STUDIES IN THE AGRICULTURAL AND FOOD SCIENCES

RECENT ADVANCES IN ANIMAL NUTRITION - 1986

WILLIAM HARESIGN
D J A COLE

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AND FOOD SCIENCES

Recent Advances in Animal Nutrition—1986

W. Haresign, PhD
D.J.A. Cole, PhD
University of Nottingham School of Agriculture

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PREFACE

This, the proceedings of the Twentieth Annual Feed Manufacturer's Conference, contains chapters on a range of subjects relating to animal nutrition.

The first six chapters are concerned with the timely topic of fats in human health and animal nutrition. Considerable media coverage has recently been given to the need of the human population to reduce its saturated fat intake in order to reduce the risks of heart disease, and the need of the farmer to produce the appropriate products. The first chapter considers the evidence available on which this advice is based, and concludes that consumers may have been misled as to the importance of dietary saturated fat intake in this respect although a lively discussion indicated a wide variety of opinion. Two further chapters consider fat characteristics of animal products, the first of these outlining likely future trends in their marketing and the second the way in which the degree of saturation of carcass fats might be manipulated by dietary means. The remaining chapters in this group consider the antinutritional factors associated with those fats and oils which may be used in livestock diets, and the new official EEC analytical methods for fat determination in animal feedingstuffs and their implications to the feed compounder and nutrition research.

The next series of chapters considers the impact that biotechnology may make on the nutrition and production of farm livestock. The first of these attempts to highlight the implication that biotechnology may have in the future, and also indicates areas in which it is already being used to improve the nutritive value of animal feeds and their utilization by the animal. This is followed by a discussion of the milk yield responses of lactating dairy cows to bovine growth hormone, a hormone which can now be produced in large quantities by recombinant-DNA techniques. The third chapter on biotechnology considers the effects that β-agonists, materials which alter the partitioning of nutrients within the body, can have on carcass composition, and illustrates that they can increase considerably lean deposition at the expense of fat content.

The final group of chapters considers a number of unrelated topics of general nutritional interest. In the past the nutritive value of forages for ruminants has been determined by chemical analysis. A recent innovation is the use of near infrared reflectance spectrometry, which is a much simpler and more rapid technique. One chapter, therefore presents the results of a recent study to adapt this technique for forage analysis. The presence of residues of materials such as antibiotics, anthelmintics and pesticides in animal products is a topic of increasing concern to public health officials and consumers. One chapter is devoted to a consideration of how these residues might arise, the extent of this problem, the safety aspects of it, and the screening that is used to help ensure that none of the food we eat exceeds the safety limits imposed.

Two chapters relate to the interaction between nutrition and animal health, the first considering the importance of micronutrient supply within the diet on the ability of the animal to fight invading disease organisms, and the second the use of probiotics to improve the performance of farm livestock. A further chapter discusses alternative methods of supplying micronutrients to ruminant livestock, and the final one considers the potential for using synthetic amino acids in diets of pigs and poultry.

The organizers and the University of Nottingham are grateful to BP Nutrition (UK) Ltd, for the support they gave in the organization of this conference.

W. Haresign
D.J.A. Cole

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Fats in Human Health and Animal Nutrition

1

DIETARY FAT AND HUMAN HEALTH

G.J. BRISSON
Centre de Recherche en Nutrition and Département de Zootechnie, Université Laval, Ste-Foy, Québec, Canada

Ischaemic heart disease, or coronary heart disease, remains the major cause of death in men, aged 30 to 60, in most countries where a high standard of living is enjoyed. In these countries, dietary fat constitutes a large proportion of the total caloric intake. It has been estimated that approximately 40% of total calories come from fat, mostly animal fat. A great deal of medical research concerned with ischaemic heart disease has been carried out during the past 30 years. Much of it was inspired by the so-called 'lipid hypothesis'.

