THE EFFECT OF NUTRITION ON THE COMPOSITION AND QUALITY OF ANIMAL FATS

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Abstract

Nutritional factors are among the most important of those which determine the composition and quality of animal fats. The composition in terms of fat acid components and characterized by relative firmness, is more affected by ingested fat than by other dietary constituents.

Various aspects of the problems of quality in lard and butter are discussed, as well as the relation of nutrition to the composition and quality of the body fats of sheep, cattle and poultry, and of the egg yolk fat of poultry.

AMONG the factors determining the composition and quality of animal fats, those of a nutritional nature take first rank. Not only does the nutrition of the animal have certain direct effects, but it is interrelated with species, environmental and other influences. To a considerable extent, these nutritional factors are subject to control by man; hence assume added importance.

Those fats which are important items of commerce are relatively few. Of the body fats, lard and beef tallow are the important ones and rank only secondary to butter. However, the problem of composition and quality does not end there. The association of fat with lean tissue in pork is evident to all and the problem of quality with respect to firmness is especially important. The importance of fat in determining the quality of beef, lamb and to a lesser extent, fowl, has been emphasized in recent years with respect to marbling. Relatively little attention has thus far been given to the fat in egg yolk.

The composition of the animal fats has been extensively studied in recent years with respect to fat acid components. Methods of analysis are still cumbersome and inexact in the sense of quantitative separation of the individual acids. Where formerly stearic, palmitic, oleic and sometimes linoleic were said to occur in body fats, there has been added to the list myristic, arachidonic, arachidic, linolenic and palmitoleic, with others in some instances. In the case of butter fat, recent additions to the known list include decenoic, tetradecenoic, hexadecenoic, arachidonic and others, as mentioned by Dr. Brown.

Largely because of the difficulties involved, progress on glyceride structure and distribution of glycerides has been relatively slow. However, it is evident that the combinations of fat acids into glycerides as well as the distribution of acids contribute to quality factors.

Quality in the animal fats receives its main emphasis in the case of butter and lard. Quality in butter is defined in terms of flavor, body texture, moisture, color, salt content and general appearance. By definition in terms of government standards, lard is the rendered fresh fat from hogs in good health at the time of slaughter, is clean, free from rancidity, and contains, necessarily incorporated in the process of rendering, not more than 1 per cent of substances other than fatty acids and fat. While nothing is said about firmness in this definition, there is a strong consumer preference for firm lard as contrasted with oily. The standard of preference is largely the result of longtime usage. In the case of lard, American preference is the result of usage of pork fat rendered from hogs grown and fattened in the cornbelt on the staple crop of that region, corn. In Europe, the fat of American corn-fed hogs is considered soft in comparison to the European lard made from hogs fed potatoes, barley and other feeds less softening than corn.

Nutritional factors concerned in the problem of fat composition and quality may be grouped as those primarily determined by the character of the diet and those in which physiological factors as governed by species, sex, heredity, environment and other functional activities regulate or more properly modify the usual course of fat formation. Of the dietary factors, chief interest in recent years has centered about the effects of ingested oils on body fats in comparison with the effects of a protein-carbohydrate diet. A number of other dietary factors also play a vital role. They may be classified as growth and fattening retardants and include vitamins, minerals, reduced or restricted intake of energy-yielding constituents, and others.

Discussion

While the term normal has often been applied in determining the characteristic composition of the fat of a particular animal species, it is to a considerable extent man-made. That is, agricultural practice has imposed restrictions on the dietary of domestic animals. This is well illustrated in the difference between the fat of hogs typified by American cornbelt and European production as already described. It has seemed logical to take as a standard of reference the fat synthesized on a diet as low as possible in fats but otherwise provided with optimum levels of dietary essentials. The herbivora, when they subsist on green forages, are probably nearest to this state since the quantity of simple fats in forages available for conversion to body fats is especially low.

Students of dairy cattle nutrition have often expressed the conclusion that the fat content of a dairy ration should approximate the fat content of the milk.

On the other hand, hogs require a high proportion of concentrate feeds. Many of these, such as peanuts and soybeans, are high in fats and what is even more to the point, hogs thrive unusually well on them. Numerous oil meals including peanut, soybeans and linseed also other millfeeds such as rice, polish rice, bran and germ products, also produce marked softening.

