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New strategies in animal feeding to improve consumer acceptance of animal products

F. Puchal Mas* and J. Mascarell**
*Facultat de Veterinària, Universitat Autònoma de Barcelona (UAB), Barcelona, Spain
**Industrial Técnica Pecuaria S.A. (ITPSA), Trav. de les Corts, 161, 08028 Barcelona, Spain

SUMMARY - Animal production is presently going through deep changes from the standpoint of product quality and consumer acceptance of animal products. New fears have been added to the well known sensitivity of consumers, frequently exacerbated by the media, towards the dangers of cholesterol, drug and antibiotic residues, etc., such as salmonella contamination of food and other foodborne diseases possibly transmissible to the consumer, such as the recent outbreaks of BSE or "mad cow disease", the broiler Hong Kong flu, etc. Both farmers and animal scientists alike should support a strong technological reaction in the sense to guarantee animal products of undoubted quality, free from any type of risks for the consumer. Current day objectives in animal production are presented and experimental results referring to the possible nutritional ways to achieve these goals are reviewed. The role of protein, amino acids and other nutrients, to increase proportion of meat while decreasing fat is discussed. The importance and possibilities of increasing the proportion of n-3 fatty acids in animal fats, without affecting their organoleptic properties, is reviewed and their implications in human health are examined. Vitamins, antioxidants and other nutrients are presented as nutritional tools to correct some of the metabolic dysfunctions brought about by genetic selection and improve the shelf life of animal products.

Key words: Animal nutrition, product quality, human health.

RESUME - *"Nouvelles stratégies en nutrition animale pour améliorer l'acceptation par les consommateurs des produits animaux". Les productions animales subissent, du point de vue de l'acceptation par les consommateurs, une situation de changement. A la déjà bien connue sensibilité du consommateur, exacerbée par les medias, vers les périls du cholestérol, les résidus de drogues et d'antibiotiques, etc., de nouvelles peurs ont été ajoutées, telles que la contamination des aliments par des salmonelles et d'autres toxi-infections alimentaires, qui pourraient être transmises au consommateur, comme le récent cas de la BSE ou maladie des vaches folles, la grippe hongkoneise des poulets, etc. Les producteurs ainsi que les chercheurs en production animale, devraient opposer, tous ensemble, une forte réaction technologique dans le sens de garantir des produits animaux d'une qualité indubitable, et libres de tout risque pour les consommateurs. Les objectifs actuels, dans la production animale, sont présentés ici, et les données expérimentels concernant les voies nutritionnelles pour les obtenir sont également révisées. L'importance de la protéine et des aminoacides, ainsi que des minéraux, pour augmenter la teneur en maigre en limitant la quantité de graisse est discutée. L'importance et les possibilités d'augmenter la teneur en acides gras n-3 dans les graisses animales, sans diminution de ses qualités organoleptiques, sont révisées en relation avec leur implication pour la santé humaine. Des vitamines, antioxydants et d'autres nutriments sont évalués comme outils nutritionnels pour corriger les dysfonctionnements métaboliques apportés par la sélection génétique, et améliorer la vie utile des denrées alimentaires d'origine animale.*

Mots-clés : *Nutrition animale, qualité des produits, santé humaine.*

Introduction

The production of food of animal origin (meat, milk and eggs) is presently going through a period of significant changes from the standpoint of consumer acceptance. The onset of the different types of problems causing this crisis comes from either modern technology in our production methods (intensive rearing, drug usage, etc.) or from the extreme sensitivity of the consumer towards product quality and health implications and quite frequently from both. Technological developments in animal nutrition and production plus the mass media communications explosion of recent years has favoured the appearance of these problems, both by easing the spread of the problem (improved facilities in animal transportation, either alive or their carcasses, from region to region or from country to country) as well as the subsequent publications of these problems, frequently in an unfounded or confused and alarming way, due to the sensationalistic eagerness of many media (press, television, etc.), frequently unsensitive to the profound economical effects that their articles and/or programs may produce in a society extremely susceptible to this type of information.

The consumption of certain types of animal products (beef, eggs, etc.) is experiencing, as a consequence of all this, a strong regression in most of the western societies, frequently not clearly evident, due to the sheer need to eat and faced with the problem to select a certain type of foods and not being able to choose from too many alternatives, as compared to the well known nutritive superiority of animal products.

The negative aspects that seem to be associated with foods of animal origin today could be classified until quite recently in two great groups: the intrinsic negative aspects, based on their own natural composition (saturated fats, cholesterol, etc.) and xenophobic aspects, that is, alien to the natural composition of these foods and a consequence of modern animal nutrition and feeding (residues from antibiotics, hormones, beta-agonists, etc.).

