OUTSTANDING ACHIEVEMENTS IN POULTRY RESEARCH DURING LAST 30 YEARS

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SUMMARY

Poultry farming has become a multinational agribusiness resulting in **disappearence** of poultry husbandry departments in universities. Development of least cost feed formulation is of great economic value. Historical developments in the field of **metabolizable** energy, amino acid bioavailability, and some newer trends are mentioned.

RISE AND FALL OF FAMILY POULTRY FARM

In the early **1950's,** about 5 million farmers also indulged in poultry production which contributed about 14% of the yearly farm income in the U.S.A. Over 50% of eggs and chickens came from farms with less than 200 birds (**Jull,** 1951). A family with about 10,000 laying hens made quite a decent living in California. Feed mills, feed stores, hatcheries, egg grading stations, and slaughtering facilities were within easy access of most small towns. Many large merchants made their living supplying ingredients from a few pounds to large quantities. Most agricultural universities had a poultry husbandry department busy researching genetics, physiology, nutrition and disease prevention, and transferring their findings to producers through extension agents. Through combined efforts of engineers, geneticists, embryologists, physiologists, nutritionists, biologists, veterinarians, and many other disciplines, poultry production became a thriving industry. Economists brought the concept of integration in **1950's,** thus changing trends rapidly.

A **collegue** quit his salaried government job to become a poultry farmer in 1954. Soon many family farms were failing. A flock of 10,000 hens was insufficient to support a family. My friend was unable to increase the flock size to 50,000. He went bankrupt and returned to his government job in 1957. Integration of the industry had started and family **farms** disappeared. By the **1970's,** poultry became a fully integrated agribusiness controlled by smart entrepreneurs with a lot a of bank credit.

Effect of integration on research and development

Development of hybrid poultry has resulted in world-wide control of supplies of commercial birds in the hands of about a dozen multinational companies, with a loss of a potentially useful genetic pool. The integrated poultry enterprises have their own research facilities, resulting in closure of poultry husbandry departments in many agricultural universities.

CHANGES IN INGREDIENTS INCORPORATION

Corn takes over

There was a -wide variety of ingredients used in poultry diets, and alfalfa meal containing up to 20% crude protein was seldom omitted until the **1970's.** Main sources of carbohydrates and some protein were barley, buckwheat, corn, hominy feed, oats, rice polish or bran, rye, sorghum, wheat and it's by-products, and even potatoes. Use of sugar

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cane molasses was also popular. A change was taking place in the structure of the American farms. The average size of a farm increased, and a single crop economy became dominant. Then hybrid corn took over, and farmers had a surplus. Eventually, corn has become the main cereal constituent of poultry diets in the U.S.A.

Soybean meal as plant protein source

Before soybean meal became the dominant plant protein source, several other plant protein sources such coconut meal, cottonseed meal, groundnut cake (peanut meal), linseed meal, sesame meal, rapeseed meal, corn gluten meal, and yeast were frequently used. Aflatoxin contamination was found to be a problem in groundnut meal and cottonseed meal, consequently soybean meal has become the main plant protein worldwide. The importance of diets based on corn and soybean meal cannot be overemphasized as diets based on other ingredients are always compared against a corn-soybean meal diet.

Commercially available amino acids

With the commercial availability of L-lysine and DL- methionine or its hydroxy analogue at a reasonable price, dietary formulations have now become much easier. Some other amino acids such as threonine and tryptophan are also now commercially available. Despite the voluminous research information, some sponsored by manufacturers of hydroxy analogue of methionine, the question of its relative effectiveness in comparison with that of methionine at an equimolar level is controversial. The producers of this product suggest that this hydroxy analogue could substitute on an equal weight for DL-methionine, but some investigators feel that only 60% of the DL-methionine requirements should be replaced by the hydroxy analogue (Sluis and Armstrong 1992).

Premixes

The art of blending vitamin and trace element premixes is controlled by engineers, and nutritionist have scant input about the carriers or diluents used in premixes. Calcium carbonate, wheat middlings, corn meal are examples of carriers and diluents used in premixes. We know that high levels of calcium reduce availability of trace elements especially in the presence of high phosphate levels. Destruction of fat-soluble vitamins is accelerated in the presence of copper and iron ions, but premixes are sold containing vitamins and trace elements mixed together. Imagine the result of storage of these premixes in hot weather. Most of the vitamin premixes would have much higher levels of incorporation of vitamins A and D than guaranteed if the vendor suspected that a laboratory to check potency of vitamins was available, otherwise you may have a few surprises about the potency of premixes.

