Evaluation of Diet for Buffalo Dairy Cows Using the Cornell Net Carbohydrate and Protein System

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ABSTRACT : The aim of this paper was to use the Cornell Net Carbohydrate and Protein System (CNCPS), that reports diet energy and protein value and animal requirements, as net energy for lactation (NE_l) and metabolizable protein (MP) respectively, to evaluate some rations for lactating Italian Mediterranean buffaloes. The investigation was carried out on six farms in the province of Caserta (southern Italy), where the milk production was controlled four times monthly on 10 animals (changing every time) chosen at different lactation days (5 categories): <2 months (A), 2-4 months (B), 4-6 months (C), 6-8 months (D), >8 months (E). Milk fat and protein were determined. Diet NE_l and MP were estimated with the CPM-Dairy program (1998) using diet component chemical characteristics; then energy and protein intakes were estimated. NE_l and MP requirements were estimated with two methods: 1) using CPM-Dairy that considers produced milk, fat and protein content, lactation phase and body condition score as main factors; 2) by applying the theory that to produce 1 kg of energy corrected milk, the buffalo needs 3.56 MJ of NE_l and the efficiency to convert the absorbed aminoacids into milk protein is lower than cow (CNCPS). As regards energy, with method 1 the requirements were satisfactory starting from category A (4 out of 6 farms) and category B (5/6 farms); however, a surplus resulted for category E (5/6 farms). With method 2 a deficit in category A (5/6 farms) and B (3/6 farms) was observed, while the energy requirements were satisfied for all categories except E, where on only one buffalo farm had a surplus of energy intake. As regards protein, with method 1 the requirements were substantially satisfied for all the categories except E (3/6 farms); with method 2 the MP trend was much less favourable than with method 1. Indeed, a protein deficit was observed for all animals in categories A and B (5/6 farms). Moreover, on one farm the protein intake never satisfied animal requirements. In our experimental conditions, the use of the CNCPS to characterise diets for lactating buffalo and to calculate their requirements led to satisfactory results. By contrast, we cannot say the same for method 2, which applies a lower use efficiency of NE and MP for lactation in buffalo compared to cow. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 10 : 1475-1481)***

Key Words : Italian Mediterranean Buffalo, The Cornell Net Carbohydrate and Protein System, Net Energy for Lactation, Metabolizable Protein

INTRODUCTION

Milk production of the Italian Mediterranean buffalo has increased substantially in recent years. Hence in-depth knowledge of animal requirements becomes very important, in order to optimise animal rationing in the different productive phases and achieve major advances in animal welfare, farm economy, and in environmental pollution control. For a long time, and on many farms until today, buffaloes were fed using cow requirements as a reference point. Besides, lactating buffaloes very often used to remain in a single group, which proved unsound both because the animals had different milk productions in terms of days in milk, and because milk composition is very variable. The studies carried out within this field in our Department (Bovera et al., 2000, Zicarelli 2001, Bovera et al., 2002) contributed to clarify buffalo intake capacity and requirements. However, the possibility of using new evaluation systems for feeds and nutritive requirements established for the dairy cow is also worth investigating for lactating buffalo. Amongst such methods, particular importance is attached to the Cornell Net Carbohydrate and Protein System (CNCPS) proposed by some Cornell University (Ithaca, NY) researchers (Russel et al., 1992; Sniffen et al., 1992; Fox et al., 1992; O'Connor et al., 1993) to express energy and protein values for cattle diets and their corresponding requirements. The CNCPS aims to calculate animal requirements according to many variables (genetic type, physiological state, breeding environment, environmental management) and to estimate the yield of the absorbed nutrients depending on digestive and metabolic changes due to the quantity and quality of the ingested dry matter. Subsequently, it is possible to balance the diet and optimise its use in order to reduce metabolite excretion (urea and methane) responsible for increased environmental pollution. For this purpose the CNCPS: a) allows feedstuff proteins and carbohydrates to be fractionated according to their response to rumen micro-population activity; b) calculates the carbohydrates and proteins that are actually demolished in the rumen and the fractions that, on the other hand, escape the pre-stomachs almost undamaged, considering the rumen fermentation rate and the rate of passage of the feed particles in the rumen-reticulum; c) estimates the net energy and the quantity of aminoacids absorbed by the animal at the intestinal level (derived from

