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NATURAL AND ARTIFICIAL DIGESTION OF CRUDE FIBER COMPARED WITH CHEMICAL METHODS OF ESTIMATION.

by

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CONTENTS AND PLAN OF TREATMENT.

In digestion trials at the Missouri Agricultural Experiment Station on feeding steers in the "Use of Food" Investigations it has been found that 84 - 65 per cent of the total feed is digested while it was observed that considerable was present in the dung undigested. That is, the total digestion coefficient runs from 84 - 65 per cent on all the seventeen animals studied on definite feed.[1] (See Table I).

1 Unpublished data.

An attempt to determine the per cent of feed found in the dung has been made by washing out the metabolic nitrogen which interferes. This feed averaged 3.15 per cent for eleven determinations given in Table I. The present study is essentially a continuation of this by reviewing the literature and studying the factors which influence the coefficient for protein and crude fibre digestion in the animal's digestive organism and therefore also the constituents of the feed in the dung.

The part consisting of the literature pertaining to the above and other nutrition studies which had been conducted and factors affecting the coefficient of digestion will be given in Part I.

The protein and crude fibre coefficients of digestion vary considerably under different conditions as given in Tables I and II in which it is shown that digestion is most efficient in Group V, (maintenance); next in Group III,(submaintenance), then Groups III, II and I respectively for crude fibre, unmasticated grain and protein. Several exceptions occur, but in general this appears to hold.

TABLE I.

Summary of Protein and Crude Fibre Coefficients of Digestion for Five Groups of Animals under Different Conditions of Feed.

	No. of Dets.	Protein Digested.	No. of Dets.	Crude Fibre Digested.	No. of Dets.	Per Cent Grain Unmasticated.
Group V maintenance	(7)	72.033	(7)	41.402	(5)	0.706
Group IV submaintenance	(2)	70.616	(1)	43.454	(0)	----
Group III retarded growth	(1)	75.013	(2)	40.465	(1)	1.948
Group II maximum growth	(2)	70.420	(1)	38.802	(2)	4.543
Group I full fed	(5)	65.455	(5)	37.793	(3)	6.014

Group V on maintenance, was fed sufficiently to maintain constant weight on a special maintenance ration consisting of corn eight parts, linseed meal 1 part or five parts grain to two of hay. While Group IV on submaintenance, was underfed resulting in a loss in weight of one-half pound per day on the same ration given for Group V. Group III was fed for retarded growth which represents conditions on the range on a ration consisting of corn 6 parts, oats 3 parts, linseed meal 1 part, that is two parts of grain to one of hay. Group II was fed for maximum growth without laying on an appreciable amount of fat. (Represented by good farm conditions). The feed consisted of the same ration fed Group III. Group I was full fed all their lives the same ration which was fed Groups II and III.

The number of determinations in three of the groups are limited, hence the conclusions are only tentative.

The per cent of unmasticated grain recovered appears to follow in the reverse order, also as shown above in Table I. The unmasticated grain was washed out of the fresh dung with water, allowing the metabolic nitrogenous matter to float off the surface. While this is a rough method, yet considerable of the coarser unmasticated grains were recovered as shown by Table I.

It is also seen that in general the per cent recovered increases with the decreased digestion coefficient for both nitrogen and for crude fibre.

TABLE II.

Summary of Maximum Variations for Protein

Digestion for Crude Fibre, and for Per Cent Unmasticated Grain.

	Det. No.	Protein Digestion Per Cent.	Det. No.	Crude Fibre Digestion Per Cent.	Det. No.	Unmasticated Grain. Per Cent.
Group V maintenance	(7)	88.502 - 61.776	(7)	51.472 - 29.417	(5)	1.195 - .367
Group IV sub-maintenance	(2)	79.657 - 61.574	(1)	43.454 -----	(0)	--- ---
Group III retarded growth		75.013 - ----	(1)	40.465	(1)	1.948 - ---
Group II maximum growth	(2)	70.024 - 70.820	(2)	40.045 37.559	(2)	5.763 - 3.322
Group I full fed	(5)	68.361 - 61.639	(5)	47.138 31.531	(3)	8.196 - 3.944

From the Table II above it is seen, variations for protein digestion were greatest respectively for (maintenance) Group V, (submaintenance) Group IV, and Group I as follows: 26.726 per cent, 18.083 per cent and 6.722 per cent, while in crude fibre digestion it was respectively for Group V, Group II and Group I, as follows: 22.055 per cent, 2.486 per cent and 15.617 per cent.

Thus the protein and crude fibre digestions vary considerable in individual animals under the same conditions of feed as well the variation obtained on different groups when on different planes of nutrition.

From the above discussion it will be seen that there is considerable of the animal's feed which is not utilized. The amount of which varies.

PART I.

A. Action on Crude Fibre and Protein in the Digestive Tract.

a. Fibre is the woody portion of plants. The walls of cells in plant tissue are chiefly cellulose. In young active growing vegetable tissue, the cell walls are thin, but as the plant increases in age, these thicken chiefly through the deposition of cellulose.

The more of this a feeding stuff contains, the more tenaceous it is other things being equal, and the more difficult of mastication. It varies considerably, 2.2 per cent for corn to 25 per cent for clover hay.

Kellner[1] says crude fibre consists of a mixt-

[1]Kellner, Sci. Feed. of Animals (Eng. Ed.), p. 13.

ure of cellulose, pentosans, lignin and cutin. Particles of cellulose and pentosans may be imbedded in the "cutin and lignin", the encrusting materials. The higher the per cent of lignin and cutin in crude fibre the closer does it approach wood in its composition. As to coarse fodders[2] Armsby says

[2]Armsby, Bul. 139, B. A. I.

the hexose group is largely represented, also the pentose group, both of which contain no inconsiderable quantity of carbohydrates. These members are less well known. The knowledge of their nutritive value is scanty.

Some idea of the composition of coarse feeds may be gained from the analyses of straw before and after fermentation, given below.[3]

[3]B. Plant Ind., Bul. 266, p. 17.

Composition of straw before and after fermentation of which the following is the average composition with apparently no change due to fermentation.

	Per Cent.
Cellulose	28.25
Vasculose	28.03
Straw gum (into xylose)	20.00
Nitrogenous materials	4.87
Ash	7.15
Water	9.52
Chlorophyll materials	0.93
Reducing sugars	2.43
Dextrin	0.05
Gums, tannins, acids	0.60
	101.83

Armsby[4] sums up the composition and determin-

[4]Armsby, Prin. of Nutrition, '08 Ed., p. 9.

ation of crude fibre as follows: "In the conventional scheme for the analysis of feeding stuffs, the carbohydrates are subdivided, not upon the basis of their chemical structure but upon the basis of their solubility. Those members of the group which can be brought into solution by boiling dilute acids and alkalies under certain conventional conditions are grouped together as "Nitrogen-free-extract" while those ingredients which resist solution under these conditions are designated as 'crude fibre'. The more common hexose carbohydrates such as starch, sugars, etc. are included in the nitrogen-free-extract while the larger part, although not all, of the cellulose is included under the crude fibre. At the same time, more or less of the pentose carbohydrates or 'furfuroid's' are found in both these groups while the crude fibre of coarse fodders contain also a variety of other ill-known compounds, somewhat roughly grouped together under the general designation of ligneous material".

