

# EVOLUTION OF LIVESTOCK PRODUCTION AND QUALITY OF ANIMAL PRODUCTS

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## Abstract

The evolution of livestock production is analysed on its historical perspective and forecasted up to year 2020. Livestock production needs at year 2020 and the amount of required animal populations are estimated on the basis of the trend of the period 1971-1999 relative to human population, consumption, and animal efficiency index. At word level, the deficit between production and needs is remarkable (42 million tons of meat, 40 million tons of milk and 5 million tons of eggs). People will eat mainly monogastric meat (about 73% of all meat), the increase in consumption of ruminant meat will be limited. The raise of animal population will be noticeable; an intensification of production will occur affecting quality of animal products and sustainability of production systems. Production policy will be necessary for balancing needs and products. The quality of products is considered, and the tools suitable for getting control over quality and safety of animal products, such as quality assurance programs, are analysed. Relationships between meat and milk characteristics and human health, and possible intervention to adjust meat and milk to a right human diet and consumer requirements, are reviewed.

*Keywords:* animal products, evolution, production, consumption, quality.

## 1. Introduction

The historic evolution of livestock production can be subdivided in five fundamental phases:

**First phase. Agropastoral.** Up to the XVII century.

During this phase, man tamed nearly all the animal species showing the fundamental characteristics subsequently reported by Galton at about half of the XIX century (Galton, 1865). To come to the point, for millennia human kind selected for rearing species and animals that better represent the ideal productive model, accept human domination and easily reproduce in captivity.

In some areas of the world the end of this phase coincides with the beginning of the agriculture improvement due to the progress of scientific and technical knowledge occurred since the beginning of 1700. Until this century, techniques such as irrigation, tillage, cultivation care and animal breeding were very similar to those used in Roman age. In fact, in 1781, in his treatise '*Cours complet d'agriculture*' on the knowledge needed for improving agriculture and breeding, the French abbot Rozier wrote "*Ce que Columella disoit aux Romains, je crois devoir l'appliquer a mès compatriotes*".

**Second phase. Differentiation of breeds.** It starts with the making of the modern breeds aimed to improve production (within 1750 and 1800, Bakewell started the selection of sheep and cattle in England). In England, James Weatherby started the first official herd book of Thoroughbred in 1791; same period of the set up of milk controls. The herd book of Shorthorn cattle was started in 1822. Briefly, this phase took all the 19th and part of the 20th century (it is still in progress for some species and in some areas). During this period, the economical boom of many countries has pushed the increase in animal production. Around 1870, for the first time, in England standard human diets were formulated (Mulder, reported by Harper, 1985), fixing 100 grams of protein/day for workers and 60 g/d for sedentary men.

**Third phase. Specialization.** It starts within the beginning of the 20th century. Agriculture and breeding start to differentiate and specialize in many countries. Some agricultural productions are entirely designed for animal breeding. Specialization for product occurs for breeds in animal species, leading to the differentiation of production systems. There is an improvement in the techniques of food conservation, machine milking and animal keeping. The transition from high to low temperature used for milk pasteurisation, together with the availability of machinery and electricity, caused the

spreading of the modern cheese industry, that in the following decades was an incentive to the breeding of milk cattle first, and meat cattle later.

**Fourth phase. Intensification of production.** Thanks to specialization, husbandry develops intensive production systems in the middle of 1900, especially in industrialised countries. Scientific knowledge allows the breeding of animals genetically selected for high production, rationally fed using available fodder resulting from the green revolution, treated with medicines and managed with sophisticated techniques. The increase in productivity per single reared animal was a better answer to the raise of request of animal products than a proportional increase of the number of animals. Therefore, during the just ended century, the scientific progress, the industrialization process and the economic development, decisively contribute to demographic and consumption growth of human population as never before: human population increase from 1.65 thousand millions in 1900 to 6 thousand millions in 2000; consumption of animal proteins per head raises about 50% in just the last 4 decades (from 19.6 g/d in 1961 to 27.6 g/d in 1998). Developed countries and/or countries characterised by environmental conditions suitable for husbandry produce a surplus that activates the world market (the export of developed countries was about 4 milion tons of meat in 1971 and 17 in 1999).

**Fifth phase. Food quality and biodiversity.** The intensification of livestock systems in many circumstances determined homogeneity of product quality, worsening of organoleptic and, often, of technologic characteristics. Moreover security of primary products has been jeopardised as well. Risks such as BSE and dioxin acted as catalytic agents, at least in Europe, in activating and speeding up the processes to guarantee food security. This trend is supported by the rising of money availability (the incidence of food on family expenses fell from 40% to less than 20% in many developed countries) and the better knowledge of human health that relates some pathologies with the composition of eaten food. Specialization and intensification of production also determined a reduction in the number of utilised breeds. A few types genetically selected for high production (Friesian and Brown among milk cattle breeds; Large White e Landrace among swine; a few lines in poultry) gradually replaced a number of breeds adapted to different environments. The spreading of intensive systems caused the disappearing of breeds in many zones. The FAO reports that in the last century about 1000 breeds vanished and that today about further 1300 are at risk of extinction (<http://www.fao.org/NEWS/2000/001201-e.htm>). The defence of biodiversity and the exaltation of the quality of products from autochthonous breeds characteristic of defined environments are leading to the coming back of breeds, zones and production techniques that seemed to be bound to disappear.

#### **Problems World will face**

The described evolution affected mainly developed countries, and on some aspects a few developing countries. Elsewhere huge differences exist among wide geographical areas, regarding breeding systems, production techniques, animal genetic resources, plant availability, human consumption.

The challenges posed by the huge increase in population size and the concerns on human health and on sustainability of livestock systems make it crucial to ask:

- ✓ What are the future needs of animal products, and how the production systems will evolve to match the increase of both quantity and quality demand in the world? (moreover, it is possible to reduce the ill-fed population that is still over 800 thousand million individuals, about a quarter of which are children less than five years old? (Omnia, 2001)
- ✓ What is the future for the policy of quality and security of animal production, and by which instruments and knowledge may be pursued?

