18. RECENT ADVANCES IN RESEARCH ON FEEDSTUFFS

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Introduction

As discussed already by many previous speakers, animal industry in Japan is quite unique and specific, compared with those of other countries. The production of egg, meat and milk increased rapidly within recent two decades and is still increasing, supported by strong and increasing demand for these animal foods. The unique charatcer of Japanese animal industry is that this drastic increase in the production is not preceded by the increase in domestic supply of feed, the raw material of animal production. Therefore, import of feed from foreign countries, especially from the United States of America, increases rapidly and the problem on feed supply is now one of the most important and urgent problems in animal industry in this country.

With regard to the problems on feed supply, many efforts have been focused from various directions. The effort to increase domestic production of feed on arable land and grassland is, of course, one of the powerful approach to solve the problem. Similarly, the effort is continuing to increase the import of feed from abroad. Effective utilization of feed at hand, based on the advanced knowledge of animal nutrition, is another approach. In this paper, however, the discussion will be limited on the problems concerning feedstuffs themselves, especially on the assessment of nutritive value of feedstuffs.

Research Projects on Feedstuffs

Research projects on feedstuffs include the assessment of nutritive value of the sample both chemically and biologically, the procedure of processing by which nutritive value of the sample will be increased or by which physico-chemical property of feedstuffs will be improved, and the procedure of preserving feedstuffs with minimum loss of nutrients and without producing any detrimental factors to domestic animals. To obtain the fundamental knowledge for these researches, the studies on the properties of individual feedstuff, i.e. physical structure, chemical composition, physiological function under various conditions to various animals at different ages and so on, are essential.

Not only the properties of the feedstuffs favorable to domestic animals, but also those unfavorable or detrimental to the animals should be studied to get the knowledge how to use the feed effectively. Especially, it becomes more and more important to study the effect of feed components on the public welfare through their residue in animal foods. Then feed components could be grouped into two. One is the contaminants, such as insecticides, heavy metals and polychlorinated biphenyl (PCB) and so on, of which pollution can not be prevented only by the effort of the people related on animal production. The other is the feed supplements, such as antibiotics, antioxidants, coccidiostats and so on, which are useful for the efficient and economical production, and the people related on animal production has responsibility to use the feed supplements safely.

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Table 1. Available energy estimated by bioassay with growing chicks

	Moisture (%)	Crude protein (%)	Available energy (kcal/g)	Note
Cereals and roots:				
Yellow corn	14.4	9.2	3.48	reference
Rice	14.1	8.0	3.45	
Cassava meal	13.5	2.0	1.7[1]	prussic acid 36 ppm
Sweet potato	12.5	3.4	1.9[1]	raw
〃			2.7[1]	cooked
Fats:				
Soybean oil			9.21	reference
Beef tallow			7.3[1]	
Mutton tallow			6.1[1]	
Yellow grease			6.1[1]	
Poultry grease			8.7[1]	
Fatty acids of sperm whale oil			7.3[1]	
Corn fermentation oil			7.5[1]	including ethyl esters
Alkaline foots			5.1	from soybean oil
〃			5.6	from rice oil
Protein source:				
Soybean meal	12.5	44.4	2.28	reference
Fish meal	9.8	63.0	3.06	reference
Safflower meal	9.2	19.8	1.8	Japanese
Yeast grown on n-paraffin A	—	64.8[2]	3.38[2]	
〃 B	—	57.7[2]	2.85[2]	
〃 C	—	57.0[2]	3.11[2]	
〃 D	—	48.6[2]	2.51[2]	
Yeast grown on sulfite-pulp waste liquor E	—	47.1[2]	2.16[2]	
〃 F	—	47.7[2]	2.30[2]	
Chlorella	8.4	51.4	2.0	
Chemicals:				
1, 2-propanediol			5.9	dietary level less than 5%
1, 3-Butanediol			6.3 (5.3)[3]	
1, 2-Propanediol dilaurate			8.9 (6.5)[3] (8.5)[4]	
1, 3-Butanediol dioctylate			8.4	
succinic acid			3.0 (3.4)[4]	dietary level less than 5%
Miscellaneous:				
Poultry manure	7.4	4.51[5]	1.8	including no litter

1) Available energy was estimated originally as percent of total digestible nutrients.
2) Dry-basis.
3) Assayed with calves and shown as digestible energy.
4) Assayed with rats and shown as digestible energy.
5) Nitrogen content.