LEAST COST DIET FORMULATIONS

Fisher and Schruben (1953) recommended the use of linear programming for formulation of diets at least cost, but needed main frame computers to accomplish the task. Once the desktop computer became a household appliance, commercial programs costing ten to thousands of dollars became available. The least cost program for

formulation of diets is one of the most important advanced tools for the poultry nutritionist. The following information is needed for least cost formulations:

(a) Nutrient requirements for growth, maintenance, and breeding of poultry as influenced by the environmental factors.
(b) Energy and nutrient composition of the available ingredients.
(c) Supply of vitamin and trace element premixes, and of amino acids such as lysine and methionine.
(d) Current price of ingredients and supplements.

The computer program then determines the blend of ingredients to satisfy the nutrient requirements at least cost. The formulation changes as the price of ingredients change. It is presupposed that carbohydrate and amino acid availability from different ingredients in balanced diets is of the same magnitude.

NUTRIENT REQUIREMENTS

The arguments about the way of expressing nutrient requirements as percent of diet, as units per kJ metabolizable energy formulation and feeding regimens continue, and contract growers follow their guidelines.

The geneticists are always manipulating the genetic make-up of the birds. The requirements of birds for nutrients are also changing (Pym et al. 1984) Despite the addition of all the known vitamins and trace elements supplements, incidence of fatty liver syndrome, sudden death syndrome, and leg weakness including ricket-like disease is increasing in certain breeds more than in others. The broiler of today is lethargic with a aberration of satiety center. The obese bird has about 35% fat on a dry matter basis.

ENERGY CONCEPTS

Scott et al. (1947) reported that a diet containing 68% corn was superior to one containing wheat or oats for broilers, and the era of high energy diets dawned. These diets were later designated as Connecticut high-energy diets. Scott et al. (1948) used the term high energy diet in his paper. To formulate high energy diets, some information is needed about the energy content of the ingredients. Fraps pioneered the studies on metabolizable energy (ME) of ingredients for poultry (Fraps et al. 1940) , but later switched over to productive energy (PE) as a better measure of the net energy of an ingredient. Hill (1957) and Titus (1955) popularized the use of metabolizable energy (ME). Hill and Anderson (1958) suggested using growing chicks and an indicator instead of total fecal collection, and a correction for nitrogen (N) retention to determine N-corrected apparent metabolizable energy (AME_n). His methodology was widely accepted because of the persuasive power of Hill. It took about 4 weeks to run a trial for AME determination. Sibbald (1989) reported that nitrogen correction was proportional to AME for 1375 feed ingredients ($AME_n = 0.009 + 0.948\ AME$). Nitrogen retention is influenced by the age of the bird, protein content of the diet, and the level of food intake.

When numerical values for ME and ME_n of ingredients as determined by different investigators are compared, nitrogen correction does not appear significant as is evident from Table 1 (Sibbald and Wolynetz 1987).

As the agronomists attempt to increase the yield of crops per hectare by manipulating genetic make-up of the crops and the agronomic inputs, the ME value of these crops also changes (Fancher et al. 1987).

Table 1   AME and AME_n (MJ/kg food) measured with broilers (B) and cockerels (C)

Average food intake g/bird/day	Bird type	MJ/kg food AME	AME_n
4.56	C	6.08	9.63
7.54	C	8.90	10.98
14.08	C	10.83	11.95
9.89	B	10.86	11.83
19.53	B	12.81	12.84
27.95	B	12.74	12.71

A new life was infused into this stagnant field by **Sibbald** (1976) who developed a rapid method (less than 4 days) for energy determination using mature roosters. He was a visionary, and developed the concept of true metabolizable energy (TME) for poultry. The implication is that the **AME** determined by the classical method must be untrue because the endogenous energy in excreta was not considered. TME is equal to **AME** plus endogenous excreta energy. **Halloran** (1980) figured that TME was about 1.1 to 1.16 x AME_n for a large number of ingredients. **Sibbald** (1983) also had to reconcile with the followers of Hill's N-correction, and   coined   the   term   "nitrogen   corrected   true metabolizable energy (TME_n)."

Farrell (1978) followed the idea of the rapid method of **Sibbald** to determine **AME** of ingredients also using adult roosters. **Sibbald** uses forced feeding of a single test ingredient. This is not favored by animal welfare advocates. Farrell trains his roosters to eat in one hour their daily ration.