Studies conducted by the Department of Agriculture in cooperation with State experiment stations in quality of meat studies with hogs have shown that a low fat diet will generally produce a uniformly hard body fat irrespective of the proportionality between protein and carbohydrate. The source and kind of carbohydrate, whether starches or sugars such as sucrose or lactose, also appear not to be important factors. In a general way, the proportion of protein and carbohydrates does not greatly influence the *quantity* of fat laid down as adipose tissue. The most noteworthy difference observed in this respect is that between starch and sucrose on the one hand and lactose on the other (14). The finding that lactose was less fattening than sucrose or starch has generally supported the conclusions of human nutrition studies. (Feyder (4) has reported that rats fed equi-caloric levels have formed more body fat on a ration containing sucrose than one containing glucose.) The fat deposited by the hog on low-fat diets is made up largely of oleic, palmitic, and stearic acids in the order named. Small amounts of linoleic, myristic, arachidonic and possible traces of other acids occur, but these do not appreciably affect the firmness of the fat. Softening is brought about in large measure by increase in the content of linoleic acid traceable in most instances to the ingested fat.

The main difference between the body fat of hogs and that of cattle and sheep similarly fed on low-fat diets appears to be in the higher proportion of the saturated acids, especially stearic in the tallows of cattle and sheep. Glyceride structure with consequent effect on melting points helps to accentuate the difference in firmness between lard and tallow.

Within the animal species some differences in body fat composition may result because of the interaction of physiological regulation with the purely dietary factors. The environmental temperature not only affects the species but the individual. Many years ago Henriques and Hanson (5) showed that a pig kept unprotected in a cold room deposited a softer subcutaneous fat than one in warm room or one protected by a sheepskin in a cold room. Only recently, Sinclair (12) in Canada has reported that the fat of winter-fed hogs had a higher iodine number than summer-fed hogs.

Inherited characteristics within a breed may also influence the type of fat deposited. At the Iowa Station, Lush and co-workers (9) have noted such a phenomenon in hogs. Unpublished work in the Department generally supports this observation. While the differences reported by Lush and co-workers are not wide, they are of sufficient significance to warrant further study in the direction of developing strains tending to form a firm fat. Neither the temperature nor the heredity factor may act alone. It is likely that on the usual diet, which contains some fat, regulation of the fat formation and deposition mechanism may shift the balance in the proportions of fat acids derived from the foods and those synthesized from carbohydrate and protein either in the direction of greater softness or greater firmness.

The soft and oily pork which finds its way into commercial channels is largely the result of feeding peanuts, soybeans, various oil meals, and other feeds high in oil content to hogs during the fattening period. During recent years, the soybean has been especially important. Frequently the fatness of the animal as determined by the relative abundance of feeds on the farm enters into the picture.

Not only is the lard from soft hogs regarded as of inferior quality as to handling and keeping qualities, but the bacon and sausage have lower sale value in communities with a strong consumer preference for firm pork. It has been claimed that soft lards become rancid more quickly than hard lards, due to the higher content of unsaturated acids. While peroxide values generally increase more rapidly on unsaturated oils it does not necessarily follow that a corresponding degree of organolytic rancidity will develop.

A comparison made in our laboratory of lards from hogs fed peanuts, corn and brewer's rice, showed that the peroxide values rose most rapidly in the soft lard from peanut-fed hogs and least rapidly in the very firm lard of the rice-fed animals. However, organolytic tests were inconclusive in indicating any difference in time of development of rancidity. The subject of rancidity is too involved to discuss further at this time. However, any claims that soft lard as a class becomes rancid more quickly than hard lards must be questioned.

The culinary properties of soft and hard lards are not greatly different as judged from work reported by the Iowa Station (11) and the Department (8). Nevertheless, it is likely that consumer preference will continue to favor the use of firm lard.

The grain and millfeed supplements used in fattening beef cattle and lambs introduce only moderate amounts of plant oils into the ration. A large number of examinations of the fat from both beef and lamb made in the Department in the course of the cooperative meat investigations have disclosed none that could be classed as soft. Lamb carcasses showed a considerable range in firmness of the adipose tissue. However, firmness was not correlated with saturation of the rendered fat, but rather with the fat content of the tissue and the fatness of the carcass.

The effect of ingested soybean, corn, menhaden and coconut oils on the firmness of beef fat has been reported in recent years by workers at the Iowa Experiment Station (2, 13). They found that the consumption of added oils at levels considered in excess of any likely to occur in practice had no deleterious effect on the firmness of the carcass or the palatability of the meat. Changes in the iodine number of the kidney, caul and back fat were slight except in the case of the kidney and caul fats from steers which received menhaden oil.

Fat metabolism in poultry appears to function similarly to that in swine in that the ingestion of oils leads to an easily demonstrable effect on the body fat and on the fat of the yolk of the egg. Hilditch and co-workers (6) point out that hen fats appear to be intermediate in character to the fat of land and marine animals as evidenced by the presence of palmitoleic acid and the relative scarcity of stearic acid. Cruickshank (3) has reported that young chickens fattened on a cereal diet deposited a moderately soft fat. The addition of 8 per cent of palm oil produced high quality carcasses with fat of natural composition, consistency, color and flavor. Mutton fat produced a hard body fat similar to the ingested material. However, it had no appreciable effect on the fat of the egg yolk in contrast to marked changes produced when linseed and hempseed oils were fed.

