The establishment of a database of Italian feeds for the Cornell Net Carbohydrate and Protein System

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ABSTRACT

A field application of the Cornell Net Carbohydrate and Protein System (CNCPS) in Italy has been limited because the feed bank is based on North American feedstuffs and still few laboratories are able to analyze feeds as requested by the CNCPS. Moreover, the standardization of analytical procedures is still not homogeneous among laboratories. This work was carried out to establish a first database for feeds commonly used in Italy, providing nutritionists and producers an accurate and current feed composition, also indicating methods and apparatus for analytical procedures potentially available for routine analysis. A total of 909 samples of hays, silages and raw materials (protein feeds, cereals and by-products) were analyzed through 1999 and 2002; analysis included protein solubility and degradability, protein fractions, structural carbohydrate fractions and the calculation of neutral detergent structural carbohydrates. When possible, average data were compared with those included in the feed bank of CNCPS ver. 3 and with those obtained by another Italian laboratory. The main differences were observed in chemical composition of forages and silages, whose composition largely depends on environmental conditions and physiological stage; protein feeds, cereals and by-products showed some differences in crude protein, soluble protein and protein fractions even in feeds of national origin.
The intent to modify the feed bank values of CNCPS for establishing an Italian data base of feeds will require a collaborative study of many laboratories not only for forages, hays and silages samples - whose composition is greatly dependent on environmental factors and agronomic techniques - but also for protein fractions, whose values are largely influenced by even small changes in analytical techniques.

Key words: CNCPS, Feed bank, Italian feed analysis, Analytical methods

RIASSUNTO

REALIZZAZIONE DI UNA BANCA DATI DI ALIMENTI ITALIANI PER IL CORNELL NET CARBOHYDRATE AND PROTEIN SYSTEM

L'utilizzazione in campo del Cornell Net Carbohydrate and Protein System (CNCPS) a livello nazionale è tuttora limitata per la difficoltà di reperire i valori analitici degli alimenti prodotti negli allevamenti o reperibili sul mercato italiano. Ciò è da imputare sia a una modesta presenza di laboratori in grado di svolgere le analisi richieste dal modello, sia alla scar-

sa corrispondenza tra le determinazioni analitiche presenti nell'archivio alimenti del CNCPS – basate su campioni prevalentemente americani - e quelle degli alimenti aziendali o comunque provenienti dal nostro Paese. Esistono poi differenze metodologiche tra laboratori nazionali che non consentono di avere risultati facilmente riproducibili e ripetibili.
Partendo da queste considerazioni, il lavoro effettuato ha avuto come finalità la realizzazione di un primo database di alimenti comunemente utilizzati negli allevamenti di bovine da latte italiani in generale, e piemontesi in particolare, fornendo ai nutrizionisti e ai tecnici del settore valori analitici aggiornati o poco noti da noi nonché indicazioni sulle metodiche e le apparecchiature da utilizzare.
Tra il 1999 e il 2002 sono stati prelevati e analizzati 909 campioni di fieni, insilati e altre materie prime (alimenti proteici, cereali e sottoprodotti). Le determinazioni hanno riguardato oltre all'analisi centesimale, anche la solubilità e la degradabilità delle proteine e le relative frazioni proteiche, i carboidrati non strutturali corretti (carboidrati solubili in detergente neutro) e le frazioni fibrose. Quando possibile, sono stati comparati i risultati analitici medi con quelli presenti nella banca dati del CNCPS versione 3 e con quelli provenienti da un altro laboratorio italiano.
Le maggiori differenze si sono osservate nei campioni di fieni e insilati; ciò anche in relazione al fatto che le due banche dati consultate suddividono tali alimenti in tipologie che non sono molto diffuse in Italia (ad esempio, percentuale di granella nell'insilato di mais o lo stadio vegetativo nelle specie foraggere).
Dal confronto delle analisi relative agli alimenti proteici, ai cereali e ai sottoprodotti sono emerse differenze per la percentuale di proteina grezza, di proteina solubile e per le singole frazioni proteiche di alcune tipologie di campioni, anche quando questi erano di origine nazionale.
Tali differenze hanno evidenziato la necessità di una maggiore standardizzazione delle procedure analitiche; la realizzazione di un database di alimenti italiano è il primo obiettivo per poter utilizzare più diffusamente in campo e con maggiore efficacia il CNCPS. Per fare ciò è necessario intraprendere un impegno collaborativo tra diversi laboratori per la determinazione dei principi nutritivi dei foraggi, dei fieni e degli insilati - categorie di alimenti i cui valori nutritivi dipendono maggiormente da fattori ambientali e gestionali a livello di singola azienda – nonché delle frazioni proteiche, che più di altri parametri risentono di variazioni anche lievi nelle metodologie analitiche.

