

Fats and carbohydrates both supply fuel for the body,but the fats contain this fuel in a more concentrated form. The body has the power of transforming the carbohydrates into fat. While the fat of the food is consumed more or less directly,part of it is stored as fat in the body. At the same time that this process is going on,the previously stored body fat is being drawn upon for use as fuel.

The protein bodies can do the work of the carbohydrates and fats in being consumed for fuel,but the carbohydrates and fats cannot do the work of protein in building or in repairing the tissues of the body.

THE FUEL VALUE OF FOODS.

Heat and muscular work are forms of energy just like mechanical power, light and electricity. Food contains the energy in a latent form, and when consumed, the body has the power of transforming it into the active forms of energy. The energy of foods is a form of potential energy, and its quantity can be determined by means of the calorimeter. The unit of potential energy is the calorie, which represents the amount of heat required to raise one gram of water, one degree centigrade. This unit is known as the small calorie. Another unit, called the large calorie, equals the heat required to raise one kilogram of water one degree centigrade. The unit of mechanical energy may be used instead of the unit of heat. This unit is called the foot ton and it is the force required to lift one ton one foot. One large calorie corresponds very nearly to 1.53 foot tons.

Now the fuel values for different classes of nutrients are not alike. According to the latest work upon this subject, we accept the following values at the present time, all of which are subject to whatever corrections future research shall deem necessary:-

1 gram protein	5.5	large calorie,	8.4	foot tons	
1 " fat	9.3	" "	14.2	"	"
1 " carbohydrate	4.1	" "	6.3	"	"

CHEMICAL CHANGES IN ALBUMINOIDS DURING DIGESTION.

The first systematic investigations on the products resulting from the digestion of proteids by pepsin in HCl, were carried out by Meissner [29] and his pupils between 1859 and 1862.

The term "parapeptone" was applied by Meissner to the neutralization precipitate obtained when the product of the digestion of a proteid by natural or artificial gastric juice is so nearly neutralized that only a faint acid reaction persists. Under these conditions a white ppt., is formed which Meissner called "parapeptone". He described it as a body insoluble in water, but soluble in the weakest acid or alkali solution and precipitated from such a solution by NaCl or HCl. Parapeptone is now believed by some authors to be the same as acid albumen or syntonin. The characteristic difference seems to be that parapeptone is unaffected by pepsin solution while the other substance is readily dissolved by it.

By the addition of a little more acid to the liquid from which parapeptone was precipitated, Meissner obtained a small precipitate, separable by filtration, which he termed "metapeptone". He found it insoluble in very

dilute acid(.17),but soluble in stronger acid.

By further treatment of the filtrate from para-and metapeptones there was found three separate soluble bodies,which he classed in the peptone group,but which differed somewhat in their reactions.

α peptone precipitated by con. HNO_3, K_4FeCN_6 and dilute acetic acid.

β peptone not precipitated by HNO_3 but by K_4FeCN_6 and strong acetic acid. Both of these bodies are now termed albumoses.

The third body corresponded to what we now call peptone properly so-called.

Upon prolonging the digestion of casein or of fibrin,a flocculent insoluble residue was obtained which Meissner called "dyspeptone". Kuhne found this substance to be composed of antialbumid and a compound called nuclein. Schutzenberger called the antialbumid a hemiprotein.

Miahle[30] called the digestion product of albuminoid,albumincse,and observed that it was soluble in water;insoluble in absolute alcohol,and not precipitated by acids or upon boiling.

C.G.Lehman[31] found that several different products resulted from digestive action. He obtained easily soluble precipitates by means of alkali and alkali earths. He also obtained precipitates by means of $HgCl_2$,basic lead acetate,dilute acetic acid and K_4FeCN_6 . He called these bodies peptones and later the same term was applied to all soluble bodies resulting from the action of pepsin solution upon albuminoids,and which were not coagulable by heat.

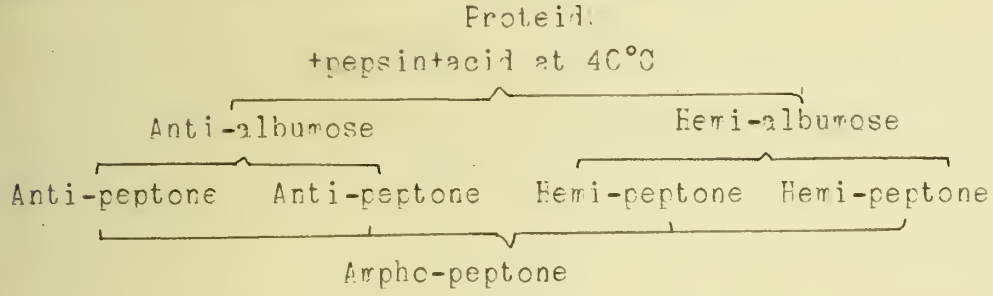
Mulder[34] continued the digestion of the albuminoid substance for four days,and so obtained products which couldnot be precipitated by any of the above reagents.

R.Herth[35],Maly[34],Kossel[35],Brucke[36] and Adamkiewick[37] all studied the products of albuminoid digestion,and obtained precipitates which were of the same character with similar reagents. The last named author obtained a mixture of two substances,one of which melts and then solidifies upon cooling. Later the same body was recognized in urine by Bence-Jones[38],and in diseased marrow by Virchon[39]. Schmidt-Mulheim[40] called the substance propeptone,and Kuhne[41] finally gave it the name of Hemialbumose as he believed it to be an intermediate product between antipeptone and its hemipeptone. The hemialbumose can be obtained by digesting albumoid with pepsin and HCl or with HCl alone. Schutzenberger found that albuminoids contain two different radicals,-one of which has the power of resisting acids and the other not.

By following the ensuing process both hemialbumose and hemipeptone

can be obtained:- The albuminoid is digested with gastric juice for a short time, neutralized, filtered, evaporated, and precipitated with alcohol. The antipeptone completely dissolves in cold water, and the hemipeptone nearly completely. The hemialbumose is obtained from this solution by precipitation with acetic acid and NaCl, and the hemipeptone by dialysis and precipitation with alcohol.

To the mixed peptones, hemipeptone and antipeptone, Kuhne and Chittenden[42] applied the name amphopeptone which indicates the double character of the substance. Gamgee's[43] opinion concerning the action of gastric juice upon proteids is represented by the following scheme:-



From a study of the foregoing paragraphs it is evident that no mention is made of the different quantities of the substances that result from digestive action. By a careful perusal of the literature upon the subject, nothing was found in the way of quantative results upon the work done along this line. Several of the compounds have been purified and thoroughly analysed. It seems evident that at the present time a quantative estimation of the products of digestion, would be of considerable value.

COMPOSITION AND CONSTITUTION OF PEPTONES AND ALBUMINOIDS.

The following is known at the present time concerning the chemical constitution of peptones, and their relation to the mother substance.:-

First-Peptones have the same percentage composition as the albuminoids from which they were derived. They are converted with the greatest ease in the organism, into other albuminous bodies, so that it becomes fairly certain that the change which the proteid molecule undergoes in passing from a native albumin to a peptone is but a very slight one.

Second-The opinion of Adamkiewicz that peptones are only salt free albuminoids is based upon the fact that peptones are not precipitated by heat, and that according to the work of Schmidt and Aronstein, the coagulation of albuminoids depend upon their salt content.

Third-Hoppe- Seyler[44] and his follwers, Wurtz, Fenninger[45] and others believed that peptones are the hydration product of their different albumin-

oids. This view was supported by the following experimenta data:-

(a) Henninger[46] heated fibrin peptone and acetic anhydrine, distilled off the acid and treated the residue with hot water. The water solution was dialysed, when there remained in the dialyser a solution which coagulated upon boiling and upon the addition of HNO_3.

(b) Henninger and Hofmeister heated peptone to 140° and obtained a body which looked very much like albumin.

Fourth,-Another theory advanced is that peptones are decomposition products of the albumincids. This view is held by such men as Mulder, Brucke, Plasz[47], and by Adamkiewicz for the products of albumincid digestion which are not precipitated by heat.

Whether the change which albumincils undergo during their transformation into peptone, is accompanied by hydration or not, it is now generally believed that the complex molecule is broken up into smaller molecules. This view is supported by the fact that peptones diffuse much more readily through membraneus tissue than do the albumincid bodies from which they were derived.

EXPERIMENT CARRIED ON IN CONNECTION WITH THE PRESENT STUDY.

