TOPIC 1. CELL CHARACTERISTICS AND DIGESTIBILITIES

What does a primary consumer, or herbivore, ingest? Forage, at the macroscopic level, but at the chemical level where digestion occurs, cells composed of many complex chemical compounds. The basic structural unit of the plant is the cell, and of the cell, the cell wall. The chemical compounds lending structural support to the cell wall include lignin, cellulose, hemicellulose, fiber-bound protein, and lignified nitrogenous compounds. These are often quite indigestible due to their complex molecular structures. Within the cell, bounded by the cell membrane and cell wall, there are lipids, sugars, organic acids, other water-soluble materials, pectin, starch, soluble proteins, and non-protein nitrogenous compounds called cell solubles. These are essentially 100% digestible.

Highly lignified cell walls, characteristic of mature and decadent plants, are quite indigestible. Thin cell walls, characteristic of young, growing plant tissue, are much more digestible. The ratio of cell wall: cell solubles forms the basis for forage digestibility, with other physical and chemical variables further influencing it. This basic relationship is discussed in UNIT 1.1: CELL COMPONENTS AND DIGESTIBILITIES.

Chemicals with inhibitory effects on digestibility are discussed in UNIT 1.2: CHEMICAL INHIBITORS OF DIGESTIBILITY. Then CELLULAR AND DIGESTIBILITY DIFFERENCES BETWEEN PLANT GROUPS such as herbaceous and woody plants, and between different kinds of herbaceous and woody plants, are discussed in UNIT 1.3.

Different plant parts serve different functions. Some parts are structural (stems), some are decorative (flower), etc. Their functions are reflected in their structures, which in turn, affect digestibilities. These are discussed in UNIT 1.4.

UNIT 1.1: CELL COMPONENTS AND DIGESTIBILITIES

Cell structure is a basic determinant of digestibility. The division of plant cells into the less-digestible cell wall and the more digestible protoplasm, called cell solubles, provides a suitable basis for estimating digestilibity based on the cell wall: cell solubles ratio, and by the realtive quantities of lignin-cutin and hemicellulose-cellulose in the cell wall.

Cell characteristics are determined with detergent analyses (Van Soest 1963a and 1963b and Fonnesbeck and Harris 1970) that partition plant cells into cell solubles and cell wall. Neutral detergent treatment removes cell solubles, leaving the cell wall and its hemicellulose, lignin, cutin, and cellulose intact. Acid detergent treatment removes the hemicellulose from the cell wall, leaving lignin, cutin, and cellulose which, as a group, are frequently referred to as acid detergent fiber (ADF). Lignin and cutin are determined by further chemcial analysis of the ADF, and cellulose by arithmetical difference.

Cellulose and hemicellulose in pure form are entirely digestible by rumen bacteria; lignin and cutin are not digestible and apparently inhibit cellulose and hemicellulose digestion (Robbins 1973: 110). The protoplasm, composed of sugars, soluble carbohydrates, starch, pectin, protein, non-protein nitrogen, lipids and other components, is 98% digestible in mule deer (Short and Reagor 1970), and sheep and cattle (Van Soest 1967). Since it is the cell wall that varies in digestibility, its characteristics determine the overall digestibility of forage consumed.

CELL WALL CHARACTERISTICS

A predictable relationship exists between dry matter digestibility and cellulose content of many deciduous browses. Dominant winter twigs from the previous summer's growth of eighteen species of deciduous browse plants were evaluated by Robbins and Moen (1975) for their cell wall characteristics and digestibilities. As the percent lignin content of the acid-detergent fiber increased, cell wall digestibility decreased. The equation expressing this relationship, modified slightly from Robbins and Moen (1975:340), is:

$$CWDP = 155.04 - 38.77 \ln LGNC; \quad R = -0.92$$

where CWDP = cell wall digestibility in percent, and
LGNC = lignin content of the acid-detergent fiber.

An equation was also devised for the relationship between cell wall digestibility and the lignin-cutin content. The equation, modified slightly from Robbins and Moen (1975:340), is:

$$CWDP = 139.97 - 33.15 \ln LGCC; \quad R = -0.93$$

where LGCC = lignin-cutin content of the acid-detergent fiber.

The predictibility of CWDP based on the lignin-cutin content of ADF is slightly better (R = -0.93 compared to -0.92) than that based on lignin content alone. Either equation could be used to estimate cell wall digestibility, depending on the information available.

These equations are for deciduous browse species, and should not be used for other plant groups, or for other plant parts. These effects are discussed in UNITs 1.3 and 1.4.

CELL SOLUBLES

Cell solubles are approximately 98% digestible in the ruminant's digestive tract (See Van Soest 1967, Short and Reagor 1970, and Robbins and Moen 1975). This can be written as:

$$CSDP = 0.98$$

where CSDP = cell soluble digestibilities in percent

OVERALL DIGESTIBILITY AS SUM OF CWDP AND CSDP

Overall digestibility can be considered to be the sum of the digestibilities of its parts. Thus the sum of the cel wall digestibility and cell soluble digestibility is an estimate of overall digestibility, providing that the relative contributions of the cell wall and cell soluble components are considered. Thus a weighted mean procedure is used, with the digestibilities of each component multiplied by the fractions of each component. The formula is:

$$TDMD = (CSFF)(CSDP) + (CWFF)(CWDP)$$

where TDMD = true dry matter digestibility in percent,
CSFF = cell soluble fraction of the forage,
CSDP = cell soluble digestibility in percent,
CWFF = cell wall fraction of the forage, and
CWDP = cell wall digestibility in percent.

