Recent Advance in Division of Carbohydrate and Protein Fractions of Ruminant Feed and Their Metabolism in Digestive Tract

Xiaohua PAN[1,2], Liang YANG[1], Hairui XIN[1], Benhai XIONG[1]*

1. State Key Laboratory of Animal Nutrition, Institute of Animal Science, Chinese Academy of Agricultural Sciences, Beijing 100193, China; 2. University of Liège, Gembloux Agro-Bio Tech, Animal Science Unit, Passage des Déportés 2. B-5030 Gembloux, Belgium

Abstract Accurate assessment of feed's Carbohydrate (CHO) and protein nutritional values and rumen metabolism are significant for dairy production. Cornell Net Carbohydrate and Protein System (CNCPS) as an important method to evaluate feedstuff nutritional values, hasn't been widely used in China. In order to illustrate updates of CNCPS systems deeply, the following sections were reviewed: (i) CHO and protein fractions were updated, CA was subdivided into CA1, CA2, CA3 and CA4 in CNCPS v6.1, protein was reclassified into PA1, PA2, PB1, PB2 and PC after CNCPS v6.1. Content of CHO and protein fractions vary in different feedstuff and affected by feed processing; (ii) Degradation rates (Kd) values for the new CA expanded scheme were updated to 0, 7, 5, 40 - 60 % h^{-1} respectively, Kd for PA and PB1 decreased to 200 % h^{-1} and 10 - 40 % h^{-1}; (iii) Equations for passage rate (Kp) initially includes Kpf (Kp of forages) and Kpc (Kp of concentrates), and adjusted by effective NDF (eNDF), while in CNCPS v5.0, Kpl (Kp of liquids) equation was added and eNDF was replaced by physically effective NDF (peNDF). In CNCPS v6.1, FpBW and CpBW were integrated into Kp equations and peNDF was abandoned. (iv) The relationship and difference among Weende system of proximate analysis, Van Soest fiber analysis[35], NRC (2001)[28] and CNCPS were analyzed. The first two systems laid the foundation for NRC (2001) and CNCPS system. The latter two systems are different in CHO and protein division, also NRC (2001) developed separate Kp equations for wet and dry forages but no equation for Kpl. CNCPS developed a Kp equation that work for wet and dry forages, and Kpl equation was established. In conclusion, the division and development of CHO and protein fractions, the update of Kd and Kp equation were reviewed systematically.

Key words CNCPS, Carbohydrate, Protein, Fraction, Metabolism

1 Introduction

In recent twenty years, the assessment of the ruminant feed nutritional values mainly focused on carbohydrate and protein content, ruminal degradation, outflow and intestinal digestion. The widely used systems for ruminant feed nutritional values include Weende system[16], Van Soest fiber analysis, NRC (2001) and CNCPS systems (The latest version is 6.1). The first two methods are the foundation for evaluation, and have been used for more than 100 years. However, both of them assess feed nutrition statically and couldn't reveal feedstuff' digestion properties in digestive tract. NRC (2001) and CNCPS 6.1 are mechanistic and dynamic mathematical models that developed from basic principles of rumen function, microbial growth, feed degradation, passage and animal physiology, also some connections and differences exist in two systems. The objectives of this study were to systematically review the subdivision and degradation of carbohydrate and protein in different CNCPS versions, also compare the different systems for ruminant feed nutritional values evaluation and the application of CNCPS in ruminant nutrition research.

