การศึกษาเปรียบเทียบวิธีวัดค่าพลังงานในอาหารสัตว์

Comparative Study of Methods Available for the Evaluation of the Energy Value of Feeds

Yarn Kananurak[1] and G.S. Sidhu[2]

The efficiency of livestock production depends on the adequate supply of energy, protein and other essential nutrients. Out of these, energy and protein constitute the most significant dietary essentials both from the standpoint of efficiency of production and economics. Since all the major organic nutrients contained in the feed are capable of supplying energy, therefore, the energy value provides a common basis for expressing the nutritive value. It has been rightly pointed out by Huffman and Duncan (1945) that the deficiency of energy is the primary cause of low productivity in livestock. Compared with this, deficiencies of vitamins and minerals, though important, occupy a secondary place.

The need for having feeding standards based on energy requirements of livestock and energy value of feeds has been stressed by a number of workers in recent years (Beeson, 1958; Blaxter, 1962; Harris, 1963). The Animal Nutrition Committee of the United States National Research Council have also expressed a desire to give energy requirements of livestock in terms of calories. For determining gross energy of feeds and feces the bomb calorimetry is usually employed. Although this method gives results with high accuracy, yet it is time consuming and requires expensive equipment and technical skill. The energy values calculated from chemical composition of feedstuffs are approximate and variable. Recently O'Shea and Maguire (1962) have described a method based on the oxidation of organic contents of feedstuffs and feces with chromic acid for the determination of gross energy values of these materials. This method was compared with conventional methods for its accuracy for determining energy value of common feedstuffs, because it possesses definite advantages over other methods.

MATERIALS AND METHODS

A wide variety of feedstuffs were collected from different sources. The concentrate feeds were sampled, ground and passed through a sieve having 10 mesh per cm. The green forages such

1 Department of Animal Science, Kasetsart University

2 Head, Department of Biochemistry, Agricultural Univ., Punjab, India

as EB_4 (*Penisetum purpuriophoedes*), "Jowar" (*Andropogon sorghum*), "Bajra" (*Penisetum typhoidium*) and alfalfa (*Medicago sative*) were cut at three stages of their growth, i.e., before flowering, flowering and milk stage. These forages were chopped, mixed, dried at 105° C in an air oven and ground in the same manner as concentrate feeds.

The feedstuffs were analysed for moisture, crude protein, ether extract, crude fibre, ash and nitrogen-free extract. The methods used for the analysis were those recommended by A.O.A.C. (1960) with the exception of crude protein which was estimated by the method of Mckenzie and Wallace (1954).

For the determination of gross energy value the following three methods were used.

1) Combustion in bomb calorimeter as described in the technical manual No. 130 of Parr Instrument Company (1960).
2) Oxidation with chromic acid as reported by O'Shea and Maguire (1962). In this method the organic compounds in feedstuffs are oxidized with chromic acid. Rozental (1957) found that while carbohydrates and fats were quantitatively oxidized to carbon dioxide and water, in most cases the protein was not quantitatively oxidized, due to the formation of non-oxidized nitrogenous end products. The oxidiation coefficients calculated by dividing the amount of 1.5 N. potassium dichromate used with the gross energy in kcal, were found to be negatively correlated with the quantities of protein in feeds. Working on the above concept, O'Shea and Maguire (1962) showed that the oxidation coefficient (C) of feeds may be calculated from the equations:

   $C = 23.39 - 0.069\,P + 0.000226 P^2$

   when the amount of ether extract was less than 10 percent, and

   $C = 24.02 - 0.1055\ P^2$ when the ether extract was more than 10 percent, where P is the percentage of protein in feeds. The gross energy value was calculated by dividing the milliliters of 1.5 N. potassium dichromate used, with the oxidation coefficient.
3) Calculation from composition of feedstuff:
   The protein, ether extract and carbohydrate in one gram of material were multiplied by factors of 5.6, 9.3 and 4.3 respectively and added up to obtain the gross energy value (Crampton, 1956).

RESULTS

The average percentage composition of feedstuffs taken up for study is given in Table 1.

Table 1. *Average percentage composition of experimental feedstuffs (each value represents an average of duplicate determination on dry matter basis)*

