SOME PERSISTENT MISCONCEPTIONS CONCERNING THE CRUDE FIBRE AND THE NITROGEN-FREE EXTRACT

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Microscopic examination of plant materials has shown that the cellular framework of different vegetable foods is not very unlike to that of wood. But in food the cells usually include considerable amounts of different substances while the cells in the wood are mostly empty. As wood was known to be a nutritionally inert material it was only natural that scientists in the first half of the 19th century considered all cell membranes as indigestible and that the nutritive value of vegetable foods depended only upon the cell contents. It seems that vegetable cell membranes were regarded as homogenous formations containing only one substance which CANDOLLE (ref. CZAPEK, 4, p. 682) called lignin. German investigators simply used the term *Holz.* It is significant that moreover the term *Holzfaser,* which was later used as a synonym of the term *Rohfaser* (= crude fibre), in the early eighteen hundreds was taken to mean the whole cell membrane substance (CZAPEK l.c.). H. DAVY was probably the first to use the term crude fibre (ref. HONCAMP and RIES, 14, p. 303). He applied this expression to a residue obtained from woody materials after extraction with boiling water and boiling alcohol.

About 1830 SPRENGEL (27, p. 251) proposed a method for determination of *Holzfaser.* He treated the sample to be analysed successively with water, alcohol, ether, diluted hydrochloric acid, diluted potassium hydroxide and chlorine water. The residue obtained was called *Holzfaser* while the dissolved substances were considered as *Nährende Theile* (nutritive fraction). SPRENGEL's method with some modifications, was used in many European laboratories during the next three decades. And his erroneous concept as to the indigestibility of wood fibre and the nutritional validity of the other fractions of the dry matter of foods persisted until the eighteen sixties.

The so-called Weende method for crude fibre detrmination developed by HENNEBERG and STOHMAN was based on the method of SPRENGEL. The special merit of the above investigators was that they were the first to criticize the method in question, although they were not able to replace it by a more suitable one. They stated that the digestibility of crude fibre of different fodders varied from 45,5 to 60,4 %, and that the digestibility of the nitrogen-free extract in some cases was lower than that of crude fibre. After estimating the elementary composition of the crude fibre of different fodders, of the nitrogen-free extract, and of the digestible and indigestible portions both of the crude fibre and of the N-free extract of the same fodders, HENNEBERG and STOHMANN concluded:

1) that in the crude fibre determination the cell wall substances are rather arbitrarily divided into two portions, the one constituting the crude fibre and the other belonging, together with sugar and starch, to the N-free extract;

2) that the crude fibre is not pure cellulose but contains also encrusts rich in carbon (lignin, suberin and cutin are named), which remain among the faeces together with the indigestible part of cellulose, whereas the digestible part of crude fibre is pure cellulose;

3) that in the crude fibre determination the bulk of the lignin and a part of the cellulose are dissolved and thus fall into the N-free extract; and

4) that the indigestible part of the N-free extract is composed mainly of lignin. (11, pp. 367, 511—514; 12, pp. 331—335; see also PALOHEIMO, 23, pp. 9—13.)

The criticism directed to the Weende method by HENNEBERG and STOHMANN is so accurate that later investigators have scarcely been able to add anything essential to it. The Weende method had proved to be not a method for estimation of the total of cell wall substances but a very rough and imperfect one for the determination of cellulose. This view was not altered after the introduction of the pentosane determinations according to TOLLENS, for it was shown that the main part of the pentosanes falls into the N-free extract (KÖNIG, 16, p. 93). Of the later criticism of the Weende method the papers of HOFFMEISTER (13, p. 243), DÜRING (6, p. 87), KÖNIG (l.c.), HONCAMP and RIES (14, pp. 306—317), MAGNUS (18, p. 34), PALOHEIMO (24, p. 281), NORMAN (ref. ELLIS, MATRONE and MAYNARD, 7, p. 285), NORDFELT, SVANBERG and CLAESSON (22, p. 135), and HELLSTRÖM (10, p. 279) may be mentioned.