The work reported herewith comprises the following experiments: (1) Seven digestion experiments with men in which meat comprised the principal part of the diet; (2) artificial digestion experiments with most of the freshly cooked meat used in the natural digestion experiments; (3) artificial digestion experiments with the air dried samples of meat in the digestion experiments. Such determinations included the estimation of the completeness of the digestion of the meat by means of an artificial pepsin solution, and also a study of the time element involved in the digestion of meat; (4) artificial digestion experiments with the feces obtained from the seven natural digestion experiments in order to determine the metabolic nitrogen; and (5) a study of the income and outgo of nitrogen in the seven experiments reported.

ANALYTICAL METHODS AND PREPARATION OF FOODS.

The diet of the experiments consisted of meat, bread, butter and milk. In experiment #27 no butter was used; in #26, 28, 29 and 30 no milk was used, while in numbers 30 and 31 both butter and milk made up a part of the diet.

The meat was cooked by boiling in all of the experiments, although the time was varied in some cases, to determine if possible the influence that this would have upon its digestibility. The cut of cooked meat was removed from the water, allowed to cool and then run through a sausage mill. This precaution was taken in order to obtain a representative sample for analysis. After the meat had been run through the sausage mill, once, it was properly seasoned with salt and pepper, and then passed through the mill two more times. The meat was now quickly put into glass jars, weighed, sterilized at 95° for one hour and placed in the refrigerator until wanted. The sample for analysis was weighed at the same time that the meat was put into the jars. It was dried in a water bath at 70° to 90° for about 48 hours, and then exposed to room temperature and moisture for 24 hours before weighing again. When the sample was ground in the mill, and passed through a one mm sieve before making the analysis.

The bread used in the experiments was put in sealed fruit jars, weighed, sterilized at 95° for one hour, and then placed in the refrigerator until wanted. Enough bread was put up to last during the entire experiment

The crust of the bread was rejected as it was hoped to thereby get a more uniform and representative sample for analysis. The sample for analysis was air dried like the meat, and kept in tightly sealed jars until it was to be analysed.

The butter was made into one ounce molds, put upon plates to drain and kept in the refrigerator one night. One-half of each mold was taken for the sample for analysis; the other half was weighed in small glass jars, and kept in the refrigerator until wanted for use.

The milk used in each experiment was mixed at the University dairy for the entire experiment and delivered at the laboratory as needed. The milk was always found to be so well mixed that it was necessary to analyize only one sample from each lot.

All the foods were analysized by the ordinary method of food analysis. Nitrogen was determined by the Kjildahl method. The samples for moisture determination were heated for 16 hours at 104° degrees. The ether extraction was continued for 24 hours in the case of meat; for 16 to 20 hours in the case of the bread, and for about 12 hours in the case of the milk. The samples for the ash were heated in the muffle until constant in weight. Carbohydrates were determined by difference in the bread and in the milk, and the fat was determined by difference in the butter.

THE TREATMENT OF THE EXCRETORY PRODUCTS.

The feces were dried at a little above room temperature in a hood, and kept removed from the dust. The feces from each experiment were kept separate and ground finely enough to pass through a [illegible] sieve before analysizing. In this instance it was found very difficult to get good results in determining the ether extract. This was no doubt due to the fact that ether dissolves other substances in the feces besides the food.

The urine from each period was collected, and the nitrogen was determined by the Kjildahl method. Samples for the determination of heat of combustion were prepared. An absorption block of cellulose was heated in a glycerine bath at 104° to constant weight. The weighed block was placed in a small watch crystal; nearly saturated with urine from a weighed flask; dried in an air bath at 50° to 55° and saturated with urine again. This process was repeated until 6 to 8 grams of urine had been added. For lack of the necessary facilities the determinations have not been made. All of the sample ahve been carefully preserved, and it is hoped that this part of the work will be finished at some future time.

Table 1.

Percentage composition of fresh foods used.

No. of experiment	Laboratory no.	Materials	% Water	N+6.25 % Protein	% Fat	Carbo-hydrates %	% Ash	Totals - %
27	1107	Raw meat	75.2	19.21	4.76	—	1.00	100.17
27	1108	Cooked meat	62.1	30.16	5.75	—	2.15	100.16
27	1116	" "	60.07	33.8	4.07	—	2.21	100.15
26+28	1119	Raw "	74.41	20.84	3.71	—	1.05	100.01
26+28	1120	Cooked "	60.07	31.57	6.27	—	1.83	99.74
29+30	1130	Raw "	76.54	20.68	1.97	—	1.07	100.26
29+30	1131	Cooked "	67.59	26.29	3.91	—	1.76	99.55
31+32	1148	" "	75.2	34.35	7.11	—	1.71	99.89
27	1109	Bread	62.1	7.47	.36	45.24	1.35	100.
26+28	1122	"	60.07	7.89	.38	46.34	.82	100.
29+30	1132	"	74.41	7.76	.38	46.51	.69	100.
31+32	1149	"	60.07	7.28	.16	44.45	.89	100.
27	1117	Milk	76.54	3.01	2.94	4.18	.69	100
31+32	1151	"	67.59	2.75	3.6	4.52	.67	100.
26+28	1123	Butter	56.72	.81	91.70	—	.55	100.
29+30	1133	"	45.58	.62	92.64	—	.34	100
31+32	1150	"	44.57	.60	89.22	—	.72	100

Table 2

Percentage Composition of Water Free Foods.

No. of Experiment.	Laboratory No.	Materials	% Protein	% Fat.	% Carbo-Hydrates	% Ash	Totals
27	1107	Raw Meat	76.94	19.07	—	3.99	100.
27	1108	Cooked "	79.25	15.11	—	5.64	100.
27	1116	" "	84.33	10.15	—	5.52	100.
26+28	1119	Raw "	81.40	14.51	—	4.09	100.
26+28	1120	Cooked "	79.58	15.81	—	4.61	100.
29+30	1130	Raw "	87.17	8.32	—	4.51	100.
29+30	1131	Cooked "	82.25	12.23	—	5.52	100.
31+32	1148	" "	79.57	16.47	—	3.96	100.
27	1109	Bread	13.73	.66	83.13	2.48	100.
26+28	1122	"	14.23	.68	83.61	1.48	100.
29+30	1132	"	14.02	.69	84.05	1.24	100.
31+32	1149	"	13.78	.31	84.22	1.69	100.
27	1117	Milk	27.82	27.17	38.63	6.38	100.
31+32	1151	"	23.83	31.20	39.17	5.80	100.
26+28	1123	Butter	.87	98.54	—	.59	100.
29+30	1133	"	.66	98.97	—	.37	100.
31+32	1150	"	.66	98.54	—	.8	100.

COMPOSITIONS OF FECES.

The two tables following show the composition of the feces. Table No. 3 shows composition of the air dried feces and No. 4 that of the feces calculated to the water-free basis.

Table 3 Percentage Composition of air-dried feces.

No. of Exp.	Lab. No.	Material	% Water	Protein N+6.25	% Fat	Carbo-hydrates %	% Ash	% Total
27	1115	Air dried feces	6.82	28.00	12.32	38.05	14.81	100.
26	1128	" " "	10.48	39.57	10.96	28.55	10.50	100.
28	1129	" " "	8.42	33.98	13.83	28.43	15.34	100.
29	1138	" " "	9.59	38.82	8.67	32.37	10.55	100.
30	1139	" " "	6.89	26.04	11.60	38.64	16.83	100.
31	1156	" " "	7.12	28.24	12.05	38.73	13.86	100.
32	1157	" " "	7.30	27.55	15.46	29.30	20.39	100.

Table 4. Percentage Composition of Water-Free Feces.

No. of Exp.	Lab. No.	Material	Protein	Fat	Carbo-hydrates	Ash	Total
27	1115	Water-free feces	30.05	13.22	40.84	15.89	100.
26	1128	" " "	44.13	12.25	31.89	11.73	100.
28	1129	" " "	37.10	15.10	31.04	16.76	100.
29	1138	" " "	42.94	9.59	35.80	11.67	100.
30	1139	" " "	27.97	12.46	41.50	18.07	100.
31	1156	" " "	30.41	12.97	41.70	14.92	100.
32	1157	" " "	29.72	16.68	31.60	22.00	100.

METHOD OF CONDUCTING THE NATURAL DIGESTION EXPERIMENTS.

In carrying on the experiments reported herewith, it was customary to carry on one experiment be each of two subjects simulatneously. Both of the subjects were in good health with apparently normal digestion, and doing active work. In the report of the experiments the subjects are designated A and B respectively.