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Table 1. Diet characteristics on the six farms (g/kg DM)

	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
Crude protein	118	101	136	119	125	132
Crude fibre	201	182	219	203	225	208
Ether extract	33	35	37	34	31	28
Ash	87	85	79	95	90	80
CHO	762	779	748	752	754	760
NDF	463	471	496	496	497	470
ADF	266	255	302	276	307	277
ADL	39	36	36	34	39	36
NSC	327	315	282	297	288	300
Protein fractions						
A	137	119	121	107	122	120
B_1	190	196	161	190	166	180
B_2	342	379	380	373	372	374
C	93	85	86	82	94	86
Carbohydrate fractions						
A	28	27	24	17	21	19
B_1	11	5	8	10	8	14
B_2	55	54	71	62	65	70
B_3	15	6	15	17	14	13
C	9	9	18	13	17	16
NE_l (MJ/kg DM)	6.10	6.20	6.05	5.98	5.82	5.95
MP (g/kg DM)	88	77	92	89	88	91
F:C	60:40	57:43	63:37	65:35	64:36	60:40

CHO=total carbohydrates (100-CP-EE-ash); NSC=non-structural carbohydrates [100-(NDF-NDIP)-CP-EE-ash), where NDIP is neutral detergent insoluble protein. Protein A: non-protein nitrogen, immediately degraded; B_1: soluble true protein, fast degradation rate; B_2: true protein, intermediate degradation rate; B_3: true protein, slow degradation rate; C: bound true protein. Carbohydrate A: sugars, fast degradation rate; B_1: starch, intermediate degradation rate; B_2: available cell wall, slow degradation rate; C: unavailable cell wall.

microbial and food protein).

Therefore, the aim of this paper was to use the Cornell Net Carbohydrate and Protein System (CNCPS) to evaluate diets for lactating buffaloes. Moreover, it appeared interesting to evaluate what was found by some authors (Bertoni et al., 1993; Di Lella, 1998) about the lower efficiency of utilization of metabolizable energy and absorbed aminoacids by buffalo compared to cow.

MATERIAL AND METHODS

Experimental design

The investigation was carried out on six buffalo farms in the province of Caserta (southern Italy), where the animals are bred at free stabling and divided into two groups (lactation and dry). The buffalo were fed total mixed ratio (T.R.M.) consisting of silage, hays, by-products and concentrates with little variations during the year.

Milk production of ten multiparous buffalo dairy cows (with different animals chosen on each occasion) was monitored four times monthly on each farm. The cows were chosen at different lactation days and divided into five categories (two animals per category): <2 months (A), between 2 and 4 months (B), between 4 and 6 months (C), between 6 and 8 months (D), >8 months (E).

At each control a sample of individual milk, representative of daily production, was collected to determine fat and protein, using the Milko Scan 139 (Foss Electric) calibrated with an appropriate standard for buffalo milk.

Body condition scores (BCS) were assigned using a scale of 1 to 9 (Wagner et al., 1988), modified for buffalo. The latter scale was chosen due to the fact that the conformation of a buffalo differs from that of a dairy cow. A fat cow which has a BCS of 5 is fatter than a buffalo which is given the same rating. Indeed, if a cow is considered to be at its best when it has a BCS of 3.5, the same cannot be said for a buffalo with the same score since the constitution of the species is different. Indeed, the welfare of a dairy cow with a "chiefly catabolic habit" cannot be identified with that of buffalo in which selection for milk production is still in its early stages. Moreover, under the same BCS, which evaluates the roundness of the shape, a buffalo is thinner than a cow. Given the same subcutanoeus fat deposition, the former has less lipid infiltration into the muscles (Zicarelli, 2001).