Those nutritional factors grouped as growth and fattening retardants bring about their effect largely through depression of body functions concerned with formation and deposition or secretion of fat. Vitamin deficiency may result in decreased food consumption and thereby retard fattening. Restriction of the energy intake of hogs has been found to reduce the fatness and the firmness of the pork. The lard rendered from the carcasses showed increased iodine numbers with restriction in feed in the case of corn fed but not in the case of wheat fed. In this case, it appears that quality of the pork may be more affected than composition of the fat, a distinction which must be made in various instances between characteristics of the adipose tissue and of the rendered or extracted fat.

Changes in butter fat brought about by feed are complicated by the presence of fat acids of low molecular weight which do not occur to any extent in the body fat or in the plant fats in feeds used by cattle. The changes in these acids naturally influence the changes in the others. In general, the mill feeds which are relatively high in ether extract when fed in large quantities, also blue grass pasture, tend to increase the iodine number (oleic acid content) and the per cent of volatile acids. Carbohydrate-rich feeds tend to produce the opposite effect.

The sustained interest in the subject of quality of animal fats is evidence of not only its importance but of continued progress in elucidating the many complex problems involved. On the one hand, there is need for a more adequate understanding of a biochemical process involved in fat formation in the animal body and on the other of the manufacture and standardization of the commercial product.

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Intermediary Metabolism Of The Lipids

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Abstract

The author reviews recent advancements in the study of the fate of lipids in metabolism. Brief discussions of the mechanism of absorption in the intestinal wall; of the role of lecithin, cephalin, sphingomyelin, and cholesterol in fat metabolism; of the metabolic changes in fats in the liver, and of the manner of oxidation of fats in the body, are presented.

This is not a general review but aims merely to deal with a few fields where recent investigations have turned up important material. Taking the metabolic events in order:

Absorption of Fat

In absorption from the intestine, it is now an accepted belief that there is a complete breakdown of the fat into the constituent glycerol and fatty acids, followed by resynthesis with apparently a rearrangement of the fatty acids in the molecule and possibly some chemical change—saturation or desaturation, or possibly dilution by fatty acids or fat from other sources. The sum of the changes results in a chyle fat somewhat different from the food fat. The change is toward the formation of a fat melting at about the animal's body temperature.

As in most other changes in fatty acid combination, phosphorization with formation of phospholipids is important as shown by the work of Sinclair (1) and Verzar and McDougall (2). There is little doubt that the fatty acids enter, to a considerable extent, into phospholipid combination in the epithelial cells of the absorbing surface of the intestine. In this connection, it is well to keep in mind the conception of Loew (3) who was one of the earliest to include the phospholipids in the theoretical scheme of fatty acid metabolism. His idea was that the phospholipid complex constitutes a framework to which the fatty acids are attached for purposes of transport and later combustion. The purpose of this combination in the intestine is for transport and possibly to lower the active mass of free fatty acids in the epithelial cells and thus hasten the diffusion from the intestine. The fatty acids thus attached to the framework are later, partly at least, shifted off again forming fat and probably cholesterol esters, two molecules of phospholipid contributing four fatty acids, three of which go to a fat molecule, the other to a cholesterol ester molecule (4). The stripped glycerophosphoric acid-choline complex can then take up more fatty acids. The percentage of phospholipid in the mucosa does not change much during fat absorption so that we have to assume either this fixed framework or a continuous passage out of the epithelium of phospholipid. The latter doesn't seem quite to fit the present facts since there is little increase of phospholipid in the thoracic duct lymph. On the other hand, the phospholipid of the blood plasma rises during fat absorption as does also the liver phospholipid, which may mean an absorption of the phospholipid directly into the blood stream. Moreover, this increased phospholipid in blood and liver contains the fatty acids being absorbed.

To what extent phosphorization takes place during these early stages of metabolism cannot be said. Most of the absorbed fat appears in the throacic duct, the blood and the liver as neutral fat, and undoubtedly most of it is transported as fat whether from the intestine or from the stores. It seems probable at present that the phosphorization is an accessory mechanism to speed the absorption of fat just as phosphorization increases the rate of absorption of dextrose (5). We cannot say to what extent phosphorization enters into the later stages of fatty acid metabolism. We don't yet know how the fat in the blood stream enters and leaves the stores nor whether, as Loew (3) and Leathes and Raper (6) believed, the fatty acids must be