Assessment of Nutritive Value of Feedstuff

In the assessment of nutritive value of a sample of feedstuff, palatability of the animal for the sample decides the value first of all. Nothing that is rejected by the animal is suitable as feed, although such a sample can be used as feed by some technique, such as mixing small amount in other feed ingredients or processing properly to make it palatable to the animal. Digestibility is the second factor to decide the value, though digestibility of some of feedstuffs can be improved by properly processing before feeding. Metabolizability of the digestible sample is the third factor to decide the nutritive value. Amino acid composition digestible protein is important to determine the value of protein source. Excretion of energy and nutrients into urine lowers the value of the sample. Heat increment, which can not be utilized by the animals for the purpose of production, is the last factor to decide the nutritive value. In ruminants, the loss of energy in expired methane should be considered.

For each of the factors mentioned above, the procedure to determine the value is devised and described in many literatures. Most of the procedures include chemical analyses of nutrients and energy with specific apparatus. Therefore, the assessment of nutritive value of feedstuffs are rather time-consuming and laborious, and requires well-trained technicians and well-equipped laboratory.

Biological assay of available energy of feedstuffs: In the author's laboratory, a biological assay procedure has been developed for the assessment of nutritive value of feedstuffs without chemical analytical procedure. Available energy of many feedstuffs has already been evaluated by the bioassay. The data are presented in Table 1.

The principle of the bioassay of available energy is based on the linear relationship between dietary energy level and growth response of the animal under the suitable, well-controlled condition. In this bioassay, a standard curve can be obtained by feeding graded levels of a standard energy source with constant amount of basal diet, and by weighing body weight gain for a certain period. A typical example is shown in Fig. 1. Caloric value of an unknown sample can be on the curve from the body weight gain on the sample, as shown in Fig. 1. Usually, cellulose powder, corn starch, soybean oil are used as a standard for th sample containing only energy, and yellow corn and soybean meal for the sample containing protein, of which metabolizable energy is 0, 3.52, 9.21, 3.48 and 2.28 kcal/g air-dry matter, respectively.

Since growth response of the animal under such a condition should be correlated with energy intake, and not with dietary energy level, a measured amount of feed should be supplied to keep feed intake constant to make growth rate of the animal directly correlated with dietary energy level. Laborious job to feed a measured amount of experimental diet daily could be avoided by feeding the diet *ad libitum*. In this case, total feed intake should be measured and the influence of different feed intake on growth response can be cancelled out by calculating body weight gain per unit of feed taken, i.e. per kg or 100 g feed, as shown in Fig. 1.

Thus, simple weighing of body weight and feed intake are enough in this bioassay. No chemical analysis is required. The data shown in Table 1 reveal that the bioassay procedure is successfully applicable to growing calves, chicks and rats.

Special, restricted pre-feeding has been devised for the bioassay with growing chicks to improve the accuracy in the assessment of small amount of sample. By this procedure, the assessment can be done with a sample of such a small amount as 50 g.

Biological assay of gross protein value: In the author's laboratory, it is now being tried to develop a bioassay procedure for the assessment of protein value biologically based on the growth response of the animal on the amount and quality of the sample protein.