The equations given above for CWDP and CSDP may be combined into a single equation for calculating TDMD.

$$TDMD + (CWFF)(139.97 - 33.15 \ln LGCC) + (CSFF)(0.98)$$

All of the symbols have been defined. Simply substitute the appropriate numbers and an estimate of TDMD will be derived.

The basic relationships between cell structure and digestibility has been discussed thus far. The arithmetic is simple; the biochemistry is not. The next UNIT includes brief discussions of chemical inhibitors of digestion, compounds which may cause departures from the cell wall - cell soluble predictions of digestibility. Then discussions of the difference between cell wall characteristic of plant groups and plant parts in relation to digestibilities are discussed in UNITs 1.3 and 1.4.

The references listed in the SERIALS list were selected on the basis of key words such as cell components, cell wall, lignin, and other indications of cell structure in relation to digestibility. References on other lists in this CHAPTER 11, especially the Genus-species list (UNIT 2.4), should also be consulted for a more thorough literature search.

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Robbins, C. T., and A. N. Moen. 1975. Composition and digestibility of several deciduous browses in the Northeast. J. Wildl. Manage. 39(2):337-341.

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Van Soest, P. J. 1967. Development of a comprehensive system of feed analyses and its application to forages. J. Anim. Sci. 26(1):119-128.

REFERENCES, UNIT 1.1

CELL COMPONENTS AND DIGESTIBILITIES

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS------------------	AUTHORS----------	YEAR
JRMGA	22--1	40	43	od--	nutri analysis, 2 brows sp	short,hl; harrell	1969
JRMGA	30--2	122	127	od--	eval, habitat, nutri basis	wallmo,oc; carpen	1977
JWMAA	38--2	197	209	od--	fiber comp, forage digesti	short,hl; blair,/	1974
JWMAA	41--4	667	676	od--	seas nutr yld,dig, pine,tx	blair,rm; short,/	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	36--4	792	796	odvi	estim digest, browse tissu	short,hl; blair,/	1973
JWMAA	35--2	221	231	odvi/	cellulos dig, chem com, mo	torgerson,o; pfan	1971
JWMAA	38--1	20	31	odvi	in vitro dig, food, ozarks	snider,cc; asplun	1974
JWMAA	39--1	67	79	odvi/	feed analyses and digestio	robbins,ct; van /	1975
JWMAA	39--2	337	341	odvi/	comp, dig, decid brws, n e	robbins,ct; moen,	1975
JWMAA	40--2	283	289	odvi	nutr qual, seed, frui, tex	short hl; epps,ea	1976
JWMAA	40--4	630	638	odvi/	digest, nutrit, 7 brows sp	mautz,ww; silver/	1976

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JRMGA	9---3	142	145	odhe	apparent digestibi, lignin	smith,ad; turner/	1956
JWMAA	30--1	163	167	odhe	eff cellulo lev, appar dig	short,hl	1966
JWMAA	34--4	964	967	odhe	cell wall dige, woody twgs	short,hl; reagor,	1970
JWMAA	38--4	823	829	odhe	utiliz fibrous alfal diets	schoonveld,gg; n/	1974

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BJNUA	40--2	347	358	ceel	dosh, seas digestn forages	milne,ja; macrae/	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
HOECD	4---1	59	65	alal	caca, seas diff, dig brows	cederlund,g; nyst	1981

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				rata			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				anam			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				bibi			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ovca			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ovda			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				obmo			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				oram			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
COVEA	67--3	307	326	hrbv	plnt fibr, herbivore nutri	van soest,pj	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
AGJOA	66--2	195	200	rumi	nutr, crwnvtch, struct con	burns,jc; cope,wa	1974
CPLSA	49--4	499	504	rumi	lign, cell wall dig, pl pa	mowat,dm; kwain,/	1969
JANCA	46--5	825	829	rumi	prep fiber resid, low nitr	van soest,pj	1963
JANCA	46--5	829	835	rumi	rapid meth, det fiber, lig	van soest,pj	1963
JANCA	50--1	50	55	rumi	deterg, plnt cell wall con	van soest,pj; win	1967
JANCA	51--4	780	785	rumi	det lignin, cellulose, adf	van soest,pj; win	1968
JANCA	56--4	781	784	rumi	study, acid-dtr fibr, lign	van soest,pj	1973

rumi continued on the next page

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	23--3	838	845	rumi	chem procedure, eval forag	van soest,pj	1964
JANSA	26--1	119	128	rumi	syst, feed anal, fora appl	van soest,pj	1967
JANSA	29--1	11	15	rumi	dig forag cellulo, hemicel	keys,je; van soe/	1969
JANSA	41--1	185	197	rumi	cell-wall fractns, digestn	johnson,wl; pezo,	1975
JDSCA	50--7	1130	1135	rumi	cell wall const, adf fract	colburn,mw; evans	1967
JRMGA	22--1	40	43	rumi	nutr analy, two brows spec	short,hl; harrell	1969
JSFAA	26--9	1433	1433	rumi	physi chem aspct, fibr dig	van soest,pj	19__
NAWTA	31---	122	128	rumi	meth, eval forag, wild rum	short,hl	1966
NETMA	17--2	119	127	rumi	predic forag dig, lab prcd	deinum,b; van soe	1969
NEZFA	13--3	591	604	rumi	carbohyd, lign comp, grass	bailey,rw; uylatt	1970
XAAHA	379--	1	20	rumi	forage fiber analys, appli	goering,hk: van s	1970

UNIT 1.2: CHEMICAL INHIBITORS OF DIGESTIBILITY

Chemical analyses of foods have been done for over 100 years. Specific groups of compounds are isolated in the proximate analysis approach, and chemical composition data given for specific foods. Early studies of the digestibilities of forages for wild ruminants yielded results that were not always explained by chemical analyses. Feeding trials of sagebrush (Artemisia tridentata) were conducted by Smith (1950), for example, who concluded that "In spite of the high volues of digestible nutrients all animals lost weight. This may have been due to. . . some quality of the sage brush not expressed by standard chemical analysis."

