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Compound feed as a factor influencing the food quality and safety

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ABSTRACT

The paper discusses on the basis of data from the literature and the results of the author's own research work how animal nutrition can be used in the "from farm to fork" chain to influence the quality of pork and poultry meat and the safety of animal products. The relevant results show, that for example in pig nutrition different ileal digestible lysine/energy (IDLYS/DE) ratios will essentially determine the fat content of meat and consequently the quality of the product. The article also highlights the fact, that the dietary IDLYS/DE ratio of genetically improved pigs substantially differs from that of the normal hybrids. While in the diet of a genetically improved pig the required IDLYS/MJ DE ratio is 0.7 g during the first phase of fattening (20–55 kg) and 0.6 g in the second phase of fattening (55–100 kg), these ratios for the normal hybrid are 0.6 and 0.5 g IDLYS/MJ DE, respectively for the two weight categories. This paper also warns, that if animal feed proteins, animal fats and various feed additives are used in a unprofessional manner, they may present a potential risk factor for the safety of the animal food product. The results of the studies discussed lead to the conclusion, that in the "from farm to fork" chain it is extremely important for the safety of products to define clear and unequivocal quality criteria and to establish an official and comprehensive control for each element of the product chain. The author proposes to conduct further systematic studies in accordance with the "from farm to fork" concept in the interest of producing high quality and safe animal food products.
(Keywords: animal nutrition, feed quality, food quality, food safety)

INTRODUCTION

In recent years almost everyone in the world is affected by various nutrition related health problems even if due to very different causes. In developed societies overeating and/or an imbalance of nutrients in the diet have led to the spreading of chronic, non-infectious diseases. In less developed societies under-nutrition causes major health problems. According to Hungarian statistics about 50% of mortalities are due to cardiovascular diseases and 30% to tumor diseases, in the pathology of which nutrition is one of the most important risk factors.

The existing research data already witness that the quality of foods of animal origin is influenced to a large extent by the quality of feed. While the world's compound feed output for 1975 was 290 million metric tons, this increased to 626 million metric tons by 2005 (*Gill*, 2006). This change is indeed striking despite the fact that the growth of production volume has slowed down in recent years.

A major portion of animal food products for the Earth's population is produced with this compound feed. The volume and quality of food produced using compound feeds is therefor by no means negligible. The purpose of this paper is to discuss how the composition, nutrient content of compound feeds, the balance of dietary nutrients influences the quality and safety of animal food products. Due to its magnitude the issue is presented primarily through pork production as an example.

MEAT QUALITY AND FOOD SAFETY

A study of the relevant literature shows that there is no uniform definition of meat quality. It is defined in general as the aggregate of the sensory, nutritional, toxicological, hygienic and technological characteristics of the meat. According to *Hofmann* (1993), however, meat quality comprises those characteristics and parameters of meat which are important from the aspect of nutritional value, human health and processing technology.

It is also obvious from the literature that meat quality is a different concept for the different participants of the production and retail chain. On this basis we differentiate hygiene, technology, sensory and nutritional value related meat quality (*Babinszky*, 1996). When examining the nutrition-physiological aspect of meat quality the definition will be different although not fundamentally. Nutrition physiology prefers low-fat meats, but another important criterion is that the meat intended for the market should be free of toxins, feed hormone preparations and other substances deleterious for the human body. This definition already involves the issue of food safety as well. Food safety is essentially the concept that the food should not be harmful for its consumer. The harms are usually classified into three groups (*Biró*, 2000):

1. *Harm caused by live agents*: this is a factor subject to the microbiological status of the food, when food bacteria may cause food poisoning, fungi may cause mycotoxicoses, viruses and parasites may damage health.
2. *Harm caused by chemical substances, toxins*: chemical contaminants (residues) can be herbicides, veterinary pharmaceuticals, chemical pollutants, excipients, etc.
3. *Harm caused by other contaminants*: in the course of processing the food may be contaminated with metal or glass fragments.