To this situation, difficult in itself, we have recently added a third group of negative points, equally xenophobic in nature, but this time with a possibly more evident pathologic effect on the consumer, much more serious and direct than those previously encountered. Let us list in this group the fear to the bovine spongiform encephalopathy (BSE) or "mad cow disease", worsened lately by the British law referring to the ban of meat products with bone, the recent swine cholera outbreak in different European countries, of extremely negative economical consequences in Europe, the publication in the press referring to broilers contaminated with *Campylobacter* spp., later proven to be unfounded and untrue, and more recently the questionable outbreak of the Hong Kong flu, as attributable to broilers and apparently transmissible to human beings and which motivated the slaughter of millions of broilers in the Hong Kong area.

The effects of these types of press releases on the animal production industry, seen with excessive frequency, creates an unduly alarmistic reaction in the consumer. The press and television programs on the Hong Kong broiler flu and the fear of a new world pandemia, has already begun its negative course in Spain and other countries. At a time when the fears to cholesterol and hormoned meats were beginning to disappear, new questions arise in our societies. "Can we eat beef?", "Should we stay away from pork?", "How about the Hong Kong chicken flu, should we refrain from eating chicken?", etc.

It is however unfortunate that we have to be faced with such an extreme degree of customer sensitivity towards the "risks" associated with the consumption of animal products. It is well known that if we should aim at "absolute" safety for animal food products, their cost might become prohibitive, considering the increasing need for food for an ever increasing world population. The benefits of using certain production stimulants for food animals should be carefully weighed against the risks envolved in their use. Unless we come upon similar products with an absolute degree of safety, which seems rather difficult to achieve, we may soon be faced with the impossibility to feed a world population that is growing at the astounding rate of 50 to 80 million people per year.

It is really unfortunate that when the technological efforts to counteract the first of these three forementioned groups (production of leaner meat, more unsaturated fats, lower cholesterol levels, etc.) and the second group (bans on the use of hormones, antibiotics, use of withdrawal periods, etc.) were being rather satisfactory, our progress has been jeopardized and set back by the appearance of the third group, against which we are relatively defenceless. However, and in spite of the strength of the negative factors against which we have to deal, much can be achieved with our knowledge and production technologies, both in nutrition as well as in management and disease prevention.

Faced with this situation of extreme sensitivity and fear to the consumption of animal products, we have to oppose a strong technological reaction, from the part of production experts and technical people alike in the sense to guarantee animal products of undoubted quality, free from any type of risks for the consumer and reestablish the consumer confidence towards the consumption of animal products.

These alarmistic trends in consumer demands, based on their extreme sensitivity towards health problems, associated either with the normal composition of these products (atherosclerosis, heart diseases, obesity, etc.) or with the xenophobic factors (hormones, drugs, antibiotic residues) or even with pathological factors (prions from "mad cows", flu viruses from broilers, etc.), plus the requirements for the production of the right type of products (leaner meats, less saturated fats, etc.) and the consequences of animal science developments in recent years (heavier weights at lower ages, greater production indexes, etc.), provide us with significant challenges and objectives in the animal production industries today (Table 1), that can be summarized in the three following demands: (i) we are asked to provide sufficient food for an ever increasing world population; (ii) we are asked to provide safe food; and (iii) we are asked to remain economically competitive.

Table 1. Objectives in animal production

Quantitative
Greater production of meat, milk and eggs
Less production of fat
Qualitative
Less saturated fats
Greater proportion of n-3 acids in the fat
Better meat texture and flavour
Greater proportion of leaner meats
More quality, both internal and external, of eggs
Productive
Better growth rates and production indexes
Better conversion rates
Greater utilization of feed by-products
Health and environmental aspects
Total absence of drug and antibiotic residues in animal products
Total absence of possible pathogen agent (prions, viruses, etc.)
Less environmental pollution

While a good part of these objectives can be attained through genetics, correct nutrient formulation, diet design and adequate management may accelerate the process in order to make animal products more attractive to the consumer. It is obvious that artificial selection will direct and accelerate changes in animals that will respond to market needs. However we should not forget that some of these genetic advances may disrupt the biological balance of the animals.

At the same time that we advance in production indexes (faster rates of growth, greater production of lean meat, etc.) we are increasingly faced with manifestations of biological dysfunctions, which threaten our progress (i.e., reproduction failures in heavily muscled animals, pulmonary hypertension syndrome (ascitis) in rapid juvenile growth, tibial dischondroplasia in broilers, etc.). Even though we can control and circumvent some of these problems by proper management practices, we should aim at properly balanced genetic advances which do not require subsequent corrective measures, either nutritional or managerial. Let us review some of the progress accomplished in line with the objectives described.

We have been able, through genetics, to significantly increase the rate of meat production, that is, greater body weight gains, both in pigs, poultry and cattle, as well as in other species. However, in many cases, these growth improvements are positively correlated with increased proportion of fat in the carcass (Barbato, 1992) in many species, such as the broiler.

We also know that not only through genetics but through proper nutrition meat production can also be improved in a significant way, not only in absolute values but in the sense of increasing protein accretion and decreasing fat production (Summers *et al.*, 1992). Both the effect of adequate protein and energy levels in the diet on lean and fat production have been clearly shown in the broiler (Fig. 1).