Parole chiave: *CNCPS, Banca dati, Analisi alimenti italiani, Metodi analitici*

Introduction

Interest in the Cornell Net Carbohydrate and Protein System (CNCPS) for rationing dairy cows has greatly increased in Italy since its first publication (Russell *et al.*, 1992; Sniffen *et al.*, 1992; Fox *et al.*, 1992; O'Connor *et al.*, 1992). The feedbank of the model has been continuously improved (Fox *et al.*, 2000) but the data still mainly refer to North American samples and they may not be representative of those in Italy. Mansbridge *et al.* (1998) referred to a similar situation for the United Kingdom, especially for grass silage, corn silage and brewers grains samples. A contribution to the establishment of a database of Italian feedstuff for the CNCPS has been proposed by Licitra *et al.* (1993a, 1993b), who determined the protein fractions and the discount of nutritive value and composition of ruminant feeds collected in Italy.

Data from commercial analysis of feedstuffs may be used by nutritionists as inputs for the CNCPS feedbank. However, they are often incomplete (no information is generally available for carbohydrates and protein fractions) or they do not specify the method used for analysis; consequently, the values are not always comparable.

The aim of this research was to provide a data set of forages, silages and raw materials values for an Italian CNCPS feedbank and to suggest, among available methods, the more repeatable, low cost and applicable to commercial laboratories.

Average chemical characteristics of analyzed feeds were compared with the CNCPS ver. 3 feedbank (Fox *et al.*, 1993) and with the results obtained by Licitra *et al.* (1993a, 1993b) to evaluate the main differences between analytical values.

Material and methods

A total of 909 samples were collected on 17 farms of the Piedmontese Po plain (NW Italy) from October 1999 to November 2002. These included: 323 silages, 59 hays, 445 protein feeds and 82 cereals and by-products (Table 1). Adopting an approach commonly used in most Italian cattle farms, samples of mixed grass hays, grass silages, and alfalfa hays were subdivided by number of cut without specific reference to the vegetative stage

Table 1. Type and number of samples.

Silages	n.	Hays	n.	Protein feeds	n.	Cereals + by-pr.	n.
Corn	172	Mixed 1st cut	17	ADM	12	Corn grain	15
Corn grain	61	Mixed 2nd cut	14	CGF	39	Barley	5
Grass 5th cut	6	Mixed 3rd cut	6	CPG	81	Wheat bran	52
Ital. ryegrass	70	Mixed 4th cut	5	SSM	84	Wheat middlings	10
Alfalfa	14	Ital. ryegrass	7	CSM	98		
		Alfalfa 2nd cut	5	WRS	21		
		Alfalfa 3rd cut	5	ESM	19		
				SM44	126		
				SM49	5		

ADM: Alfalfa dehydrated meal; CGF: corn gluten feed; CPG: whole corn pressed germ; SSM: sunflower seed meal; CSM: canola seed meal; WRS: whole roasted soybean meal; ESM: extruded soybean meal; SM44: soybean meal 44% CP; SM49: soybean meal 49% CP.

of plants. All corn silages were at dough stage without additives. Corn grain and barley were produced by local farmers, while protein feeds, other cereals and by-products samples had different origins. Soybean seed meal with certified high protein content (49% CP) was analyzed separately. Feeds with less than 5 samples of different origin were not considered in this study.

Samples were sent to the laboratory of the *Dipartimento di Scienze Zootecniche* (Department of Animal Sciences) of Turin for analysis. Silages were previously dried in a ventilated oven for 18 hours at 38°C; all samples were grinded at 2 mm with a Buehler-MLI 204 (non-forage samples) or a Retsch mill (forage samples).

Dry matter (DM), ash, ether extract (EE) and crude protein (CP), NDF, ADF and ADL were measured according to the methods of AOAC (2000).

For NDF, ADF, ADL, soluble protein (SolP), degradable protein (DegP) and protein fractions (A, B1, B, B3 and C) the apparatus and/or analytical methods applicable to commercial laboratories are listed.

NDF

When analyzed without using a heat-stable α-amylase, NDF values can be elevated by residual starch; this offers one explanation for the high values reported for corn hominy feed in the NRC (1989) and in some analytical reports. Presence of starch in NDF is problematic because the carbohydrates involved have very different fermentation and digestion characteristics. Thus the use of heat-stable α-amylase in NDF analysis is recommended for all feeds, included forages and non-grain feeds.

For grain and grain containing feeds we suggest to heat the sample for 5 min to 85 °C with 30 ml of 8M urea plus 0.05 of heat stable amylase (Sigma A-3306) for removing starch; after 12 h at room temperature, the sample is diluted with 100 ml of ND solution plus 0.05 ml of amylase and handled as for forages and non-grain feeds.

For NDF analysis, as well as for ADF, we used Berzelius beakers (600 ml); condensers were made from 500 ml round-bottom flasks and used for refluxing. Heating of hotplates was calibrated so that a 100 ml of ND solution boiled within 4 min; heating is then reduced to provide a moderate particle agitation.