In summary it can be concluded that food safety is influenced by biological, chemical and physical factors (*Biró*, 2000). It should be noted however, that there is general agreement in the literature that the acceptability of a given food product incorporates the criteria of safety and of quality. In other words: even though safety and quality are separate units in their characteristics, at the same time there are numerous linkages between the two sets of criteria (*Biró*, 2000). This means that the two ideas are inseparable which should be borne in mind when producing foods of animal origin in animal agriculture.

THE RELATIONSHIP BETWEEN ANIMAL FEEDING, FOOD QUALITY AND FOOD SAFETY

In the last 10 years animal nutritionists have frequently dealt with the question of how animal nutrition can be used for influencing the quality of pork for example so that it may best satisfy the criteria of human nutrition. The experiences show, that the quality of animal food products, and thus of meat can be influenced, i.e. improved or deteriorated by feeding - just as by other environmental factors. Of the various nutritional factors affecting meat quality the method and intensity of feeding, the quantity and quality of nutrients fed and their relative proportions should be highlighted. It should also be noted, that the various chemical additives and pharmaceuticals used in a non-professional manner may also exert a negative influence on the quality of meat. The effect of animal feed on meat quality is presented through the following examples.

Polyunsaturated fatty acids

Omega-3 (ω-3) polyunsaturated fatty acids (PUFA) have become a focal point for research studies conducted in the fields of animal nutrition and human nutrition, both.

The results of clinical studies have shown, that consumption of these fatty acids will alleviate or completely eliminate certain diseases (coronary heart problems, psoriasis, certain inflammatory conditions). It also improves the development of sight in healthy and prematurely born infants, the dermal health status of adults, brain functioning and the productions of certain hormones (*Barlow* and *Pike*, 1991).

Fish oils contain ω-3 polyunsaturated fatty acids in abundance. The results of numerous studies have shown that when the diets of growing/finishing pigs or of broilers are supplemented with fish meal or fish oil, the level of long-chain ω-3 polyunsaturated fatty acids in the meat will increase in response (*Hulan et al*., 1988, 1989; *Chanmugam et al*., 1992; *Arbuckle et al*., 1994).

A potential problem is, that diets containing up to one percent of fish oil already may lead to a non-desirable off taste. In several countries the traditional consumer preference is for pork as opposed to fish, and consequently the consumers are more sensitive to any "fish taste" in pork. Linolenic acid is a short-chain ω-3 PUFA to be found in large quantities in vegetable oils, for example in rapeseed oil. The "double-zero" (low erucic acid and low glucosinolate level) and low fiber varieties of rape can be successfully fed to pigs and broilers. The research results suggest that rapeseed oil incorporated in the diet at 6% may increase the ω-3 fatty acid level of pork and poultry meat.

The influence of animal feed on the protein and fat content of meat

From the aspect of human nutrition physiology the protein and fat level, their ratio to each other, and the level of intramuscular fat are probably among the most important parameters. The protein and fat deposition of growing/finishing pigs is influenced by several factors. The most important of these is the genetic potential of the animal for protein deposition and for feed intake. The relationship between these two factors is discussed by several theories. Of these a commonly used concept is the so-called linear-plateau theory published by *Bikker* (1994) and shown in *Figure 1*, according to which protein deposition increases linearly with the energy intake up to the limit of the genetic potential for protein deposition.

The growth performance and the chemical composition of the carcass (the meat quality) is also affected by the amino acid/energy ratio of the diet. It is well known, that for pigs the primary limiting amino acid is usually lysine. *Table 1* illustrates the strong correlation between ileal digestible lysine intake and average daily weight gain, and also between the daily protein deposition and the feed conversion rate (*Halas* and *Babinszky*, 2000). In consequence it is indispensable that we aim for creating the best possible lysine / energy (DE) ratio during diet formulation in order to enhance protein deposition. The trial results show, that in the case of growing pigs (between 25 and 60 kg of live weight) the lowest fat deposition level can be expected with an 0.63 g ileal digestible lysine/MJ DE ratio. The data from these studies suggest, that any deviation from this lysine / energy ratio will lead to a higher fat content of the carcass and consequently to the deterioration of the meat quality. The results of the relevant studies also show, that the ratio determined for the 25–60 kg live weight will decrease to 0.50 g ileal digestible lysine/MJ DE during the second phase of fattening (between 60 and 105 kg of live weight).