As already described enough food was weighed out at the beginning of the experiment to last throughout the experiment. Each subject took the jars of weighed food just as wanted. The meat and sometimes the milk were kept at the temperature of steam for 15 minutes and the milk was heated from 40° to 80° to suit the taste. It was sometimes used cold. The foods were kept in the refrigerator until wanted, and no trouble was experienced in preserving them pure and sweet. If a jar of food remained incompletely used up at the close of the experiment, it was weighed again, and the amount used then determined. We believe that a method of this kind gives better results than would be obtained by weighing the food, as needed from time to time. It reduced the number of analyses to a minimum, and prevents errors in weighing the food, on account of the loss of water that would occur when foods are kept exposed to the air for ever a short time.

Each experiment was preceded by a supper of milk, together with a little bread and butter in some cases. In the course of this meal, gelatin capsules containing from 1 to 1.5 grams of lampblack were taken. The experiment proper then commenced the next morning and continued for two days of for six meals. The breakfast after the last meal of the experiment was made up of milk and bread again together with about the same amount of lampblack that was used at the beginning of the experiment.

The lampblack was used of course to separate the feces due to the diet under investigation from those coming from the food taken before and after the experiment. It was assumed that none of the feces coming from the given diet were colored by the lampblack. Although this method of separation is fairly satisfactory there is no doubt but that the largest error entering into the results obtained from natural digestion experiments is due to the imperfect separation of the feces. Any improvements along this line would add largely to the value of this method.

The urine was collected for the two days of the experiment, beginning with 7 A.M. of the day of the first meal which was always breakfast and ending with 7 A.M. of the following, the last meal of the experiment which was always supper. It is not at all certain that the urine eliminated during this period represents the total urine derived from the diet of

the experiment. No method is yet known for separating the urine due to the experiment from that due to the food used before and after the experiment. We further have no definite knowledge concerning the nitrogen lag, so that the urine collected merely represents that derived from the time covered by the experiment.

In the tables which follow sufficient details are added to elucidate the results. The tables show the amount of food taken and the weight of the different nutrients in the various foods. The amount of each nutrient is calculated from the values given in Table 1 for the food and in Table 2 for the feces. The column marked "total organic matter" represents the sum of the protein, fat and carbohydrates.

CALCULATION OF THE COEFFICIENTS OF DIGESTIBILITY OF THE MIXED DIET AND OF THE MEAT ALONE.

In order to calculate the digestibility of the total foods used in the experiment, the amount of nutrients found in the feces was subtracted from the total nutrients contained in the food, and the remainder divided by the weight of the food first used. The results obtained in experiment 26, table 5 may be used to illustrate this step. The total weight of protein used was 221.47 grams. The protein found in the feces was 18.11 grams. The amount digested would be the difference between the two amounts, i.e. 202.96 grams. The coefficient of the digestibility of the protein in the diet under study would be found by dividing 202.96 by 221.47, and multiplying the quotient by 100 to get the value expressed in per cent. The coefficient of the digestibility of all the other nutrients would be obtained by a similar process.

Since the digestibility of the foods used along with the meat in our study have been studied with considerable care, it is possible to calculate the digestibility of the meat alone by using the factors already found for the other foods. Some of the values taken are bound to be more or less arbitrary, as some of them were obtained in Europe where many of the conditions are different than in our own country. The values taken for the digestibility of bread used were those recently published by Woods.[49] He found 85.% of the protein, 80% of the fat, and 98% of the carbohydrates of bread to be digestible. From a study of the results of digestion experiments both in this country and in Europe, it has been assumed that 98% of the protein, 95% of the fat, and 99% of the carbohydrates of milk, and 98% of the butter consumed with milk are available to the body. These values were taken as the basis for estimating the digestibil-

ity of the meat after taking into account the metabolic products in the feces as estimated by means of the pepsin solution.

In order further to elucidate the matter, experiment 26, table 5 may be considered again. The total protein consumed during the two days of the experiment was 221.47 grams. Of this amount 1.2 grams was derived from the butter, 48.28 grams from the bread, and the remaining portion from the meat. Since 97% of the protein from the butter, and 85% of that from the bread were assumed to be digested, there remained a total of 12.69 grams of protein in the feces which were due to the meat used. The coefficient of the digestibility of the protein in the meat was then found by subtracting 12.6 grams from 176.58 grams, the weight of the protein in the meat used, dividing the remainder 164.19 by 176.78, and finally multiplying the quotient by 100. The digestibility of the fat in the meat was determined in like manner.

A similar procedure was gone through calculating the digestibility of the meat after the metabolic products in the feces had been determined. Again, in the case of experiment 26, 54.43% of the nitrogen in the feces was found to be soluble in pepsin solution and hence treated as nitrogen derived from the metabolic products. 45.57% of the nitrogen in the feces was therefore derived from the undigested protein from the food used. The value found by Woods for the digestibility of bread after he had made correction for the metabolic products, was used as the basis for estimating the digestibility of the meat.

DIGESTION EXPERIMENT NO 28.

Kind of food. Lean beef round, from animal about 6 years old. Cooked by heating in water for 2 hours at 80°-85°. Bread and butter.
Subject: A.
Weight.-At beginning 162.5 pounds; at end 160 lbs.

During the first part of this experiment the subject eliminated 828.65 grams urine containing 2.04% or 16.80 grams nitrogen. During the second day he eliminated 1194.29 grams of nitrogen. The total weight of nitrogen in the urine for the entire experiment was therefore 35.69 grams. The average nitrogen balance per day is as follows: Income in food, 18.04 grams; outgo in urine 17.82 grams, and in feces, 1.53 grams making a loss of 1.31 grams of nitrogen corresponding to 8.25 grams of protein.

Table 5 Results of Digestion Experiment No. 26.

Lab. No.	Material	Weight of fresh mat.	Wt. of water free mat.	% of Nitrogen	Weight of Nitrogen	Wt. of Protein	Wt. of Fat	Wt. of carbo hydrates	Weight of Ash	Wt. of total organic matter
		/								
1123	Butter	160.00	148.90	.123	.197	1.30	146.72	—	.88	148.02
1122	Bread	549.82	304.77	1.262	6.939	43.38	2.09	254.79	4.51	300.26
1120	Meat	560.00	222.15	5.170	28.952	176.79	35.11	—	10.25	211.90
	Total.	1269.82	675.82		36.088	221.47	183.92	254.79	15.64	660.18
1128	Feces	48.38	43.30	6.32	3058	19.11	5.30	13.81	5.08	38.22
	Weight of Food Digested		632.52		33.030	202.36	178.62	240.98	10.56	621.96
	Coefficient of Digestibility of Total food used.		93.59			91.37	97.12	94.62	67.52	94.30
	Weight of Estimated Feces from Food, other than meat.					6.51	1.85	13.81		
	Estimated Feces from Meat.					12.60	3.45			
	" amount of meat digested					164.19	31.66			
	Coefficient of digestibility of meat without correcting for metabolic products.					92.87	90.11			
	Weight of protein in feces undigested by pepsin solution.					8.70				
	Coefficient of digestibility of protein in total food after correcting for metabolic products.					96.07				
	Weight of feces from food other than meat undigested by pepsin solution					2.29				
	Coefficient of digestibility of meat after correcting for metabolic products.					96.37				

DIGESTION EXPERIMENT NO. 27

Kind of food:- Beef round from animal about five years old. Cooked by heating in water at 80°-85° for two hours. Bread and milk.

Subject:-E.

Weight.-At beginning 144.7 pounds, at end 143.1 pounds.

Duration.- Two days, with six meals.

During the first day of the experiment the subject eliminated 1089.99 grams of urine containing 16[illegible] or 17.99 grams of nitrogen. During the second day he eliminated 1166.99 grams of urine containing 2.05% or 23.91 grams of nitrogen. The total weight of nitrogen in the urine for the entire exreriment was therefore 41.94 grams. The average nitrogen balance per day is as follows:- Income in food 24.49 grams; outgo in urine, 20.62 grams and in feces .84 grams; making a gain of 3.78 grams of nitrogen corresponding to 17.25 grams of protein.

DIGESTION EXPERIMENT NO.28

Kind of food:- Beef round from animal about six years old. Cooked by heating in water at 80°-85° for two hours. Bread and butter.

Subject:- E.

Weight.- At beginning 143.1 pounds, at end 144.9 lbs.

Duration.- Two days with six meals.