The filter manifold was a Tecator 1021 Cold Extractor for P3 glass crucibles with a hot-water system constructed directly above the filtering manifold.

ADF

The values of ADF can be inflated by contamination with pectin, a type of "neutral detergent-

soluble fiber" that is indigestible by mammalian enzymes, but very rapidly fermented by rumen microbes. In acid detergent, some of the pectin remains unextracted or is precipitated under the acid conditions; the retention of pectin in ADF does not appear to be quantitative, therefore a simple calculation for its correction is not possible. This retention is a particular problem in high pectin feeds, such as citrus pulp and beet pulp, where analytical values of ADF can be higher than NDF values. The method that achieves a more accurate value for ADF in pectin-containing feeds is sequential analysis for NDF and then ADF performed on the same sample. Sequential analysis - labor intensive and not commercially available - has not been applied in this study.

In our ADF analysis, we used the same apparatus for NDF.

ADL

The "permanganate lignin" method was not used in this study, because samples must be dried and ground to pass through a mesh screen of less than 1 mm. But heat-drying of wet forages or silages at temperature above 50°C shows analytically significant increases in the yield of lignin and fiber, and large particles are poorly penetrated by the reagents and yield low values.

We used the "sulphuric acid" method of AOAC.

NDSC (Neutral Detergent Soluble Carbohydrates)

The carbohydrates soluble in neutral detergent (NDSC) are the most digestible portion of the plant (98%) and are rapidly fermented (Van Soest, 1967). They are a compositionally diverse group and include organic acids, sugars, starches and fructans from the cell content, and pectins and β–glucans from the cell wall. The complexity of NDSC precludes their direct measurement by chemical analysis.

In this study the NDSC is calculated by the following equation:

100 - (Crude Protein + (NDF - NDIP) + Ether Extract + Ash)

where: NDIP is the protein fraction bounded to NDF.

This equation avoids subtracting the protein twice.

All of the errors from the component analyze accumulate in NDSC and the source of crude protein within a feed is the main source of error in the NDSC calculation. The effect of a miscalculation is of special concern with feeds high in non-protein nitrogen. Due to such mathematical artifact, NDSC estimates are prone to error.

Degradable protein

Feedstuffs contain a variety of protein fractions, each having various rates of degradation and thus differently affected by pH. For example, soybean meal protein digestion responds to pH in a quadratic manner with degradation, being highest at pH 6 - 6.5 and lower at pH 5.5 and pH 7. Wohlt *et al.* increased degradability of soybean meal from 27 to 57% raising the buffer pH from 5.5 to 7.5. For this reason, it is most accurate to use a stable buffer with a pH similar to that of the rumen (6.7) for degradability analysis. Moreover, in the rumen there are many factors (initial lag time for solubilization, variations in microbial population, supply of enzymes, etc.) that create a complex combination of multiple order reactions which break down feed proteins (Van Soest, 1994). A constant enzyme/protein substrate ratio must be specified in any commercial laboratory procedure; we used a commercial enzyme solution which contains both exo and endopeptidase activity at 330 x 10^{-3} units/ml concentration, or the *"Streptomyces griseus"* method, a modification of a procedure proposed by Pichard and Van Soest (1977) for estimation of N in residue (undegradable protein). In detail: weigh a sample containing approximately 15 mg of N into a 125 ml Erlenmeyer flask; add 40 ml of borate-phosphate buffer pH 6,7; keep in waterbath at 39°C for 1 hour; add 10 ml protease solution and remove after 18 hours; filter through a 541 Whatman filter paper using several washes of water; estimate N in residue by Kjeldhal.

Soluble protein (Fraction A + B1)

Soluble protein includes non-protein nitrogen and true soluble protein (Fraction A + B1); in this study it has been determined using the method of Krishnamoorthy *et al.* (1982) as described by Licitra *et al.* (1996), but modified for incubation temperature and time. In detail: a 0.5 g of dry feed

sample is weighed into a 125 ml Erlenmeyer flask; after adding 50 ml of borate-phosphate buffer pH 6.7 (12.2 g/l NaH_2PO_4 x H_20 + 8.91 g/l Na_2B_4O7 x $10H_2O$), the flask is stoppered and placed in a water bath at 39°C for one hour. No sodium azide solution is used to control microbial growth. The sample is filtered through a 541 Whatman filter paper using several washes of buffer and the residue plus paper transferred into a Kjeldhal tube for estimation of N in residue (insoluble true protein).

Non-protein nitrogen (Fraction A)

The nitrogen passing into the filtrate after precipitation with a specific reagent is non-protein nitrogen (NPN) (Fraction A). In this work we used tungstic acid as precipitating agent, which cuts off at a peptide size of about 3 amino acids, following the procedure described by Licitra *et al.* (1996).