The quality of the sagebrush which Smith speculated on was discribed by Nagy et al. (1964) as a result of research on the effects of essential oils on the growth and metabolism of rumen microorganisms of mule deer. Sagebrush essential oils inhibited the growth of deer rumen microorganisms. Appetite and rumen movements ceased completely when 7-pound daily portions of sagebrush were introduced through the rumen fistula of a steer. A sagebrush extract had been found to inhibit certain bacteria in 1946 (Carlson et al. 1946). Maruzella and Lichtenstein (1956) demonstrated that the majority of over 100 volatile oils exhibited some kind of antibacterial action. Thus the evidence for chemical inhibitors of digestion in plants has been available for over 30 years. Knowledge of the effects of different inhibitors on diet digestibilities are not yet well understood, however.

Fraenkal (1959) called attention to the role of secondary plant compounds as defense mechanisms of plants against herbivores. Such compounds afford a chemical protection, which is much more subtle and difficult to recognize than thorns and spines which afford a mechanical protection. Secondary substances include such things as glucosides, saponins, tannins, alkaloids, essential oils, and organic acids. Those substances, apparently not involved in the basic metabolism of a plant, do reduce herbivory. It must also be pointed out that wild ruminants make up a very small portion of the worldl's herbivores; insects, though much smaller, have the potential for greater practical import in the entire vegetation than wild ruminants do.

The subject under consideration here is not the roles of chemical inhibitors as defense mechanisms in plants, but the effects of chemical inhibitors on digestion. The presence of inhibitor-containing plants on the range makes it possible for them to be included in the diet. The foraging pressure on the range has a part in determining whether such plants will be consumed. Generally speaking, they are not consumed if there is an ample supply of other forage plants available, or consumed in small enough quantities that the inhibitors have little or no effects on overall diet digestibility.

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Carlson, H. J., H. D. Bissell, and M. G. Mueller. 1946 Antimalarial and antibacterial substances separated from higher plants. J. Bacteriol. 52(2):155-168.

Fraenkal, G. S. 1959. The raison d'etre of secondary plant substances. Science 129:1466-1470.

Maruzella, J. C., and M. B. Lichtenstein. 1956. The in vitro antibacterial activity of oils. Jour. Amer. Phar. Assoc. Sci. Ed. 45(6):378-381.

Nagy, J. G., H. W. Steinhoff, and G. M. Ward. 1964. Effects of essential oils of sagebrush on deer rumen microbial function. J. Wildl. Manage. 28(4):785-790.

Smith, A. D. 1950. Sagebrush as a winter feed for deer. J. Wildl. Manage. 14(3):285-289.

REFERENCES, UNIT 1.2

CHEMICAL INHIBITORS OF DIGESTIBILITY

SERIALS

CODEN	VO-NU	BEPA	ENPA	SCSB*	KEY WORDS-----------------	AUTHORS----------	YEAR
				alkd			

CODEN	VO-NU	BEPA	ENPA	SCSB*	KEY WORDS-----------------	AUTHORS----------	YEAR
APMBA	15--4	777	784	esol	odhe, dosh,fir,rumn microb	oh,hk; sakai,t; /	1967
APMBA	15--4	819	821	esol	rumi antibacter, sagebrush	nagy,jg, tengerdy	1967
APMBA	16--1	39	44	esol	odhe,rumen microb inhibitn	oh,hk; jones,mb;/	1968
APMBA	16--3	441	444	esol	odhe sagebrush, antibacter	nagy,jg; tengerdy	1968
CJFRA	2---3	250	255	esol	odhe,d fir genot,brws pref	radwan,ma	1972
FOSCA	16--1	21	27	esol	odhe,d fir, microb fermnta	oh,jh; jones,mb;/	1970
JPHAA	45--6	378	381	esol	rumi <u>in vitro</u>, antimicrobi	maruzzella,jc; 1/	1956
JWMAA	14--3	285	289	esol	sagebrush as a winter feed	smith,ad	1950
JWMAA	28--4	785	790	esol	odhe sagebru, rumen microb	nagy,jg; steinho/	1964
JWMAA	44--1	107	113	esol	odvi,juniper, terpenoi con	schwartz,cc; nag/	1980
JWMAA	44--1	114	120	esol	odhe, junipr, volatile oil	schwartz,cc; reg/	1980

*SCSB = Secondary Substances

CODEN	VO-NU	BEPA	ENPA	SCSB	KEY WORDS------------------	AUTHORS----------	YEAR
				flvd			

CODEN	VO-NU	BEPA	ENPA	SCSB*	KEY WORDS------------------	AUTHORS----------	YEAR
				glcs			

CODEN	VO-NU	BEPA	ENPA	SCSB	KEY WORDS------------------	AUTHORS----------	YEAR
ADAGA	19---	107	149	mnrl	silica in soils,plnts,anim	jones,lhp; handre	1967
JDSCA	51-10	1644	1648	mnrl	effect of silica, digestib	van soest,pj; jo/	1968
JWMAA	34--3	565	569	mnrl	alal, comp, herbage, alask	kubota,j; rieger/	1970