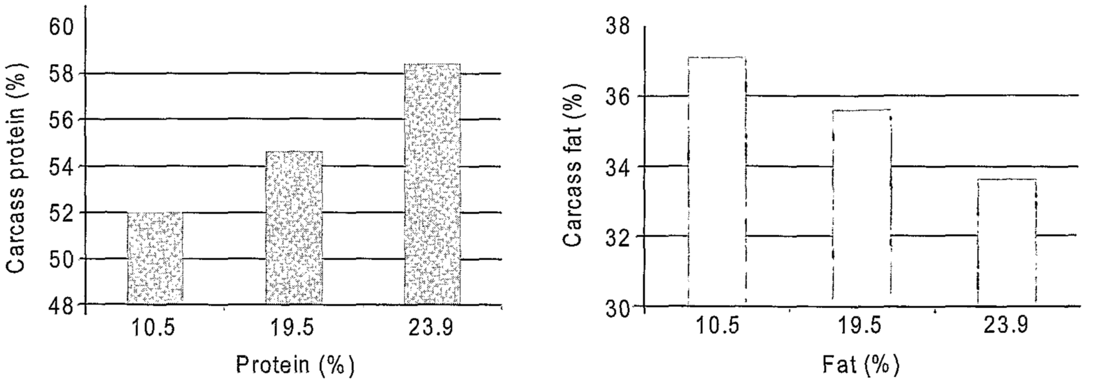

Fig. 1. Influence of dietary protein levels on broiler carcass protein and fat content (Summers *et al.*, 1992).

The study of protein levels in the production of leaner meats has led us into the finding that this effect was not exactly due to protein itself but to its amino acid components, mostly lysine. The results of Moran and Bilgili (1990) working with lysine levels in the broiler, while all other nutrient were kept identical, seem quite conclusive on this respect. Increasing lysine levels not only significantly increased protein accretion and simultaneously reduced fat deposition (Table 2), but increased proportion of desirable cuts in the carcass, both refrigerated (Table 3) and after cooking (Table 4).

Table 2. Influence of lysine on the refrigerated broiler† carcass composition (Moran and Bilgili, 1990)

Lysine (%)	H_2O (%)	Protein (%/DM)	Fat (%/DM)	Ash (%/DM)
0.85	66.1	41.3	44.2	6.9
0.95	65.7	45.1	37.2	8.3
1.05	67.2	46.7	34.3	9.4

†Males: 28-42 days

Table 3. Influence of lysine on proportion of cuts of the refrigerated broiler† carcass (Moran and Bilgili, 1990)

Lysine (%)	Carcass cuts (%)				
	Wings	Drums	Breast	Backs	Necks
0.85	13.0	15.8	29.9	14.3	7.5
0.95	12.9	16.2	30.2	14.0	7.3
1.05	12.9	16.0	30.4	13.9	7.2

†Males: 28-42 days

Table 4. Influence of lysine on the composition of the cooked broiler† carcass (Moran and Bilgili, 1990)

Lysine (%)	Cooked carcass (%)		
	Meat	Skin	Bone
0.85	57.1	14.4	27.5
0.95	59.2	13.1	26.0
1.05	59.6	12.3	26.9

†Males only

While lysine stands out as an essential amino acid in order to obtain highest breast yield in poultry (Sell *et al.*, 1994), the importance of reducing crude protein levels in the diet, while keeping adequate amino acid balance has been shown to maintain protein accretion and breast yield in turkeys (Table 5), as demonstrated by Kidd *et al.* (1997), and to simultaneously reduce nitrogen excretion and therefore ammonia in litter as a means to decrease pollution, while at the same time minimizing leg weakness and increasing profitability.

Table 5. Effect of crude protein and supplemental L-threonine on performance of male turkeys (Kidd *et al.*, 1997)

Parameter	Crude protein (%)†		
	100 + Thr 0.0 (%)	92 + Thr 0.2 (%)	84 + Thr 0.2 (%)
Liveweight (kg)	12.39[ab]	12.38[ab]	11.99[ab]
Cold carcass (% BW)	79.16[a]	79.72[a]	80.36[a]
Breast (% cold carcass)	28.17[abc]	28.96[abc]	27.67[c]
Drums (% cold carcass)	13.98[b]	13.17[cd]	13.88[bc]

†Based on NRC (1994) recommendations
a,b,c: Values with the same letter do not differ significantly

Some of the further developments in protein and amino acid nutrition, such as the concept of ideal protein, has resulted in significant findings related to protein levels, production performance and environmental pollution. Results from the work conducted in pigs (Tuitoek *et al.*, 1997) show that for as long as ideal protein amino acid ratios are maintained, through addition of synthetic amino acids, maximum performance can still be obtained (Table 6) at significantly lower protein levels (from 16.6 to 13.0%), while decreasing very dramatically nitrogen excretion and therefore environmental pollution.