True soluble protein (Fraction B1)

True soluble protein (TSP : Fraction B1) was calculated with the following equation:

Fraction B1 = Psol - NPN

Neutral detergent soluble protein (Fraction B2)

Neutral detergent soluble protein (NDSP: Fraction B2) is the difference between insoluble protein and protein insoluble in neutral detergent

It was calculated with the following equation:

Fraction B2 = 100 – Fractions (A + B1 + B3 + C).

Neutral detergent insoluble protein (Fraction B3)

All samples were analyzed for NDIP to determine Fraction B3 and to estimate NDSC (Neutral Detergent Soluble Carbohydrates).

Cell wall bound proteins include indigestible (ADIP: Fraction C) and digestible protein (NDIP: Fraction B3). We determined NDIP by filtering NDF on paper followed by Kjeldhal (Krishnamoorthy *et al.*, 1982) without sodium sulfite and urea-amylase (Licitra *et al.*, 1996).

Acid detergent insoluble protein (Fraction C)

Protein fractions that have low biological availability, such as nitrogen associated with lignin or Maillard reaction products, are recovered in acid-detergent fibre (Fraction C); the boiled samples were filtered through Whatman 54 filter paper using mild vacuum suction and the residue washed with hot water. Residue and paper were transferred into a Kjeldhal flask for protein determination (ADIP).

Results and discussion

Analytical results are shown in tables 2 to 5; data were compared with the values of the CNCPS ver. 3 feedbank and those determined by Licitra *et al.* (1993a, 1993b)

Table 2 shows the chemical composition of silages.

The CNCPS feed bank includes 2 types of corn high moisture grain with different NDF; our samples

Table 2. Chemical composition of silages.

		Corn HM grain	Corn	Grass 5th cut	Ryegrass	Alfalfa
n.		61	172	6	70	14
DM	%	59.5±5.5	34.4±4.6	20.0±5.3	27.1±4.3	48.2±7.4
Ash	%DM	1.8±0.3	4.4±0.6	12.0±6.8	14.1±3.7	14.6±3.9
NDF	"	21.1±4.9	42.4±5.0	40.9±0.2	55.2±7.1	43.1±4.4
ADF	"	9.6±0.4	25.5±3.4	28.7±4.1	37.3±4.8	39.0±2.7
ADL	"	1.3±0.1	2.6±0.7	12.8±0.1	3.7±1.3	7.0±0.7
Fat	"	3.7±0.5	3.3±0.4	5.0±2.3	3.4±0.8	2.5±0.3
NDSC	"	65.3±1.5	42.6±2.2	29.7±3.8	15.9±3.8	22.5±2.3
CP	"	8.9±0.7	8.4±3.2	15.6±6.8	13.4±4.0	19.9±2.6
DegP	%CP	50.4±9.4	65.4±2.6	63.2±1.9	70.5±1.3	66.4±1.2
SolP	"	43.9±7.7	53.6±8.2	55.2±8.8	58.7±8.4	59.5±7.3
NDFN	%DM	0.9±0.2	1.0±0.2	3.1±1.0	2.1±0.5	2.5±0.5
ADFN	"	0.4±0.1	0.7±0.1	1.1±0.4	1.2±0.2	1.7±0.1
A	%CP	27.5±3.9	37.3±1.8	41.7±3.2	50.1±1.0	50.8±5.1
B1	"	16.4±3.8	16.3±3.7	13.5±2.7	8.6±0.9	8.7±2.7
B2	"	46.7±5.4	35.1±4.1	26.6±0.2	26.1±0.5	27.6±1.1
B3	"	5.0±2.3	2.1±0.9	10.9±5.7	6.4±1.7	3.6±2.0
C	"	4.4±0.1	9.2±0.5	7.3±1.9	8.8±1.5	9.3±0.7

HM: high moisture.

showed lower DM (59.5 vs. 72.0) and higher NDF (21.1 vs. 9.0 or 10.5) compared with the samples of the model; CP and protein solubility were similar.

In the model, corn silages are subdivided into 5 categories based on the percentage of grain (25%, 35%, 40%, 45% and 50%), while in our study we did not consider the different types of corn silage. The average DM, NDF and CP values resulted similar to the CNCPS corn silage with 45% grain. However, for SolP our data are closer to the CNCPS corn silage with 35% or 40% grain. The NDSC value is poorly comparable to the NSC (Non Structural Carbohydrates) of the CNCPS, which consider starch as equal to 100% of it.

The average soluble protein of corn silage samples analyzed by Licitra did not differ from our data, except for A and B3 fractions, which resulted higher (49.1 vs. 37.3 and 8.5 vs. 2.1 respectively) probably for the higher DM, NDF and ADF content.

No comparison has been done for grass silages and Italian ryegrass silage, as they are not included in the CNCPS feedbank and were not analyzed by Licitra.

For alfalfa silage, our samples were not subdivided into categories as in the CNCPS (early, medium and full bloom), but NDF, ADF and ADL show that they were probably collected in early or medium bloom. Crude protein is closed to the early bloom alfalfa silage of CNCPS (19.9% vs. 19.0%), but Psol is higher (59.5 vs. 50).