Therefore, an estimation is necessary of the trend in animal products need and of the consistency of the main animal species. Then, the main techniques and knowledge regarding security and quality of animal products will be discussed.

## **2. Food demand and animal production up to 2020**

### **2.1 Meat**

To estimate meat needs, the procapite consumption of beef, sheep and goats, swine and poultry meat (98% of total meat consumption) and the size of human population has been projected to 2020 (Table 1). A linear equation over annual data provided by FAO from 1971 to 1999 (FAO, 2001) resulted to be the most appropriate (equations of higher grade often resulted in non-sense figures at

2020). The total consumption for each product was obtained by multiplying the procapite consumption by population size, separately for developed and developing countries and the sum of both was taken as total world consumption. The total procapite meat consumption worldwide will reach 46.2 kg in 2020, against 37.9 of 1999. The absolute increment will be almost the same in developed countries (from the present 77.1 to 87.1 kg) and in developing countries (from 26.9 to 36.5 kg). In developed countries the highest average consumption would be for poultry meat (32.1 kg/year), slightly over pork consumption (31.6 kg vs 29 kg in 1999), beef meat shows a decrease of nearly 2 kg (20.8 vs 22.4). In developing countries, instead, the highest procapite consumption at 2020 will remain pork, with an increase of 44% (16.1 vs 11.2 kg of 1999), poultry is expected to show a similar per cent increase, even if with lower absolute values (10.4 vs 7.3 kg), while the increase of beef consumption would be of slightly more than 1 kg (Table 1, columns d-c).

The values obtained with the above calculations are partially different from those reported in literature. While we estimate a total meat consumption at 2020 of 87 kg for developed countries and of 46 worldwide, Delgado et al. (1999) report 83 and 39 kg, respectively. However, our estimations in developed countries may be down biased because the negative trend on average consumption occurred in many countries after 1989, caused by extraordinary events whose effects are not over yet. Among those events we should remember a) the fall down for geopolitical reason in breeding and meat consumption in the ex USSR that represents about nearly 25% of the total people in developed countries (from 55.1 in 1992 to 36.7kg in 1999); b) the BSE and dioxin cases that affected directly European countries in the '90s, and cut down consumption in several countries. Anyhow, it may be supposed that there is space for a further increase as, some countries (10, with a total population of 445 million people) are nowadays consuming from 99 to 126 kg meat procapite/year, and nearly all of them show a growing trend in the last decade. In 2020, 7648 millions people inhabiting the world will need globally 349 million tons: 146.2 of pork, 111.3 of poultry meat, 76.3 of beef, 15.6 of sheep and goat meat. In developing countries 6166 million people will use in 2020 about 221 million tons, against 128 million tons needed by the 1482 million people of the developed countries. At world level, the highest absolute increase is expected for pork, 56 million tons (+61.4%) of which even 47 in developing countries. Comparing expected consumption and expected production (Table 1, columns f-h), the World meat deficit will be about 41.5 million tons. Developing countries show a deficit for all products, while in developed countries is expected a slight deficit for pork and poultry, and surplus for beef and for sheep and goat meat. This exceeding production will compensate only a 5% of the total deficit in developing countries .

## **2.2 Milk**

To project milk data (expressed as the sum of the values from all the species), production and consumption have been extrapolated in a similar way of meat. At world level, following FAO data, milk consumption procapite/year would increase of only 2 kg (97 vs 95), due to an increment in developing and a slight contraction in developed countries (estimated on whole milk and milk excluding butter). Altogether, there will be a deficit between needs and production of nearly 40 million tons (Table 1), nevertheless the global increase of production is about 134 million tons (702 vs 568). Buffalo milk shows the most significant increase in percentage of production (+43%), against 35% of sheep and goat milk and about 20% for cattle. The raise in buffalo milk production will concern developing countries only (Table 2).

## **2.3 Eggs**

The projection method was the same used previously. At a world level, eggs consumption procapite/year would increase by 30% (10.3 vs 8.0), due completely to developing countries (9.9 vs 6.7), remaining almost stable in developed countries (Table 1). The absolute number of eggs eaten in developing countries in 1999 would double in 2020 (31 vs 61 million tons). World deficit will be slightly lower than 5 million tons.

FAO doesn't give explanation of the differences between total production and total consumption in the year 1999 per eggs and the other products (bovine and pig meat) (Table 1, columns e and g). Probably they are due to the utilization of reserves and errors.

### **3. Animal figures and breeding systems**

To satisfy the estimated needs at 2020, the expected values relative to consumptions and productions clearly show that corrections must occur within the next 20 years in order to correct the wide foreseen discrepancies and to avoid possible risks. Since consumption cannot obviously overcome production, different scenarios are possible to match them:

- a) to associate the use of traditional animal species with the exploitation of new animal protein sources, such as aquaculture (FAO forecasts a 7 times increase in the quantities provided by aquaculture by now).
- b) to further on increase animal efficiency. This way would occur especially in developing countries (Table 3, column c). But it crashes against technical and organizational situations in several countries. Moreover, rules on environmental sustainability, animal welfare, security and quality of products are quickly increasing and partially will restrain this way.
- c) to raise the number of animals. In this case it will be necessary at World level an increment of heads higher than the ones expected projecting 1971-1999 consistency data (Table 1, column j). About 1.3 thousand millions swine (+43% respect to 1999), 1.8 thousand millions cattle (+34%), 2.3 thousand millions sheep and goats (+30%) should be reared in 2020 worldwide. Without any doubt, those are numbers difficult to withstand. As well, this solution encounters different technical and environmental impediments and limitations relative to the availability of surface and animal food.