Kellner[5] calls attention to the fact that the

[5]Kellner, Sci. Feed. of Animals, Eng. Ed., p. 110.

pentosans have not yet been prepared in a pure form. Their presence in crude fibre is inferred from the fact that on boiling this portion of the plant with dilute acid, characteristic pentose sugars, such xylose, are formed. The pentosans must be regarded as being the mother substance of these sugars.

Cellulose and the pentosans have the same percentage composition (44.4 per cent carbon) while lignin and cutin which are less known, are richer in carbon, the former having 55 - 60 per cent and the latter 68 - 70 per cent. The components of the crude fibre are so intermingled that the particles of cellulose and the pentosans may be imbedded in the cutin and lignin.

b. Nutritive value of crude fibre. Considerable work has been done on coarse fodders and crude fibre. More attention was early given to the lower nutritive value of coarse fodders than that of the concentrates. It has been generally accepted that the nutritive value of crude fibre is considerable for certain classes of animals as it has been proven that an ox and goat can subsist on coarse straw. The coarse fodders are more digestible for ruminants than for the horse or pig. Kellner[6] shows that the ox is able to digest as

[6] Kellner, Land. Vers. Sta. 1906, 63, p. 313.

much as 11 per cent more or less of digestible roughness (straw) than sheep. He accounts for this in this way. The contents of the last part of the intestines of the ox remains more watery and hence is subject to more complete fermentation. Thus crude fibre and nitrogen-free-extract are decomposed by bacteria in the intestines to organic acids, CO_2 and CH_4, of which the first is absorbed into the circulation while the last two are given off, out of the body.

The per cent of this undigested crude fibre and nitrogen-free-extract is equal to a loss of 4.3 per cent methane and 13.7 per cent heat value of the total substance. While with hard food stuffs as wheat straw, the loss is still more, estimated at 20 per cent of the heat value.

Kellner also found that in finely divided form (straw pulp from paper works) the crude fibre has the same effect as pure starch and that 57 per cent of the heat value was stored up. That fat can be formed from crude fibre as well as fat from nitrogen-free-extract.[7]

[7] Ibid. p. 82.

He gives a comparison of the production value of oil cake meals (concentrates) with the coarse fodders in which he shows that in value they differ from the latter by

30 - 80 per cent. In brief the following is true of coarse fodders:

1. The work of mastication and of digestion is considerable. (e.g. On chopped straw).
2. This causes a depression of the digestibility of the other food. (Proven by feeding sawdust).
3. They may cause processes of excessive decomposition in the intestines.

Decomposition may proceed so far that it serves as a source of heat and does not serve for the formation of flesh or fat.

It is usual to regard the difference between the food and dung as being digested but in the case of difficultly digestible food, a portion is not really digested but has undergone putrefaction. (In certain cases food consists of organic acids, this has no food value for the formation of new tissue, this may partially account for the interference of the digestive substance).

Assimilation in coarse fodders depends on:

1. The amount of work required for mastication and digestion.
2. The extent of putrefaction.

The general conclusions given above are further elucidated by some of Armsby's[8] work and discussions which will be briefly referred to.

[8] Armsby, pp. 183, 538.

Energy required in digestion.

The difference in the nutritive value of coarse fodder and grains arises largely from the difference in the amounts of energy used in digestion and assimilation. Kellner on extracted straw, in cattle digestion trials, has shown that the difference is not merely due to the presence of crude fibre but is related rather to the physical properties of the feeding stuffs. Zuntz has also shown that the same factor largely affects the work of mastication in the horse.

Practical value of cellulose in feeding.

From experiments it has been shown that the products of digestion of cellulose by ruminants are substantially of equal value with those of the digestion of starch. This however, does not mean that starch and cellulose are of equal value in ordinary feeding stuffs. The material here worked on had been largely freed from encrusting materials so that the coefficient of digestion was 88.3 per cent for organic matter, 95.3 per cent crude fibre, while on wheat straw it was 52.5 per cent for crude fibre. This lead to the conclusion that the influence of physical condition are the causes rather than chemical, of the differences observed.

Not all results of experiments by investigators however, agree with the above conclusions. In general the following conclusions hold:

1. Crude fibre in ruminants is necessary for bulk.
2. Ruminants are able to digest more crude fibre than other animals. (Goat or cow rather than sheep or horse).
3. This is due to the great bacterial activity in the small and large intestine.
4. Crude fibre is equal to starch in feeding value.
5. Its depressing effect is due to the great amount of

work of mastication and of digestion necessary.

6. Its physical condition of hardness determines its effect on the digestibility of a feed.

7. Some energy is lost by putrefactive decomposition changes through formation of gases CO_2, CH_4 and perhaps indigestible organic acids which contain energy as heat.

c. Nitrogen present in small amounts in crude fibre.

The crude fibre as ordinarily determined contains some crude protein, enough so that Kellner[9] gives a method of ob-

[9] Kellner, Eng. Trans. p. 110.

taining the "true quantity" of crude fibre. The method used is given below. "If a small quantity of finely-ground food material be boiled successively with given quantities of dilute H_2SO_4, water, dilute caustic potash, and again with water, a residue is left which after washing with alcohol and ether, may be dried and weighed. This residue consists principally of crude fibre along with a <u>little crude protein</u> and <u>mineral substance</u>, and if these last two are estimated separately in a portion of the residue, and their weight deducted from the total weight, then the <u>true quantity</u> of crude fibre is obtained. Crude fibre obtained in the above manner is free from nitrogen, and consists of a mixture of cellulose, pentosans, lignin, and cutin".

d. Influence of large quantities of feed and the individual coefficients of digestion of nitrogen and crude fibre.

As to the influence of the quantity and mixing of of the food upon digestion, the following conditions have been found to hold:

1. If coarse fodder is the only food stuff given, then small or larger quantities do not affect digestion as has often been shown.

2. However, if varyingly large rations in which the ratio between coarse and concentrated feeds is kept constant, the ration seems to be digested to a less degree the larger the daily ration is as shown by Kellner in the Table V.

TABLE V.

Effect of Quantity of Daily Ration on Digestion Coefficients When Ratio Between Coarse and Concentrated Feeds is Kept Constant.

Kgs. Dry matter Feed Consumed	Per Cent Organic matter digested.
10.84	76.0
13.01	74.7
15.18	72.8
10.84	75.8

Four consecutive digestion trials were made in which a ration of 10.84 kgs. of feed (dry matter) was fed with 76.0 per cent digested. This was increased to 13.01 kgs. in another trial when the per cent digested fell to 74.7. On further increasing the ration to 15.18 kgs. still less, 72.8 per cent was digested. This is a decrease of 3.2 per cent of organic matter digested. The diminution of the amount of food digested in the larger ration was equally evident in the various food constituents except the crude fat. In decreasing the ration to the quantity of feed used in the first digestion trial, an increase in the digestion coefficient for organic matter was obtained equal within two-tenths to that obtained in the first digestion trial.