Regarding hays (Table 3), the CNCPS subdivides grasses and legumes hays into categories based on their vegetative stage. This approach, also used by Licitra, is certainly correct, but it was not applicable on the farms where we collected samples. In our study we grouped the samples into categories based on the number of cutting when clearly specified; due to this different approach, it is not possible to compare the data, which show substantial differences for most of the parameters. Moreover, chemical composition of hays is extremely variable, depending on cultivar, environmental conditions, soil composition, vegetative stage and number of cutting..

The amount and type of protein in protein feeds are of main interest in animal nutrition.

The composition of protein feeds is shown in Table 4; whole corn pressed germ (CPG) and

Table 3. Chemical composition of hays.

		Mixed 1st cut	Mixed 2nd cut	Mixed 3rd cut	Mixed 4th cut	Italian ryegrass	Alfalfa 2nd cut	Alfalfa 3rd cut
n.		17	14	6	5	7	5	5
DM	%	88.3±0.9	87.1±1.2	87.3±2.0	86.7±0.1	88.5±0.5	88.2±0.7	88.0±2.5
Ash	%DM	11.1±3.8	10.8±2.5	12.0±1.4	12.6±1.4	10.6±1.6	9.4±1.3	8.3±2.2
NDF	"	65.5±2.8	59.5±3.7	48.4±10.0	58.5±5.5	63.6±7.5	50.6±5.4	53.5±5.7
ADF	"	40.4±2.4	36.3±2.3	34.1±3.3	39.0±3.5	39.3±5.7	38.0±3.1	39.4±2.4
ADL	"	3.9±0.8	4.9±1.0	4.0±0.8	4.1±0.1	4.1±0.8	7.8±0.9	8.4±0.3
Fat	"	2.0±0.9	2.4±0.3	2.9±0.4	2.0±0.4	1.3±0.2	1.6±0.2	1.6±0.2
NDSC	"	15.4±2.0	20.6±1.9	27.8±2.9	19.6±1.7	17.6±2.9	24.3±2.2	23.5±2.5
CP	"	9.2±1.6	10.7±1.8	14.3±1.2	11.3±0.4	8.9±2.6	16.9±1.9	17.5±2.5
DegP	%CP	56.1±3.0	53.9±3.1	57.3±2.4	57.3±7.5	69.3±1.4	66.0±1.9	61.6±1.8
SolP	"	26.7±6.3	20.8±2.1	25.1±2.8	29.2±7.5	37.2±0.5	33.3±0.3	32.5±2.6
NDFN	%DM	3.2±1.1	4.0±0.6	5.3±1.6	4.0±0.8	2.0±0.1	2.8±0.1	4.4±0.5
ADFN	"	1.2±0.1	1.5±0.1	1.5±0.1	1.5±0.1	1.3±0.1	1.9±0.1	1.9±0.1
A	%CP	12.1±6.1	6.0±1.5	16.1±0.9	16.7±9.3	25.8±1.1	21.2±1.5	24.1±4.1
B1	"	14.6±0.2	14.8±0.8	9.0±0.9	12.5±1.8	11.4±1.0	12.1±1.8	8.4±1.5
B2	"	47.1±2.9	36.7±5.1	37.8±12.7	35.3±1.0	36.8±1.0	49.2±0.8	42.1±3.4
B3	"	20.1±6.4	25.5±3.5	26.3±9.4	22.0±6.7	8.1±1.6	6.0±1.3	14.4±0.5
C	"	6.1±3.1	17.0±0.9	10.8±0.4	13.5±1.8	17.9±2.7	11.5±0.7	11.0±1.3

extruded soybean meal (ESM) are not included in the CNCPS ver. 3 feedbank and for these feeds no comparison was made, as well as for alfalfa dehydrated meal (ADM), whose composition is highly variable in relation with the variety, the vegetation stage and the drying process.

Canola seed meal (CSM), whole corn pressed germ (CPG), whole roasted soybean (WRS), and soybean 49% CP (SM49) were not analyzed by Licitra, and therefore not compared with our data.

Among feedstuffs, protein feed composition is commonly considered as less variable than silages or hays, however our analysis showed some significant differences among laboratories.

Compared with CNCPS, lower values of CP were observed for CGF (25.6 vs. 22.6), CSM (40.9 vs. 38.3) and WRS (42.8 vs. 38.8), and higher values for SSM (25.9 vs. 32.0). No differences were observed for CP of SM44 and SM49.

Compared with Licitra, different values of CP were observed for CGF (25.5 vs. 22.6) and ESM (41.6 vs. 44.9).