Probably, all the three ways to increase production will take place. Anyway, the production intensification worldwide will be advocated. Swine and Poultry, species more easily adaptable to intensification processes, will be the most affected (Nardone and Gibon, 2000). However this process should be regarded cautiously, because it can cause enough problems on systems sustainability (Thompson and Nardone, 1999; van der Zijpp, 1999) as well as on food quality and safety.

### **4. Quality and security**

#### ***4.1 Meaning of quality***

The main objective of quality management is to offer to the consumer what he requires, and also to find appropriate methods to certify the product itself.

The concept of quality is always changing because of the emergence of new products and new requirements of the consumer (Aumaître, 1999).

Evolution and meaning of the quality concept can be synthesized as follow: within the Pasteurian era, quality was believed to rely only on assessment of microbiological status of the food product. During the '60s quality was seen as certification of centesimal composition. In the '70s quality was primarily the absence of chemical residues (Zero Residue), while the '80s have seen the introduction of the Maximum Residue Level (MRL) acceptable for food additives, drugs and contaminants (Nardone and Valfrè, 1999).

The widespread use of "hard production technologies" such as food additives, drugs, growth promoters, new food ingredients and by-products (not only in the developed countries) has led the consumer to be more and more careful and to give preference to foods which are: a. safe (no risks for health); b. easily digestible; c. energy-poor; d. good sources of vitamins, trace minerals, essential fatty acids, etc. As a consequence, in the '90s the quality concept has been widened and re-defined as Total Quality (Valfrè and Moretti, 1991).

#### ***4.2 International agreements***

In the second half of the last century, FAO and WHO designed a program on food security and defence of product quality at world level, relying on Commission of "*Codex Alimentarius*". Codex makes easier the match among food regulations of the participating countries (about 160), becoming a useful tool for reaching the objectives of WTO market globalisation. This matching got a higher importance after the Doha agreement of the end of 2001 among the 144 members of WTO, relative to an increase of agricultural exchange. European Union (EU), as well, committed itself to guard product quality and food security. EU provides exact rules (2081/92 e 2082/92) to guard products with respect to area of production (PGI), origin denomination (PDO) and traditional specialities (TSG) (Boyazoglu,

1999). The EU protects today labels of about 550 products, 150 of which are cheese or milk derivatives (S. Ventura, 2001 personal communication). Also the WTO Doha agreement acknowledges the geographic specificity of productions. Essentially, regulations on quality and security concern fodder security, animal health and welfare, contaminants and residues, food hygiene, additives, flavouring, food conditioning and irradiation.

Traceability, meant as the possibility to track food, fodder or animals during all the phases from production to transformation and distribution, is of a special relevance today.

#### ***4.3 Security check and quality assurance***

In order to get security of food, specific criteria known as Longitudinally Integrated Safety Assurance (LISA) or Total Quality Management (TQM) are spreading around and specific procedures are applied, having part along the food production chain targeting different level of Total Quality. Preparatory programs such as Good Manufacturing Practices (cGMPs) are implemented. Nowadays, at international level, the Hazard Analysis and Critical Control Points (HACCP) is the better known methodology in use to guarantee security. It is a well known system of risk management that addresses food safety through the analysis and control hazards in all the steps of food production processes,

Today HACCP is designed for use in all segments of the food industry, in particular: processing, manufacturing, distributing and merchandising. However, because of costs, HACCP is still in its infancy at present in animal production systems. It seems useful to underline that the system is valid even in this area, but the methods employed are subject to changes after new scientific or technical discoveries.

This kind of security-check is spreading out in Europe, USA and other geographical area. It will be necessary to pay attention to specific elements, at the moment underestimated, such as mycotoxins to provide protection to the consumer (Riley and Norred, 1999). Mycotoxins are wide spread problems of food supplies in most countries. Their production is mostly unavoidable and depends on different environmental factors in the field and/or during storage. Dietary exposure to mycotoxins represent a potential risk for human health, even though toxicological information is still very limited especially for what concerns the effects of chronic and simultaneous exposure (Lopez-Garcia, 1998). Natural occurrence of aflatoxin M1 in milk and in milk products is increasingly reported (Galvano et al., 1996). Many outbreaks in farm animals are caused by aflatoxins, fumonisins and zearalenone. Mycotoxin contaminated products cause also significant economic and trade problems at every stage of marketing (Bhat, 1991; Pitt, 1995).

Finally, market globalisation will lead to an enhancement of product quality standards in all exporting countries. Therefore, it will be necessary to respect WTO quality rules, while competition will push to exceed the minimum agreed requirements.

#### ***4.4 Product quality***

The meat and milk characteristics more related with human health and with some factors affecting their quality are discussed therein.

##### ***Meat***

Due to risks of coronary heart disease (CHD) in the last two decades the traditional healthy image of red meat has gradually been eroded. The healthiness of the meat depends on the relationship that it has (or it is thought to have) with human health. The position taken by physicians on risks determined by red meat will be of growing importance, as red meat is still identified as one of the major sources of saturated fatty acids. Limitations in fat and cholesterol intake are thought to be important measures to prevent obesity and atherosclerotic risks (Chizzolini et al., 1999). More recently, human diets including lean red meat are being linked to positive changes in lipid biochemistry (Beauchesne-Rondeau et al., 1999).

According to Higgs (2000), human blood cholesterol levels are increased by inclusion of beef fat but not by lean beef in an otherwise low fat-diet. The presence of long chain n-6 and n-3 PUFA's in lean meat can reduce thrombotic tendencies. Not all saturated fatty acids have a hypercholesterolemic effect: the most atherogenic is thought to be the myristic acid and has about four times the hypercholesterolemic effect of palmitic acid; while stearic acid is neutral.