No.	Feeds	*Crude protein percent	Ether extract percent	*Crude fibre percent	Nitrogen-free extract percent	Ash percent
	Green forages					
1.	EB4 (before flowering)	7.95	2.23	31.47	42.61	15.74
2.	—— (flowering)	3.98	1.95	33.57	51.05	8.34
3.	—— (ripe stage)	2.19	0.64	37.36	51.46	8.34
4.	Jowar (before flowering)	7.31	2.25	32.37	51.13	6.94
5.	—— (flowering)	5.71	1.38	37.09	50.09	6.73
6.	—— (milk stage)	2.82	1.09	40.56	50.69	4.84
7.	Bajra (before flowering)	9.30	2.63	32.98	41.07	14.02
8.	—— (flowering)	7.39	2.12	34.39	44.83	11.27
9.	—— (milk stage)	5.44	2.05	31.11	54.25	7.15
10.	Alfalfa (before flowering)	24.61	2.13	36:32	27.76	9.18
11.	—— (flowering)	19.39	1.39	28.63	41.61	8.44
	Dry roughages					
12.	Rice straw	3.68	1.31	38.61	37.05	19.35
13.	Wheat straw	2.46	1.52	45.88	40.94	9.20
	Concentrates					
14.	Broken rice	8.40	1.41	0.64	88.01	1.55
15.	Corn meal	10.86	5.13	2.23	80.22	1.56
16.	Bajra grain	13.59	5.60	1.89	76.62	2.40
17.	Rice polish	10.83	11.03	10.88	58.52	8.74
18.	Wheat bran	16.73	4.86	9.47	62.51	6.43
19.	Gram husk	4.64	0.20	48.25	39.79	7.12
20.	Cotton seed cake	26.81	6.54	36.75	23.60	6.30
21.	Sarson oil cake	36.42	11.40	10.79	30.89	10 50
22.	Groundnut cake	46.07	8.12	10.82	29.32	5.67
23.	Corn gluten meal	43.07	4.49	3.68	46.96	1.80
24.	Meat meal	45.27	9.91	2.56	29.32	12.94
25.	Fish meal	62.16	10.58	1.17	8.10	17.99

* The values represent average of three determinations.

Table 2. *The comparison of gross energy values of feedstuffs measured by different methods and the relationship of organic matter to the quantity of chromic acid used for oxidation*

No.	Feedstuff		Gross energy value Kcal/g material			Percent difference		Organic matter in dry matter (percent)	Dichromate (1.5 N) used to oxidize/g of oven dry feed (ml)
			By bomb-calori-meter	Calculated from chemical composition	By chromic acid oxidation	between 3 & 4	between 3 & 5		
1.	2.		3.	4.	5.	6.	7.	8.	9.
1.	EB_4	(before flowering)	3.800	3.838	3.805	1.00	0.13	84.26	88.06
2.	——	(flowering)	4.192	4.043	4.151	3.55	0.98	91.66	95.98
3.	——	(ripe)	4.165	4.001	4.175	3.94	0.24	91.66	97.05
4.	Jowar	(before flowering)	4.245	4.210	4.271	0.82	0.61	93 06	97.79
5.	——	(flowering)	3.969	4.197	3.972	5.74	0.08	93 27	93.85
6.	——	(milk stage)	4.242	4.181	4.167	1.60	1.93	95.16	95.09
7.	Bajra	(before flowering)	3.877	3.949	3.863	1.86	0.36	85.98	87.90
8.	——	(flowering)	4.131	4.017	4.043	2.76	2.13	86.73	92.51
9.	——	(milk stage)	4.282	4.165	4.287	2.73	0.12	92.85	98.70

10.	Alfalfa (before flowering)	4.475	4.331	4.464	3.22	0.25	90.82	97.47
11.	——— (flowering)	4.388	4.265	4.382	2.80	0.37	91.56	96.63
12.	Rice straw	3.650	3.581	3.655	1.89	0 09	80.65	84.47
13.	Wheat straw	4.247	4.010	4.246	5.58	0.02	90.80	98.68
14.	Broken rice	4.488	4.414	4.257	1.65	5.30	98.45	96.72
15.	Corn meal	4.577	4.629	4.636	1.14	1.28	98.44	105.20
16.	Bajra grain	4.650	4.654	4.739	0.09	1.92	97.60	106.60
17.	Rice polish	4.682	4.617	4.654	1.39	0.80	91.26	111.50
18.	Wheat bran	4.670	4.484	4.720	3.98	1.07	83.57	105.30
19.	Gram husk	3.936	4.064	3.925	3.25	0.28	92.88	90.53
20.	Contton seed cake	4.661	4.705	4.485	0.945	3.76	93.70	97.34
21.	Sarson cake	4.992	4.892	5.058	2.00	1.32	89.50	106 30
22.	Groundnut cake	5.140	5.061	5.099	1.54	0.80	94.33	105.40
23.	Corn gluten meal	5.184	5.008	5 481	3.40	5.90	98.20	114.20
24.	Meat meal	4.851	4.828	4.978	0.47	2.64	87.06	92.34
25.	Fish meal	5.379	4.869	5.370	9.95	0.17	82.01	107.80

It could be observed from the data in Table 1 that crude protein, ether extract and ash showed a general tendency to decrease as the green forages approached maturity while the crude fibre tended to increase. Variable values were obtained with respect to nitrogen-free extract, though it showed a tendency to increase with maturity.

The gross energy values of the feedstuffs as measured by the three methods, are summarized in Table 2.

The statistical analysis of the data in Table 2 showed that:

1. The gross energy values as calculated from the chemical composition were significantly different from those determined with bomb calorimeter, the "value" (2.661) obtained from the data being higher than the "t-value" (2.064) at 5% level.

2. The difference between gross energy values as determined with chromic acid oxidation and bomb calorimeter were not significant.