2 Characterization of feed fractions in CNCPS system

2.1 Carbohydrate fraction The changes of carbohydrate fractions in CNCPS from the first version to the version 6.1 were demonstrated in Table 1. In CNCPS versions prior to 6.1, carbohydrate fractions were divided into CA, CB1, CB2 and CC[12, 39], sugars, organic acids, and oligosaccharides were included in the CA, starch and soluble fiber compounds in the CB1. Some limitations of the previous schemes have become apparent: (i) the CHO fractions and degradation rates were not precisely defined and generally measured; (ii) Besides, it does not account for the various processing treatments' effects on NFC digestibility[29]; (iii) In addition, the description and ruminal digestibility of the fraction containing starch and soluble fiber were highlighted[31]; (iv) CHO fractions in NFC differ in rate and extent of fermentation, products of fermentation, and contribution to animal performance[15]. For example, organic acids, which present high concentration in forages, are used less efficiently for microbial growth compared to sugars. Silages are rich in lactate, and contrary to VFA, lactate could produce microbial protein[10, 26]. So in CNCPS v6.1, the carbohydrate pools have been expanded to eight fractions: CA1 (acetic, propionic and butyric acid), CA2 (lactic acid), CA3 (organic acids), CA4 (sugars), CB1 (starch), CB2 (soluble fiber), CB3 (available NDF) and CC (unavailable NDF). The expanded CHO scheme provides a more biologically correct and appropriate feed description that closely related to rumen fermentation characteristics to account for variation in changes in silage quality and diet NFC composition. However, to fully account for differences in feed CHO utilization, further improvements in the methodology used to estimate the fractions and their

Received: May 2, 2016 Accepted: July 2, 2016
Supported by National Natural Science Foundation of China (31572435); Creative Workgroup on Dairy Industry of Beijing City 2012.
* Corresponding author: bhxiong@iascaas.net.cn

corresponding degradation rates, inclusion of dietary factors in dry matter intake predictions, and prediction of ruminal VFA production and pH are necessary.

Table 1 Comparison of the carbohydrate fractions in different versions of CNCPS

CNCPS prior to 6.1		CNCPS 6.1	
CA	Sugars, organic acids and short oligosaccharides	CA1	Acetate, Propionate, Butyrate
		CA2	lactate
		CA3	Organic acids
		CA4	Sugars
CB1	Starch and soluble fiber	CB1	Starch
CB2	Available NDF	CB2	Soluble fiber
		CB3	Available NDF
CC	Unavailable NDF	CC	Unavailable NDF

2.2 Protein fraction Table 2 demonstrated the evolution of protein fractions in different CNCPS versions. The original CNCPS fractionates CP into 5 fractions (PA, PB1, PB2, PB3 and PC) based on solubility in protein precipitant agents, buffers, and detergent solutions[12, 30, 39]. However, recent researches found some limitations of the previous protein division scheme. Firstly, the assumption that the N insoluble in neutral detergent and in acid detergent represents slowly degradable and unavailable protein fractions, respectively, is not valid for all feeds[7]; Secondly, the assumption that all of the NPN fraction enters the ammonia pool completely and does not provide amino N that can stimulate microbial growth has underpredicted the microbial protein production[2]; Thirdly, the assumption that fraction A is completely degraded does not account for the contributions of free amino acids and peptides to the RUP flows[2, 37]; However, some small peptides and free AA may escape rumen degradation and flow through to the small intestine[14], and Choi *et al.* (2002) suggested 10% of the AA flowing through to the small intestine originated from dietary NPN sources[6], also Velle *et al.* (1997)[36] infused free AA into the rumen at various rates and showed that up to 20% AA could escape degradation and flow to the small intestine. Based on the limitation mentioned above, an evolution of the protein division was made in the latest versions by Van Amburgh *et al.* (2010)[32], Higgs *et al.* (2012)[17] and Van Amburgh (2013)[33], who re-divide protein into PA1 (ammonia), PA2 (soluble non-ammonia crude protein), PB1, PB2 and PC, this new configuration shifted a considerable amount of protein from PA1 to PA2. As PA2 fraction contributes MP to the animal, the new scheme enhances the accuracy of the predicted MP supply.