Scientists in the field of animal science, as well as meat, egg and milk producers are concerned about the sustained propaganda and incomplete or controversial information leading consumers throughout the world to believe that food products of animal origin, because of the type of fat they contain, might constitute a hazard to their health. Therefore, it appears necessary to review data accumulated in connection with the lipid hypothesis, and take position on the diet/heart disease theory, an issue which remains confusing for the consumer and prejudicial to the animal industry.

This chapter is based on a *position paper* adopted by the Canadian Society of Animal Science and the Agricultural Institute of Canada at a joint meeting held 24–26 June 1985 in Charlettetown, Nova Scotia, Canada. The positions relate to the prevention of ischaemic heart disease in the population at large and pertinent dietary recommendations to be made to the general public. Therefore, these positions address the population in general, the free-living people as opposed to people living in institutions or requiring special medical care due to whatever causes.

THE LIPID HYPOTHESIS

The lipid hypothesis is based in part on epidemiological studies indicating a moderate mathematical correlation between the level of serum cholesterol and the probability of developing clinical ischaemic heart disease (Kannel, 1976). Such studies led to the first part of the lipid hypothesis associating the development of atherosclerosis in man, ischaemic heart disease, and the level of cholesterol in blood.

Other studies, based on vital statistics and food disappearance records in different countries, led to another mathematical association (simple correlation coefficient) between the consumption of foods containing cholesterol and mortality rate due to coronary heart disease (Stamler, 1979). The second part of the lipid hypothesis, inspired partly by such an association, tends to link ischaemic heart disease, serum cholesterol and the intake of foods containing cholesterol.

It can be observed, however, that in countries where there is a tendency towards a greater consumption of foods containing cholesterol, there is also a tendency for a higher consumption of sugar, eggs, fat, milk, meat, as well as the consumption of other commodities such as cigarettes, etc. (Stamler, 1979); all these commodities are related to one another. When variables are associated with one another, as in this case, simple correlation coefficients are meaningless in attempting to explain a relationship between a disease, in this case ischaemic heart disease, and the consumption of given commodities. Stepwise multiple regression analysis would be more appropriate.

When such an analysis was applied to data from 30 countries, it was found that sugar and cigarette consumption could explain most of the relationship between commodity consumption and ischaemic heart disease (Armstrong *et al.*, 1975). Adding the consumption of meat, milk, butter and eggs, had an insignificant effect on the relationship. This may explain why Yudkin (1957) who analysed data for 15 countries, found no association between coronary mortality and the intake of animal fat, calories from fat, butter fat and vegetable fat.

Furthermore, it is to be noted that a mathematical association between two variables, whatever the level of probability from the statistical point of view, is not necessarily a demonstration of a cause-and-effect relationship. Therefore, epidemiological studies based on commodity consumption in different countries are not necessarily supportive evidence for the lipid hypothesis.

Nutrition policies originating primarily in the USA are being promoted on the assumption that eventually the lipid hypothesis will be supported by adequate scientific evidence. These policies include recommendations to reduce the intake of dietary cholesterol and consequently of red meat, eggs, butter fat, cheese, pork and poultry meat. It is possible that these nutritional policies are still premature. In fact, a great number of physicians, nutritionists and investigators do not agree with such policies and recommendations, primarily inspired by a hypothesis that has not been scientifically shown to be true (Ahrens, 1976; Olson, 1977; Harper, 1978; Harper, 1979; McMichael, 1979; Ahrens, 1979a; Reiser, 1979; National Nutrition Consortium, 1980; American Council on Science and Health, 1980; American Academy of Pediatrics, 1983).

A rationale of the Diet-Heart Statement of the American Heart Association was published in an attempt to explain to the general public the logic of its specific dietary recommendations; that is, a substantial reduction in dietary cholesterol and the consumption of saturated fats, which, in practice, means a substantial reduction in the daily consumption of food items of animal origin (Grundy *et al.*, 1982). A critique of this rationale written by Reiser (1984) ended as follows: 'Thus the Rationale is not a logical explanation of the dietary recommendations but an assemblage of obsolete and misquoted references. Since rational explanations for the recommendations are essential for their acceptance, the public to whom they are addressed is justified in remaining skeptical of them'. This critique is indicative of weaknesses with regard to the evidence used to support the lipid hypothesis.

