Parameters of the Cornell Net Carbohydrate and Protein System (CNCPS)

Protein-Fractions (N-Fractions)

The estimation of rumen microbial protein synthesis and by pass protein is based in part of extensive chemical fractionation of protein. The analytical methods were summarized and published by Licitra et. al (1996). Currently, the five fractions A1, A2, B1, B2 and C are determined in the CNCPS system. The classification into the fractions (not the analytics!) is different to the original classification.

Tab. 1: Protein fractions (mod. Licitra et al. 1996, Higgs et al. 2015, Van Amburgh et al. 2015, Tedeschi and Fox 2017, p. 439 ff).

<table>
<tr><th>Licitra et al.</th><th>CNCPS system</th><th>Licitra et al.</th><th>CNCPS system</th><th>Degradation rate</th></tr>
<tr><td rowspan="2">A</td><td>A1</td><td rowspan="2">non-protein nitrogen</td><td>Ammonia</td><td>already degraded</td></tr>
<tr><td rowspan="2">A2</td><td rowspan="2">buffer soluble true protein</td><td rowspan="2">quick degradation</td></tr>
<tr><td>B1</td><td>buffer soluble true protein</td></tr>
<tr><td>B2</td><td>B1</td><td>buffer insoluble true protein</td><td>buffer insoluble true protein</td><td>variable degradation</td></tr>
<tr><td>B3</td><td>B2</td><td>AD-soluble protein bound to the fiber</td><td>AD-soluble protein bound to the fiber</td><td>slow degradation</td></tr>
<tr><td>C</td><td>C</td><td>Maillard product or protein insolubly bound to ADF</td><td>Maillard product or protein insolubly bound to ADF</td><td>difficult to degrade/indigestible</td></tr>
</table>

Abbreviations

ADICP or ADIP (AD-insoluble protein) = Acid Detergent Insoluble Crude Protein:
Describes the crude protein insolubly bound to the cell wall (in g/kg DM). This fraction is almost indigestible for the animal and increases sharply, for example, in heat-damaged feeds. The ADICP corresponds to fraction C.

Ammonia (NH3)/Fraction A1:
Ammonia is a volatile nitrogen compound and is counted among the non-protein nitrogen. It is mainly formed by the degradation of protein compounds during the ensiling process and it is a product of amino acid degradation (desmolysis). Amino acid degradation is mainly caused by proteolytic clostridia, but in some cases also by lactic acid bacteria. Another N source for the formation of ammonia can be the nitrate contained in the plant. The content of NH3 is an indicator for the quality of the ensiling process and is usually examined in silages.

NDICP or NDIP = Neutral Detergent Insoluble Crude Protein:
The NDICP is the crude protein, which is after boiling in neutral detergent solution still insoluble, means the protein insolubly bound to the cell wall (NDF). The NDICP is used in context of the crude protein fractionation (determination of rumen undigestible protein or by pass protein (RUP)), the correction of NFC (non-fiber carbohydrate) and calculation of energy in the United States (NRC,2001).

Buffer soluble crude protein (BSP):
Describes the proportion of low-molecular protein compounds that are soluble in borate buffer and can be degraded very quickly in the rumen. This includes the non-protein nitrogen and low-molecular protein compounds.

True protein (TP):
The true protein describes all N-compounds, means amino acids, which are connected to each other via a peptide bridge and thus correspond to the definition of "protein". For the determination of the true protein several methods are available, which also lead to different results (up to 10% deviation).

Crude protein corrected for NH3-N (g/kg DM):
During the drying of silages, a part of the ammonia is lost and thus is not included in the crude protein determination. However, the non-analyzed part of the ammonia contributes to the nitrogen supply of the animals and must be also considered. This is realized by correcting (increasing) the analyzed crude protein content by the volatile ammonia-N content.

Carbohydrates

Within the CNCPS model also carbohydrates are differentiated similarly to the N compounds.

Tab. 2: Carbohydrate fractions of the CNCPS model

Fraction	Composition	Calculation/Analysis
CHO	Carbohydrates	=100-CP-EE-CA
aNDFom	ash-free NDF after amylase treatment	aNDFom
NFC-1	non-fiber carbohydrate	=CHO-aNDFom
NFC-2	non-fiber carbohydrates adjusted for protein content in aNDFom	= CHO - aNDFom - NDIP
A1	volatile fatty acids	Acetic, propionic and butyric acid
A2	Lactic acid	Lactic acid
A3	other organic acids	other organic acids
A4	water soluble carbohydrates	water soluble carbohydrates (sugar and fructans)
B1	starch	starch
B2	soluble fiber	= NFC - A1 - A2 - A3 - A4 - B1
B3	potential soluble fiber	= aNDFom - C
C	non-digestible fiber	= (Lignin*2,4) or uNDF240h

NDIP: ND-insoluble protein, EE: ether extract (crude fat), CP: crude protein, CA: crude ash, uNDF240h: indigestible fiber/NDF after 240h incubation in rumen fluid (mod. Higgs et al. 2015, Van Amburgh et al. 2015, Tedeschi and Fox 2017)

The differentiation of carbohydrate fractions is used in the CNCPS model to derive degradation rates (Kd), estimate energy, microbial protein synthesis, and metabolizable protein.