The accuracy of TME has been questioned by a number of workers (Farrell 1981; Hartel, 1986, **1987),** and **Sibbald (Sibbald** and Wolynetz **1987)** has demonstrated missionary zeal in his rebuttals, and perhaps won, because the future edition of Nutrient Requirements of Poultry will also lists TME_n values according to discussions in the last Poultry Science meeting. A comparison of AME_n, TME, and TME_n of some ingredients is given in Table 2.

Farrell et al. (1991) have compared the methods of ME determination using 4 different different diets, and conclude that "apparent metabolizable energy system should be retained."

Least cost formulations rely heavily on the information on effect of ME and contents on the price of an ingredient. Rapid determination of protein poses no problem, but of ME it is still too slow. Most laboratories are equipped to conduct proximate analysis. We go full circle to develop regression equations correlating proximate composition of an ingredient with its ME value **(Sibbald** 1989; Fisher 1989; Janssen and Carre' 1989). The general expression acceptable in The European Economic Community is as follows:

$$ME_n \text{ (MJ/kg)} = 0.3431 \text{ (\% fat)} + 0.1551 \text{ (\% crude protein)} + 0.1301 \text{ (\% total sugars as sucrose)} + 0.1669 \text{ (\% starch)}$$

It is questionable whether this expression is any better than many used previously. We may have to wait for another prophet to start another cult of ME values strictly acceptable by computers and not by questioning human beings.

Table 2 AME_n and TME_n of some commonly used ingredients on a dry matter basis

Ingredient	MJ/kg		
	$AME_n{}^1$	TME^2	$TME_n{}^2$
Barley	12.4	14.0	13.4
Corn (Maize)	15.6	17.2	16.4
Corn gluten meal, 60% CP	17.3	18.4	17.3
Feather meal	10.3	16.1	14.3
Meat meal	9.1	11.9	11.8
Millets	11.7	15.5	14.6
Oats	11.8	13.1	12.0
Peanut meal (Expeller)	11.4	12.2	11.2
Sorghum	15.8	16.7	16.1
Soybean meal, 48% CP	11.3	12.5	11.5
Wheat	14.7	15.5	14.8

1. NRC, 1984
2. Sibbald, 1986

AMINO ACID AVAILABILITY

Rat nutritionists published a lot of information on the biological value of different proteins as an indicator of their value for humans. The information was of no value in practice because the combination of proteins needed to balance the amino acid requirements had a biological value higher than that of the individual components.

Previously, the first limiting amino acid in a protein was regarded as an index of the nutritive value of a protein. With the development of amino acid determination by some form of chromatography, reports started appearing on the availability of amino acids in various protein sources based on their measurement in the diet and in excreta (urine and faeces). The amounts of endogenous amino acids excreted by normal and colostomised 4-week old chicks were 43 mg and 54 mg per 4 hours (McNab 1989), and 39 mg/4 hours by adult cockerels (Bragg et al. 1969). Elwell and Soares (1975) compared several procedures for assay of amino acid availability. Likuski and Dorrell (1978) used the methodology of TME to determine amino acid availability. Sibbald (1986) has compiled very useful information on bioavailability of amino acids from many feed ingredients.

Maiorino et al. (1986) found that true amino acid availability in corn, milo, soybean meal, wheat bran, and alfalfa meal was markedly influenced by tallow. The values varied for different amino acids. Unless the digestibility coefficients of amino acids in the dietary protein are the sum of the digestibility coefficients of the amino acids of the ingredient proteins, these data would be have no practical importance except for the bibliography of the investigators. After all, we have to publish or perish!

VITAMIN SUPPLEMENTATION

Vitamin B_{12} was the last vitamin to be discovered in 1948. Most of the vitamins except biotin are available at a reasonable price and are routinely added to poultry diets neglecting the contribution of other ingredients.

GROWTH HORMONES

The role of vitamin D has been better understood during the last 3 decades, and led by laboratories of DeLuca (Chen and DeLuca 1973) and Norman (Tsai and Norman 1973) with some argument about who deserves the priority credit. Vitamin D functions like a hormone. If the use of vitamin D supplements was not already accepted, I doubt that it would be cleared for use. People dislike the word hormone. We call growth hormones somatotropins to escape from that dilemma.