Diets

All the dietary components were analysed for chemical composition according to ASPA (1980), the structural

Table 2. Average milk production and characteristics for each category on the six farms (mean±SE)

	Milk production (kg/d)	Protein (%)	Fat (%)	Corrected milk (kg/d)	ECM (kg/d)
Farm 1					
A	9.98±0.45	4.52±0.16	7.67±0.19	11.98±0.53	19.02±0.74
B	8.91±1.13	4.26±0.08	7.85±0.07	10.69±1.36	16.88±1.43
C	7.39±0.80	4.47±0.13	8.80±0.17	8.87±0.96	15.19±1.34
D	6.11±0.87	4.62±0.14	8.66±0.48	7.33±0.05	12.57±1.20
E	5.80±0.44	4.88±0.07	8.29±0.12	6.96±0.53	11.84±0.79
Farm 2					
A	9.20±0.49	4.62±0.18	7.70±0.08	11.04±0.59	17.70±0.95
B	7.88±0.79	4.56±0.11	8.32±0.33	9.46±0.95	15.77±1.27
C	6.40±0.53	4.62±0.13	8.61±0.28	7.68±0.63	13.12±0.89
D	5.50±0.56	4.61±0.13	9.05±0.25	6.60±0.68	11.60±0.94
E	5.23±0.46	4.81±0.15	9.14±0.39	6.28±0.55	11.24±0.83
Farm 3					
A	11.10±0.98	4.38±0.24	7.74±0.19	13.32±1.17	21.04±1.50
B	7.79±0.45	4.49±0.08	8.35±0.34	9.35±0.53	15.55±0.81
C	7.60±0.67	4.46±0.16	8.84±0.26	9.12±0.81	15.65±1.13
D	6.34±0.42	4.61±0.14	9.24±0.29	7.61±0.50	13.54±0.78
E	4.08±0.41	4.93±0.06	9.58±0.44	4.90±0.49	9.09±0.76
Farm 4					
A	14.21±0.74	4.30±0.16	7.31±0.08	17.05±0.88	25.93±1.31
B	10.01±0.91	4.26±0.18	7.82±0.13	12.01±1.10	18.92±1.42
C	8.91±0.76	4.46±0.17	8.10±0.21	10.69±0.91	17.43±1.24
D	6.07±0.62	4.63±0.17	9.11±0.36	7.28±0.75	12.87±1.03
E	2.55±0.24	4.74±0.07	9.66±0.07	3.06±0.29	5.64±0.71
Farm 5					
A	11.08±1.12	4.30±0.09	8.23±0.45	13.30±1.34	21.63±1.57
B	10.52±1.28	4.53±0.10	8.51±0.35	12.62±1.53	21.28±1.71
C	6.70±0.95	4.40±0.11	9.40±0.39	8.04±1.14	14.26±1.42
D	6.34±0.78	4.54±0.07	8.96±0.29	7.61±0.93	13.23±1.27
E	5.40±0.63	4.45±0.13	9.84±0.42	6.48±0.76	11.86±0.99
Farm 6					
A	10.34±0.70	4.51±0.15	8.03±0.25	12.41±0.84	20.20±1.17
B	10.00±0.25	4.60±0.07	8.14±0.39	12.00±0.30	19.82±0.41
C	7.76±0.63	4.54±0.11	8.73±0.40	9.31±0.76	15.95±1.08
D	5.65±0.63	4.64±0.11	8.96±0.26	6.78±0.76	11.87±0.97
E	3.98±0.58	4.68±0.07	8.89±0.36	4.78±0.70	8.35±0.83

Corrected milk: real milk×1.20 (lead factors); ECM: milk at 3.10 MJ/kg. Categories A: <2 months, B: between 2 and 4 months, C: between 4 and 6 months, D: between 6 and 8 months, E: >8 months.

carbohydrates were analysed according to Van Soest (1991) and the protein and carbohydrate fraction according to CNCPS (Sniffen et al., 1992, Licitra et al., 1996). Consequently, it was possible to estimate the chemical composition and the protein and glucide fractions of the diets used on each farm.