3. The organic matter content of the green forages and roughages was positively related with the quantity of 1.5 N. potassium dichromate used, correlation coefficient of +0.819 indicating a very close relationship between the two characters. However, in the concentrate feeds no such relation was observed ($r = +0.0417$). This could be due to greater variation in ether extract and protein contents in different concentrates.

DISCUSSION

The values given in Table 2, on the composition of different feeds lie within the range of values reported by Sen (1951). However, there are a few exceptions. The lower values obtained in *bajra* for crude protein during the present investigation than those reported in literature may be due to the varietal, manurial and climatic differences, and the variations in the exact identification of stages at which the crop was analysed. This may also be the case with values obtained for other feedstuffs.

Data on the gross energy values of feedstuffs available is not extensive. The gross energy values, 5.140, 4.670, 4.247 & 3.650 kcal/g have been obtained by bomb calorimeter. These compare very favorably with the values of 5.374, 4.255 & 3.843 reported by G.S. Sidhu (1961, personal communication) for the same feedstuffs.

It is obvious from the data in Table 2 that the gross energy values as determined by chromic acid oxidation are comparable with those obtained by combustion in the bomb calorimeter which is considered to give accurate values. On the other hand the values calculated from proximate composition of feedstuffs (Table 2) are different from those obtained by bomb calorimeter. This shows that reliance can be placed on the chromic acid oxidation method for determining gross energy value of common feedstuffs. O'Shea and Maguire (1962) have shown that the gross energy value of sheep feces can also be determined accurately with this method and it is reasonable to believe that the same will hold true for the feces of cattle. In that case, chromic acid oxidation method can provide a simple and reliable technique for determining the digestible energy of feeds. This method, however, connot be used for an accurate determination of gross energy value of urine, since urea which is its main partially oxidized nitrogenous compound, is completely unaffected by chromic acid. Hence for the determination of metabolizable energy of feed, an estimate of the energy loss through urine may be arrived at by using the accepted figure of 2.17 times number of gram of urinary nitrogen while that through combustible gases may be made by applying the equation evolved by Axelsson (1949) $Y_2 = 1083\,X_2^{0.638}$ in which Y_2 = methane energy in kcal, and X_2 = digested carbohydrates in kg. By using these calculations, it may be possible to obtain a fairly accurate estimate of the metabolizable energy value of different feedstuffs using chromic acid oxidation method.

SUMMARY

Two methods for the determination of gross energy value of a number of cattle feeds, viz., oxidation with chromic acid and as calculated from the chemical composition were compared with the standard method of bomb calorimeter.

The chromic acid oxidation method, after applying a correction due to incomplete oxidation of protein, gave gross energy values which were not different statistically from those obtained by the bomb calorimeter while the values obtained by calculation from chemical composition were different.

It has also been suggested that the chromic acid oxidation method could be used for the determination of gross energy values of feed in place of the bomb calorimetry with convenience and advantage.

A close relationship was found to exist between the organic matter content of dry roughages, forages and the quantity of chromic acid used for oxidation, while no such relationship was observed in the case of concentrates presumably due to their having greater variations in protein and fat contents.

สรุป

ในการศึกษาครั้งนี้ ได้เปรียบเทียบวิธีวัดค่าพลังงานทั้งสิ้นในอาหารบางชนิดสำหรับสัตว์ใหญ่โดยวิธีอ็อกซิเดชันด้วยกรดโครมิก กับวิธีคำนวณจากองค์ประกอบทางเคมีในอาหารต่าง ๆ แล้วเปรียบเทียบกับวิธีมาตรฐานแบบใช้เครื่องบอมบ์แคลอริมิเตอร์

วิธีอ็อกซิเดชันด้วยกรดโครมิกนั้น หลังจากที่ได้คำนวณแก้ไขเนื่องจากการอ็อกซิเดชันของโปรตีนไม่หมดสิ้นแล้ว ปรากฏว่าให้ค่าพลังงานทั้งสิ้นโดยไม่แตกต่างทางสถิติจากค่าที่วัด โดยวิธีใช้เครื่องบอมบ์แคลอริมิเตอร์ แต่วิธีคำนวณจากองค์ประกอบทางเคมีนั้นให้ค่าแตกต่างไป

จากผลการศึกษานี้ พอจะแนะนำได้ว่าวิธีอ็อกซิเดชันด้วยกรดโครมิกอาจนำมาใช้หาค่าพลังงานทั้งสิ้นในอาหารสัตว์ได้แทนวิธีใช้เครื่องบอมบ์แคลอริมิเตอร์ โดยมีภาษีและความสะดวกเหนือกว่ากัน

ได้พบความสัมพันธ์อย่างใกล้ชิด ระหว่างปริมาณสารอินทรีย์ของอาหารหยาบแห้ง หญ้า กับปริมาณของกรดโครมิกที่ใช้สำหรับอ๊อกซิเดชั่น แต่ความสัมพันธ์ดังกล่าวนี้ไม่ปรากฏในกรณีของอาหารข้น ทั้งนี้อาจเนื่องมาจากปริมาณโปรตีนและไขมันในอาหารข้นมีแตกต่างกันมาก

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