2.3 Analysis of CHO and protein fractions of common feedstuff Table 3 lists the CHO and protein fractions for common feedstuff and these contents were calculated by the equations according to Tylutki *et al.* (2008)[42]. For the new CA expanded scheme, CA1 mainly remains in wet feeds because VFAs are partly volatilized during oven drying. CA2 is the predominant organic acid in ensiled feeds, which can reach up to 50 – 150 g kg^{-1} DM[25], CA2 also presents in molasses and corn as the degradation product of invert sugar[1], CA3 is almost undetectable in silages[25], but in fresh forages, citric, malic, and aconitic acids can comprise more than 10% of the DM[9], the possible reason is that organic acid degraded in the process of silage. From Table 3, we can conclude that the contents of CHO and protein fractions vary in different feedstuff. For example, sugar is the most abundant fraction for molasses beet and accounts for 700 g kg DM, while in corn or wheat, CA4 content doesn't reach 50 g kg^{-1} DM basis. Feed processing like roast, extraction and ensilage would change the proportion of each fraction, compared with soybean whole raw, PB1 content of roasted soybean whole decreased from 165.7 to 22.6 g kg^{-1} DM, while PB2 increased from 213.9 to 353.1 g kg^{-1} DM, which will reduces the ruminal degradation of soybean protein. Also, sugar or starch would be utilized by bacteria and degraded into VFAs or organic acids during silage, so CA4 content of alfalfa green chop decreased by 69.53% after silage (101.1 g kg^{-1} vs 30.8 g kg^{-1}, DM basis).

Table 2 Comparison of the protein fractions in different versions of CNCPS

CNCPS prior to v6.5		CNCPS 6.5[33]	
PA	NPN (ammonia, peptides and AAs)	PA1	Ammonia
		PA2	Soluble true protein
PB1	Soluble true protein		
	Rapidly degraded protein	PB1	Moderately degradable protein
PB2	Intermediately degraded protein	PB2	Slowly degradable protein, bound in NDF
PB3	Slowly degradable true protein		
PC	ADIP	PC	Unavailable CP

3 Degradation and passage rates of CHO and protein fractions

For ruminants, carbohydrate and protein fractions are firstly degraded by rumen microflora for microbial protein synthesis, and the residue of feedstuff not digested in the rumen will pass to the intestine for further digestion or not. However, as the difference in chemical composition and structure, CHO and protein fractions differ in Kd and Kp, and the degraded quantity of fractions were determined by the simple relationship Kd/(Kd + Kp). So it's important to study the degradation and passage properties of different fractions for the accurate prediction of feedstuff' effective nutrition.

3.1 Degradation rate Table 4 demonstrated the changes in degradation rates of the various fractions. CA is subdivided into four fractions and each has its own degradation rates. Degradation rate value for CA4 was downward from 200 – 300 % h^{-1} to 40 – 60 % h^{-1} (rumen retention time of 100 to 150 min) based on in vitro

fermentation studies of Molina (2002)[26], who used a mixed sugar fermentation with mixed rumen bacteria by gas production. Further, Kd of PA reduced from 10 000 % h^{-1} (retention time of 0.6 min) to 200 % h^{-1}, for the 10 000 % h^{-1} was generated to represent the rate of solubilization and not necessarily microbial uptake. Besides, the degradation rate variation in some ranges mainly because the composition of the sugar fraction in feeds and their ability to support microbial growth are different. Take CA4 for example, the fermentation rates of 40 % h^{-1} for glucose and 16 % h^{-1} for arabinose when fermented with a fiber source. As five carbon sugars support less microbial growth than hexoses[41], degradation rates for feeds containing mainly sucrose were set at 40 % h^{-1} for the sugar fraction[26], but for milk derived products the assigned degradation rate for sugars is 30 % h^{-1} as lactose supports less microbial growth than sucrose[24]. For silages, with the exception of immature corn silages, the sugar fraction mainly are arabinose and other simple sugars derived from the hydrolysis of the side chains of pectin and hemicelluloses[20], thus a rate of 20 % h^{-1}, closer to the arabinose fermentation rate was assigned to the sugar fraction of silages.