In order to estimate the net energy for lactation (NE_l) and the metabolizable protein (MP) content of the diets the CPM-Dairy program (1998) and all the diet parameters were used.

Estimation of requirements

In estimating energy and protein requirements for buffalo cows, the amounts needed for maintenance were identified with the requirements that CNCPS (CPM-Dairy, 1998) attribute to dairy cows with identical weight, BCS, lactation phase and yield level. The animal live weight was equal to 650 kg±4.1 (mean±SE). Buffalo requirements for lactation were calculated using milk production corrected for the lead factors (Stallings and McGillard, 1984) (corrected milk=real milk×1.20), in order to allow for the fact that all the lactating buffaloes were fed in only one group. To calculate production requirements we followed two methods:

Method 1 (CNCPS) : The corrected milk of each buffalo and their fat and protein content was fitted in the CPM-Dairy program, that estimates requirements on the basis that for 1 kg of standard milk (4% fat, 3.1% protein) 3.10 MJ is required and the use efficiency of metabolizable protein is equal to 65% (Fox et al., 1992).

Table 3. Net energy and metabolizable protein intake for animal categories with the two methods

Categories	A	B	C	D	E
	Net energy for lactation (% requirements)				
Method 1	94.10	97.89	102.26	107.84	116.07
Method 2	83.79	88.11	92.94	98.68	107.46
P<	0.0076	0.0119	0.0036	0.0013	NS
SEM	3.79	3.91	3.02	1.18	5.61
	Metabolizable protein (% requirements)				
Method 1	93.05	98.00	103.6	107.1	113.18
Method 2	78.88	84.64	91.48	96.22	104.66
p<	0.0008	0.0042	0.0084	0.0061	NS
SEM	3.68	4.43	4.56	3.85	8.33

Categories A: <2 months, B: between 2 and 4 months, C: between 4 and 6 months, D: between 6 and 8 months, E: >8 months. SEM: standard error of the means. NS: not significant.

Method 2 : The corrected milk was converted into buffalo energy corrected milk (ECM=3.10 MJ/kg) using the formula (Di Palo, 1992; Di Palo and Cheli, 1995):

$$Y=1+0.01155[(X-40)+(Z-31)]$$

where Y is the quantity (kg) of ECM equivalent to 1 kg of milk produced, and X and Z are, respectively, the grams of fat and protein contained in 1 kg of milk produced. Then we followed the guidelines of Di Lella (1998), according to which the Italian Mediterranean buffalo, in order to produce 1 kg of ECM, needs 3.56 MJ rather than 3.10 (CNCPS) of net energy for lactation and that the buffalo efficiency conversion of the absorbed aminoacids into milk proteins (N×6.38) is 50%. Such efficiencies, lower then CNCPS cow, may well be due to the still highly variable milk production aptitude of the Italian Mediterranean buffalo (Bertoni et al., 1993; Di Lella 1998).

Net energy (NE_l) and metabolizable protein (MP) intake were calculated using dry matter intake (DM intake), estimated according to the following equation (Campanile et al., 1998):

$$\text{DM intake (kg)}=[0.091\times\text{metabolic weight (kg)}]+[0.275\times\text{ECM (kg)}].$$

In order to evaluate the application of the CNCPS to buffalo rationing, the energy (NE_l) and protein (MP) average intake were related to their respective requirements and the results in the range 90-110% were considered satisfactory. The range was chosen because the buffalo in the first 90 days of lactation meets at least 8% of its own requirement using body reserves while in the second lactation phase it uses at least 6% of intake to reconstitute the body reserve (Campanile et al., 2001).

Statistical analysis

Both intakes of NEl and MP (% requirements) estimated with the two methods were compared for each buffalo category (A, B, C, D, E) with the analysis of variance, using the GLM procedure (SAS, 2000). The statistical model was:

$$y_{ij}=\mu+M_i+\varepsilon_{ij}$$

where y=intake of NEl or MP, M=mean, M_i=method effect (=1, 2), ε_{ij}=error term.