Kellner also calls attention to the fact that the depression of digestion is not as a rule large, still in total daily rations it may mean a considerable quantity. In the Table V given, one pound less organic matter was digested when the larger ration was given.

Kellner accounts for this depression in a simple way. He says, "that by the consumption of large quantities of food the passage through the alimentary canal is more rapid although this organ possesses a certain distensibility and so digestion may not be perfect. When large quantities of easily digestible food are consumed it is possible that the intestine is not able to cope with it and so some of the nutrients escape unabsorbed".

Below[10] in Table VI are shown the effect of

10 Unpublished data.

rations for steers Group III, approximating conditions on the range, and for those full fed (Group I) on the coefficients of digestion.

TABLE VI.

Influence of Large Quantities of Feed on the Nitrogen and Crude Fibre Coefficients of Digestion.

Plane of Nutrition.	No. Dets.	Per cent digested Protein.	No. Dets.	Per cent digested crude Fibre.	No. Dets.	Unmasticated grain.
Group III (Range)	(1)	75.01	(1)	40.5	(1)	1.95
Group II (Farm)	(2)	70.4	(2)	38.8	(2)	4.54
Group I (Full Fed)	(5)	65.5	(5)	37.8	(3)	6.01

The underscored figures bear out the above facts as far as the limited number of comparisons permit. With an increased ration, an average for crude fibre of 9.5 per cent decrease in digestion was obtained; 2.7 per cent for crude fibre; and 4.6 per cent for unmasticated grain.

Effect of the Addition of Carbo-hydrates.

The one-sided addition of digestible carbohydrates to a food causes, under certain conditions, a greater or less depression of digestion. This fact has been constated by numerous experiments on ruminants and pigs. Thus by the addition of starch to hay, or sugar or cellulose to hay, also the addition of feeds rich in carbohydrates as potatoes, mangels, etc. when added to a ration poor in crude protein, the digestion of the various components of the food is diminished.[11]

[11] Kellner, p. 36.

With the addition of such materials, the feces of the animals are considerably richer in nitrogen substances. On analyzing the feces more crude protein is found than when the basal ration is given without any such addition.

Effect of Addition of Crude Protein to Ration.[12]

[12] Ibid, p. 38.

The increase of crude protein in a food causes not only no depression of digestion of the other components but, on the contrary, minimizes the depressing effect of large quantities of nitrogen-free substances; for example, ruminants are being fed with a mixture of hay and straw and a lot of potatoes, then, as has been shown, (Kellner, p. 36) the nitrogen-free substances are not completely digested, in fact, part of the easily digested starch passes into the feces.

When a food rich in protein, say cottonseed cake meal is added to the ration, no traces of starch are found in the dung, for digestion has been completed. The addition of non-protein substances (amides, amino acids, etc.)

act similarly to the protein, and raises the digestion when it is depressed by large doses of carbohydrates.

After thorough investigation of this phenomena, it has been proved that a complete digestion of all constituents of the food is assured if the total ration contains 8 to 10 parts of digestible nitrogen-free substance to each part of crude protein.

This ratio applies particularly to ruminants; if the proportion of carbohydrates is in excess of these figures, then some of the otherwise digestible materials pass into the feces. For pigs, for instance, less protein is necessary as 1:12 nitrogen-free extract.

The rations used in Table VI were 1:4.6 and the other greater, both were well within the above limits.

e. Effect of non-proteins on the coefficient of digestion.

Non-protein investigations for the formation of fat have only been made with asparagin. Upon sheep it has been shown that these materials cannot be changed into body fat. This agrees perfectly with the fact that asparagin, when it is not changed by the bacteria of the intestines, possesses no protein-saving action. All food nutrients which are capable of conversion into body fat in the body possess at the same time the power of economizing protein.

This fact has been proved by most thorough investigations that only those materials are digested which, inclusive of the pentosans, posses the same percentage composition and heat value as carbohydrates of the class of pure starch and of pure cellulose.

According to Kellner (l. c.) the production value of these compounds is doubtful, "Whether the nitrogen compounds of non-protein nature which contain more carbon than asparagin can take part in the formation of fat has not yet been decided. In fact, the whole question as to the position of these materials in the food supply requires more investigation".

Kellner (l. c.) in summarizing the present status of this class of compounds, makes the following statement: "As far as it has been proved, it may be said that ruminants receiving a food poor in protein but rich in non-protein, can utilize the latter to make flesh, but not fat, the change being brought about by help of the bacteria in the partly digested food".

Investigations have been carried on, on the non-protein compounds in molasses and other substances as potatoes and mangels in maintaining nitrogen equilibrium in ruminants but the conclusion arrived at is that "only with substances which result from the decomposition of protein by pancreatic juice and which contain therefore all that is in the protein, has the effect on carnivora been shown to be the same as with the protein themselves". The following conclusion from Kellner may further elucidate this: "Ruminants[13] behave differently to the carnivora and herbivora as regards the non-protein of the food. Fundamental differences in the way in which the nu-

[13] Kellner, Eng. Trans.

trients are treated in the body cells are in any case not to be expected. The various species, however, do differ in the manner in which the work of the alimentary canal is performed, and it is here that an explanation must be sought. Most probably the differences are caused by the bacteria, for ammonia and asparagin are known to be excellent food for them. It may be that these microörganisms, with the assistance of the nitrogen-free substances, form proteins in one part of the intestines, which are again digested in another part".

f. Other factors effecting the coefficient of digestion.

1. Salt. This acts as a stimulant unless given in large quantities when it acts as a purgative.

B. ARTIFICIAL DIGESTION OF FEEDS AND DUNG COMPARED TO NATURAL DIGESTION.

1. Metabolic nitrogen present in excrement with crude fibre: method of estimation by artificial digestion.

For a long time it has been desirable to obtain a laboratory digestion method of feeding stuffs which would give comparable results with that obtained in the animal digestion. One disturbing factor which interfered in such a method was the estimation in the dung of the amount of metabolic nitrogen which was present.

Numerous observations, on record, have been made in digestion trials which show that more nitrogen in the feces was obtained than contained in the ration.

However, Morgan [14] found in fifteen out

14 Morgan, A., Beger, C., and Westhaussar, F., Die landwirtschaftlichen Versuch-Stationen, Band. 73, p. 337, Berlin, 1910.

of eighteen digestion trials upon straw, a feed containing practically no non-protein, that the nitrogen of the feces exceeded that of the feed.

The first attempt at a quantitative determination of the amount of fecal nitrogen in the excreta of herberorous animals was made by Kellner [15] who estimated the

15 Kellner, O. Biedermann's Centralblatt für Agrikultur chemie, Jahrgang 9, pp. 107-110, also pp. 763-765. Leipzig 1880.

average amount of metabolic nitrogen in the feces at 0.4 gram per 100 grams organic matter digested.

a. Metabolic Nitrogen.

It has been shown that the daily addition of starch to a ration of meadow hay increases the amounts of crude protein, nitrogen-free-extract, and crude fibre found in the feces. This depression of digestion due to starch was also observed when other carbohydrates as sugar or cellulose were added to hay.