Table 1 Content of carbohydrate and protein fractions in common feedstuff

Feedstuff		CHO	CA1	CA2	CA3	CA4	CB1	CB2	CB3	CC	CP	PA	PB1	PB2	PB3	PC
Energy	Wheat bran	727.0				47.4	218.0	50.5	326.6	84.5	170	20.9	48.8	71.4	22.1	6.8
feedstuff	Wheat ground	825.0				21.2	651.0	35.5	93.8	17.5	142	12.8	29.8	93.7	2.8	2.8
	Corn ground steam rolled (34 lb)	857.3				15.6	755.6	7.8	74.0	4.3	90	4.4	6.9	67.1	3.6	8.1
	Corn high moisture 22% coarse	850.5	31.0	10		18.4	721.9	14.6	77.8	4.8	98	10.7	16.7	63.1	2.7	4.7
	Corn grain whole	851.7		10		21.3	737.6	1.8	76.2	4.8	90	6.7	10.4	63.9	4.5	4.5
	Molasses beet	795.0		40	40	700.0		15.0			85	42.5	42.5			
	Beet pulp	721.0				99.8	30.0	239.9	245.5	105.8	147	21.6	50.4	10.3	56.3	8.4
Protein	Corn dist light spirits	506.0				24.0	80.0	96.0	210.0	96.0	304	26.6	49.4	133.8	51.4	42.9
feedstuff	Peanut meal solvent CP 48%	386.0				134.0	110.4	53.6	54.4	33.6	520	20.6	151.0	296.4	46.8	5.2
	Cottonseed meal CP 42 %	449.9				82.5	17.4	117.3	64.1	168.6	420	3.2	59.9	290.7	24.5	41.8
	Cottonseed delint	525.0				68.6	4.9	24.5	232.6	194.4	230	3.2	61.2	142.6	9.2	13.8
	Cottonseed fuzzy	530.0				22.9	2.5	25.5	170.0	309.0	235	3.1	58.5	149.4	5.2	18.8
	Soybean meal extruded	351.1				81.0	27.0	84.9	83.1	75.2	437	7.0	51.5	344.4	22.4	11.6
	Soybean Whole Raw	324.0				123.0	33.0	63.8	99.4	4.8	428	22.6	165.7	213.9	17.2	8.6
	Soybean Whole Roasted	326.0				137.3	36.8	71.1	76.0	4.8	428	3.1	22.6	353.1	34.5	14.7
Roughage	Grass pasture	72.5			40	77.4	4.1	82.3	428.8	92.4	160	1.5	30.5	99.2	23.7	5.1
	Legume pasture	617.8			60	147.0	6.1	93.1	185.6	126.0	240	1.6	70.4	129.6	33.6	4.8
	Alfalfa green chop	705.0			80	101.1	15.8	119.0	182.8	206.4	170	20.4	30.6	78.2	27.2	13.6
	Grass hay	750.0			30	72.0	36.0	102.0	437.4	72.6	160	46.8	25.2	48.0	30.9	9.1
	Alfalfa hay	705.0			20	87.5	15.6	189.3	186.2	206.4	170	23.8	35.7	73.1	23.8	13.6
	Grass silage	737.0	17.7	50		47.7	22.7	88.9	404.4	105.6	160	52.0	28.0	40.0	27.2	12.8
	Alfalfa silage	697.0	15.5	50		30.8	15.4	196.1	182.8	206.4	170	55.3	29.8	44.2	13.6	27.2
	Corn Silage (25% DM)	848.1	25.7	50		13.5	347.8	14.6	298.1	98.4	80	23.4	12.6	30.5	9.6	3.9

Note: Unit of index above is g kg^{-1} DM; " " in the above table means 0 g kg^{-1} DM.