PALOHEIMO and PALOHEIMO (25, p. 1) have developed a method for determining the total of vegetable membrane substances as a whole and of the crude fibre in different foods. Table 1 permits such an examination. In materials used as food or fodder the amount of membrane substances remaining in crude fibre seems, with only few exceptions, to vary between 42 and 64 per cent. Furthermore, by using the method of PALOHEIMO the pectins together with some of the pentosanes are dissolved, and consequently the percentages of membrane substances presented in table 1 must be regarded as minimum values. Thus it is evident that authors, who regard the crude fibre as equivalent to the total of the membrane substances make a grave mistake. But it is a still greater misconception to regard the N-free extract as valuable carbohydrates comparable to sugar or starch. By subtracting the figures in the last column of table 1 from 100, figures are obtained which give the percentages of that fraction of the membrane substances that falls into the N-free extract. It appears that in foods and fodders 36—58 % of membrane substances belong to the said fraction.

Table 1. Relative amounts of the total membrane substances and of the crude fibre in different vegetable materials.

Material analyzed	Per cent in dry matter membrane substances	Per cent in dry matter crude fibre	% crude fibre of membrane substances
Filter paper	99.6	89.8	90.2
Spruce wood	90.9	73.8	81.2
Birch wood	90.8	59.5	65.5
Hulls of sunflower seeds	87.5	64.6	73.8
Peanut hulls	83.8	71.9	85.8
Rye straw	82.1	51.1	62.2
Oat straw	73.8	47.0	63.7
Corn cobs	72.0	36.1	50.1
Oat hulls	71.6	34.1	47.6
Rye chaff	66.8	34.3	51.3
Timothy grass			
at beginning of bloom	62.1	32.8	52.8
Poa pratensis			
at full bloom	60.0	29.2	48.7
with panicles, before blooming	56.6	28.0	49.5
Red clover stalks	55.3	40.6	73.4
Timothy grass			
leaf stage II	54.2	26.9	49.6
Oat chaff	51.3	25.7	50.1
Alopecurus pratensis			
leaf stage	47.7	23.3	48.8
Festuca pratensis			
leaf stage	42.0	22.4	53.3
Red clover leaves	30.7	18.2	59.3
Wheat bran	21,5	9.1	42.3
Spinach leaves	18.0	9.9	55.0
Cabbage, head, wlthout stem	14.0	12.6	90.0
Carrots	12.8	10.0	78.1
Wheat kernels	5.0	3.0	60.0
Potatoes, peeled	3.9	3.0	76.9
Wheat flour, white	0.7	0.3	42.9

The most serious weakness in the Weende system of analysis is the fact that in foods and fodders the main part of lignin, the most worthless of the membrane substances, falls into the N-free extract together with the sugar and starch. This is shown in table 2 which gives the results of some determinations made in this laboratory. The table shows that in hay and straw about 2/3 of the lignin are dissolved by the treatments ot the crude fibre determination while in peanut hulls and spruce wood, which are totally worthless materials in the feeding of animals, almost the whole ot the lignin remains in the crude ribre. As none of the lignin is dissolved by the acid treatment of the Weende method one must conclude that the dissolving is caused by the treatment witb the alkali.

Table 2. The behaviour of lignin in the crude fibre determination.

Material analyzed	Crude fibre % of dry matter	Lignin % of dry matter	The lignin of crude fibre% of crude fibre	% lignin dissolved in the crude fibre determination
Timothy hay	34.6	8.5	8.9	63.5
Rye straw	47.4	11.3	7.5	68.8
Peanut hulls	74.7	24.9	33.2	0.4
Spruce wood	76.1	24.3	31.7	0.7
Cow feaces	33.6	21.9	30.7	53.0

In spite of the criticism, which has elucidated the real character of the crude fibre and the N-free extract, misconceptions concerning these fractions are still very persistent. Even in most authoritative textbooks and in papers of excellent scientists erroneous ideas or wrong ways of expression are found. Some proofs are quoted below.