It is known that the feces of the animals are considerably richer in nitrogenous substances than the food digested when on a nitrogen-free feed. These are derived from the digestive juices and the mucous membranes of the intestines called metabolic nitrogen.

This would tend to decrease the coefficient of digestibility, however, it would only be an apparent one.

Stutzer [16] in 1881 later developed a labor-

[16] Stutzer, A., Jr. für Landwirtschaft, Jahrgang 28, pp. 195-208; also pp. 435-453. Berlin, 1881.

atory method with pepsin and trypsin digestion. Pfeiffer [17]

[17] Pfeiffer, Th., Jr. für Landwirtschaft, Jahrgang 33, pp. 149-192. Berlin, 1885.

Ibid. Jr. für Landwirtschaft, Jahrgang 34, pp. 425-453. Berlin, 1886.

Ibid. Zeitschrigt für Physiologische Chemie, Band. 10, pp. 561-576. Strassburg, 1886.

using this method, fed two pigs a nitrogen-free ration of starch, sugar, oil, paper pulp, and ash ingredients. To this ration at a later period pure digestible protein (conglutin) was added. He confirmed Kellner's results by observing in the first period that the feces contained an average of 0.4 grams Nitrogen per 100 grams of digested dry matter. This must have been in the form of metabolic products, since the feed contained no Nitrogen.

In the second experiment in which the protein was assumed to be digestible, 0.39 grams metabolic nitrogen was obtained. Kellner also reports similar results upon a sheep receiving non-nitrogenous matter.[18]

[18] Die Ernährung der Landwirtschaftliche Nutztiere, 5th Ed., p. 32.

One important result of the artificial digestion method is the fact that these metabolic nitrogenous products in the fresh dung are soluble in pepsin hydrochloric acid, leaving thus a residue insoluble in pepsin.

The results of the digestibility of feeds estimated by this artificial digestion method are based on the pepsin insoluble residue obtained, which is practically the same in amount as obtained from the laboratory digestion of the dung from the same feeds.

Kühn[19], by modifying Stutzer's method had ob-

[19] Kühn. Die landwirtschaftlichen Versuchs-Stationen Band 44. 1894 p. 204.

tained the following results using different feeds under very different feeding conditions.

TABLE VII.

Comparison of pepsin-insoluble Nitrogen Obtained from Feed and Dung by Kühn's Method on Twenty-two Digestion Trials.

No. of Oxen.	No. of Digestion trials.	Feeds Used.	Protein Digestion for Pepsin by Kühn's Method. In all feed. gms.	In the dung. Total gms.	Comparison with that in the feed. More gms.	Less gms.
8	22	Basal ration with 3 supplementary rations.	919.1	933.2	34.9	15.3
		Total average of all experiments.	41.8	42.9	1.1	--

Thus Kühn[20] has shown that the pepsin insol-

[20]Kühn - The landwirthshaftlichen Versuchs-Stationen, Nobbe Band 44. 1894, p. 205.

uble nitrogen of the feed reappears quantitatively in the feces or "this conclusion holds that in ruminants the pepsin insoluble Nitrogen of feeds goes through the animal digestion completely or untouched".

In the dung there are three forms of nitrogen termed metabolic nitrogen, indigestible nitrogen and digestible protein, parts of which may appear in the feces undigested.

The above method enables one to determine the three forms of nitrogen. First the per cent of metabolic nitrogen in the dung may be determined by feeding special nitrogen-free rations in digestion trials. Second the indigestible and digestible nitrogen can also be determined by the above method.

b. Effect of bacteria and non-proteins on the Nitrogenous Constituents in Digestion.

Considerable work has been done in the last six years on this phase affecting the coefficient of digestibility. In general, the tendency of the methods of investigation are to eliminate as many of the complex chemical compounds in a ration as possible feeding individual compounds or rather classes of compounds. No attempt will be made to enter into a detailed discussion of this subject. However, a brief reference is worthy of mention here.

Armsby has summarized this work in a fifty page bulletin, No. 139 - B. A. I. (1911), in which is discussed the investigations on "The Nutritive Value of the Non-protein of Feeding Stuffs". Among other things are given discussions on: The nutritive value of non-protein for herbivora.

A. Non protein a source of protein.

Sources of information available.

1. The later experiments of Kellner on lambs and cows.

2. Morgan et al., '07, '08, '09 Investigations on milking animals for milk production.

3. Experiments from the laboratory for agricultural research in Copenhagen (on dairy cows for milk production).

B. The effect of non-protein or total production.

C. Direct utilization of ammonium salts.

Armsby's[21] résumé of this subject is given

[21]Bul. 139. B. A. I., pp. 45-46.

verbatim:

"1. Amino acids and amides, which ordinarily constitute the larger part of the non-protein of vegetable substances, are kotabolized in the animal body, their nitrogen appearing in the urine.

2. In carnivora and omnivora, neither the single substances of the foregoing groups nor the mixtures of them contained in plant extracts, have been shown to be capable of performing the functions of protein.

3. In ruminants a conversion of non-protein into protein appears to be affected by the microörganisms of the digestive tract. The extent of this conversion appears to be relatively greater in the case of ammonium salts and asparagin

than in that of vegetable extracts.

4. The protein formed thus from non-protein seems to be digested subsequently. The apparent formation of indigestible protein observed by some investigators appears to be due to an increase in the metabolic products contained in the feces, caused by a specific action of the extracts upon the digestive tract.

5. By means of its conversion into bacterial protein, the non-protein of feeds, may serve indirectly for maintenance and also as a source of protein for milk, and probably for growth, in rations deficient in protein.

6. The limiting factor in the indirect utilization of the non-protein of the feed appears to be the extent to which it can be converted into protein in the digestive tract rather than any inferior nutritive value of the protein thus formed as compared with that originally present in feed.

7. The non-proteins are much inferior to the proteins in nutritive value for productive feeding. The prime effect of a substitution of non-proteins in the ration is a very marked falling off in the production. The indirect utilization of non-protein simply serves to prevent this decrease from becoming as great as it otherwise would, and so in case of need to compensate partially for a deficiency of protein. On the other hand, with a reasonable supply of digestible protein the addition of non-protein usually fails to increase the production of nitrogenous matter.

8. Recent experiments raise the question of the possibility of a direct utilization of NH_3 as a source of protein by the higher animals.

Conclusions.

Digestibility of Crude Fibre.

1. Crude fibre is shown to be a rather indefinite term chemically which includes a rather indigestible class of vegetable tissue consisting chiefly of cellulose or substances similar to starch, which is estimated chemically on the basis of insolubility in acid and alkalie.

2. Crude fibre has some feeding value but this is greatest for ruminants. Crude fibre in the condition in which it is used in digestion trials is equal to starch in nutritive value being in addition necessary for bulk. Some animals as the goat or ox are able to subsist alone on coarse fodders high in crude fibre as straw, due to the great bacterial activity in the small and large intestine.

3. In digestion, crude fibre has a depressing effect on the feed consumed, due to its physical condition of hardness rather than chemical. This necessitates considerable work of mastication and digestion.