NDF-digestibility

The NDF digestibility means the NDF degradation in the rumen, because this is the main location for digestion. A digestion in the small intestine practically does not takes place. In the large intestine, 5-20% of the NDF can still be degraded (digested). The extent of degradation depends on the feed and the residence time in the rumen. For coarse feeds the three measuring times 30h, 120h and 240h are recommended. The first measuring time point (30h) corresponds to the mean residence time of a feed particle at high feed intake. The second measurement time point (120h) is needed for the calculation of the degradation rate and the passage rate. The third measurement time point (240 h) is used to determine the non-degradable/indigestible NDF. From the difference between the NDF content and the

undigestible fraction, the potentially degradable NDF can be determined. The determination of NDF digestibility can be done in situ or in vitro using nylon bags.

Abbreviations

NDFD30 [% NDF] = neutral detergent fiber digestibility 30 hours: Digestibility of the aNDFom during a 30-hour incubation in rumen fluid. The value is given as a percentage of the NDF.

NDFD120 [%NDF] = neutral detergent fiber digestibility 120 hours: Digestibility of the aNDFom during a 30-hour incubation in rumen fluid. The value is given as a percentage of the NDF.

NDFD240 [% NDF]: neutral detergent fiber digestibility 240 hours: Digestibility of the aNDFom during a 30-hour incubation in rumen fluid. The value is given as a percentage of the NDF.

uNDF30 [g/kg TS] = indigestible neutral detergent fiber 30 hours: Content of indigestible NDF after incubation during 30 hours in rumen fluid. The information is given in g/kg DM.

uNDF240 [g/kg TS] = indigestible neutral detergent fiber 240 hours: Content of indigestible NDF after incubation during 240 hours in rumen fluid. The information is given in g/kg DM.

pNDF [g/kg TS] = potential degradable Content of neutral detergent fiber: Content of potentially degradable NDF. The information is given in g/kg dry matter. The pNDF is calculated according to the equation = aNDFom [g/kg DM] - uNDF240 [g/kg DM].

Due to intensive research activities, the orientation values are constantly adapted. Currently, the following orientation values can be used in the ration calculation and for the evaluation of feeds.

Tab. 3 u. 4: Requirements for uNDF and NDFD content in feeds and rations.

Criteria	forage uNDF30	TMR uNDF30	TMR uNDF240
% of body mass	0,35-0,40 (0,30min)	0,55-0,85	0,25-0,35
kg/animal and day	2,3-2,8	4-6	1,8-2,5
g/kg DM	100-140	170-270	75-130

Parameter	Grass silage	Corn silage	alfalfa silage
NDFD30 [% NDF]	50-70	40-60	40-55
NDFD240 [% NDF]	75-90	65-85	65-80

Starch degradability (by pass starch 7h)

In rations with a high starch content the knowledge of the ruminal degradability of the starch, means the resistance of the starch, is essential. The aim is to avoid rumen acidosis, but also excessive flooding of starch into the large intestine (leaky gut syndrome). The determination is done with an in vitro test in rumen fluid (7 hours). In corn silage, the percentage of resistant starch is between 12 - 22 %. Whether a value is good or bad depends on the composition of the ration, the starch content and the proportion of corn silage in the ration.

fermentation acids

In the CNCPS system, the determination of fermentation acids is mandatory, because they are assigned to the carbohydrate fractions A1 and A2. In silages, the acetic acid content should be between 1.5 and 3.5%, butyric acid <0.3% and lactic acid between 2-8% in dry matter. In mixed rations, the total acid content should be <6% and the lactic acid content <4%.

Kernel processing score (KPS)/Corn silage processing score (CSPS)

Corn kernels can only be completely digested by cattle in a chopped state (halved or quartered). Whole kernels (even if they are cut) are found undigested in the feces. Thus, the rumen microbes and thereby the animal deprives energy and starch. This is not detected by the classic nutrient analysis. If the proportion of corn silage in the ration is high, inadequately processed kernels lead to a decrease of starch digestion and energy supply as well as the appearance of corn starch in the feces. One way of quantitatively measuring and evaluating the quality of grain size reduction is the degree of the Kernel processing score. With this laboratory method the proportion of starch content, which is present in small particles (<4.75 mm) is measured. From U.S. studies the following target values were derived for the CSPS/KPS: >70% optimum, 50-70% needs improvement, and <50% insufficient.

Measurement of minerals by NIR

For more than 20 years American laboratories offer the determination of mineral nutrients with NIR. Due to its physical principle, the NIR method is only suitable for the determination of organic substances. However, it is possible to establish a mathematical relationship between NIR spectra and mineral content. The determination of minerals is nevertheless subject to significantly greater errors than the determination of organic compounds. The sender must decide, depending on the subject, whether a determination by NIR is justified or whether the reference method must be used.

State: December 2022