The quantity and quality of meat production can also be improved, other than through protein and amino acid nutrition, by the use of new natural ingredients, inert mineral components, without any apparent residue problems, such as magnesium silicates (Exal™) in some species, such as the pig (Parisini *et al.*, 1993; Castaing, 1994; Castaing and Noblet, 1997) and the broiler. Results from Castaing (1994) show the effects of sepiolites on growth, with significant results on lean meat yield and less fat deposition (Table 7), apparently due to improved digestibility coefficients, which in turn will decrease nitrogen excretion and therefore improve environmental conditions.

Probably one of the most important characteristics that we refer to, when we speak of meat quality is its fat content. If we take customer acceptability criteria as a general index, meat shoud contain a minimum amount of fat (Wood, 1984) which guarantees not only good flavour (Mottram and Edwards, 1983) but good texture and avoid excessive drying out when being cooked. We know that lipids are the major components of fat and therefore maximum attention should be paid to their composition in fatty acids and their effects on meat characteristics, customer acceptability and health implications to the consumer.

Table 6. Effects of crude protein levels on carcass characteristics of pigs† slaughtered at 100 kg LW (Tuitoek *et al.*, 1997)

Parameter	Crude protein levels (%)		
Growing	16.6	15.0	13.0
Finishing	14.2	12.8	11.0
Live weight (kg)	101.7	102.1	101.6
Carcass dressing (%)	84.1	84.4	84.2
Retail cuts			
Ham (kg)	8.91	9.00	8.66
Loin (kg)	9.48	9.29	9.57

†Gilts: Growing 20-55 kg; finishing: 55-100 kg

Table 7. Effects of sepiolite (Exal™) on production performance in growing-finishing pigs (Castaing, 1994)

Parameter	Sepiolite levels (%)	
	Basal	2.0
Initial weight (kg)	23.7	23.7
Final weight (kg)	104.4	104.7
Daily gains (g)	717	740
Days to slaughter	113	110
Feed: gain	2.94	2.90
Carcass dressing (%)	77.5	77.4
Dorsal fat, X-2 (mm)	19.1	16.2
Dorsal fat, X-4 (mm)	17.7[b]	15.7[a]
Muscle thickness, X-5 (mm)	54.9	56.1
Carcass muscle (% FOM)†	54.2[b]	56.1[a]

†FOM: % muscle based on Fat'O'Meter readings
a,b: Values with the same letter do not differ significantly

Animal fat, including cholesterol, has been traditionally held responsible for the higher rates of mortality in western societies and associated with a high consumption of animal products. Even if the relationship between cholesterol and coronary heart disease has not been clearly defined, the general impression is that reduction of cholesterol intake will reduce the risk of heart disease. While we know that it is rather difficult to significantly decrease the level of cholesterol in foods of animal origin (meat, eggs and milk), and although recent research seems to indicate that cholesterol by itself is not as detrimental as it was initially thought (Keys *et al.*, 1965; Allred, 1993; Nestel, 1993), important reductions in the cholesterol content of some products (meat, eggs, etc.) can be easily achieved, for example in poultry meat (Bakalli *et al.*, 1995), along with significant reductions in triglycerides and simultaneous increases in HDL, known to be depressors of cholesterol in man (Table 8), by the use of supranutritional levels of Cu.

Table 8. Influence of Cu on poultry meat cholesterol and plasma triglycerides and HDL levels† (Bakalli *et al.*, 1995)

Parameter	Cu supplementation (ppm)	
	0	250
Body weight gain (kg)	1.846[b]	1.963[a]
Feed: gain	1.993[a]	1.883[b]
Plasma cholesterol (mg/100 ml)	149.15[a]	129.10[b]
Plasma HDL cholesterol (mg/100 ml)††	90.10[b]	103.27[a]
Plasma triglycerides (mg/100 ml)††	53.30[a]	30.19[b]
Breast muscle cholesterol (mg/100 g wet tissue)	57.22[a]	43.15[b]
Breast muscle Cu (mg/g wet tissue)	0.358	0.410

†Broilers 0-42 days
††Broilers 0-21 days
a,b: Values with the same letter do not differ significantly

It is known that Cu deficiencies will result in increases of blood cholesterol levels in most species, including man (Lei, 1991). Therefore, the slight increases of Cu content, if any, in poultry meat thus treated should be looked at as a further positive point, in as far as human health is concerned, considering that the supply of Cu in human diets is generally considered to be unsuficient.

The presence of high levels of long chain saturated acids, as well as their ratio with polyunsaturated ones seems to be more responsible for the elevated levels of blood plasma cholesterol of low density (LDL or low density lipoproteins) than cholesterol levels by themselves. It has been reported that when increasing the proportion of polyunsaturated fatty acids over saturated acids, that is, increasing the U:S ratio LDL cholesterol levels decrease significantly (Schonfeld *et al.*, 1982; Dietschy *et al.*, 1993).