Factors Affecting the Coefficients of Nitrogen and Crude Fibre Digestion.

1. If coarse fodder alone is given, then quantity does not raise or lower the coefficient of digestion.

2. When the ratio between coarse and concentrated feeds is kept constant, however, then large rations varying in quantity seem to be digested to a less degree the larger the daily ration.

3. The addition of carbohydrates alone to a ration causes a greater or less depression of digestion for ruminants

especially, when the ratio of digestible nitrogen-free substances to crude protein exceeds 8 to 10 parts to 1. If the carbohydrates fall within this ratio, complete digestion of all the constituents occurs.

4. The non-proteins in the digestion of ruminants upon the whole, appear to have a protein-saving action and thus can replace protein for maintenance and probably for production to some extent. This conclusion appears to hold only when the rations contain insufficient protein.

Artificial Digestion of Feeds Compared to the Digestion in the Animal. (On Dung).

A laboratory method on the digestion of feeds by means of pepsin hydrochloric acid has been modified by Kühn which gives comparable results to that obtained in digestion trials. The important point in this method is that the indigestible substances are also insoluble in pepsin hydrochloric acid solution.

Effect of Bacteria and Non-proteins on Protein in Digestion.

Briefly, the protein formed from non-protein which appears to be affected by the microörganisms of the digestive tract, seems to be digested subsequently and may serve indirectly for maintenance and also as a source of protein for milk and probably for growth, in rations deficient in protein.

In regard to the extent and utilization of non-protein of feeds, the limiting factor for this indirect use, appears to be the extent to which it can be changed into protein in the digestive tract rather than any inferior value of the protein so formed as compared with that present in the feed.

PART II.

CHEMICAL DETERMINATION OF CRUDE FIBRE IN FEEDS AND FEEDING STUFFS.

Origin and Significance of Method.

Historical (1846 - 1890).

The methods[1] in use for the analysis of cattle feeds do not represent the actual composition and nutritive value of those feeds but give approximate ingredients divided into classes of substances which are comparable with the same classes in other feeds.

[1] Chem. Bul. 28, Proceedings A.O.A.C. 1889, p. 118.

Among this class is the determination of crude fibre constituting a class of rather indigestible substances, not necessarily a pure product of cellulose.

This method has been studied, modified and discussed for the past 65 years, both in Germany and more especially in the past 25 years in this country.

The defense made of the method against its inaccuracy and variable results is that it is a practical method giving fairly constant results but not necessarily scientifically accurate.[2]

[2] 7th Annual Proceedings A.O.A.C. 1888, Kühn, p. 19.

Concerning the accuracy of the method compared in regard to actual feeding trials, the report of the director of the Office of Experiment Stations, 1889, says "the results of actual feeding tests do not always agree with those obtained by analysis and recommended in feeding standards".[3]

[3] Rept. of Director of O. E. S., 1889.

Hence it seemed desirable to investigate further the origin and significance of this method.

A method of determining fibre was first proposed by Horsford[4] on vegetable foods. He digested for fibre

[4] Analen die Chemie und Pharmacie, LVIII, 1846, 170.

with dilute HCl renewed then, from time to time, digested with NaOH; this he continued for two months.

Poggiale[5] made this criticism of the method

[5] Chem. Centr-bl., 1859, 844.

that the successive treatment with acid and alkali causes a loss of cellulose by conversion into glucose. To avoid this, it is interesting to observe that he boiled out the sugar and starch with 300 cc. of H2O to which 6 cc. of strong HCl is added and determines sugar in the filtration.

The first one to use this method in cattle feeds and to remark on the difficulty of filtration was Eisenstück[6] who digested with 3 per cent HCl and with NaOH, washing

[6] Die Versuchs Stationen, III, 1861, 237.

with absolute alcohol and with ether warmed slightly. Only in the case of oil seed cake, did he use previous extraction with ether; the filtration of HCl was very tedious; to overcome this he used a pressure of 8 to 10 feet columns of water and then finished in one day in some cases.

Hofmeister[7] made the first use of this method with

[7] Die Versuchs Stationen, VI, 1864, 325.

digestion trials on sheep. He used paper cullulose. He makes much account of a previous treatment of substances with alcohol and ether, this rendered filtration easier especially if much fat was present. He ran a large number of determinations and gave conclusions as to method to be followed. This consisted chiefly of 2 hours digestion with sufficient amount of 3 per cent H_2SO_4 at 80°, then filtration and washing and the same repeated with KOH; digested finally with 30 cc. concentrated acetic acid at boiling heat.

The next important advance in this method was by Henneberg. This is known as the "Original Weende Method".

Original Weende Method.

still in use today but with several modifications.

A three gram charge was boiled with 50 cc. of 5 per cent H_2SO_4 with constant replacement of H_2O; he siphoned off the extract, boiled 30 minutes with 200 cc. H_2O with replacement of evaporated H_2O and again siphoned off; this was repeated with H_2O. Then he carried out a similar set of operations with 5 per cent solution of KOH and with H_2O and collected the residue on a weighed filter. All siphoned liquids were allowed to stand an hour for settling, siphoned off the clear alkaline liquid and placed the sediment on the above filter, washed as long as alkaline, then put the acid sediment on the same filter, washed twice with H_2O, alcohol and ether; dried, weighed and determined ash.

Mention in above method is first made of replacing evaporated water, length of digesting and boiling with definite quantities. Nothing is said of fineness of sample and how the strength of acid is determined, how results compare in feeds with that in digestion trials, nor as to accuracy and constancy of results.

Contemporary methods in extensive use with this one being tried only at this time were the following:

Gronven's method[9]: digested 6 hours with 5

[9] H. Schultz. Zur Kenntniss der Chicorie. Die Versuchs-Stationen, IX, 1867, 215.

per cent H_2SO_4, washed residue, dried and digested in same manner with 3 per cent NaOH solution.

Schulte's method: maceration of feed with $KClO_3$ and concentrated HNO_3.

Of the above methods it is interesting to note in the literature that G. Kühn and others followed Henneberg's method with slight modifications.

Several important points were brought out in the discussion of Crude Fibre determination in the 6th session of German Agricultural Chemists [10] in 1869 among which were the

[10] Die Versuchs-Stationen, XI, 1869, 198.

following: Stohman said that Schulte's method gave no pure product of constant composition. Frühling said the Weende Method yields a pure product but with the same sample one can get constant results only by the most careful maintenance of constant strength of solution and equal times of treatment. He tried stronger acid and alkali without any gain in accuracy.

No uniform results were obtained with Schulte's method. G. Kühn maintained that in the use of the method the object of the work was not necessarily to get pure cellulose, but to establish a method that with both fodders and excrements will give uniform results. Experience has strengthened this assertion.

J. König[12] on cellulose determination is the

[12] Die Versuchs-Stationen, XVI, 1873, p. 415.

first investigator who remarks as follows on the influence of fineness of sample on the results: "as to fineness of material, best results are obtained if made fine enough to pass through a 0.5 mm. mesh" but he thinks this is impracticable as material must be dried and reground many times to get all through. He recommends the use of 1 mm. mesh sieve.