Analytical data of soluble protein were in general agreement with the CNCPS feedbank except for SSM (38.7 vs. 30.0) and CSM (27.1 vs. 32.4). More differences were observed between the data reported by Licitra and ours of CGF (28.4 vs. 43.7), SSM (20.8 vs. 38.7) and ESM (10.4 vs. 17.2). The fractioning of Psol into A and B1 fractions showed more substantial differences; for example, the A and B1 fractions of CGF were respectively 7.3 vs. 26.2 and 21.1 vs. 17.5 in the samples of Licitra and ours; for SSM: 12.4 vs. 17.8 and 8.3 vs. 20.9; for ESM: 9.0 vs. 7.4 and 1.3 vs. 9.8.

The other fractions were in many cases significantly different among data sets. For the following feeds, average values of fraction B3 were higher in our samples than in CNCPS: CGF (29.6 vs. 8.0), CSM (14.6 vs. 10.6), SM44 (10.1 vs. 5.0); on the contrary, for SSM, WRS and SM49 we found lower values. For ESM we did not analyze and calculated the B3 and B2 fractions due to the loss of the samples.

Comparing the data reported by Licitra, we

Table 4. Chemical composition of protein feeds.

		ADM	CGF	CPG	SSM	CSM	WRS	ESM	SM44	SM49
n.		12	39	81	84	98	21	19	126	5
DM	%	88.9±1.3	87.6±1.4	86.7±0.7	88.7±1.1	88.8±1.4	90.1±1.9	87.4±2.0	87.0±0.7	87.9±0.9
Ash	%DM	11.1±1.8	6.8±0.7	2.5±0.5	7.1±0.4	8.0±0.8	5.7±0.2	7.7±1.3	7.4±0.6	7.0±0.5
NDF	"	48.9±7.3	46.5±3.8	57.0±6.2	46.6±4.7	34.6±3.5	24.6±3.7	20.8±6.2	17.1±3.4	10.5±1.1
ADF	"	33.8±5.9	13.1±0.7	19.5±4.3	35.4±2.6	22.3±0.7	21.1±3.3	10.0±2.2	8.8±2.1	6.0±2.5
ADL	"	7.0±1.6	1.7±0.5	8.6±5.0	11.1±0.5	8.1±0.5	3.1±0.8	1.9±0.5	1.1±0.8	0.5±0.2
Fat	"	2.0±0.5	3.2±0.5	13.7±3.4	1.9±1.0	1.4±0.6	19.6±2.4	16.6±1.6	1.2±0.3	1.2±0.4
NDSC	"	24.2±3.0	28.8±1.2	9.6±2.5	16.7±1.9	24.4±1.2	16.8±1.4	13.2±3.3	29.7±1.0	31.6±6.4
CP	"	19.0±3.2	22.6±1.6	26.4±2.5	32.0±2.6	38.3±1.6	38.8±1.5	44.9±5.4	49.3±1.7	54.0±1.4
DegP	%CP	46.6±6.7	55.1±6.2	31.5±6.2	77.3±5.1	52.8±9.9	44.9±5.9	47.2±13.4	63.1±7.5	61.2±8.7
SolP	"	29.9±1.7	43.7±4.9	17.1±3.8	38.7±4.8	27.1±7.1	13.2±3.6	17.2±5.8	15.5±5.2	21.9±8.6
NDFN	%DM	5.3±0.5	7.9±1.7	9.4±2.7	4.1±1.2	6.7±1.6	5.5±2.3	3.3±1.1	4.7±1.9	3.8±0.9
ADFN	"	2.1±0.3	1.0±0.5	1.4±0.4	1.8±0.1	2.6±0.6	4.0±1.1	2.0±0.9	1.3±0.5	3.1±0.8
A	%CP	17.3±3.4	26.2±6.6	11.9±3.0	17.8±1.9	16.8±2.6	6.9±2.2	7.4±3.1	6.7±1.1	15.5±3.6
B1	"	12.6±5.0	17.5±2.2	5.2±1.3	20.9±4.8	10.3±1.0	6.3±1.5	9.8±2.4	8.8±3.0	6.4±2.0
B2	"	38.5±8.3	21.7±2.8	42.4±4.6	48.3±6.8	52.0±2.0	67.1±5.5	nd	71.2±3.5	73.1±5.7
B3	"	20.3±4.5	29.6±4.5	35.0±4.4	6.5±0.3	14.6±2.3	12.3±3.0	nd	10.1±3.5	3.0±0.7
C	"	11.3±2.0	5.0±2.3	5.5±1.0	6.5±0.2	6.3±0.4	7.4±0.9	4.0±1.2	3.2±0.8	2.0±0.4

ADM: Alfalfa dehydrated meal; CGF: corn gluten feed; CPG: whole corn pressed germ; SSM: sunflower seed meal; CSM: canola seed meal; WRS: whole roasted soybean meal; ESM: extruded soybean meal; SM44: soybean meal 44% CP; SM49: soybean meal 49% CP; nd: not determined.

found significant differences for B3 of CGF (29.6 vs. 5.4), SS44 (10.1 vs. 2.7) and SSM (6.5 vs. 13.4).