When looking at the fatty acid composition of fats and the results of research conducted to evaluate the effect of the different groups of fatty acids on coronary heart disease, most saturated long chain fatty acids, mainly palmitic (C16:0), miristic (C14:0) and lauric (C12:0) acids have been found to be hyperlipemic (Kinsella, 1988), and therefore favouring the onset of the disease, while caproic, caprilic and capric (C6:0, C8:0 and C10:0) do not seem to affect blood cholesterol levels. On the other hand, stearic acid (C18:0) and polyunsaturated fatty acids, mostly those belonging to the n-3 familly (linolenic, eicosapentanoic and docosahexanoic acids), as well as the long chain monounsaturated acid (oleic acid), considered as the typical representative of the mediterranean diet, appear to be beneficial not only to circulatory pathologies (Keys *et al.*, 1965; Bonamone and Grundy, 1988; Kisella, 1988; Keli *et al.*, 1994; Katan, 1995; etc.) but their positive effects seem to extend to other metabolic diseases such as rheumatoid arthritis (Lands, 1993; Nordstrom *et al.*, 1997), the incidence of which appears to diminish when the intake of n-3 acids increases.

If we look now at the content of these fatty acids, specially the n-3 polyunsaturated acids, that is, the "good ones" plus stearic and oleic acids, we will find that while the content of oleic acid is relatively good, between 34 and 48% in most types of fats, including milk fat, the saturated acids, mainly palmitic, are found at levels of 22 to 28%, while only trace amounts of the polyunsaturated ones (EPA and DHA) are rarely detected (Table 9).

Considering the beneficial effects of polyunsaturated fatty acids on human health, particularly those belonging to the n-3 family, many researchers have studied the possibility of supplying the minimum dietary requirements through foods containing high levels of these acids, be them from vegetable origin, for instance flaxseed-based foods, high in linolenic acid (Cunnane *et al.*, 1994; Nordstrom *et al.*, 1995), through fish, considered to be the richest food in these acids (Keli *et al.*, 1994; Katan, 1995) or through other animal products in which the proportion of these fatty acids has been increased through animal feeding.

Table 9. Fatty acid composition of animal fats (Barroeta and Xalabarder, 1991)

Fatty acid (%)	Milk	Beef	Pork	Chicken
Saturated				
12:0	2	-	-	-
14:0	10	3	1	1
16:0	28	28	22	23
18:0	10	2	13	6
Monounsaturated				
18:1	34	43	48	36
Polyunsaturated				
18:2 n-6	3	3	10	20
18:3 n-3	-	1	1	1
20:5 n-3 (EPA)	-	-	-	-
22:6 n-3 (DHA)	-	-	-	-

The relative difficulty of obtaining vegetable foods with high levels of n-3 fatty acids, has moved animal nutritionists to study the possibility of increasing their content in animal fats, through the feeding of feeds rich in these nutrients, while decreasing at the same time the proportions of the saturated fatty acids. In monogastric species the reduction of saturated fatty acids, as well as the simultaneous increase of the polyunsaturated ones in their body fat has been found to be relatively easy in the broiler (Ratnayake *et al.*, 1989; Olomu and Baracos, 1991; Blanch *et al.*, 1996) (Table 10) and in the egg yolk (Hargis *et al.*, 1991; van Elswyck *et al.*, 1992; Marshall *et al.*, 1994; van Elswyk, 1997) as well as in the pig (Irie and Sakimoto, 1992; Specht-Overholt *et al.*, 1997; etc.) (Tables 11 and 12). Even if it is accepted as more difficult to change the fatty acid profile in the fat of ruminant meat, significant and very promising results have been obtained, specially through the finding that rumen microorganisms do not hydrogenate EPA nor DHA (Ashes *et al.*, 1992), both in sheep (Lough *et al.*, 1992), cattle (Mandell *et al.*, 1997) and even in the dairy cow (Wonsil *et al.*, 1994). Through the use of unsaturated fats (Fulfat canola and soy lecithin) Lough *et al.* (1992) were able to increase the proportion of stearic acid in subcutaneous fat while miristic and palmitic acid, both considered highly hyperlipemic, decreased significantly. Similar results, working with cattle (Mandell *et al.*, 1997), indicate that the use of fish meal in fattening cattle will result in significant levels of n-3 acids in the fat of the *longissimus dorsi*, that may reach a 4 to 6 fold increase with respect to control levels (Table 13) without impairing the rest of productive indexes.

Table 10. Effect of supplemental yellow grease (S) and linseed oil (L) on fat composition of the *M. Sartorius* in the chicken (Olomu and Baracos, 1991)

Parameter	6% S 0% L	4.5% S 1.5% L	3.0% S 3.0% L	1.5% S 4.5% L
Fatty acids (%)				
SFA	37.3	38.2	35.2	32.4
MUFA	43.4	40.9	36.8	36.6
PUFA	18.1	19.7	26.7	29.9
n-3 FA	1.9	4.5	8.4	10.8
n-6 FA	16.2	15.2	18.3	19.1

Once accepted that fatty acid composition of meat fat can be significantly changed, we should question the levels to be achieved, given the possibility of taste effects on modified fats. Other than the general recommendations of the American Heart Association, advising that a maximum of 30% of calories come from fat and that all fats should have an ideal proportion of saturated, monounsaturated and polyunsaturated fatty acids at equal parts, we have very few dietary recommendations as to the levels of polyunsaturated fatty acids and specially n-3 fatty acids. It has been suggested, however, that normal requirements should be around 1 to 3 grams per day of n-3 fatty acids in order to maintain an optimal health status (Barlow and Pike, 1991), of which a minimum of 30 to 40% should be present as preformed EPA and DHA (Uauy-Dagach and Valenzuela, 1992).