Many authors use the term crude fibre as a substitute for membrane substances. So for instance MANGOLD (19, p. 95): »*Nun bildet aber die Rohfaser die Stütz- und Hüllsubstanz aller Pflanzenteile, und besteht die Wandung der einzelnen Zellen — — — aus einer Rohfaserhülle, die den Zellinhalt umschliesst.*» MAYNARD in his textbook (20, p. 45) writes about »factors governing the digestion of crude fibre» although he evidently and quite consciously means the vegetable membrane substances. One often meets especially in treatises on human physiology, the word cellulose meaning cell wall substances in general; see e.g. EVANS (8, p. 865). It is regrettable that AXELSSON who has so extensively examined the influence of crude fibre on animal nutrition has not extended his studies to apply also to membrane substances as a whole, for which the crude fibre is only an exponent. We refer to his textbook *Djurnäringens grunder* (2, pp. 216—221). Many misconceptions occur as to the relative nutritive value of the crude fibre and the N-free extract. The fact that the latter fraction is dissolved by the treatments of the Weende method seems to justify the use of synonyms such as »soluble carbohydrates»; see e.g. DUKES (5, p. 254), LINTON and WILLIAMSON (17, p. 14), and ASHTON (1, p. 13). Nearly all authors dealing with animal nutrition seem to neglect the fact that in some fodders the digestibility of the crude fibre is lower than that of the N-free extract. In *Handbuch der Lebensmittelchemie II* GROSSFELD (9, p. 936) writes about *Rohfaser: »Er bildet den unlöslichen bzw. schwerlöslichen Teil der Zellmembran»*. Lignin is not mentioned among the substances belonging to the N-free extract. The same view is presented by MORRISON (21, p. 7), AXELSSON (2, p. 28), HÖIE and TILREM (15, p. 87), VONTOBEL (29, pp. 181, 182), and the Russian authors POPOV (26, p. 18) and TOMME (28, p. 9). It is noteworthy that even MAYNARD (20, p. 42) neglects to mention lignin among substances constituting the N-free extract.

Although it is generally known that lignin is a polymerisation product of compounds which contain benzene nuclei, and that lignin contains 63—67 % carbon, while the carbon content of carbohydrates is only 40—45 %, some authors still insist on counting lignin among carbohydrates. So one can read for instance in

LINTON's and WILLIAMSON's book (17, p. 12): »Lignin is a very complex polysaccharide or group of polysaccharides». It is also very surprising to find that BRIEGER in KLEIN's *Handbuch der Pflanzenanalyse I* (3, p. 592) puts forth that lignin remains intact in boiling with 5 % sodium hydroxide.

Conclusion

The criticism of the Weende method for crude fibre determination presented in this paper is not meant to undermine the said method. Owing to the fairly great positive correlation between the content of crude fibre and the content of the membrane substances as a whole, and to the equally positive correlation between crude fibre and lignin on the other side, the crude fibre must be seen as a valuable criterion when the character of a food is to be estimated. This is especially so if the percentage of crude fibre is calculated from the dry matter. But in scientific works it is important to realize that crude fibre is only a very arbitrary fraction of vegetable membrane substances. Especially when the processes occurring in the digestive tract are to be studied it is advisable to take into consideration the membrane substances or the membrane carbohydrates as a whole, if one does not prefer to deal with the different membrane substances separately. As to the N-free extract, this fraction is misleading to such a degree that it would be best to omit it from the food tables. The author recommends the food table pattern shown in table 3.[1] It may be said