CODEN	VO-NU	BEPA	ENPA	SCSB	KEY WORDS------------------	AUTHORS----------	YEAR
AMNTA	105--	157	181	phnl	plant phenolics: eco persp	levin,da	1971
BIJOA	139-1	285	288	phnl	polyphenl-protein interact	haslam,e	1974
BOREA	10---	1	65	phnl	conif, lich-biol, econ sig	perez-llano,ga	1944
JSFAA	10--2	135	144	phnl	constit, prunus domesticus	hillis,we; swain,	1959
PYTCA	5---3	423	438	phnl	plant phenolic comp, enzym	loomis,wd; battai	1966

CODEN	VO-NU	BEPA	ENPA	SCSB	KEY WORDS------------------	AUTHORS----------	YEAR
AGJOA	45--7	335	336	tann	tan, palatab, sericea lesp	wilkins,hl; bate/	1953
AGJOA	46--2	96	97	tann	palatabi, sericia lespedez	donnelly,ed	1954
AGJOA	66--2	195	200	tann	phnl, nutri val crwn vetch	burns,jc; cope,wa	1976
CRPSA	11--2	231	233	tann	rel tan lev,nutr val,seric	cope,wa; burns,jc	1971
CRPSA	14--5	640	643	tann	eff, in vitr, dry mat,prot	schaffert,re; le/	1974
ECOLA	51--4	565	581	tann	seas chan, oak tanni, nutr	feeny,p	1970
JANSA	34--3	465	468	tann	dosh, nutr val, soybn meal	driedger,a; hatfi	1972
JAGRA	58--2	131	139	tann	seas var, cont,lespedz ser	clarke,id; frey,/	1939
JSFAA	23-10	1157	1162	tann	lucern tan, infl dig enzym	milic,bl; stojan/	1972
NAREA	44-11	803	815	tann	tann, role in forage quali	mcleod,mn	1974

tann continued on the next page

CODEN	VO-NU	BEPA	ENPA	SCSB*	KEY WORDS-----------------	AUTHORS----------	YEAR
PYTCA	2---4	371	383	tann	chnges in ripening fruits	goldstein,jl; swa	1963
PYTCA	4---1	185	192	tann	inhibitn of enzymes by tan	goldstein,jl; swa	1965
PYTCA	7....	871	880	tann	seas change, tan, oak leav	feeny,pp; bostock	1968
PYTCA	8--11	2119	2126	tann	oak leaf inhib prot hydrol	feeny,pp	1969
PYTCA	12...	1809	....	tann	tan, hebaceous leguminosae	bate-smith,ec	1973
PYTCA	15--9	1407	1409	tann	condnsd, pastur legume spp	jones,wt; broadh/	1976
PYTCA	16--9	1421	1426	tann	astringent tanni, acer spp	bate-smith,ec	1977
SCIEA	193--	1137	1138	tann	microb degrad, condens tan	grant,wd	1976

CODEN	VO-NU	BEPA	ENPA	SCSB	KEY WORDS-----------------	AUTHORS----------	YEAR
AMEBA	28---	1	82	otss	rata antibiot eff, lich, s	vartia,ko	1950
AMNTA	108--	268	289	otss	mamm, herb, plnt sec compn	freeland,wj; janz	1974
APMBA	15--4	954	996	otss	rumi bac grwth,tetrzl slts	tengerdy,rp; nag/	1967
BSECB	5---3	177	183	otss	seas var,palata, pteridium	cooper-driver,ga/	1977
BTBCA	72---	157	164	otss	rata antibioti activ, lich	burkholder,pr; ev	1945
CRPSA	16--2	225	229	otss	suppr in vitro, crwn vetch	burns,jc; cope,w/	1976
ENDEA	10--4	95	99	otss	rata antibact substn, lich	bustinza,f	1951
JDSCA	40-10	1945	1946	otss	inhi rumn cellulas,sericea	smart,wwg,jr; be/	1961
JRMGA	29--5	356	363	otss	rumi, maj plant toxi, w us	james,lf; johnson	1976
JWMAA	44--3	613	622	otss	rata diges, rangifer forag	person,sj; pegau/	1980
PNASA	30--9	250	255	otss	rata antibiot activ, lichn	burkholder,pr; m/	1944
PYTCA	14--4	1107	1113	otss	phytochm,proanthocyanidins	bate-smith,ec	1975
ZTTFA	24--4	200	204	otss	ceel,doca, rumn cllys,bark	prins,ra; geelen,	1968

*SCSB = Secondary Substance

alkd = alkaloids**
esol = essential oils
flvd = flavonoids
glcs = glucosides**
mnrl = minerals
otss = other secondary substances
phnl = phenols, phenolic compounds
tann = tannins

**These were not used in the serials lists; additional publications may be available on these substances.

UNIT 1.3: CELLULAR AND DIGESTIBILITY DIFFERENCES BETWEEN PLANT GROUPS

Herbaceous and woody plants are differentiated on taxonomic bases, and they also have distinct differences in their cellular characteristics and digestibilities. The major difference is the larger quantity of crude fiber in the woody plants; the larger quantity of fiber is what makes the plants woody. This difference affects forage availability as woody browse is often the only forage available to deer and moose living in the northern forests in the winter when snow covers herbaceous material from the previous growing season.

There are differences in the cellular characteristics and digestibilities of different kinds of herbaceous plants too. Grasses and legumes have been studied because of their importance to domestic animals, with considerable emphasis on the time of cutting as well as the taxonomic groups of these forages.