RESULTS AND DISCUSSION

Diets

Table 1 shows the dietary characteristics of the 6 farms. Zicarelli (2001) reports the energy density (MUF/kg DM; MUF=Milk Feed Unity=1,700 kcal) and crude protein content (g CP/kg DM) of diets utilized for lactating buffalo, related to the milk production and composition. In our investigation, on only one farm the CP content was lower and on three farms it was higher than the indicated value

Table 4. Net energy for lactation intake (% requirements) with the two methods for the animal categories on the 6 farms (mean±ES)

Categories	A	B	C	D	E
Method 1					
Farm 1	98.32±2.34	100.45±3.06	103.51±2.93	109.78±1.94	112.63±2.23
Farm 2	102.4±3.35	104.72±3.20	110.33±3.15	113.53±2.41	114.73±2.84
Farm 3	93.95±2.70	102.24±3.37	101.93±2.49	106.12±1.881	118.34±2.43
Farm 4	87.44±2.95	95.17±2.90	98.08±1.41	106.60±1.50	128.04±3.54
Farm 5	88.72±2.55	90.03±2.52	99.80±1.71	102.69±1.24	104.75±2.22
Farm 6	93.68±2.46	94.71±2.41	99.89±2.09	108.31±2.30	117.94±2.93
Method 2					
Farm 1	87.39±2.93	90.96±3.14	94.18±2.16	100.03±1.42	101.88±3.06
Farm 2	91.07±3.25	94.63±3.39	100.39±2.30	104.27±2.19	105.26±3.35
Farm 3	83.73±2.60	92.70±3.43	92.49±1.96	96.92±1.37	109.10±3.55
Farm 4	77.11±2.02	85.92±2.76	88.32±1.40	97.45±1.72	121.40±4.01
Farm 5	79.84±2.09	80.29±2.29	91.76±1.79	93.97±1.50	97.21±2.75
Farm 6	83.61±2.39	84.17±2.28	90.52±1.76	99.42±1.93	109.94±3.52

Categories A: <2 months, B: between 2 and 4 months, C: between 4 and 6 months, D: between 6 and 8 months, E: >8 months.

Table 5. Metabolizable protein intake (% requirements) with the two methods for the animal categories on the 6 farms (mean±SE)

Categories	A	B	C	D	E
Method 1					
Farm 1	94.65±2.09	99.86±3.20	104.03±3.13	106.91±2.64	105.53±3.94
Farm 2	84.03±2.02	88.59±2.19	92.80±2.13	96.33±1.87	96.04±3.56
Farm 3	97.82±3.34	108.24±3.47	111.77±3.45	111.77±2.83	119.64±4.24
Farm 4	88.70±2.47	98.37±2.78	99.77±2.47	108.81±2.88	125.60±5.33
Farm 5	95.31±3.03	94.92±2.68	107.73±3.817	106.23±2.82	112.51±3.77
Farm 6	97.80±3.13	97.99±2.93	105.74±3.17	112.56±3.583	119.74±4.97
Method 2					
Farm 1	80.76±2.43	86.90±2.61	91.66±2.81	95.68±2.20	94.48±5.01
Farm 2	72.12±1.91	77.40±2.19	82.67±2.49	87.18±2.31	87.01±4.00
Farm 3	82.84±2.17	95.13±2.69	99.75±3.01	99.75±2.82	110.77±5.48
Farm 4	73.45±1.82	84.44±2.54	86.24±2.29	97.44±2.24	121.62±5.59
Farm 5	80.91±2.43	80.52±2.28	96.03±3.34	95.71±2.10	102.35±4.89
Farm 6	83.17±2.50	83.43±2.66	92.50±2.90	101.54±2.79	111.73±5.53

Categories A: <2 months, B: between 2 and 4 months, C: between 4 and 6 months, D: between 6 and 8 months, E: >8 months.