Humans have been scared of death from heart attacks due to high cholesterol in their blood, they are reducing their dietary fat intake. Consequently the testing of beta-adrenergic agonists on growth and carcass characteristics of poultry is quite active. The trade names of some of these compounds are clenbuterol (American Cyanamid), L-640,033 (Merck), Cimaterol (American Cyanamid) and BRL35135 (Beecham) (Muir, 1988). The studies on cimaterol (Dalyymple et al. 1984) and L-640-033 (Muir et al. 1985) suggested some reduction in carcass fat of broilers. Farrell is also interested in this field (Aijun and Farrell 1991). But the acceptance of somatotropin-treated poultry for meat by the general public is questionable.

NUTRITION AND IMMUNE RESPONSE

Several studies indicate that the nutrient requirements for optimum immune response of poultry are less than those for optimum growth (Glick et al. 1983; Klasing 1988).

COMPARISON OF DIETS OF 1963 AND 1993

A better measure of understanding of the advances during the last 30 years is to compare a diet of 1963 with one of 1993. Due to cost and shortage of supply, alfalfa meal and fish meal are no longer popular. Meat meal is still used widely. The main differences are the levels of vitamins and trace elements used. Selenium addition is now routine.

CONCLUSION

Just as the poultry industry has changed, so too has the attitude of some editors of poultry science journals. If the investigators who made most of the fundamental discoveries in nutrition were to submit their papers today, they would be rejected for lack of statistical analysis and the small number of experimental animals. Most institutes lack funds and facilities to run commercial-type experiments, and are never sure if a difference in price of their diets of 2 cents per kg is really significant. To the agribusiness accountant, a difference of even 0.5 cents per kg implies a profit or loss of million of dollars per year.

Table 3   Broiler starter diets of 1963 and 1993 (kg/1000 kg)

Ingredient	1963	1993
Alfalfa meal	15.0	-
Corn	542.0	520.8
Soybean meal, 48% CP	237.5	328.5
Corn gluten meal, 41% CP	25.0	-
Corn gluten meal, 62% CP	-	41.5
Dist. solubles + grain	20.0	-
Meat and bone meal	50.0	25.0
Fish meal, 60% CP	50.0	-
Fat	50.0	67.5
Dicalcium phosphate	2.5	17.3
Calcium carbonate	2.5	13.0
Salt	2.5	3.5
DL-Methionine	0.04	1.6
L-Lysine.HCl	-	0.5
Vitamin supplement	2.5*	5.0**
Trace element supplement	0.25	-
Coccidiostat	0.5	0.8
Calculated		
AME_n, kcal/kg	3,168	3,221
CP, %	24	23.2
Lysine, %	1.39	1.25
Methionine + Cystine, %	0.88	0.94

* Supplement supplied per kg diet: Vitamin A, 4,400 IU; vitamin D_3, 1,100 ICU; vitamin E, 2.2 IU; vitamin B_{12} 0.01 mg; riboflavin, 4.4 mg; niacin, 27.5 mg; pantothenic acid, 8.8 mg; menadione, 1.5 mg; Folic acid, 0.33 mg; ethoxyquin, 100 mg; manganese, 13.2 mg; zinc, 9.9 mg; iron, 4.4 mg; copper, 0.55 mg; iodine, 0.28 mg; cobalt, 0.11 mg.

** Supplied the following per kg diet: Vitamin A, 8,000 IU; vitamin D_3, 2,000 ICU; vitamin E, 8 IU; menadione, 2 mg; riboflavin, 5.5 mg; pantothenic acid, 13 mg; choline, 500 mg; Vitamin B_{12}, 0.02 mg; folic acid, 0.5 mg; thiamine, 1 mg; pyridoxine, 2.2 mg; biotin, 0.05 mg; ethoxyquin, 100 mg; manganese, 65 mg; iodine, 1 mg; copper, 6 mg; zinc, 55 mg; iron, 80 mg; selenium, 0.3 mg.

REFERENCES

AIJUN, Y., and FARRELL, D. J. (1991). Br. Poult. Sci. 32: 337-342.

BRAGG, D-B., IVY, C.A. and STEPHENSON, E.L. (1969). Poult. Sci. 48: 2135-2137.

CHEN, T.C., and DELUCA, H.F. (1973). J. Biol. Chem. 248: 4890-4895.

DALRYMPLE, R.H., RICKS, C.A., BAKER, P.K., PENSAK, J.M., GINGHER, P.E. and INGLE, D.L. (1984). Poult. Sci. 63: 2376-2383.

ELWELL, D., and &ARES, Jr., J.H. (1975). Poult. Sci. 54: 78-85.

FANCHER, B.I., JENSEN, L.S., SMITH, R.L. and HANNA, W.W. (1987). Poult. Sci. 66: 1693-1696.