Table 4 Feed degradation rates (Kd, % h^{-1}) used for CHO and protein pools in CNCPS v6.1 and prior to version 6.1 1

Component	Prior to v 6.1	v 6.1
CA1	Not modeled	0
CA2	Not modeled	7
CA3	Not modeled	5
CA4	300 – 500	40 – 60
CB1	20 – 40	20 – 40
CB2	20 – 40	20 – 40
CB3	4 – 9	4 – 9
CC	0	0
PA2	10 000	200
PB1	130 – 300	10 – 40
PB2	3 – 20	3 – 20
PB3	0.05 – 2.0	For forages, 4 – 9
PC	0	0

Note: 1 This table refers to Van Amburgh *et al.* (2010)[32]; 2For the new protein scheme, the degradation rates for PA1, PA2, PB1, PB2 and PC are 200 % h^{-1}, 10 – 40 % h^{-1}, 3 – 20 % h^{-1}, 4 – 9 % h^{-1}, 0 % h^{-1}, respectively[17].

3.2 Passage rate Table 5 showed the development of equations for feed passage rates and their difference compared with NRC (2001). Particle size, forage to concentrate ratio, hydration rate and intake level can affect the passage rates of feeds[4, 43]. Sniffen *et al.* (1992)[39] incorporated these effects into the equations for Kpf and Kpc, and Kp was adjusted for particle size using effective NDF (eNDF), but lacking equation for Kpl. As Kpl could affect the soluble nutrient digestion[19], outflow of rumen metabolites[23], rumen undegraded protein ratio[12] and microbial growth[11], Fox *et al.* (2004)[12] adding the Kpl equation to CNCPS v5.0, and Kp rates were adjusted by peNDF. The CNCPS version 6.1 absorbed Seo's researching results, integrating FpBW (Forage DMI as a proportion of BW), CpBW (Concentrate DMI as a proportion of BW) and FDMI (Forage Dry matter intake) factors into the Kp equations, also the peNDF adjustment factor is abandoned, for the double accounting for the particle sizes. For the soluble pools, they were predicted to flow out of the rumen with the solids passage rate in CNCPS prior to v6.1, thus with the high degradation rates and the slow passage rates, all the soluble fractions were considered to be degraded in the rumen. To be more appropriately reflect the biology of the cow, the CNCPS V6.1 re-

assigned the soluble pools to the liquid passage rate equation, which increasing the predicted outflow of soluble components, thus reducing microbial yield and estimated ammonia production as well as rumen N balance.

Table 5 Equations for feed passage rates in different CNCPS versions and NRC (2001)

Reference	Equation	Adjust factor, *Af*
Sniffen(1992)	$Kpf = 0.388 + (0.002 \times DMI/BW^{0.75}) + [0.0002 \times \text{forage2(\% DM)}]$	100/(eNDF + 70)
	$Kpc = -0.424 + 1.45 \times Kpf$	100/(*eNDF* + 90)
NRC (2001)	Kpf, *wet forage* $= 3.054 + 0.614\ X_1$	No
	Kpf, dry forage $= 3.362 + 0.479\ X_1 - 0.007X_2 - 0.017X_3$	No
	$Kpc = 2.904 + 1.375\ X\_0.020X_2$	No
CNCPS v5.0	$Kpf = [0.38 + (0.022 \times DMI \times 1000/BW^{0.75}) + 2.0 \times \text{forage}^2]/100$	100/(*NDF* × *peNDF*/100 + 70)
	$Kpc = [-0.424 + (1.45 \times Kpf \times 100)]/100$	100/(*NDF* × *peNDF*/100 + 90)
	$Kpl = (4.413 + 0.191 \times DMI \times 1000/FBW)/100$	No
CNCPS v6.1	$Kpf = 2.365 + (0.214 \times FpBW) + (0.734 \times CpBW) + (0.069 \times FDMI)$	No
	$Kpc = 1.169 + (1.375 \times FpBW) + (1.721 \times CpBW)$	No
	$Kpl = 4.524 + (0.223 \times FpBW) + (2.046 \times CpBW) + (0.344 \times FDMI)$	No

Note: Kpf Passage rate of forages; Kpc Passage rate of concentrate; Kpl Passage rate of liquids; DMI Dry matter intake; BW Body weight; eNDF Effective NDF; peNDF Physical effective NDF; FBW Full body weight; FpBW Forage DMI as a proportion of BW; CpBW Concentrate DMI as a proportion of BW; FDMI Forage Dry matter intake; X_1 DMI as a proportion of BW; X_2 Concentrate as a proportion of DMI; X_3 NDF as a proportion of DMI.