Digestibilities may be calculated with regression equations having cell characteristics as the independent variable. A single relationship, however, cannot be used for all forages. Rather, regression equations need to be derived for different plant groups. Equations need to be derived for different groups of plants such as grasses, legumes, etc., because the slopes of the regression lines appear to be related to taxonomic groups. Equations have not yet been derived for sufficiently large numbers of species in all groups; grasses and legumes have been evaluated most thoroughly because of their importance as forages for domestic animals.

LICHENS

Very limited amounts of research have been conducted on the cellular characteristics of lichens in relation to digestibility. Person et al. (1980) give data on two species, which is not enough to derive generalized equations for lichens as a group. Simple regression equations for the relationships between digestibility and fiber composition of different arctic forages in four different groupsg (lichens, shrubs, grass-like plants, and forbs) are given by Person et al. (1980); some of their results may be useful when evaluating material in the rest of this UNIT.

GRASSES

A wide range in the cell wall components of grasses exists for different species (See Van Soest 1965: 837; and Moen 1973: 169). They are generally less digestible than legumes, but a wide range in the phenology of different species results in grasses being available at different stages of growth throughout much of the growing season.

LEGUMES

Legumes may be generally more digestible than grasses because of their lower cell wall component. Alfalfa had about 40-60% cell wall compared to 45-72% for different grasses (Van Soest 1965: 837; and Moen 1973: 169). Legumes are much more important as forages for domestic ruminants than wild ones; they are raised and harvested for their high nutritive values.

FORBS

The forbs analyzed by Whittemore and Moen (1980) were highly digestible. Deer need high quality forage during the summer to meet their increased metabolic requirements at that time and to build up fat reserves to survive the winter period of low quality forages (Moen 1978). It is often difficult to detect evidence of selective grazing on forbs and other summer foods, and their importance to the animal is easily underestimated. There is a need for more detailed observations of foods consumed on the summer range and their relationship to the winter survival of white-tailed deer (Whittemore and Moen 1980).

DECIDUOUS BROWSES

The current annual growth (CAG) of deciduous browse is the part of woody plants preferred by browsing animals. The distal portions of the CAG is more digestible than the proximal portion. In fact, Whittemore and Moen (ms in preparation) suggest that it is necessary to know the length intervals of the twig before a digestibility estimate can be given. Digestibilities decrease from the distal to the proximal portion as less meristematic and more structural tissue is found along that length gradient.

There is a predictable relationship between browse dry matter digestibility and cell soluble content, but this is not enough to estimate dry matter digestibility because of variations in cell wall content (Robbins and Moen 1975). The cell walls of browse species tend to be relatively low in diggestibility due to the high lignin-cutin content. An equation expressing this relationship from Robbins et al. (1975:72) is:

$$CWDG = 146.59 - 34.61 \ln LCUC$$

where CWDG = in vivo cell wall digestibility, and
LCUC = lignin-cutin content expressed as percent of the acid-detergent fiber.

The predictability of this relationship and the estimated cell-soluble digestibility (0.98) form a basis for general prediction of forage true dry matter digestibility (TDMD):

$$TDMD = 0.98\ (CSCP) + (CWCP)\ (139.97 - 33.15 \ln LGCC$$

where 0.98 = digestibility of cell solubles,
CSCP = cell soluble content in percent of forage,
CWCP = cell wall content in percent of forage, and
LGCC = lignin-cutin content as a percent of the acid-detergent fiber.

CONIFEROUS BROWSES

The current annual growth of coniferous browse is the part preferred by browsing animals. Again, the distal portions of the CAG is more digestible. The range in digestibility from the distal end for 2-year-old growth in hemlock was as great as the range in average digestibilities of preferred foods to starvation foods (Moen, unpublished data).

OTHERS

A fungus (Polyporus squamosus) and a moss (Atrichum sp.) were analyzed by Whittemore and Moen (1980), and digestibilites found to be 41 and 39%, respectively. These are quite low. Digestibilities of other fungi and mosses have not been measured.

The references in the SERIALS list were selected on the basis of key words such as cell components, cell wall, lignin, and other indicators of cell structure in relation to digestibility of forages in different plant groups. References in other lists in this CHAPTER 11, especially the Genus-species list (UNIT 2.4), will provide additional information for nutritive analyses.

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Van Soest, P. J. 1965. Symposium on factors influencing the voluntary intake of herbage by ruminants:voluntary intake in relation to chemical composition and digestibility. J. Animal Sci. 23(3):834-843.

REFERENCES, UNIT 1.3

CELLULAR AND DIGESTIBILITY DIFFERENCES BETWEEN PLANT GROUPS

SERIALS

CODEN	VO-NU	BEPA	ENPA	PLGR*	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	16--2	476	480	dest	digestib live oak, chamise	bissell,hd; weir,	1957
JRMGA	18--2	139	144	dest	fecal cellulo,esti pl tiss	short,hl; remmeng	1965
JWMAA	35--4	732	743	dest	limit, wint aspn brws,mich	ullrey,de; youat/	1971
JWMAA	36--3	885	891	dest	dig, est metabl aspn brows	ullrey,de youat/	1972
JWMAA	39--1	67	79	dest	feed analysis, digestion	robbins,ct; soes/	1975
JWMAA	39--2	337	341	dest	comp, digest, decidu brows	robbins,ct; moen,	1975

CODEN	VO-NU	BEPA	ENPA	PLGR	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	31--3	448	454	evst	dig cedar, jack pine brows	ullrey,de; youat/	1967
JWMAA	32--1	162	171	evst	dig cedar, balsam fir brow	ullrey,de; youat/	1968
PCGFA	10---	53	58	evst	nutri probl, sou pine type	lay,dw	1956
ZEJAA	9---2	54	62	evst	[on digest fresh fir bark]	ueckermann,e; har	1963