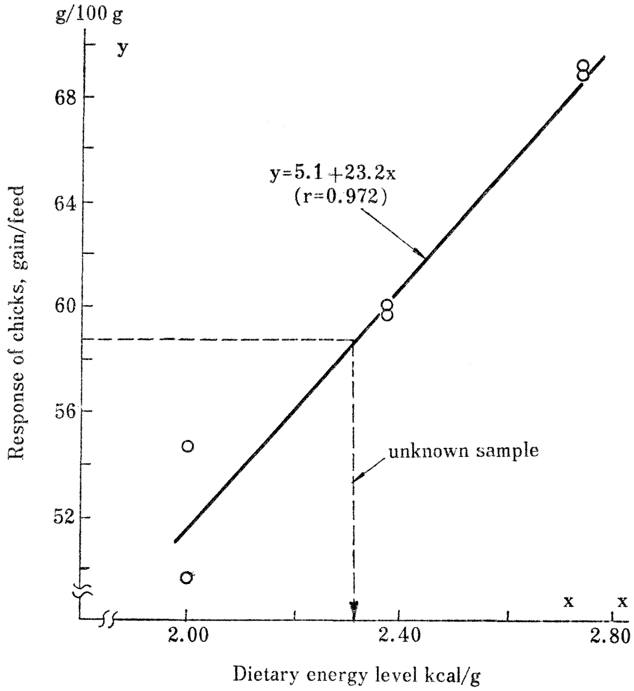

Fig. 1. Response of chicks for 6 days on standard and test diets.

The procedure was originally proposed by Heiman et al., in 1939 as determination of gross protein value, and up to the present, the procedure has been adopted by many workers without fundamental modification in the procedure. Since in the procedure of Heiman et al., casein is used as a standard protein source, of which amino acid composition is known to be unfavorable for growing chicks, a mixture of casein, L-arginine, DL-methionine and glycine is used as the standard protein source in author's laboratory. Chicks pre-fed the chick starter diet restrictedly are used as in the bioassay of available energy. Experimental period is cut down to be oniy 6 days. And, statistical procedure of slope ratio assay is applied to make the assessment more accurate and reliable.

By this improved procedure, the assessment of various protein source, both natural, such as domestic production of safflower meal, and artificial, such as yeast grown on *n*-paraffin, has been carried out.

Pollution of Animal Food by Feed Supplements, Especially by Antibiotics

To obtain fundamental knowledge on the transfer of the dietary antibiotics into eggs and meat and on the residue of antibiotics in milk, instilled into the udder for the treatment of mastitis, four-year research project has been carried out since 1971.

Antibiotics in egg and meat: No antibiotics of 6 kinds tested already, i.e., spiramycin, tylosin, oxytetracycline, chlortetracyline, penicillin and bacitracin, were detected in the meat and liver of the chicks and in the egg, both obtained during feeding the antibiotics at dietary level of 20 ppm, which is the level allowed to use for the purposes of growth promotion and of improvement of feed efficiency.

Following Equations 1 and 2 are found fit to describe the behaviour of dietary spiramycin (SP) and oxytetracycline (OTC), i.e., the transfer into eggs after feeding antibiotics and the disappearance from eggs after the withdrawal of dietary antibiotics,

$$y=(0.000348x\ -0.0121)\cdot T_1\cdot e^{-0.292T_2} \quad \text{(1)}$$

$$y=(0.0000364x-0.0090)\cdot T_1\cdot e^{-0.632T_2} \quad \text{(2)}$$

where, x is dietary antibiotic level (ppm), T_1 is days on antibiotic feeding, which is equal to or less than 7, T_2 is days after the withdrawal of dietary antibiotic, and y is average antibiotic content in whole egg laid on T_1+T_2 days after the start of antibiotic feeding. During feedng antibiotic, T_2 should be zero, and x and T_1 should be the fixed value after the termination of antibiotic feeding.

Comparing the coefficient for x in Equations 1 and 2, it is suggested that about 10 times (=0.000348/0.0000364) more dietary SP is transferred into eggs than dietary OTC is. Ratio of constant and coefficient for x in the parenthesis, i.e., 0.0121/0.000348=35 for SP and 0.0090/0.0000364=247 for OTC, indicates the highest limit of dietary antibiotic, below which no antibiotic could be detected in whole egg even after seven days of feeding antibiotic.

The coefficient for T_2 in Equations 1 and 2 indicates the rapidness of disappearance of the antibiotic from whole egg after the withdrawal of dietary antibiotic. The speed can be more easily understood by calculating biological half life, which is the ratio of $\log_e 2$ to the coefficient for T_2. Biological half life of OTC is 1.1 days, which is shorter than 2.4 days for SP and similar to 1.3 days for tyrosine.