Position

The lipid hypothesis associating atherosclerosis, ischaemic heart disease and the consumption of foods of animal origin is prejudicial to the world animal industry when it is used as a basis for adopting nutritional guidelines and recommendations addressing the general public; consequently, scientific data dealing with the inherent assumptions of this hypothesis should be analysed and position should be taken on each point.

Dietary cholesterol and blood cholesterol

The lipid hypothesis carries the assumption that the intake of dietary cholesterol in the form of food products of animal origin would be responsible for elevated blood cholesterol in populations where the incidence of ischaemic heart disease is high. This question has been extensively studied in different subgroups of the population. Some studies go as far back as 1956 when Keys *et al.* (1956) studied the serum cholesterol level and cholesterol intake in 50-year-old healthy businessmen and professionals living in Minnesota, USA. Two groups were formed, those whose cholesterol intake was 400 mg/day (Group 1) and those whose intake was 1000 mg/day (Group 2). They found that serum cholesterol levels were 249 ± 41 and 256 ± 43 mg/100 ml for Groups 1 and 2, respectively. The small difference in the serum cholesterol level between these two groups of men was not statistically significant. The authors concluded: '. . . in the adult man the serum cholesterol level is essentially independent of the cholesterol intake over the whole range of natural human diets'.

The Tecumseh study could be used as another example where the same conclusion was reached (Nichols *et al.*, 1976). In this study, the average daily intake of cholesterol of 2000 free-living people was calculated and the serum cholesterol level of all subjects was measured. It was found that blood cholesterol varied independently of dietary cholesterol. This was further evidence that in free-living people, dietary cholesterol is not the element controlling the concentration of cholesterol in blood.

The egg is perhaps the most commonly consumed cholesterol-rich food. One whole egg contains 250 mg of cholesterol. It is normal that most studies dealing with the effect of dietary cholesterol on blood cholesterol used the egg as a source of dietary cholesterol. In one of these studies, 116 male volunteers averaging 46 years of age added two eggs (about 500 mg of cholesterol) daily to their regular diet, while a similar group maintained their usual diet without adding eggs. After three months, the treatments were reversed and lasted an additional three months: those taking two additional eggs daily discontinued adding the eggs and those who had kept their usual diet added two eggs as planned. It was observed that adding two eggs daily to the diet, or withdrawing them (*Table 1.1*), had no effect on average serum cholesterol levels (Flynn *et al.*, 1979). This is a clear contradiction of the lipid hypothesis.

It should be remembered at this point that cholesterol is essential to animal life. It is the precursor of many substances such as bile acids, male and female sex hormones, and adrenal cortical steroid hormones. Cholesterol is also essential for the formation of healthy cell membranes. The total content of cholesterol in the

Table 1.1 SERUM CHOLESTEROL LEVELS IN MEN ADDING OR WITHDRAWING TWO EGGS DAILY TO AND FROM THEIR USUAL DIET FOR A PERIOD OF THREE MONTHS (mg/100 ml)

Group 1			*Group 2*		
Initial	*+Eggs*	*−Eggs*	*Initial*	*−Eggs*	*+Eggs*
214 ± 35	213 ± 301	213 ± 30	203 ± 39	198 ± 36	198 ± 40

After Flynn *et al.* (1979)

body is about 140 g, of which about 120 g is present in membranes (Newsholme and Leech, 1983). Since the body is in a dynamic rather than a static state, all body cells must be constantly provided with cholesterol. A constant supply is ensured by the intake of cholesterol as food, on the one hand, and in many animal species including man, by biosynthesis in specialized organs such as the liver and the intestine, on the other.