CODEN	VO-NU	BEPA	ENPA	PLGR	KEY WORDS-----------------	AUTHORS----------	YEAR
CNJNA	60---	189	192	frbs	compos digestib herb forag	whittemore,s;moen	1980

CODEN	VO-NU	BEPA	ENPA	PLGR	KEY WORDS-----------------	AUTHORS----------	YEAR
JANSA	38--1	149	153	gras	compar,dig, grasses, niger	olubajo,fo; van /	1974
JANSA	39--2	423	434	gras	intk, digest, napier grass	grant,rj; van soe	1974

CODEN	VO-NU	BEPA	ENPA	PLGR	KEY WORDS-----------------	AUTHORS----------	YEAR
JWMAA	31--3	443	447	hedi	previous diet, dige alfalf	nagy,jg; vidacs,/	1967

*PLGR = Plant group

CODEN	VO-NU	BEPA	ENPA	PLGR	KEY WORDS------------------	AUTHORS-----------	YEAR
JWMAA	12--1	109	110	hemo	select most nutrit forages	swift,rw	1948

CODEN	VO-NU	BEPA	ENPA	PLGR	KEY WORDS------------------	AUTHORS-----------	YEAR
				lgms			

CODEN	VO-NU	BEPA	ENPA	PLGR	KEY WORDS------------------	AUTHORS-----------	YEAR
AZOFA	8--3	385	389	lich	nutr val, lichens, lapland	pulliainen,e	1971

CODEN	VO-NU	BEPA	ENPA	PLGR	KEY WORDS------------------	AUTHORS-----------	YEAR
CAFGA	41--1	57	78	many	diges, naturl, artif foods	bissell,hd; harr/	1955
JWMAA	16--3	309	312	many	diges, some native forages	smith, ad	1952
JWMAA	28--4	791	797	many	digest cedar, aspen browse	ullrey,de; youat/	1964
JWMAA	35--4	698	706	many	forage dige, diet s upland	short,hl	1971
JWMAA	36--1	174	177	many	qual, wint fora, ark ozark	segelquist,ca; s/	1972
JWMAA	40--4	630	638	many	dig,rel nutr, 7 n brows sp	mautz,ww; silver/	1976
NEZFA	13--3	591	604	many	crbhyd, lign, grass, legum	bailey,rw; ulyatt	1970
XFPSA	136--	1	11	many	habi, pine-hardwd, louisia	blair,rm; brunett	1977

CODEN	VO-NU	BEPA	ENPA	PLGR	KEY WORDS------------------	AUTHORS-----------	YEAR
CNJNA	60---	189	192	othr	compos digestib herb forag	whittemore,s;moen	1980

*PLGR = Plant Group

dest = deciduous shrubs and trees
evst = evergreen shrubs and trees
frbs = forbes
grss = grasses
hedi = herbaceous dicots
hemo = herbaceous monocots
lgms = legumes
lich = lichens
many = two or more plant groups
othr = others

CHAPTER 11, WORKSHEET 1.3a

Cell wall percents and predicted digestibilities

The relationship between percent cell wall and in vitro digestibility may be demonstrated with data in Table 1 of Whittemore and Moen (1980). The percents cell wall and measured in vitro digestibilities given below may be used to calculate linear regression equations for digestibilities, the dependent variable, of stems and leaves and of the floral parts in relation to percents cell wall (the independent variable).

Calculate linear regression equations for the two sets of data below. PTCW = percent cell wall, and DMDP = dry matter digestibility in percent.

	Floral parts		Stems and leaves	
Scientific name	PTCW	DMDP	PTCW	DMDP
Anaphalis margaritacea	48.1	83.1	46.7	77.4
Aster novae-anglicae	33.1	85.8	51.0	67.9
Chrysanthemum leucanthemum	43.7	79.8	55.8	69.8
Daucus carota	26.7	91.2	59.1	70.8
Eupatorium maculatum	50.1	72.2	45.5	72.5
Impatiens biflora	30.9	87.2	40.3	79.2
Linaria vulgaris	27.1	86.3	49.8	73.7
Plantago major	54.1	67.7	32.2	82.7
Solidago graminifolia	39.2	76.1	43.1	74.6
Solidago juncea	45.6	72.0	57.5	62.9
Taraxicum officinale	32.6	87.1	34.7	91.3
Trifolium pratense	41.8	79.9	51.6	72.0

The calculated equations are, for the floral parts:

DMDP = ______ + ______ PTCW

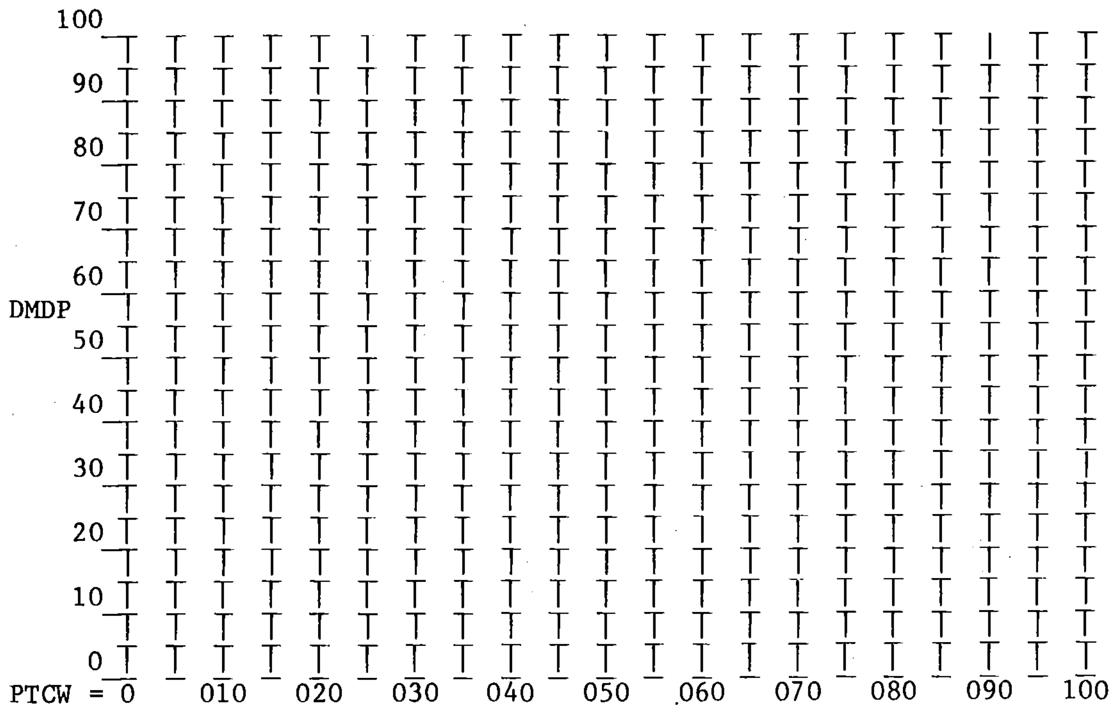
and for the stems and leaves:

DMDP = ______ + ______ PTCW.

Similar analyses may be made for other species reported in the literature. Non-linear regressions may result in best fits for different sets of data.

Plot the data on the grid on the back of this page. Note how similar the slopes (b) are; all the data were combined and a single linear regression used to express the relationship between percent cell wall and digestibility in the published paper. The equation is:

$$DMDP = 113.7 - 0.8\ PTCW;\ R^2 = 0.93$$



LITERATURE CITED

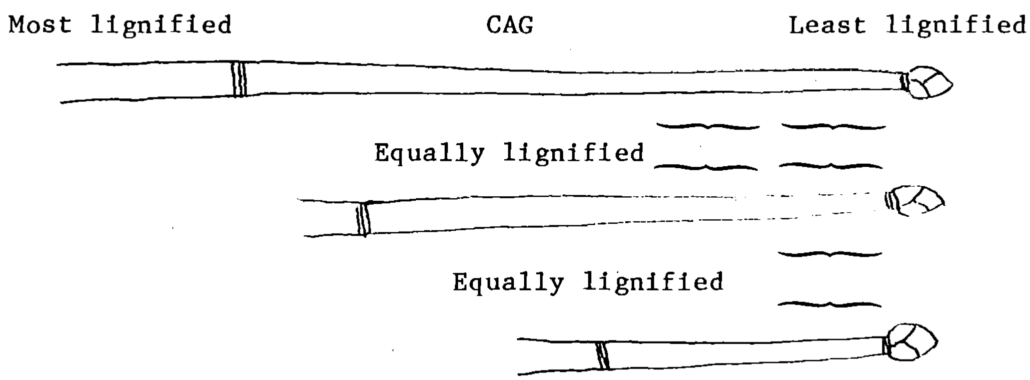
Whittemore, S. and A. N. Moen. 1980. Composition and in vitro digestibilities of various sommer foods of white-tailed deer. Can. J. Anim. Sci. 60:189-192.

UNIT 1.4: CELLULAR AND DIGESTIBILITY DIFFERENCES BETWEEN PLANT PARTS

It is desirable to consider the cellular characteristics of the parts of a single plant before considering several species, since variations between some of the plant parts may be greater than differences between species. Unfortunately, many published data on nutritive characteristics of different species are not accompanied by identification of the plant parts analyzed. Differences in cellular characteristics of different plant parts are related to their functions.

STEMS

Stems provide structural support for most plants, and therefore one would expect their cell walls to be rather rigid and firm. This suggests that the stems are highly lignified, with complex molecules of high molecular weights. The older parts of the stems are expected to be more highly lignified than the younger, growing parts.



Current annual growth (CAG) is the one part of a stem that is often analyzed in wild ruminant nutrition. Differences in cell structures are expected for different lengths of current annual growth and at different times during the growing season, however. Data on cell characteristics of stems or parts of stems are scarce; there is a need for many more laboratory analyses of growth and time effects on these characteristics of importance in nutritive analyses.