During the first day of the experiment the subject eliminated 1165.54 grams urine containing 1.76% or 20.48 grams of nitrogen. During the second day he eliminated 1078.66 of urine containing 2.04% or 21.94 grams of nitrogen. The total weight of nitrogen in the entire exreriment was therefore 42.42 grams. The average nitrogen balance per day is as follows:- Income in food 28.97 grams, outgo in urine 21.21 grams, and in feces .65 grams; making a gain of 1.51 grams of nitrogen corresponding to 9.43 grams of protein.

Table 6. Results of Digestion Experiment. No. 27.

Lab. No.	Material	Weight of fresh mat.	Wt. of water free mat.	% of Nitrogen	Weight of Nitrogen	Weight of Protein	Weight of Fat	Wt. of carbohydrates	Weight of Ash	Weight of total organic matter
1117	Milk	775.5	83.90	.481	3.73	23.34	22.80	32.41	5.35	78.55
1109	Bread	500.0	272.10	1.196	5.98	37.35	1.80	226.20	6.75	265.35
1108	Meat	497.5	189.35	5.230	26.02	150.04	28.61	—	10.70	178.65
1116	"	235.0	94.19	5.408	12.71	79.43	9.57	—	5.19	89.00
	Total	2008.0	639.54		48.44	290.16	62.78	258.61	27.99	611.55
1115	Feces	38.29	35.68	4.485	1.68	10.72	4.72	14.57	5.67	30.01
Weight of food digested			603.86		46.76	279.44	58.06	244.04	22.32	581.54
Coefficient of digestibility of total food used.			94.42			96.31	92.48	94.37	79.74	95.09
Weight of estimated feces from food other than meat						6.07	.59	.65		
Estimated feces from meat						4.65	4.13			
" amount of meat digested						224.82	34.05			
Coefficient of digestibility of meat without correcting for metabolic products.						97.98	89.18			
Weight of protein in feces undigested by pepsin solution						5.69				
Coefficient of digestibility of protein in total food after correcting for metabolic products.						98.04				
Weight of protein in feces from food other than meat undigested by pepsin solution.						2.44				
Coefficient of digestibility of meat after correcting for metabolic products.						98.58				

TABLE 7. RESULTS OF DIGESTION EXPERIMENT No. 28.

Lab. No.	Material	Weight of fresh mat.	Wt. of water free mat.	% Nitrogen	Weight of Nitrogen.	Weight of Protein	Wt. of carbo hydrates	Weight of Ash	Weight of Fat	Total wt. of organic matter
1123	Butter	100.	93.06	.123	.123	.81	—	.55	91.70	92.51
1122	Bread	500.	277.15	1.262	6.310	39.45	231.7	4.1	1.90	273.05
1120	Meat	780.	309.43	5.17	40.316	246.25	—	14.27	48.90	295.16
	Total	1380.00	679.64	5.435	46.749	286.51	231.7	18.92	142.51	660.72
1129	Feces	23.98	21.96		1.303	8.15	6.81	3.68	3.32	18.28
	Weight of total food digested.		657.68		45.446	278.36	224.89	15.24	139.19	642.44
	Coefficient of digestibility of total food used.		96.77			97.16	97.06	80.55	97.67	97.23
	Weight of estimated feces from food other than meat.					5.92	6.81		2.21	
	Weight of estimated feces from meat					2.23			1.11	
	Estimated amount of meat digested					244.02			47.8	
	Coefficient of digestibility of meat without correcting for metabolic properties					99.91			97.74	
	Weight of protein in feces undigested by pepsin solution.					2.84				
	Weight of estimated amount of total protein digested.					283.67				
	Coefficient of digestibility of protein in total food after correcting for met. products					99.01				
	Weight of protein in feces from food other than meat.					2.04				
	Estimated weight of protein in feces due to meat after correcting for m. p.					2.8				
	Coefficient of digestibility of meat after correcting for metabolic products.					99.67				

DIGESTION EXPERIMENT NO. 29

Kind of food:- Beef round from animal about four years old. Cooked by heating in water at 90° to 95° for one hour. White bread and butter.

Subject:- A.

Weight.- At beginning 169.0 lbs, at end 168.5.

Duration.- Two days with six meals.

During the first day of the experiment the subject eliminated 894.69 grams of urine containing 1.85% or 16.87 grams of nitrogen. During the second day he eliminated 988.70 grams of urine containing 2.09% or 18.78 grams of nitrogen. The total weight of nitrogen eliminated in the urine during the entire experiment was therefore 17.55 grams. The average nitrogen balance per day is as follows:- Income in food, 17.25 grams, outgo in urine 17.55 grams in feces, 1.52 grams; making a loss of 1.82 grams of nitrogen corresponding to 11.38 grams of protein.

DIGESTION EXPERIMENT NO. 30

Kind of food:- Beef round from animal about four years old. Cooked by heating in water for one hour at 90°-95°. White bread and butter.

Subject.- B.

Weight.- At beginning 151.1 lbs., at end 147.2 lbs.

Duration.- Two days with six meals

During the first day of the experiment the subject eliminated 994.25 grams of urine containing 1.61% or 16.01 grams of nitrogen. During the second day he eliminated 995.91 grams of urine containing 1.96% or 19.51 grams of nitrogen. The total weight of nitrogen eliminated was therefore 35.52 grams. The average nitrogen balance per day is as follows.- Income in food, 18.27 grams; outgo in urine 17.76 grams, and in feces .56 grams making a gain of .95 gram of nitrogen corresponding to 5.94 grams of protein.

TABLE 8. RESULTS OF DIGESTION EXPERIMENT No. 29.

Lab. No.	Material	Weight of fresh mat.	Wt. of water free mat.	Per cent of Nitrogen.	Weight of Nitrogen.	Weight of Protein	Weight of Fat	Wt. of carbo hydrates.	Weight of Ash	Weight of total organic matter.
1133		135.0								
1133	Butter	600.0	126.36	.1	.185	.84	125.06	—	< .46	125.90
1132	Bread	640.0	332.04	1.242	7.452	46.56	2.28	279.06	4.14	327.90
1131	Meat	1375.0	204.54	4.206	26.918	168.26	25.02	—	11.26	193.28
	Total		662.94	6.210	34.505	215.66	152.36	279.06	15.86	647.08
1138	Feces	38.75	35.03		3.03	15.04	3.36	12.54	4.09	30.94
Weight of total food digested			627.91		31.475	200.62	149.00	266.52	11.77	616.14
Coefficient of digestibility of total food used			94.72			93.04	97.79	94.07	74.21	95.24
Estimated weight of estimated feces from food other than meat.						6.98	2.96	12.54		
Weight of estimated feces from meat.						8.06	.4			
Estimated amount of meat digested.						160.20	24.62			
Coefficient of digestibility of meat without correcting for metabolic products.						95.21	96.16			
Weight of protein in feces undigested by pepsin solution.						6.57				
Coefficient of digestibility of protein in total food after correcting for metabolic products.						96.96				
Weight of protein in feces from food other than meat after correcting for metabolic products.						2.46				
Estimated weight of protein in feces due to meat after correcting for m.p.						4.12				
Coefficient of digestibility of meat after correcting for metabolic prod						97.55				

29

TABLE NO. 9. RESULTS OF DIGESTION EXPERIMENT NO. 30.

Lab. No.	Material	Weight of fresh mat.	Wt of water free mat.	Per cent of Nitrogen	Weight of Nitrogen	Weight of Protein	Weight of Fat.	Weight of carbo-hydrates	Weight of Ash	Weight of total organic matter
1										
1133	Butter	95.0	88.92	.1	.095	.59	88.01	—	.32	88.60
1132	Bread	500.0	276.70	1.242	6.21	38.80	1.9	232.55	3.45	273.25
1131	Meat	766.5	244.97	4.206	32.24	201.51	29.97	—	13.49	231.48
	Total	1361.5	610.59		38.545	240.90	119.88	232.55	17.26	593.33
1139	Feces	27.1	25.23	4.165	1.129	7.06	3.14	10.47	4.56	20.67
Weight of total food digested			585.36		37.416	233.84	116.74	222.08	12.70	572.66
Coefficient of digestibility of Total food used.			95.87			97.07	97.03	95.5	73.58	96.52
Weight of estimated faces from food other than meet.						5.82	2.14	1047		
Weight of estimated feces from meat.						1.24	1.00			
Estimated amount of meat digested.						200.27	28.97			
Coefficient of digestibility of meat without correcting for metabolic products.						99.38	96.66			
Weight of protein in feces undigested by pepsin solution.						3.76				
Coefficient of digestibility of protein in total food after correcting for metabolic products.						98.44				
Weight of protein in feces from food other than meat after correcting for metabolic products.						2.05				
Estimated weight of protein in feces due to meat after correcting for m.p.						1.71				
Coefficient of digestibility of meat after correcting for m.p.						99.2				

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DIGESTION EXPERIMENT NO.21.