The level of circulating blood cholesterol in healthy human beings is mainly the result of mechanisms controlling the synthesis of cholesterol at the cellular level (Brown and Goldstein, 1976; White *et al.*, 1978; Newsholme and Leech, 1983; Brown and Goldstein, 1984). Cell membranes have specific receptors for the Apo B of low density lipoproteins (LDL). The attached LDL carrying blood cholesterol penetrate the cells where they are disintegrated to deliver their content of cholesterol. Free cholesterol then:

(1) slows down the biosynthesis of new cholesterol molecules by inhibiting the enzyme hydroxymethylglutaryl coenzyme A reductase,
(2) slows down the synthesis of the Apo B receptors,
(3) activates the enzyme acyl coenzyme A:cholesterol acyltransferase.

These reactions tend to curtail the accretion of cholesterol in blood plasma.

Such a feedback mechanism may explain why Simons *et al.* (1978) came to the conclusion that, under the conditions of their experiment, '. . . no relationship could be demonstrated between absorbed dietary cholesterol and plasma cholesterol levels'. The above mechanism, however, may not function to the same extent in all individuals, so that dietary cholesterol may tend to increase blood cholesterol levels in some individuals and not in others. For the population in general, however, the scientific evidence cited above shows that large variations in cholesterol intake do not reflect themselves in serum cholesterol level.

In view of these observations and many others summarized or reviewed by Mann (1977), McGill (1979), American Council on Science and Health (1980), and Brisson (1981), it appears justified to take the following position:

Position

> The intake of cholesterol in the form of food products of animal origin has an insignificant effect on the concentration of cholesterol in the blood of healthy persons representative of the population in general.

TOTAL CHOLESTEROL *VS* ABSORBED CHOLESTEROL

Dietary cholesterol is obtained primarily from foods of animal origin such as beef, pork, poultry meat, veal, lamb, milk fat, seafood and eggs. In spite of the sustained interest in the suspected relationship between dietary cholesterol and blood cholesterol, in relation to atherosclerosis and ischaemic heart disease, limited information is available on both the cholesterol content of foods of animal origin and the percentage absorption of exogenous cholesterol in normal humans.

A summary of available data on food cholesterol and analytical methods used, published by Sweeney and Weihrauch (1976), clearly showed that the mean cholesterol content of various food items appearing in present food composition tables are of doubtful practical meaning. Often, values reported for the same food item, by different investigators, vary by more than 100%. Many factors, other than analytical method, may affect the cholesterol content of foods of animal origin. Such factors include animal species, age, sex, breed, particular meat cut, cooking, canning, season and country of production, etc.

Furthermore, total food cholesterol content obtained by chemical analysis may have little significance from the biological point of view, because of poor and extremely variable absorption. In human beings, cholesterol absorption expressed as a percentage of cholesterol intake, may vary from 15 to 71%, with an average near 40% (Grundy and Ahrens, 1970; Quintao, Grundy and Ahrens, 1971; Grundy and Mok, 1977). This means that nearly 60% of the cholesterol taken in food would not pass into the blood but would be excreted in the faeces.

Factors, other than individual variation, may also influence the absorption rate of cholesterol. Among these is the presence of plant sterols in the intestinal lumen. Plant sterols interfere with the absorption of cholesterol, but 'their high degree of potency for this action is generally not appreciated' (Grundy and Mok, 1977). As a consequence, the absorption of cholesterol in a mixed diet may be lower than 40%. Therefore, meaningful values for the cholesterol content of food items of animal origin are likely to be much lower than publicized in the media and sometimes appearing in the scientific literature.

There is a need for reinvestigation of the cholesterol content of foods by recently developed and more appropriate methods. Until this is done, many cholesterol values presently available for foods of animal origin can only be considered as approximations and should be used with caution. There is also a need for more studies regarding the rate of absorption of cholesterol taken in the form of mixed diets representative of what is normally consumed by free-living people. 'What really matters too is the effect of foods in the range that people normally consume' (Truswell, 1978).