Figure 1

Linear-plateau and curvilinear relationship between protein intake and protein deposition in case of two different energy intakes (*Bikker*, 1994)

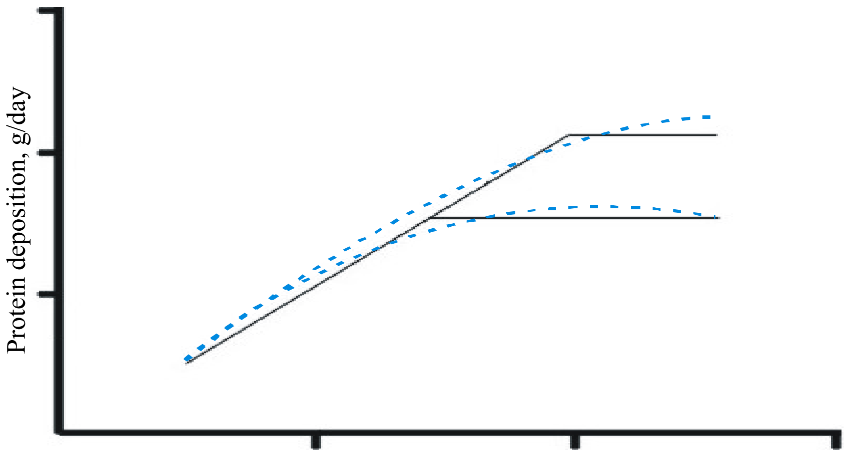


Table 1

The relationship between daily ileal digestible lysine intake, daily weight gain, daily protein deposition and feed conversion ratio (FCR), (*Halas* and *Babinszky*, 2000)

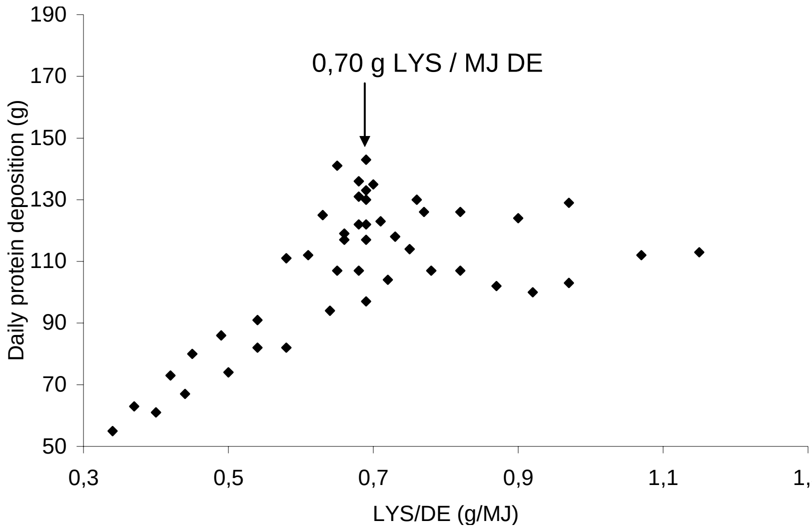
Body weight	Correlation		
	Daily weight gain	Daily protein deposition	FCR
30–60 kg	r= 0.94 P=0.0001	r=0.78 P=0.001	r=-0.94 P=0.0001
60–105 kg	r=0.89 P=0.0001	r=0.77 P=0.0013	r=-0.87 P=0.0001

The data in *Figure 2* are a summary of the relationship between total lysine/energy and protein deposition on the basis of various data from the literature (*Szabó*, 2001). Despite their rather high variance the data show that between 20 and 55 kg live weight the daily protein deposition is usually the highest beside an 0.70 g total lysine/MJ DE ratio, which corresponds to an 0.6 g ileal digestible lysine / MJ DE ratio. It should be noted however, that the foregoing lysine/energy ratios pertain to hybrids with a so-called average genetic potential (normal pig). Three categories were set up for hybrids in the literature (*Close*, 1994):

– Superior, genetically improved pigs;
– Normal pigs;
– Traditional, unimproved pigs.