Kind of food:- Beef round from animal about 8 years old. Cooked by heating in water for three hours at 80°-85°. White bread, butter and milk.

Subject.- A

Weight.- At beginning 178lbs, at end 178 lbs.

Duration.-Two days with six meals.

During the first day of the experiment the subjected eliminated 886.80 grams of urine containing 1.75% or 16.39 grams of nitrogen. The urine for the second day of the experiment was lost. The average nitrogen balance per day calculated upon the basis of that eliminated in the urine for the first day is as follows:- Income in food 12.92; outgo in urine 16.39 grams, and in feces .42 grams, making a gain of 3.89 grams nitrogen corresponding to 24.31 grams of protein.

DIGESTION EXPERIMENT NO.22.

Kind of food.- Beef round from animal about 2 years old. Cooked by heating in water for three hours at 80°-85°. White bread, butter and milk.

Subject.- B

Weight.- At beginning 152 lbs, at end 151.6.

Duration.- Two days with six meals.

During the first day of the experiment the subject eliminated 774.08 grams of urine containing 2.03%, ot 15.71 grams of nitrogen. During the second day he eliminated 810.88 grams containing 2.24% or 18.16 grams of nitrogen. The total weight of nitrogen eliminated in the urine during the entire experiment was therefore 33.87 grams. The average nitrogen balance per day is as follows:- Income in food 16.62 grams; outgo in urine 16.94 grams and in feces .42 grams, making a loss of .74 grams of nitrogen corresponding to 4.62 grams of protein.

TABLE No. 10. RESULTS OF DIGESTION EXPERIMENT No. 31.

Lab No.	Materials	Weight of fresh mat.	Wt. of water free mat.	Percent of Nitrogen	Weight of Nitrogen	Wt. of Protein	Wt. of Fat	Weight of carbohydrates	Weight of Ash.	Wt. of total organic matter
1150	Butter	220.80	199.91	.096	.212	1.32	197.00	—	1.59	198.32
1149	Bread	600.00	316.68	1.163	6.978	43.68	.96	266.70	5.34	311.34
1148	Meat	302.67	130.66	5.426	16.420	103.96	21.52	—	5.18	125.48
1151	Milk	496.80	57.33	.448	2.224	13.66	17.88	22.46	3.33	54.00
	Total	1620.27	704.58	4.515	25.834	162.62	237.36	289.16	15.44	689.14
1156	Feces	18.04	16.76		.815	5.10	2.17	6.99	2.50	14.26
			687.82		25.019	157.52	235.19	282.17	12.94	674.88
			97.62			96.86	99.09	97.58	83.81	97.95

Weight of estimated feces from food other than meat.	6.82	4.31	.45	
Weight of estimated feces from meat	Higher than amount actually found.			
Coefficient of digestibility of meat without correcting for metabolic products.				
Weight of protein in feces undigested by pepsin solution.	2.42			
Coefficient of digestibility of protein in total food after correcting for metabolic products.	98.50			
Weight of protein in feces from food other than meat after correcting for metabolic products.	2.58			
Estimated weight of protein in feces due to meat after correcting for m.p.	—			
Coefficient of digestibility of meat after correcting for met. prod.	100.00			

TABLE NO. 11. RESULTS OF DIGESTION EXPERIMENT 32.

Lab. No.	Materials	Wt. of fresh mat.	Wt. of water free mat.	% of Nitrogen	Wt. of Nitrogen	Wt. of Protein	Wt. of Fat	Wt. of carbohydrates	Wt. of Ash	Wt. of total organic matter
1150	Butter	80.00	72.43	.096	.768	.48	71.38	—	.57	71.86
1149	Bread	488.25	257.70	1.163	5.678	35.54	.78	217.03	4.35	253.35
1148	Meat	400.00	172.68	5.426	21.704	137.40	28.44	—	6.84	165.84
1151	Milk	1135.5	131.04	.448	5.087	31.23	40.88	51.32	7.61	123.43
	Total		633.85		33.237	204.65	141.88	268.35	19.37	614.48
1157	Feces	18.85	17.47	4.41	.831	5.19	2.91	5.52	3.85	13.62
			616.38		32.406	199.46	138.57	262.83	15.52	600.86
			97.24			97.46	97.88	97.94	80.12	97.78

Weight of estimated feces from food other than meat	Calculated feces higher than those actually found.
Weight of estimated feces from meat.	
Coefficient of digestibility of meat without correcting for metabolic products.	
Weight of protein in feces undigested by pepsin solution.	2.36
Coefficient of digestibility of protein in total food after correcting for metabolic products.	98.85
Weight of protein in feces from food other than meat after correcting for metabolic products.	2.50
Estimated weight of protein in feces due to meat after correcting for metabolic products.	—
Coefficient of digestibility of meat after correcting for metabolic products.	100.00

In table 12 is summarized the results of all of the experiments, showing the digestibility of the total diet. In table No.13 is summarized the coefficients of the digestibility of the meat without making any corrections for the products of metabolism found in the feces. Table No.14 shows a summary of the estimated coefficients of digestibility of the protein in the total diet after making the correction for the metabolic products in the feces as determined by means of pepsin solution. Table No.15 summarizes the coefficient of digestibility of the meat alone after finding the amount of protein in the portion of the feces undigested by means of pepsin solution, which was derived from other portions of the diet besides the meat. The value used in the case of bread was the same as that found by Woods. 5.28% of the protein in the bread was estimated to be undigested, and hence present in that portion of the feces unaffected by pepsin solution. In like manner it was estimated that 2% of t the protein in the milk, and 1% of that in the butter was undigested.

In all of the above cases the coefficient of digestibility for each subject is shown, and the average for both subjects indicated.

TABLE No. 12. SUMMARY. – SEVEN DIGESTION EXPERIMENTS

Coefficient of digestibility of total food showing average for each subject.

No. of Exp.	Kinds of food	Subject	% water free material	Percent Protein	% Fat	% carbo-hydrates	% Ash	% total organic matter
26	Meat, Bread, Butter	A	93.59	91.37	97.12	94.62	67.52	94.30
29	" " "	A	94.72	93.04	97.79	94.07	74.21	95.24
31	" " " Milk	A	97.62	96.86	99.09	97.58	83.81	97.95
Average of 3 experiments			95.31	93.76	98.00	95.42	75.18	95.83
27	Meat, Bread, Milk	B	94.42	96.31	92.48	94.37	79.74	95.09
28	" " Butter	B	96.77	97.16	97.67	97.06	80.55	97.23
30	" " "	B	95.87	97.07	97.30	95.50	73.58	96.52
32	" " Milk "	B	97.24	97.46	97.88	97.94	80.12	97.78
Average of 4 experiments			96.08	97.00	96.33	96.22	78.50	96.65
" " 7 "			95.70	95.38	97.17	95.82	76.84	96.24

TABLE No. 13.

DIGESTIBILITY OF NUTRIENTS OF Meat ALONE WITHOUT CORRECTING FOR METABOLIC PRODUCTS IN FECES.

No. of Experiment	Kind of Food	Subject	% Protein	% Fat
26	Meat	A	92.87	90.11
29	"	A	95.21	96.16
31	"	A	Estimated weight of feces higher than total found.	
	Average			
27	Meat	B	97.98	89.18
28	"	B	99.91	97.74
32	"	B	Estimated weight of feces higher than total found.	
30	"	B	99.38	96.66
Average of 5 experiments				

TABLE No. 14.

COEFFICIENT OF DIGESTIBILITY OF PROTEIN IN TOTAL FOOD AFTER CORRECTING FOR METABOLIC PRODUCTS.

No. of experiment.	Kinds of Food	Subject	% of Protein digested in total food
26	Meat – Bread – Butter	A	96.07
29	" " "	A	96.96
31	" " " Milk	A	98.50
	Average of 3 experiments		97.18
27	Meat – Bread – Milk	B	98.04
28	" " Butter	B	99.01
30	" " "	B	98.44
32	" " " "	B	98.85
	Average of 4 experiments		98.58
	" " 7 "		97.88

TABLE No. 15.

COEFFICIENT OF DIGESTIBILITY OF PROTEIN OF MEAT ALONE AFTER CORRECTING FOR METABOLIC PRODUCTS.