Table 3. A pattern for the construction of a food table

Food	Total composition: Water %	Total composition: Crude protein %	Total composition: Crude fat %	Total composition: Crude carbohydrates %	Total composition: Ash %	Digestible nutrients: Crude protein %	Digestible nutrients: Crude fat %	Digestible nutrients: Crude carbohydrates %	Food units per kg	kg per food unit	kg dry matter per food unit	Cruude fibre %	Crude fibre % of dry matter
Wheat straw	15.0	4.3	1.5	73.6	5.6	0.7	0.5	32.1	0.19	5.3	4.3	37.6	44.2
Corn meal . .	13.8	10.0	4.7	69.8	1.7	7.2	4.2	51.3	1.06	0.95	0.8	2.7	3.1

that the per cent figures under the heading »Crude carbohydrates» have no significance but it may also be stated that they are by no means misleading, as are the percentages of N-free extract. On the other hand the figures which give the percentage of digestible crude carbohydrates are most useful criteria in judging the foods. In this case the attribute »crude» is almost superfluous.

In scientific theory as well as in practice it may be detrimental if one claims to know more about a thing than one actually does. Thus it may be best to keep the group of crude carbohydrates undivided when one computes the figures for the usual feed tables. For scientific purposes the group may be divided, but not into crude fibre and N-free extract.

[1] This pattern was presented by the author at the Vth International Congress of Zootechnie in Paris 1949.

Summary

By the usual Weende method the vegetable membrane substances are divided most arbitrarily into two groups, crude fibre and nitrogen-free extract. The bulk of lignin falls in the latter fraction which also contains the valuable cell enclosure carbohydrates, sugars and starch. Many misconceptions even amone eminent scientists still prevail concerning the crude fibre and the N-free extract. It is too often forgotten that N-free extract also contains lignin, and that in some cases crude fibre is a more valuable food fraction than the N-free extract. However, the per cent figure of crude fibre, especially when calculated of the dry matter, is a useful criterion in estimating the value of foods. N-free extract, on the other hand, is only a misleading concept and should be omitted. It would be best to leave it out also from the food tables.

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SELOSTUS:

ERÄISTÄ ITSEPINTAISISTA RAAKAKUITUA JA TYPETTÖMIÄ UUTEAINEITA KOSKEVISTA VÄÄRINKÄSITYKSISTÄ

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Tavanomaisessa ns. Weenden analyysijärjestelmässä tulevat kasvien soluseinämäaineet eli kettoaineet varsin mielivaltaisesti jaetuiksi kahteen ryhmään: raakakuituun ja typettömiin uuteaineisiin. Pääosa ligniinistä, joka on arvottomin kaikista rehun aineosista, joutuu pääasiassa uuteaineisiin, johon myös arvokkaat solunsisällyshiilihydraatit joutuvat luetuiksi.

Ihmis- ja eläinravitsemusta käsittelevässä kirjallisuudessa esiintyy jatkuvasti virheellisiä käsityksiä raakakuidun ja typettömien uuteaineiden olemuksesta. Varsin yleistä on, että pätevimmätkin ravitsemustieteen ammattimiehet katsovat raakakuidun aina edustavan rehun vähäarvoisinta osaa, kun taas typettömät uuteaineet samaistetaan sokerin ja tärkkelyksen sekä niihin verrattavien aineiden kanssa. Aivan yleisesti unohdetaan, että typettömät uuteaineet usein sisältävät runsaasti ligniiniä ja että joissakin tapauksissa kuidun sulavuus on suurempi kuin uuteaineiden. Koska rehujen kuituprosentti on selvästi vuorosuhteellinen sekä kettoaineiden kokonaismäärään että rehun ligniinipitoisuuteen, voidaan kuitenkin kuituprosenttia, varsinkin jos se lasketaan kuiva-aineesta, pitää varsin käyttökelpoisena rehun puisuuden eli olkisuuden kriteriona. Toiselta puolen typettömät uuteaineet on kauttaaltaan harhaanjohtava käsite, jonka käytöstä olisi luovuttava. Tekijä ehdottaa nimenomaan, että tämä aineryhmä jätettäisiin pois tavanomaisista rehutaulukoista.