In ruminants, lipids are mainly accumulated as triacylglycerols in adipocytes located in subcutaneous, inter and intramuscular adipose tissue and abdominal. There are important breed differences in the proportions of body fat in the various deposits (Demeyer and Doreau, 1999). Minet et al., (1996 in Demeyer and Doreau, 1999) found between Holstein and dual purpose Belgian Blue differences on dissectable fat in carcass of bulls of about 500 kg (252 g/kg vs 242) and very high on intramuscular fat in longissimus thoracis (46.4 g/kg vs 22.0).

The most striking evidence in the genetic determination of meat composition in cattle is between the so called "double-muscled" breeds and the others. Particularly, the fat of double muscled carcasses is very low in respect to "normal" carcasses (about one half the fat tissue content and one third the intramuscular fat) and a much higher percentage of polyunsaturated fats have been observed in the intramuscular fat of double-muscled animals (Webb et al, 1998). Therefore, this kind of meat might be very appealing for consumers willing to restrict their daily intake of fat from meat.

The double-muscled condition results from disrupting mutations in the myostatin genes, notably the 11bp deletion (nt821(del11)) in Belgian Blue, a G>A transition at nucleotide 938 (C313Y) in Piedmontese (Grobet et al 1998) and G>T transversion that introduces a premature stop codon in Marchigiana (Cappuccio et al., 1998; Karim et al., 2001).

If the consumer will conform to the physician's line to eat meat with low fat content, the development of double muscled cattle populations or the introgression of one of the myostatin alleles in other breeds can be hypothesised.

Results from molecular genetics are very promising also in pig and poultry to produce healthier pork and poultry meat.

The porcine insulin-like growth factor 2 (IGF2) gene was recently identified as the prime candidate gene for a paternally expressed quantitative trait locus (QTL) affecting muscle development and fat deposition on pig. This IGF2-linked QTL affects both skeletal and cardiac muscle development in a European Wild Boar/Large White Domestic Pig intercross. The only known paternally expressed locus in adults (i.e. the only allele expressed is the one inherited from the sire) in this region is IGF2 and the QTL mapped to the same position as IGF2. The Large White allele at the IGF2-linked QTL had major effects on muscle mass, lean meat content, heart weight and back-fat thickness (Jeon et al., 1999).

The regulation of IGF2 expression has been analysed in detail in other mammals and shown to be subject to a complex regulation at both the transcriptional and post-transcriptional level. The particular inheritance mechanism makes it crucial the development of appropriate mating schemes for the exploitation of this gene .

In chicken, selection for immune response parameters may lead to improved general disease resistance. Because disease resistance and immune response are hard-to-measure quantitative traits with low to moderate heritability, they may respond more efficiently to marker-assisted selection (MAS) than to phenotypic selection.. Three microsatellite markers exhibited significant association with immune response: (1) ADL0146 on Chromosome 2 associated with antibodies (Ab) to SRBC and Newcastle disease virus (NDV), (2) ADL0290 on linkage group 31 affecting Ab to NDV, and (3) ADL0298 on linkage group 34 associated with Ab to E. coli and survival (Yonash et al., 2001).

The possibility to exploit MAS for genetic resistance to diseases allows the reduction of pharmaceuticals in husbandry, diminishing the risk of residues in the meat. This perspective may be of positive impact on human health considering the forecasted increase on poultry meat consumption.

Also nutrition is an easier way to reduce carcass fat content. Effects of different energetic levels and composition of diets on carcass fat content are well known on cattle (Restle et al., 1998), pig (Almeida Barbosa et al., 2000) and poultry (Gonzalez-Esquerria and Leeson, 2000). More recent researches showed that feeding of monogastric animals by conjugated linoleic acid (CLA) can have a positive effect on the increase of lean meat and body fat reduction. The integration with vegetable and fish oil of diets for pig results in an enhancement of n-3 PUFA (Enser et al., 1996; Enser et al., 2000). Also, the use of linseed increases the levels of n-3 fatty acids in broiler breast meat (Cordeiro Rosa et al., 2000).

This method does not work as well in ruminants. First, because digestion at the ruminal level makes unsaturated fatty acids biohydrogenated (only few unsaturated fatty acids can bypass rumen

determining a n-3 PUFA increase in beef). Second, because in rumen trans fatty acids, having part in atherogenesis, are formed during biohydrogenization (Demeyer and Doreau, 1999).

Slaughter weight is an other mean affecting carcass fat content (Steen and Kilpatrick, 2000).

Concerning tenderness, that is another qualitative characteristic consumer is searching for, there are some interesting perspectives.

Recent findings make it possible to select for tenderness in beef by identifying breeds and individuals having a gene with highly significant and consistent association with tenderness (Barendse, 2001). Some tropical breeds such as Santa Gertrudis and Brahman seem to have a higher frequency of "tough" gene.

Several other researches are in progress to identify loci affecting meat tenderness. A comparative linkage maps of bovine and human was constructed in studies to identify potential positional candidate genes from QTL position estimates and to provide a resource of genetic markers to support MAS. One gene with known effects on muscle development (MYOD1) and a second (CALCA) involved in regulation of calcium levels, a key factor in post-mortem tenderisation, were mapped (Rexroad et al., 2001).

Scientists of the Cooperative Research Centre (CRC) of Australia consider electrical stimulation of the carcass a good non genetic factor to improve significantly tenderness of beef. They also found that high growth rates during the last 100 days of an animal life could improve eating quality. According to Burrow (2001) an estimation of beef toughness is possible also on live animal evaluating its temperament by an electronic measure called "flight time" (the amount of time taken by an animal to travel 2 metres).

In pig breeding, some researches demonstrated the positive influence of available surface per head on meat quality as tenderness and cooking loss (Beattie et al., 2000); in wild boar Matassino et al. (2001) found histochemical differences among muscles affect pork cooking quality.