No. of experiment	Kind of Food	Subject	% Protein digested in meat alone.
26	Meat	A	96.37
29	"	A	97.55
31	"	A	100.00
	Average of 3 experiments		97.97
27	Meat	B	98.58
28	"	B	99.67
30	"	B	99.20
32	"	B	100.00
	Average of 4 experiments		99.36
	" " 7 "		98.67

METABOLIC PRODUCTS IN THE FECES.

As already mentioned in the tables experiments were made to determine if possible the amount of metabolic products in the feces under study for each different experiment. The character of these metabolic products has already been referred to in the present discussion.[50] It is of considerable importance in digestion experiments to determine these products, as otherwise the digestibility of the food under study may be too low if no account is made of the metabolic products always present in the feces. Unfortunately the methods at present in use for determining these values are not so fully satisfactory as they might be. The methods in common use are (1) the treatment of the feces with certain solvents, (2) the determination of the amount of nitrogen in the feces during a carbohydrate diet, and (3) the determination of the amount and composition of feces during complete or partial fasting. Only the first of these methods was employed in the present study, and in this case, the solvent used, as already noted was pepsin solution. This method is generally supposed to give somewhat unsatisfactory results, as the pepsin has been found to dissolve out portions of the meat which would be normally indigestible in the body. However, it gives perhaps as accurate results as any of the methods now in use.

The treatment of the feces was very much the same, as that given to the meat which will be referred to further on under the heading of the artificial digestion of meat. In this study only 1.25 grams of pepsin were dissolved in one litre of .33% HCl. The weighed samples of feces were treated with 100 cc of the above pepsin solution, kept in the flask in the water bath for 24 hours at 37° to 40°, and filtered. The residue was thoroughly washed, dried, the tops of the filters cut off, to get rid of soluble matters which had dried there, and the nitrogen then determined by the Kjildahl method.

The following table No. 16 shows the summary of the results obtained in this manner.

Summary of Metabolic Nitrogen in Feces as Determined by Pepsin Solution.

Table No. 16

Digest exp. no.	Kind of Food	Grams of nitrogen in food	Weight of air-dried feces	Nitrogen in feces		Treatment with pepsin solution.			
						Nitrogen in feces undissolved by treatment		Nitrogen digested	
				Per Cent	Grams	Per Cent	Grams	Grams	Per Cent
26	Meat-Bread-Butter Entire diet	36.09	48.38	6.32	3.06	2.88	1.39	34.70	96.07
	Meat alone	28.95	—	—	2.02	—	.37	28.58	96.37
27	Meat-Bread-Milk Entire diet	48.48	38.29	4.485	1.68	2.39	.91	47.53	98.04
	Meat alone	38.73	—	—	.74	—	.40	38.33	98.58
28	Meat-Bread-Butter Entire diet	46.75	23.98	5.435	1.30	1.89	.45	46.30	99.01
	Meat alone	40.32	—	—	.36	—	.13	40.19	99.67
29	Same as 28	34.51	38.75	6.21	3.03	2.71	1.05	33.46	96.96
	" " "	26.92	—	—	1.30	—	.66	26.26	97.55
30	" " "	38.55	27.10	4.165	1.13	2.22	.60	37.95	98.44
	" " "	32.24	—	—	.20	—	.27	31.97	99.20
31	" " Milk	25.83	16.76	4.515	.82	2.05	.38	25.45	98.50
	" " "	16.42	—	—	—	—	—	16.42	100.00
32	" " "	33.24	18.85	4.41	.83	2.01	.37	32.87	98.85
	" " "	21.70	—	—	—	—	—	21.70	100.00

Table No.17 shows the income and the outgo of nitrogen and the corresponding loss or gain of protein, in a tabulated form for the seven digestion experiments.

The ash was determined in the urine of all the digestion experiments in order to get some idea of the amount of mineral matter actually used by the body. (See Table No.18.) It is commonly believed that the mineral matters in the urine have been metabilized, and hence cannot be looked upon in the light of undigested matter. As the water used by both subjects was not distilled, the sum total of the ash excreted in the feces and in the urine, exceeds that taken into the body in the foods used. For this reason not very much importance is attached to this portion of the work. However, as it is, it seems rather remarkable that such a large amount of ash as shown in Table 18 should be given out, by the body in a two days experiment. No record was kept of the amount of water used, so that no estimate can be made of the amount of ash coming from that source.

TABLE NO. 17.

INCOME AND OUTGO OF NITROGEN.

GAIN OR LOSS OF PROTEIN.

Exp No	SUBJECT	Day of exp.	Weight of Urine per day	Per Cent of Nitrogen.	Weight of nitrogen per day.	Total weight of nitrogen in urine per exp.	Weight of nitrogen in feces for entire exp.	Weight of nitrogen in food	Wt. of nitrogen gained per day	Weigh of same lost per day	Weight of Protein gained per day	Wt. of same Lost per day
26		1st	823.65	2.04	16.80	—	—	—	—	—	—	—
	A	2nd	1134.29	1.66	18.83	35.63	3.06	36.08	—	1.31	—	8.25
29		1	884.63	1.85	16.37	—	—	—	—	—	—	—
	A	2	922.70	2.03	18.73	35.10	3.03	34.51	—	1.82	—	11.38
31		1	Lost	—	16—	—	—	—	—	—	—	—
	A	2	936.80	1.75	16.39	—	.82	25.83	3.89	—	24.31	—
27		1	1083.32	1.60	17.33	—	—	—	—	—	—	—
	B	2	1166.32	2.05	23.91	40.24	1.68	48.44	2.76	—	17.25	—
28		1	1165.54	1.76	20.48	—	—	—	—	—	—	—
	B	2	1078.66	2.04	21.94	42.42	1.30	46.75	1.51	—	9.43	—
30		1	994.25	1.61	16.01	—	—	—	—	—	—	—
	B	2	995.31	1.96	19.51	35.52	1.13	38.55	.95	—	5.94	—
32		1	774.08	2.03	15.71	—	—	—	—	—	—	—
	B	2	810.88	2.24	18.16	33.87	.83	33.24	—	.74	—	4.63

TABLE No. 18. INCOME AND OUTGO OF ASH.

Experiment Number	Subject.	Weight of ash in food	Weight of ash in urine	Weight of ash in feces	Apparent Loss of ash to body.
26	A	15.64	18.55	5.08	7.99
29	A	15.86	18.74	4.09	6.97
31	A	15.44	Lost 1st day	2.50	
27	B	27.99	30.03	5.67	7.71
28	B	18.92	24.66	3.68	9.42
30	B	17.26	21.19	4.56	8.49
32	B	19.37	23.96	3.85	8.44

THE ARTIFICIAL DIGESTION OF MEAT WITH PEPSIN SOLUTION.

The artificial digestion of meat by means of pepsin solution was made the source of a considerable part of the present study. The methods in use for this kind of work have already been elaborated somewhat, so that at this point only those tried in connection with the present work will be described.

The first method used consisted in treating a weighed sample of the meat with 200 cc of .2% HCl containing 2.5 grams of pepsin per liter. The mixture was heated for 24 hours at 38°-42° and filtered. Considderable experimenting was necessary before satisfactory results were obtained in the filtering process. On account of the slowness with which the solution filtered, an attempt was made to determine the digestibility of the meat by determining the nitrogen in aliquot parts of the filtered solution. The unavoidable evaporation of the solution and the use of large factors to get at the total amount digested, soon proved that this method would be impracticable. Such a proceedure has been used by Chittenden [51] in determining the digestibility of fish flesh. The error would not be so noticeable in foods that are less digestible than meat, but yet we believe from our experience that such a method cannot give satisfactory results.

After the above trials only the undigested residue was worked with. The best methods for bringing about the filtration was also studied. Qualitative filter paper permitted very rapid filtration but the undigested residue was not all retained upon the filter. The suction pump, and hardened filter paper were tried, but this was not found very satisfactory. It was inconvenient and required too much attention, besides being about as slow as without the use of the pump. The method that proved to give the best results was the following:- Hardened, quantitative filter paper, 9 cc in diameter containing .1 mg of nitrogen per paper, was folded so as to present a corrugated appearance and expose practically all its surface to the filtering solution. The paper contained thirty two folded sectors. Such folded filter papers were placed in two funnels held one above the other, and the flask containing the filtering solution inverted in the top funnel so that the solution would run into the filter continually. Such an arrangement required but very little watching. The residue was washed free from pertones, and both filter papers with residues were put into Kjildahl flasks, and the nitrogen determined. The tops of the

filter papers were cut off when necessary and practicable.