Fraction C was the less variable among protein fractions, however some differences were observed for CGF, SSM and SM44 of CNCPS samples, and for CGF, SSM and ESM samples analyzed by Licitra.

Due to the different values of Psol, B3 and C fractions, some types of feeds have shown substantial differences in the B2 percentage, the highest being observed for CGF analyzed by Licitra (56.1) and our (21.7).

The other analytical parameters of protein feeds were in general agreement among data sets, even if some differences were observed for NDF, which resulted slightly higher in our samples than others (with the exception of CSM of CNCPS). Only the CGF samples analyzed by Licitra showed significantly high values of NDF and ADF - even compared with the CNCPS data - which could partially explain the high percentage of B3 and C protein fractions.

For cereals and by-products (Table 5), the results of our analysis were generally in agreement with CNCPS; some differences were observed for soluble protein and NDF of corn grain (17.0 vs. 11.0 and 17.5 vs. 9.0 respectively for our data and CNCPS), and for ash and NDF of wheat middlings (6.3 vs. 2.4 and 40.8 vs. 35.0).

Licitra analyzed barley samples which resulted significantly lower than ours in Psol (13.4 vs. 21.1), B1 (4.1 vs. 18.9) and B3 (14.9 vs. 56.1), and higher in B2 (66.0 vs. 19.0). Also wheat bran differed for CP and most of the protein fractions, while corn grain samples were in better agreement.

Table 5. Chemical composition of cereals and by-products.

		Barley	Wheat bran	Corn grain	Wheat middl.
n.		5	52	15	10
DM	%	88.5±1.2	86.7±0.9	87.4±1.7	87.3±1.8
Ash	%DM	2.9±0.2	5.2±0.7	1.5±0.4	6.3±1.9
NDF	"	32.4±4.3	42.1±4.2	17.5±3.1	40.8±4.0
ADF	"	5.4±1.0	12.9±1.4	4.5±1.0	11.5±1.2
ADL	"	0.8±0.2	3.0±0.4	0.2±0.1	3.1±0.1
Fat	"	1.6±0.2	3.8±0.6	4.0±0.7	3.3±1.2
NDSC	"	58.6±1.0	36.6±1.3	69.6±1.1	36.9±1.7
CP	"	11.0±0.3	17.9±1.1	9.9±0.8	17.9±1.0
DegP	%CP	37.4±0.3	54.5±6.1	22.7±2.4	60.5±1.9
SolP	"	21.1±6.0	41.4±3.3	17.0±2.3	41.4±4.4
NDFN	%DM	6.6±1.0	5.5±1.5	2.6±0.7	5.2±1.5
ADFN	"	0.4±0.1	0.7±0.1	0.7±0.3	0.7±0.1
A	%CP	2.2±1.7	16.7±3.1	12.5±5.1	21.9±4.5
B1	"	18.9±8.2	24.7±4.7	4.5±2.5	19.5±8.2
B2	"	19.0±7.1	28.6±3.3	51.9±1.8	27.4±12.4
B3	"	56.1±11.0	26.2±6.1	24.5±3.9	27.3±8.3
C	"	3.8±0.1	3.8±0.5	6.6±3.2	3.9±0.4

Conclusions

As expected, the study indicates that the establishment of a database of Italian feeds for CNCPS can only be partially based on the original feedbank of the model. Comparing our data with those of Licitra *et al.* (1993a, 1993b) we found a poor reproducibility of some parameters (particularly protein and carbohydrate fractions) in similar and apparently homogeneous feeds, such as protein feeds and cereals. As underlined by Bovera *et al.* (2003), the reason for these differences is probably due to the use of non-homogenous apparatus and/or procedures between laboratories. On the contrary, the good level of standardization of procedures within our laboratory has allowed a good repeatability of most of the analyzed parameters.

Regarding forages, in the CNCPS feedbank the single species are analyzed at a different vegetative stage, and there are no data on permanent meadows, mountain pastures or mixed hays. For the first two categories, the chemical composition could be predicted knowing the prevalent species, their frequency and their vegetative stage in a certain period for a determined area, but many common species of Italian permanent meadows or pastures are not included into the CNCPS feedbank.

For hays, additional information needed by Italian nutritionists is the chemical composition of single or mixed species according to the number of cut.

Confirming the conclusions of Bovera *et al.* (2003), our data showed that the characteristics of protein feeds, cereals and by-products bought on the Italian market can be significantly different

not only from those included in the original CNCPS feedbank, but also from similar products of the national market analyzed by other Italian laboratories at different times. Because the precision of the CNCPS in predicting animal responses to variations of feed composition requires information on feed carbohydrate and protein fraction composition, for an easy use of the model in Italy there is the need of an accurate feedbank based on samples collected locally and analyzed with more standardized procedures.