Figure 2

The influence of dietary total lysine and digestible energy ratio on the protein deposition of growing pigs based on the review of literature (Szabó, 2001)



The average daily weight gains and protein content of the empty body characteristic of each category are shown in *Table 2*.

Table 2

Three categories of pigs have been identified depending upon their rate and composition of body gain (*Close,* 1994)

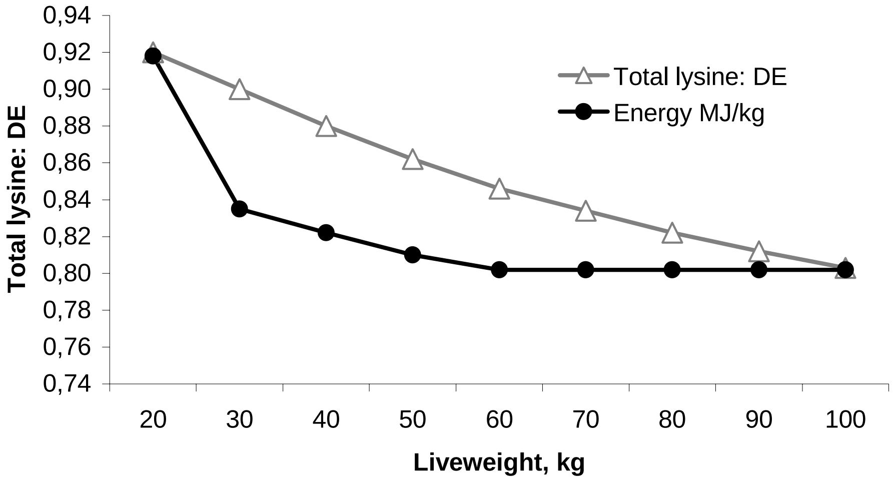
Categories	Growth rate (kg/d)	Protein content of empty body (g/kg)
Superior, genetically improved pigs	up to 1.2	180
Normal pigs	up to 1.0	170
Traditional, unimproved pigs	up to 0.8	160

Remarks: For animals it has been assumed that maximum growth rate is achieved at a body weight of 60 kg and is maintained constant thereafter up to 100 kg body weight that is, in a linear-plateau fashion.

Results of the studies conducted so far show, that when the lysine/energy ratio in the diet of hybrids belonging to the first category (improved pigs) is the same as in the feed of normal pigs, these will deposit access fat by the end of the fattening period, i.e. the quality of the meat will deteriorate substantially. For this reason *Varley* (2001) suggests to feed these pigs with a diet containing 0.7 g ileal digestible lysine per MJ DE during the first phase of fattening (between 20 and 55 kg of live weight), and 0.6 g during the second phase (between 55 and 100 kg live weight) (*Figure 3*).

Figure 3

Lysine and digestible energy requirements for improved pigs (*Varley,* 2001)



These data stress the importance of knowing the genetic potential of our growing/finishing herd, because this knowledge is indispensable during diet formulation for establishing a proper lysine/energy ratio so that the quality of meat can satisfy the criteria of human nutrition even in the case of the improved, high-producing pigs.

This perception has also contributed to the necessity of nutritionists, geneticists, molecular biologists, human nutrition biologists, physicians and biochemists all working together in order to produce quality meat. This research cooperation has yielded molecular nutrition as a new field in animal nutrition.