According to Faucitano et al. (1998) stunning voltage (200V) and immediate bleeding-out at slaughtering affect positively post-mortem acidification of some muscles in pig carcass. In live pigs the DNA test for halothane gene related to PSE meat is largely employed (Sellier and Monin, 1994).

As far as sheep meat is concerned Sañudo et al. (1998) widely reviewed, with a special attention to Mediterranean production systems, more than 40 factors, classifying the effects on carcass quality (dressing percentage, weight, fatness, conformation), and meat quality (tenderness, juiciness, colour, flavour). Tenderness and shear force are significantly affected by carcass weight. Mean shear force values are higher for median weights than those from heavier or smaller carcasses (Hernando et al., 1996). This means that in the early ages, the changes in toughness, as in other quality parameters, as juiciness, can occur much more quickly than at greater weights (Sañudo et al., 1998).

To control meat characteristics various techniques are available (Monin, 1998). Molecular biology techniques will be of a great interest to implement new product certification referred to species, breed, animal category (age, sex, etc). These techniques already allow to differentiate among species (Castellanos et al., 1997). sex and individuals, as well as the diffusion of methodologies to discriminate among breeds is foreseeable (A. Valentini, 2002 personal communication).

Finally the considered elements indicate that, for a better match with human nutrition requirements, improvements should be achieved by genetics or management actions on meat composition that will ensure a fundamental role of meat in human diet also in the future. In fact, meat is a source not only of proteins but also of many micronutrients (cobalt, chromium, copper, magnesium, phosphorus), of iron, zinc, selenium (one of the major antioxidant protecting against CHD and cancer), glutathione (reducing in intestinal tract the mutagenicity of aflatoxins), vitamins (A, B, B<sub>12</sub>, D) that, in the right concentration, are essential nutrients (Higgs, 2000).

### Milk

In the last years the interest in milk quality is increased (Boland et al., 2001). Various factors (genetics, nutrition, management, environment, animal health) and their interactions affecting milk characteristics have been examined (Bernabucci and Calamari, 1999, Chilliard et al., 2001, Nardone and Valfrè, 1999).

Classical analysis of quantitative traits affecting milk quality are expanding, by the inclusion of non-additive variance components or major genes (Goddard, 2001). Further progresses are envisaged from the use of genes and marker data whose mapping and identification might explain the majority of the variance in the breeding objectives (Georges, 2001).

Karijord et al. (1982) estimated the heritability of the proportion of fatty acids ( $h^2$  from 0.05 to 0.26) and found positive genetic correlation between milk fat percentage and short-chain fatty acids. Vos and Groen (1998) have showed that selective breeding over three generations has allowed the reducing of fat/protein ratio. These indicate that genetic approaches by selecting animals for reducing milk fat percentage can modify fatty acids (FA) composition.

Conjugated linoleic acid (cis-9 trans-11: CLA) is found in milk and a wide range of health benefits have been shown including: inhibition of carcinogenesis, atherosclerosis and immune stimulation (Boland et al., 2001). Recent work reported CLA prevents the development of diabetes in obese and glucose-intolerant Zucker diabetic fatty rat (Houseknecht et al., 1998).

Desaturation of vaccenic acid (trans-11 octadecenoic acid) by the stearoyl CoA desaturase (SCD) is a significant source of milk CLA. Different breed of cattle have different levels of unsaturated fatty acids in milk fat (Boland et al., 2001). This implies that genetic factors, possibly regulation in expression of SCD, may affect CLA levels. However, genetic factors affecting milk CLA levels are not investigated in dept.

Genetic variants of milk proteins have been widely studied for their relationships with technological properties of cattle ( $\kappa$ -casein-BB and  $\beta$ -casein-BB genotypes are deemed to determine shorter curd firming time: Mariani and Battistotti, 1999), sheep and goat ( $\kappa$ -CN-BB and  $\alpha$ 1-CN-AA have positive effects on cheese yield and cheese making properties (Amigo et al., 2000).

The increase or modification of milk constituents through the genetic engineering of the bovine mammary gland to improve the efficiency of manufacturing milk products has been proposed (Wall et al., 1997). Production of monoclonal antibodies that are (or appear) human could have clinical benefits: abciximab (Reopro<sup>TM</sup>) for the prevention of acute cardiac ischemia following coronary angioplasty, rituximab (Rituxan<sup>TM</sup>) for the treatment of non-Hodgkin B-cell lymphoma, trastuzumab (Herceptin<sup>TM</sup>) for metastatic breast cancer, infliximab (Remicade<sup>TM</sup>) for severe Crohn's disease and rheumatoid arthritis (Dickman, 1998). In the last years particular meaning is given to the expression of recombinant proteins in the milk of transgenic animals for the production of complex polypeptides (Vaughan et al., 1998). Recently Pollock et al. (1999) obtained high-level expression of active recombinant human or humanised IgG in the milk of transgenic goat.

Increasing of casein might be important for human health, besides the importance for cheese making. The caseinophosphopeptide (CPP) group, which are naturally released during tryptic digestion of caseins, is a specific agent to promote recalcification of teeth (Reynolds, 1993). Moreover, this peptide act by inhibiting the action of angiotensin converting enzyme (ACE). This enzyme converts angiotensin 1 into angiotensin 2. Inhibition of ACE will lower blood pressure with an antihypertensive effect (Meisel, 1997), improving immune defence and nervous system activity (Meisel, 1993). These peptides/hydrolysates may be classified as functional food ingredients and nutraceuticals due to their ability to provide health benefits i.e. as functional food ingredients in reducing the risk of developing a disease and as nutraceuticals in the prevention/treatment of disease (Fitzgerald and Meisel, 2000).