FARRELL, D.J. (1978). Br. Poult. Sci. 39: 303-308.

FARRELL, D.J. (1981). Wld. Poult. Sci. J. 37: 72-83.

FARRELL, D.J., THOMSON, E., DU PREEZ, J.J. and HAYES, J.P. (1991). Br. Poult. Sci. 32: 483-499.

FISHER, C. (1989). In "Recent Developments in Poultry Nutrition", pp. 27-53, editors D.J.A. Cole and W. Haresign, (Butterworths, London).

FISHER, W.D. and SCHRUBEN, L.W. (1953). J. Farm Econ. 35: 471-483.

FRAPS, G.S., CARLYLE, E.C. and FUDGE, J.F. (1940). Texas Agric. Exp. Station Bull. Number 589.

GLICK, B., TAYLOR, R.L., MARTIN, D.E., WATABE, M., DAY, E.J. and THOMPSON, D. (1983). Poult. Sci. 62: 1889-1893.

HALLORAN, H. (1980). Poult. Sci. 59: 1552-1553.

HARTEL. H. (1986). Br. Poult. Sci. 27: 11-39.

HARTEL, H. (1987). Br. Poult. Sci. 28: 784-788.

HILL, F.W. (1957). Proceedings of the Cornell Nutrition Conference, pp. 22-32, Cornell, Ithaca, NY.

HILL, F.W. and ANDERSON, D.L. (1958). J. Nutr. 64: 587-603.

JANSSEN, W.M.M.A. and CARRE', B. (1989). In "Recent Developments in Poultry Nutrition", pp. 78-93, editors D.J.A. Cole and W. Haresign, (Butterworths, London).

JULL, M.A. (1951). "Poultry Husbandry". (McGraw-Hill Book Co., New York).

KLASING, K. C. (1988). Poult. Sci. 67: 626-634.

LIKUSKI, H.J.A. and DORRELL, H.G. (1978). Poul. Sci. 57: 1658-1660.

MCNAB, J.M. (1990). Proceedings of the 7th European Symposium on Poultry Nutrition, 1989, pp. 49-57. World Poultry Science Association, Barcelona.

MAIORINO, P.M., AL-HOZAB, A.A., MITCHELL, R. and REID, B.L. (1986). Poult. Sci. 65: 2304-2313.

MUIR,, L.A., WIEN, S., DUQUETTE, P.F. and OLSON, G. (1985). J. Anim. Sci., 61 (Supplement): 263 (abstract).

MUIR, L.A. (1988). Designing Foods. Animal Product Options in the Marketplace., pp. 184-193. (National Academy Press, Washington, D.C.)

NRC. (1984). Nutrient Requirements of Poultry (eighth revised edition). (National Research Council. National Academy Press, Washington, D.C.).

PYM, R.A.E., NICHOLLS, P.J., THOMAS, E., CHOICE, A. and FARRELL, D.J. (1984). Br. Poult. Sci. 25: 529-539.

SCOTT, H.M., MATTERSON, L.D. and SINGSEN, E.P. (1947). Poul. Sci. 26: 554 (abstract).

SCOTT, M.L., HEUSER, G.F. and NORRIS, L.C. (1948). Poult. Sci. 27: 773-780.

SIBBALD, I.R. (1976). Poult. Sci. 55: 303-308.

SIBBALD, I.R., BARRETTE, J.P. and PRICE, K. (1980). Poult. Sci. 59: 805-807.

SIBBALD, I.R. and MORSE, P.M. (1983). Poult. Sci. 62: 138-142.

SIBBALD, I.R. (1986). The T.M.E. system of feed evaluation: methodology, feed composition data and bibliography. Technical Bulletin 1963-4E. (Research Branch, Agriculture Canada, Ottawa, Ontario).

SIBBALD, I.R. and WOLYNETZ, M.S. (1987). Br. Poult. Sci. 28: 752-784.

SIBBALD, I.R. (1989). In "Recent Developments in Poultry Nutrition", pp. 13-26, editors D.J.A. Cole and W. Haresign, (Butterworths, London).

SLUIS, WIEBE V-AN DER and ARMSTRONG, H. (1992). Misset Wld. Poult. 8 (7) 20-21.

TITUS, H.W. (1955). The Scientific Feeding of Chickens. 2nd edition. The Interstate, Danville, IL.

TSAI, H.C. and NORMAN, A.W. (1973). J. Biol. Chem. 248: 5963-5975.