Some feed ingredients and feed additives as potential risks for food safety and potential solutions

The production of safe food (e.g. meat) also demands investigating whether the key feed ingredients and additives present any risk. With respect to the principal feed ingredients it is known, that grains may primarily be a risk factor due to toxins produced by various fungi. The number of already known mycotoxins exceeds one thousand, but the discovery of further mycotoxins is more than likely. Of the known ones approximately 100 mycotoxins have proven harmful effects, and of these about 15–20 are of outstanding significance in human and veterinary health. From the aspect of their harmful effects aflatoxins, fusarium toxins and mycotoxins produced by certain storage moulds are of major importance. Mycotoxins may be produced on the field prior to harvesting, and in case of suboptimal storage conditions also after harvesting. The prolonged feeding of contaminated grains may lead to an accumulation of toxins in the animal body. But even low levels of toxins may intensify their damaging effect through interaction impairing thereby the quality and nutritional value of the animal products, e.g. milk, egg, organs (liver, kidney, brain, heart, etc.) and to a lesser extent of meat as well.

No definitive protection against the harmful effects of mycotoxins exists as yet, but they can be alleviated by means of e.g. selective breeding, professional agro-technology, plant protection and storage practices. The attempts to bind the feed toxins inside the gastrointestinal tract with various additives in many cases are promising, but further systematic studies are required.

Dietary proteins of animal origin may mean a risk factor for the health of livestock and for producing safe animal food products. A case in point is the BSE scandal erupting a couple of years ago. The results of the relevant studies show however, that by complying with the animal health regulations and the technology standards of meat meal production, and with a strict control of this compliance this risk factor can almost entirely be eliminated. Another solution for supplying safe protein in adequate quantity and quality to the pig and poultry industries is to use more of the vegetable protein sources and to replace the animal protein sources with plant protein sources.
In pig nutrition for instance the proper way for replacing the animal protein sources with vegetable protein sources in the concentrates is if during diet formulation we first determine the energy content of the diet in accordance with the age and class of the animal, and then the ileal digestible lysine/DE ratio. Next we determine the ratio of the other amino acids to lysine using the ideal protein concept. The necessary amino acid percentages can be provided by incorporating industrial (crystallized) amino acids in the compound feed.

Another component to watch for in the diet formulation is that the digestible phosphorous content of plant protein sources remains below that of feed ingredients of animal origin. This necessitates that we use the digestible phosphorous value when formulating the diet and in order to enhance the digestibility of the plant derived dietary phosphorous it is advisable to incorporate a phytase enzyme at the level of 500 U/kg of diet. Provided that the diet of growing / finishing pigs is formulated on the foregoing basis, we need not expect any reduction in meat production or deterioration of meat quality when replacing protein sources of animal origin to plant protein sources (*Babinszky* and *Vincze* 2004).

Animal fats of uncertain origin and prepared with unsuitable technologies should also be treated as a risk factor both in poultry nutrition and in pig nutrition. A case in point is the dioxin scandal several years ago. The single most important dioxin contaminant source for poultry and pig is the feed ingredients of animal origin, and as first among these animal fat. According to the literature the dioxin content of animal fat is accumulated in the fat tissues of the animal by close to 90% efficiency. This chlorine containing aromatic chemical compound is an extremely aggressive toxic compound.
The solution for alleviating the harmful effects of dioxin is a careful selection of the fat source, compliance with the manufacturing technology standards and the relevant animal health regulations, together with a strict control of this practice. Replacing animal fat as an energy source with carbohydrates is also a viable solution, but the energy source should always be decided after a careful consideration by the nutritionist. This is necessary, because the relevant respiratory studies show, that when pigs produce body fat or milk fat from dietary carbohydrate (e.g. starch) the energetic efficiency is lower when they use dietary fat for the purpose. This is the reason why we experience a drop of feed intake in hot, poorly ventilated houses when high levels of carbohydrates are fed. In consequence of the lowered nutrient supply also the meat quality may suffer (*Babinszky*, 1998).

A wide variety of **additives** (e.g. antioxidants, flavour and colour enhancers, technological additives, various types of growth promoters, pharmaceuticals, and previously growth promoting antibiotics, etc.) are incorporated in today's compound feeds. Several of these can be considered a risk factor, such as for instance the antibiotics used as growth promoters.

It is well-known, that antibiotics are essentially banned in the EU for growth promoting purposes, because they may result in residues and resistance in the animal body, and may cause cross-resistance in the human body.