Position

There is little accurate information on the cholesterol content of food of animal origin as produced and consumed in a given country. Furthermore, available data indicate that the absorption of dietary cholesterol may be limited and extremely variable from one individual to another. Under such circumstances, results of chemical analyses may bear little significance on a biological basis. This is additional justification for the Government not to permit the labelling of foods for their cholesterol content nor using cholesterol content in advertising food items.

Saturated *vs* polyunsaturated fatty acids

Dietary fats consist of mixed triglycerides which are formed by the esterification of glycerol with saturated and unsaturated fatty acids. Fats are said to be saturated if they contain a large proportion of saturated fatty acids, as compared with unsaturated fats which are rich in unsaturated fatty acids. Stearic acid is an example of a saturated fatty acid, and linoleic acid of a polyunsaturated fatty acid. Fats of animal origin are generally considered to be saturated and fats of vegetable origin unsaturated. The two types of fat contain both saturated and polyunsaturated fatty acids but the ratios differ in each class. The ratio of polyunsaturated to saturated fatty acids in a given dietary fat is called the P/S ratio. The P/S ratio of fat produced by ruminant animals varies between about 0.03 and 0.1; fat produced by monogastric animals, pigs and poultry, has a ratio varying from about 0.2 to 1.3, depending upon the nature of the fat included in the diet of the animals.

The interest in polyunsaturated and saturated fats, in relation to ischaemic heart disease, goes back to the 1950s when some investigators considered the possibility that the daily consumption of large amounts of vegetable fats rich in polyunsaturated fatty acids (PUFA) might help to lower blood cholesterol in patients suffering from coronary heart disease (Ahrens *et al.*, 1957).

Epidemiological studies of the same nature as those discussed above, carried out in different countries, led to the calculation of a statistically significant simple correlation coefficient between the consumption of saturated fat and the incidence of mortality due to ischaemic heart disease (Keys, 1970). Such studies carried the same faults as those presented above and were severely criticized, principally by Wood (1981). Furthermore, it must be realized that, although statistically significant correlations were found between consumption of saturated fatty acids and ischaemic heart disease in these epidemiological studies, a negative correlation between the intake of PUFA and ischaemic heart disease was never observed; in fact, in all these studies, the consumption of PUFA expressed as a percentage of total calories varied within narrow limits (4 to 7%) from one country to another.

Nevertheless, a moderately good simple correlation is generally recognized between dietary saturated fatty acids and ischaemic heart disease, when populations in different parts of the world are compared. But when the comparisons are made within the same cultural community, or for individuals, the correlation disappears (Oliver, 1982). Despite such divergent observations, it was hypothesized that substituting polyunsaturated fats for saturated fats in the diet would result in a lowering of serum cholesterol and, according to the lipid hypothesis, a lowering of the incidence of ischaemic heart disease. In view of the fact that animal fat is generally saturated, compared with vegetable fat, and since the influence of the nature of the fat consumed on the incidence of ischaemic heart disease is still hypothetical, it is important for everyone concerned to take a position on this matter.

The National (USA) Diet-Heart Study is an example of studies carried out to verify the hypothesis that substituting polyunsaturated fat for saturated fat in the diet would result in a lowering of blood cholesterol (National Diet-Heart Study Research Group, 1968). The study included 1000 men aged 40–59 years, known to be healthy and to have no history of heart diseases. The control diet was representative of the North American diet: saturated fat provided 12% of energy and polyunsaturated fat, 5%. The experimental diet was typical of diets recommended on the basis of the lipid hypothesis: polyunsaturated fat provide 11% of calories and saturated fat, 7%. The P/S ratio was 400% higher in the experimental than in the control diet. The cholesterol content of both diets was maintained constant at approximately 140 mg/Mcal (586 mg/MJ). The experiment lasted 52 weeks.