The strength of HCl best suited to the work was experimented with. Three strengths of the acid were used.-i.e.,.2%,.3% and .2% at start with subsequent addition of 10%.HCl until solution had a strength of .5%. The method that gave most uniform and most satisfactory results was that in which .3% HCl was used. The results of these experiments are shown in tabular form in Table No.20

More work would have been done in the way of determining the differences,if there are any,between raw and cooked meat if our methods had been worked outa little more satisfactorily earlier in the work.. The results of the work done along this line are shown in Table No.19. In these experiments .2% HCl was used. The samples Nos.1107 and 1108, 1119 and 1120;and 1130 and 1131 are from the same cuts of beef. The first number in each pair being the raw meat,and the second number being the sample of cooked meat. The methods of proceedure were not very well worked out at this time,so that the results obtained are a little questionable in their accuracy. As they stand they seem to vary considerably from the popular notions upon the subject. Chittenden [5?] found cooked meat to be 5% less digestible than raw,andthe common belief is that such is the case. We found very little difference in the digestibility of the two. However,we are reporting too few results to be able to draw general deductions. It will no doubt require more sensitive means than those employed to test the relative digestibility of different kinds of meat,and the influence which cooking may exert upon them.

In sample NO.1148,.3% HCl was used. All determinations were kept at 38°-42° for 24 hours.

TABLE No 19.

THE DIGESTIBILITY OF RAW AND COOKED MEAT IN PEPSIN SOLUTION.

Lab. No.	Kind of Meat.	Per cent digested in pepsin solution
1107	Raw beef, round- animal about 6 years old	97.32
1108	same cut as #1107.- Cooked for 2 hrs. at 80°-85°	97.55
1119	" " " #1107	98.03
1120	" " " #1119 " " 2 " " 80°-85°	97.82
1130	Raw beef round- animat about 4 yrs old	97.54
1131	Same cut as #1130-Cooked for 1 hour at 80°-85°	97.64
1148	Beef round-cooked for 3 hrs. at 80°-85°. 2 yr. old.	97.97

The larger part of our work was obviously done upon the air dried samples of the above meats. Mention has already been made of the study of the best strength of HCl to use. Along with this was found the completeness of the digestion of the air dried samples of meat. These results are shown in table 20, which contains for matters of comparison, some results belonging to the time element studied.

THE TIME ELEMENT IN THE DIGESTIBILITY OF MEAT.

After the completeness of the digestion of the samples of meat had been studied, the next step was to try to determine the time necessary for the digestion of meat. Pepsin solution was used again, as in the preceding experiments. Here again considerable preliminary work was required in order to get a satisfactory method for carrying on the work. As it is, the method used was not capable of making close enough differentiations when small differences are involved.

A careful endeavor was made to find some way of checking the action of the pepsin. Chittenden[53] remarks that any lowering of the temperature from 38° to 40° causes an immediate effect upon proteolysis. "Exposure to a low temperature retards proteolytic action, doubtless in the same manner that cold checks or retards other chemical changes." With this idea in mind experiments were made to determine the action of the pepsin solution at room temperature, and at the temperature of the refrigerator to find if in that way the action of the pepsin would be stopped. This gave results which showed that such a scheme would not do for this kind of work.

Attention was then called to the destructive action of certain disinfectants or other chemicals upon entzymes. Kuhne[54] first pointed out that pepsin is distroyed by digestion with weak alkaline solutions. Bertels[55] and Dubs[56] found that large amounts of chloroform decrease the digestive power of pepsin. Other investigators worked along this line and they have found various other chemicals to exert the same power. We tried chloroform, $HgCl_2$ and formalin. Chloroform seemed to slightly precipitate peptones or at least threw them partly out of solution. $HgCl_2$ also tended to form a slight precipitate in the peptone solution and hence its use was abandoned as well as that of the chloroform. The formalin formed no precipitate and we found it to be the most satisfactory reagent that we could employ for the purpose of checking the digestive action of

the pepsin. It did not completely check the peptic action however, We weighed samples of the meat in the digesting flasks; measured 400 cc of the regular pepsin solution and added 10 cc of commercial formalin to this solution, and placed the mixture in the flask with the meat. The flasks were kept at room temperature for 24 hours and filtered. The results of these tests are shown in table 20.

Samples of meat were treated with HCl alone in order to determine how much action was due to the pepsin alone. These results are also shown in the table just referred to. From the average of the two sets of results thus obtained it is seen that the pepsin even in presence of the formalin digested 25% more of the protein in the meat than did the HCl solution alone. On the other hand, by comparing the average of the results obtained by means of the formalin and the pepsin, and the pepsin solution alone when allowed to act at room temperature for 24 hours, we find that the formalin prevented about 55% of the protein from being dissolved.

As we would naturally infer, the most digestible portions of meat would go into solution first when treated with pepsin. By adding formalin after the action had gone on for 1 hour or more there is little doubt but much more than 55% of the action that would take place during the filtering would be checked. In our experiments one set of flasks were allowed to run just one hour at 38° to 40°, 10 cc formalin added and immediately filtered. Another set was treated in just the same way, except that the flasks were kept at room temperature for 23 hours more before filtering. Some of the results seemed to indicate very conclusively that the formalin had checked the further action of the pepsin. Sets of determinations were made that were digested for exactly three hours, and formalin then added, and solution immediately filtered. The results of these experiments are shown in tabulated form in table 21

TABLE No. 20 TREATMENT OF AIR-DRIED MEAT IN DIFFERENT WAYS, CONNECTED WITH ARTIFICIAL DIGESTION.

LABORATORY No.	AIR DRIED MEAT.	100 cc. pepsin solution at start. Added 10% HCl until solution had strength of .5%	100 cc. pepsin solution containing 2.5 gr. pepsin per liter of .33% HCl. Kept at 38° to 42° for 24 hours	100 cc. pepsin solution of .2% HCl. Kept at 38° to 42° for 24 hours	100 cc. pepsin solution of .33% HCl. Kept at room temperature 24 hours and filtered	100 cc. pepsin solution of .33% HCl. Kept in refrigerator at 4° for 24 hours and filtered in refrigerator	100 cc. pepsin solution of .33% HCl added 10 cc formaline to pepsin and kept at room temperature for 24 hrs.	100 cc. pepsin solution of .33% HCl Kept at room temperature for 24 hours and filtered
		%	%	%	%	% digested	%	%
1107	Beef round - animal 6 yrs. old, raw meat	—	98.08	—	95.59	90.87	40.08	23.43
1108	Same as 1107. Cooked for 2 hrs. at 80° – 85°	97.15	97.76	—	95.22	—	—	—
1116	Beef round, animal 5 yrs. old, Cooked 2 hrs. at 80° – 85°	—	97.58	96.50	96.72	92.40	34.37	8.98
1119	Raw beef round, animal 6 yrs. about	97.22	97.69	97.11	95.29	93.03	—	18.73
1120	Same cut as 1119. Cooked for 2 hrs. at 80° – 85°	—	97.65	96.89	94.32	—	45.35	12.38
1130	Raw beef, round – Animal about 3 yrs. old	—	97.43	96.82	94.19	—	37.96	12.08
1131	Same cut as 1130. Cooked for 1 hr. at 80° – 85°	—	98.11	96.21	94.87	—	40.18	13.99
1148	Beef round from 2 yr. old Cooked for 3 hrs. at 80° – 85	—	97.93	96.24	95.47	—	38.94	10.57
	Average of determinations	97.19	97.78	96.63	95.21	92.10	40.61	15.63

In table No.21 only the average of the best two or three analyses are shown. Good many other results were obtained which varied considerably from those shown in the table. Hardly enough are obtained to indicate any positive differences between the different kinds of meat experimented with. The samples are the same as already described under tabel No.20

'Time Element Involved in the' Digestion of Meat.

TABLE No. 21.

Lab. No.	1 hour and formaline filtered at once. Used 100 c.c. pepsin .33% HCl	1 hour and formaline kept 23 hours before filtering Same pepsin solution	3 hours and formaline filtered at once.
1107	% 81.60	% 80.54	% 82.94
1116	75.62	74.05	80.50
1120	73.66	75.29	84.08
1130	66.22	64.91	81.39
1131	67.82	69.42	82.98
1148	75.06	76.10	86.20
Average	73.33	73.39	83.02

In table 22 is given a summary of the digestibility of protein in different meats experiments with, and as determined by different methods.

Table No. 22

Digestibility of different meats as determined by different methods.