Table 11. Effect of supplemental fish oil on fatty acids (%) in pork fat (Irie and Sakimoto, 1992)

Parameter	Fish oil (%)			
	0	2	4	6
Fatty acids (%)				
SFA				
Miristic acid (C14:0)	1.7	1.8	1.9	2.0
Palmitic acid (C18:0)	24.6	24.4	23.9	25.0
Stearic acid (C18:0)	18.6	19.1	18.6	17.6
MUFA				
Oleic acid (C18:1)	39.4	37.4	36.9	35.9
PUFA				
Linoleic acid (C18:2)	9.0	9.1	8.3	8.4
Linolenic acid (C18:3)	1.7	1.9	2.2	2.2
EPA (C20:5)	0.1	0.4	0.9	1.3
DHA (C22:6)	0.5	0.7	1.2	1.4

Table 12. Effect of supplemental flaxseed (15%) on fatty acid composition of bacon for 42 days prior to slaughter at 127 kg liveweight (Specht-Overholt *et al.*, 1997)

Parameter	Control diet	Flaxseed (15%)
Fatty acids (%)		
SFA		
Miristic acid (C14:0)	1.2	1.1
Palmitic acid (C16:0)	20^{c}	18 d
Stearic acid (C18:0)	10^{c}	9.4^{c}
MUFA		
Oleic acid (C18:1)	44^{b}	38^{d}
PUFA		
Linoleic acid (C18:2)	18	17
Linolenic acid (C18:3)	1.3^{b}	12^{d}
EPA (C20:5)	0.035^{b}	0.089^{c}
DHA (C22:6)	0.062^{d}	0.055^{cd}
n-3 FA	1.5^{b}	12^{b}
n-6 FA	20^{c}	19^{b}

a,b,c,d: Values with the same letter do not differ significantly

Table 13. Effect of fish meal feeding to cattle[†] on longissimus dorsi fatty acids (Mandell, *et al.*, 1997)

Parameter	Fatty acids (%)		
	0.0	5.0	10
n-3 FA (mg/100 g fresh weight)	37	63	77
EPA 20:5 (mg/100 g fresh weight)	5.2	19.1	29.8
DHA C22:6 (mg/100 g fresh weight)	1.8	9.7	10.9
EPA and DHA (mg/100 g fresh weight)	7.0	28.8	40.7

[†]Steers fed for 168 days before slaughter

These data have recently been confirmed by research showing that an intake of 3 grams daily of n-3 fatty acids (typical of the japanese consumer, with a very low incidence of coronary heart disease) will decrease the risk of mortality due to cardiovascular problems by 80% as compared to present day levels in the United States (Hirai *et al.*, 1989) and that the risk may disappear altogether, as is the case with some eskimo societies, where the ingesta of these acids increases to 10 grams per day and the mortality due to coronary heart disease is practically nil.

Under this assumption and considering the results of taste panels, it can be concluded that the meat from broilers fed high levels of n-3 fatty acids can have as much as 0.2 to 0.3 g of EPA and DHA per 100 grams of edible meat (Ratnayake *et al.*, 1989; Olomu and Baraco, 1991) without significant changes in its organoleptic characteristics. Based on similar results with pigs (Irie and Sakimoto, 1992; Specht-Overholt *et al.*, 1997) and other species such as lambs (Lough *et al.*, 1992) and cattle (Mandell *et al.*, 1997), it can be concluded that the intake of the recommended levels of n-3 acids could be easily achieved by the daily consumption of between 200 and 300 grams of chicken, pork or beef and even with less consumption of meat if we take into account that one egg can easily contain (after proper feeding of the hen) 0.178 g/yolk and even higher levels (0.30 to 0.46 g) of these acids. Always assuming that no fish is consumed, as even the smallest percentage of fish consumption would certainly decrease the need to obtained this polyunsaturated acids from meat products.

Based on these data, it is estimated that the consumption of 100 grams of beef would supply approximately 75 mg of these n-3 acids, of which about 39 would be EPA and DHA, 100 g of chicken meat could easily provide 106 mg of n-3 fatty acids, of which 80 mg as EPA and DHA, one egg would easily supply 200 mg of EPA and DHA and three slices of bacon could easily provide 12 grams of these acids (Table 14).