A recent research has shown a relationship between the development of child-onset diabetes and some  $\beta$ -casein variants (Elliot et al., 1999). Those authors found that the insulin-dependent diabetes mellitus (or IDDM) incidence was significantly correlated with variants of  $\beta$ -casein (A1 and B). More recently Thorsdottir et al (2000) reported the possibility that the consumption of  $\beta$ -casein A1-type variants is a risk factor for the development of IDDM. Those variants with a histidine at position 67 of the amino acids sequence, were positively correlated with IDDM. No correlation between consumption of  $\beta$ -casein A2 and A3 variants with a proline at position 67 of the amino acids sequence was observed. The diabetogenic effect of  $\beta$ -casein A1 and B was proposed to be related with a bioactive seven acid peptide  $\beta$ -casomorphin-7 (BCM-7) released after the digestion of  $\beta$ -casein A1

and B. Sun and Cade (1999) have also proposed that BCM-7 could be responsible in the induction of some cases of autism and schizophrenia.

Since specific  $\beta$ -casein variants are risk factors in the development of certain diseases, the selection of  $\beta$ -casein with proline at position 67 may be desirable.

Advent of genomic DNA analysis techniques contributes to improve milk production traits in sheep and goats. Individual differences in candidate genes for improving milk and casein yield in goats are already part of a breeding plan in France. It is very likely that within milk protein structural genes other quantitative alleles will be found which determine differences in nutritional and technological properties of milk through the modification of the ratios among protein fractions (Moioli et al., 1998).

Clark and Sherbon (2000) reported that in goat milk  $\alpha$ s1-CN was positively correlated in order with percent casein, solids-not-fat, total protein, total solids and fat and coagulation time. However, percent total solid, solid non fat and protein were more highly correlated with coagulation properties than  $\alpha$ s1-CN. So, selection of goats with high solids is recommended if cheese-making is the objective.

Several Countries use SCC as an additional source of information in a multi-trait model to estimate breeding value for mastitis resistance, and Quantitative Trait Locus (QTL's) for SCC and for clinical mastitis have been reported (Heringstad et al., 2000). Detection of putative QTL's for mastitis resistance may in the future make marker assisted selection an alternative or a supplementary selection strategy for improving mastitis resistance in dairy cattle.

Nevertheless, a further reduction of a low SCC by genetic selection may impair the cows' immune system (Schukken et al., 1994). Some researches showed that herds with low SCC (< 150.000) had higher incidence of clinical mastitis than herds with SCC > 250.000 (Miltenburg et al., 1996). This may indicate that a very low SCC is not optimal and that optimal udder health will not necessarily be at the lowest possible level of SCC. It is therefore doubtful whether a long term selection should be for the lowest possible concentration of SCC in milk (Heringstad et al., 2000).

Some fatty acids, such as butyric acid, oleic acid, C18 to C22  $\omega$ -3 polyunsaturated fatty acids and CLA, have a positive role for human health, and animal feeding can influence milk fat synthesis and composition (Chilliard et al., 2001). CLA in milk fat from pasture fed cows seems to be higher than concentrate-fed animals (MacGibbon and Hill, 1998). Animals fed with diets of maize silage have milk more rich in short chain FA. Marine oils are rich in very long-chain (C20-C22) polyunsaturated FA (C20:5  $\omega$ -3: eicosapentenoic acid, EPA; C22:5  $\omega$ -3: docosapentenoic acid, DPA; C22:6  $\omega$ -3: docohexaenoic acid, DHA) and supplementation with fish oil to diet increases the mean CLA content in cow milk fat more of 300% (Barclay et al., 1998).

Polyunsaturated  $\omega$ -3 fatty acids have a wide range of functional and structural role on the organism: anti-atherogenic anti-inflammatory and anti-thrombosis (Cocchi, 1999). The intake of  $\omega$ -3 fatty acids is known to have a relevant preventive and therapeutic effect. In particular DHA has mainly an instrumental action in the organism. DHA seems to be very important in: brain development and growth; reproductive apparatus development and growth; optomeninx tissue development and growth. EPA is mainly a direct precursor of the prostaglandins (series 3) that are antiplatelet drugs.

The biohydrogenation in the rumen reduces the increase of the percentage of EPA and DHA in milk from feeding marine algae and fish oil to the milk (2.6 and 4.1% for EPA and DHA, respectively, reviewed by Chilliard et al., 2001). In fact, when infused post-ruminally, the transfer efficiency of EPA or DHA is much higher (18-33 or 16-25%, respectively) than when given in the diet (Chilliard et al., 2001). Another possible reason for the low transfer efficiency of EPA and DHA to the milk is due to the fact that although they are present in triglycerides, they are concentrated in cholesterol ester and phospholipid fractions of plasma, which are slightly used in the mammary gland (Chilliard et al., 2001).

Whey protein may be beneficial for human health, as shown by studies in animal and human, and experimental data have demonstrated that the major component bovine lactoferrin (bLF) inhibits colon carcinogenesis and is potential for chemoprevention of colon and other cancers (Tsuda et al., 2000). Meisel (1997) reports also the antimicrobial activity of lactoferrin, widely considered to be an

important component of the defence against microbial infection. Buttermilk may also have a protective role in the oesophagus, while skimmed rather than whole milk may be beneficial for squamous epithelium (Tuyns et al., 1987). Bezault et al. (1994) have shown the inhibitory potential of bLF against chemically-induced and hereditary intestinal carcinogenesis, in addition to metastasis of transplanted tumours.