With the banning of growth promoting antibiotics their alternatives are increasingly in the focus of attention. **The alternatives of growth promoting antibiotics** can be listed under several groups, such as probiotics, prebiotics (oligosaccharides), or the mixture of the two, the symbiotics. Various organic acids, feed enzymes and herbal extracts (herbs, spices, essential oils) can also be considered as alternatives.

Table 3 presents the influence of feeding a probiotic product on the digestibility of nutrients and on nitrogen retention, on the basis of studies conducted with weaned piglets (*Babinszky* and *Tossenberger*, 2003).

Table 3

The influence of probiotics on the digestibility of selected nutrients and on N-retention in weaned piglets (*Babinszky* and *Tossenberger*, 2003)

Item	Treatment	
	Control group	Probiotic group
Digestibility (%)		
- crude protein	78.7^{a}	83.2^{b}
- crude fat	53.0^{a}	60.4^{b}
- N-free extract	91.6^{a}	91.9^{a}
N-retention (g/day)	12.9^{a}	14.5^{b}

^{a,b}Within a row, means without a common superscript letter differ (P<0.05).

Organic acids as an alternative of growth promoting antibiotics are frequently proposed in the feeding of weaned pigs. *Table 4* summarizes the results of studies conducted by *Babinszky et al*. (1998). During the trial 6.5 g formic acid/kg of feed and 9.8 g formic acid/kg of feed was incorporated in the diets of weaned piglets. The results of the tests prove that even in the case of 6.5 g formic acid/kg of feed the piglet performance improves significantly compared to the control (non-supplemented) group.

Table 4

The influence of formic acid on the performance of weaned piglets (*Babinszky et al.*, 1998)

Parameters	Treatments		
	Control	I*	II**
Average daily feed intake, g	591^{a}	616^{ab}	636^{b}
Average daily weight gain, g	303^{a}	341^{b}	358^{b}
Feed conversion ratio, kg/kg	1.98^{a}	1.83^{b}	1.81^{b}

*I. 6.5 g formic acid/kg diet; **II. 9.8 g formic acid/kg diet; ^{a,b}Within a row, means without a common superscript letter differ (P<0.05).

In general it can be stated therefore, that these preparations can be applied with an efficiency quite similar to that of the antibiotics, but it should also be noted, that the effect of these preparations is also depending to a large extent on the herd breed, age, class, health status and the type of diet fed. With herbal preparations a further difficulty can be that the active substance can not be identified exactly as a chemical compound, i.e. it can not measured precisely. For this reason in a part of the relevant studies not even the composition and dosage of the active substance is known. In consequence further extensive studies are required both in pig and in poultry (broiler) nutrition, and in the field of chemical analyses as well.

The "from farm to fork" food production chain in research work and in the production of animal food products

The feed examples discussed in the foregoing are suitable for solving one or another partial problem. In the interest of producing high quality and safe animal food products (e.g. meat) however, it is necessary nowadays to examine the entire chain both in research and in the production of animal products. Therefore the production of high quality and safe animal food products demands that already at the first link of the animal product production chain, i.e. at field crop production high quality and safe production practices are in place. Accurate information are required about soil management, plant protection, and whether GMO grain is produced on the farm in question. The next link in the production chain is the animal feed industry. At this step in addition to the feed ingredients of plant origin also the industrially manufactured feed ingredients and feed supplements need to be controlled. Furthermore, each step of the compound feed manufacturing process and eventual manipulations in the feed mill (such as hydrothermic treatment, extruding, expanding, micronizing or other) should be controlled.