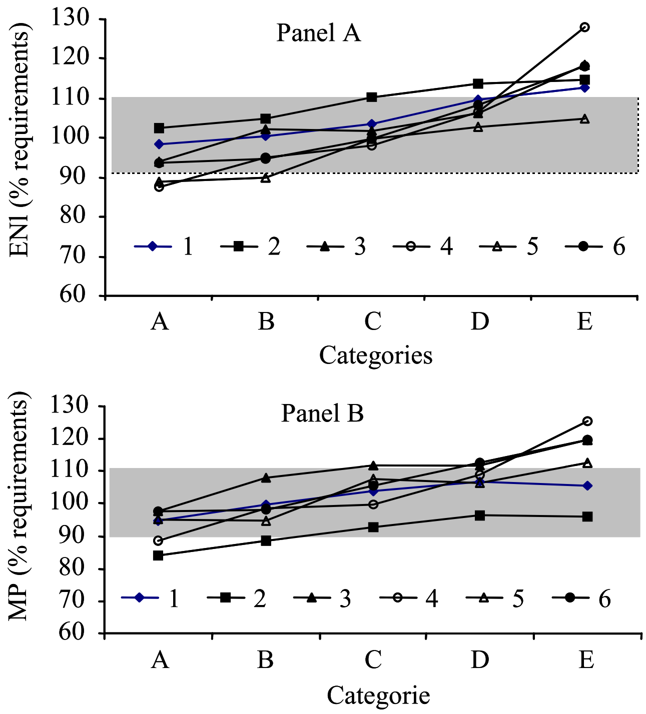

Figure 1. Method 1 (CNCPS) : Energy (Panel A) and protein (Panel B) intake for animal categories on the 6 farms. Categories A: <2 months, B: between 2 and 4 months, C: between 4 and 6 months, D: between 6 and 8 months, E: >8 months.

(120 g/kg DM). Regarding energy concentration, one farm showed a higher concentration and two farms showed a lower energy concentration than the indicated value (0.84 MUF/kg DM).

Milk

Average milk production on the 6 farms was estimated by multiplying the average milk production of the 40 animals of the 5 categories (Table 2) by the standard lactation period (equal to 270 d); in our case it was slightly higher than the national average (2,147 kg) reported by the AIA (2001) on farm 4, approximately the same on farm 5, and lower on farms 1, 2, 3 and 6.

On all farms milk yield quantity and quality, related to the days in milk, follows the physiological trend of lactation: a decrease in the quantity produced and increase in the fat and protein content.

Requirement satisfaction

Table 3 shows the net energy and metabolizable protein intake (% requirements) for each animal categories estimated with the two methods. Data analysis shows that method 2 (which considers a lower energy and protein use efficiency for milk production for buffalo than CNCPS) results in a significantly higher ($p<0.01$) of energy and protein with respect to the requirement than method 1 (CNCPS). There were no significant differences between the two methods in category E (>8 months), also du to the higher variability. Given such results, it seems worth discussing the obtained data for each animal category in the six farms (Tables 4 and 5). In order to facilitate this discussion the data are also reported as graphs (Figure 1 and 2).

The average dry matter intake on the six farms was in the range 14.3 and 16.3 kg/d. On all farms the tested animals showed an average BCS appropriate to the lactation phase, which shows that the formula used on the 6 farms surveyed was appropriate.

Method 1 (CNCPS) : regards the energy balance (Figure 1-Panel A), the intake/requirement ratio was satisfactory since for category A animals on 4 of the 6 farms (nos. 1, 2, 3, and 6) and category B animals on 5 of the 6 farms (nos. 1, 2, 3, 4 and 6). However, the NE_l increase proved outside the range 90-110 for the animals in the last lactation phase (category E) on 5 of the 6 farms. Different results were found on farm 2 where from the 6th lactation month an