Milk quality may also be influenced by some innovative technologies. Among them one particularly under investigation for the influence on quality are the Automatic Milking Systems (AMS) that have been available commercially just since 1992. The principal markets for the machines are in countries characterised by high labour cost, high yielding cows and high milk price. AMS can influence milk production and milk quality. AMS increases milk yield and milking frequency from twice to three times or more per day requiring a minimum extra amount of labour (Kruip et al., 2000). Contradictory results are reported about the effects of AMS on milk quality. Several authors found that after the introduction of AMS milk quality decreased, particularly fat, proteins percentage while total bacterial plate count, SCC, freezing point and the amount of free fatty acids increased significantly (Jepsen and Rasmussen 2000; Klungel et al., 2000). Moreover, the probability that mastitis pathogens might be transmitted from cow to cow is greater, because one AMS milks 50 to 60 cows. Milk harvested by AMS remains in the milk equipment for a longer time compared with conventional system. This might explain the higher bacterial growth in milk of AMS. Moreover, in AMS, cleaning of the udder and teats may not be as good as manual cleaning, and cleaning with AMS itself may not have been optimal because of the construction of the system and lack of a well-adapted cleaning protocol (Klungel et al., 2000). These studies indicate that particular attention should be paid to cleaning of the milking installation and cooling of the milk to assure the quality of raw milk.

In sheep and goat milk refrigeration limits the development of mesophilic microflora, but it may encourage psychophilic microflora that can cause defects of bitterness or rancidity in cheese. Milk is influenced also by the presence of pharmaceutical residues, detergent and disinfectant substances, that might delay or block the normal fermentative processes of cheesemaking, as well as constituting a health risk to the consumer. Pesticides, too, and certain mycotoxins may reach the milk when the animal ingests contaminated feed (Pirisi et al., 2000).

A recent study on dairy ewes (Negrão et al., 2001) showed that the increase from twice to thrice daily milking caused a milk yield gain of 34.5%, and that the total concentration of milk protein did not change.

Milk quality and production in subtropical and tropical areas can be impaired by heat stress (Johnson, 1987). A review of literature on cows' milk production in these areas indicates that heat stress causes lower milk yield and a worsening of milk quality. When cows are exposed to heat stress milk fat and protein content decrease (Bernabucci and Calamari, 1998). Some authors reported a higher proportion of long-chain fatty acid (C18 and more) during warm months (Palmquist et al., 1993). Heat stress has a negative effect on titratable acidity, casein number and  $\alpha$ s1-casein and  $\beta$ -casein contents (Nardone et al., 1992, Lacetera et al., 1996; Bernabucci and Calamari., 1998). Milk calcium, phosphorous, magnesium and lactose contents in heat-stressed cows generally decline, whereas milk chloride increases (Bernabucci and Calamari, 1998). Freezing point of milk generally increases during summer (Pakard and Ginn, 1990). Finally, it is also widely reported a negative effect of heat-stress and hot season on cheesemaking properties of milk (Calamari and Mariani, 1999). Further researches are required to understand the mechanisms involved in milk protein fractions, milk fatty acids and freezing point changes under hot weather.

## 5. Conclusion

Consumption of an increasing human population is growing faster than the increase in production and in number of animal population. Therefore, it is a formidable task to assure enough and healthy food for the populations of the different areas of the world. The fulfilment of the global product requirements will determine the diffusion of more and more pig and poultry, characterised by shorter reproductive and productive cycles, higher birth rate and conversion index. Besides, other species and production systems such as aquaculture could be developed. On one side, the quality and safety policy that is correctly spreading in the world could restrain production within developed

countries. From the other side, the stronger the demand for increasing the amount of products, the smaller are food quality and security requirements at a world level. The policy of animal products quality, is very promising and ready to be put in practice, even if limited to zones at medium-high economic level. The agreement of producers, technicians and all the categories involved is fundamental. A growing research and transfer engagement is foreseeable and desirable concerning quality of products, using traditional tools and even more by molecular genetics. Also feeding management can hardly contribute in order to increase nutritional value of animal products regarding human health and consumer requirements

Man will have to cope with complex problems, whose resolution will require a big effort in terms of capability and seriousness, independently from country, origin and religion.

## 6. Acknowledgements

The author thanks Umberto Bernabucci and Alessio Valentini for help in literature search and preparation of the manuscript, M. Stella Ranieri in search and elaboration of data, Bruno Ronchi for information given, Lorraine Pariset for linguistic corrections of the manuscript and Daniela Pirazzi for collaboration.

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Table 1. Uman population, meat, milk and eggs consumption and production; stocks of cattle pig, sheep and goat and productivity per head in Developed and Developing Countries and in the World. Year 1999 and projections to 2020

	Human population		Consumption				Production		Stock		Productivity	
	1999	2020	Procapite		Total		1999	2020	1999	2020	per head	
	N (000)		kg/year		T		T		N		kg	
	a	b	c	d	e	f=(bxd)	g	h	i	j	k=(g/i)	l=(h/j)
<b>BOVINE MEAT</b>												
Dev.ed C.	1.302.638	1.481.876	22,4	20,8	29.372.363	30.774.469	30.240.747	34.352.990	332.357.743	297.183.990	91,0	115,6
Dev.ing C.	4.675.758	6.166.355	6,2	7,4	28.614.072	45.471.554	25.955.565	35.173.780	#####	#####	25,8	28,7
World	5.978.396	7.648.231	9,7	10,0	57.986.435	76.246.024	56.196.312	69.526.771	#####	#####	41,9	45,6
<b>PIG MEAT</b>												
Dev.ed C.	1.302.638	1.481.876	29,0	31,6	37.963.185	46.817.051	38.436.914	46.607.379	296.310.936	324.708.394	129,7	143,5
Dev.ing C.	4.675.758	6.166.355	11,2	16,1	51.835.911	99.310.214	50.401.454	77.508.716	611.525.148	785.104.944	82,4	98,7
World	5.978.396	7.648.231	15,1	19,1	89.799.096	146.127.265	88.838.368	124.116.095	907.836.084	#####	97,9	111,8
<b>POULTRY</b>												
Dev.ed C.	1.302.638	1.481.876	22,2	32,1	29.021.958	47.504.335	31.787.705	46.733.282				
Dev.ing C.	4.675.758	6.166.355	7,3	10,4	33.816.214	63.832.408	33.321.108	48.592.375				
World	5.978.396	7.648.231	10,5	14,6	62.838.172	111.336.743	65.108.813	95.325.657				
<b>SHEEP AND GOAT MEAT</b>												
Dev.ed C.	1.302.638	1.481.876	2,2	1,9	2.851.223	2.782.349	3.310.087	3.668.038	415.880.678	433.205.195	8,0	8,5
Dev.ing C.	4.675.758	6.166.355	1,7	2,1	7.942.425	12.853.661	7.783.487	10.882.444	#####	#####	5,8	6,3
World	5.978.396	7.648.231	1,8	2,0	10.793.648	15.636.010	11.093.574	14.550.483	#####	#####	6,3	6,8
<b>TOTAL MEAT</b>												
Dev.ed C.	1.302.638	1.481.876	77,1	87,1	100.967.641	129.015.160	105.395.034	132.675.546				
Dev.ing C.	4.675.758	6.166.355	26,9	36,5	124.837.572	225.210.178	123.151.832	180.091.969				
World	5.978.396	7.648.231	37,9	46,3	225.805.213	354.225.338	228.546.866	312.767.516				