3.3 Possible problems for CHO and protein fractions Kd and Kp values Avornyo (2012)[3] compare three methods (gravimetric, Curve peeling technique, and Cornell values) to estimate protein B2 and B3 degradation rates in the rumen. The results showed that no statistical difference founded among three methods for the degradation rates of protein B2, whereas for protein B3, the degradation rate estimated with the gravimetric method was highest followed by the curve peeling method and then the Cornell values ($P < 0.01$). So the degradation rates assigned to protein B3 in the Cornell databank needs re-examination. Generally, prediction equations of Kp in CNCPS have been developed separately for forage, concentrate and liquid feed, and all Kp equations are based on DMI. However, there some questions found for CNCPS Kp prediction: 1) the equations in CNCPS have been developed based on large sets of empirical data using data of Cr – mordanted fiber as a Kp marker (CNCPS). However, marker type could influences Kp[18] estimated values and Kp equations of forages and concentrates in CNCPS were not corrected for the effect of marker[38]; 2) In CNCPS, Kp for concentrate and forage were calculated separately, and one Kp equation for all forages no matter dry and met forages[38]. However, it is't possible to separate Kp of forages and concentrate particles, and there are interaction effects between concentrate and forages, as Colucci *et al.* (1990)[8] observed that Kp of both forage and concentrate particles decreased when the proportion of concentrate in the diet to dairy cows increased as well as Stensig *et al.* (1998)[40] reported that increased starch supplementation in the diet to dairy cows decreased ruminal particle passage rate; 3) Kp equations in CNCPS don't containing forage type factors. Forage type affect Kp as Krizsan *et al.* (2010)[21] indicated that the fastest Kp of iNDF was reported for corn silage diets (2.66 % h^{-1} and 2.87 % h^{-1}); the alfalfa hay diet was in between (1.65 % h^{-1} and 2.17 % h^{-1}), and Kp was lowest for grass hay (1.27 and 1.34 % h^{-1}) when fed to dairy cows supplemented with concentrate or without any supplementation. Krizsan *et al.* (2010)[21] conducted a meta-analysis of studies using the flux/compartmental pool method with indigestible neutral detergent fiber (iNDF) as internal marker to evaluate Kp equations in CNCPS. He established two models for feeds based on NDF intake: Kp (% h^{-1}) = 1.19 + 0.0879 × NDF intake (g kg^{-1} of body weight) + 0.792 × proportion of concentrate NDF of total NDF + 1.21 × diet iNDF: NDF ratio when forage type was not included, and Kp (% h^{-1}) = F + 1.54 + 0.0866 × NDF intake for forage type. The models combined the feed type (concentrate, forage and forage type) and forage maturity factors, and by meta-analysis, he reported that prediction of Kp in CNCPS may overestimated and intake of NDF performed better as a predictor of Kp than DMI. So more research is needed to confirm the importance of relative forage differences in a rumen model and to separate animal effects from feed factors in predictions of ruminal particulate matter Kp.

4 Comparison of Weende, Van Soest, NRC (2001) and CNCPD in CHO and protein fraction and digestive metabolism

4.1 Weende and Van Soest fiber analysis – static feed nutrient evaluation methods For feed chemical composition division, there are mainly Weende feed proximate analysis, Van Soest fiber analysis, CNCPS and NRC systems. Weende analysis system, also called 'Feed Proxinate Analysis', was established by Henneberg and Stohmann (1860)[16], which divided feed nutrient into six fractions: moisture, crude protein (CP), ether extract (EE), crude fiber(CF), ash and nitrogen-free extracts(NFE). This concept has been used in feed evaluation systems for more than 150 years and still widely used in China's feed quality evaluation. However, there has been much dissatisfaction with this system, for example, the crude protein or crude fiber weren't subdivided to predict their nutritive availability and the NFE content was overestimated because most of the lignin and hemicellulose were

extracted into the NFE. Based on Weende analysis system, Van Soest (1967)[34] corrected the CF and NFE and established detergent fiber analysis method, CF was subdivided into cellulose, hemicellulose and lignin according to their solubility in neutral detergent and acidic detergent. This analysis method laid the foundation for the carbohydrate and protein fractions division.