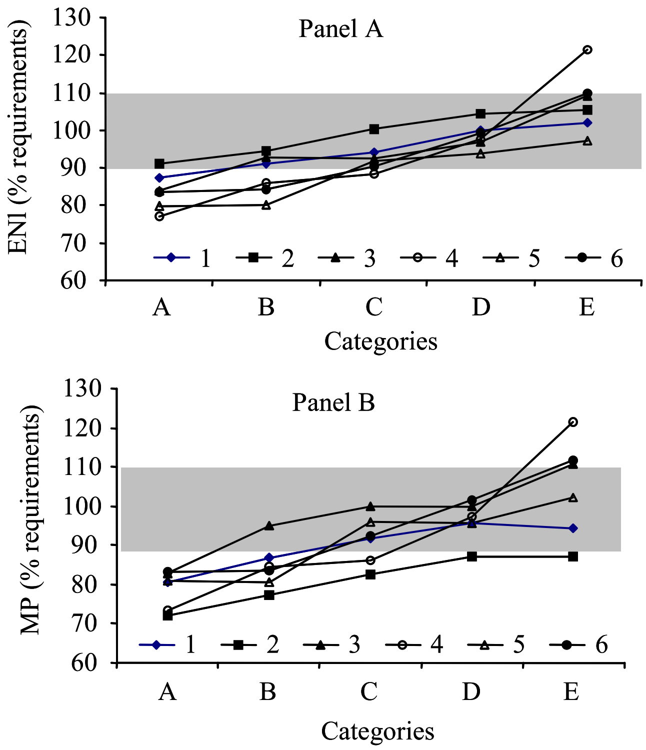

Figure 2. Method 2 : Energy (Panel A) and protein (Panel B) intake for animal categories on the 6 farms. Categories A: <2 months, B: between 2 and 4 months, C: between 4 and 6 months, D: between 6 and 8 months, E: >8 months.

energy intake surplus to requirements occurred. These results may well have been affected by the higher energy diet concentration (NE_l=6.20 MJ/kg DM) and the low milk production of farm 2 compared to the other farms.

As regards the protein balance (Figure 1-Panel B), the diet covered the protein requirements substantially until the 8th lactation month, and later (category E) there was a surplus on 4 of 6 farms. In particular, on farm 1 there was consistently good satisfaction of the protein requirements and on farm 2 this occurred from the 4th lactation month. The latter farm shows the lowest satisfaction curve because of the low MP diet content (77 g/kg DM).

Method 2 : With regard to the net energy for lactation (Figure 2-Panel A), the increased requirement to produce 1 kg of ECM (3.56 vs. 3.10 MJ) induced the energy satisfaction of animal requirements from category C animals onwards on 5 out of 6 farms. Only on one farm did the buffaloes that had calved 8 months previously intake a surplus of energy.

Metabolizable protein (Figure 2-Panel B) shows a clearly worse trend compared with method 1 because of the net increase in requirements due to the lower efficiency (50 %) in using MP. Protein requirements were satisfied on 4 of the 6 farms only in the animals of category C. Only after 6 lactation months (category D) on 5 out of 6 farms did the animals manage to satisfy their MP requirements. Moreover, on farm 2, because of the low diet protein content (101 g/kg DM), the animals never satisfied their requirements.

The measurement of BCS during the trial showed little variation (constantly between 6.5 and 7.0). This means that the mobilization and/or the reconstitution of body reserves were very poor. In the light of these results we can hypothesize that method 2 is inappropriate to evaluate the energy requirements of buffalo cow. Indeed, it would be difficult to explain the lack of energy requirements satisfaction in the first 6 months of lactation (farms 4, 5 and 6) without variation in animal BCS.

For the same considerations, method 2 appears inappropriate to evaluate the metabolizable protein requirements: adopting method 2, the protein concentration of diets was non sufficient for more than 5 months of lactation. In these conditions, according to Zicarelli (2001), with the consequence of BCS variations, the low nitrogen values should cause a growth hormone increase which stimulates fat mobilisation. In addition, the deficit of protein requirements for a long period could not explain the milk production registered in the present trial.

CONCLUSIONS

From the data of our investigation, the adoption of CNCPS to evaluate the diets for lactating buffalo and to calculate their energy and protein requirements appears to lead to satisfactory results. Milk production records and the results of BCS measurements agree with the satisfaction of nutritive requirements found using this method. On the other hand, method 2 supplied results which cannot explain animal performance.

If our results are confirmed by further research, carried out with a larger number of farms and animals, the adoption of CNCPS could represent a very sound method to improve the management of buffalo feeding.

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