<b>EGGS</b>												
Dev.ed C.	1.302.638	1.481.876	12,4	12,0	16.272.304	17.815.722	18.326.098	20.876.586				
Dev.ing C.	4.675.758	6.166.355	6,7	9,9	31.132.284	61.185.128	35.496.450	53.450.161				
World	5.978.396	7.648.231	8,0	10,3	47.404.588	79.000.851	53.822.548	74.326.747				
<b>MILK</b>												
Dev.ed C.	1.302.638	1.481.876	n.a.	n.a.	n.a.	n.a.	343.329.363	388.016.682				
Dev.ing C.	4.675.758	6.166.355	n.a.	n.a.	n.a.	n.a.	224.663.252	314.003.221				
World	5.978.396	7.648.231	95,0	97,0	n.a.	742.171.254	567.992.615	702.019.903				
computed by linear equation on FAO data (1971-1999)												

Table 2. Buffalo, camel, cow, goat and sheep milk production in Developed and Developing Countries and in the World. Year 1999 and projections to 2020

	<b>Buffalo</b>		<b>Camel</b>		<b>Cow</b>		<b>Goat</b>		<b>Sheep</b>		<b>Total</b>	
	<b>1999</b>	<b>2020</b>	<b>1999</b>	<b>2020</b>	<b>1999</b>	<b>2020</b>	<b>1999</b>	<b>2020</b>	<b>1999</b>	<b>2020</b>	<b>1999</b>	<b>2020</b>
	<b>T</b>		<b>T</b>		<b>T</b>		<b>T</b>		<b>T</b>		<b>T</b>	
Dev.ed C.	169.352	153.415	0	5.845	337.763.415	381.339.183	2.437.984	2.928.174	2.958.612	3.590.066	343.329.363	388.016.683
Dev.ing C.	64.232.718	91.905.664	1.294.587	1.606.251	144.233.965	199.616.328	9.812.702	13.801.321	5.089.280	7.073.657	224.663.252	314.003.221
World	64.402.070	92.059.079	1.294.587	1.612.096	481.997.380	580.955.511	12.250.686	16.729.495	8.047.892	10.663.723	567.992.615	702.019.904
computed by linear equation on FAO data (1971-1999)												

Table 3. Expected productivity per head of bovine, pigs, sheep and goats to make equal production to consumption in the year 2020, on the basis of the values of projected consumption and stock

	<b>Consumption</b>	<b>Stock</b>	<b>Productivity</b>
	<b>(from Table 1, col. f)</b>	<b>(from Table 1, col. j)</b>	<b>per head</b>
	<b>2020</b>	<b>2020</b>	<b>2020</b>
	<b>T</b>	<b>N</b>	<b>kg</b>
	<b>a</b>	<b>b</b>	<b>c=(a/b)</b>
<b>BOVINE</b>			
Dev.ed C.	30.774.469	297.183.990	103,6
Dev.ing C.	45.471.554	1.226.282.402	37,1
World	76.246.024	1.523.466.392	50,0
<b>PIG</b>			
Dev.ed C.	46.817.051	324.708.394	144,2
Dev.ing C.	99.310.214	785.104.944	126,5
World	146.127.265	1.109.813.337	131,7
<b>SHEEP AND GOAT</b>			
Dev.ed C.	2.782.349	433.205.195	6,4
Dev.ing C.	12.853.661	1.714.344.636	7,5
World	15.636.010	2.147.549.831	7,3

Table 4. Expected stocks of cattle, pigs, sheep and goats necessary to make equal production to consumption in the year 2020, on the basis of the values of projected consumption and productivity

	<b>Consumption</b>	<b>Productivity</b>	<b>Stock</b>
	<b>(from Table 1, col. f)</b>	<b>per head</b>	<b>(from Table 1, col. l)</b>
	<b>2020</b>	<b>2020</b>	<b>2020</b>
	<b>T</b>	<b>kg</b>	<b>N</b>
	<b>a</b>	<b>b</b>	<b>c=(a/b)</b>
<b>BOVINE</b>			
Dev.ed C.	30.774.469	115,6	266.226.594
Dev.ing C.	45.471.554	28,7	1.585.299.224
World	76.246.024	(1)	1.851.525.818
<b>PIG</b>			
Dev.ed C.	46.817.051	143,5	326.169.156
Dev.ing C.	99.310.214	98,7	1.005.937.705
World	146.127.265	(1)	1.332.106.861
<b>SHEEP AND GOAT</b>			
Dev.ed C.	2.782.349	8,5	328.602.935
Dev.ing C.	12.853.661	6,3	2.024.876.438
World	15.636.010	(1)	2.353.479.373
(1) the average world value is different than in table 1 because of diverse proportion between consumption and production in Dev.ed and Dev.ing countries			