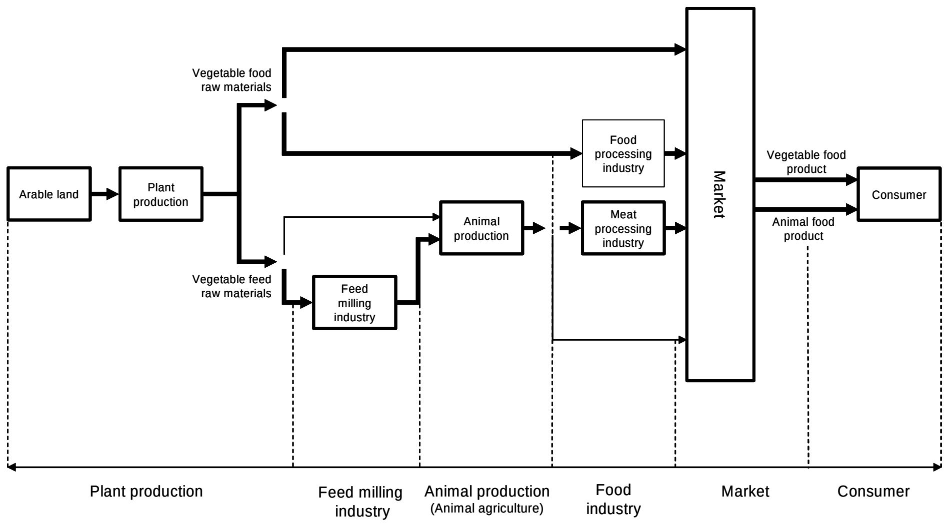
The resulting compound feed is transferred to the pig operation, where all important data of each phase in the feeding and fattening process must be recorded together with the herd data. Having reached the slaughter weight the herd is transported to the slaughterhouse or the processing plant. Here again each processing stage is controlled and the data are entered in the central terminal (data file) of the product chain, where upon the evaluation of the data it can be discovered immediately if the activities at a certain point of the production chain deviate from the regulations, or if the data measured do not meet the regulations and the quality criteria.

At the end of the product chain the output is a "food product of planned quality and safety derived from a planned feed" controlled at every stage of production, and which when delivered to the supermarket shelves and cold counters can also be verified by the consumers themselves with the help of a bar-code.

Figure 4 presents the entire food production chain outlined in the above under the title "from farm to fork". The purpose of this research and development and innovation (R+DI) project is to supply to the consumers animal products of the highest possible quality and safety. To this end however, crop production, feed industry, livestock production and the food processing industry and trade need to work in very close cooperation. Above all this it is also necessary that the researchers involved in the fields of animal nutrition, human nutrition, nutrition biology, nutrition immunology, molecular nutrition and also the information technology specialists work together.

Figure 4

The „from farm to fork" food production chain



Such a highly qualified research team committed by the foregoing philosophy will naturally be able to perform any high standard work only in case it possesses a high standard research basis, laboratories and a sufficiently comprehensive and accurate technical data base, quality criteria pertaining to each member of the production chain, and a high standard informatics background (software, hardware). This type of high level cooperation enables the controlling of every single point of the product chain in the interest of producing safe animal products.

In recent years the number of programs called "from farm to fork chain", "from field to consumer chain" or "from feed to food chain" is continuously increasing in the EU, the US and Canada, equally. It is a task of the near future that Central Europe should participate in these and similar research programs more intensively.

CONCLUSIONS

The following main conclusions can be drawn on the basis of the preceding chapters:

- high quality and safe animal food products can only be produced in case the elements of the product chain are built on each other in a planned manner and all participants of the production chain use the most advanced knowledge of their relevant field;
- it is a further precondition, that quality criteria are clearly defined, so that all elements of the product chain can be the subject of official and full-scope control. One of the most important criteria of producing high quality and safe animal food products is that on the basis of the "from farm to fork" philosophy we start dealing with the issue of food quality already at the field crop production stage;
- feed ingredients and feed additives may present a risk in the production chain, but these risk factors can be largely reduced through using expert knowledge and target-oriented control;

- also following from the "from farm to fork" philosophy it should be made clear already at the stage of feed ingredient production and compound feed manufacturing that the compound feed is intended for the production of animal food products. The quality of the animal product (human food) can be improved by the feed; but it can also be deteriorated by it;
- one "tool" for improving meat quality is target-oriented animal nutrition, but this is not a sole and exclusive precondition for achieving it;
- further systematic studies suiting the "from farm to fork" principle are required for producing high quality and safe feeds and animal food products.

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