4.2 NRC (2001) and CNCPS systems – dynamic feed nutrient evaluation methods The feed proximate analysis and Van Soest fiber analysis method evaluate feed nutrition statically, not considering factors like animal body condition, feed particle size, digestion. Both NRC (2001) and CNCPS system represent a large step to the dairy industry in that feed composition is described by carbohydrate and protein fractions and their degradation rates, as well as rumen fermentation and animal factors were integrated in two systems. However, there are still some difference and relationship between NRC (2001) and CNCPS for carbohydrate and protein fractions, degradation and passage rates, mainly including: (i) For carbohydrate and protein fractions, NRC (2001) absorbed the theoretical achievements of CNCPS before 2001, and divided carbohydrate simply into structural carbohydrate (SC) and non – structural carbohydrate (NSC), protein was subdivided into three fractions according to in situ method: Protein A (NPN, solubilized protein, and protein in particles smaller than the porosity of the nylon bag), protein B (potentially degradable protein) and protein C(unavailable protein, the remaining nitrogen at the end of predetermined incubation time). Whereas the CNCPS adopted the chemical partitioning method (solubility) to partition carbohydrate into eight fractions as described above, and protein was subdivided into five fractions (PA, PB1, PB2, PB3 and PC). (ii) Using different index to describe feed nutrient. NRC (2001) uses DM, CP(%DM), NDIP(%CP), ADIP(%CP), EE(%DM), NDF, ADF, Lignin(%DM), Ash (%DM), while CNCPS6.1 uses DM, OM(%DM), CP(%DM), SP(%CP), NPN(%CP), ADIP(%CP), NDIP(%CP), NFC(%DM), Sugar(%DM), Starch (%DM), SF(%DM), ADF(%DM), NDF(%DM), peNDF(%NDF), Lignin (%NDF), Ash (%DM). (iii) As showed in Table 5, the NRC (2001) and CNCPS models use different equations for predicting passage rate of undigested feed. NRC (2001) developed separate equations for wet forages and dry forages and found that the Kp of wet forages was higher ($P < 0.01$) than that of dry forages (0.0432 h^{-1} versus 0.0377 h^{-1}), and Kp equation for liquid was not developed, though the liquid Kp may affect digestion of soluble nutrients[19], outflow of end products of fermentation[23], peptide escape[12] and microbial growth[11]. Because of the lack of data for both development and evaluation, CNCPS system developed one equation for forages Kp prediction, wet forage and dry forage are not calculated separately, and Kp equation for liquid was also established. (iv) NRC (2001) uses RDP = A + B (Kd/Kd + Kp) and RUP = B(Kp/Kd + Kp) + C to calculate RUP and RDP, respectively, which is similar to CNCPS system.

5 Conclusions

CNCPS is a dynamic ruminant nutrition model that integrate animal, environment, physiological functions and metabolic processes, also carbohydrate and protein fractions and their degradation and passage rates continuously update. This update has allowed us to predict feed availability with more accuracy. Also the feed library and programs like CPM Dairy, AMTS. Cattle, NDS, DinaMilk of CNCPS help predict feed nutritional values and optimize ruminant diets more accurately and efficiently. However, the assessment of feed nutritional values mainly based on Weende system in China, and CNCPS was not commonly used for its meticulous division of carbohydrate, protein fractions, and complicated index, which is difficult to be determined for producer. So for the utilization of CNCPS in China's ruminant production, feedstuff database should be built and the integration of CNCPS models with computer technology should be further strengthened to realize China's precision farming.

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