Table 14. Estimated EPA and DHA human daily requirements

Supplied by[†]	Daily supply (mg)	Estimated daily requirements (mg)
Beef (100 g)	39	
Poultry (100 g)	80	
Bacon, 3 slices (19 g)	12	
Eggs (one egg)	200	
Total EPA and DHA	331	300-400

[†]From animals fed n-3 enriched diets

Present trends to increase the proportion of polyunsaturated fatty acids in the fat of meat are however faced with the increased oxidation risk of these meats, due to the increased concentrations of these highly oxidation-sensitive fatty acids. The shelf life of these meat products may rapidly deteriorate unless nutritional and feeding measures are taken to avoid these oxidation processes.

The observation that fats, particularly if they are unsaturated, may go through this type of oxidative processes is well known. The risk of oxidative deterioration of meats however, can be easily prevented through the use of antioxidants in the feed, either natural such as alpha-tocopherol or vitamin E (Mecchi *et al.*, 1953; Webb *et al.*, 1972; Marusich *et al.*, 1975; Bartov and Bornstein, 1981; Gray, 1990; etc.) or synthetic, such as ethoxyquin, BHT, etc. (Webb *et al.*, 1972; Bartov and Bornstein, 1981; etc.). Table 15 shows the results of vitamin and antioxidant supplementation of broiler diets on meat fat peroxidation while Table 16 shows results from Gray (1990) with pigs fed supplemented and unsuplemented diets with vitamin E on the quality and shelf life of pork.

Table 15. Effect of supplementing broilers diets with vitamin E, ethoxiquin and BHT on carcass fat stability (Barstov and Bornstein, 1981)

Experimental variables			Carcass fat values		
BHT (mg/kg)	Ethoxiquin (mg/kg)	Vitamin E (mg/kg)	α-tocopherol (mg/kg)	Peroxide index (meq/kg)	Thigh TBARS (µg/g)
0	0	0	n.a.	56.6	171
0	0	40	12.0	45.1	103
0	125	0	n.a.	46.9	157
0	125	40	18.0	32.1	58
125	0	0	n.a.	44.3	183
125	0	40	16.6	37.3	112

Table 16. Effect of vitamin E supplementation of feed (10, 100 and 200 IU/kg) on oxidation, colour and dripping losses in pork chops kept a 4°C (Gray, 1990)

Storage time (days)	TBARS			Hunter's A value			Dripping losses (%)		
	10	100	200	10	100	200	10	100	200
0	0.28	0.27	0.27	10.7	11.6	11.5			
3	1.54	0.56	0.35	10.3	11.0	11.7	19.0	16.2	10.2
6	2.96	0.94	0.58	7.3	9.2	10.2	20.1	19.5	12.2
10	5.17	2.96	1.93	7.2	7.9	8.5	21.3	21.2	14.1

Other animal products, such as eggs, can also be negatively affected by poor management practices and environmental factors. Internal egg quality is normally judged by albumen quality and egg yolk colour. Internal egg quality and more specifically albumen or egg white quality is presently based on Haugh Units, which measure the height of the thick albumen closest to the yolk. This type of measurement however, does not take into account the proportion of thin albumen, which in many cases is detrimental to different egg processing industries. While internal egg quality, based on thick albumen Haugh Units, is normally referred to changes due to house temperature or storage conditions and can be improved through the feeding of certain mineral supplements (Robinson and Mosey, 1975; Jensen and Maurice, 1980; Brufau *et al.*, 1988; etc.), the proportions of thin albumen seem to depend more on genetic factors (Table 17) than in feeding practices (Leeson and Caston, 1997), and could probably be improved through genetic selection.

Table 17. Egg characteristics of commercial layers from different genetics make up (Leeson and Caston, 1997)

Bird age (weeks)	Genetic make up	Egg weight (g)	Total albumen weight (g)	Thick albumen height (mm)	Thin albumen area (cm^2)
22	Compact	47.4	26.2	8.1	73.4
	Spreading	46.4	26.4	7.8	85.7*
30	Compact	52.7	29.0	7.9	81.6
	Spreading	53.5	30.4	7.6	98.6*
46	Compact	58.1	30.8	7.5	91.7
	Spreading	58.9	32.8	6.9	117.2*
66	Compact	62.3	32.5	6.9	93.0
	Spreading	63.2	34.3	6.4	115.6*

Values with * differ significantly from their equivalent figure in the age group

Another important characteristic of internal egg quality is egg yolk pigmentation. For many years consumers have associated a bright yellow or reddish egg yolk, as well as a golden-yellowish skinned bird, with healthy animals (Sunde, 1992). While the pigmentation of the broilers skin has drastically changed to white in many countries, with no decline in customer acceptance, the yellow skinned broilers continues to be the preferred product in many other countries (David Williams, 1992). The pigmentation of the egg yolk, however, continues to be a sign of good internal egg quality everywhere and the preferred food selection (Fletcher, 1992; David Williams, 1992), although with a certain degree of variation in the colour hue, depending on countries and even regions within countries.

As we continue to improve our productivity, some undesirable traits may appear and we should be able to anticipate or rapidly correct these biological unbalances. We should not forget that selection for increased productivity may result in undesirable syndromes such as muscle myopathies (Grunder *et al.*, 1984), pulmonary hypertension syndrome in broilers (Julian, 1993), reduced immunological competence (Dunnington *et al.*, 1987), tibial dischondroplasia in broilers, etc.