Henneberg[13] later suggests that fineness of

[13] Die Versuchs-Stationen, XXXIII, 1879, 66.

material may affect the results and suggests that tests be made of the range of this effect by working on material of different degrees of fineness. Krauch[14] did further work and criticized

[14] Chem. Bul., Bur. of Chem., p. 20.

the method showing that after the treatment of vegetable substances with cold water and with malt extract, alcohol and ether, they give no reaction for starch. This he calls the "Grund substanz". He considers that this consists essentially of cellulose and lignin. He shows that some of this is dissolved by 1.25 per cent acid and alkali and is calculated with Nitrogen-free-extract to a large extent in the case of some fodders.

It remained for H. Wattenberg[15] to point out the difficulties

[15] Jr. für Landwirthschaft, XXVII, 1880, 273.
Chem. Bul. 28, U. S., p. 19.

and sources of error in the original Weende Method. He also proposed modifications which are substantially in use today, known as the Wattenberg Method.

Wattenberg: Difficulties and errors.

1. Six times siphoned off and clarification of liquid by settlings.
2. The sediment which thus settles out from the acid liquid and washings escapes treatment with alkalie.
3. Each time after siphoning there is a variable quantity of acid and alkalie left in the dish.
4. Boiling in an evaporator makes it difficult to estimate the amount of water necessary to add in order to keep the volume constant.

Wattenberg's Proposed Modifications: (In use at present day).

1. Evaporation replaced by the use of a blue mark at 200 cc.
2. Draws the liquid off by suction through filter paper on gauze tied over mouth of funnel.
3. Gets nearly all the liquid off and rinses any substance on the paper back into the dish again.

4. Uses a new filter paper for each drawing off.
5. Boils only once with water.
6. For second washing merely pours boiling water on.
7. Can complete one determination in a day.

Comments on The Above Method by Principal Workers.

Richardson[16] in the Bureau of Chemistry U. S.

[16] Chem. Bul. 1 (U.S.Dept. Agri. 1883) p. 18.

Dept. of Agriculture used the usual method except that the time of digestion was two hours with 5 per cent acid and alkali on a steam bath. Among these early workers were S. M. Babcock [17]

[17] 2nd Ann. Rept. N. Y. State Exp. Sta., 1883, 163.

at the New York Experiment Station who used the Wattenberg modification with an asbestos filter. H. P. Armsby[18] at the Wis-

[18] 3rd Rept. Wis. Exp. Sta., 1885, 134.

consin Experiment Station followed substantially the Weende Method as modified by Wattenberg.

Waldemar and von Knierem[19] who worked on the

[19] Zeitsch. für Biologie, XVI, 1885, 67.

digestion of cellulose with various kinds of animals, carefully tested and compared Henneberg's Weende Method with Schulte's and with Müllers. This last was rejected as unreliable; the other two methods gave results agreeing well but Schulte's method was not found to be any better and took more time. Henneberg's gave good results if special pains were taken to reduce the substance to a fine powder.

W. Hofmeister [20] later observed in the deter-

[20] Die Versuchs-Stationen, XXXIII, 1886, 153.

minations of crude fibre and "Holz gummi" that the previous removal of the fat makes the action of the reagents easier as well as aids filtration. To prevent frothing in boiling Failyer and Willard[21] and later Withers[22] proposed the use of an inverted

[21] Kans. Agri. Exp. Sta., 1889, 119.
[22] Jr. Anal. Chem. IV, 1890, 36.

condenser on the flask and also conducted in a blast of air which, impinging on the surface of the liquid, kept the foaming of the liquid under control. Withers concluded from his tests on the use of acid and alkaline solution of different degrees of strength and of treatment for different periods of time, that difference in results followed such variations.

From the preceding work and that of others, the American Official Chemists in their 6th annual proceedings [23]

[23] 6th Ann. Proc., A. O. A. C. 1889.

reported on the analysis of feeding stuffs among which was the crude fibre determination; they called attention to the necessity of observing the following points:

1. To determine the strength of acid and alkaline solutions by titration.
2. That the volume of liquid in boiling be kept constant.
3. Uniform and fine pulverization of the sample necessary.
4. Prevention of frothing in boiling.
5. Difficult and long tedious filtrations unsolved.

Minor Proposed Modifications. (1890-1913).

Rapid and easy filtrations on certain feeds rich in protein has not been accomplished. As is well known, the filtration of such materials is difficult and tedious. The official method[24] dismisses this subject by saying "Filter through linen, asbestos, or glass wool".

[24] Bur. of Chem., Bul. 107, p. 56 revised.

Many methods have been proposed to overcome this in which the modifications consisted chiefly of two classes.

1. Means by which rapid filtration is accomplished.
2. The elimination of the linen cloth strainer which is unscientific, necessitating transfer to a crucible.
3. Rendering unnecessary the previous extraction of fat which would considerably shorten the method.

As will be shown later the indefinite character of this filter and its efficiency is questionable.

With the NaOH filtration most of the difficulty is encountered in such feeds as linseed meal, cotton seed meal, and dried feces.

(a.) The filtration by suction with an inverted filter[25]

[25] J. W. Pickel; p. 280 Jr. Ind. & Eng. Chem., June 1910.

[25] G. M. MacNider, pp. 281, 282, ibid.

consists in using a linen cloth tied over the top of carbon filter funnels of different diameters applying suction and placing the funnel in the solution to be filtered off.

The results reported by this method are a rapid filtration except on cotton seed meal and similar products which clog the filters readily and require considerable time to complete them.

The same results were verified by the writer working on linseed and cotton seed meal and dried feces, all fat-free.

(b). A simple modification was proposed by MorganP. ~~Sweeney~~[26]

[26] Bur. Chem. Bul. 137, p. 159.

which avoided the previous extraction of the fat and the tedious sulphuric acid filtration.

The modification consisted in neutralizing the 200 cc. of 1.25 per cent H2SO4 solution with a 10 per cent of NaOH solution and phenolphthalein indicator; then added NaOH of equivalent strength (3.656 per cent) to make the total solution the same strength as in the Official method (1.25 per cent).

In his published results there is shown a tendency to higher results than those obtained by the official method as reported in Table I. He makes no attempt to account for this higher result.

TABLE I.

Sweeney Modification Compared to the Official Method.

Sample No.	Official Method.	Sweeney Method.	Higher than Official Method.
2933	5.97	6.29	.32
3011	7.32	7.40	.08
3067	4.62	4.82	.20
738	4.10	4.16	.06
3069	5.17	5.67	.50
743	11.04	11.01	.03
3072	1.90	2.38	.48
Average higher results			.24

The writer also compared the Sweeney method with the official method, using cotton seed meal, linseed meal, and dried feces, all of which are exceedingly difficult to filter. The results are given in Table II.

TABLE II.

Official and Sweeney Methods Compared on Cottonseed, Linseed Meal and Feces.