Exp. No.	Kind of meat.	Lab. No.	Artificial digestion	Natural digestion	Natural digestion with corrections obtained by pepsin solution
26	Cooked 2 hrs. 80-85 Round	1120	97.82	92.87	96.37
28	" 2 " " " "	1120	97.80	99.91	99.67
27	" " " " " "	1116	97.58	97.98	98.58
29	" 1 " " " "	1131	97.64	95.21	97.55
30	" 1 " " " "	1131	97.64	99.38	99.20
31	" 3 " " " "	1148	97.97	98.50	100.00
32	" " " " " "	1148	97.97	98.85	100.00
27	" 2 " " " "	1108	97.55	97.98	98.58
	Average		97.75	97.59	98.76

In the above table the digestibility of only the cooked meat is shown. In the artificial digestion column, the values given are those found for the fresh cooked meat except in No1116 where we had no result upon the freshly cooked, and hence substituted the value found for the air dried sample. The results obtained show fairly close agreement, by the different methods of determining the digestibility. This fact is especialy true in the case of the artificila and natural digestion results.

COMPARISON OF RESULTS OBTAINED WITH THOSE FOUND PUBLISHED.

Atwater[57] reports four digestion experiments in which beef, roasted and boiled comprised the principal part or the entire part of the diet. The average of the four experiments is as follows:-

	Protein	Fat	Ash
Atwater's an, for 4 ex:	97.5C	88.7C	88.5C
Our average for 5 "	97.07	98.97	----

The differences found are not so large wher we consider the fact that some of the experiments were made when digestion experiments methods were not so well developed as they are at the present time.

Chittenden's results have already been referred to. We did not find near the same difference which he did between the digestibility of raw and that of cooked meat. He found the former 5% more digestible than the latter. We found the digestibility of both very nearly alike, by the persin solution.

Stutzer[58] found about 17% more of raw than of cooked meat digested by persin solution containing .2% HCl. He worked entirely with the air dried sample. We fail to understand how he could find such a large difference.

K.Forster[59] found that when small amounts of meat were consumed at frequent intervals more was digested than when larger amounts were consumed, at less frequent intervals. The coefficients of digestibility which he obtained were:-protein 97.28% and fat 85.5%. The former agrees well with our value while the latter is considerably lower. He found the order of digestibility of differently prepared meats to be as follows:- smoked beef, roast beef, beef boiled in hot water at start, corned beef, broiled beef, and beef boiled in cold water at start.

Königsberg[60] found roasted beef to be more digestible than raw or boiled meat.

Considerable work has been done in trying to determine the time required for the digesting of meat.

Dr.Beaumont[61] found beef to require from three to three and a half hours for digestion, in his experiments upon St.Martin.

Jessen[62] found meat to require from two to four hours in his experimentswith men by use of stomachpump. Raw beef required 2 hours; half-boiled beef 2 1/2 hours; well boiled beef 3 hours; half roasted meat 3 hours and well roasted meat 4 hours. In his experiments with dogs much

more time was required.

Ladd[62] has reported a few experiments in testing the digestibility of raw and cooked beef from the same cut by means of pepsin solution. In a communication from him, we learn that he did not use anything to stop the further action of pepsin when he once started the filtering at the end of a definite time. He found a difference of 5 to 6 percent., between the digestibility of the raw and cooked meat at the end of 1 1/2 hours. Our average at the end of three hours was about seven percent., less than what he found, while our average at the end of 24 hours was about 3% higher than his average at the end of 18 hours.

CONCLUSIONS.

1. That of the nutrients of a diet in which meat is the principal food the following coefficients of digestibility were found as the average for seven experiments:- protein 95.98%; fat 97.17%; carbohydrates 95.82%; ash 76.64%; and total organic matter 96.24%

2. That after correcting for the feces due to foods other than meat the following values were found for the digestibility of meat alone, as the average of five experiments:- protein 97.07% and fat 98.97%

3. That from 45% to 65% of the nitrogenous matters in feces are soluble in pepsin solution, and hence that that amount may be considered as due to the metabolic products present.

4. That after applying corrections for the metabolic products present, the coefficients of the digestibility of the protein in total food as the average of seven experiments was 97.88% and of the protein in the meat alone 98.67%.

5. That as determined by artificial digestion the average digestibility of the protein of three samples of raw meat was 97.68%, of the same air dried 97.73%, of the protein in four samples of freshly cooked meat 97.75%, and the same air dried 97.61%.

6. That about 97.75% of the protein of food is digested within one hour, and from then on the digestion progresses much more slowly. Methods for determining small differences in the digestibility of different meats are at the present time not delicate enough to show conclusive differences

7. That the age of the animals studied appeared to have little effect upon the digestibility of the meat. Wider ranges in the ages would no doubt exert considerable influence.

8. That cooking the meat for different lengths of time has but little effect upon its digestibility. Such factors as the age of the animal may enter in here, and from our results we would not be entitled to draw any definite conclusions.

9. That there is but very little difference in digestibility between raw and cooked meat. We found the latter just a trifle more digestible.

10. That a great deal more work will be required before any general deductions can be drawn.

In conclusion, I wish to express my grateful thanks to Dr. Grindley for all the help that I have received from him in the course of the present study.

INDEX TO REFERENCES CITED.

1. Commerce and navigation tables,1900,3,4 & 5 r.,519
2. " " " " " " "
3. Phys.chem.of the an.body Gamgee. p., 64
4. " " " " " " " " 65
5. " " " " " " " " 67
6. " " " " " " " " 67
7. Mem.de l'Acad,des Sciences 1752, p.,461
8. Stevens,De alimentorium concoctione Edin 1777
9. Spallanzani Exp.,sur la dijestion de l'homme,etc. 1783
10. M'kendrick's Physicl. pp.,248 and 254
11. Muller's archiv. 1838 pp 90-198
12. Pfenger's Arch vol.II p.,198 vol.III p.,198
13. Landn.Journ. 28 (1880) pp.,199 &495
14. " Jahrbuch,1890 vol.19 pp.,149-187
15. Report Med.Exp.,Station 1891 p.,888
16. Zeits.fur Phys.chem.1888 v.,10,p.,561,v.,11,p.,1
16b Landn vers.Stat. v.,44
15 " " " 1895 vol.,46 .p.,198-200
18. Bul.21 U.S.dept.of Agr'l p.,58
19. Konig chem.d.Mensch nat.& gen.I 1889 p.,87
20. Zeits.fur Biol. 1879 p.,115 1880 p.,119
21. Bul 21. p.,57
22. " 21 p.,57
23. Jour.of Phys.II pp.,226 to 268
24 " " " 14 pp.,488 to 508
25. N.Y.Ag.Ex.Sta. 1886 p.,204
26. Zeits fur Physiol chim II pp.,1 to 24
27. Gottingen Exp.Sta. Record.
28. Bul. 21 p.,12
29 Gamger Phy.chem.of ani.Body p.,114
30. Jour.de Phar.et de chim 1850 p.3
31 Lehnbuch de Phys.u.chim 1850
32. Arch fur d.Holland Fett,zur Nat. u.Hist.kunde 1858-61
33. Zeits fur Phys.chimie vol.,1
34. Pfluger's arch. IX & XX
35 " " vc.XIII
36. Sitzungs.der Wiener Akad.vol.61

37. Natur u.Wahrwert des Peptoms Berlin 1878
38. Med.chim Transet 1880
39. Virchour's arch. Bd.IV
40. Arch.fur Anat u.Physiol 1880
41. Zeits fur Biol. 1883-1884
42. Kuhne weitere Metcheilungen p.,9
43. Phy.chem of An.Body,Gamgee p.,185.
44. " " " " " " p.,229
45. Comptes renans 1878.
46. Zeits fur Phys chim vol.,II 1878-79 p.,206
47. Pfluger's archiv. vol.IX
48. U.S.dept.of Agr'l Bul.85 p.,82
49. " " " " " " p.,44
50 See page
51 Am.chem.Jour. vol VI 1884,p.,822
52 " " " " Vi " p.,881
53 Digestive Proteclysis p.,18
54. Verhandlungen des Heidelberg Med Vereins Feb 1876
55. Virchrow's archiv. vol.,180 p.,497
56. " " " 184 p.,519
57. Bul 31 p.,61
58. Landn,Vers.Stat.vol.40 p.,821
59. Zeits,unter Nahr u.Gin 1888 vol.2 p.,782
60. Bied.Centr. 1888.p.,208
61. M'Kendrick's Physiol. p.,857
62. Zeits.fur Biol.new ser.vol.1,4888 p.,189
63. N.Dak. 19th annual Report 1900 p.,12

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A.

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May 30th 1901.