Also, last but not least, we should keep in mind the adverse effects of preslaughter management techniques on meat quality, which can easily be improved. Increased production of epinephrine and glucocorticoids in animals exposed to preslaughter stresses have been shown to significantly affect meat quality. Dark, firm and dry meat (DFD) in beef and pale, soft and exudative meat (PSE) in pork are two good examples of these forms of preslaughter stress, and while data on poultry is limited, several researchers working with broilers (Wood and Richards, 1975; Kannan *et al.*, 1997) and turkeys (Froning *et al.*, 1978) have reported not only poultry meat quality changes as due to preslaughter stress, but increased populations of Salmonella and *Campylobacter* spp. during transport and holding prior to slaughter (Stern *et al.*, 1995; Eric Line *et al.*, 1997).

These potential difficulties may be increased when diets are formulated to maximize yields (Praharaj *et al.*, 1996). Although some of these deterrents may be counteracted by excellent management, we have to be aware that poor husbandry, often forced by economical needs (greater densities, lower animal welfare, etc.) will result, through the release of cytokines such as interleukin-1 (Klasing, 1988), interleukine-6 (Memon *et al.*, 1994) and other factors, such as the tumor necrosis factor (Dinarello, 1984), etc., in situations where a chronic immune stimulation system is established, altering metabolic processes (Webel *et al.*, 1997; Williams *et al.*, 1997) and resulting in a decreased productivity and a simultaneously impaired immunological competence, with the whole sequelae of disease problems and unavoidable drug residues, used to hold back these pathological dysfunctions.

While it is increasingly difficult to design strategies to counteract the physiological unbalances caused by genetic advances, some important results are already being achieved, in particular referring to immunocompetence. The importance of immunomodulators to improve cellular and humoral immune functions and resistance to infections has increased in recent years. Several results point out the stimulating effects of polyunsaturated fatty acids (Marshall *et al.*, 1983; Parmentier *et al.*,

1997) as well as different vitamins and microminerals on immune competence. There is clear evidence that low Vitamin A levels, not necessarily hyponutritional, will result in impaired immune functions and reduced resistance to disease in most animal species (Friedman *et al.*, 1989; Friedman *et al.*, 1991; Ross, 1992). Other vitamin deficiencies and/or low levels, have also been shown to depress immune responses in the broiler, such as Vitamin D (Aslam *et al.*, 1995; Lessard *et al.*, 1996), Vitamin E (Haq *et al.*, 1994), etc.

The administration of the recently available vitamin D3 metabolites, such as 25-hydroxy D3 and 1.25-dihydroxy D3, have not only been shown to increase immune responses (Aslam *et al.*, 1992; Mireles and Sun Kim, 1997) but reduced the incidence of tibial dischondroplasia in broilers, while significantly increasing blood titters against Newcastle and Bronchitis. The authors (Mireles and Sun Kim, 1997) conclude that the onset of tibial dischondroplasia maybe related to changes in immunocompetence and therefore associate impaired immune functions with some of the physiological dysfunctions brought about by maximum performances. Not only have micronutrients such as vitamins been seen to stimulate immune responses but the accurate formulation of other nutrients has also been shown to improve immunocompetence in some species, such as low Ca levels (Garlich *et al.*, 1992), the presence of Zn and Mn in organic and quelated forms (Ferket and Qureshi, 1992), etc.

Through this necessarily brief summary of nutritional research we have seen how most of the frequently publicized negative aspects of foods of animal origin can be not only corrected back to normal but even further improved, to provide healthy foods that will not only afford an adequate supply of nutrients to the human being but provide us at the same time with healthy nutrients that will help us prevent some of the modern diseases of affluent societies: cholesterol levels, coronary heart disease, arthritis, etc.

We have also seen how meat production can be significantly increased in all species and how by improving leanness and fat content adequately, meat can be made not only tasty but preventive of certain human metabolic disorders. Meat, milk and egg quality can also be made to resist unchanged for days in the supermarket or the refrigerator and their quality improved to the point of becoming not only just as tasty as the "old country farm product" but preventive as well of many human metabolic disorders.

While some of the metabolic dysfunctions of our production animals or some of the diseases that may affect them may be more difficult to overcome, present research conducted on immunocompetence, disease prevention, management and animal welfare, etc., are sufficient guarantees that we will continue to have a generous supply of high quality animal products.

To summarize this brief review I will assume the risk of advancing the promise that in a very near future, in a not too distant tomorrow, we will be able to have a good and tasty couple of fried eggs with bacon, a good stake, a tasty piece of "serrano" ham or perhaps drink a wholesome glass of milk (certainly not skimmed) without the fear of drug residues nor the guilty feelings that so frequently overcome us when we break our carefully controlled eating habits in as far as animal products are concerned. It will all be the result of the production of stress-free animals, carefully fed and managed and free of diseases that could possibly be transmitted to the human being.

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