	Cotton Seed Cake.		Linseed Cake		Dung.	
	Official Method.	Sweeney Method.	Official Method.	Sweeney Method.	Official Method.	Sweeney Method.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
	9.33	10.50	6.63	6.88	19.37	21.18
	8.96	10.15	6.80	6.95	20.16	18.65
		11.13		8.17		20.00
		8.42		6.59		19.93
		10.70		6.62		
		10.50		6.31		
				7.75		
				7.59		
				6.58		
				7.32		
Average	9.15	10.23	6.72	7.08	19.77	19.94
Max. Var.	.37	2.71	.17	1.86	.79	2.53
Averages Compared		1.08		.36		.17

Average high (20 determinations) 0.54.

Thus it is seen that the Sweeney method gives higher results when compared to the Official Method on certain feeds rich in protein as cotton seed and linseed meals, also with feces.

The reasons for the considerable variations reported by the A. O. A. C.[27] on the Sweeney Modification

[27] Bur. of Chem. Bul. 152, p. 201.

were studied. These variations were found by comparing the results of Ulman, Gilroy, Hill, and Bidwell and Goodrich which resulted in the rejection of the Sweeney Modification.

The most marked variations in this method were obtained by Ulman and Gilroy of Penn. State College on the same samples. They compared the results by the Sweeney Modification to the results obtained by one of them on the Official Method. This method of comparison eliminates any variation due to faulty manipulation and the individual factor and makes the variation on the Sweeney Modification appear higher than it otherwise would.

This point is distinctly brought out in the third column of Table III, in which it is seen that Ulman's results are considerably higher than those of any of the other workers.

TABLE III.

Variation in the Results by the Sweeney Method and the Official Method Compared.

Sample No. and Name.	Official Method.	Sweeney Method.	Difference Plus or Minus.
Ulman - Pa.	Per Cent.	Per Cent.	Per Cent.
5272 - Calf meal	6.61	8.02	1.41
5274 - Dairy feed	10.48	12.80	2.32
5278 - Cotton seed	28.35	31.22	2.87
5343 - Alfalfa meal	28.35	30.00	1.65
5351 - Cottonseed "	9.52	13.78	4.26
5378 - Gluten feed	6.55	8.10	1.55
Gilroy - Pa.			
5272 - Calf meal	6.61	6.76	.15
5274 - Dairy feed	10.48	11.48	1.00
5278 - Cottonseed feed	28.35	31.32	2.97
5343 - Alfalfa meal	28.35	28.04	- .31
5351 - Cottonseed "	9.52	11.07	1.55
5378 - Gluten feed	6.55	7.85	1.30
Hill - N. C.			
3954 - Cottonseed feed	22.15	22.85	.70
3956 - Corn Chops	8.10	8.59	.49
3984 - Wheat bran	9.18	9.32	.14
3902 - Seocopes	9.55	9.88	.33
3933 - Middlings	1.37	1.48	.08
3940 - Ship stuff	6.35	6.26	- .09
Bidwell & Goodrich Washington, D. C.			
C - Cottonseed feed	22.33	21.39	.06
D - " " "	20.87	20.57	- .30
E - Cold press meal	24.18	24.50	.32
G - Corn product	8.23	8.56	.33
H - Wheat bran	9.67	11.25	1.58
I - " "	11.15	11.46	.31
J - Hen feed	3.42	3.75	.35
K - Gluten feed	7.86	8.53	.67
L - Feed meal	6.13	6.64	.51

Average per cent high (first set omitted) 21 determinations, .64

The criticisms made of this method were:

1. The method gave higher results in all but four cases, many of which were higher by over one per cent.
2. The maximum variation compared to the Official method was .08 to 4.26 per cent high.

These man gave as a reason for high results that the presence of a large per cent of fat reduced the solvent action of both the acid and alkalie.

In the table given, it is to be observed that the per cent crude fibre runs quite uniformly high even if the first set is omitted. These unusually high results in the first set are quite possibly due to improper manipulation as insufficient washing; they are considerably higher than obtained by the other chemists.

If we omit the results reported by Ulman, it will be noticed that in the other 21 determinations, one is above 2 per cent and that the average of these 21 determinations is 0.64 per cent high for the Sweeney Method. This is in close agreement with the results reported by the writer.

Further the A. O. A. C. work was done on various samples. The same samples of feed were not sent to each chemist. This brings in other varying factors, that of different samples of feeds, etc. Therefore their data does not fully warrant the general conclusions drawn.

The objection to the Sweeney method, is that filtration is done with a linen cloth which at times clogged.

c. Methods of Filtration.

Various methods of filtration were investigated in an attempt to find a substitute for linen. In addition to the method of Invert Suction, the porous Alundum filtering crucible was tried which proved to be slow and clogged easily.

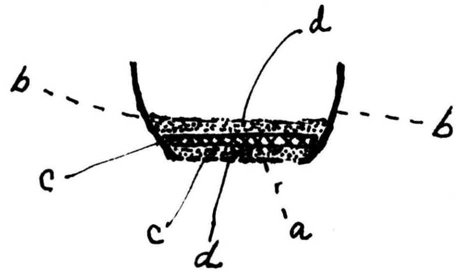
Next was used the Monroe crucible consisting of a Gooch crucible in which has been precipitated Ammonium platinic chloride, dried and ignited to porous platinum. This gave rapid efficient filtrations. On igniting the crude fibre, however, the edges curled up and made repairs necessary. As suggested by Snellings[28] a platinum gauze disk of

[28] Jr. Chem. Soc. Vol. 31 - 4 - Snellings, p. 456 - 461.

wire 52 mesh of .004 inch wire per square inch was used on which was precipitated ammonium platinic chloride. This gave a firm base and prevented curling and cracking on ignition.

The Modified Monroe Crucible.

However, another difficulty arose. The platinum Gooch crucibles were often in demand for other work - hence it was attempted to prepare a platinum cup containing this Monroe metallic filter as given in figure I.



Platinum Cup Which Fits in the Gooch Crucible.

a. base of cup
b. sides of platinum cup
d. metallic or porous platinum
c. wire gauze

This platinum cup is 1.0 cm. high and its diameter is such that it just fits inside in the bottom of a platinum Gooch crucible. To protect the metallic platinum mat, a perforated platinum disk was placed on top, protecting the surface in ignitions and in brushing off the ash.

These worked well. After continued use it was found however, that at times small particles of platinum from the surface would be brushed out with the ash. This made an uneven surface. It was found that for routine work these metallic surfaces were too delicate to withstand continued use.

Ordinary Gooch Crucibles and Bell Jar with Moderate Suction.

Six asbestos Gooch crucibles were next carefully prepared by building up the filtering surface with four grades of ignited asbestos, beginning with coarse on the bottom, then adding medium, fine and very fine. These grades were prepared by separating in water. The fine and very fine grade was used on top. The filling medium was made somewhat thicker than usual. They were then dried, ignited, and tested for rapid filtration with water. If not satisfactory, the work was repeated until they filtered readily. With these was used moderate suction in a bell jar. It was found that working on cotton seed meal, linseed meal and dried feces with the Sweeney Modification, a filtration with washing in boiling hot water till free from alkalie as shown by the phenolphthalein indicator could be accomplished on a set of four in an hour. Occasionally one would take longer.