Antibiotics in milk: Content of antibiotics in milk decreased rapidly and exponentially after the instillment of penicillin (PC) and streptomycin (SM) into the udder under the condition of milking twice a day. Biological half lives of PC and SM are 3.4 and 4.5 hours, respectively. After 72 hours, actually no residue of both PC and SM was detected in milk. The findings reveal that the excretion of antibiotic and be explained by the model of dilution of remaining antibiotic in the udder after milking by newly secreted milk.

Recsearh on Novel Feed Sources

Many efforts have been made to find new feed sources which have not been used hitherto as feed.

As shown in Table 1, cassava meal, which is not popular in this country, various oily by-products and other natural products were tested for their nutritive values, especially for available energy.

Re-utilization of poultry manure as poultry feed has been studied in several laboratories and poultry farms. Relatively low available energy of the manure makes the re-utilization as poultry feed difficult. Experiments to feed poultry manure to swine and ruminants are carried out or schemed.

Microbial protein, such as yeast grown on various carbon sources, is one of the most hopeful protein sources, both from the viewpoint of high quality and possibility of mass production in future.

Among the various experiments on the utilization of yeast grown on n-paraffin as feedstuffs, collaborative works are being carried out at six prefectural poultry experiment or breeding stations on the effect on reproductive ability of breeding hens. In each station, about 200 female and 30 male one-day-old chicks were divided into two equal groups. Control diet was fed to a group and experimental diet containing 15% of the yeast was fed to the other. Mating females and males on the same diet, chicks of the second generation were obtained and reared similarly by feeding the same diet as fed to their parents. Chicks of the third generation were obtained and reared under the same plan, and so on. At this time, hens of the fifth generation are just starting to lay.

In Table 2, data of three generations at six stations are summarized and presented.

Table 2. Summary of data of 3 generations at 6 stations

		Average of 3 generations	
		Control	Yeast
Number of males		271	271
Number of females		1, 895	1, 881
At 20 wks of age:			
Body wt. gain	kg	1. 45	1. 38**1)
Feed intake	kg	8. 11	7. 81
Feed/gain		5. 59	5. 66
Viability	%	95. 9	93. 9
Maturity:			
Age, at 50% lay	day	164	167*
Egg wt., at 50% lay	g	45. 3	46. 1
Egg production:			
Hen-day	%	62. 4	60. 5
Hen-housed	%	58. 2	57. 8
Feed intake	g/day	107	107
Feed conversion		3. 52	3. 68
Egg wt.	g	53. 4	53. 4
Body wt., 36 wks old	kg	1. 78	1. 74
Viability	%	91. 3	94. 1*
Hatchability test:			
Number of egg set		20, 296	20, 296
Fertility	%	94. 0	95. 3
Hatchability of fertile egg	%	79. 2	82. 3

1) Difference between control and yeast is significant statistically.
*: 5% level.
**: 1% lavel.

Yeast grown on *n*-paraffin has actually no detrimental effect, while feeding the yeast resulted in significantly higher viability, in other words lower mortality, during laying period. Although growth rate of the chicks on the yeast was slower and their sexual maturity was later than those on the control diet, the differences were discussed to be due to the difference in energy and protein levels between the two experimental diets, and not to the nature of the yeast. Good fertility and hatchability of more than 20 thousand eggs tested also indicate no detrimental effect of the yeast on heredity. All of the chicks newly hatched were healthy. No abnormality due to the yeast feeding has been reported after the histo-pathological examination of 60 hens each on the control and yeast diets.

In the National Institute of Animal Industry, similar long-term feeding experiment of the yeast as mentioned above with chicks is being carried out with mice of both sexes. At this time, mice of the seventh generation are growing and no detrimental effect of the yeast has been reported.

As shown in Table 1, several chemicals, mainly glycols and their esters, are expected to be hopeful as energy source for animals and poultry. The chemicals resemble neutral fat in physical and chemical properties, so that they could be used as feed ingredient to make dietary energy level up, resulting improved feed efficiency.