The establishment of an Italian database should therefore be realized through a collaborative study among laboratories located in different parts of Italy. While our samples are already available for such study, the results of the analysis will be soon available online upon request.

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REFERENCES

A.O.A.C., 2000. Official methods of analysis. 17th Ed. AOAC International, suite 500, 481 North Frederick Av., Gaithersburg, MA 20877-2417 USA.

BOVERA, F., SPANGHERO, M., GALASSI, G., MASOERO, F., BOCCIONI, A., 2003. Repeatability and reproducibility of the Cornell Net Carbohydrate and Protein System analytical determinations. Ital. J. Anim. Sci. 2: 41-50.

FOX, D.G., BARRY, M.C., TYULUTKI, T.P., O'CONNOR, J.D., SNIFFEN, C.J., CHALUPA, W., 1993. A manual for using the Cornell Net Carbohydrate and Protein System for evaluating cattle diets. Revised for CNCPS Release 2. Cornell Cooperative Extension, Anim. Sci. Dept., Ithaca, NY, USA.

FOX, D.G, SNIFFEN, C.J., O'CONNOR, J.D., RUSSELL, J.B., VAN SOEST, P.J., 1992. A Net Carbohydrate and Protein System for evaluating cattle diets: III. Cattle requirements and diet adequacy. J. Anim. Sci. 70: 3578-3596.

FOX, D.G., TYLUTKI, T. P., PELL, A.N., VAN AMBURGH, M.E., CHASE, L.E., PITT, R.E., RASMUSSEN, C.N., TEDESCHI, L.O., DURBAL, W.M., 2000. The Net Carbohydrate and Protein System for evaluating herd nutrition and nutrient excretion: model documentation. Animal Science Department, Mimeo 213, Cornell University, Ithaca, NY, USA.

KRISHNAMOORTHY, U., MUSCATO, T.V., SNIFFEN, C.J., VAN SOEST, P.J., 1982. Nitrogen fractions in selected feedstuffs. J. Dairy Sci. 65: 217-255.

LICITRA, G., CAMPO, P., CARPINO, S., LANZA, M., VAN SOEST, P. J., 1993a. Adeguamento del valore energetico degli alimenti al variare del livello nutritivo nelle vacche da latte. pp 119-124 in Proc. 10th Nat. Congr. A.S.P.A., Bologna, Italy.

LICITRA, G., CARPINO, S., CAMPO, P., BIONDI, L., FOX, D.G., 1993b. Frazioni azotate e fattori di riduzione della degradabilità ruminale al variare del livello nutritivo nelle vacche da latte. pp 111-117 in Proc. 10th Nat. Congr. A.S.P.A., Bologna, Italy.

LICITA, G., HERNANDEZ, T. M., VAN SOEST, P. J., 1996. Standardization of procedures for nitrogen fractionation of ruminant feeds. Anim. Feed Sci. Tec. 57: 347-358.

MANSBRIDGE, R.J., BLAKE, J.S., MOSS, A.R., BENDING, I., 1998. The establishment of a UK database for the Cornell Net Carbohydrate and Protein System. Page 116 in Proc. B.S.A.S. (Br. Soc. Anim. Sci.), Penicuik, UK.

NATIONAL RESEARCH COUNCIL, 1989. Nutrient requirements of dairy cattle. 6th revised ed. National Academy Press, Washington, DC, USA.

O'CONNOR, J.D., SNIFFEN, C.J., FOX, D.G., CHALUPA, W., 1993. A Net Carbohydrate and Protein System for evaluating cattle diets: IV. Predicting amino acid adequacy. J. Anim. Sci. 71: 1298-1311.

PICHARD, G., VAN SOEST, P. J., 1987. Protein solubility of ruminant feeds. pp 91-98 in Proc. Cornell Nutr. Conf. for Feed Manufacturers. Cornell University, Ithaca, NY, USA.

RUSSELL, J.B., O'CONNOR, J.D., FOX, D.G., VAN SOEST, P.J., SNIFFEN, C.J., 1992. A Net Carbohydrate and Protein System for evaluating cattle diets: I. Ruminal fermentation. J. Anim. Sci. 70: 3551-3561.

SNIFFEN, C.J, O'CONNOR, J.D., VAN SOEST, P.J., FOX, D.G., RUSSELL, J.B., 1992. A Net Carbohydrate and Protein System for evaluating cattle diets: II. Carbohydrate and protein availability. J. Anim. Sci. 70: 3562-3577.

VAN SOEST, P.J., 1967. Development of a comprehensive system of feed analysis and its application to forages. J. Anim. Sci. 26: 119-124.

VAN SOEST, P. J., 1994. Nutritional ecology of the ruminant. Cornell Univ. Press, 2nd Ed., Ithaca, NY, USA.

WOHLT, J.E., SNIFFEN, C.J., HOOVER, W.H., 1973. Measurement of protein solubility in common feedstuffs. J. Dairy Sci. 56: 1052-1057.