The Gooch crucibles were used repeatedly by brushing out the ash. They improved with use.

This method worked well if the Gooch crucibles were properly prepared. This eliminated the use of linen cloth. It was found if more than moderate or slight suction was used, filtration was impeded.

d. Kennedy's Modified Sweeney Method.

On the theory that in feeds rich in protein, the acid digestion dissolves out certain nitrogenous bodies, pentosans, gums, etc., and that when the hot alkali solution is added in the Sweeney Method they again precipitate, Miss Kennedy[29] attempted to eliminate this error by dissolving out

29 Jr.Ind. & Eng. Chem. 1912, Vol 4, No. 8, p. 600.

these precipitated materials by washing with boiling hot 1.25 per cent sulphuric acid.

The following results were obtained:

TABLE IV.

Comparison of Sweeney Method (Modified by Miss Kennedy), to the Official Method.

Sample.	Official Method Per Cent.	Sweeney Per Cent.	Method High Over Official Method.	Modified Sweeney Method Per Cent.	High Over Official Method.
Bran	11.76	14.13	2.37	12.33	0.57
Sucreen feed	14.12	15.75	1.63	14.55	0.43
Sugar and flax feed	6.90	7.44	0.54	7.10	0.20
Oil meal	7.87	10.14	2.27	8.81	0.94
Bran	11.24	12.95	1.71	11.75	0.51
Average high			1.70		0.53

While the feeds analyzed are not representative and no results of cotton seed meal are given, it is noticeable that the result for oil meal is 0.94 per cent, being the highest. The average result of this method - 0.53 per cent - is high compared to the average by the official method but which compares closely to the result obtained by the Sweeney Modification by the writer. It is thus seen that the averages run high by approximately the same per cent as the other methods. Miss Kennedy's modification runs about as high as found by other workers on the Sweeney method itself. It thus appears that the problem has not been completely solved by her if the results by the official method are the correct ones.

There is one advantage to the above Kennedy method in that neutralization is eliminated as a separate process.

e. The Forbes Mensching Modified Sweeney Method.

Recently a simple filtration method has been proposed by Forbes and Mensching[30] which eliminates the unstand-

[30] E. B.Forbes & Mensching - Jr.Ind.& Eng. Chem. May 1913, p. 258.

ardized linen strainer, also the transfer of crude fibre. It substitutes an efficient sand asbestos Gooch filter which allows rapid filtration on linseed and cotton seed meal aided with concentrated HCl to facilitate washing followed by washing with hot water. They use 1 to 2 gram charges without previous extraction of the fat. The amount of sand in the filter consists of 10 - grams or 1/2 inch above the asbestos pad. Very fine acid-washed sand compacted by water and suction was used. Coarse sand did not prove satisfactory as it allows the fibre to pass through and clog the asbestos pad.

TABLE V.

Forbes and Mensching's Modified Sweeney Method.

	Official Method	Modified Method.	
	Per Cent.	Forbes Modified Method. Per Cent.	High over Official Method. Per Cent.
Cow peas	5.58	5.62	.04
Linseed meal	9.13	9.13	.00
Corn meal	2.26	2.75	.49
Soy beans	4.71	4.83	.12
Dist. grains corn	12.30	12.40	.10
Oats, grain	12.14	12.16	.02
Wheat bran	8.34	8.62	.28
Wheat grain	8.28	8.32	.04
Patent flour	0.11	0.25	.14
Gluten feed	8.92	8.84	.08
Cotton seed meal	7.04	7.15	.11
Average of 11 samples			.13

On 25 determinations from 11 different samples an average of 0.13 per cent high was found. This difference is negligible.

Forbes and Mensching obtained high results (Table V) on corn meal and wheat bran, 0.49 and 0.28 per cent respectively. These substances, chemists usually regard as offering no particular difficulty for the determination of crude fibre compared to that of linseed and cotton seed meal.

Thus it is seen the Forbes and Mensching method gives results closer to the official method than any of the others.

They found that results check with one another more satisfactorily and that the method is easier of filtration. They also found that the fat in the charge on a one or two gram sample did not affect results which is quite different from the conclusions obtained by the A. O. A. C. for 1912. They studied the causes for higher results and pointed out that there are objections in the comparison of any new method to the results obtained by the official method on account of the lack of definiteness as to the character of the cloth strainer and also due to the incomplete retention of the crude fibre of some feeds by such a strainer in the official method. Some fibre is also liable to adhere to the cloth filter in transferring to a crucible.

The causes they give rather tend toward low results by the official method, for undissolved woody and chitinous particles which pass through the linen strainer, are found. These they identified microscopically in the filtrate. They however, were retained by the sand asbestos filter. Microscopically both the filtrate and crude fibre from their method and the official method showed no evidence of contamination. In their method no gummy or protein substances were observed.

The following table comparing the results obtained by different workers is of interest.

TABLE VI.

Summary of the Results by the Various Methods Compared to the Official Method.

By whom reported.	No. of determinations	Average per cent high.
A. O. A. C. report on Sweeney method.	21	0.64
Miss Kennedy's modification.	10	0.53
Halverson's report on Sweeney method.	20	0.54
Average		0.57
Sweeney modification (own report)	14	0.24
Forbes & Mensching's results.	22	0.13

The results of comparison (Table VI) show, that the A. O. A. C. report of the result on the Sweeney Method, that of Miss Kennedy's Modification, and that of the writer on the Sweeney Modification, run uniformly high with the Official Method or respectively 0.64 per cent, 0.53, 0.54, or an average on all of 0.57 per cent. Sweeney's own report shows that the method runs 0.24 per cent high. The results of the Forbes and Mensching Modification are 0.13 per cent high. This result, to one familiar with crude fibre determinations, is negligible.

The writer found that carefully built Gooch crucibles with moderate suction, using a bell jar gave rapid filtration. The addition of 10 to 12 grams of fine acid-washed sand in preparation of the crucible for the difficult cotton seed meal, linseed meal and dried feces would, it appears, materially aid in these difficult filtrations.

Thus the various theories and studies we have given, attempt to account for the results obtained by the various methods; of which that of Forbes and Mensching appears most promising.

Recapitulation.

1. It has been shown that the Sweeney Method runs high by .64 per cent.

2. That the Kennedy Sweeney Method runs 0.53 per cent high, almost as high as the Sweeney Method and is not more accurate.

3. That the results by the Forbes and Mensching Sweeney Method are more concordant and agree closely (0.13 per cent) with the Official Method.

4. That the Forbes Mensching sand asbestos Gooch crucible offers a rapid efficient means of filtration, eliminating the unstandardized cloth strainer and the transferring of the crude fibre.

5. That by combining the Kennedy Forbes Sweeney Method, the objectionable and unscientific features of the crude fibre determination would be eliminated, thus fulfilling the following requirements in the method as modified.

(1). Requiring only one rapid, efficient filtration.

(2). Elimination of transferring the crude fibre from cloth to crucible.

(3) Neutralization is accomplished by one operation, that of adding the NaOH solution of strength 3.52 per cent, direct when ready for the alkaline digestion.