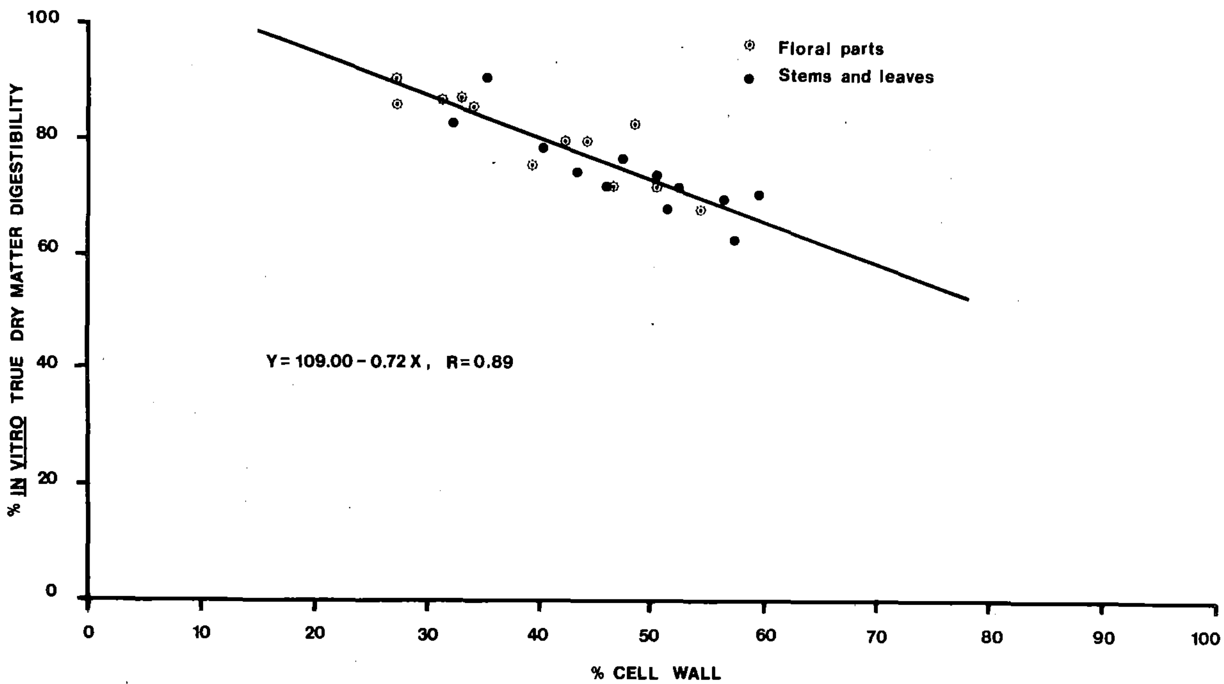
LEAVES

Leaves of annuals and deciduous plants go through an annual cycle of emergence, maturation, and decadence. Cell walls are expected to become thicker and more lignified as the leaves mature, of course. Decadent annual and deciduous leaves also lose nutrients through translocation, so their nutritive contents change as cell structures change through time.

Two-year old and older leaves are present on evergreens. Cell structural changes are expected to be less after the first year of rapid growth and maturation.

FLOWERS

The delicate petals, anthers, stamens, and other floral parts of flowering plants are expected to have thinner cell walls than the supporting structures. The figure below shows that the floral parts of herbaceous species tend to have lower percents cell wall than the stems and leaves tabular data in Whittemore and Moen (1980). The rigidity of the petals is due more to turgid cells as a result of a high free-water content than to rigid cell walls.



FRUITS AND SEEDS

Fruits and seeds show considerable variation in their structural characteristics. Fruits are often fleshy with a high water content. Seeds are often covered by rigid protective structures, and have pericarps that are often quite strong. Materials inside of the protective structures may be structurally quite weak.

LITERATURE CITED

Whittemore, S. and A. N. Moen. 1980. Composition and digestibility of various herbaceous forages of the white-tailed deer. Can J. Anim. Sci. 60(1):189-192.

REFERENCES, UNIT 1.4

CELLULAR AND DIGESTIBILITY DIFFERENCES BETWEEN PLANT PARTS

SERIALS

CODEN	VO-NU	BEPA	ENPA	PLPA*	KEY WORDS------------------	AUTHORS----------	YEAR
CNJNA	60--1	189	192	flwr	compos, diges summer foods	whittemore,s; moe	1980

CODEN	VO-NU	BEPA	ENPA	PLPA	KEY WORDS------------------	AUTHORS----------	YEAR
				frut			

CODEN	VO-NU	BEPA	ENPA	PLPA	KEY WORDS------------------	AUTHORS----------	YEAR
CNJNA	60--1	189	192	leav	compos, diges summer foods	whittemore,s; moe	1980
PYTCA	7....	871	880	leav	seas changes, tannin contn	feeny,pp; bostock	1968
PYTCA	8--11	2119	2126	leav	inhib eff tann prot hydrol	feeny,pp	1969

CODEN	VO-NU	BEPA	ENPA	PLPA	KEY WORDS------------------	AUTHORS----------	YEAR
ECOLA	49--5	956	961	seed	caloric val, 4 sites, kans	johnson,sr; robel	1968

CODEN	VO-NU	BEPA	ENPA	PLPA	KEY WORDS------------------	AUTHORS----------	YEAR
CNJNA	60--1	189	192	stem	compos, diges summer foods	whittemore,s; moe	1980
ZEJAA	9---2	177	184	stem	[on digest fresh fir bark]	ueckermann,e; har	1963

CODEN	VO-NU	BEPA	ENPA	PLPA	KEY WORDS------------------	AUTHORS----------	YEAR
JWMAA	40--4	630	638	twig	dig, rel nutr, 7 n species	mautz,mm; silver/	1976

*PLPA = Plant part

CODEN	VO-NU	BEPA	ENPA	PLPA	KEY WORDS------------------	AUTHORS----------	YEAR
CPLSA	49--4	499	504	many	ligni, in vitr dig, pl prt	mowat,dm; kwain,/	1969
JWMAA	35--2	221	231	many	cellulo dig, chem, missour	torgerson,o; pfan	1971
XFPSA	136--	1	11	many	habi, pine-hardwd, louisia	blair,rm; brunett	1977

*PLPA = Plant part

flwr = flowers
frut = fruit
leav = leaves
many = two or more plant parts
seed = seeds
stem = stems
twig = twigs